STUDIES ON THE FOSSIL FLORA OF NIPANIA, RAJMAHAL SERIES, INDIA — *PTERIDOPHYTA*, AND GENERAL OBSERVATIONS ON NIPANIA FOSSIL FLORA

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ABSTRACT

The paper describes several silicified pteridophytic remains, *Lycoxylon indicum* (SRIVASTAVA) emend., *L.* Type 2, *Sphenopteris* sp., *Cladophlebis sahnii* sp. nov., 5 types of petioles and rachises, 3 types of sori, 3 types of isolated sporangia, 2 new species of *Solenostelopteris* Kershaw (*S. nipanica* sp. nov. and *S. sahnii* sp. nov.), 3 new species of *Dictyostelopteris* gen. nov. (*D. rajmahalense* sp. nov., *D. fasciosteloides* sp. nov. and *D. jacobi* sp. nov.) and *Tinpaharia sinuosa* Jacob.

In general composition the fossil flora of Nipania seems to compare with the fossil flora of Jabalpur and the Kota Stages of the Upper Gondwana and is, therefore, believed to belong to the uppermost strata in the Rajmahal Stage.

INTRODUCTION

PTERIDOPHYTIC remains consisting of a lycopodiaceous stem and two types of fern rachises from the Nipania chert were first reported by Srivastava (1935, 1937). Later Srivastava described a *Lycopodium*-like stem under the name *Lycoxylon indicum* Srivastava (SRIVASTAVA, 1946). Rao in 1943 described some detached and empty sporangia and spores while in 1948 he reported *Gleichenia*-like petiole remains from the chert. Several pteridophytic microspores and a few megaspores have recently been described by me from the Nipania chert (VISHNU-MITTRE, 1953, 1954).

Our knowledge of the silicified pteridophytic remains from the other Jurassic deposits in India has so far been confined to a few isolated sporangia and spores and a rhizome, *Tinpaharia sinuosa* Jacob (JACOB, 1938, 1943, 1950) and a silicified osmundaceous stem, *Osmundites sahnii* Vishnu-Mittre (VISHNU-MITTRE, 1955).

From the Mesozoic outside India silicified pteridophytic remains have been described by Seward (1894, 1907, 1911), Kidston & Gwynne-Vaughan (1907), Kershaw (1910), Stopes & Fujii (1910), Sinnott (1914), Sahni (1920), Marshall (1926), Ogura (1927, 1930), Edwards (1933), Rao (1934) and Arnold (1950).

The material here described consists of equisetaceous and lycopodiaceous axes, fern fronds, isolated rachises and petioles, isolated sori, isolated sporangia and filicinean stem fragments. Though the fragmentary nature of the material in hand has not permitted the correlation of the vegetative remains with the fertile ones, yet their structural details have advanced our knowledge of the anatomy of Jurassic Pteridophyta about which, excepting few families (Cythaeaceae and Osmundaceae, etc.), practically nothing has been known so far.

Material and methods are the same as reported earlier (VISHNU-MITTRE, 1957).

My thanks are due to Dr. K. R. Surange for kindly going through the manuscript.

DESCRIPTION

Equisetales

Genus *Equisetites* Sternberg

Equisetites rajmahalense Old. & Morr.

The fragmentary specimen, 1·5 × 1-2 mm., probably representing the apical part of a branchlet, is identical with *Equisetites rajmahalense* Old. & Morr. and is the first report from Nipania.

Lycopodiales

Lycoxylon (Srivastava) emend.

The late Mr. B. P. Srivastava instituted the genus *Lycoxylon* for a silicified *Lycopodium*-like axis possessing parallel-banded stele, discovered from the Nipania chert.

Srivastava (1946) described only one species of the genus *Lycoxylon*, *L. indicum* Srivastava. During the recent investigations of the plant-remains from the Jurassic deposits at Nipania, some more axes, resembling in their stelar anatomy the modern *Lycopodium*, were discovered.

All the specimens described here are included in the genus *Lycoxylon* Srivastava. According to Srivastava's diagnosis, this genus accommodates only those *Lycopodium*-like axes which possessed a parallel-banded stele. Taking into consideration the variety and plasticity of stelar anatomy in modern *Lycopodium*, it appeared justifiable to emend the diagnosis of the genus *Lycoxylon* so as to include in it all fossil *Lycopodium*-like axes.

The referring of the additional axes with radial and mixed steles either to the only species *L. indicum* or raising them to the rank of new species will only be possible when more material is investigated.

Emended Diagnosis — Axes with stelar type as in the genus *Lycopodium*. Inner cortex made up of thick-walled cells. Metaxylem tracheids with scalariform pitting.

The specimens, six in number, were discovered in thin sections of the chert. Further serial sectioning showed that only one of them was more than 1 cm. long while the others were only about 5-6 mm. long.

Lycoxylon indicum Srivastava

Pl. 1, Figs. 1, 2; Text-fig. 1

The stele in this species, four fragmentary specimens of which are available, consists of parallel bands of xylem. One of the specimens is represented by a single cross-section about 1 mm. across. Two specimens measure about 5-6 mm. in length and about 1 mm. in diameter, only two serial sections of which are available. One of them shows branching also (Pl. 1, Fig. 1). These three specimens resemble *L. indicum* except that they have only sixteen protoxylem groups while there are twenty protoxylem groups in *L. indicum*.

The fourth specimen (Text-fig. 1), two serial cross-sections of which are available, measures only 670 μ across. It is more or less circular in outline and has three to four xylem plates with large polygonal elements, 20-26 μ across, and 6-7 protoxylem groups. A branching axis of this is also discovered. This specimen differs from *L. indicum* not only in its small size but also in less number of the xylem plates and the protoxylem groups. It might probably belong to the apical region of an axis of *L. indicum*.

There is another axis (Pl. 1, Fig. 2; Text-fig. 2), about 0·5 mm. in diameter, the stele of which is of the stellate pattern with seven arms. The number of arms can be made out by the number of protoxylem groups, some of which are seen in cross-section while the others are obliquely cut.

The above specimen is presently included in *L. indicum* because of insufficient material and the plasticity noted in modern *Lycopodium* in the parallel-banded and the radial types of the steles. In its very small size the specimen is believed to belong to the younger axis of *L. indicum*. With more material it may be possible to show in future whether this fragment belonged to a distinct species or a type different from *L. indicum*.

***Lycoxylon*, Type 2**

Pl. 1, Fig. 3; Text-fig. 3

A single specimen, about 0·75 mm. in diameter, shows its stelar portion slightly displaced towards one side of the axis leaving a wide gap on the other side. The inner cortex (Pl. 1, Fig. 3), pericycle and phloem sheath are preserved. The endodermis shows thickening of the radial walls (Text-fig. 3). The pericycle is made up of cells two layers in thickness.

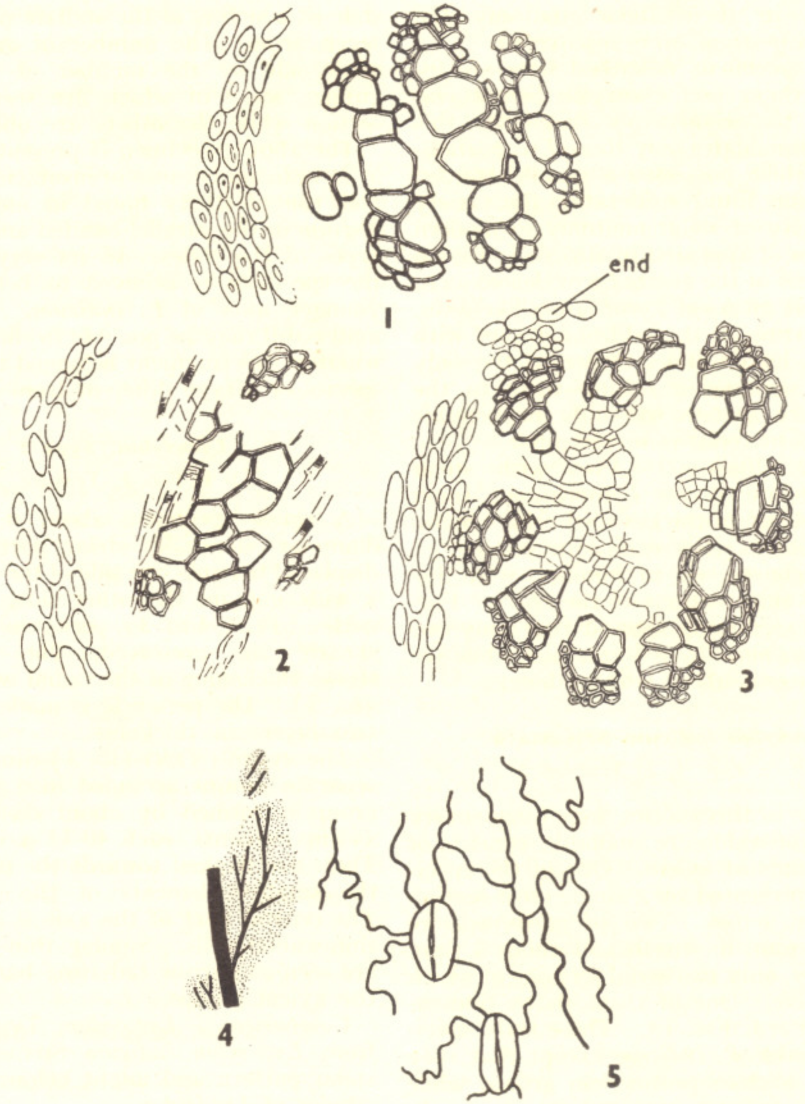
The xylem (Text-fig. 3) consists of nine separate groups arranged in a ring. Each group is formed by about six large metaxylem elements, each 40-33 μ in diameter. These are flanked towards the periphery by the smaller elements of the protoxylem. The central part of the axis is occupied by thin-walled cells. Similar thin-walled cells are seen as narrow radiating bands between the xylem groups.

Comparison — *Lycoxylon*, Type 2, differs from *Lycoxylon indicum* Srivastava in its stelar pattern and might belong to another species of *Lycoxylon*.

DISCUSSION

The parallel-banded, radial and mixed types of steles in the specimens described here resemble very much the stelar patterns found in modern *Lycopodium*. Probably these three types of axes belonged to *Lycopodium*-like plants.

If it were not known that a great degree of plasticity exists in the stelar pattern of modern *Lycopodium*, these axes might have been regarded as belonging to different species. Holloway (1919, p. 208) distinguished three main cycles of affinity in



TEXT-FIGS. 1-5 — 1, *Lycoxylon indicum* Srivastava emend. Cross-section of a part of a probably younger axis. × 153. 2, cross-section of a part of another axis showing radial stele. × 153. 3, *Lycoxylon*, Type 2. Cross-section of a part of an axis showing mixed stele. × 153. 4, *Cladophlebis sahnii* sp. nov. A fragmentary specimen. × 5. 5, epidermal cells and the stomata. × 190.

Lycopodium, namely the *Selago-Phlegmaria* section, *Inundata-Cernua* section and the *Clavata* section. These sections are characterized respectively by steles of the stellate (or radial) type, the mixed type and the parallel-banded type. Holloway (1919) concludes that the section *Clavata* has a persistent normal stele and the plasticity may be found in other sections of the genus. Hill (1914, p. 82), on the other hand, finds that the radial and the parallel-banded types of steles may occur in the same stem and associated with the crescentic and amphivasal types of steles also. Hill (1914, 1919) cautions against attempts to place the species of *Lycopodium* in definite categories on the basis of the characters of the stele which, according to him, vary considerably in the same species in different regions of a stem, e.g. in *L. carinatum*, *L. varium*, *L. phlegmaria*, *L. phyllanthum*, *L. hamiltonii* and *L. selago* (HOLLOWAY, 1919, p. 173; FIG. 5). There are also cases where the banded stele is found in the adult stage while the young parts and the ultimate branches possess the radial structure, e.g. *L. clavatum* (JONES, 1905), *L. fastigiatum* (HOLLOWAY, 1919), *L. wightianum* (CHOWDHURY, 1937) and *L. reflexum* (HILL, 1919). Nevertheless, Holloway (1919) looks upon the parallel-banded type as persistent.

Less plasticity has, however, been noted in the mixed type of the stele. According to Holloway (1919, p. 184) in the *Inundata-Cernua* section of the genus *Lycopodium* the stele is persistent right from the early seedling stage, except in *L. cernuum* where the phloem shows considerable differentiation. The mixed type of the stele, as achieved in some of the species belonging to *Urostachya* (*Selago-Phlegmaria*) section, e.g. *L. varium* and *L. billardieri* (HOLLOWAY, 1919, pp. 171-173), is very much different from that found in *Inundata-Cernua* section of the genus.

Thus in the light of the great plasticity in the stellate and parallel-banded stele in modern *Lycopodium* the axis with radial stele is included in *Lycoxylon indicum* which otherwise includes axes with parallel-banded stele. Since less plasticity is noted in the mixed stele in the living *Lycopodium*, the Nipania specimen showing the mixed stele is described as a distinct type.

Whether Stems or Roots ? — In the absence of the outer layers of the cortex which would bear the leaf-traces and leaf-bases, it is difficult to determine whether the present specimens belonged to stems or roots. In certain species of modern *Lycopodium* the vascular cylinder of the root is similar to that of the stem, e.g. *L. annotinum* and *L. complanatum* (RUSSOW, 1872), *L. wightianum* (CHOWDHURY, 1937, p. 200), and aerial roots of *L. volubile* (HOLLOWAY, 1916, p. 239). The stelar anatomy of the cortical roots varies in different species and sometimes in the same species, as *L. phlegmaria* (CHOWDHURY, 1937, pp. 210, 211; PL. 14, FIG. 28; TEXT-FIG. 16a). Although the stelar structure of the root is generally different from that of its own stem, it may resemble that of a stem belonging to the other sections of the genus. For instance, a stem of *L. selago* (*Selago-Phlegmaria* section) has a radial stele, while the roots, particularly the older ones, may have parallel-banded stele which resembles the stele of the stem in some species of the *Clavata* section (SEXELBEY, 1908, p. 22).

Besides these three kinds of the axes, microspores and megaspores belonging to the Lycopodiaceae (VISHNU-MITTRE, 1954, pp. 120, 121, 125) have also been described from Nipania chert. It is interesting to note that the stelar pattern in these axes remarkably compares with that of three or four sections of the modern *Lycopodium*. Similarly the spore Types 1 and 2 in the subgroup *Reticulatisporites* (VISHNU-MITTRE, 1954, p. 120) compare with the spores of some species of modern *Lycopodium*. The occurrence of several *Lycopodium*-like axes probably belonged to different species of *Lycoxylon*. Whatever may be the value of the lycopodiaen material described here it is undoubtedly certain that Lycopodiaceae, not very unlike its modern representatives, existed in the Jurassic horizon. Lycopodiaen megafossils so far known either from the Palaeozoic or from the Rhaetic are very much unlike the modern forms in being woody or large plants. Jurassic lycopods of Nipania were herbaceous in habit like the modern lycopods. When did the lycopods attain the herbaceous habit is unknown, but it must have been somewhere in the pre-Jurassic period.

Filicales

A. FRONDS

Genus *Sphenopteris* Bgt.

Sphenopteris sp.

The specimen, about 5 mm. long, consists of linear, narrow and dichotomously branched segments with entire margins and a round apex. Each segment is traversed by a single vein.

The epidermis consists of sinuous cell walls. Stomata not seen. Mesophyll is made up of cubicular cells.

Comparison — In its external characters the specimen compares with the pinnules of the impressions described as *Sphenopteris khairbaniensis* Ganju from the Rajmahal Hills, Bihar (GANJU, 1946), but differs from it in its shorter segments. The anatomy of *S. khairbaniensis* is not known.

Genus *Cladophlebis* Bgt.

Cladophlebis sahnii sp. nov.

Pl. 1, Figs. 4, 5; Text-figs. 4, 5

There are three specimens: a fragment of a frond, about 2·8 cm. long, with a complete pinna 1·5 cm. long, and three fragments of pinnae from about 6 mm. to 1·5 cm. long.

Rachis is broad; pinnules $1\text{-}3 \times 1\text{-}1{\cdot}5$ mm., shorter and broader with a round to bluntly pointed apex, attached by the whole of the broad base to the axis of the pinna. Midrib is well marked. Secondary veins arise from it at a wide angle and run more or less obliquely upwards to the edge of the lamina and dichotomize there. Pinnules are entire. But for the presence of double dichotomy in the lowermost secondary vein, single dichotomy is noted as a rule.

The specimens are petrified and studied in more or less surface sections only.

Anatomy — Secondary veins are made up of elongated rectangular cells. Each vein or veinlet is lined on either side by a single row of broader cells. The lamina in between the veins consists of shorter cells which are more or less round.

In one of the specimens few stomata are seen scattered while the epidermal cells are not preserved. Few sinuous, walled epidermal cells are seen in a pinnule of another specimen (PL. 1, FIG. 4). In a third specimen (TEXT-FIGS. 4, 5) both the stomata and the sinuous epidermal cells are seen. The stomata are ellipsoidal in shape.

In some pinnules of one of the specimens (PL. 1, FIG. 4) along the margin are seen what appear to be ridges made up of elongated thick-walled cells arranged at right angle to the length of the pinnule (PL. 1, FIG. 5). These ridges are seen not only near the termination of the secondary veins but also occurring between the veins. These might perhaps represent the interstitial ridges.

Comparison — *Cladophlebis sahnii* is the only species in the genus *Cladophlebis* whose anatomy is known. Some anatomical details, revealed by maceration, in the laminar portion of *C. indica* were, however, described by Jacob (1938, pp. 11-13). The pitted cells and the cavities filled with brown substance in the laminar portion of *C. indica* are not observed in Nipania specimens.

Though in external features *C. sahnii* approaches *C. denticulata* but nothing is known about the anatomy of the leaves of *C. denticulata*.

B. ISOLATED PETIOLES OR RACHISES AND SECTIONS OF LAMINEAE

The detached specimens in the Nipania chert comprise five Types.

Type 1

Pl. 1, Figs. 6, 7

The petiole, about 2×2 mm., a single cross-section of which is available, has an unbroken deeply inrolled horse-shoe-shaped stele enclosed in a thick sclerotic sheath. The stele is more or less wavy with the protoxylem groups tucked in. The endarch protoxylem groups are about 12-13 in number. Each protoxylem group is made up of small xylem tracheids enclosing an open space — a sort of an island of parenchyma (PL. 1, FIG. 7).

Comparison — The petiole resembles very much the petiole of *Gleichenia* (BOWER, 1926, pp. 197, 198; FIG. 479), but for the large number of protoxylem groups in the Nipania specimen which in *Gleichenia* are only 3 or 4. Petioles resembling *Gleichenia* were reported from Nipania by Rao (1948, p. 253).

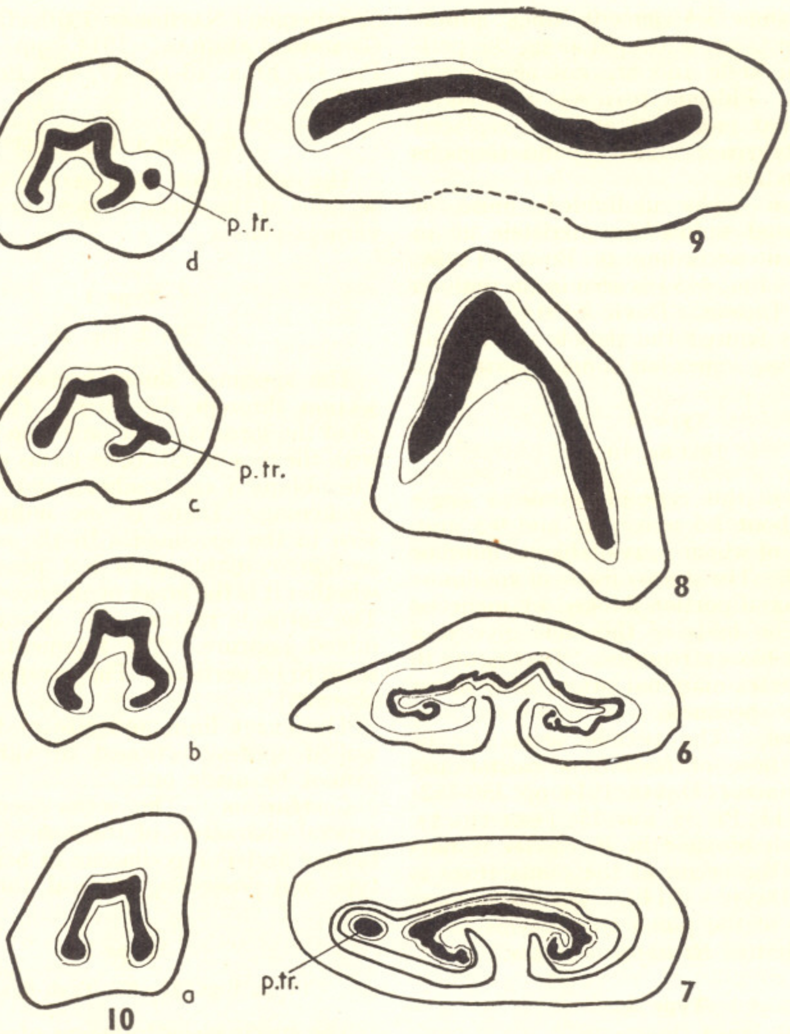
The C-shaped stele of our fossil petiole resembles also the petiolar stele of Osmundaceae which has large number of protoxylem groups. The soft parenchyma surrounding the dark sclerotic sheath, a regular and recurring feature of the Osmundaceous leaf-bases (BOWER, 1926, p. 134), is not known in the Nipania specimen.

Type 2

Text-figs. 6, 7

The petiole, about $1 \times 0{\cdot}5$ mm., in two serial sections, more or less oval in shape, is flattened perhaps due to preservation. The C-shaped xylem band has incurved margins. It is continuous and very much fluted. Protoxylem groups, twelve to fourteen in number, are endarch and do not enclose any island of parenchyma.

The ground tissue mostly crushed consists of thick-walled smaller cells. In one of the sections, cut more or less obliquely by the metaxylem, tracheids show the scalariform thickening, while the annular pitting is seen in the protoxylem elements.



TEXT-FIGS. 6-10 — 6, petiole Type 2. Cross-section of a specimen showing sinuous nature of the C-shaped stele with incurved margins. × 26½. 7, cross-section of another specimen showing the outgoing pinna trace. × 23½. 8, 9, petiole Type 3. Cross-sections from two different specimens. × 23½. 10, petiole Type 4. Four serial cross-sections (*a-d*) showing the extramarginal origin of the pinna-trace (*p.tr.*). × 23½.

Text-fig. 7 shows an outgoing pinna-trace in a solitary cross-section of another ± similar specimen.

Comparison — The specimen shows closer resemblance to the petioles of *Tinpaharia sinuosa* Jacob, a Jurassic fern known from Tinpahar in the Rajmahal Hills, Bihar, but differs from it in the absence of island of parenchyma enclosing the protoxylem groups.

Type 3

Text-figs. 8, 9

There are four specimens in 1-3 serial sections. The petioles, about 1 × 1-1·5 mm., are oval or triangular (TEXT-FIGS. 8, 9) and possess a more or less thick band of stele, straight or shaped like an inverted V, but the margins are not incurved. The stele is continuous. The band is 5-8 cells thick;

metaxylem alone 3-4 elements thick; protoxylem elements are scattered along the periphery of the stele and are not aggregated into groups. Phloem, pericycle and endodermis are not preserved and are replaced by an empty space. The ground tissue is sclerenchymatous.

Comparison — The undivided, more or less attenuated saddle-like meristele as in the specimen, according to Bower (1926, pp. 160, 161; FIG. 445) is seen in the petioles of modern *Anemia*. Davie (1914; PL. 33, FIG. 4) has figured the petiole of *Anemia collina* showing somewhat similar characters.

Type 4

Text-fig. 10

The stele in this type of petiole, a single specimen, about 3·5 mm. long and 9·5 mm. in diameter, of which is available, is more or less plicated. The stele consists of an almost concave abaxial portion flanked by incurved margins. The folds of the stele give it a regular hook-like extremities. Text-figure 10 shows the extra-marginal origin of a pinna trace in the specimen.

Comparison — The petiole seems to be similar to those of *Balantium culcita* and *Histiopteris incisa* (DAVIE, 1914, pp. 350-352; PL. 34, FIG. 13; PL. 35, FIG. 15; TEXT-FIG. 1). But the arch of stele in *B. culcita* is flat-topped and the origin of the pinna trace is marginal (DAVIE, 1914). The extra-marginal origin of the pinna trace seems to be similar to that of *Histiopteris incisa*.

Type 5

Pl. 1, Figs. 8, 9

Closely associated with the petiole Type 2 but not in organic connection, the slide shows a fragmentary isolated pinnule cut in cross-section, only two serial sections of which could be prepared. In one of the veins the specimen shows a C-shaped trace with incurved margins (PL. 1, FIG. 9). The trace has only 4-5 protoxylem groups. The softer tissues are not preserved. It is surrounded all round by a sclerenchymatous tissue which forms a ring round it. The mesophyll of the lamina is loose.

Comparison — Very much similar anatomy is described in the isolated fossil pinnules believed to belong to *Osmundites spetsbergensis* Nath. from the Tertiary of Nordenskiöldsberg and Van-Mijensberg, Spitzbergen (NATHORST, 1910, cf. KIDSTON & GWYNNE-VAUGHAN, 1914, pp. 471, 472; PL. 42, FIGS. 13-16, 17, 18; PL. 43, FIGS. 25-27).

C. ISOLATED SORI

The isolated sori are also discovered in thin sections of the chert. They are sectioned in various planes.

Type 1

Pl. 2, Fig. 10

The specimen shows probably a vertical section through the sorus. The receptacle (*r*) of the sorus is borne on a vein which along with the mesophyll tissue forms an elevation. The obliquely cut tracheids show scalariform thickening. There is one indusium (*ind.*) seen in the specimen. In the only isolated section available it is not possible to say whether it is the lower or the upper indusium. The sorus is mature and appears to be of mixed nature. The fragmentary annuli seem to be vertical. The paraphyses are not observed.

The exact form and size of the smooth-walled spores sectioned in various planes cannot be made out.

Comparison — The sorus seems to show general characters of the sori of Dennsteadtiaceae and Polypodiaceae in being a mixed type and possessing vertical annuli.

Type 2

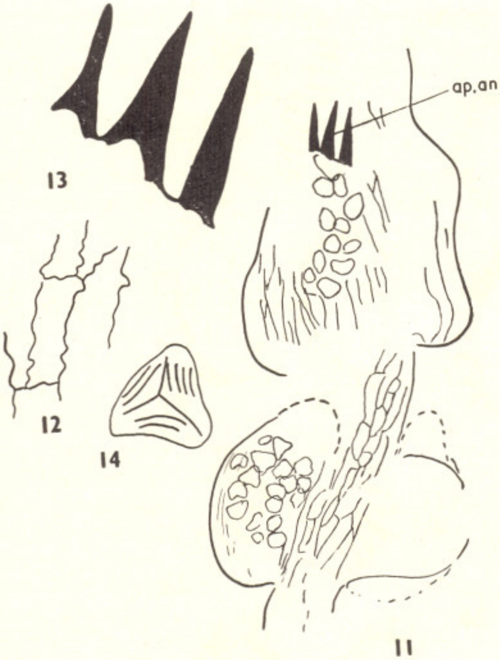
Pl. 2, Figs. 11, 12; Text.-figs. 11-14

The specimen, a fragment of a fertile leaf, bears 5-6 sporangia singly arranged in a linear row.

The sporangia are large, $1 \times 2{\cdot}5$ mm. to 0·5 mm. Annulus (*ann.*) apical made up of elongated thick cells arranged vertically a little below the apex (*ap. pl.*). Only two of these cells are seen in a vertical section of a sporangium (PL. 2, FIG. 12). These cells are very finely striated, with striations at right angle to the length of the annulus.

Spores 95 μ, tetrahedral, triangular, triradiate. Exine made up of parallel-running and dichotomizing ridges. Angles round and sides retracted.

Another specimen (TEXT-FIG. 11), about $3{\cdot}3 \times 1{\cdot}2$ mm., shows ovoid sporangia, $847 \times 500\ \mu$, arranged singly on either side of the lamina. This specimen probably shows a



TEXT-FIGS. 11-14 — 11, Sorus Type 2. A fragment of a fertile leaf bearing 3 ovoid sporangia each with apical annulus. × 53½. 12, epidermal cells on the wall of a sporangium. × 250. 13, a part of annulus enlarged. × 250. 14, a spore. × 250.

surface section while the specimen described above shows an oblique vertical section. The annulus in the sporangia of this specimen is also apical, only three teeth-like remains of which are preserved in one of the sporangia (TEXT-FIGS. 11, 13). The wall of the sporangium is made up of rectangular cells with wavy walls (TEXT-FIG. 12). The spores are exactly similar to the spores of the specimen described above except that they are slightly smaller in dimensions above 88·8 μ in size (TEXT-FIG. 14).

Comparison — In possessing individual sporangia with apical annulus and striated trilete spores, the specimen seems to show affinities with the Schizaeaceae.

In general characters the specimen compares with the impressions of various species of *Klukia* (RACIBORSKI, 1890 & 1894; SEWARD, 1910; BOWER, 1926; OISHI, 1939; HARRIS, 1946) known from the Jurassic of Poland and the inferior Oolite of Yorkshire Coast. The Nipania specimens being fragmentary, detailed comparisons cannot be made. Further the spores, known only in *Klukia exilis*, are different (HARRIS, 1946, p. 362).

The schizaeaceous nature of the specimen is further confirmed by the architecture of the spore wall which is very much like that of the spores of *Anemia* and *Mohria* (KNOX, 1938, p. 447; BOWER, 1926, p. 167, FIG. 451, K). In the wavy nature of the cells of the sporangia the second specimen differs from *Anemia*, the sporangia of which have straight-walled epidermal cells (DIELS cf. ENGLER & PRANTL, 1902, p. 357).

Type 3

Pl. 2, Figs. 13, 14

The fragmentary specimen is completely carbonized. It consists of a cylindrical axis made up of rectangular cells elongated along the length of the axis. It bears at its right angle a small lateral branch which gives off two to three secondary branches, each of which ultimately branches into two and bears a sac-like sporangium.

The sporangia, ruptured irregularly, are swollen bodies. Annulus or any other mode of dehiscence is not observed. The wall of sporangium is made up of elongated polygonal cells (PL. 2, FIG. 14). Spores not seen.

Comparison — Branched sporangiophores with sporangia devoid of annulus are not known so far in the fossil state. Amongst the living plants branched sporangiophores, bearing sporangia devoid of annulus, are met within the Ophioglossaceae, viz. *Helminthostachys* (BOWER, 1926, p. 74, FIG. 374, C).

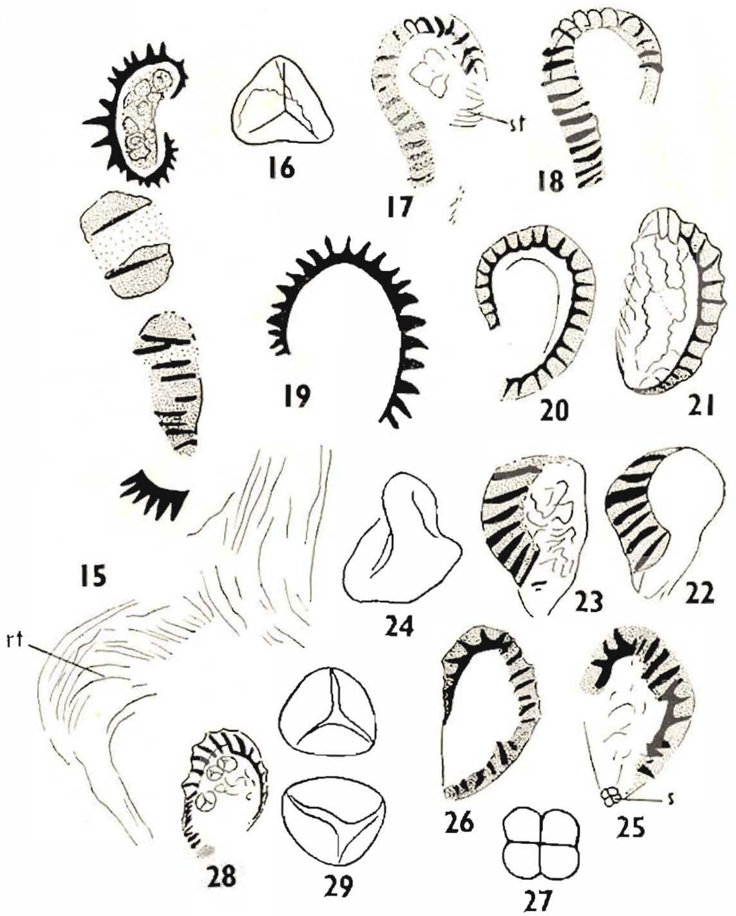
D. ISOLATED SPORANGIA

There is plenty of record of the fossil sporangia *in situ*. The detached fossil sporangia are scantily known. From the Jurassic rocks of India Jacob (1938) and Rao (1943) described the isolated fossil sporangia. Under the name *Schizaeopteris mesozoica*, Stopes and Fujii (1910) described certain isolated schizaeaceous sporangia from the Upper Cretaceous of Hokkaido in Japan.

Type 1

Pl. 3, Fig. 17; Text-figs. 15-33

Sporangia, 350-550 × 150-400 μ, with a vertical, probably oblique, incomplete, annulus; stomium transverse. Spores, 25-35 μ, tetrahedral, trilete, smooth-walled.



Sporangium Type 1

TEXT-FIGS. 15-29 — 15, a specimen showing annuli of four sporangia arranged in a vertical row and with a reflexed tissue (*rt*) below. × 53½. 16, a spore from the topmost sporangium of above specimen. × 250. 17, 18, a sporangium at two different focii. *St.*=stomium. × 53½. 19, 20, indentations of two more sporangia. × 53½. 21, a sporangium showing the sinuous epidermal cells. × 53½. 22, 23, another sporangium at two different focii. × 53½. 24, a spore from above. × 250. 25, 26, another sporangium at two different focii showing a stalk (*st*). × 53½. 27, cross-section of a stalk from above. × 250. 28, another sporangium with spores. × 53½. 29, spores from above enlarged. × 250.

Type 1 is represented by more than 16 specimens. The stalk, preserved in one case (TEXT-FIGS. 25, 26) is four-celled, while in another sporangium (TEXT-FIGS. 30, 31) the stalk is vertically cut so the number of cells it is made up of is not known. In several sporangia the annulus seems to be vertical and oblique (TEXT-FIGS. 17-19, 22, 23, 25, 26, 30-33). In one of the specimens shown in Text-fig. 15, measuring about 3·1 mm. in length, four fragmentary to complete annuli are seen preserved in a linear row with a partly reflexed tissue (*rt*) below. The specimen probably belongs to a sorus and the reflexed tissue probably represents the indusium. A more or less complete indentation in the above specimen measures 381 × 180 μ in size and the trilete spores (TEXT-FIG. 16) measures about 27·5 μ in size. The spores in the sporangium, about 360 μ in size shown in Text-fig. 28, are 26·30 μ with the open trilete, while in another sporangium (TEXT-FIGS. 22, 23) about 400 μ, the spores are 30-35 μ in size. Stomium, wherever seen, is found to be transverse.

The wall of the sporangium is seen preserved only in four sporangia. It consists of wavy epidermal cells in the sporangium shown in Text-fig. 21 and straight-walled epidermal cells in the sporangia shown in Text-figs. 30-33.

The specimen in Pl. 3, Fig. 17, shows two sporangia partly overlapping one another. The spores measure 66 μ in size.

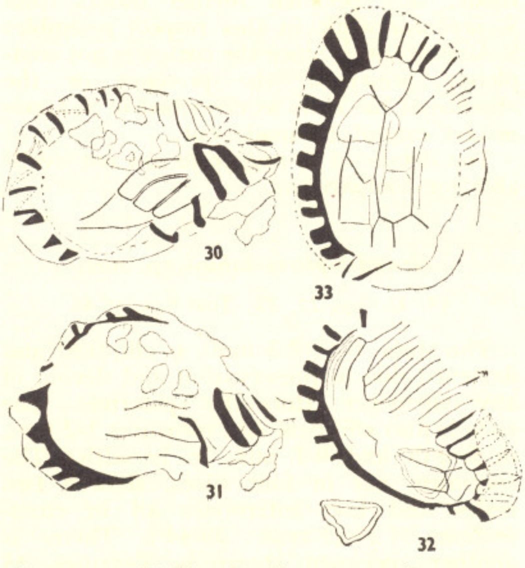
Isolated and empty sporangia with vertical annuli from Nipania chert were first described by Rao (1943). Sporangia with vertical incomplete, oblique annuli and transverse dehiscence occur in the Dennsteadtiaceae, Dicksoniaceae and Polypodiaceae.

Type 2

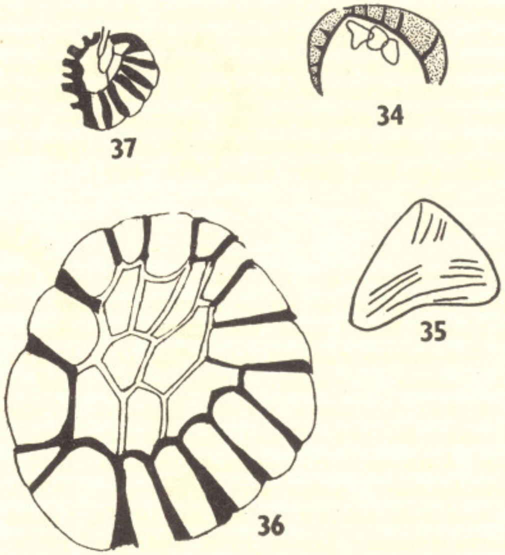
Pl. 2, Figs. 15, 16; Text-figs. 34, 35

Sporangium, 480 × 260 μ, with a vertical and probably oblique annulus. Spores, 41-50 μ, tetrahedral, trilete. Spore wall ornamented with very fine, often dichotomizing, ridged and assymmetrical striations.

Tex-fig. 34 shows another fragmentary specimen with similar spores *in situ* (TEXT-FIG. 35).



TEXT-FIGS. 30-33 — 30, 31, a sporangium at two different focii showing the oblique annulus, straight-walled epidermal cells. × *ca.* 15. 32, 33, two more sporangia showing the oblique annulus, stomium spores and straight-walled epidermal cells. × *ca.* 15.



Sporangium Type 2

TEXT-FIGS. 34-37 — 34, a fragmentary sporangium with spores. × 53½. 35, a spore from above. × 250. 36, 37, indentations of two sporangia showing transverse annulus. × 153½.

More or less similar spores with comparatively thicker striations are described from the same chert as *Liratosporites* Type 1 (VISHNU-MITTRE, 1954, p. 119; PL. 1, FIGS. 10, 14-16) and shown to belong to the Cyathaeaceae than the Schizaeaceae (VISHNU-MITTRE, 1954, p. 125). This is confirmed by the non-schizaeaceous type of the annulus in the specimen.

Type 3

Pl. 3, Fig. 18, Text-figs. 36, 37

The specimen (TEXT-FIG. 36) about 170 μ in diameter is seen from its distal end. The annulus appears to be uniseriate, horizontal and complete. Spores not preserved.

The specimen in Text-fig. 37 shows another similar sporangium at lower magnification.

The specimens show characters of the sporangia of Gleicheniaceae (BOWER, 1926, p. 205; FIG. 489; EAMES, 1936, p. 186; FIG. 120).

The sporangium shown in Pl. 3, Fig. 18, about 240 × 166 μ, is made up of cells with straight walls and with a broad base. Annulus appears to be apical, transverse, consisting of 14-16 columner thick-walled cells. Since the plane of section is not known, it is not possible to say definitely about the nature of the annulus which reminds one of the schizaeaceous sporangia as well as the gleicheniaceous sporangia (BOWER, 1926, pp 167, 206; FIGS. 451, 489).

E. STEMS

Our knowledge of the structure of the Jurassic filicinean stems is very meagre and is chiefly based upon the following species: *Osmundites dunlopi, O. kolbei, O. gibbiana, O. sahnii* (SEWARD, 1907; KIDSTON & GWYNNE-VAUGHAN, 1907; SAHNI, 1920; VISHNU-MITTRE, 1955); *Gleichenites boodlei* and *Rhizomopteris gunni* (SEWARD, 1911); *Cyathocaulis nakogensis* (OGURA, 1927); *Ciboticaulis tateiwave* (OGURA, 1927); *Tinpaharia sinuosa* (JACOB, 1938, 1943 and 1950).

The stems described here comprise six new types. They are all fragmentary, measuring about 2 mm. to hardly about 25 mm. in length. In comparatively longer fragments several serial sections, while in smaller ones only 2-5 serial sections could be made. The specimens show either a solenostele or dictyostele. With the exception of one or two specimens which are devoid of roots or petioles or their traces, the rest have either both or either of them.

Because of the specimens being fragmentary and their details not completely known, the comparisons are only restricted to the Mesozoic silicified ferns.

Genus *Solenostelopteris* Kershaw

Solenostelopteris nipanica sp. nov.

Pl. 3, Figs. 19-21

The fragmentary specimen (PL. 3, FIG. 19), about 1 mm., in diameter, is only available in a single cross-section.

The cortical tissue is crushed and poorly preserved. It appears to be soft and parenchymatous. The innermost part of this tissue is comparatively darker in colour than the rest (PL. 9, FIGS. 19, 20). In the outer region are seen a root trace (*r.tr.*) and a C-shaped structure probably a petiole trace (*p.tr.*) both cut obliquely (PL. 3, FIG. 20).

The central ground tissue is sclerized and is made up of slightly radially elongated hexagonal cells with air spaces between them. The cells of the ground tissue in the centre are crushed. The cells at the periphery of this medullary tissue are smaller in size and less sclerized. In between the central ground tissue and the solenostele there is an irregular parenchymatous layer 1-2 cells thick. No parenchyma is noted in the sclerized layers of the ground tissue.

The stele is a solenostele and the specimen shows probably a cross-section through an internode slightly above the nodal region as it appears from the complete ring of the solenostele and a departing root trace and a petiole trace.

The xylem band is 1-3 tracheids wide. Xylem parenchyma is present. Protoxylem elements are exarch, in groups and also singly scattered along the metaxylem tracheids. Endodermis, phloem and pericycle mostly crushed and very indistinctly preserved.

The petiole trace appears to be C-shaped in outline with slightly incurved margins. No other structural details are noted in the petiole trace as well as in the root trace both of which are obliquely cut.

Comparison — In the absence of sclerized nature of the inner cortex the specimen differs from *S. japonica* and *S. loxsomoides*. In the absence of parenchymatous layer in the outer sclerized layers of the central ground tissue, the specimen further differs from *S. japonica* while in this respect resembles *S. loxsomoides*. Since the cortex is not completely preserved, the presence or the absence of the hairs as described in *S. loxsomoides* cannot be made out.

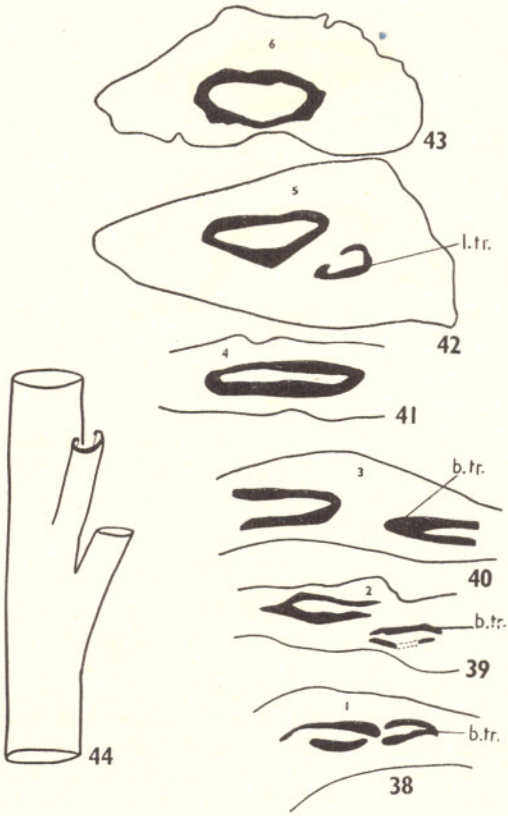
The details of *S. radicicula* are not available for comparisons.

Solenostelopteris sahnii sp. nov.

Pl. 3, Figs. 22, 23; Text-figs. 38-46

The stem, 6-8 $\times$ 2-3 mm., is elliptical and flattened due to preservation and devoid of any emergences from the epidermis. The stele is also elliptical and measures 1-2 mm. in length and 0·5 mm. in breadth. The specimen, cut in four slices, showed two nodes and four internodes all in cross-sections (TEXT-FIGS. 39-44). There is another specimen shown in Text-figs. 45 and 46 which is available in two serial cross-sections.

Three zones are recognized in the cortex (PL. 3, FIG. 23), viz. an outer 5-6-celled



Solenostelopteris sahnii sp. nov.

TEXT-FIGS. 38-44 — 38-43, six serial cross-sections of the stem showing the origin of a branch-trace (*b. tr.*) and a leaf-trace (*l. tr.*). × 28. 44, a restoration of the solenostele. × 4.

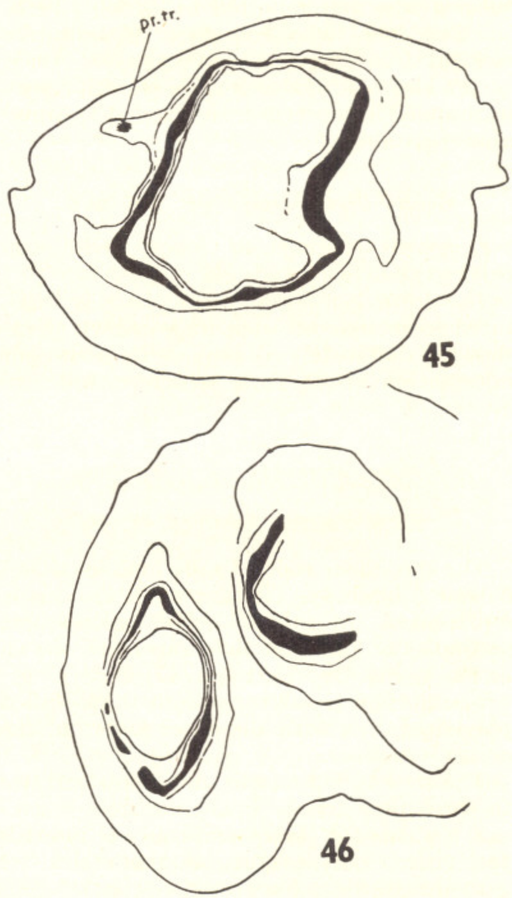
with lumina filled with some black substance and cells tangentially elongated (PL. 4, FIG. 24), a middle zone of 4-5 thick-walled large polygonal cells (PL. 4, FIG. 25). In a slightly oblique section the cells of the middle layer cut obliquely and appearing in patches look like the islets of thick-walled tissue (PL. 4, FIG. 26). The inner layer consists of small-celled mostly crushed tissue.

The stele is a solenostele and its continuity is broken here and there only by the departure of the leaf-traces, the gaps thus produced are closed up in the internodal region above before the next leaf-trace departs.

The stele is amphiphloic; endodermis, phloem and pericycle are poorly preserved. The xylem band is not uniformly thick. In its thickest part it is 4-5 elements thick (PL. 3, FIG. 23; PL. 4, FIG. 27). Xylem parenchyma is present. Tracheids show scalariform thickening. The protoxylem elements are scattered rather than arranged in groups.

A root trace is a diarch plate of xylem forming more or less an oval mass with poorly preserved cells around it perhaps representing the softer tissues (PL. 4, FIG. 28).

Mode of Branching — Following the stele from below it shows a complete solenostele. It is interrupted a little distance up by the departure of a branch trace and soon becomes a complete ring again. About 1-2 mm. beyond this stage the stele gives of a leaf-trace. Soon after the departure of the leaf-trace the stele again assumes the ring shape. A restoration of the stele by superimposing the serial sections is shown in Text-fig. 44.



TEXT-FIGS. 45, 46 — *Solenostelopteris sahni* sp. nov. Two serial cross-sections of another specimen. *pr. tr.*=root-trace. × $3\frac{3}{4}$.

Comparison — *S. sahnii* differs from *S. nipanica* and from the other species of *Solenostelopteris* chiefly in the nature of its ground tissue and the distribution of its various layers. The specimen also differs in size. It differs from *S. japonica* in the absence of parenchyma in the outer layers of the central ground tissue and from *S. loxsomoides* in the absence of the multicellular hairs.

Genus *Tinpaharia* Jacob

Tinpaharia sinuosa Jacob

An obliquely cut rhizome, about 2·5 cm. long and 1 cm. broad, obtained in five thick serial sections is identical with *Tinpaharia sinuosa* Jacob.

From Nipania the occurrence of *Tinpaharia* was first reported by Jacob (1938, pp. 248, 249) who compared *Matonia*-like rachises from Nipania (SRIVASTAVA, 1935, p. 285) with *Tinpaharia sinuosa.* Rhizomes surrounded by petioles are now discovered from Nipania.

Genus *Dictyostelopteris* gen. nov.

Diagnosis — Stems of fossil ferns, vascular system a dictyostele.

The form genus *Dictyostelopteris* is instituted to include all such fragmentary stems showing dictyostely as provide us with poor information about their structure and affinities.

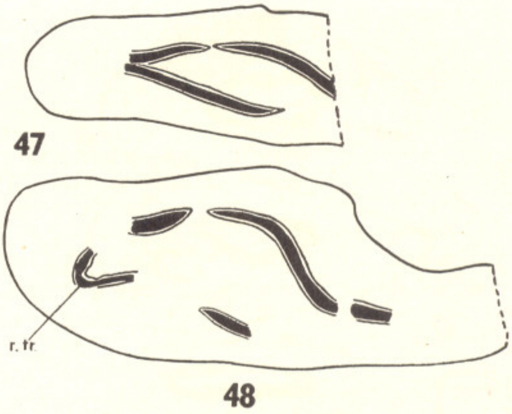
Dictyostelopteris rajmahalense sp. nov.

Pl. 4, Fig. 29; Text-figs. 47, 48

The specimen, about 5 mm. long, oval and flattened laterally, a fragment of an axis is represented by three serial microscopic sections the two complete ones are shown in Pl. 4, Fig. 29; Text-figs. 47, 48.

The ground tissue consists of thick-walled polygonal cells with the outer layers of the cortex crushed.

The stele is dictyostelic and consists of two to three meristeles. Each meristele is convex towards the cortex and concave towards the pith. The margins of the steles are turned inwards. Each meristele is 1-3 cells thick at the middle and tapers gradually towards both the ends. Metaxylem elements are large and hexagonal. Parenchyma present. Protoxylem exarch, in groups, 10-12 in each meristele.



TEXT-FIGS. 47, 48 — *Dictyostelopteris rajmahalense* sp. nov. Two serial cross-sections of a stem *r. tr.* = leaf-trace. × *ca*. 10.

A partly preserved leaf-trace probably in the stage of formation is seen in one of the sections only (TEXT-FIG. 48). The tissue in this region is crushed and has disappeared. Owing to this the exact nature and the origin of the leaf-trace could not be studied.

Comparison — In the nature of ground tissue, size and shape the specimen differs from *Dictyostelopteris* sp. and from *Tinpaharia sinuosa.* From *T. sinuosa* it also differs in the absence of sclerenchymatous sheaths enclosing the meristeles.

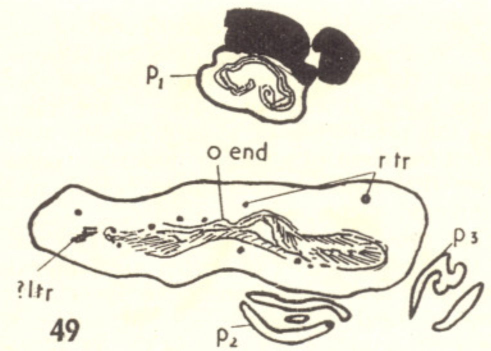
Dictyostelopteris jacobi sp. nov.

Pl. 5, Figs. 30, 32; Text-figs. 49-54

The fragmentary specimen, about 7×2 mm. in three serial sections is very much flattened dorsiventrally perhaps due to preservation.

Three petioles (p_1, p_2, p_3), one complete and the rest fragmentary, surround the rhizome in a spiral manner (TEXT-FIG. 49). Hairs or other appendages are not noted except on the petiole. Several root-traces in various stages of their departure are found in the cortex. Some obliquely cut tracheids are also seen in the cortex (*l.tr.*), probably they belonged to an outgoing leaf-trace. The structural details of most of the tissues are obliterated partly because of oblique sectioning and partly due to flattening.

The cortex, the major part of which is crushed, appears to have been sclerotic.



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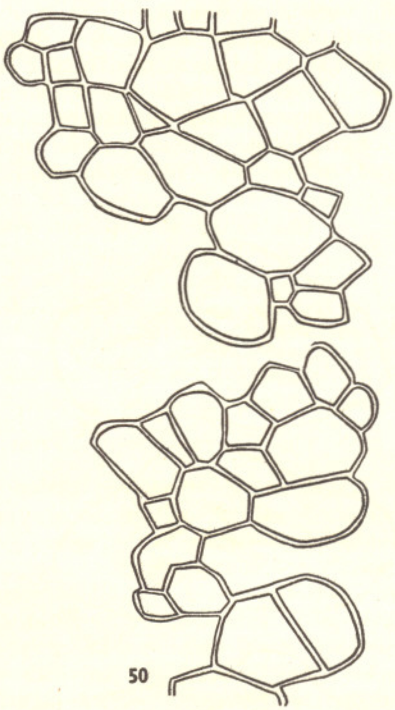
Dictyostelopteris jacobi sp. nov.

TETX-FIG. 49 — A cross-section of the type specimen showing the stem surrounded by three petioles. *o. end*=outer endodermis, *r. tr.*=root-traces. P_1, P_2, P_3 =petioles, *?l.tr.*=leaf-trace. $\times 3\frac{1}{2}$.



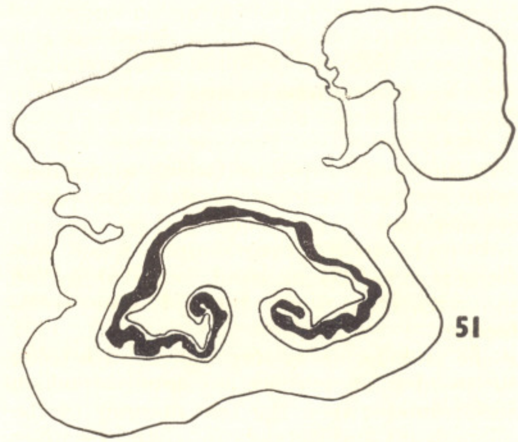
50

TEXT-FIG. 50 — A part of the meristele. × 95.

The tissue in the outer and inner cortex consists of broader polygonal cells.

The outer endodermis is well represented while the phloem and pericycle are crushed (PL. 5, FIGS. 30, 32).

The rhizome is traversed by an advanced type of a dictyostele. The meristeles, 4-6 tracheids thick at the thickest region (TEXT-FIG. 50) are wavy in outline. Xylem parenchyma is present. Metaxylem is made up of scalariform pitting. The exarch protoxylem (PL. 5, FIG. 32) occurs in groups. Island of parenchyma not recognizable. The number of the protoxylem elements not



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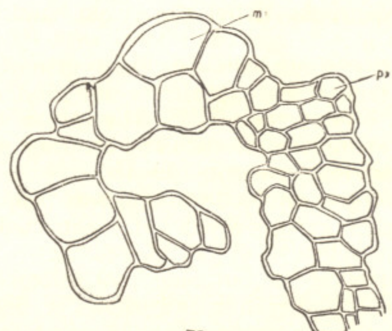

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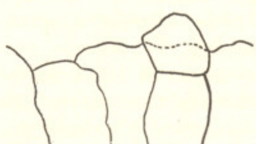

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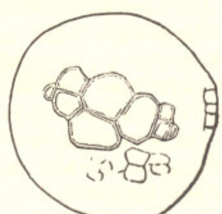


54

TEXT-FIGS. 51-54 — 51, *Dictyostelopteris jacobi* sp. nov. Cross-section of a part of a petiole. With pad-like tissue on the adaxial side of the petiole. $\times 3\frac{1}{2}$. 52, a part of the meristele of above. *mt*=metaxylem, *px*=protoxylem. × 63. 53, hairs from the petiole. 54, a cross-section of a root. × 63.

recognizable owing to the oblique cutting. The outer endodermis and the softer tissues are preserved here and there.

On the adaxial side of the complete petiole there lies a brown black sclerenchymatous pad-like tissue (PL. 5, FIG. 31; TEXT-FIGS. 49, 51). It is made up of polygonal cells which are elongated at the periphery. Multicellular hairs are seen arising from the abaxial side of the petiole (TEXT-FIG. 53). The xylem in the petiole forms an undivided wavy C-shaped band with incurved margins and lies in a cavity surrounded all round by the sclerenchymatous tissue (TEXT-FIG. 51). The xylem band is 2-4 cells thick (TEXT-FIG. 52).

Protoxylem groups are twenty in number. Each incurved margin encloses one protoxylem group. The phloem and pericyle are only represented by an empty space surrounding the xylem band bounded by an undifferentiated layer probably the endodermis.

The endodermis is surrounded by a thick sheath of sclerenchyma a column of which rises from between the free margins of the xylem band and extends into, and occupies the space enclosed by, the xylem band. It spreads in a semicircular form with its two lateral extensions following the course of the xylem band right up to its marginal curvature (TEXT-FIG. 51). The other two petiole are only represented by the fragments of the sclerenchymatous sheath.

Root traces are found to originate from the protoxylem groups which get constricted off from the xylem band (PL. 5, FIG. 32). The metaxylem in the outgoing root-traces consists of 3-5 elements and shows a diarch plate with two protoxylem groups (TEXT-FIG. 54). Xylem in the root trace is surrounded by phloem, pericycle and endodermis with only endodermis well represented. Free roots are not preserved.

Comparison — From *Tinpaharia sinuosa*, the only Jurassic fern with a dictyostele, the specimen differs in the absence of sclerenchymatous sheath enclosing the meristeles and in the absence of island of parenchyma in the protoxylem groups.

Dictyostelopteris fasciosteleoides sp. nov.

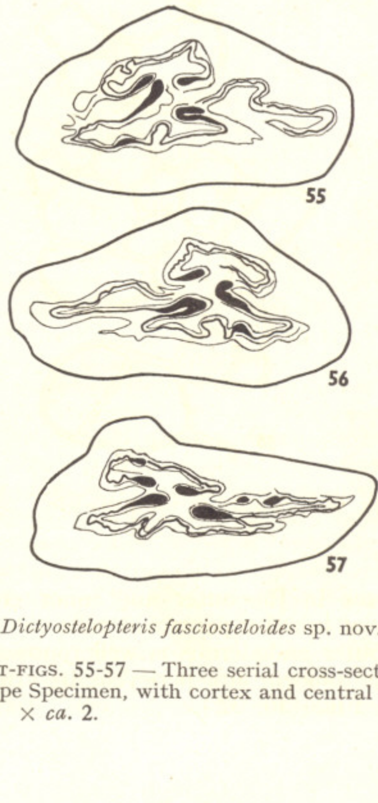
Pl. 5, Figs., 33-36; Text-figs. 55-61

The specimen (PL. 5, FIG. 33; TEXT-FIGS. 55-57), about 8 mm. long in four serial cross-sections, ovoid in shape and devoid of any hairs, scales or roots, is described as a rhizome though the oblique orientation of the outgoing trace, absence of roots or root-traces and the occurrence of a very closely associated fragment of a lamina indicate a possibility that the specimen might belong to a compound rachis.

The ground tissue is sclerized. The cells in the middle region of cortex are larger as compared to the inner and outer layers. In some cortical cells some sort of reticulate tissue is seen (TEXT-FIG. 58). At places the inner cortex extends as a short column into the central ground tissue of the rhizome and merges with it.

The central ground tissue, intercepted by the convoluted and fluted meristeles, forms a stellate outline with very much prolonged arms (PL. 5, FIG. 33; TEXT-FIGS. 55-57).

The stelar region, about 3×2 mm. in cross-section, consists of 3-4 meristeles each 1-2 elements thick except at the free incurved ends where it is 3-4 elements thick (TEXT-FIG. 60). Each meristele is very much fluted and occasionally overlapping itself. It is amphiphloic. Phloem (*ph.*) is well preserved while the pericycle and the



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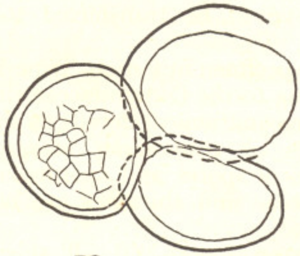
Dictyostelopteris fasciosteloides sp. nov.

TEXT-FIGS. 55-57 — Three serial cross-sections of the Type Specimen, with cortex and central ground tissue. × *ca.* 2.



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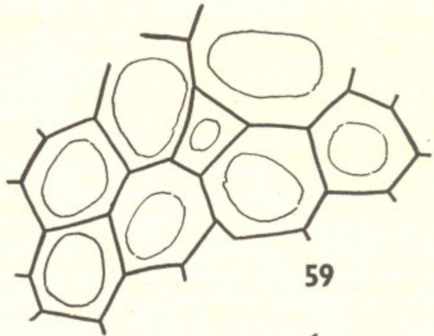

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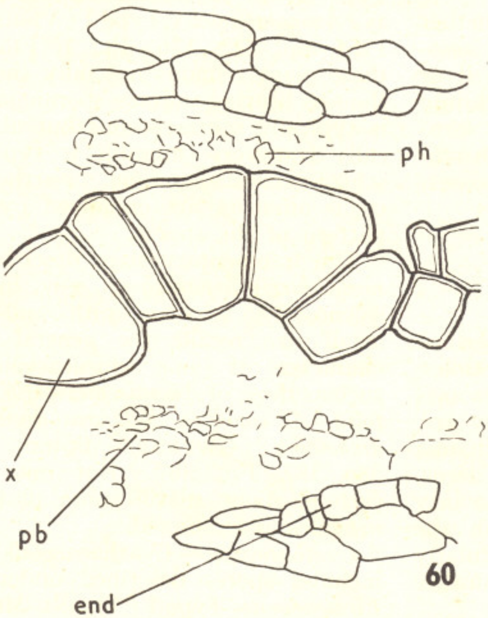

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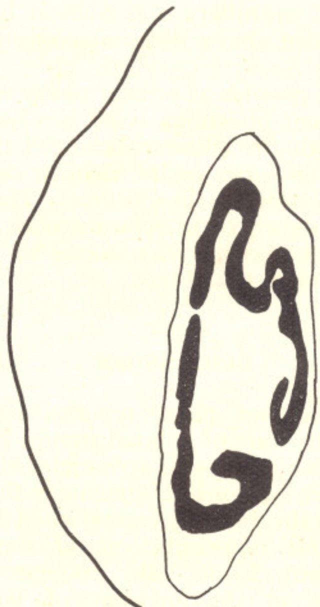

61

TEXT-FIGS. 58-61 — 58, 59, cross-section of the cortical tissue. Fig. 58 shows the reticulate pitting in one of the cortical cells. × 250. 60, a part of the meristele. *end*=endodermis, *ph*=phloem, *x*=xylem. × 250. 61, cross-section of the outgoing leaf-trace. × 53½.

endodermis (*end.*) are only recognizable at certain regions.

The free ends in some meristeles are fused together. The protoxylem is exarch and the groups of protoxylem are situated in the curvatures formed by the fluted meristeles. The protoxylem is made up of annular and spiral tracheids. The metaxylem consists of scalariform tracheids only.

Traversing the cortex is seen an obliquely placed C-shaped very much fluted trace (PL. 5, FIGS. 33, 34; TEXT-FIG. 61). It has not been possible to study its origin for want of material. An isolated petiole trace with identical ground tissue possessing a sinuous C-shaped xylem band shown in Pl. 5, Fig. 35 also probably belonged to a similar rhizome.

Lying very close to the stem is seen a section of a fragment of lamina '*c*' and another '*b*' also in close vicinity (PL. 5, FIGS. 33, 36).

A sorus '*a*' described under Sorus Type 2 is also seen lying in close proximity with the rhizome.

Comparison — The specimen in possessing very much corrugated meristeles and obliquely placed leaf-trace compares with a Cretaceous fern *Fasciostelopteris tansleii* (STOPES & FUJII, 1910). It differs from it in less number of the meristeles and slightly discontinuous leaf-trace. The origin of the leaf-trace and the nature of the pericycle cells are not known in the specimen so further comparisons with *F. tansleii* cannot be made.

In wavy nature of the steles, the petiole trace, and in the absence of sclerenchymatous sheath enclosing each meristele and in the absence of medullary and cortical bundles, the specimen shows dicksoniaceous characters.

It is not possible at present to say whether the fragment of lamina lying in close association with the rhizome belonged to it or not but the sorus in its vicinity certainly had no relation to the rhizome. The sorus has been shown to be schizaeaceous in affinities while the specimen seems to possess dicksoniaceous characters.

DISCUSSION

The filicinean plant remains described above, consisting of isolated fronds, petioles, rachises, laminae, sori, sporangia, rhizomes and spores, however, fragmentary they are, show that the Jurassic vegetation of Nipania had several representatives of the ferns. These plant fossils add to our scanty knowledge of the anatomy of both the sterile and the fertile ferns, particularly that of the stems from the Jurassic horizon.

Some of these fragmentary plant remains possess some such typical characters as to suggest their relationship with the modern ferns. Based on the affinities of these the representatives of the following families of the Filicales are recognized.

Osmundaceae — It is represented by *Cladophlebis sahnii* sp. nov. and a fragmentary rachis described as Petiole Type 5.

The form genus *Cladophlebis* was retained by Harris (1932, p. 30) for sterile osmundaceous fossil leaves. To the species *C. sahnii* described here is also referred a fragmentary frond possessing what appear to be like the interstitial ridges on the pinnules. Since it is not possible to prove that these ridges represent the soral initials, the specimen is included in the species *Cladophlebis sahnii*. Should it be proved that the leaves with interstitial ridges are fertile, the specimen will have to be transferred to the genus *Todites*.

The specimen in Petiole Type 5 is believed to belong to the Osmundaceae since it shows the same anatomical details as shown by the pinnules of *Osmundites skidgatensis*. The remains of spores and sporangia of the Osmundaceae and rhizomes are not found in Nipania.

Schizaeaceaceae — Of all the families of Filicales this family is represented by more convincing plant remains. The material includes two sori described under Sorus Type 2 and schizaeaceous spores described as ?*Azonomonoletes* Type 1 (VISHNU-MITTRE, 1954, pp. 122, 126; PL. 1, FIG. 24). In these plant remains not only the nature of the sori bearing solitary sporangia on lamina is typically schizaeaceous but also the apically transverse annulus is typical of the schizaeaceous sporangia. Further schizaeaceous affinities are enhanced by the exine pattern of the spores.

The fragmentary stem described as *Solenostelopteris nipanica* sp. nov. in possessing solenostely, sclerotic pith and extremely small size recalls the general anatomical characters of some schizaeaceous rhizomes such as those of *Anemia mexicana*, *A. adiantifolia*, *A. coriacea*, *Schizaea digitata* and *S. dichotoma* (GWYNNE-VAUGHAN, 1901, pp. 386, 387; FIG. 38). But one cannot be certain about it till more material of *S. nipanica* is examined.

Cyathaeaceae — Cyathaeaceous material includes spores described under the name *Liratosporites* Type 1 (VISHNU-MITTRE, 1954, pp. 119, 123; PL. 1, FIGS. 10, 14-16) and two sporangia described under Sporangium Type 2. None of the stems described here show cyathaeaceous affinities.

Gleicheniaceae — Sporangium Type 3 possessing gleicheniaceous type of annulus might have belonged to the Gleicheniaceae. Some of the solenostelic stems also might belong to this family but nothing can be said at present with certainty.

Deansteadtiaceae or *Dicksoniaceae* — *Tinpaharia sinuosa* Jacob has been shown to belong either to Deansteadtiaceae or Dicksoniaceae (JACOB, 1938, 1950). Rhizomes and petioles of *T. sinuosa* also occur in Nipania as described above.

About the affinities of the other filicinean plant remains nothing can be said at present.

GENERAL OBSERVATIONS ON THE FOSSIL FLORA OF NIPANIA

Comparison with Indian Fossil Floras — The Nipania fossil flora consists of an abundance of ferns, conifers and Pentoxyleae. Nilssoniales are completely absent and Bennettitales are very poorly represented.

The prevailing plant forms in the chert are *Nipanioruha*, *Nipaniostrobus*, *Carnoconites* and *Nipaniophyllum*. The most characteristic plant fossils include *Nipaniophyllum*, *Nipanioruha* and *Carnoconites*. The fossil flora of Nipania is typical in the absence of large-leaved Cycadophytes.

In the abundance of ferns and conifers the fossil flora of Nipania differs from the fossil flora of the Rajmahal Hills which is characterized by the abundance of cycadophytes, particularly the large-leaved ones and the ferns with a variety of the conifers (FEISTMANTEL, 1877 a, p. 154; WADIA, 1953, p. 197). Feistmantel based his conclusions on the study of eleven fossiliferous localities. Since then we have known several more localities and consequently our knowledge regarding the fossil flora of the Rajmahal Hills has greatly advanced. A comparative study of the floristic composition of all the localities in the Rajmahal Hills shows that some localities, viz. Amarjola, Chilgojori, Malipara, Kulkipara, Bindrabun (*Brindabun*) near Tinpahar, Sakrigali Ghat (softer bed), Kunjbana, etc., have not yielded any large-leaved cycadophytes but in the abundance of other cycadophytes, ferns and a negligible presence of conifers, the fossil flora of these localities resembles the typical flora of the Rajmahal Hills.

Besides Nipania there are some more cherty localities known in the Rajmahal Hills, viz. Chilgojori, Tinpahar and Bindrabun. Petrified plant remains have also been described from Amarjola. Individual comparisons of Nipania flora made with the floras of these localities reveals that each locality had its own characteristic vegetation which formed a distinct association of its own with some elements of the association common with those of the other localities. *Pentoxylon*, *Bucklandia* and *Ptilophyllum* are common in Amarjola and Nipania. *Brachyphyllum*, *Ptilophyllum* and *Bucklandia* are common in Nipania and Chilgojori. *Tinpaharia* is common in Tinpahar and Nipania.

Close to Nipania some leaf impressions are also found. Sahni & Rao (1933) reported the impressions of *Nilssonia fissa* from this area. Recently I discovered from near Dumurchir close to Nipania the following leaf impressions.

Thinnfeldia indica Fst., *T. odontopteroides* Bgt., *Dicksonia* (*Sphenopteris*) *bindrabunensis* Fst., *Clathropteris* sp., *Cladophlebis denticulata* Bgt., *Ptilophyllum cutchense* Morris, *Taeniopteris spatulata* McCl., *Brachyphyllum mammillare* Bgt., *Pagiophyllum* sp. cf. *P. divaricatum*, P. sp. cf. *P. peregrinum*, *Elatocladus conferta*, *E. jabalpurensis*, *E.* sp. cf. *Retinosporites indica* Holden.

In the absence of the large-leaved cycadophytes and in the abundance of conifers and ferns and few remains of cycadophytes this assemblage of leaf impressions resembles the fossil flora of Nipania though in most of its species it resembles the impressions known from the other localities in the Rajmahal Hills.

Floristic comparisons made with the other stages in the Rajmahal series show that in the abundance of ferns and conifers the Nipania fossil flora compares with the Floras of Jabalpur and Kota stages (WADIA, 1953, pp. 197, 198). In the absence of the large-leaved cycadophyta, the fossil flora of Nipania further compares with that of the Jabalpur group (FEISTMANTEL, 1877b, p. 100).

Comparison with Fossil Floras outside India — The cherts abounding in Jurassic plant remains from outside India are not many. Petrified Jurassic conifers are rare (HARRIS, 1953), so also the Jurassic ferns (KIDSTON & GWYNNE-VAUGHAN, 1907; SINNOTT, 1914; SEWARD, 1907, 1911; OGURA, 1927) and these are very different from the ferns and conifers described from the Nipania chert. Practically nothing is known about the Pentoxyleae from the Jurassic deposits outside India.

The following silicified plant remains known from the Cretaceous rocks of Japan (STOPES & FUJII, 1910) show common characters with the Nipania fossils: *Schizaeopteris mesozoica*, *Solenostelopteris loxosomoides* *Fasciostelopteris japanica*, *Niponophyllum cordaitiforme*, etc.

Age of the Nipania Deposits — The difference of the Nipania fossil flora in its general composition and in certain typical forms from the fossil flora of the Rajmahal Hills and its resemblance in this respect with the fossil flora of the Jabalpur and the Kota Stages shows that the Nipania deposits might belong to the uppermost strata in the Rajmahal Stage.

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EXPLANATION OF PLATES

PLATE 1

1. *Lycoxylon indicum* Srivastava. A cross-section of an axis from slightly above the nodal region showing dichotomy. × 65.

2. *L. indicum* Srivastava. A cross-section of an axis showing the stellate type of the stele. × 350.

3. *L.* Type 2. Cross-section of a part of the inner cortex in an axis. × 175.

4. *Cladophlebis sahnii* sp. nov. A fragment of a pinna. × 10.

5. A pinnule showing the interstitial ridges. × 60.

6. Petiole Type 1. A cross-section. × 90.

7. The stelar region of above shown enlarged. × 280.

8. Petiole Type 5. Cross-section of a fragment of a lamina showing two lateral veins. × 90.

9. One of the lateral veins from above shown enlarged. × 350.

PLATE 2

10. Sorus Type 1. The specimen *Ind*=Indusium, *r*=receptacle. × 100.

11. Sorus Type 2. A part of the sporophyll showing the sporangia. × 70.

12. A sporangium from above enlarged showing the apical annulus (*ann.*) apical plate (*ap. pl.*) and the spores (sp.).

13. Sorus Type 3. The specimen. × 70.

14. A part of the wall of sporangium from above. × 250.

15. Sporangium Type 2. × 39.

16. *Liratosporites* Type of spores from above. × 280.

PLATE 3

17. Sporangium Type 1. Vertical annuli of two sporangia lying over one another with *in situ* smooth-walled trile, tetrahedral spores. × 280.

18. Sporangium Type 3. A sporangium probably showing the apical annulus and the straight-walled cells of the wall. × 280.

19, 20. *Solenostelopteris nipanica* sp. nov. The type specimen. × 13, × 50. *R.tr.*=root trace. *P.tr.*=petiole trace.

21. A part of above showing the sclerized pith (*P*), outer and inner layers of Cortex (*O.L.* & *I.L.*). × 170.

22. *Solenostelopteris sahnii* sp. nov. A cross-section of the rhizome showing the leaf-trace (*l.tr.*). × 20.

23. Cross-section of a part of stem showing ground tissue, the Solenostele. *O.T.*=outer layer, M=middle layer, *I.N.*=inner layer, *R.tr.*=root trace. × 50.

PLATE 4

24, 25. *Solenostelopteris sahnii* sp. nov. Cross-section of a part of cortex showing the outer (*O.T.*) and middle layers (*M*). × 58, × 250.

26. Cross-section of a part of stem showing islands of tissue (*in*) in the cortex. × 85.

27. Cross-section of a part of the meristele showing metaxylem (*Mx*) protoxylem (*pr.*) and xylem parenchyma (*x.par*).

28. Cross-section of a part of the meristele with a recently detached root trace. × 40.

29. *Solenostelopteris rajmahalense* sp. nov. A cross-section of the specimen. *L.tr.*=leaf trace. × 13.

PLATE 5

30. *Dictyostelopteris jacobi* sp. nov. A cross-section of the stem showing cortex, Stelar region and the root traces (*R.tr.*). × 25.

31. Cross-section of a petiole trace. × 18.

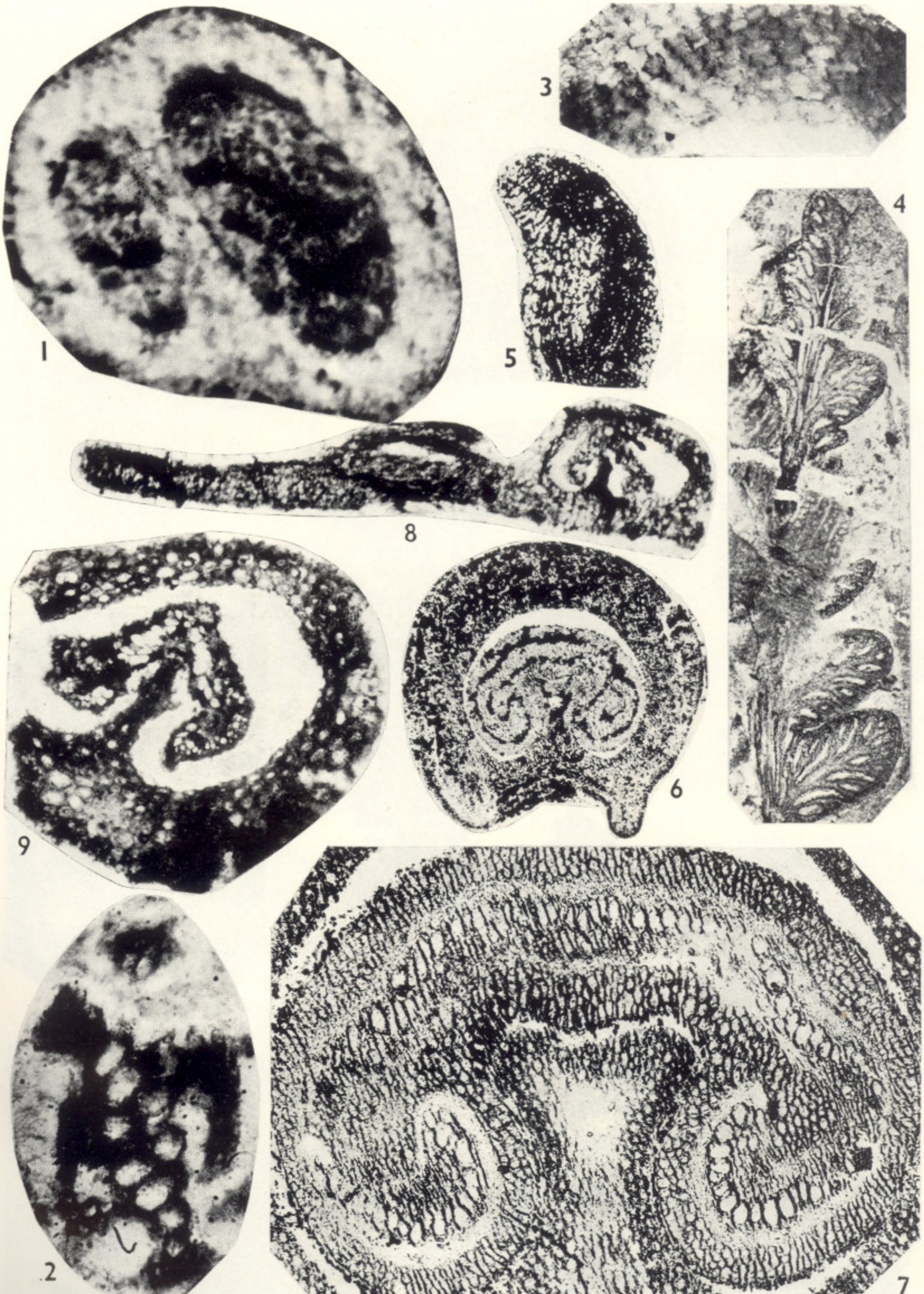
32. Cross-section of a part of the stem showing the origin of the root traces (*R.tr.*). *px.*= protoxylem. *end.* endodermis. × 40.

33. *Dictyostelopteris fasciosteloides* sp. nov. A cross-section of the Type specimen. × 15. *a*= a sorus described in Sorus Type 2. *b* and *c*=fragments of lamina.

34. Obliquely orientated leaf-trace in the cortical region of the specimen. × 75.

35. Cross-section of an isolated petiole. × 150.

36. Cross-section of a part of the specimen enlarged to show the closely lying leaf fragment. × 75.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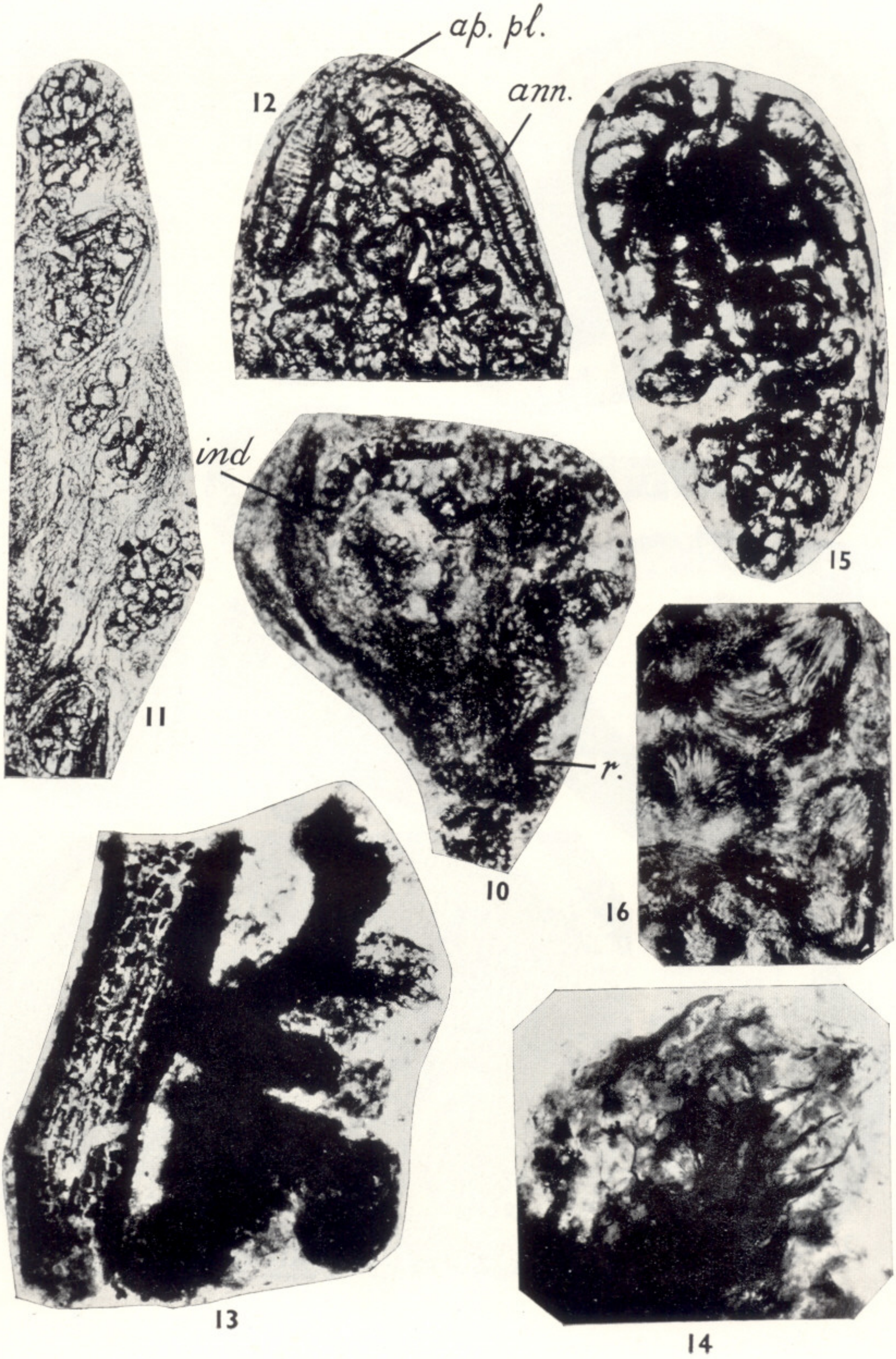
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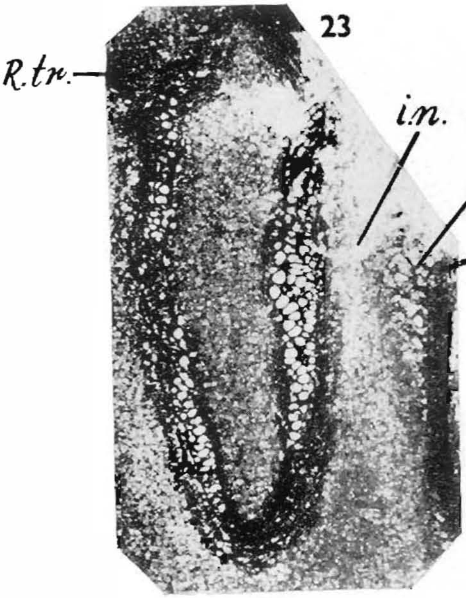

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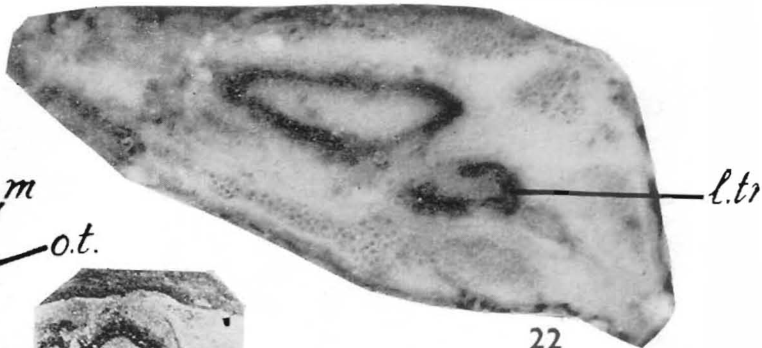

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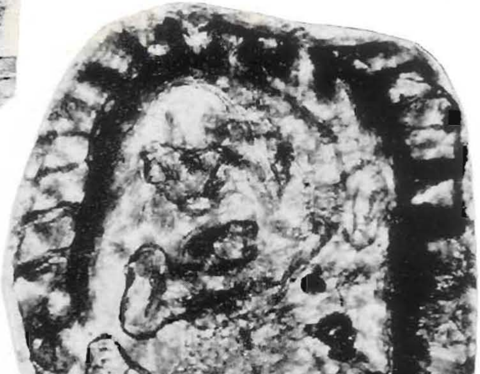

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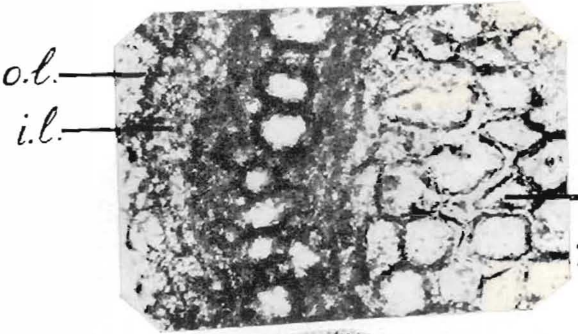

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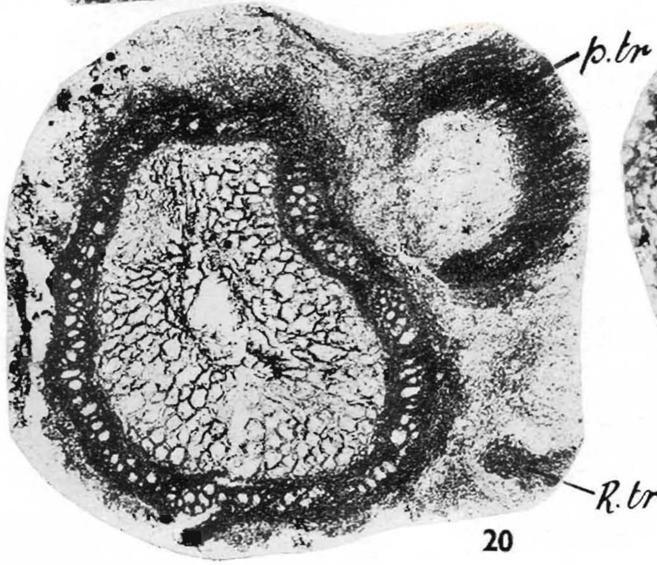

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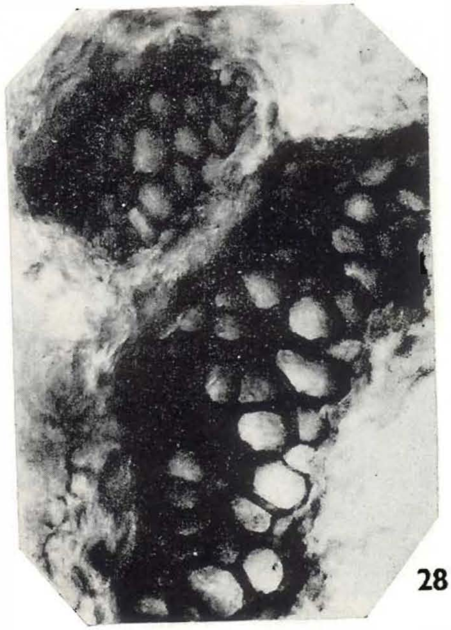

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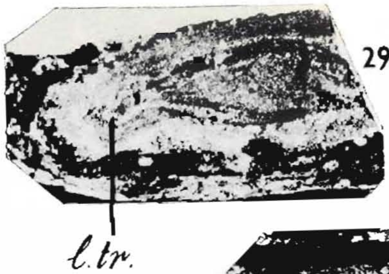

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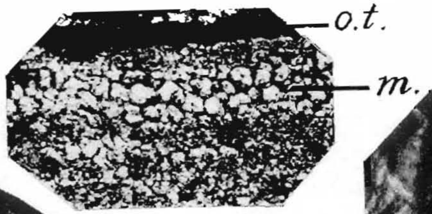

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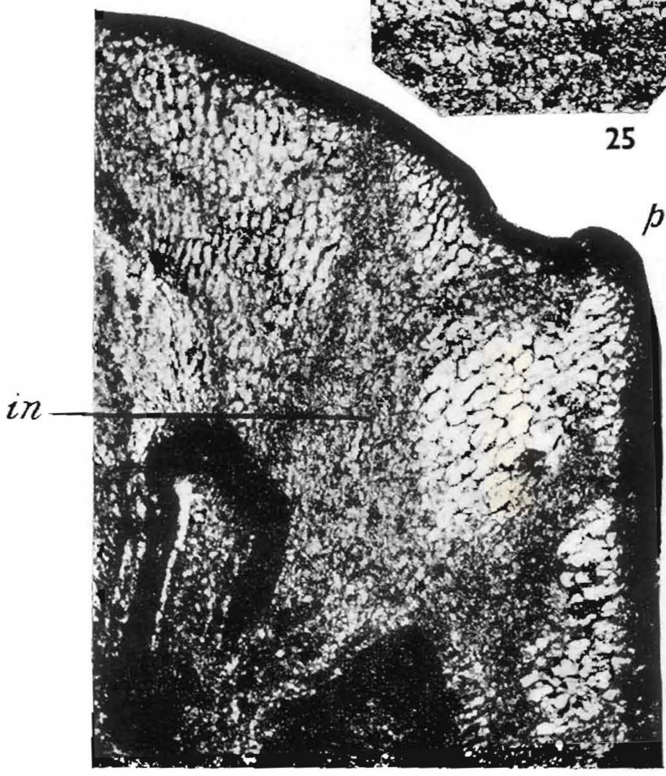

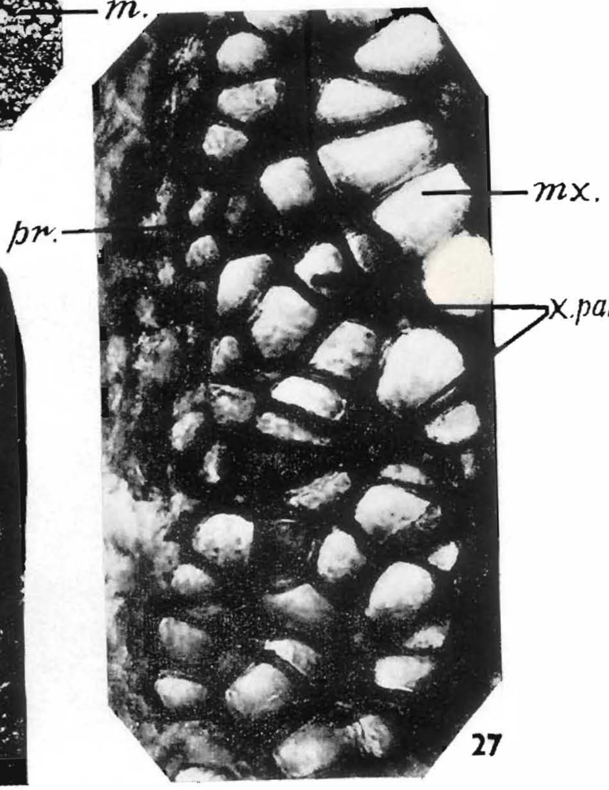

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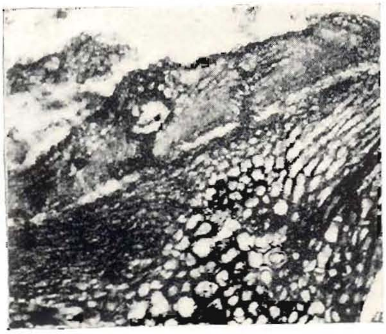

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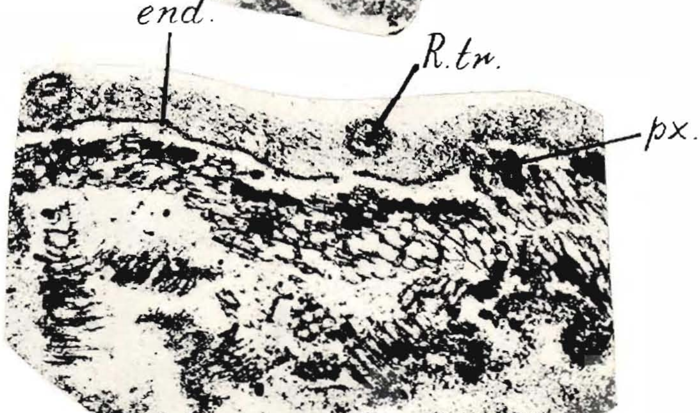

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