

# SOME NEW SPECIES OF *GLOSSOPTERIS* FROM THE KAMTHI FORMATION OF HANDAPA, ORISSA

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## Abstract

The paper deals with the morphological details of seven new species of *Glossopteris*, viz., *Glossopteris kamthiensis* sp. nov., *G. maheshwarii* sp. nov., *G. acuminata* sp. nov., *G. utkalensis* sp. nov., *G. hinjridaensis* sp. nov., *G. inaequalis* sp. nov. and *G. dhenkanalensis* sp. nov. This is an additional and useful knowledge to the hitherto less known Kamthi flora of India.

## Introduction

The genus *Glossopteris* comprises 85 per cent of the total plant population in the Handapa locality. Subramanian and Rao (1960) recorded four species, viz., *Glossopteris indica*, *G. communis*, *G.?* *retifera* and *G.?* *angustifolia* from Handapa. Khan also (1969) recorded three more species from the same locality, which are *Glossopteris conspicua*, *G. browniana* and *G. cf. damudica*. Except for these meagre reports no detailed work has been carried out on the genus *Glossopteris* from this locality. It is found that there are many more already known species of the genus *Glossopteris* as compared to what is reported earlier, besides a few new species.

## Material

The described specimens were collected from the fossiliferous beds exposed in the Hinjrida Ghati section (20° 58' : 84° 43') near Handapa Village in Dhenkanal District of Orissa. The leaves were found in the form of impressions on the pinkish yellow to pinkish brown, hard, compact, fine-grained calcareous shales.

## Description

*Glossopteris kamthiensis* sp. nov.

Pl. 1, figs 7, 8; Text-fig. 2-F

*Diagnosis*—Leaf very narrow, uniformly wide; lorate oblong in shape with mucronate apex; midrib stout, distinct, persists upto the apex; secondary veins very thin, arched, bifurcate and anastomose 2-3 times from midrib to the margin; meshes very narrow, elongated and narrow polygonal.

*Holotype*—Specimen no. B.S.I.P. 35923; Upper Permian; Kamthi Formation; Hinjrida Ghati, near Handapa Village, Dhenkanal District, Orissa.

*Derivation of name*—The species is named after Kamthi Formation.



*Description*—This species is represented by only one completely preserved specimen. The leaf is small, very narrow and more or less uniform in width throughout its length. The shape of the leaf is lorate oblong and its length/width ratio is 7:1. The leaf measures 3.5 cm in length and 0.5 cm in width at its widest part. The apex of the leaf is mucronate and the base seems to be acute normal. The margin of the leaf is entire except that it is broken on the right side near the apical region. The midrib is broad, flat, striated and persisting upto the apex and its thickness being 1 mm at the base, 0.5 mm in the middle and 0.25 mm at the apex of the leaf.

The venation is dense and uniform throughout the leaf. The secondary veins emerge from the midrib at a very acute angle (10-15°) and run almost parallel to the midrib upto a small distance and arch backwardly forming curves to meet the margin at about 45-55°. The meshes thus formed by the secondary veins are very narrow and are comparatively small near the margin. The meshes are oblong polygonal to narrow polygonal and are almost uniform in shape throughout the leaf. 2-3 meshes are formed in the full course of a vein from the midrib to the margin. No cross connections between the secondary veins are observed.

Concentration of veins/	1/4 cm <sup>2</sup> in the middle part of the leaf	11-13
„ „ meshes/	1/4 cm <sup>2</sup> in the middle part of the leaf	15-17

*Comparison*—The shape and venation pattern of this leaf distinguishes it from all the known species of *Glossopteris*. In the nature of its size and ribbon or strap-like shape, *Glossopteris kamthiensis* shows some resemblance to *Glossopteris taenioides* Feistmantel, 1882, *G. wilkinsonii* Feistmantel, 1878, *G. gopadensis* Banerji *et al.*, 1976, *G. senii* Srivastava, 1969 and *G. sp. 3* of Chandra & Prasad 1981.

The species *Glossopteris taenioides* was described by Feistmantel in 1882 from the Karharbari beds of South Rewa Gondwana Basin, Giridih Coalfield. Both *G. taenioides* as well as *G. kamthiensis* are narrow ribbon-like forms and the secondary veins form 2-3 meshes from midrib to margin. *G. taenioides* differs from the new species in having a very wide midrib and having secondary veins passing straight to the margin and forming broader meshes.

*Glossopteris wilkinsonii* instituted by Feistmantel (1878) is from the Lower Gondwana Formation of New South Wales, Australia. *G. wilkinsonii* seems to be a bigger leaf with secondary veins emerging at right angles to the midrib which pass out horizontally to the margin. *Glossopteris gopadensis* instituted by Banerji *et al.* in 1976 from the Panchet Group (Lower Triassic) of Nidpur, M. P., is a bigger form and also comparatively broad. The midrib in *G. gopadensis* is thin and the secondary veins pass out more or less straight to the margin forming 4-5 narrow elongate meshes, whereas in *G. kamthiensis* secondary veins arch backwardly while passing to the margin. Also the venation in *G. gopadensis* is dense. Srivastava (1969) described *G. senii* from the Lower Triassic of Nidpur, M. P. It is a strap-shaped narrow leaf but differs from *G. kamthiensis* in having wide angle of emergence of secondary veins as well as their straight passing out to the margin.

*Glossopteris sp. 3* of Chandra and Prasad, 1981 from the Kamthi Formation of Kanhargaoon, Maharashtra, is very much similar with *G. kamthiensis* in having strap-shaped leaf form and arched secondary veins. *G. sp. 3* of Chandra and Prasad is a slightly bigger form. The specimen of Chandra and Prasad is also included here under *G. kamthiensis* sp. nov. Since the present specimen differs from all hitherto known species, it has therefore been assigned to a new species.



*Glossopteris maheshwarii* sp. nov.

Pl. 1, figs 2, 3, 4, 5; Text-fig. 1-A, C

*Diagnosis*—Leaf very small, petiolate, narrow elliptic to narrow oblong; apex acute, base acute normal; midrib medium, striated, persists upto apex; secondary veins emerge at acute angles, arch, bifurcate and anastomose to form 3-4 uniform narrow and small meshes, arranged in a straight line between midrib to margin; meshes penta to polygonal.

*Holotype*—Specimen no. B.S.I.P. 35921; Upper Permian; Kamthi Formation; Hinjrida Ghati, near Handapa Village, Dhenkanal District, Orissa.

*Derivation of the name*—The species is named after Dr Hari K. Maheshwari, who made a significant contribution in the study of Handapa flora.

*Description*—There are two almost complete specimens of this species in the collection. The leaves are very small and the shape of the leaves is narrow elliptic to narrow oblong. In one of the specimens the lamina is uniformly wide throughout its length, while in the other leaf it is spindle shaped, that is broadest in the middle part and tapering towards both the ends. The length width ratio of the leaf is 3-4:1. The length of the leaves ranges between 3.1 to 3.4 cm and the width between 0.7 to 0.9 cm at their widest part. The apex of the leaf is acute and the base is acute normal. The petiole is well preserved in one of the specimens which is 0.5 cm long. The margin of the leaf is entire. The midrib is medium, flat, striated and persists right up to the apex. The thickness of the midrib is 1 mm at the base, 0.5 mm in the middle and 0.25 mm at the apical part of the leaf.

The secondary veins emerge from the midrib at about 20-25°, slightly curved backwardly and meet the margin at 45°. The meshes are arranged almost straight from the midrib to the margin. They are broad and long up to the middle part of the lamina and are hexa to polygonal in shape, while the meshes near the margin are very small and narrow and are pentagonal to hexagonal in shape. There is a uniformity in the shape and size of the meshes throughout the lamina. 3-4 meshes are formed during the course of the secondary veins from midrib to the margin. A few cross connections are also present.

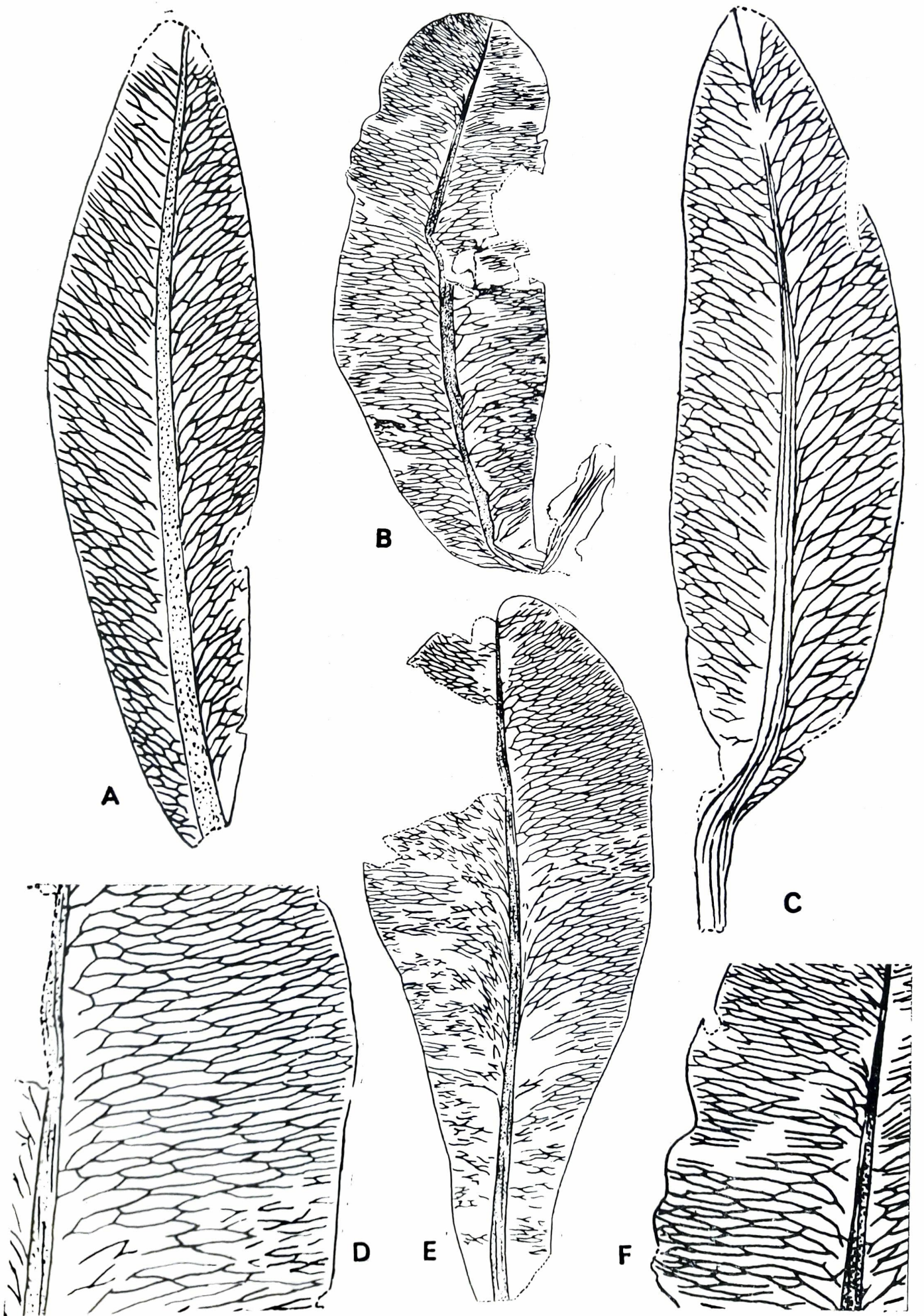
Concentration of veins/1/2 cm<sup>2</sup> in the middle portions of the leaves. 15-20

Concentration of meshes/1/2 cm<sup>2</sup> in the middle portions of the leaves. 30-40

*Comparison*—The shape and venation pattern of this species is distinct from all the known *Glossopteris* species. Because of its very small size and narrow form it shows some resemblance to *Glossopteris gopadensis* Banerji *et al.*, 1976, *G. senii* Srivastava, 1969, *G. taenioides* Feistmantel, 1882, *G. tortuosa* Zeiller, 1902, *G. rewaensis* Chandra & Surange, 1979, *G. taeniensis* Chandra & Surange, 1979 and *G. kamthiensis* sp. nov. *Glossopteris gopadensis* and *G. senii* were described from the Lower Triassic beds of Nidpur, M. P. and differ from the presently described species in their very narrow strap shaped leaf forms. They also differ in having very thin secondary veins running more or less straight up to the margin to form very narrow elongate polygonal meshes, whereas the meshes in *G. maheshwarii* are comparatively broad and oblong polygonal in shape.

The species *Glossopteris taenioides* belongs to the Karharbari Formation of the South Rewa Gondwana Basin and is also a narrow ribbon like form with very wide midrib. The leaf of *G. taenioides* which is based on an incomplete specimen seems to be larger than *G. maheshwarii*. 2-3 meshes are formed from the midrib to the margin in *G. taenioides* which





Text-fig. 1



are uniformly wide throughout the lamina, whereas the meshes in the presently described new leaf are broader near the midrib and narrow towards the margin.

The species *Glossopteris tortuosa* belongs to the Raniganj Formation of the Raniganj Coalfield and is different from the present species in having horizontally running and zigzag secondary veins forming equally broad and long trapezoidal meshes throughout the lamina.

The leaves of *G. rewaensis* and *G. taeniensis* described from the Raniganj Formation of the South Rewa Gondwana Basin, Auranga Coalfield and Karharbari Formation of the South Karanpura Coalfield respectively, have a slight resemblance in overall look with the described new species to a certain extent. The species *G. rewaensis* is a quite big, oblanceolate form with a very thick midrib. The venation pattern of both the species *G. rewaensis* and *G. maheshwarii* is more or less similar except that the secondary veins arch much more in the former species as compared to the nearly straight nervation in the later species. *Glossopteris taeniensis* is a small, narrow obovate leaf with obtuse apex. The venation pattern of both the species *G. taeniensis* and *G. maheshwarii* is quite different. The meshes in *G. taeniensis* are quite broad and long and uniform throughout the lamina, while the meshes in the described species are broader near the midrib and gradually narrowing towards the margin.

*Glossopteris kamthiensis* sp. nov. also differs in having very narrow and strap shaped leaf with very thin, arched secondary veins forming very narrow linear meshes. From above comparison it is apparent that none of the known *Glossopteris* species shows resemblance with the described species and therefore, a new species has been instituted.

*Glossopteris acuminata* sp. nov.

Pl. 1, figs 1, 6; Text-fig. 3-C

*Diagnosis*—Leaf oblanceolate with acuminate apex; leaf broadest at the apical part; midrib stout, persists up to the apex; secondary veins acute, arch and travel straight to the margin; bifurcation of the secondary veins rare in the acuminate part, 2-3 elongate polygonal meshes from midrib to the margin.

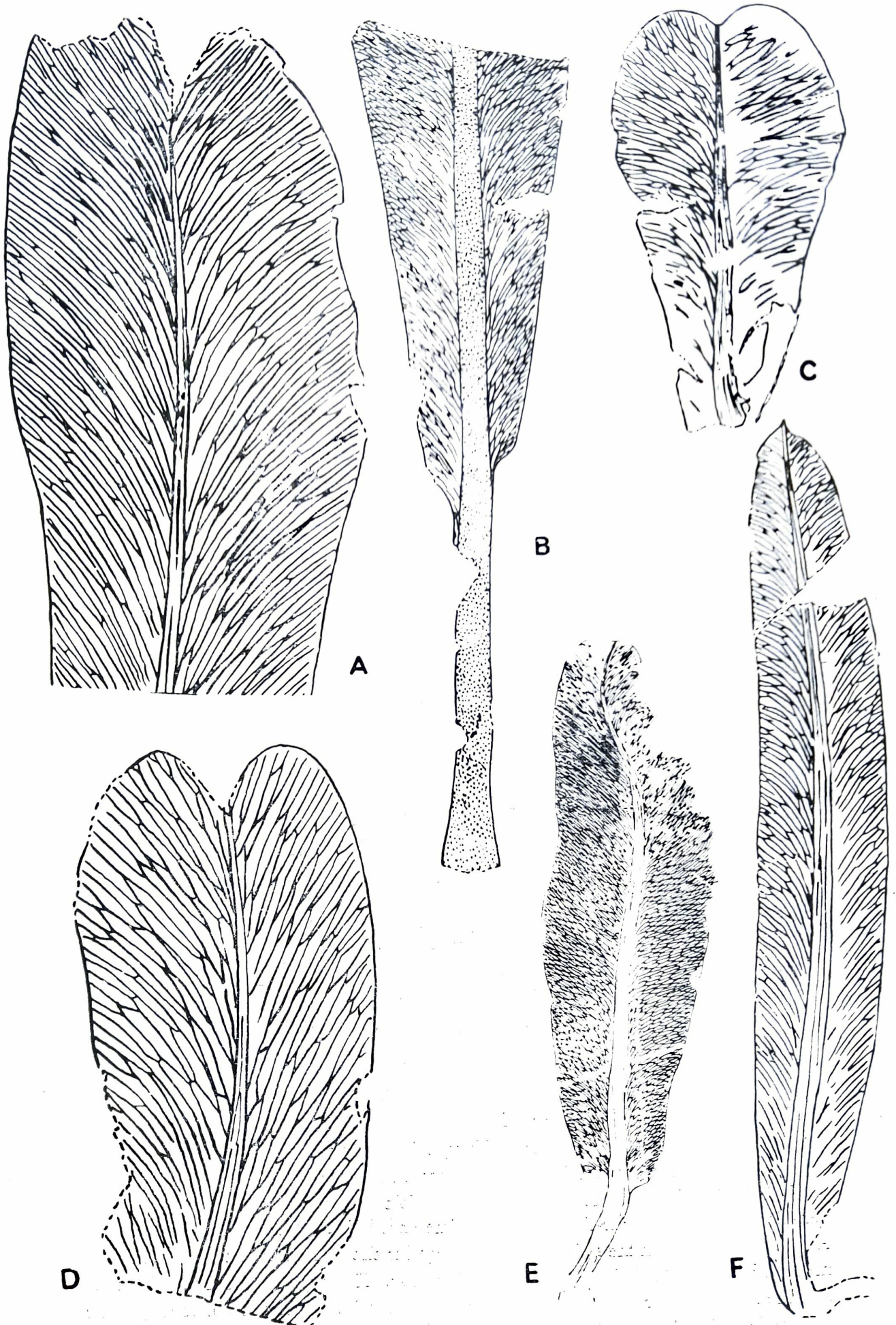
*Holotype*—Specimen no. B.S.I.P. 35920; Upper Permian; Kamthi Formation; Hinjrida Ghati, near Handapa Village, Dhenkanal District, Orissa.

*Derivation of the name*—The species is named after its characteristic acuminate apex.

*Description*—This species is represented by a single specimen in the Handapa collection. The specimen is a characteristic complete leaf which is small in size and looks like a spindle. The leaf is widest near the apical part which is prolonged to form a characteristic acuminate apex. The lamina gradually narrows towards the base. The shape of the leaf is oblanceolate to narrow oblanceolate; length/width ratio being 4:1. The

Text-fig. 1—A, *Glossopteris maheshwarii* sp. nov.: Almost a complete leaf enlarged to show the details of venation pattern. Specimen no. 35922,  $\times 4$ ; B, *Glossopteris utkalensis* sp. nov.: Almost a complete oblanceolate leaf showing the details of venation pattern and a curved petiole. Specimen no. 35925,  $\times 2$ ; C, *Glossopteris maheshwarii* sp. nov. A complete Holotype specimen enlarged to show the details of venation pattern and a small petiole. Specimen no. 35921,  $\times 4$ ; D, *Glossopteris utkalensis* sp. nov. A portion of the leaf in the apical region, enlarged to show the details of venation pattern. Specimen no. 35924,  $\times 4$ ; E, *Glossopteris utkalensis* sp. nov. Holotype specimen showing the retuse apex and the lateral veins running horizontally to the margin. Specimen no. 35924,  $\times 2$ ; and F, An enlarged portion, in the apical region of the leaf in fig. 2 showing the details of venation pattern.  $\times 4$ .





Text-fig. 2



length of the leaf is 5.5 cm and the width is 1.4 cm at its widest part (2.1 cm from the apex). The acuminate apex of the leaf is very characteristic feature of the species. This apical prolongation is 1 cm in length. The base of the leaf is acute cuneate. The margin is entire.

The midrib is broad, flat, striated, persists up to the apex but becomes very thin at the apical tip. The thickness of the midrib is 2 mm near the base and 1.5 mm in the middle part of the leaf. The secondary veins emerge from the midrib at a very low angle 12-15° then arch backwards very close to the midrib and travel straight and horizontally to the margin to meet it at 70-80°. The secondary veins bifurcate and anastomose to form elongate meshes which are oblong polygonal in shape. The meshes are strikingly broad near the midrib, then become comparatively narrow and long up to the middle part of the lamina, but near the margin they are small and very narrow. The secondary veins bifurcate and anastomose 2-3 times in their course from midrib to the margin, so the meshes in the widest part of the leaf are 2-3. At the apical and basal regions, meshes are very short and narrow. In the apical prolongation, bifurcation of the secondary veins is rare. The meshes are uniform in their general shape throughout the lamina. A few cross connections are also seen here and there.

Concentration of veins/1/2 cm<sup>2</sup> at the widest part of the leaf

(a) Near the midrib	8—9
(b) Near the margin	15—17

Concentration of meshes/1/2 cm<sup>2</sup> at the widest part of the leaf

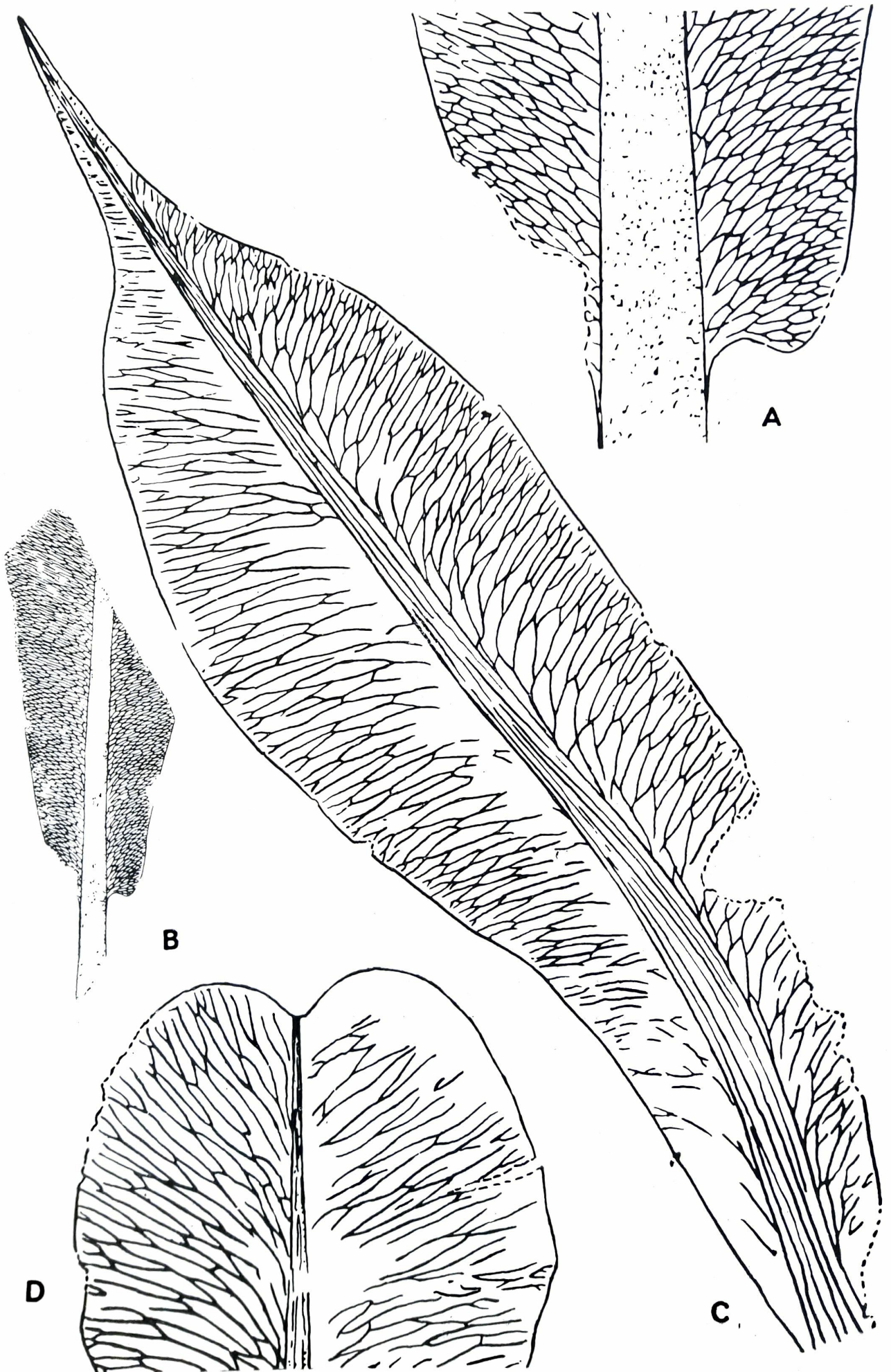
(a) Near the midrib	11—12
(b) Near the margin	18—20

*Comparison*—The described leaf is very characteristic in having an acuminate apex. Although different distinct types of apices are known to occur in *Glossopteris* species but so far no *Glossopteris* species is known to have acuminate apex. The species are *Glossopteris-retusa* Maheshwari, 1965 (having retuse apex), *G. emarginata* Maheshwari & Prakash, 1965 (emarginate apex), *G. orbicularis* Feistmantel, 1881 (emarginate apex and circular shape of the leaf) and *Glossopteris pandurata* Pant & Gupta, 1971 (rounded apex with a slight notch).

The species *Glossopteris retusa* and *G. orbicularis* are known from the Raniganj Formation of the Raniganj Coalfield, while the species *G. emarginata* and *G. pandurata* from the Barakar Formation of the Rajmahal Hills, Bihar and Karharbari Formation of the Giridih Coalfield, Bihar, respectively. The venation in *Glossopteris retusa*, *G. emarginata* and *G. pandurata* is of *G. communis* type with very thin and dense secondary veins forming very

Text-fig. 2. A, *Glossopteris hinjridaensis* sp. nov. : Upper portion of the leaf enlarged to show the dense *Glossopteris communis* type of venation pattern. Specimen no. 35926, × 4; B, *Glossopteris inaequalis* sp. nov. : Basal portion of the leaf showing unequal laminar lobes and a long petiole. Specimen no. 35928, × 1. C, *Glossopteris dhenkanalensis* sp. nov.: Almost a complete Holotype specimen showing the emarginate apex and details of venation pattern. Specimen no. 35931, × 2; D, *Glossopteris hinjridaensis* sp. nov.: Holotype specimen enlarged to show the emarginate apex and dense venation pattern. Specimen no. 35927, × 4. E, *Glossopteris inaequalis* sp. nov.: Specimen showing almost a complete leaf with a petiole. Specimen no. 35930, × 1; and F, *Glossopteris kamthiensis* sp. nov. showing a complete, very narrow leaf having mucronate apex and very fine secondary veins. Specimen no. 35923, × 4.





Text-fig. 3



narrow meshes. The venation of *Glossopteris orbicularis* is also distinct with broad uniform meshes throughout the lamina.

The presently described species shows some resemblance in venation pattern with *Glossopteris stricta* Bunbury, 1861, but the size of the leaf of the later species is too big with altogether different type of leaf shape. Being a small sized leaf it shows some resemblance to the fertile scales known from the Lower Gondwana formations belonging to *Glossopteris* but it is distinct from all the known fertile scales in having a distinct midrib.

Since the presently described characteristic leaf is distinct from all the known species of *Glossopteris*, it is given a new specific name.

*Glossopteris utkalensis* sp. nov.

Pl. 2, figs 1, 3, 6, 7 ; Text-fig. 1B, D, E, F

*Diagnosis*—Leaf oblanceolate with retuse-obtuse apex; leaf widest in the apical region; midrib stout, persists upto the apex; secondary veins acute in the lower portion, while in the upper half emerge at wide angles, arch and travel horizontally to the margin with an inward curvature in the apical portion of the leaf; broad and small pentagonal to polygonal meshes near the midrib and narrow elongate, oblong polygonal meshes in the rest of the lamina.

*Holotype*—Specimen no. B.S.I.P. 35924; Upper Permian; Kamthi Formation; Hinjrida Ghati, near Handapa Village, Dhenkanal District, Orissa.

*Derivation of the name*—The species is named after ancient State "Utkal", now known as Orissa to which these specimens belong.

*Description*—This species is represented by only three specimens in the collection. Two of the leaves are almost complete. The leaves are small in size, broadest in the apical portion and tapering gradually towards the base. The shape of the leaf is oblanceolate and length/width ratio is 3:1. The most complete leaves are 5.5 cm and 5.6 cm in length and their width being 1.6 cm and 2.3 cm respectively at their widest part. The petiole is preserved only in one leaf which is 1 cm long. Ill preserved apex is present in two specimens. In one of the specimens it looks to be obtuse while in the other it seems to be retuse which is preserved only on the right side of the lamina. The base is badly preserved in only one specimen. The margin of the leaf is wavy. The midrib is medium to broad, flat as well as grooved, striated and persistent right up to the apex. The thickness of the midrib is between 2-2.5 mm at the base, 1-1.5 mm in the middle and 0.5 to 1 mm at the apex of the leaves. The secondary veins are thin and the overall venation is dense. The secondary veins emerge at a very low angle 15-25° from the midrib in the lower portion of the leaves, then arch backwards very close to the midrib forming curves and travel straight up to the margin to meet it at 70-80°. In the upper half of the leaves the secondary veins emerge at wide angle 35-45° and travel horizontally to the margin with a slight inward curvature. The secondary veins bifurcate and anastomose 4-7 times in

Text-fig. 3—A, *Glossopteris inaequalis* sp. nov.: Showing the basal region of the Holotype, enlarged to show the unequal basal lobes and details of venation pattern. Specimen no. 35929,  $\times 4$ ; B, *Glossopteris inaequalis* sp. nov. Holotype showing the unequal basal lobes and the petiole. Specimen no. 35929,  $\times 1$ ; C, *Glossopteris acuminata* sp. nov.: Almost a complete leaf enlarged to show the acuminate apex and *Glossopteris stricta* type of venation pattern. Specimen no. 35920,  $\times 4$ ; and D, *Glossopteris dhenkanalensis* sp. nov. : Upper portion of the Holotype specimen enlarged to show the emarginate apex and the details of venation pattern. Specimen no. 35931,  $\times 4$ .



their full course from midrib to the margin and form quite broad and small meshes very close to the midrib which are pentagonal, hexagonal or polygonal in shape but towards the margin they are narrow, elongate and are oblong polygonal in shape. At the margin the meshes are very small and narrow and are pentagonal or oblong polygonal in shape. In one of the specimens the secondary veins at the apex, travel to the margin with an inward curvature, while in the other specimen meshes are very narrow and long and are narrow polygonal in shape. The cross connections are also seen.

Concentration of veins/cm<sup>2</sup>

(1) In the upper part of the leaf	Near the midrib 13-15 Near the margin 30-35
(2) In the middle and lower part of the leaf	Near the midrib 10-12 Near the margin 20-25

Concentration of meshes/cm<sup>2</sup>

(1) In the upper part of the leaf	90-100
(2) In the middle and lower part of the leaf	60-70

*Comparison*—The *Glossopteris* species known from the Lower Gondwana formations of India having wide angle of emergence of secondary veins and their more or less horizontal travelling to the margin are, *Glossopteris damudica* Feistmantel, 1881, *G. mohudaensis* Chandra & Surange, 1979, *G. rhabdotaenioides* Pant & Singh, 1971, *G. nimishea* Chandra & Surange, 1979, *G. karanpurensis* Kulkarni, 1971, *G. euryneura* Maheshwari, 1965, *G. lanceolatus* Pant & Singh, 1971, *G. stricta* Bunbury, 1861, *G. gopadensis* Banerji *et al.*, 1976, *G. senii* Srivastava, S.C., 1969, *G. tortuosa* Zeiller 1902 and *G. maculata* Pant & Singh, 1974.

The fronds of *Glossopteris damudica*, *G. mohudaensis* and *G. rhabdotaenioides* are elliptic in shape and differ from *G. utkalensis* in having very wide and big lamina and long, narrow oblong meshes throughout the lamina.

The leaves of *Glossopteris nimishea* and *G. karanpurensis* are very big in size with many narrow, oblong polygonal meshes.

The species *Glossopteris euryneura*, *G. lanceolatus* and *G. stricta* are characteristically long, lanceolate or strap shaped leaves. In *G. euryneura* secondary veins fork once or twice from midrib to the margin and the meshes are very long. *G. lanceolatus* differs from the described species in having very narrow uniform meshes throughout the lamina. *G. stricta* can again be distinguished from *G. utkalensis* in their strikingly broad meshes near the midrib and very narrow ones towards the margin.

*Glossopteris gopadensis* and *G. senii* are very small and narrow forms and are different from the present species in having very narrow and long meshes.

In *Glossopteris tortuosa* the secondary veins follow an undulating or zigzag course from midrib to the margin with trapezoidal meshes. Therefore, it is also distinct from *G. utkalensis*.

Pant and Singh's *Glossopteris maculata* shows some resemblance to *G. utkalensis* but it also differs from the later in having broad, small, penta or hexagonal meshes as compared to comparatively narrow, long and oblong polygonal meshes of *G. utkalensis*.

The Handapa specimens thus can not be identified with any of the known species of *Glossopteris* and therefore, have been placed under a new specific name, *Glossopteris utkalensis*.



*Glossopteris hinjridaensis* sp. nov.

Pl. 2, figs 2, 4, 5, 8; Text-fig. 2-A, D

*Diagnosis*—Leaf small and narrow, broadest in apical region, gradually tapering towards base; oblanceolate to narrow oblanceolate with emarginate apex; midrib broad, persistent; secondary veins very thin, emerge at acute angles; venation *G. communis* type; meshes very narrow, elongated, narrow polygonal in shape; bifurcation and anastomosing of the veins only 2-3 times.

*Holotype*—Specimen no. B. S. I. P. 35927; Upper Permian; Kamthi Formation; Hinjrida Ghati near Handapa Village, Dhenkanal District, Orissa.

*Derivation of the name*—The species is named after Hinjrida Ghati to which the species belongs.

*Description*—There are five specimens in the collection but none of them is preserved with a complete leaf. The leaf is narrow, small in size, wider in the apical portion and gradually tapering towards the base. The shape of the leaf is oblanceolate to narrow oblanceolate and length/width ratio is 4-6:1. The apex of the leaf is emarginate with a deep notch in the centre. The base is not preserved in any of the specimens. The length of the preserved leaves ranges between 2.1 to 3.9 cm but the complete leaf might have been 5-7 cm long. The width of the leaves ranges between 0.9 to 1.3 cm at their widest part. The margin of the leaf is entire. The midrib is medium to broad, striated, flat and persisting right upto the apex. The average width of the midrib ranges between 1 to 2 mm at the basal end and 0.5 mm to 1 mm in the middle part of the leaf.

The venation is dense and of *G. communis* type. The secondary veins are thin and form uniform meshes throughout the lamina. The secondary veins emerge from the midrib at a very acute angle 10-15° and after running parallel to the midrib for some distance, arch backwardly and run up to the margin to meet it at 30-45°. The meshes are elongated, very narrow and uniform in shape and size throughout the lamina. The shape of the meshes is narrow polygonal, only 2-3 meshes are formed in the course of a vein from midrib to the margin. The cross connections between the veins are absent.

Concentration of veins/1/2 cm <sup>2</sup>	in the upper portion of the leaf	16-22
Concentration of meshes/1/2 cm <sup>2</sup>	„ „ „	20-24

*Comparison*—In its overall shape of the leaf including apex and venation pattern, the species shows some resemblance to *Glossopteris retusa* Maheshwari, 1965, *G. angusta* Pant & Gupta, 1971, *G. pandurata* Pant & Gupta, 1971 and *G. emarginata* Maheshwari & Prakash, 1965.

*Glossopteris retusa* is described from the Raniganj Formation of the Raniganj Coalfield and resembles *G. hinjridaensis* in its *G. communis* type of dense venation but differs in having retuse apex and two deep lateral notches near the apex. The species *Glossopteris angusta* belongs to the Karharbari Formation of the Giridih Coalfield, Bihar and is comparatively bigger leaf with round apex, although its venation is similar to the presently described leaf.

Similarly *G. pandurata* is also from the Karharbari Formation of the Giridih Coalfield, Bihar and shows resemblance with *G. hinjridaensis* in the type of venation pattern only. The apex of *G. pandurata* is much flattened and is definitely different from the emarginate apex of the described leaf. *G. emarginata* from the Barakar Formation of the Rajmahal Hills shows some resemblance with *G. hinjridaensis*. The leaf of *G. emarginata* has



an emarginate apex with a similar dense venation pattern as in the described leaf but *G. emarginata* is a big leaf and its shape is also different that is oblong. The secondary veins in *G. emarginata* in the apical region 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, while in *G. hinjridaensis* there is no such inward curvature of secondary veins in the apical region.

Since the presently described leaf is distinct from all the known species of *Glossopteris*, it has therefore been given a new specific name *G. hinjridaensis*.

*Glossopteris inaequalis* sp. nov.

Pl. 1, figs. 1, 3, 4, 5 ; Text-figs. 2 B, E; 3-A, B

**Diagnosis**—Leaf small to medium, broadest in the middle, tapering towards both the ends; shape narrow oblong to lorate oblong; apex obtuse, base obtusely abnormal to unequally auriculate with unequal lobes; long, stout petiole; midrib very broad, stout, persistent; secondary veins acute, arched, travel up to margin at wide angles 50-75°; venation compact, 6-8 small, narrow uniform meshes arranged in a line, meshes oblong polygonal.

**Holotype**—Specimen no. B.S.I.P. 35929; Upper Permian; Kamthi Formation; Hinjrida Ghati near Handapa Village, Dhenkanal District, Orissa.

**Derivation of name**—The species is named after its characteristic asymmetrical and unequal basal lobes.

**Description**—There are nine specimens of this species in the Handapa collection, out of them only two leaves are almost complete and the rest of them are portions of the leaves. The leaf is petiolate, small to medium in size, broadest in the middle portion and gradually tapering towards both the ends. The shape of the leaf is narrow oblong to lorate oblong and the length/width ratio is 4.5 :1. The length of the most complete two leaves is 9.3 cm and 17.3 cm including the length of the petioles and their width is 2.3 and 3.7 cm respectively at their widest part. The complete leaf might have been upto 19-20 cm in length. The width of the leaves ranges between 2.3 to 4.2 cm. The margin of the leaf is entire. The apex is preserved only in one specimen which is slightly broken but it looks to be obtuse. The base is preserved almost in all the specimens and is very characteristic in shape. It is unequally lobed. Unlike other *Glossopteris* species, the lamina at its basal end meets the midrib at different distances on both the sides, it means that the two lobes are unequal and asymmetrical. The distance of meeting of both the lobes of the lamina to the midrib is 3 to 6 mm in different specimens. The base is obtusely abnormal in some specimens and unequally auriculate in the rest. The petiole is well preserved almost in all the specimens which is quite stout and ranges between 1.8 to 5.2 cm in length and 3 to 7 mm in width.

The midrib is very broad, stout, flat, striated with spots and persistent right upto the apex. The thickness of the midrib ranges between 3.5 to 4.5 mm at the base, 2.5 to 3 mm in the middle and it is 0.5 mm at the apex of the leaf. The secondary veins emerge from the midrib at acute angles 15-25°, then arch backwardly very close to the midrib and continue to the margin to meet it at 45-50° in the upper portion of the leaf and 65-75° in the middle and lower parts of the leaf. The venation is very compact. The secondary veins bifurcate and anastomose 6-8 times in their full course from the midrib to the margin and form equal number of small and narrow, uniform meshes throughout the lamina. The meshes are arranged almost in a line from midrib to the margin and are oblong



polygonal in shape. The meshes are slightly broad and small very close to the midrib in the basal portion of the leaf particularly so around the basal lobes of the lamina. Towards the margin the meshes become comparatively narrow and at the margin they are again very small. There is a uniformity in the shape and the size of the meshes throughout the lamina. The cross connections are present here and there between the veins.

(1) Concentration of veins/cm <sup>2</sup> in the middle portion of the leaf	
(a) Near the midrib	32-34
(b) Near the margin	38-42
(2) Concentration of meshes/cm <sup>2</sup> in the middle portion of the leaf	
(a) Near the midrib	55-60
(b) Near the margin	80-95

*Comparison*—The presently described *Glossopteris* species is a distinct and characteristic species and shows no resemblance with any of the known *Glossopteris* species. It can be compared with some of the *Glossopteris* species which are known with well developed petioles. These species are, *Glossopteris sastrii* Pant & Singh, 1974, *G. maculata* Pant & Singh, 1974, *G. radiata* Pant & Singh, 1971, *G. elongata* Dana, 1849, *G. stricta* Bunbury, 1861, *G. barakarensis* Kulkarni, 1971, *Glossopteris longicaulis* Feistmantel, 1879 and another genus *Belemnopteris* Feistmantel, 1876.

All the three *Glossopteris* species, viz., *G. sastrii*, *G. maculata* and *G. radiata* belong to the Raniganj Formation of the Raniganj Coalfield, W. Bengal. *G. Sastrii* and *G. maculata* resemble the presently described species in having obtuse or rounded apex but the venation pattern including the shape of the meshes of both the species is different, as in *G. sastrii* only 2-3 very long meshes are formed and in *G. maculata* the meshes are broadly polygonal. The rounded base of *G. radiata* shows some resemblance up to a certain extent with the base of some of our specimens but *G. radiata* is characterised by its radiating of venation pattern. *Glossopteris elongata* described from the New Castle, Australia differs from *Glossopteris inaequalis* in having acute normal base and *G. retifera* type of venation pattern. The species *Glossopteris stricta* which belongs to the Kamthi Formation of Silewada and Kampti, Maharashtra, is characterised by having typical venation pattern. There is some resemblance in their petioles.

*Glossopteris barakarensis* known from the Barakar Formation of the South Karanpura Coalfield, resembles with the presently described species only in its petiolate nature of leaf form, otherwise the venation pattern and the type of base in *G. inaequalis* is very different and characteristic. The species *Glossopteris longicaulis* which is described from the Karharbari Formation of the Karharbari Coalfield, slightly resembles with *G. inaequalis* in having elongated petiole and more or less similar meshes but the later differs from *G. longicaulis* in its characteristic abnormal obtuse or auriculate base. The genus *Belemnopteris* resembles with the presently described species only in the presence of basal lobes. Moreover, in this genus the midrib is tricostate and the secondary veins are horizontally travelling and the meshes are broadly polygonal.

From the above discussion it is concluded that none of the known *Glossopteris* species resembles with *G. inaequalis*. Therefore, it has been given a new specific name.

*Glossopteris dhenkanalensis* sp. nov.

Pl. 3, figs. 2, 6; Text-figs. 2C, 3D



*Diagnosis*—Leaf small, very broad at the apex, gradually narrowing towards the base; shape narrow obovate, apex emarginate; midrib broad, stout, persistent; secondary veins very much arched, travel to the margin at wide angles 70-80° with graceful curves; secondary veins bend inwards towards the apical notch in the apical region; 2-3 long slightly broad oblong polygonal meshes formed between midrib and margin.

*Holotype*—Specimen no. B.S.I.P. 35931; Upper Permian; Kamthi Formation; Hinjridda Ghati near Handapa Village, Dhenkanal District, Orissa.

*Derivation of name*—The species is named after Dhenkanal District in Orissa state.

*Description*—There is only one specimen of this species in the collection which is almost a complete leaf. The leaf is small and broadest at the apical region. The lamina of the leaf is symmetrical and is very narrow at the base which expands considerably upwards to give it a spatulate form. The shape of the leaf is narrow obovate and the length/width ratio being 2:1. The length of the leaf is 3.3 cm and the width is 1.7 cm at its widest part. The margin of the leaf is entire and deeply notched at the apex. The apex is emarginate, while the base is not preserved.

The midrib is quite broad, evenly broad up to the middle part of the leaf, then gradually tapers towards the apex but persisting right up to the end. The thickness of the midrib is 2 mm at the basal end and 1.5 mm in the middle part of the leaf. The secondary veins emerge from the midrib at a very acute angle (15-20), run almost parallel to the midrib up to a short distance, then arch backwards near the midrib and proceed to the margin at a wide angle (70-80°) with graceful curves. In the apical region the secondary veins instead of turning away from the midrib, bend towards the apical notch from both sides. The secondary veins form immediately after arching, dichotomise and anastomose to form long, slightly broad, oblong polygonal meshes. The meshes are uniform in size and shape throughout the lamina except near the margin where they are short and small. 2-3 meshes are formed during the course of a vein from midrib to the margin. A few cross connections are present.

Concentration of veins/cm<sup>2</sup> in the upper portion of the leaf 28-30

Concentration of meshes/cm<sup>2</sup> in the upper portion of the leaf 45-50

*Comparison*—The species *Glossopteris dhenkanalensis* does not resemble with any of the known *Glossopteris* species of the Lower Gondwana of India. In its overall shape and very small size, it shows some resemblance with the known *Glossopteris* species such as *Glossopteris emarginata* Maheshwari & Prakash, 1965, *G. pandurata* Pant & Gupta, 1971, *G. retusa* Maheshwari, 1965, *G. orbicularis* Feistmantel, 1881, *G. taeniensis* Chandra & Surange, 1979 and the Australian species *Glossopteris spathulato-Cordata* Feistmantel, 1878.

*Glossopteris emarginata* which is known from the Barakar Formation of the Rajmahal Hills, resembles in some respect to *G. dhenkanalensis* in having emarginate apex and inward curvature of the secondary veins in the apical region. *G. emarginata* is a big oblong leaf and its venation pattern is also very dense with very narrow, elongate, narrow polygonal meshes. *Glossopteris pandurata* described from the Karharbari Formation of the Giridih Coalfield, is a pandurate leaf with a flattened apex and the venation pattern of this species is very dense (*G. communis* type) with long narrow polygonal meshes. *G. retusa* belongs to the Raniganj Formation of the Raniganj Coalfield. It is a different leaf having retuse apex and two deep notches on both the sides of the lamina near the apex. Moreover, the venation pattern of *G. retusa* is also very fine and of *G. Communis* type with elongate, very narrow meshes. *Glossopteris orbicularis* which is also known from the Raniganj Formation



of the Raniganj Coalfield, is almost a circular petiolate leaf. *G. dhenkanalensis* resembles *G. orbicularis* in the emarginate type of apex and in shape and size of the meshes, but the secondary veins in *G. orbicularis* run almost parallel to the outer leaf margin, while in *G. dhenkanalensis* veins after emerging from the midrib, travel to the margin at wide angles. Inward curving of the secondary veins in *G. dhenkanalensis* is seen only in the apical emarginate region. *Glossopteris tazniensis* belongs to the Karharbari Formation of the South Karanpura Coalfield and is a very small leaf with obtuse apex and the venation pattern is also very different from the described leaf.

*Glossopteris dhenkanalensis* sp. nov. also shows some resemblance with *Glossopteris spathulato-cordata*, known from the upper Coal Measures (Upper Permian) of New South Wales, Australia. Both *G. spathulato-cordata* and *G. dhenkanalensis* are small, spathulate leaves with emarginate apex. But *G. spathulato-cordata* is a wide obovate, flabellate apexed and petiolate leaf form. The midrib in this species is evanescent, while in *G. dhenkanalensis* it is persistent. The meshes in *G. spathulato-cordata* are broadly polygonal and very few (mostly two), while in *G. dhenkanalensis* they are comparatively narrow, much more in number and more or less uniform throughout the lamina.

The species *Glossopteris dhenkanalensis* is based upon a single specimen but it is so characteristic that we have no hesitation in assigning it to a new species.

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## Explanation of Plates

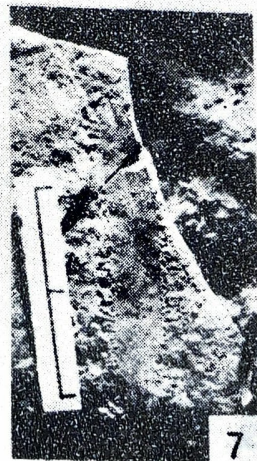
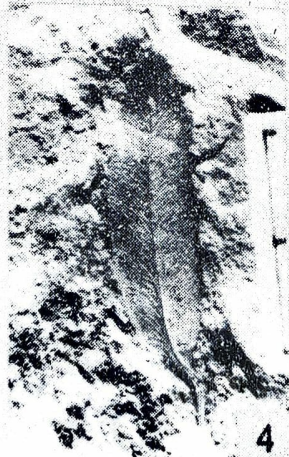
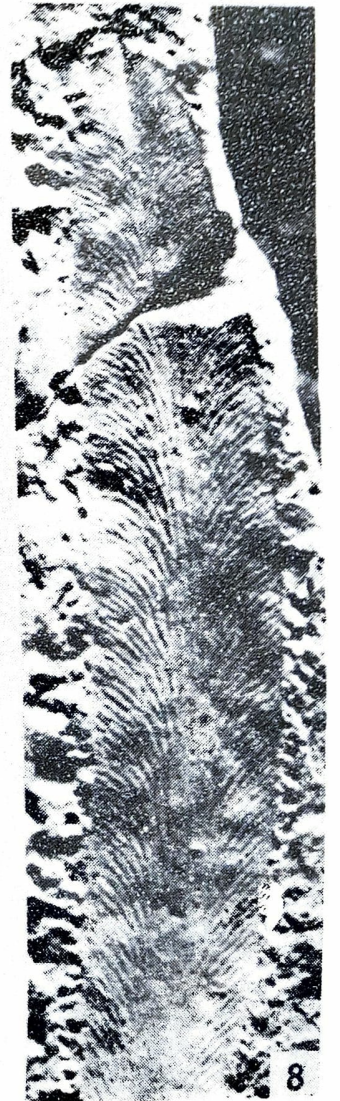
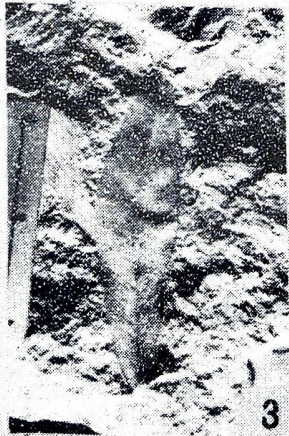
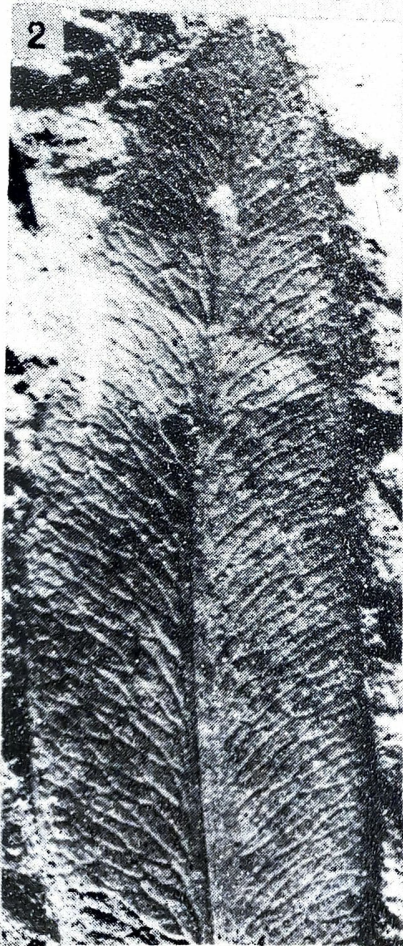
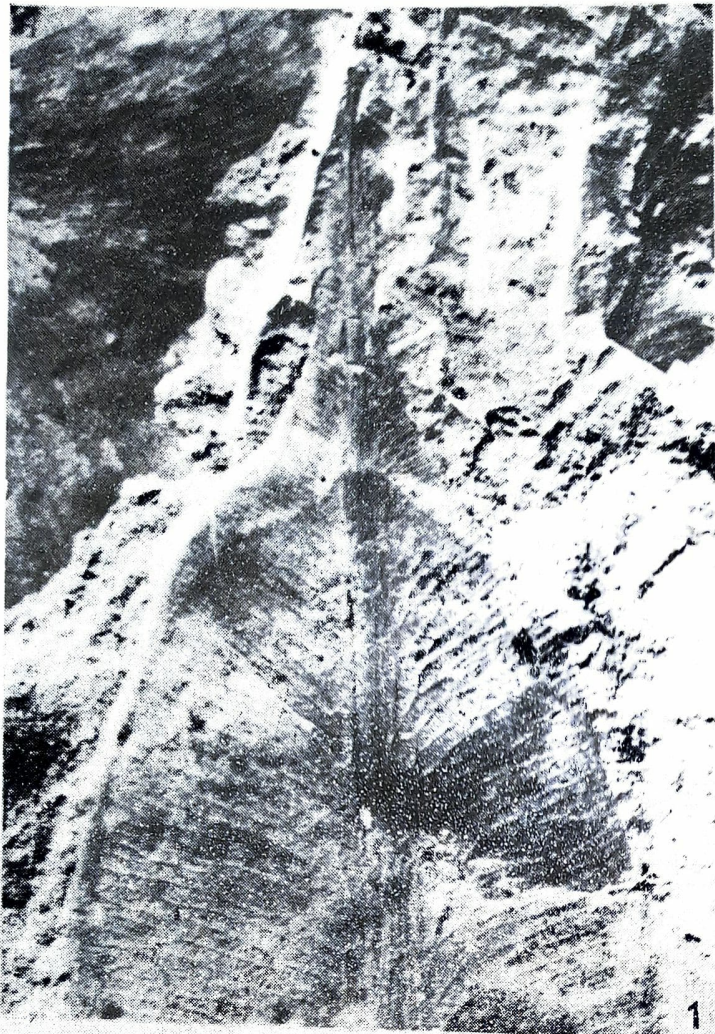
### PLATE 1

1. *Glossopteris acuminata* sp. nov.  
Upper portion of the Holotype enlarged to show the acuminate apex and the details of venation pattern. Specimen no. 35920,  $\times 4$ .
- 2, 5. *Glossopteris maheshwarii* sp. nov.  
Upper portions of the specimens enlarged to show the details of venation pattern. Specimen nos. 35921 and 35922,  $\times 4$ .
3. *Glossopteris maheshwarii* sp. nov.  
Specimen showing a complete, small, narrow, elliptic leaf. Specimen no. 35922,  $\times 1$ .
4. *Glossopteris maheshwarii* sp. nov.  
Holotype showing a very small, narrow oblong complete leaf with a petiole. Specimen no. 35921,  $\times 1$ .
6. *Glossopteris acuminata* sp. nov.  
Holotype showing a complete oblanceolate leaf having acuminate apex. Specimen no. 35920,  $\times 1$ .
7. *Glossopteris kamthiensis* sp. nov.  
Holotype showing very narrow, linear oblong complete leaf. Specimen no. 35923,  $\times 1$ .
8. Upper portion of the leaf in fig. 7 enlarged to show the mucronate apex, fine lateral veins and very narrow linear meshes.  $\times 4$ .

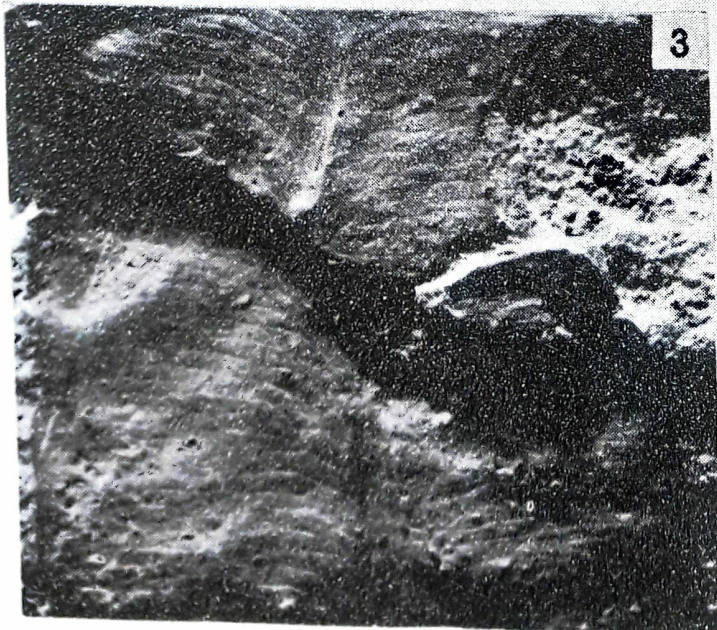
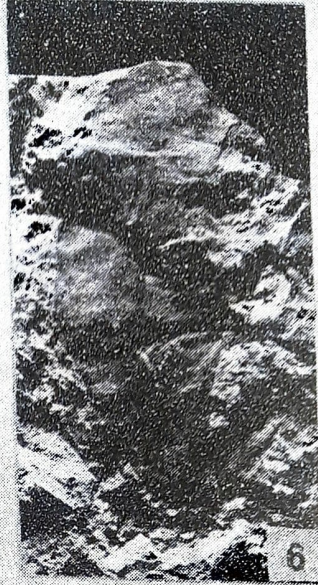
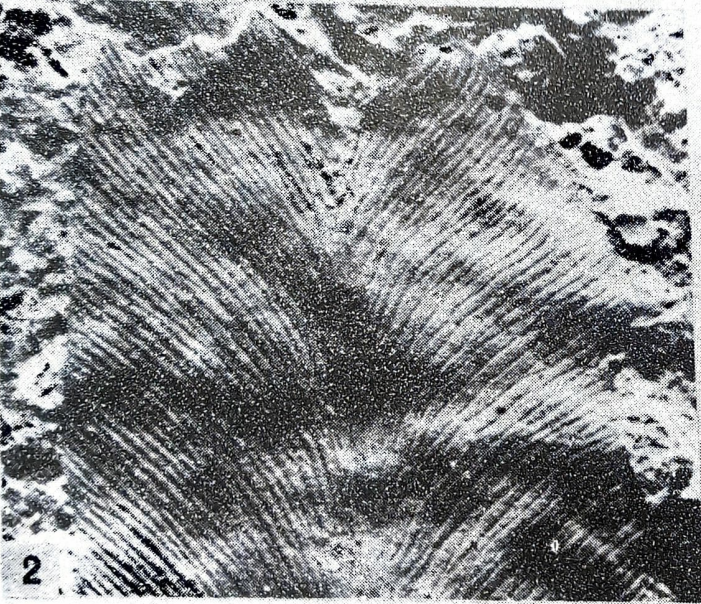
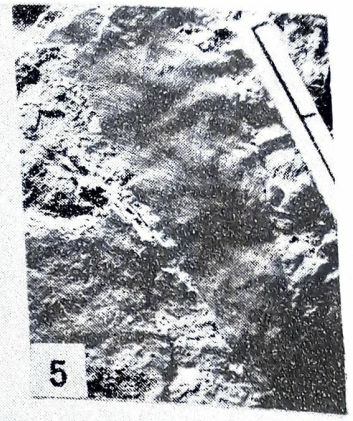
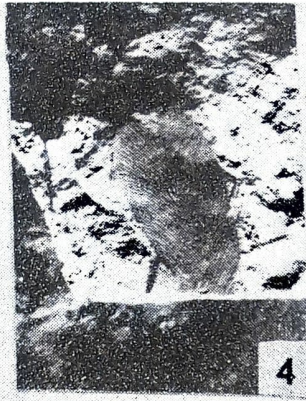
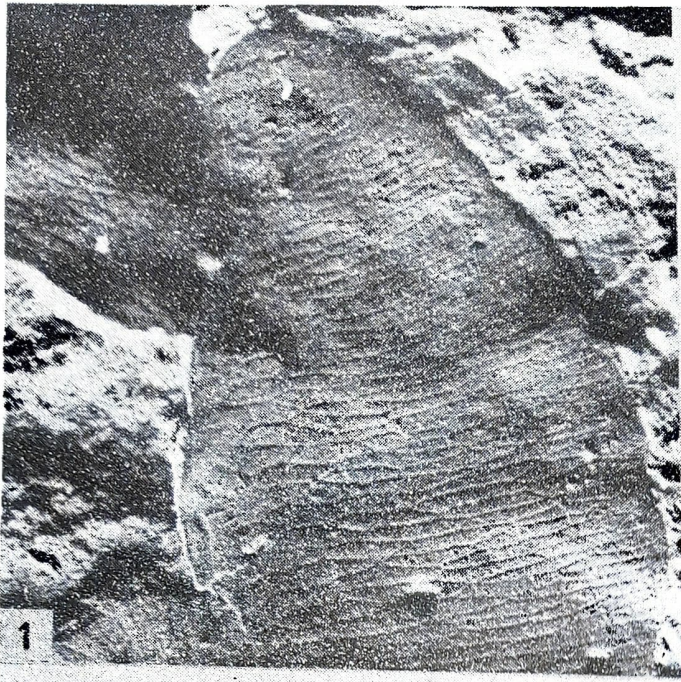
### PLATE 2

1. *Glossopteris utkalensis* sp. nov.  
A portion from the upper part of the Holotype enlarged to show the retuse apex and upwardly curving lateral veins. Specimen no. 35924,  $\times 4$ .
2. *Glossopteris hinjridaensis* sp. nov.  
Upper portion of the leaf enlarged to show very narrow linear meshes and dense venation pattern. Specimen no. 35926,  $\times 4$ .
3. *Glossopteris utkalensis* sp. nov.  
Middle portion of the specimen enlarged to show the secondary veins running horizontally to the margin with oblong polygonal meshes. Specimen no. 35925,  $\times 4$ .
4. *Glossopteris hinjridaensis* sp. nov.  
Holotype showing almost a complete leaf. Specimen no. 35927,  $\times 1$ .
5. *Glossopteris hinjridaensis* sp. nov.  
Specimen showing almost a complete leaf having very thin secondary veins. Specimen no. 35926,  $\times 1$ .
6. *Glossopteris utkalensis* sp. nov.  
Specimen showing almost a complete leaf with a curved petiole. Specimen no. 35925,  $\times 1$ .
7. *Glossopteris utkalensis* sp. nov.  
Holotype showing almost a complete, narrow obovate leaf with retuse apex and horizontally running lateral veins. Specimen no. 35924,  $\times 1$ .
8. Enlargement of the leaf in fig. 4 showing emarginate apex and dense venation pattern with long, narrow, polygonal meshes.  $\times 4$ .











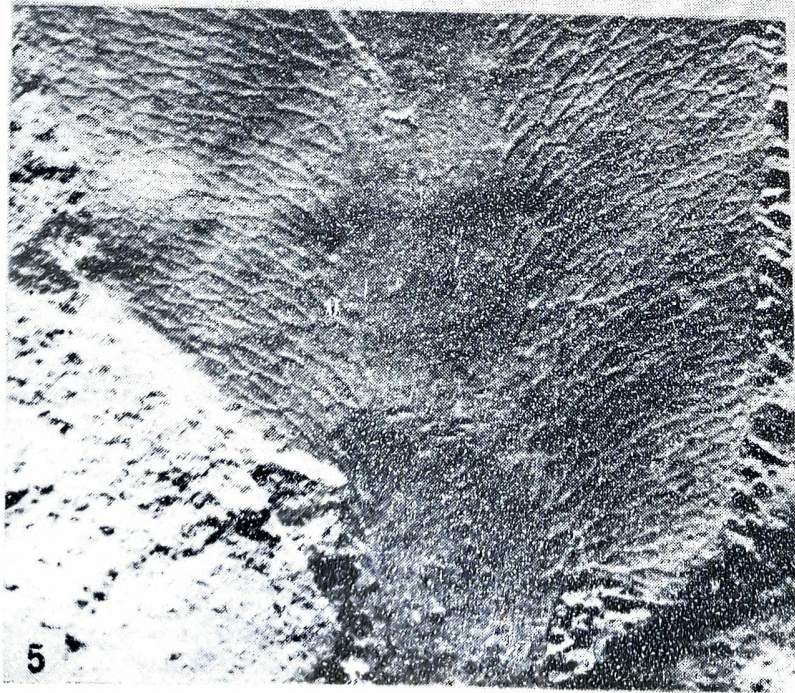




PLATE 3

1. *Glossopteris inaequalis* sp. nov.  
Basal portion of the leaf showing unequal basal laminar lobes and a long petiole. Specimen no. 35928, × 1.
2. *Glossopteris dhenkanalensis* sp. nov.  
Specimen showing almost a complete spatulate leaf with emarginate apex. Specimen no. 35931, × 1.
3. *Glossopteris inaequalis* sp. nov.  
Holotype showing unequal basal lobes and the petiole. Specimen no. 35929, × 1.
4. *Glossopteris inaequalis* sp. nov.  
Specimen showing almost a complete leaf with unequal basal lobes and a long petiole. Specimen no. 35930, × 1.
5. Enlargement of the basal portion of the leaf in fig. 3 showing unequal basal laminar lobes and the details of venation pattern. × 4.
6. Enlargement of the upper portion of the leaf in fig. 2 showing emarginate apex and the details of venation pattern. × 4.