

STUDIES IN THE GLOSSOPTERIS FLORA OF INDIA—21. PLANT MEGAFOSSILS FROM THE LOWER GONDWANA EXPOSURES ALONG BANSLOI RIVER IN RAJMAHAL HILLS, BIHAR

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ABSTRACT

The present paper contains a description of plant megafossils from the Bansloi valley Lower Gondwana beds. The various fossils have been referred to 11 genera and 18 recognizable species. One species is new. The species recognized are *Phyllothea* sp., *Stellothea robusta*, *Schizoneura gondwanensis*, *Sphenophyllum speciosum*, *Pecopteris pteopteroids*, *Pecopteris* sp., *Alethopteris* sp. A., *Alethopteris* sp. B., *Sphenopteris hughesii*, *S. lobifolia*, *Noeggerathiopsis* cf. *N. hislopii*, *Glossopteris angustifolia*, *G. communis*, *G. indica*, *G. damudica*, *G. brownii*, *G. parallela*, *G. retifera*, *G. emarginata* sp. nov., *G. formosa*, *Gangamopteris* cf. *G. cyclopteroides*, *Gangamopteris* sp. and *Vertebraria* sp.

INTRODUCTION

THE name Rajmahal Hills is applied to the area bounded on the north by the river Ganga, on the east principally by alluvial plains and partly by the Ganga; on the south by Dwarka river and the districts of Birbhum and Bhagalpur (BALL, 1877). Their greatest length from north to south is about one hundred miles (FOX, 1934) and their maximum width about thirty miles.

Ball (*l.c.*) gives the general succession of the sedimentary deposits in these hills as follows in descending order:

Alluvium

Laterite

Gondwana System

Rajmahal Group

Dubrajpur Group

Barakar Group (Damuda series)

Talchir Group

Metamorphic series.

The Damuda series in the Rajmahal Hills cover an area of about seventy square miles and occur in patches in fringes roughly between long. 87° and long. 87° 35', and between lat. 24° 15' and lat. 25° 10'.

The rocks of the above group possess the same lithological characters as have been

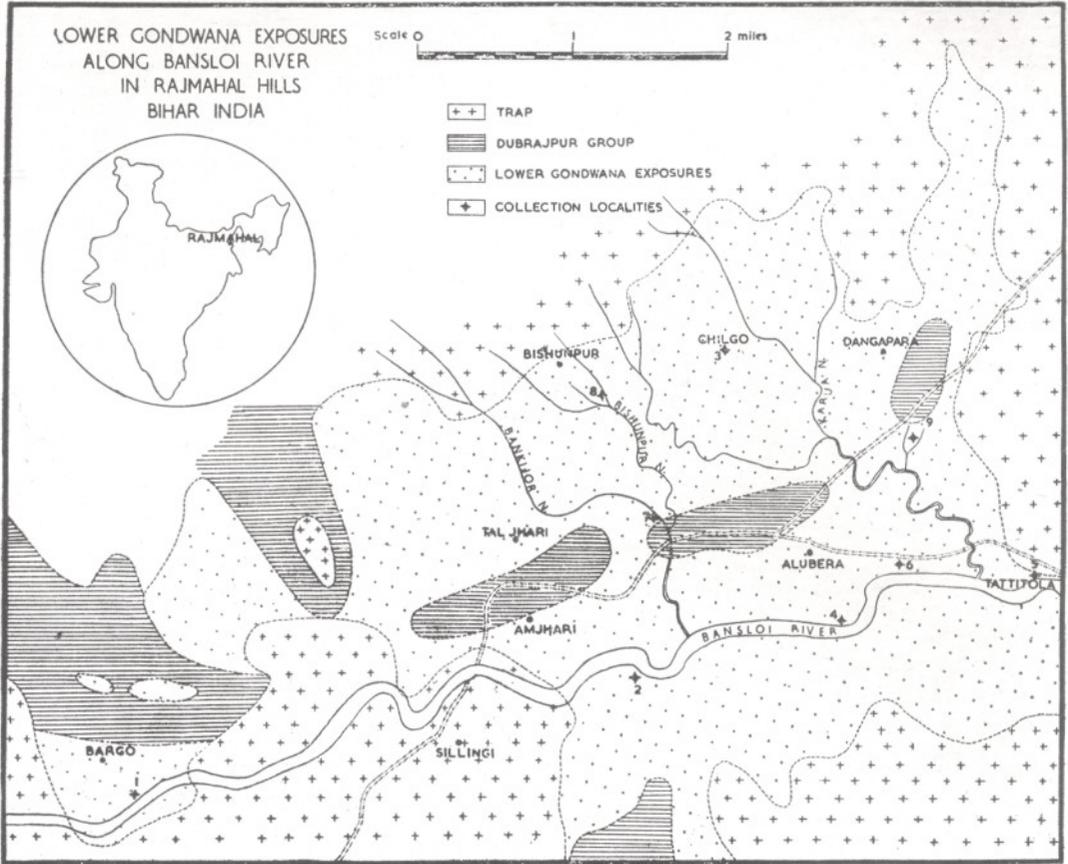
generally found in the Damuda coal measures in India. The thickness does not exceed 500 feet in any of the sections exposed in these hills. In places it thins out to nothing, the superimposed Dubrajpur beds or trap, as the case may be, gradually overlapping the gneisses or Talchirs.

The area investigated is a part of the above formations between the latitudes 24° 30'–24° 35' and longitudes 87° 25'–87° 30' (Survey of India Topo Sheet No. 72 P/6; TEXT-FIG. 1). The main river of the area is the Bansloi flowing in the west-east direction and receiving its tributaries from the north. This river during the rainy season turns into a violent torrent, otherwise it contains little water for the rest part of the year. Two main tributaries of Bansloi river in the area are Bankijor nalla which meets it about 1 mile southwest of Alubera, and Karua nalla meeting it about 1½ miles southeast of Alubera. The general elevation of the hills and plateaus varies from 500 to 800 feet above the sea. No considerable jungles of large forest trees exist in this area except in certain regions which are devoid of cultivation or population.

The rocks of the area consist of felspathic, friable grits and sandstones intercalated with arenaceous and carbonaceous shales. The sandstones are of various shades and usually the cementing material is ferruginous. Due to the uneven hardness of these sandstones, weathering of the rock often results in pot holes of various sizes and rough surfaces. Some of these sandstones exhibit current or graded bedding. In a few localities thin coal seams are also present. The general direction of the dip is 8–15° in NE.

So far no detailed work has been done on the fossil flora of the Lower Gondwana beds of the Rajmahal Hills. In his memoir on the Geology of Rajmahal Hills, Ball (1877) mentions *Cyclopteris* sp. ? and *Phyllothea* sp.

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TEXT-FIG. 1 — Map of the Bansloi river valley showing localities from where collections of Lower Gondwana fossils were made.

from the Talchir rocks and some leaves of *Glossopteris* from the Barakar shales near Ramgarh, south of Brahmini river. *Cyclopteris* sp. ? of Ball was later described as *Gangamopteris cyclopteroides* by Feistmantel (1876b). In his other work on the fossil plants of the Damuda series of Rajmahal hills Feistmantel (1880) described *Glossopteris communis*, *G. indica*, *G. angustifolia*, *Phyllothea* sp., *Phyllothea robusta*, *Vertebraria indica*, *Taeniopteris danaeoides*, and a few winged seeds. *Phyllothea robusta* which lacks the characteristic leaf-sheath and has leaf segments united only at the base, has now been transferred to a new genus, *Stellothea* by Surange & Prakash (1962).

MATERIAL AND METHODS

The material for the present study which comprises impressions and a few compres-

sions preserved on ferruginous shales and carbonaceous shales respectively was collected by one of us (G.P.) who also studied the geology of the area. The ferruginous rock usually appears like a shale, but at many places it is not well-bedded. Generally the specimens are fragmentary and stained by some yellow or brown substance. Sometimes a coating of a white substance occurs on the fossils.

In case of the specimens on black shale there is little contrast between the fossil and the matrix. For photographing such specimens use of red, green or yellow light filters was found to give good results. The impressions on ferruginous shales are usually clear and there was not much difficulty in photographing them.

The megafossils were collected from the localities in the vicinity of Tattitola and

Alubera in the Bansloi valley. Except one sample (477, Loc. 3) all were collected from the beds which lie buried deep under the soil. Details of the localities are given below (TEXT-FIG. 1).

Loc. 1. *Near Bargo*:

The section exposed by Bansloi river near Bargo consists of:

6. Coarse grained sandstones
5. Carbonaceous shales
4. Coaly shales
3. Carbonaceous shales
2. Coal
1. Coarse grained sandstones (not visible in the section because of high level of water in the river).

Bed Nos. 3 and 5 are fossiliferous.

Loc. 2. *About 1½ miles SW of Alubera*:

The sequence of the section on the left bank (upstream) of Bansloi river shows:

8. Earthy shales
7. Gritty shales
6. Earthy shales
5. Hard black rock
4. Black shales
3. Coal
2. Black shales
1. Red gritty sandstone

Bed no. 6 contains fragmentary plant remains.

Loc. 3. *Near Chilgo*:

A few years back, a coal pit was worked out here in which the coal layer is seen underlying a thick mass of alluvium. A few fragmentary remains of plants (mostly leaves) were collected from the shales obtained from colliery rejections.

Loc. 4. *About ¾ mile SSE of Alubera*:

Here the rocks are carbonaceous shales and coarse grained sandstones. The shale band overlies the sandstone band and is exposed on the surface. The thickness of this shale band is less than a foot.

Loc. 5. *Near Tattitola*:

The rocks of this locality are exposed on the right bank of the Bansloi river (upstream). The section reveals:

11. Coarse friable gritty sandstones (ferruginous and micaceous)
10. Brown arenaceous shales
9. Coarse-grained micaceous sandstones
8. Arenaceous shales
7. Coarse-grained micaceous sandstones
6. Carbonaceous shales (sandy)
5. Argillaceous sandstones
4. Coarse felspathic sandstones

3. Ferruginous sandstones
2. Coarse felspathic micaceous sandstones

1. Coarse ferruginous sandstones
- Bed nos. 3 and 6 are fossiliferous.

Loc. 6. *About ¾ mile ESE of Alubera*:

The sequence of the section in the Bansloi river is:

5. Coarse grained sandstone
4. Slaty shales
3. Coaly shales
2. Slaty shales
1. Red sandstone

Loc. 7. *Along Bankijor nalla*:

About a furlong from the junction of the nalla from Bishunpur with Bankijor nalla, on the left bank (upstream) of Bankijor nalla a coal bed is exposed. On the right bank of the nalla coaly and sandy shales underlain by gritty sandstones are exposed.

Loc. 8. *Along nalla originating near Bishunpur*:

About a furlong from the junction a coaly shale bed is exposed on the right bank of the nalla. It is underlain by sandstone and overlain by brown shales. Similar exposures occur in the nalla at many places.

Loc. 9. *Near Dangapara*:

In a tributary of Karua nalla a thin band of coaly shale is exposed about ¾ mile SSE of Dangapara.

DESCRIPTION

Genus *Phyllothea* Brongn.

Phyllothea sp.

Only one incomplete specimen (PL. 1, FIG. 1) was found near Tattitola. The stem which is different from the more common species *Stellothea robusta* Surange & Prakash measures about 5 cm. in length and 6 mm. in breadth. It is striated and divided into nodes and internodes. The nodal regions are not distinctly marked. The stem is devoid of leaf-sheaths but some leaflets scattered near the stem seem to be linear and narrow and are distinct from those of *Stellothea robusta*.

Genus *Stellothea* Surange & Prakash

Stellothea robusta Surange & Prakash

This species which is so far known only from Rajmahal hill area was first assigned

by Feistmantel (1880) to the genus *Phyllothea*. Surange & Prakash (1962), however, placed it in a new genus *Stellothea* as it shows no leaf-sheaths and instead the leaves are attached on a disc. Fig. 2 on Pl. 1 represents one more specimen of this species.

Genus *Schizoneura* Schimp. & Moug.

Schizoneura gondwanensis Feistm.

Several specimens of this species are present, but unfortunately they are all fragmentary. The leaf-sheaths are attached at the successive nodes, which in the figured specimen (PL. 1, FIG. 3) are nearly 3 cm. apart. The preserved portion of the stem measures 7 cm. in length and 3 mm. in breadth. It is articulated and ribbed. The leaf-sheaths are about 6 cm. long and 1.2 cm. broad at the widest. The veins are nearly 1 mm. apart and 8-10 in number in each lobe, traversing longitudinally.

The genus *Schizoneura* has a broad vertical range. Stem impressions referred to *Schizoneura* were first reported from the Talchir beds of India. This genus attains its maximum development in the Raniganj stage and is also found in the Panchets. So far, only two species are known from India, viz. *Schizoneura gondwanensis* and *Schizoneura wardii*. The present specimen compares closely with Feistmantel's specimens of *Schizoneura gondwanensis*.

Equisetalean Stem — A few leafless equisetaceous stem impressions occur on ferruginous and carbonaceous shales but most of them are badly weathered. The stems are generally narrow but a few of them are considerably broad.

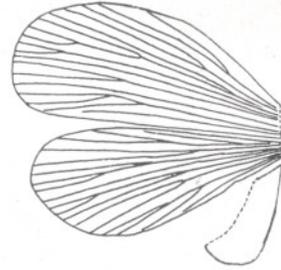
In one of the specimens (PL. 1, FIG. 4) the stem measures 10 cm. in length and 1.2 cm. in breadth and shows six nodes which are nearly 1.2 cm. apart from one another. The internodes are ribbed, the ridges and grooves being parallel, about 10-12 per centimetre and continuous from one internode to the other.

The fossils cannot be assigned to any one of the known equisetalean genera.

Genus *Sphenophyllum* Brongn.

Sphenophyllum speciosum (Royle) M'Clell.

This species is represented by an impression of one half of a leaf-whorl not attached to a stem (PL. 1, FIG. 5; TEXT-FIG. 2). The



TEXT-FIG. 2 — *Sphenophyllum speciosum*, enlarged line drawing of photo in PL. 1, FIG. 5 to show details of venation. $\times 2$.

leaves are dimorphic and vary in length and shape; the upper two are more or less equal in size, each leaf being ovate, entire and horizontally spreading. The leaves are about 2 cm. long and 9 mm. broad in the broadest part. The third leaf (part of the lower pair) is egg-shaped, 1.2 cm. long and 5 mm. wide, and vertically hanging downward. The veins enter the base of a leaf and each vein dichotomizes a number of times spreading out fan-wise.

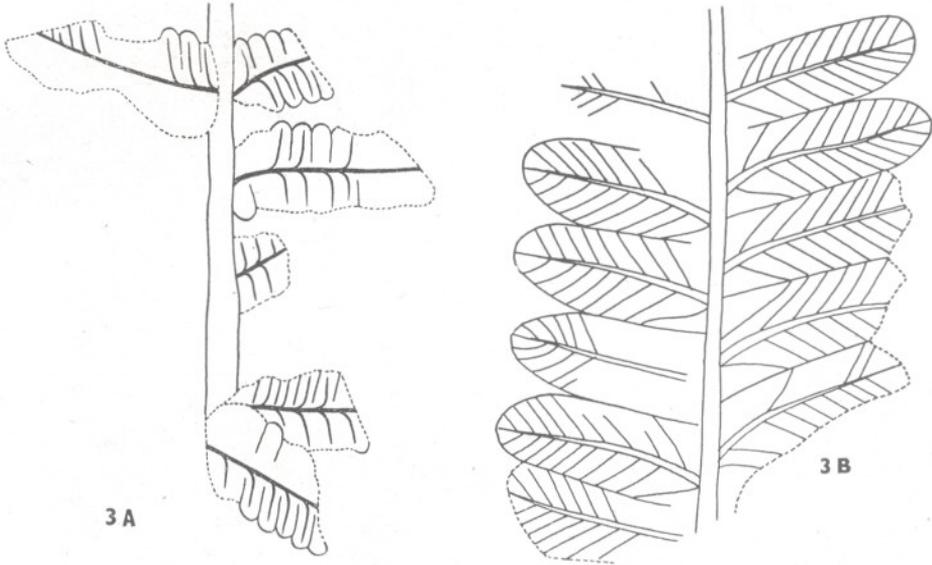
Although the specimen described is fragmentary, its leaves are very characteristic of *Sphenophyllum speciosum*. There is, therefore, no doubt in referring it to *S. speciosum*.

Genus *Pecopteris* Brongn.

Pecopteris phegopteroides (Feistm.) Arber (? = *Pecopteris arborescens* Schloth)

The solitary specimen (TEXT-FIG. 3A) shows a part of the frond with only 4 pinnae in attachment with the rachis. The frond is compound, bipinnate with pinnae set almost at right angles to the rachis. The pinnules are longest in the median portion of the pinna and are shorter towards the apex and the base. The average length and breadth of the pinnules are 6 mm. and 2.5 mm. respectively. The pinnules (PL. 1, FIG. 6; TEXT-FIG. 3B) are closely set, inserted slightly obliquely and are oblong in shape with their lateral margins parallel. They have an obtuse apex and a connate base. The midrib of the pinnules is prominent persisting almost up to the apex where it sometimes forks into two. The lateral veins come out at acute angles and are simple.

The present specimen agrees with the figures of *Alethopteris phegopteroides* given by Feistmantel (1881, VOL. III, PT. 2; PL. 13,



TEXT-FIG. 3 — *Pecopteris phegopteroides*. A. outline sketch $\times 1$, B. a part of the frond enlarged to show details of venation. $\times 4$.

FIG. 1). Arber (1905) later placed this species under *Pecopteris* because of its close similarity in habit and nervation with some of the Pecopterids of the Upper Coal Measures and Lower Permian rocks of the Northern Hemisphere. In India this species is so far known only from the Raniganj stage. Recently it has been reported to occur in association with Cathaysian elements in S. E. Anatolia (WAGNER, 1962). Walton (1929) considers it to be the *Cyathea* form of *Pecopteris arborescens* Schloth.

Pecopteris sp.

The specimen (PL. 1, FIG. 7; TEXT-FIG. 4) is incomplete and the preserved portion of the frond is about 3 cm. long. The frond is pinnate; pinnules alternate to sub-opposite, linear-oblong, attached obliquely to the rachis, closely set with their margins almost parallel, contiguous and nearly 5 mm. broad (the length and apex of the pinnule are not known). Midvein stout (perhaps extended up to the apex) and slightly arched near the rachis. Lateral veins numerous, come out obliquely from the midrib, simple or forked and closely placed.

The specimen does not compare with any species of *Pecopteris* nor does it show sufficient characters to be assigned to a new species. It is, hence, referred as *Pecopteris* sp.



TEXT-FIG. 4 — *Pecopteris* sp., enlarged line drawing of the frond represented in PL. 1, FIG. 7. $\times 2$.

Genus *Alethopteris* Sternb.

Alethopteris sp. A

The specimen is a part of a compound and probably bipinnate frond, and shows only two ultimate pinnae each of which is 2.5 cm. broad (PL. 1, FIG. 8). The rachis of the pinna is strong and about 1 mm. broad at the base. The pinnules are oblong, sub-

opposite, with almost parallel margins and an obtuse apex. The pinnules are wholly attached at the base and are decurrent at the lower side (TEXT-FIG. 5). The average distance between the two pinnules is 1.5 mm. The midvein of the pinnules is clear and prominent and just before reaching the apex it bifurcates into two. At the point of its origin it is, for a short distance, decurrent with the rachis. The lateral veins are simple, about 1 mm. apart and pass out obliquely from the midrib and extend up to the margin.

The species is represented by two specimens. In the other specimen the ultimate pinnae is less broad and the distance between two pinnules is also comparatively small. The specimens are too fragmentary to be compared satisfactorily with the known species of the genus.



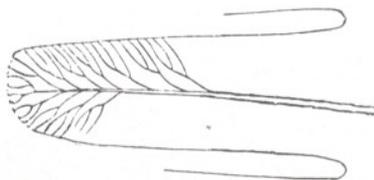
TEXT-FIG. 5 — *Alethopteris* sp. A, enlarged line drawing of a part of the frond to show details of venation. $\times 2$.

Alethopteris sp. B

The specimen represents only a portion of a pinnate frond. The pinnules are oblong with obtuse apex, and attached obliquely to the rachis (PL. 1, FIG. 9). They are 2.3 cm. long and 6.7 mm. broad, wholly attached to the rachis by their bases and

closely set. The midrib is distinct and prominent in the basal region and faint towards the apex. Lateral veins are numerous, arising obliquely from the midrib and are simple or forked once or many times (TEXT-FIG. 6). A few veins seem to come out from the rachis itself.

Due to incompleteness of the frond it can not be compared definitely with the known fronds of *Alethopteris*. It differs from *Alethopteris* sp. A in the presence of frequently dichotomizing secondary veins of the pinnules.



TEXT-FIG. 6 — *Alethopteris* sp. B, a pinnule enlarged to show details of venation. $\times 2$.

Genus *Sphenopteris* Brongn.

Sphenopteris hughesii (Feistm.) Arber

The specimen (PL. 1, FIG. 10) shows an incomplete impression of a bipinnate frond. The frond is 4.5 cm. long and 3.5 cm. across. Ultimate pinnae are sub-alternate, elongate and come out from the axis almost at about 45° . The pinnules are 7-8 mm. in length and 3.5 mm. in breadth in the widest part, sub-opposite with lobed margin and obtusely pointed apex. The midvein of a pinnule is thin and flexuous and persists almost to the apex. The lateral veins come out from the midvein at acute angles giving off branches to each lobe.

In the shape of the frond and the nature of the venation of the pinnules this specimen resembles *Dicksonia hughesi* Feistm. (FEISTMANTEL, 1881; PL. 23, FIG. 2). This species was transferred to the genus *Sphenopteris* by Arber (1905) as its fructification is not perfectly known. He also pointed out close similarity between *S. hughesii* and the Australian species *S. lobifolia*. However, in the former species the rachis is not 'winged'. The venation of the pinnules in the two species is also different. Hence the two species can be maintained separately. Undoubted specimens of *S. hughesii* are so far known only from the Raniganj stage.

Sphenopteris lobifolia Morris

Incomplete impression of a bipinnate frond (PL. 1, FIG. 11) with a 'winged' rachis. Pinnae are obliquely set, sub-alternate, linear-lanceolate, pinna-rachis flexuous. The pinnules are oval-lanceolate, slightly lobed and with obtuse apex. Midvein of the pinnules is slightly sinuate and gives off forked branches to the lobes.

Arber (1905) included in this species a number of other species described by McCoy from Australia. Srivastava (1955) reported this species for the first time from the Raniganj stage of the Lower Gondwana of India. The present specimen resembles most with Srivastava's specimen.

Genus *Noeggerathiopsis* Feistm.*Noeggerathiopsis* cf. *N. hislopii* Bunb.

The specimen (PL. 1, FIG. 12) represents a fragmentary impression of a leaf, the upper portion of which is broken. The specimen is nearly 9 cm. long, 1.5 cm. broad at the widest, sublinear with lamina contracted at the base. Numerous sub-parallel and dichotomously branched veins enter the base of the leaf and pass straight upwards without anastomosing. There are about 15 veins per cm. in the broadest part of the leaf which agrees with that known in *Noeggerathiopsis hislopii*.

The incompleteness of the specimen does not permit a detailed comparison. However, on the nature of venation, it may be referred to *Noeggerathiopsis* and probably to *N. hislopii*.

Genus *Glossopteris* Sternb.*Glossopteris angustifolia* Brongn.

Incomplete impression of an elongate, narrow and linear leaf; apical and basal regions missing. The incomplete specimen (PL. 2, FIG. 13) measures 7.5 cm. in length and 1.8 cm. in breadth in the widest part. The leaf gradually contracts towards the base; the apex was probably acute. Midrib is prominent, about 1.5 mm. wide in the lower part and persists throughout the preserved length of the lamina. Secondary veins come out of the midrib at very acute angles and after a gentle curve near the midrib pass straight to the margin. They

are dichotomous and anastomose to form narrow and elongate meshes.

There has been some confusion about the specific rank of this species. Seward (1897) included it as a variety of *Glossopteris brownii* while Brongniart, Feistmantel and Zeiller kept it as a distinct species. Arber (1905) regarded the leaves of *G. angustifolia* to be narrower fronds of *G. indica* though he kept both the species as separate. Plumstead (1952) thinks these to be similar to *G. brownii*. But the cuticular studies on *G. indica* (ZEILLER, 1896), *G. angustifolia* (SAHNI 1923), and *G. brownii* (SRIVASTAVA, 1957) show that the epidermal characters of all the three species are quite distinct and different and as such their distinct specific ranks should be maintained. In India *G. angustifolia* is known to occur in all the stages from the Karharbari to the Panchet.

Glossopteris communis Feistm.

Incomplete impression of the leaf, broken at the apex. The leaf (PL. 2, FIG. 14) measures 14.3 cm. in length and 3.1 cm. in breadth in its widest part. The leaf gradually contracts towards the base. Midrib is stout, about 2 mm. wide in the basal region and persists throughout the preserved length of the lamina. Secondary veins are numerous, close, come out at very acute angles from the midrib and with a broad curve pass out to the margins. The secondary veins dichotomize and anastomose forming narrow-elongate meshes of almost same size throughout the lamina.

This specimen agrees with the descriptions and figures of *Glossopteris communis* (FEISTMANTEL, 1881; PL. 26, FIG. 4). Feistmantel, (1876) first proposed the name *G. communis* for long and broad leaves with long and narrow meshes. However, Zeiller (1896) and Arber (1905) did not support him and included such fronds under *G. indica*. But Srivastava (1957) showed that epidermal characters of *G. communis* and *G. indica* were distinct and different. *G. communis* is known from Talchir, Barakar, Raniganj and Panchet stages of the Lower Gondwana of India. The present specimen is more comparable with the Damuda forms described by Feistmantel (1881; VOL. III, Pr. 2; p. 98).

Glossopteris indica Schimp.

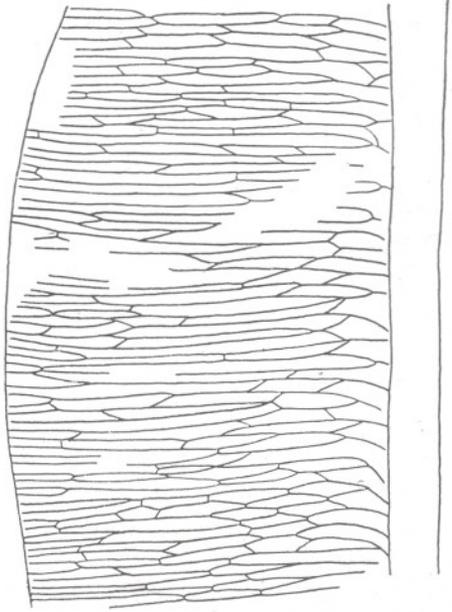
The specimen (PL. 2, FIG. 15) is an incomplete impression of a leaf, apical and basal

portions of which are broken. The leaf is lanceolate in shape. The incomplete specimen measures 19 cm. in length and 4.2 cm. in breadth in the widest part. The apex was probably acute. Midrib is stout, prominent and persistent throughout the preserved portion of the lamina. Secondary veins pass out at acute angles from the midrib, are crowded, dichotomous and arched near the midrib. They anastomose to form broad and short meshes near the midrib and narrower and longer meshes towards the margin.

The venation of this leaf is similar to that of *Glossopteris indica* (FEISTMANTEL, 1881, p. 101; PL. 38, FIG. 4). This species was first placed by Brongniart as a variety of *G. brownii* but later Schimper raised it to specific rank and was supported by Feistmantel. Zeiller (1896), however, merged in it *G. communis* and was supported by Arber (1905). Plumstead (1952) described the fructification of *G. indica* as *Scutum dutoitides* (*Hirsutum dutoitides*, PLUMSTEAD, 1958). Sen (1955) described the fructification of *G. communis* (*Lanceolatus communis*) which is quite unlike that described by Plumstead for *G. indica*. Recently Plumstead (1962) has separated the leaf which bore *H. dutoitides* from *G. indica* and placed it under a new species, viz., *G. seawardii*. However, Srivastava (1957) has pointed out the difference in epidermal structure of the two species. Thus the distinctness of *G. indica* from *G. communis* is beyond doubt. But *G. indica* in itself seems to be a complex species because *G. arberi* (SRIVASTAVA, 1957) and *G. jamottei* (HØEG & BOSE, 1960) have venation similar to *G. indica*. The present specimens are placed under *G. indica* in view of the opinion that this name should be restricted for impression forms.

Glossopteris damudica Feistm.

The specimen (PL. 2, FIG. 16) is an incomplete impression of a large leaf on a carbonaceous shale with poorly preserved carbonized crust. The basal and apical parts are broken and only the middle portion is preserved, measuring nearly 7 cm. in length and 5.6 cm. in breadth in the widest part. Midrib is prominent and stout. Lateral veins (TEXT-FIG. 7) emerge at acute angles from the midrib but immediately afterwards follow a course almost at right angles to the



TEXT-FIG. 7 — *Glossopteris damudica*, enlarged line drawing of a part of the leaf represented on Pl. 2, Fig. 16 to show venation. $\times 2$.

midrib. They dichotomize and anastomose forming broad and short meshes near the midrib and longer and narrower meshes towards the margin of the lamina.

This specimen is identical with those figured and described as *Glossopteris damudica* by Feistmantel (1881; PL. 30, FIG. 1) from the Ironstone Shale stage of Damuda series. Arber (1905) pointed out that the venation in *G. ampla* is more oblique than in *G. damudica* but as he did not attach any importance to this character included this species as well as Bunbury's *G. musaeifolia* under *G. ampla* Dana. Halle (1911) pointed out that *G. ampla* is quite distinct from the Indian leaves. Recently Archangelsky (1958) has again separated *G. damudica* from *G. ampla* and has published one figure of each to show the difference between the two species. *G. ampla* is believed to be \pm orbicular in shape and the veins arise at an acute angle from the midrib. *G. damudica* is \pm taeniopteroid in shape, with the two margins nearly parallel to each other and the veins emerging nearly at right angles from a stout midrib. In the present material all the specimens examined show characters agreeing with those of *G. damudica*. *G. damudica* is

known from the Damuda Division of the Lower Gondwanas of India.

Glossopteris brownii Brongn.

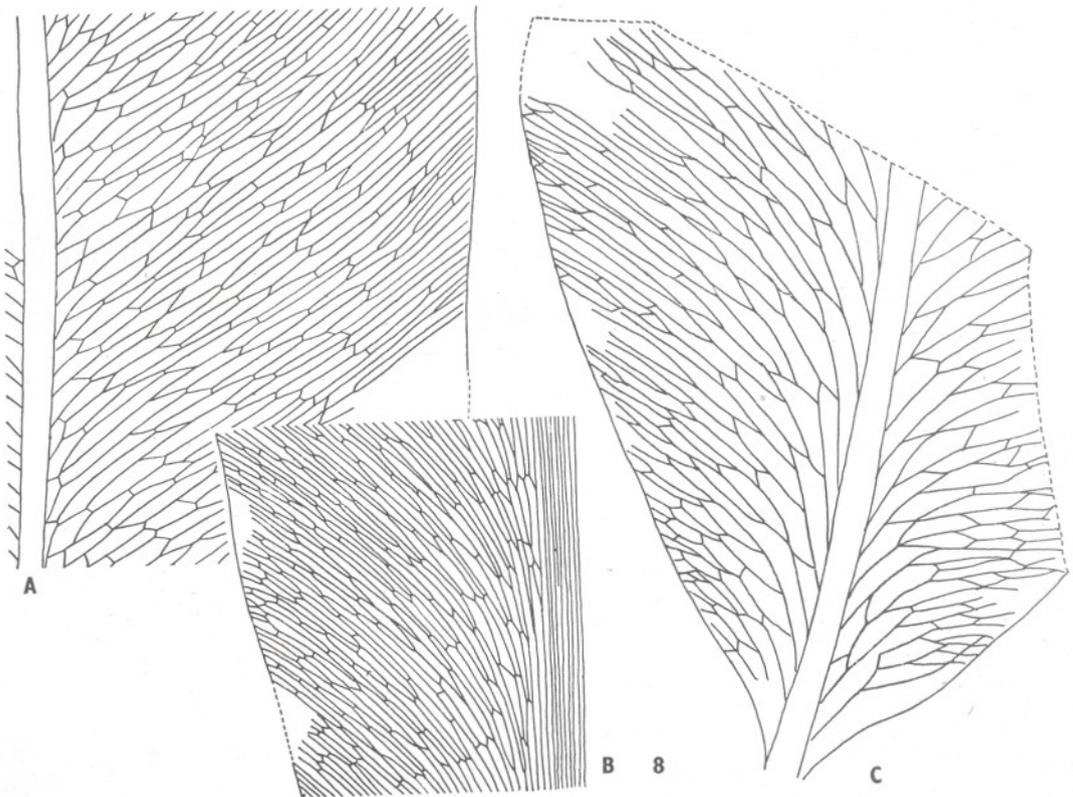
About 18 specimens of this species have been examined. The figured specimen (PL. 2, FIG. 17) is an incomplete impression of a leaf with poorly preserved carbonized crust. The specimen is broken both in the lower and the upper part of the leaf. The specimen measures 12.2 cm. in length and 6 cm. in breadth in the widest part. The complete leaf was probably oval-spathulate in shape and gradually contracted towards the base. Midrib is prominent and broad, 2.5 mm. wide in the basal region and 1.5 mm. in the apical region and persists throughout the preserved length of the lamina. Secondary veins form an acute angle with the midrib and show a short bend near it. Their remaining course through the lamina is

more or less straight. They are dichotomous and anastomose to form polygonal, open elongate meshes, broader and shorter near the midrib and narrower and longer towards the margin.

This species is predominant in this collection and exhibits a variety in the form and shape of the leaves. The venation is also of varied types. Different types of venation met within this species are represented in (TEXT-FIG. 8 a-c). This species has been variously regarded as similar to *Glossopteris indica* or *G. angustifolia*. Cuticular studies by Srivastava (1957) have, however, conclusively proved that all of them are separate species.

Glossopteris parallela Feistm.

Feistmantel (1878) instituted the species *Glossopteris parallela* to describe some simple, elongate oval leaves of large size found



TEXT-FIG. 8a-c — *Glossopteris brownii*, line drawings of parts of three leaves to show range of variation in venation of this species. × 2.

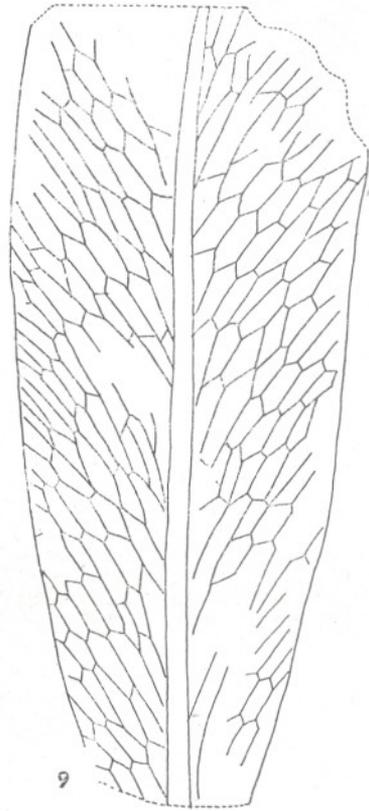
in the Upper Coal Measures at Bowenfels, New South Wales. The midrib gave rise to secondary veins at acute angles which formed distinct oblong-polygonal meshes. Arber (1905) included this species in *G. brownii* but he was not very sure of it. He remarked "It is possible that if further and more complete specimens of this or Feistmantel's other species were obtained, and better figures of them reproduced, some of those included here with *G. Browniana* might be found distinct...". Plumstead (1962) believes the characteristic venation of *G. parallela* to be distinctive and hence maintains its specific status.

The specimen represents a compression of a leaf on a carbonaceous shale with poorly preserved carbonized crust. The specimen (PL. 3, FIG. 18) is broken both at the apex and the base and measures 11.2 cm. in length and 5.3 cm. in breadth in the widest part. The leaf was probably very large with a prominent and stout midrib measuring about 3.5 mm. in width in the basal part. The secondary veins emerge from the midrib at acute angles and pass straight towards the margin. The veins are almost parallel. They dichotomize and anastomose to form distinct oblong-polygonal meshes which gradually become narrower towards the margin.

This specimen agrees in details of shape, size and venation with the description and figure of *Glossopteris parallela* Feistm. (FEISTMANTEL, 1890; PL. 18, FIG. 3). Recently this species has been recorded from Theron Mts., Antarctica by Plumstead (1962) but in the specimen illustrated by her (*l.c.*, PL. 13, FIGS. 3, 4) the veins reach the margins at comparatively broader angles.

Glossopteris retifera Feistm.

It is an incomplete leaf impression, measuring 10.5 cm. in length and 2.7 cm. in breadth in the widest part. The leaf (PL. 3, FIG. 19, partly reproduced) is broken both at the base and the apex. It is linear-lanceolate in shape. Midrib is stout, 2.5 mm. thick in the basal part and about 1.5 mm. thick in the upper part. Secondary veins (TEXT-FIG. 9) come out of the midrib at pretty acute angles and are arched near the midrib, forming open, broadly polygonal meshes, not much longer than broad and of almost equal size throughout the lamina.



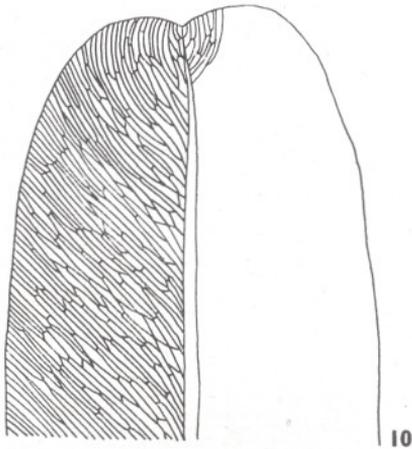
TEXT-FIG. 9 — *Glossopteris retifera*, enlarged line drawing of a part of the leaf represented on PL. 3, FIG. 19 to show venation. $\times 2$.

This specimen compares favourably with specimens of *Glossopteris retifera* described and figured by Feistmantel (1881; PL. 28, FIG. 10). Previously this species was reported only from India, but later it was found from several other countries such as South Africa and Argentina. In India it occurs in the Barakar, the Ironstone Shale and the Raniganj stages.

Glossopteris emarginata sp. nov.

This species is represented by a single specimen, with counterparts, which is broken in the basal region. It is in the form of an impression on a ferruginous shale. The leaf (PL. 3, FIGS. 20, 21) is simple and oblong in shape with an entire margin and an emarginate apex. The incomplete specimen is 9.9 cm. in length and 2.8 cm. in breadth.

In the center is a distinct and stout midrib which in the counterpart is about 2 mm. broad and continues up to the apex. The secondary veins come out of the midrib at acute angles and after a gentle arch pass straight to the margins. The veins dichotomize and anastomose to form elongate-polygonal meshes which are slightly narrower near the margins. The number of the veins per cm. at the margin is 18-23. In the apical region (TEXT-FIG. 10) the secondary veins, instead of turning away from the midrib, bend towards it so that they run almost parallel to the lateral leaf margin and finish at the margin of the apical portion.



TEXT-FIG. 10 — *Glossopteris emarginata* sp. nov., enlarged line drawing of the apical part of the leaf represented on Pl. 3, Fig. 20 to show the details of venation. $\times 2$.

Diagnosis — Leaf oblong with emarginate apex. Midrib distinct and stout, persists up to the apex. Secondary veins acute, arched, dichotomous and anastomosing; meshes elongate-polygonal. In the apical part the secondary veins bend towards the midrib, run almost parallel to the leaf margins and finish in the margin of the apical portion.

Holotype — 32862, Birbal Sahni Institute of Palaeobotany, Lucknow.

Age — Lower Permian.

Horizon — Barakar stage.

Locality — Near Tattitola, Bansloi Valley, Rajmahal hills, Bihar.

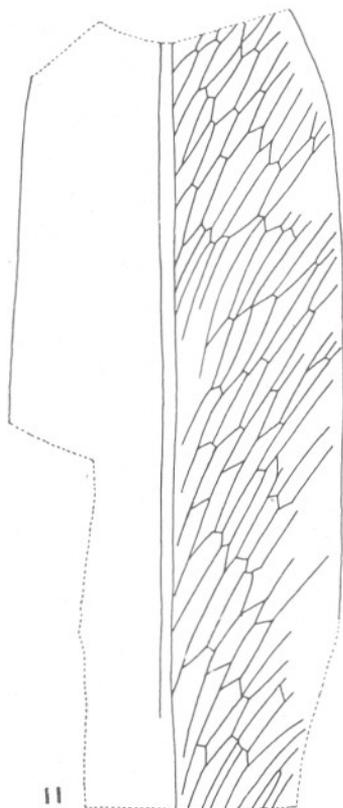
Comparison — The shape and venation of this leaf distinguishes it from all the known species of *Glossopteris*. In the nature of its

apical portion *G. emarginata* resembles *G. orbicularis* Feistm., *G. spathulato-cordata* Feistm. and *G. colpodes* Pant. *G. colpodes* is essentially recognized by its epidermal structure and as such is not comparable with the present species which is based only on impression. In *G. orbicularis* and *G. emarginata* the venation in apical portion is almost similar but *G. orbicularis* is small in size and almost circular in shape as compared to *G. emarginata* which is a long and oblong leaf. In *G. spathulato-cordata* secondary veins in the upper portion, unlike *G. orbicularis* or *G. emarginata*, do not bend towards the midrib and run parallel to it, but instead they pass straight to the margins. The venation of *G. emarginata* is comparable with some forms of *G. brownii* Brongn. except in the apical region. The leaves of *G. brownii* are mostly spathulate, oval-linear, linear, sub-oval (or oblong?) with obtuse, rounded or obtusely pointed apex (ARBER, 1905) while in the present case the leaf is oblong with a notched apex. The venation in the apical portion of the present specimen is quite peculiar and is not known to occur in the leaves of *G. brownii*. The present specimen, therefore, is assigned to a new species.

Glossopteris formosa Feistm.

It is an incomplete impression of a leaf on a ferruginous shale. The apical and basal parts of the leaf are missing and hence a definite idea of its shape cannot be had but probably it was linear-lanceolate. The length of preserved portion of the leaf (PL. 3, FIG. 22) is 8.7 cm. and the breadth is 1.2 cm. The midrib is prominent and strong. Secondary veins (TEXT-FIG. 11) arise from the midrib at very acute angles. They dichotomize and anastomose to form open, oblong-polygonal meshes of almost equal size throughout the leaf lamina. The meshes measure approximately 8 mm. in length and 1 mm. in breadth.

The form and venation of the leaf compare with those of *Glossopteris formosa* var. *major* as given by Feistmantel (1882) from South Rewah. Arber (1905) included it in *Glossopteris formosa* and his view was confirmed by the result of cuticular study of broad and narrow forms of *G. formosa* by Srivastava (1957). Arber (1905) remarked that *G. formosa* is a narrow leaf type corresponding to *G. retifera* or *G. conspiciua* although he kept



TEXT-FIG. 11 — *Glossopteris formosa*, enlarged line drawing of the leaf represented in Fig. 22, Pl. 3 to show venation. $\times 2$.

all the three as distinct species. The results of Srivastava's (*l.c.*) study have now shown beyond doubt that the epidermal structures of all the above three species are different.

Genus *Gangamopteris* McCoy

Gangamopteris cf. *G. cyclopteroides* Feistm.

It is an incomplete impression of a leaf of which only a small portion, 5 cm. long and 2.2 cm. broad, is present (PL. 3, FIG. 23). Due to fragmentary nature of the specimen no idea can be formed about its shape, apex or base. A few sub-parallel median veins in the centre give off lateral veins at acute angles. The lateral veins are dichotomous and anastomose to form long meshes which are comparatively broader towards the centre of the leaf (PL. 3, FIGS. 23 & 24).

This specimen shows a venation pattern characteristic of *Gangamopteris cyclopteroides* but due to the incompleteness of the specimen it has been described as *Gangamopteris* cf. *G. cyclopteroides*.

Gangamopteris sp.

Impression of an incomplete leaf on a ferruginous shale; the apical and basal portions of the leaf are missing in the specimen. The incomplete leaf (PL. 3, FIG. 25) measures 7 cm. in length and 2.2 cm. in breadth in the widest part. The leaf was probably linear-lanceolate in shape. In the lower part of the frond are few closely placed, prominent sub-parallel median veins (false midrib) which in the upper part become resolved into finer veins. Lateral veins radiate out at very acute angles from the median veins and some of them seem to arise from the base of the lamina. The lateral veins follow a flexuous course and are dichotomous. Anastomosing of the lateral veins is rare and the few meshes formed are long and narrow.

In its shape and nature of venation this leaf resembles the type specimen of *Gangamopteris flexuosa* Srivast. (SRIVASTAVA, 1957) kept in the mesium of Birbal Sahni Institute of Palaeobotany, Lucknow except that the type specimen has a slightly broader lamina. *G. flexuosa* is essentially based on its cuticle, which is lacking in the present case. It is, therefore, referred as only *Gangamopteris* sp.

Genus *Vertebraria* Royle

Vertebraria sp.

This species is represented by six specimens. Most of them are incomplete and consist of two longitudinal series. In one of the specimen (PL. 3, FIG. 26) the preserved portion is 8 cm. long and 2.5 cm. broad, consisting of longitudinal series of almost square areas separated by two longitudinal ridges. The areas of the longitudinal series are transversely separated by grooves. The dimensions of these areas vary considerably.

Formerly only one species of *Vertebraria* was known from the Gondwana rocks. But recently two more species of this genus have been described (SURANGE & MAHESHWARI, 1962). Of these *Vertebraria myelonis* differs

from these specimens because of the presence of a central region probably representing a pith. The other species *V. raniganjensis* differs from *V. indica* only in anatomical structure and there is no difference in the external form of the two species. As anatomical details are not known it is very difficult to assign the present specimens to the *Vertebraria indica* or *V. raniganjen-*

sis. Hence, they are described as *Vertebraria* sp.

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EXPLANATION OF PLATES

PLATE 1

1. *Phyllothea* sp. Specimen No. 32876. $\times 1$.
2. *Stellothea robusta*. Specimen No. 32861. $\times 1$.
3. *Schizoneura gondwanensis*. Specimen No. 32857. $\times 1$.
4. Equisetaceous stem, showing nodes and internodes, the latter being distinctly ribbed. Specimen No. 32854. $\times 1$.
5. *Sphenophyllum speciosum*, one half of a leaf whorl showing three leaves. Specimen No. 32855. $\times 1$.
6. *Pecopteris phegopteroides*, a part of the frond enlarged to show details. Specimen No. 32864. $\times 2$.
7. *Pecopteris* sp. Specimen No. 32858. $\times 1$.
8. *Althopteris* sp. A, showing two pinnae. Specimen No. 32851. $\times 1$.
9. *Althopteris* sp. B, a pinna showing forked veins in the pinnules. Specimen No. 32853. $\times 1$.
10. A pinna of *Sphenopteris hughesii*. Specimen No. 32856. $\times 1$.
11. A pinna of *Sphenopteris lobifolia*. Specimen No. 32860. $\times 1$.
12. *Noeggerathiopsis* cf. *N. hislopii*. Specimen No. 32866. $\times 1$.

PLATE 2

13. *Glossopteris angustifolia*. Specimen No. 32871. $\times 1$.
14. *Glossopteris communis*. Specimen No. 32877. $\times 1$.
15. *Glossopteris indica*. Specimen No. 32859. $\times 1$.
16. *Glossopteris damudica*. Specimen No. 32865. $\times 1$.
17. *Glossopteris brownii*. Specimen No. 32868. $\times 1$.

PLATE 3

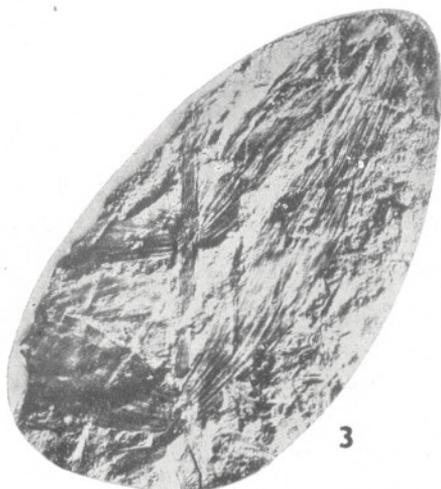
18. *Glossopteris parallela*. Specimen No. 32867. $\times 1$.
19. *Glossopteris retifera*, a part of Specimen No. 32869. $\times 1$.
20. *Glossopteris emarginata* sp. nov. Specimen No. 32862 (Holotype). $\times 1$.
21. Counterpart of the leaf in Fig. 19. $\times 1$.
22. *Glossopteris formosa*. Specimen No. 32863. $\times 1$.
23. *Gangamopteris* cf. *G. cyclopteroides*. Specimen No. 32874. $\times 1$.
24. *Gangamopteris* cf. *G. cyclopteroides*. Specimen No. 32874. $\times 1$.
25. *Gangamopteris* sp. Specimen No. 27911. $\times 1$.
26. *Vertebraria* sp. Specimen No. 32852. $\times 1$.



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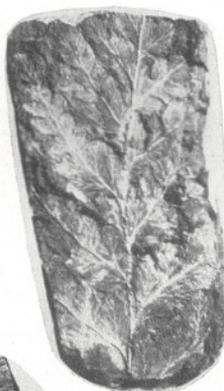
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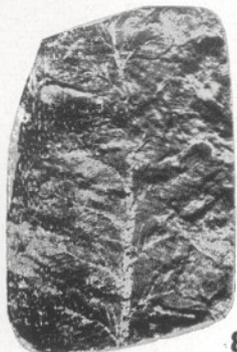
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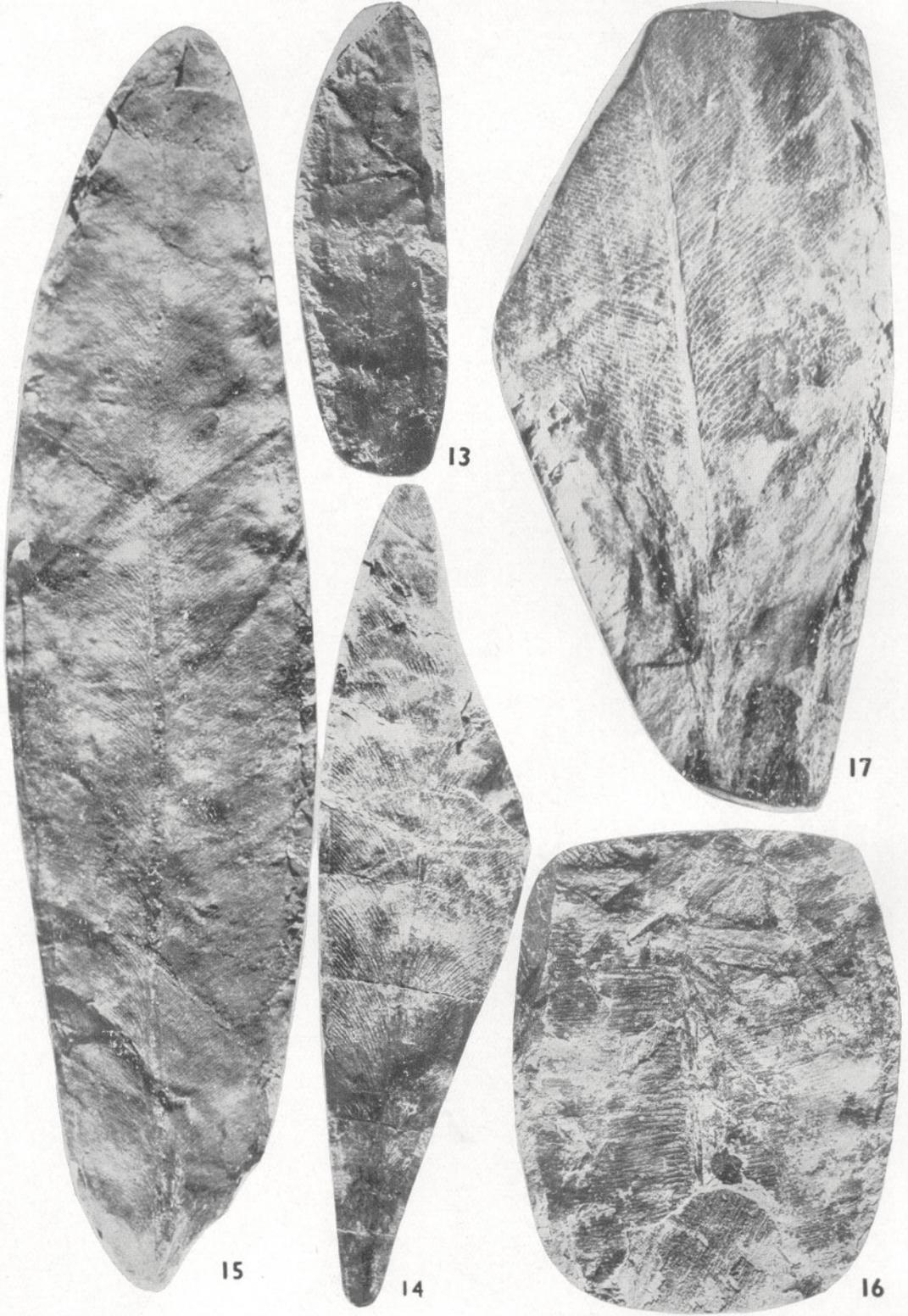
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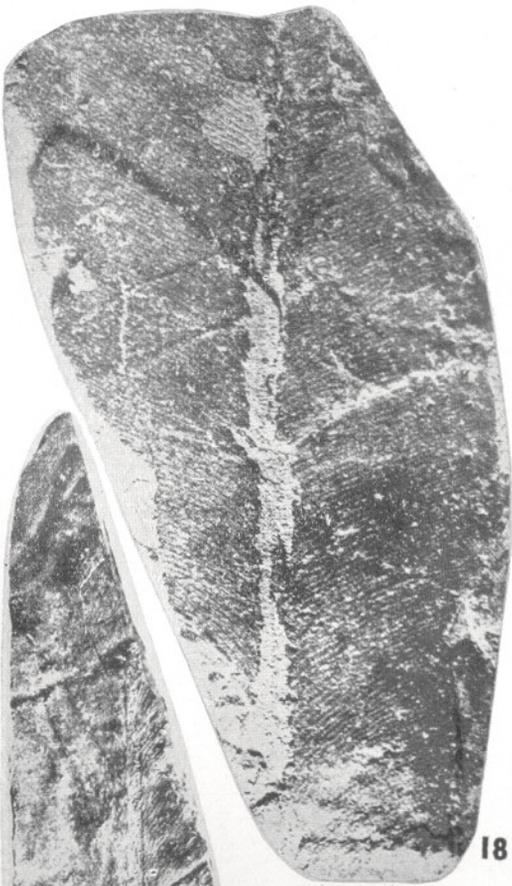


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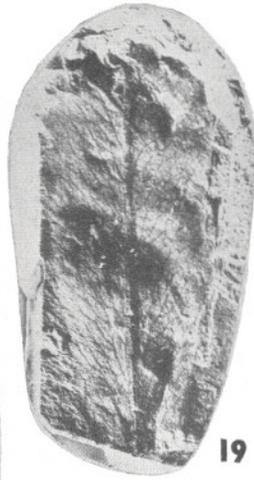


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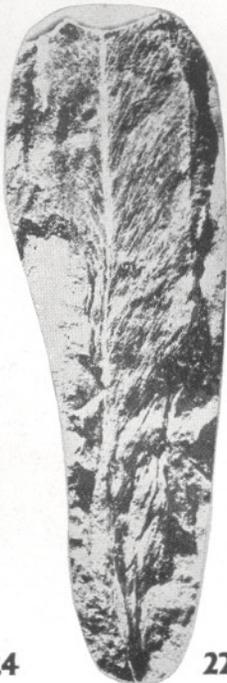
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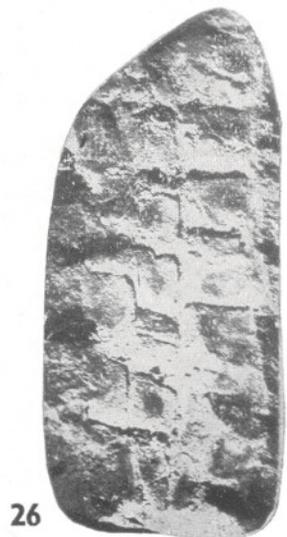
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