Epidermal morphology of some Indian species of the genus *Glossopteris* Brongniart

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Nineteen species of the genus *Glossopteris* are described from the Barakar Formation of Churulia Area, Raniganj Coalfield, India. Epidermal features of sixteen species have been investigated. In the rest, the carbonified crust is not preserved. Nine species, viz., *Glossopteris asansolensis, G. bunburyana, G. danae, G. manjuiae, G. schopfii, G. schimperi, G. ednae, G. kusumiae* and *G. roylei* are new. Nomenclature of *G. damudica* has been revised and the new species *G. danae* is established on the basis of revised nomenclature.

Key-words—*Glossopteris*, Epidermal morphology, Barakar Formation, Raniganj Coalfield, Gondwana, India.

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सारांश

ग्लॉसॉप्टेरिस ब्रोन्गनिआ प्रजाति की कुछ भारतीय जातियों की अधिचर्मीय आकृरिकी

हरिकृष्ण माहेश्वरी एवं रजनी तिवारी

रानीगंज कोयला-क्षेत्र में चुरुलिया क्षेत्र के बराकार शैल-समूह से **ग्लॉसॉप्टेरिस** प्रजाति की 19 जातियों का वर्णन किया गया है। इनमें से 16 जातियों के अधिचर्मीय लक्षणों का अन्वेषण किया गया है तथा शेष तीन जातियों में कार्बनी पपड़ी परिरक्षित नहीं हो पाई है। **ग्लॉसॉप्टेरिस आसनसोलेन्सिस, ग्लॉ० बनबरियाना, ग्लॉ० डानाई, ग्लॉ० मंजुई, ग्लॉ० शॉफ़ई, ग्लॉ० शिम्पेराई, ग्लॉ० एडनी, ग्लॉ० कुसुमी** एवं **ग्लॉ० रॉयलाई** नामक 9 जातियाँ नई हैं। **ग्लॉ० दमुदिक्स** के नामकरण में संशोधन किया गया है तथा इसी के आधार पर **ग्लॉ० डानाई** नामक एक नई जाति बनाई गई है।

AFTER initial epidermal studies on the leaves of *Glossopteris indica* Schimper by Zeiller (1896), epidermal morphology of a large number of species of the genus *Glossopteris* has been investigated. Sahni (1923) described the cuticular structure of *G. angustifolia* Brongniart, the first cuticular preparation for the genus from India. Srivastava (1956) studied the cuticular structure of sixteen species of *Glossopteris*, 6 species of *Gangamopteris* and one species of *Palaeovittaria*. On the basis of this study Surange and Srivastava (1956) arranged these species under six groups, each group probably representing a taxon of generic rank. Later, Pant (1958) and Hϕeg and Bose (1960) described cuticular features of *Glossopteris* species from Permian of Tanzania and Zaïre, respectively.

A major work on the cuticular features of *Glossopteris* species was subsequently carried out by Pant and Gupta (1968, 1971) and Pant and Singh (1971, 1974) from the Indian Gondwana. Sporadic reports were also made by other workers.

The present paper deals with the study of morphographical and cuticular features of nineteen species of the genus *Glossopteris* (nine species are newly instituted) from the Barakar Formation (Early Permian) of Churulia Area, Raniganj Coalfield. So far, cuticular features of three species have been described from the Barakar Formation and only one from the Raniganj Formation of this area, i.e., *G. ornatus* (Chandra & Srivastava, 1981).

The specimens of *Glossopteris* leaves investigated by us were collected from an abandoned quarry, in the north-eastern part of the East Raniganj Coalfield, about 250 metres east of Churulia railway station.

The main exomorphic characters used for determination of species are shape, nature of apex, base and margin, nature of midrib, density of lateral

veins, dichotomies and anastomoses of veins and shape and size of meshes. Thirty readings, each for determining the density of veins and size of meshes, were taken. Lawrence (1955) and Melville (1969) have been followed for morphographic terms.

The cuticular characters used for distinguishing species are: nature of cuticle (amphi-, epi- or hypostomatic), nature of anticlinal cell walls (straight, undulate or sinuous), nature of surface walls (papillate or non-papillate, with or without hairs) and nature of subsidiary cells (unspecialised or specialised, i.e., papillate with papillae overhanging guard cells).

OBSERVATIONS

Genus—*Glossopteris* Brongniart 1828

Revised diagnosis—Leaves simple, sessile or petiolate, entire or slightly notched in the upper half; shape, size, apex and base variable; midrib prominent, flat or elevated, persistent or evanescent, when flat, with longitudinally running parallel striations or pits or sometimes both, anastomoses of striations absent; lateral veins arising from midrib at acute angles, arched or more or less straight, dichotomising and anastomosing variously to form meshes of various shapes and sizes, density of veins usually lesser near midrib than near margins.

Leaf cuticle usually hypostomatic, occasionally amphistomatic, laminar region of upper and lower surfaces of leaf either undifferentiated or differentiated into vein and mesh areas; cells over vein areas narrow, elongated, rectangular or squarish, arranged end-to-end in linear rows; cells over mesh areas of various shapes and sizes and arranged irregularly; lateral walls of cells usually straight, sometimes undulate or sinuous; surface walls mostly unspecialised, sometimes papillate, trichomes generally absent; stomata haplocheilic, present only in mesh areas, distributed and oriented irregularly, stomatal index variable; stomatal apparatus haplocheilic, monocyclic, rarely dicyclic or amphicyclic; guard cells sunken or normal, subsidiary cells unspecialised or with papillae overhanging guard cells; cells over the midrib squarish or rectangular, arranged in rows, stomata usually absent over midrib.

Glossopteris karanpuraensis Kulkarni 1971

Pl. 1, figs 1, 5; Text-fig. 1B

Description—The incomplete leaf compression has an ill-preserved carbonified crust. The preserved portion of the leaf measures 19 cm in length and 4.5 cm in width, at the widest, which is about 5 cm below the preserved apical portion. The overall shape of the leaf probably was lanceolate. The leaf has an entire margin and gradually narrows down towards base. Midrib is distinct, strong, elevated, striated lengthwise, apparently persistent and 1 mm wide. Lateral veins emerge from midrib at acute angles (36°-44°), take a slight outward curve, and after successive dichotomies and anastomoses approach the margin at an angle between 67°-80°. Number of veins varies from 10(12) 14 per cm near the midrib and 17(20.7) 25 per cm near the margin. The vein dichotomies are usually of gamma and lambda types or rarely of chi type. The cross connections between the veins, which form meshes, are of zeta and eta types. The size of the meshes varies considerably in different parts of the leaf. The shape of the meshes is mostly deltoid, planoconvex, biconvex or sometimes, arcuate or angled near the midrib and usually trapezoidal or pentagonal elsewhere.

The carbonified crust yielded ill-preserved pieces of cuticle which did not show cellular details.

Chandra and Surange (1979, p. 35, pl. 2, fig. 2; pl. 6, fig. 5) have compared *G. karanpuraensis* with *G. nimishea* on the basis of equally large size. However, the latter differs in having an elliptic shape and in having arched lateral veins which do not turn upwards near margins as in *G. karanpuraensis*. Chandra and Surange (1979, p. 32, 200) have placed *G. parallela* as described by Maheshwari (1965) under *G. nimishea* in the synonymy of the species as well as their description of plates (p. 200), whereas, under the heading "observation" they have mentioned that it is the *G. parallela* of Maheshwari and Prakash (1965) which they consider as *G. nimishea* and not that of Maheshwari (1965). However, the former differs from *G. nimishea* in having parallel veins and oblong, polygonal meshes.

Glossopteris pandurata Pant & Gupta 1971

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

1965 *Glossopteris spathulo-cordata* Feistmantel: Maithy. *Palaeobotanist* **13**, p. 257, pl. 5, fig. 34.

1967 "Attached leaves of *Glossopteris angustifolia* type" Pant, *Phytomorphology* **17**, p. 352, fig. 11.

1971 *Glossopteris pandurata* Pant & Gupta, *Palaeontographica* **132B**, p. 148, pl. 21, fig. 39; text-fig. 2A.

Revised diagnosis—Leaves spathulate, apex broad, obtuse, base narrow, tapering, margins entire; midrib distinct, persistent, 2 mm wide in basal region, gradually thinning towards apex, striated

lengthwise, lateral veins emerge from midrib at acute angles, gracefully curve outwards to meet the margin, number of veins 11 to 21 per cm near midrib, 23 to 28 per cm near margin, vein dichotomies usually of gamma or lambda type, cross connections between veins usually of zeta type, meshes usually arcuate near midrib, trapezoidal elsewhere, fibres may or may not be present.

Holotype—Specimen no. 1180, Divya Darshan Pant collection, Botany Department, Allahabad University; Early Permian, basal Barakar (Karharbari) Formation, Giridih Coalfield.

Description—The leaf compression has an ill-preserved carbonified crust. No cuticle could be recovered. The specimen is almost complete, measures 9 cm in length and 4.6 cm in width, at the widest, which is about a centimetre below the apex. The overall shape of the leaf is spathulate with an entire margin and a broadly obtuse, notched apex. The leaf gradually narrows down towards the base; but the base is unknown. Midrib is strong, faintly striated lengthwise, 2 mm wide in basal region and persists right up to the apex. Lateral veins emerge from midrib at acute angles (13°-16°), become gradually curved, and after successive dichotomies and anastomoses approach the margin at angles of 47°-54° in the middle region of leaf, at angles of 70°-80° near apex and at some places in the basal region, at angles of 30° and 35°. The number of veins varies from 11 (14.3) 21 per cm near the midrib to 23(25) 28 per cm near the margin. The vein dichotomies are of gamma or lambda type, and the cross connections between the veins, which form the meshes, are of zeta type. The size of meshes varies in different parts of the leaf. The shape of meshes is usually arcuate near the midrib, rarely deltoid as seen in the apical region; elsewhere, the meshes are trapezoidal.

Remarks—In the apical region, the lateral veins instead of curving outwards, away from the midrib, curve inwards and terminate at the margin of the notched apical portion. In having a notched (?emarginate) apex and peculiar venation pattern in the apical region, the present specimen differs from the holotype (Pant & Gupta, 1971, pl. 21, fig. 39; text-fig. 2A).

The species was instituted for a detached pandurate leaf with broad, obtuse apex, having a distinct, persistent midrib and 45 to 50 lateral veins per cm halfway between midrib and margins. Pant and Singh (1974) revised the diagnosis according to which the leaves are attached to an axis, concentration of veins, instead of 45 to 50 as mentioned originally, is 24 per cm and meshes show one or more fibres running parallel to veins or occasionally crossing to join main veins. Our specimen, however, does not show fibres.

Glossopteris pandurata is comparable to *G. spathulo-cordata* Feistmantel (1878, 1890, pl. 20, figs 5-8), *G. emarginata* Maheshwari & Prakash (1965, pl. 3, figs 20, 21; text-fig. 10) and *G. retusa* Maheshwari (1965, pl. 3, figs 20, 21; text-figs 12, 13). In *G. spathulo-cordata* the meshes are broader. *G. emarginata* differs in having an oblong shape. *G. retusa*, though compares in having a notched (retuse) apex, differs in shape, which is obovate. Moreover, the notches present on both the margins, just below the apex in *G. retusa* are absent in *G. pandurata*. The specimen referred to *G. pandurata* by Srivastava (1977, pl. 1, fig. 6) has been transferred to *G. churiensis* Srivastava (1977, pl. 2, figs 8, 9) by Chandra and Surange (1979) on the basis of their observation that the meshes in the latter species also are elongate and narrow. However, from photographs and text-figures (Chandra & Surange, 1979, pl. 1, fig. 10; pl. 17, fig. 14; pl. 26, fig. 5; text-figs 9E, e, 22C, c, 48J, 54H) it appears that the meshes were actually broad and polygonal. One of the specimens described by Maithy (1965, pl. 5, fig. 34) as *G. spathulo-cordata* has been merged here with *G. pandurata* on the basis of similarity in shape and venation pattern. This specimen was earlier merged with *G. angusta* by Chandra and Surange (1979) on the basis of similarity in their shape and venation pattern. The photographs of *G. angusta* (Pant & Gupta, 1971, pl. 21, fig. 33; Chandra & Surange, 1979, pl. 1, fig. 9) show a picture entirely different from the specimen described by Maithy.

PLATE 1 →

Glossopteris karanpuraensis Kulkarni 1971

1. Impression of a leaf with patches of highly oxidised coalified crust. BSIP Specimen no. 36449A. × 1.
5. A part of leaf in fig. 1 enlarged to show venation. × 2.

Glossopteris communis Feistmantel 1876

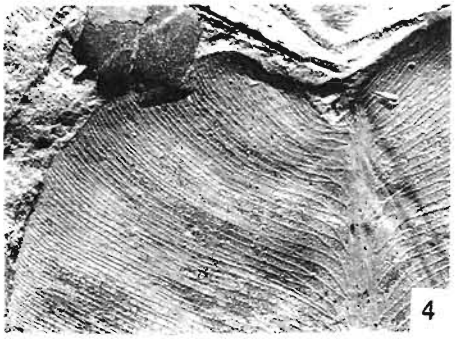
2. Middle portion of a leaf-impression showing dense venation. BSIP Specimen no. 36450. × 1.

Glossopteris pandurata Pant & Gupta 1971

3. Impression of an almost complete leaf showing an obtuse, notched apex and patches of highly oxidised, coalified crust. BSIP Specimen no. 36451A. × 1.
4. Apical part of leaf in fig. 3 enlarged to show venation. × 2.

Glossopteris pseudocommunis Pant & Gupta 1968

6. Basal part of a leaf-compression showing a flat midrib with prominent pits. BSIP Specimen no. 36452A. × 1.



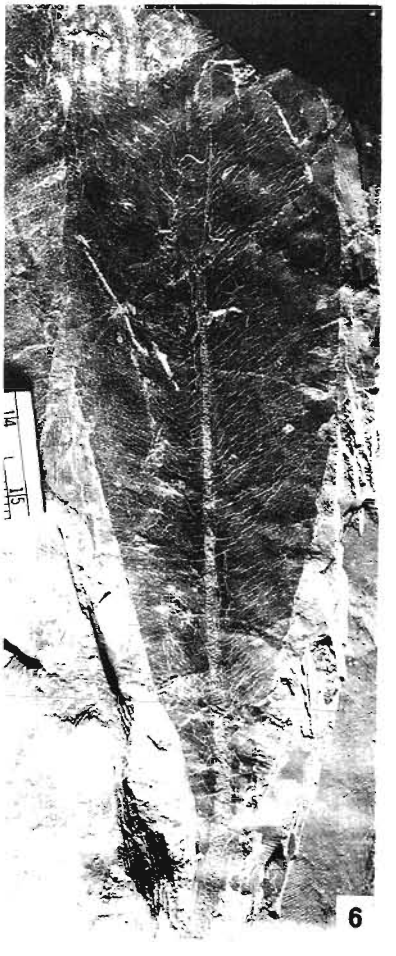


PLATE 1

Text-figure 1—A, *Glossopteris communis* Feistmantel: middle part of a leaf showing venaon, BSIP Specimen no. 36450 × 1; **B,** *Glossopteris karanpuraensis* Kulkarni: impression of an incomplete leaf showing venation, BSIP Specimen no. 36449A × 1; **C,** *Glossopteris pandurata* Pant & Gupta: leaf-impression showing a pandurate apex and characteristic venation in apical region, BSIP Specimen no. 36451 × 1; **D,** *Glossopteris pseudocommunis* Pant & Gupta: an almost complete leaf showing an attenuate base and a flat midrib with pits, BSIP Specimen no. 36452B × 1; **E,** *Glossopteris pseudocommunis* Pant & Gupta: leaf-impression showing venation and a flat, striated midrib with pits, BSIP Specimen no. 36453 × 1.

Glossopteris communis (Feistmantel 1876) emend. Pant & Gupta 1968

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

Neotype (here designated)—Specimen no. 5022, Geological Survey of India Museum, Calcutta; Early Permian, basal Barakar (Karharbari) Formation, Mathadi no. 1 shaft (now abandoned), Giridih Coalfield.

Glossopteris communis was established by Feistmantel (1876) for a certain leaf type from the Damuda Group of Raniganj Coalfield. The specimen he illustrated (Feistmantel, 1876, pl. 21, fig. 5) normally would have been taken as the type of the species. This particular specimen or any other specimen of the same collection is not traceable, and hence necessitates the selection of another type. Pant and Gupta (1968, p. 71) chose G.S.I. specimen no. 5088 as the lectotype of this species. However, for some unspecified reasons, Chandra and Surange (1979, p. 29) assigned another specimen (G.S.I. specimen no. 5022) as the holotype/lectotype. Both the specimens come from the Talchir Group (Karharbari Formation) of Giridih Coalfield and form a part of collection described by Feistmantel (1879, pl. 17, fig. 2; 1880, pl. 31, fig. 5, respectively). Article 7.5 of the ICBN (1988) does not allow selection of a lectotype from any material other than the original. Evidently, the lectotypes selected by Pant and Gupta (1968) and Chandra and Surange (1979) are not a part of the original material of Feistmantel (1876) which was from the Damuda Group of Raniganj Coalfield. As none of the material consulted by Feistmantel (1876) is traceable, a neotype is chosen here under Article 7.8 of ICBN (1988).

Description—The species is represented by several specimens. None of the specimens have a carbonified crust. The overall shape of the leaves is oblong-lanceolate with entire margins. Apex or base is not preserved in any but the leaves gradually taper towards base. Leaves measure 16.8 to 20.6 cm in length and 5.2 to 5.5 cm in width at the widest, which is approximately midway between the base and apex. Midrib is prominent, faintly striated lengthwise, 3 mm wide at basal region and persists right up to the apical region where it is 0.5 mm wide. Lateral veins emerge from the midrib at acute angles (20°-40°). Soon after emergence, the veins curve outward and after successive dichotomies and anastomoses approach the margin at an angle between 68°-86°. The density of veins varies from 14 to 23 per cm near the midrib to 27 to 40 per cm near the margin. Vein dichotomies usually are of gamma type, and the cross connections between the veins, which form the meshes, are usually of zeta type, rarely of eta type. The size of meshes varies in different parts of the leaf. Meshes are usually arcuate in shape, rarely deltoid near the midrib and mostly trapezoidal elsewhere. At places, pentagonal meshes are also present.

Remarks—The species *Glossopteris communis* was proposed by Feistmantel (1876, pl. 21, fig. 5). A detailed diagnosis, description and more illustrations of the species were given later (Feistmantel, 1879, pl. 17, figs 1, 2, 2a). Srivastava (1979, p. 74), it seems, was under the impression that though Feistmantel (1876) proposed the name of this species, yet he did not give diagnosis, description and illustration. Feistmantel not only has illustrated his specimen (1876, pl. 21, fig. 5) but has also given a diagnosis (p. 376).

Srivastava (1956, pl. 2, fig. 13; pl. 3, figs 14, 16) described cuticular features of a *G. communis* type of leaf. Pant and Gupta (1968, p. 72) opined that the name *G. communis* Feistmantel cannot be used for Srivastava's leaf since its cuticle is different from one of the original specimens of *G. communis* (specimen no. 5088 in the GSI Museum). They were of the view that leaves other than the lectotype of *G. communis* should not be assigned to *G. communis*, since carbon of only this particular specimen yielded cuticle on maceration. Pant and Gupta, therefore, renamed Srivastava's leaf as *G. pseudocommunis*. However, the cuticle of the specimen of *G. communis* as described by Pant and Gupta is very fragmentary and does not give a detailed information regarding the type and nature of stomata and midrib cuticle. Moreover, presence or absence of crust is a preservational factor and to assign any leaf to a particular species only on the basis of presence or absence of cuticle is not advisable. Therefore, all the *Glossopteris* leaves (as reported by previous workers) which show communis type of morphology, irrespective of the preservation of carbonified crust have been included here under *G. communis*.

Chandra and Surange (1979) have restricted the name *G. communis* to those leaves which resemble the leaves figured by Feistmantel (1879) from the Karharbari Formation. These authors believe that the leaves possessing communis type of venation pattern from Barakar Formation and Raniganj Formation are different in shape and size and it cannot be imagined that all these different forms of leaf with good deal of vertical distribution could be borne by a single species. They, therefore, transferred leaves referred to *Glossopteris communis* from Barakar and Raniganj formations under a new specific name, *Glossopteris raniganjensis*. However, the author of

the species *G. communis* (Feistmantel, 1876, p. 376) has himself mentioned that "This species, the commonest near Raniganj is also not wanting in other places .....".

Chandra and Surange have also placed various leaves described as *G. communis* (Feistmantel, 1881, pl. 36A, figs 1, 2; Maheshwari & Prakash, 1965, pl. 2, fig. 14; Kar, 1968, pl. 1, fig. 7) under *G. indica* since they believe that form and venation pattern of these leaves are similar to *G. indica*. However, all these leaves show dense venation pattern typical of *G. communis*. Two of these leaves which have been described by Maheshwari and Prakash (1965) and Kar (1968) are incomplete, so question of their form being similar to *G. indica* does not arise and the one described by Feistmantel (1881) is typically oblong-lanceolate in shape, which is characteristic of *G. communis*. Chandra and Surange (for example, p. 72) have mentioned that cross connections are entirely absent in *G. communis*, which is not the case, since the leaves studied presently show distinct cross connections, as was also reported by Feistmantel (1879).

Rigby, Maheshwari and Schopf (1980) reported *G. communis* (figs 26-30) from Australia. One of their leaves (fig. 26) differs in having spathulate shape so it could be a new species.

Glossopteris pseudocommunis Pant & Gupta 1968

Pl. 1, fig. 6; Pl. 2, figs 1-9; Text-figs 1D, E; 2A-F, 3F

1956 *Glossopteris longicaulis* Feistmantel: Srivastava, *Palaeobotanist* **5**, p. 23-25, pl. 10, figs 62-64, 66; text-figs 28-30.

Diagnosis—Leaves oblanceolate in shape, apex acute, base attenuate, margins entire; midrib distinct, flat, striated lengthwise, apparently persists up to apical region, 2 mm wide at base, thinning towards apex, prominent pits present in between striations; lateral veins emerge from midrib at acute angles (2° to 7°), dichotomise, anastomose and curve gracefully outwards to meet margin, concentration of veins 9 to 20 per cm near midrib, 22 to 33 per cm near margin, meshes arcuate near midrib, trapezoidal elsewhere.

Leaves amphistomatic; upper cuticle differentiated into vein and mesh areas, cells over veins narrow-elongate, rectangular to elongate-polygonal, arranged end-to-end in linear rows, cells over meshes rectanguloid, squarish to polygonal, arranged irregularly or end-to-end in rows; lateral walls straight to slightly undulate; surface walls non-papillate; stomata few, anomocytic, distributed and orientated irregularly, stomatal apparatus monocyclic, subsidiary cells 5 to 7 in number, unspecialised.

Lower cuticle also differentiated into vein and mesh areas; cells over veins narrow, elongated, arranged end-to-end in linear rows, cells over meshes irregular to polygonal in shape, arranged irregularly, lateral walls straight to slightly undulate; surface walls non-papillate; stomata as on upper surface, numerous; subsidiary cells 6 to 8 in number, unspecialised.

Cuticle of midrib non-stomatiferous, not distributed into striated and nonstriated areas, cells normally rectangular to squarish, sometimes polygonal or triangular, lateral walls straight to slightly undulate, sometimes arched, thick; surface walls unspecialised.

Neotype—BSIP Specimen no. 36452B, slide no. 36452B-1; Birbal Sahni Institute of Palaeobotany, Lucknow, Early Permian, Barakar Formation, Churulia area, Raniganj Coalfield.

The species *Glossopteris pseudocommunis* was first proposed by Pant and Gupta (1968, p. 72) for a leaf (BSIP specimen no. 5650) described by Srivastava (1956, pl. 2, figs 12, 13; pl. 3, figs 14, 15, 16; text-figs 5, 6) under the name *Glossopteris communis*. Pant and Gupta, though renamed Srivastava's leaf and described it in short, the description was not accompanied by an illustration or figure of the species. However, the name of the

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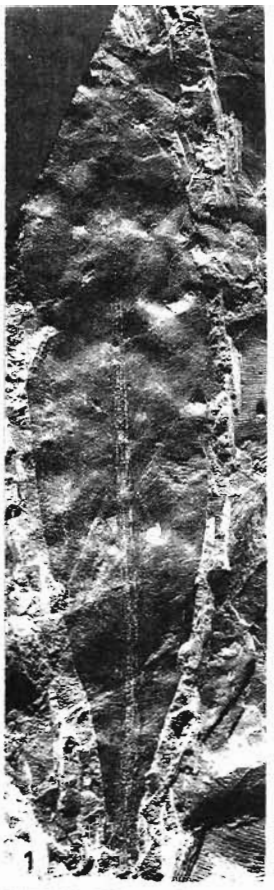
PLATE 2

Glossopteris pseudocommunis Pant & Gupta 1968

1. Another leaf specimen showing well-preserved coalified crust. BSIP Specimen no. 36452B. × 1.
2. A part of leaf in fig. 1 enlarged to show venation. × 3.
3. Upper cuticle of lamina from the leaf in pl. 1, fig. 6 showing vein and mesh areas and straight to slightly undulate lateral walls. BSIP Slide no. 36452A-1. × 70.
4. Midrib cuticle from the leaf in Pl. 1, fig. 6 showing squarish to rectangular, thick-walled cells arranged end-to-end in rows. BSIP Slide no. 36452A-2. × 70.
5. Upper cuticle of lamina from the leaf in fig. 7 showing a stoma. BSIP Slide no. 36453-1. × 400.
6. A part of leaf in fig. 7 enlarged to show venation. × 2.
7. Compression of a leaf showing petiolate base and well-preserved carbonified crust. BSIP Specimen no. 36453 × 1.
8. Upper cuticle of lamina from the leaf in pl. 1, fig. 6 showing a stoma. BSIP Slide no. 36452A-3. × 625.
9. Upper cuticle of lamina from the leaf in fig. 7 showing cells near margin. BSIP Slide no. 36453-2. × 250.



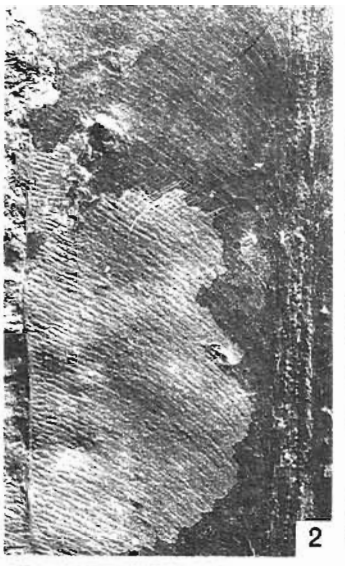
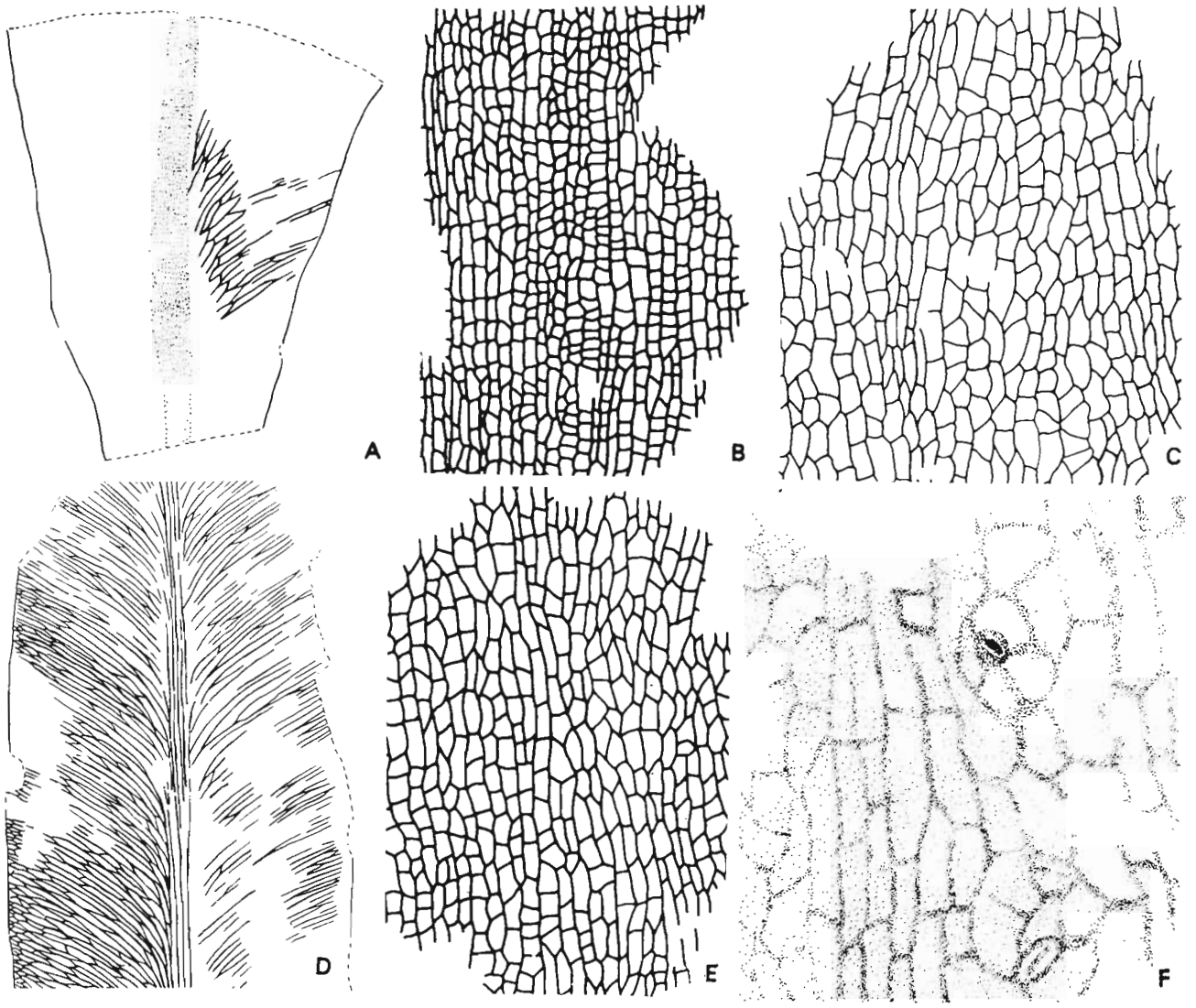


PLATE 2



Text-figure 2—*Glossopteris pseudocommunis* Pant & Gupta: **A,** basal part of a leaf magnified to show venation, BSIP Specimen no. 36452A × 2; **B,** midrib cuticle, BSIP, Slide no. 36452A-2 × 70; **C,** upper cuticle of lamina showing vein and mesh areas, BSIP Slide no. 36452A-1 × 70; **D,** a part of leaf magnified to show venation, BSIP Specimen no. 36452B × 2; **E,** upper cuticle of lamina showing vein and mesh areas, BSIP Slide no. 36452B-1 × 70; **F,** upper cuticle of lamina showing stomata, BSIP Slide no. 36452A-3 × 250.

species is valid under the Article 38.1 of the International Code of Botanical Nomenclature (1988) as the authors have referred to the previously and effectively published figures (that of Srivastava, 1956). A diagnosis of the species, not given by the authors, has been given here.

Pant and Gupta also did not assign a holotype to the species. The specimen which could have been assigned as type (BSIP specimen no. 5650, Srivastava, 1956) is not traceable. Therefore, a neotype is chosen here under provisions of Article 7.8 of ICBN (1988).

Description—The specimens are incomplete and measure 10.4 to 13.5 cm in length and 2.4 to 3.8 cm in width, at the widest middle part. The overall shape probably was oblanceolate, with an attenuate base and an entire margin. Apex is not preserved. The midrib is distinct, flat, striated lengthwise, persists up to the apical region (although in one of the specimens it is indistinct in the upper half due to overlapping of other leaves), 2 mm wide at base and 1 mm wide in the apical region. Prominent pits are present in between the striations. Lateral veins emerge from midrib at acute angles (26°-40°), take an outward curve and after successive dichotomies and anastomoses, approach the margin at an angle between 59°-75°. The concentration of veins is 9 to 20 per cm near the midrib and 20 to 33 per cm near

the margin. The vein dichotomies usually are of gamma type and cross connections between the veins, which form the meshes, are usually of zeta type, or very rarely of psi-lambda type. The size of meshes varies in different parts of leaf. Shape of the meshes is arcuate near the midrib and mostly trapezoidal elsewhere.

The carbonified crust, though looked good under incident light, broke up into small fragments during chemical treatment. It has been possible to recover some pieces of cuticle showing salient features. The leaf is amphistomatic, although only one stoma is seen on the upper cuticle while the lower cuticle shows many stomata.

The upper cuticle of lamina is differentiable into vein and mesh areas through shape and arrangement of cells. Veins show anastomoses. The cells over the veins are usually narrow, elongate, rectangular to elongate-polygonal, sometimes short and squarish, and are arranged end-to-end in almost linear rows. The cells are 49-168 μm in length and 28-70 μm in width. The cells in the mesh areas are rectanguloid, squarish to polygonal in shape, 63-140 μm long and 35-77 μm wide. Lateral walls of cells are 4-22 μm thick over veins and 4-14 μm thick over meshes, straight to slightly undulate. Surface walls are non-papillate. The stoma is haplocheilic, 32-35 μm in length and 12-26 μm in width. The stomatal apparatus is monocyclic and has 5-7 subsidiary cells, 20-40 μm long and 12-30 μm wide, polygonal in shape. Guard cells are 32-36 μm in length and 6-10 μm in width with 2 μm thick walls. The stomatal pore is 20-31 μm long and 2-6 μm wide. Stomatal index varies from 1.96 to 3.03.

Lower cuticle of lamina is also differentiable into vein and mesh areas in the same way as the upper cuticle. The cells over the veins are elongate rectangular and are arranged end-to-end in linear rows measuring 50-172 μm in length and 12-40 μm in width. Lateral walls are straight to slightly undulate and 2-10 μm thick. Cells in the mesh areas are irregular to polygonal, 12-60 μm long and 12-58 μm wide with 2-4 μm thick straight to slightly undulate lateral walls. The surface walls of cells both over veins and over meshes are non-papillate. Stomata are 18-42 μm in length and 6-24 μm in width, haplocheilic and irregularly distributed and oriented. The stomatal apparatus is monocyclic and has 6-8 subsidiary cells, 6-40 μm long and 4-24 μm wide, polygonal to irregular in shape. Guard cells are 18-42 μm in length and 2-10 μm in width with 2 μm thick walls. The stomatal pore is 12-36 μm long and 2-8 μm wide. Stomatal index varies from 1.66 to 18.36 depending upon the location of the cuticular pieces on the leaf.

The cuticle from the midrib portion is non-stomatiferous and does not show distinctive distribution of cells as all the cells are of one type, i.e., very thick-walled (4-14 μm), 42-98 μm long, 28-49 μm wide, rectangular to squarish, sometimes polygonal and triangular and arranged end-to-end in linear rows as over the veins. Lateral walls of the cells over the midrib are straight to undulate, sometimes arched.

Remarks—*Glossopteris longicaulis* described by Srivastava (1956, pl. 10, fig. 62) is merged here with *G. pseudocommunis* on the basis of similarity in venation pattern. Chandra and Surange (1979, p. 27) have also mentioned that Srivastava's *G. longicaulis* is different from *G. longicaulis* of Feistmantel in venation. It is likely that the fragment of *G. longicaulis* represents the basal part of *G. pseudocommunis*. *G. pseudocommunis* also resembles *G. brongniartii* (Pant & Gupta, 1968) in venation pattern and cuticle of lamina. However, the latter differs in having spathulate shape and striated and non-striated stomatiferous areas in the lower cuticle of midrib. Another specimen which is included in this species is figured in Plate 2, figs 5-7, 9; Text-figs 1E, 3F. The specimen, in many respects, is similar to *G. pseudocommunis* but differs in being oblong in shape and apparently petiolate. Although, the size is of no significant value, the stomata in this leaf are longer than those described above.

Glossopteris rhabdotaenioides Pant & Singh 1971

Pl. 3, figs 1, 4, 6; Text-fig. 3A-E

Description—All the specimens are incomplete, only middle parts of the leaves are preserved which measure 7.4-13.7 cm in length and 4.4-10 cm in width. Midrib is distinct, elevated, striated lengthwise and 1-3 mm wide. Lateral veins emerge from the midrib at acute angles (30°-50°), thereafter run straight, parallel to each other and after successive dichotomies and anastomoses approach the margin approximately at right angles. Number of veins varies from 9 to 15 per cm near the midrib and 16 to 33 per cm near the margin. The vein dichotomies usually are of gamma and lambda types or rarely of chi and psi types. Cross-connections between the veins, which form the meshes, are mostly of zeta and eta types or rarely of psi-lambda type. Shape of the meshes is mostly deltoid, angled or rarely arcuate near the midrib, and commonly pentagonal or elongate-polygonal and less commonly hexagonal or trapezoidal elsewhere.

The carbonified crust has yielded very small pieces of cuticle showing few details. Leaf is probably hypostomatic. Non-stomatiferous cuticle of

the lamina is differentiable into vein and mesh areas through shape and arrangement of cells. The cells are 39-108 μm in length and 16-52 μm in width with 2-11 μm thick lateral walls and unspecialised surface walls. Cells in the mesh areas are polygonal in shape, 32-84 μm long and 14-68 μm wide with 2-8 μm thick, straight to slightly undulate lateral walls. Surface walls are non-papillate. The cells over the veins are narrow, elongate, rectangular and arranged end-to-end in rows.

Stomatiferous cuticle of the lamina does not show demarcation of vein and mesh areas. The cell outlines are indistinct. The stomata are haplocheilic and measure 20-43 μm in length and 8-22 μm in width. Stomatal apparatus has 5-6 subsidiary cells measuring 11-17 μm in length, 11-24 μm in width with 2 μm thick walls. Guard cells are 20-35 μm in length and 3-21 μm in width with 2 μm thick walls. The stomatal pore is 10-30 μm long and 3-8 μm wide.

The cuticle from the midrib portion is non-stomatiferous and does not show distinctive distribution of cells. The cells are squarish to rectangular, sometimes irregular in shape and are arranged end-to-end in rows. They are 70-136 μm long and 30-50 μm wide with 4-6 μm thick, straight to undulate lateral walls.

Remarks—G. rhabdotaenioides is comparable to *G. damudica* Feistmantel in venation pattern. Incidentally, Feistmantel placed a variety of forms under *G. damudica* (1881, pl. 30, figs 1, 2; pl. 31, figs 1-3; pl. 32, fig. 1; pl. 40, fig. 6) but did not designate a holotype for the species. Pant and Singh (1971) chose a lectotype (specimen no. 5266 of Feistmantel's collection, GSI Museum, Calcutta) for the species on the basis of cuticular studies. This particular leaf is narrow, petiolate, with tapering base, entire margins. Lateral veins not horizontal, meeting margins at about 65°. Meshes broad, polygonal, broader near midrib than elsewhere. A few years later, Chandra and Surange (1979, p. 32) designated this specimen (specimen no. 5266) as holotype of a new species *G. nimishea*. This designation of holotype by Chandra and Surange of the same specimen which was earlier chosen by Pant and Singh as lectotype for a different species is illegitimate under articles 7.13 and 63.1 of the International Code of Botanical Nomenclature (1988). Therefore, we propose to merge *G. nimishea* with *G. damudica* as conceived by Pant and Singh (1971) on the basis of priority in publication. The specimen chosen by Pant and Singh as lectotype of *G. damudica*, however, does not show typical characters of the species as were originally conceived by the author of the species. According to Feistmantel (1881, p. 105, pl. 30A, fig. 1), the leaf of *G. damudica* is of great size with obtuse or in some cases slightly emarginate apex and thick midrib; the lateral veins pass out from midrib at almost a right angle (which, however, is not true, because lateral veins always emerge from midrib at very acute angles), getting somewhat more oblique in the apical portion. The venation pattern is distinct with the meshes broadly and shortly trigonal or polygonal near the midrib, and long and narrow near the margins.

The leaf considered by Pant and Singh as *G. damudica* is longer and much narrower, its apex is also not known. Moreover, meshes throughout the leaf lamina are broad-polygonal. This leaf is, therefore, of a different type from specimen no. 5261 which fits accurately with the original description of *G. damudica* by its original author, Feistmantel (1881). However, lectotype chosen by Pant and Singh has to be accepted according to article 8.1 of ICBN (1988). Therefore, a new species is proposed here for specimen no. 5261, GSI Museum, Calcutta (Feistmantel, 1881, p. 105, pl. 30, fig. 1).

Glossopteris danae sp. nov.

1881 *Glossopteris damudica* Feistmantel: *Mem. geol. Surv. India Palaeont. indica*, ser. 12,

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PLATE 3

Glossopteris rhabdotaenioides Pant & Singh 1971

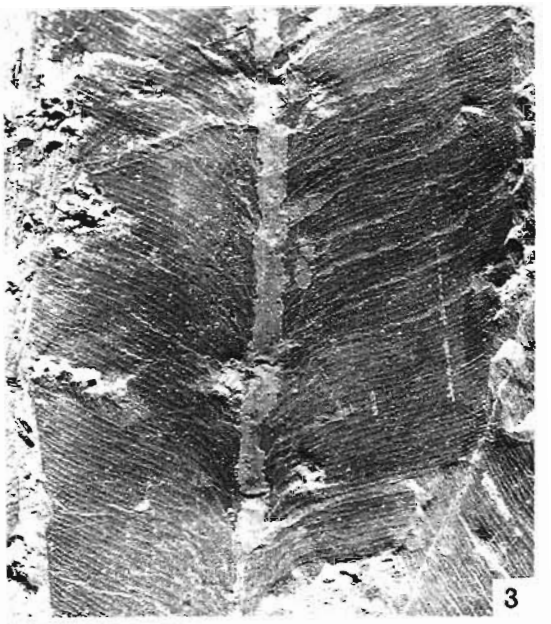
1. A leaf showing veins at right angles to the midrib and patches of ill-preserved carbonified crust. BSIP Specimen no. 36454. × 1.
4. A part of leaf in fig. 1 enlarged to show venation and pentagonal meshes. × 2.
6. Lower cuticle of lamina from the leaf in fig. 1 showing a stoma (the cell outlines are not visible). BSIP Slide no. 36454-1. × 400.

Glossopteris obscura Pant & Singh 1971

2. An incomplete leaf-compression showing a flat midrib and a narrow base. BSIP Specimen no. 36458. × 1.
3. A part of leaf in fig. 2 enlarged to show venation and trapezoidal meshes. × 2.
5. Lower cuticle of lamina from the leaf in fig. 2 showing a stoma (marked by an arrow) and obscure cell outlines. BSIP Slide no. 36458-1. × 400.

Glossopteris asansolensis sp. nov.

7. Lower cuticle of lamina from the middle region of leaf in pl. 4, fig. 1 showing vein and mesh areas. BSIP Slide no. 36460A-1. × 100.
8. Lower cuticle of lamina from the leaf in pl. 4, fig. 1 showing a sickle-shaped stoma (marked by an arrow). BSIP Slide no. 36460A-1. × 400.



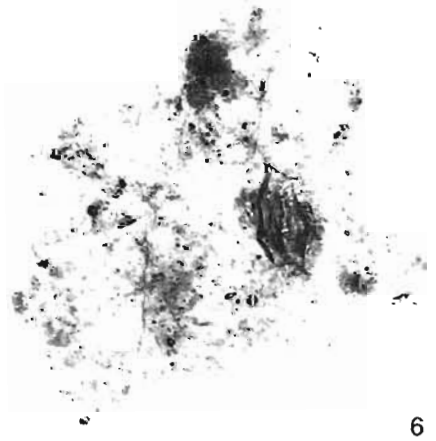
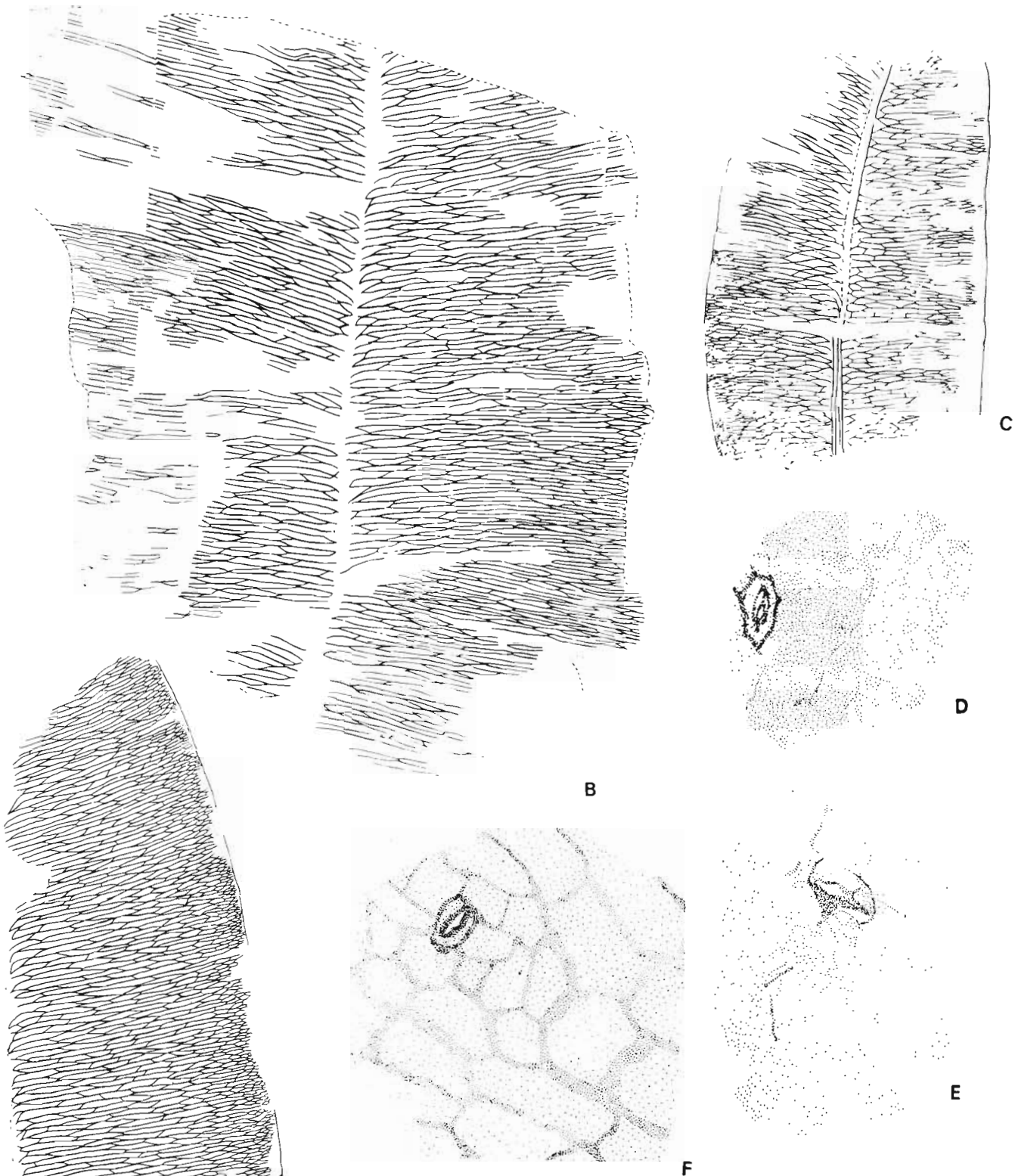


PLATE 3



Text-figure 3—A-E, *Glossopteris rhabdotaenioides* Pant & Singh: **A,** right half of a leaf fragment showing venation, BSIP Specimen no. 36455A × 1; **B,** leaf fragment showing venation, BSIP Specimen no. 36457 × 1; **C,** another leaf fragment showing venation, BSIP Specimen no. 36454 × 1; **D,** lower cuticle of lamina showing a stoma, BSIP Slide no. 36454-1 × 400; **E,** lower surface of lamina showing a stoma, BSIP Slide no. 36451B-1 × 400; **F,** *Glossopteris pseudocommunis* Pant & Gupta; upper cuticle of lamina showing a stoma, BSIP Slide no. 36453-1 × 400.

3(3), p. 105, pl. 30, figs 1, 2; pl. 31, fig. 1; pl. 40, fig. 6 (partim).

1886 *Glossopteris damudica* Feistmantel: Feistmantel, *Mem. geol. Surv. India Palaeont. indica*, ser. 12, **4** (2), p. 28, pl. 1, fig. 3.

1902 *Glossopteris damudica* Feistmantel: Zeiller, *Mem. geol. Surv. India Palaeont. indica*, n. ser. **2**, p. 13, pl. 4, figs 5-7.

1905 *Glossopteris ampla* Dana: Arber, *Catalogue of the fossil plants of the Glossopteris flora in the Department of Geology*, British Museum Natural History, London, p. 78, text-fig. 20.

1962 *Glossopteris damudica* Feistmantel: Plumstead, *Trans. Antarctic Expedition* 1955-1958, Scientific Report no. 9 (Geology-2), p. 40, pl. 5, figs 1, 7.

1963 *Glossopteris damudica* Feistmantel: Cridland, *Am. J. Bot.* **50**, p. 189, fig. 10.

1968 *Glossopteris damudica* Feistmantel: Vimal & Singh, *J. palaeont. Soc. India* **5-9**, p. 34, pl. 1, fig. 1.

1969 *Glossopteris damudica* Feistmantel: Sah & Maheshwari, *J. Sen Memorial Volume*, p. 372, pl. 1, fig. 5.

1977 *Glossopteris damudica* Feistmantel: Srivastava, *Palaeobotanist*, **23**, p. 212, pl. 2, fig. 11.

1979 *Glossopteris damudica* Feistmantel: Chandra & Surange, *Revision of the Indian species of Glossopteris*, Monograph no. **2**, p. 39, pl. 4, fig. 2; pl. 20, fig. 1; pl. 36, fig. 1; text-fig. 34A.

1985 *Glossopteris* cf. *damudica* Feistmantel: Anderson & Anderson, *Palaeoflora of South Africa*, p. 138, pl. 135, figs 1-3; pl. 136, figs 1, 2; text-fig. 2.

Diagnosis—Leaf shape and length unknown, apex broad, emarginate, base unknown; margins entire; midrib distinct, persistent, striated lengthwise, thinning towards apex; lateral veins arise from midrib at very acute angles (1°-3°), dichotomise, anastomose, meet margin at an angle between 65°-70°; vein dichotomies usually of gamma type, cross connections between veins usually of zeta type; meshes short, broad, trigonal, apparently deltoid, angled or sometimes arcuate near midrib and mostly trapezoidal, elongate, narrow elsewhere.

Holotype—Specimen no. 5261, Geological Survey of India Museum, Calcutta (Feistmantel, 1881, p. 105, pl. 30, fig. 1), Kulti Formation, Kulti, Raniganj Coalfield.

Comparison—Glossopteris danae is comparable to *G. rhabdotaenioides* (Pant & Singh, 1971, pl. 7, figs 41, 45), *G. damudica* (Feistmantel, 1881, p. 105, pl. 32, fig. 1; Pant & Singh, 1971, p. 22), *G. ampla* Dana (Rigby, Maheshwari & Schopf, 1980, p. 6, figs 13, 14) and *G. taeniopteroides* Feistmantel (Banerjee & Ghosh, 1970, text-fig. 7) in venation pattern, but differs from all of them in either course of veins or shape of meshes. *G. rhabdotaenioides* has broad, polygonal, elongate meshes which are shorter near midrib and the lateral veins meet the margin at approximately 90°. *G. damudica* shows broad, polygonal meshes which are shorter and slightly broader than elsewhere near midrib but apparently of uniform size throughout the leaf lamina, lateral veins meeting the margins at approximately 65°. The leaves of *G. damudica* are also much longer and narrower in size. *G. ampla* differs by showing long and narrow meshes which are narrowest near margins. *G. taeniopteroides* shows narrow, elongate, polygonal meshes. Lateral veins in this species run closely parallel to each other and meet the margins at approximately 90°.

Distribution—Karharbari Formation (Auranga Coalfield, Srivastava, 1977); Barakar Formation (Bansloi Valley Coalfield, Sah & Maheshwari, 1969; Raniganj Coalfield, Feistmantel, 1881; Talcher Coalfield, Feistmantel, 1881; Auranga Coalfield, Feistmantel, 1886; Tatapani and Ramkola coalfields, Feistmantel, 1881); Kulti Formation (Raniganj Coalfield, Feistmantel, 1881; Chandra & Surange, 1979); Raniganj Formation (Himgir, Sohagpur, Ramkola, Raigarh and Wardha coalfields, Feistmantel, 1881); Kamthi Formation (Nagpur area, Feistmantel, 1881); ?Panchet Formation (Shahdol District, Vimal & Singh, 1968); from unknown horizon of Permian age (South Rewa Basin, Zeiller, 1902). The species is also known from Upper Ecca Formation (South Africa, Anderson & Anderson, 1985); Whichaway Nunataks (Antarctica, Plumstead, 1962); Mount Glossopteris Formation (Mount Schopf, Ohio Range, Antarctica, Cridland, 1963.

Glossopteris damudica Feistmantel emend.

1977 *Glossopteris* sp. cf. *G. ampla* Dana: Srivastava, *Palaeobotanist*, **24**, p. 57-58, pl. 3, fig. 15.

1979 *Glossopteris nimishea* Chandra & Surange, *Revision of the Indian species of Glossopteris*, Monograph no. **2**, p. 32, pl. 2, fig. 2; pl. 4, fig. 1; pl. 6, fig. 5; pl. 16, fig. 7; pl. 18, fig. 4; pl. 19, fig. 10; pl. 45, fig. 1; text-figs 17Bb, B_2, 34C, 35Aa_1 a_2 D, 47K, 52H, 53A.

Emended diagnosis—Leaf shape, length and apex unknown, base attenuate, margins entire; midrib prominent, stout, striated lengthwise, wider at base, gradually narrowing further upwards; lateral veins arise from midrib at acute angles, dichotomise, anastomose, meet margin at angle of 65°, vein

dichotomies of gamma and lambda types; cross-connections between veins of zeta type; base of meshes near midrib apparently deltoid, meshes near midrib short, broad, polygonal or triangular and narrow, elongated and trapezoidal elsewhere.

Upper cuticle of lamina not differentiated into vein and mesh areas; cells squarish, polygonal; anticlinal walls thick, straight, stomata absent.

Lower cuticle of lamina differentiated into vein and mesh areas; cells over meshes polygonal, arranged irregularly, cells over veins narrow, elongated, rectanguloid, arranged end-to-end in rows; anticlinal walls both over veins and meshes straight, thin; meshes stomatiferous; stomata few, anomocytic (haplocheilic), monocyclic, sparsely distributed, irregular in orientation, subsidiary cells 4-5 in number, polygonal in shape.

Cuticle of midrib not differentiable into striated and non-striated areas, cells long, narrow, rectanguloid, arranged end-to-end in longitudinal rows; anticlinal walls of cells straight, thick; stomata absent.

Lectotype—Specimen no. 5266, Geological Survey of India Museum, Calcutta (Feistmantel, 1881, pl. 32A, fig. 1); Barakar Formation, Kumardhubi, Raniganj Coalfield.

Description—Length of the preserved portions of leaves is about 20 cm and the width varies from 4 to 12 cm. Midrib is 3 mm wide at base, thinning towards apical region. Lateral veins arise at acute angles from midrib and meet margins at an angle between 60° to 85°. Density of veins is 13 per cm near midrib, gradually increasing towards margins.

Cells of upper cuticle of lamina measure 19-30 × 15-21 μm in size with 5 μm thick lateral walls. Surface walls are non-papillate.

Lower cuticle of lamina is much thinner than upper cuticle, differentiated into vein and mesh areas. Cells over veins measure 45-75 × 18-30 μm and those over meshes measure about 66 μm in size. Lateral walls of cells are about 0.7 μm thick. Surface walls are non-papillate. Stoma measures 62 μm. Guard cells are about 22 μm long.

Cells of midrib are 45-75 μm long and 18-30 μm wide. Lateral walls of cells are 1.5-11 μm in width; surface walls are non-papillate.

Remarks—Chandra and Surange (1979, p. 40) placed the leaf described as *G. damudica* by Srivastava (1956, p. 6, figs 37-41) under *G. lanceolatus* (Pant & Singh, 1971, p. 9, pl. 5, figs 25-29; text-figs 4B-K) which, however, is not appropriate, because both the species differ in their morphographical as well as cuticular characters. Whereas, *G. lanceolatus* is lanceolate in shape with acute apex and rounded base, shape and apex of *G. damudica* are not known and the base is tapering. Course of veins also differs in both the species. Lateral veins meet the margin at 90° (Chandra & Surange, 1979) in *G. lanceolatus* while those of *G. damudica* meet at an angle between 75°-80°. Moreover, midrib of this species is much thinner than that of *G. damudica* of Srivastava where the midrib is stout and striated lengthwise. Cuticles of both the leaves show different characteristics. The cells of upper surface are obscure in *G. lanceolatus* with 1-3 μm thick lateral walls while those of Srivastava's leaf are very distinct with 5 μm thick lateral walls. Subsidiary cells on lower surface of lamina are papillate in the former species with papillae overarching guard cells. Papillate subsidiary cells are, however, absent in *G. damudica* as described by Srivastava. Few stomata are present in *G. damudica* of Srivastava; stomatal frequency is 102 per sq mm in *G. lanceolatus*.

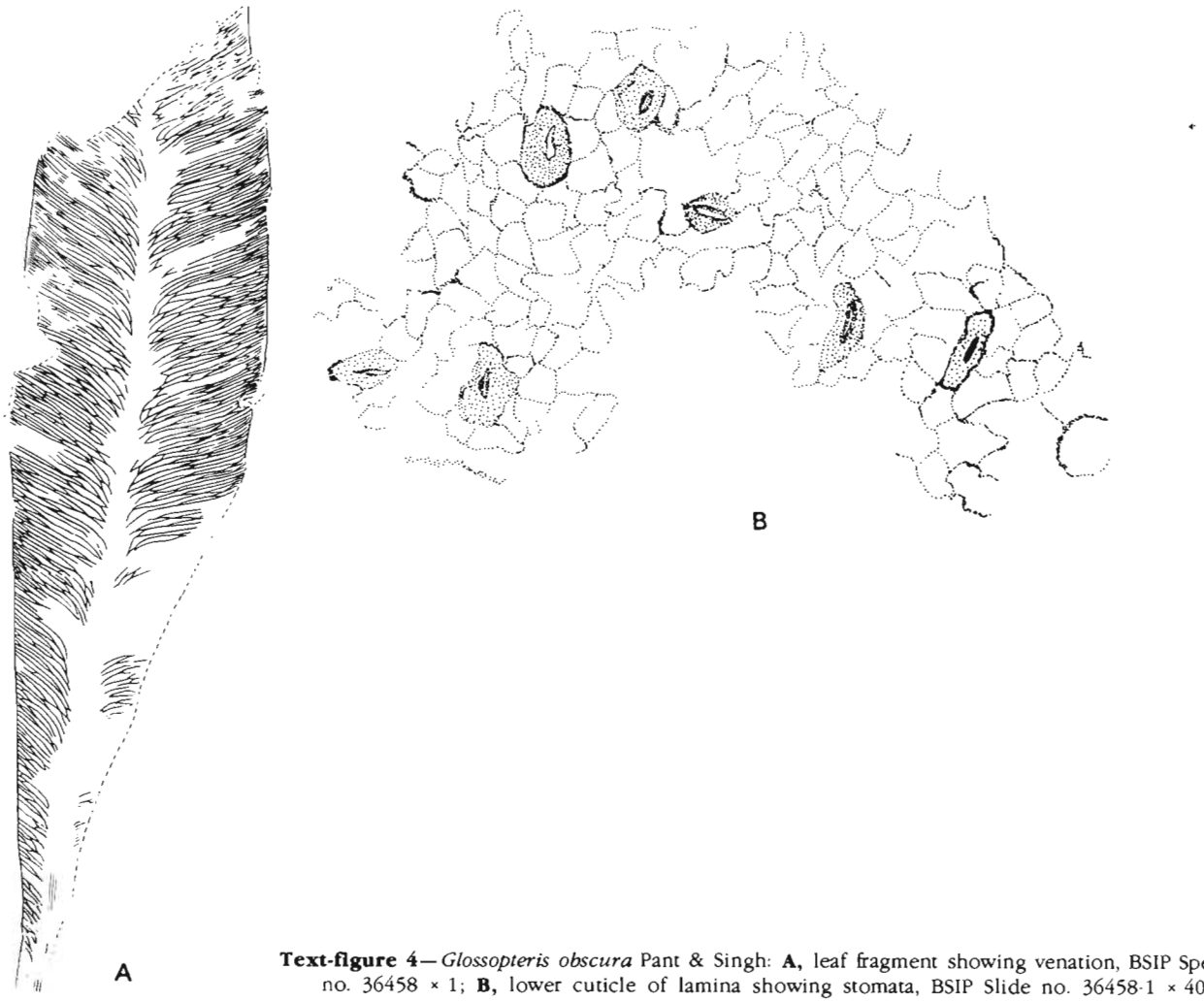
Glossopteris obscura Pant & Singh 1971

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

Description—The leaf compression has a well preserved carbonified crust but the apical half of leaf is not preserved. Lower half of the leaf measures 11.6 cm in length and 3.2 cm in width at the widest. Midrib is distinct, striated lengthwise, elevated and 2 mm wide. Lateral veins emerge from midrib at acute angles (25°-35°), take a graceful outward curve and after successive dichotomies and anastomoses approach the margin at an angle between 46°-64°. The number of veins varies from 9(11.1)14 per cm near the midrib to 19(21.4)26 per cm near the margin. Vein dichotomies usually are of gamma type and the cross connections between the veins, which form the meshes, are usually of zeta type, rarely of psi-lambda type. The size of meshes varies in different parts of the leaf, while shape of meshes is mainly arcuate, rarely deltoid near the midrib and mostly trapezoidal elsewhere.

The carbonified crust, though looked good under incident light, broke up into small fragments during chemical treatment. The cuticle, therefore, shows very few details. The leaf is probably hypostomatic. Non-stomatiferous cuticle of lamina is not differentiable into vein and mesh areas. The cells are polygonal in shape, 40-92 μm long and 30-50 μm wide with 2-8 μm thick, straight lateral walls. The surface walls are without papillae.

Stomatiferous cuticle of lamina is faintly differentiable into vein and mesh areas through shape and arrangement of cells. Cells over the veins are narrow, elongate-rectangular and are arranged end-to-end in rows. The cells are 56-62 μm long and 12-18 μm wide. Lateral walls are straight or slightly



Text-figure 4—*Glossopteris obscura* Pant & Singh: **A,** leaf fragment showing venation, BSIP Specimen no. 36458 × 1; **B,** lower cuticle of lamina showing stomata, BSIP Slide no. 36458-1 × 400.

undulating and 2 μm thick. The cells in the mesh areas are polygonal, arranged irregularly, 24-34 μm long and 18-30 μm wide with 2 μm thick, undulate lateral walls. Surface walls are non-papillate in both the areas. Stomata are 20-38 μm in length and 10-24 μm in width, haplocheilic and irregularly distributed and oriented. Stomatal apparatus is monocyclic and has 6-8 subsidiary cells, polygonal in shape, 10-36 μm long and 12-30 μm wide with 2 μm thick walls. Guard cells are 20-38 μm in length and 4-14 μm in width with 2 μm thick walls. The stomatal pore is 12-26 μm long and 2-6 μm wide. Stomatal index varies from 2.04-9.57.

The cuticles from both the surfaces of midrib are non-stomatiferous and do not show distinctive distribution of cells which are 54-118 μm long, 36-60 μm wide, squarish to rectangular and arranged end-to-end in linear rows. Lateral walls of the cells are 4-10 μm thick, straight to slightly undulating.

Remarks—Chandra and Surange (1979) placed *G. obscura* under *G. subtilis* Pant & Gupta 1971 on the basis of similarity in morphographical characters. These two species seem to be different in mesh pattern. Similarly cuticle of both the species also shows much difference.

Glossopteris asansolensis sp. nov.

Pl. 3, figs 7-8; Pl. 4, figs 1, 7; Text-fig. 5A-F

Diagnosis—Leaves lanceolate in shape, apex acute, base narrow, tapering; margins entire; midrib distinct, striated lengthwise; lateral veins emerge at acute angles from midrib, dichotomise, anastomose, gracefully curve outwards to meet the margin; venation dense, density of veins 8 to 14 per cm near midrib, 17 to 20 per cm near margin; meshes arcuate near midrib, trapezoidal elsewhere; stomata present only on one surface.

Non-stomatiferous cuticle differentiated into vein and mesh areas, cells over veins narrow, rectangular, arranged end-to-end in linear rows, cells over meshes broader, rectanguloid to polygonal,

arranged end-to-end in rows; lateral walls of cells straight; surface walls non-papillate.

Stomatiferous cuticle differentiated into vein and mesh areas, cells over veins narrow, rectangular, arranged end-to-end in linear rows, cells over meshes polygonal to irregular, irregularly arranged; lateral walls of cells straight to undulate; surface walls non-papillate; stomata anomocytic, irregularly distributed and oriented, stomatal apparatus monocyclic, subsidiary cells 7 to 8 in number, non-papillate.

Midrib cuticle undifferentiated; cells squarish to rectangular, arranged end-to-end in linear rows; lateral walls thick, straight; surface walls unspecialised.

Holotype—Specimen no. 36460A, slide no. 36460A-1, Birbal Sahni Institute of Palaeobotany, Lucknow; Early Permian, Barakar Formation, Churulia area, Raniganj Coalfield.

Description—There are two specimens in the collection and both have well-preserved carbonified crust. The specimens are almost complete and measure 14.1-15.0 cm in length and 3.1-3.9 cm in width at the widest, which is about 1/3 length above the base. Overall shape of the leaves is lanceolate with entire margin, acute apex and gradually tapering base; the basalmost portion, however, is not known. Midrib is distinct, flat and striated lengthwise (pits present in between the striations in one of the leaves), 3 mm wide at base and gradually becomes evanescent towards apex. Lateral veins emerge from midrib at acute angles (10°-25°), curve outwards, and after successive dichotomies and anastomoses approach the margin at an angle between 43° to 73°. The density of veins varies from 8-17 per cm near the midrib and 17-29 per cm near the margin. Vein dichotomies usually are of gamma type and the cross-connections between the veins, which form the meshes, are usually of zeta type, rarely of psi-lambda type. The size of the meshes varies in different parts of leaf. The shape of the meshes is arcuate near midrib and mostly trapezoidal elsewhere.

The carbonified crust, though looked good under incident light, broke up into small fragments during chemical treatment. However, it has been possible to recover some good pieces of cuticle showing salient features. The leaves probably were hypostomatic.

The upper cuticle of lamina is differentiable into vein and mesh areas through shape and arrangement of cells. The cells over the veins are narrow, rectangular, arranged end-to-end in almost linear rows, 80-144 μm long and 40-62 μm broad. Cells in the mesh areas are usually rectanguloid, rarely polygonal in shape, 68-144 μm long and 40-104 μm wide. Lateral walls of cells, both over the veins and meshes, are 4-10 μm thick and straight; surface walls are non-papillate.

The lower cuticle of lamina is also differentiable into vein and mesh areas. Cells over the veins measure 62-110 μm in length and 18-28 μm in width. Lateral walls are straight or slightly undulating, and 2-10 μm thick. Cells in the mesh areas are polygonal to irregular, 26-52 μm long and 20-38 μm wide with 2 μm thick, straight to slightly undulating lateral walls and unspecialised surface walls. The stomata are 20-38 μm in length and 4-18 μm in width, haplocheilic and irregularly distributed and oriented. The stomatal apparatus is monocyclic and has 7-8 subsidiary cells. Guard cells are up to 38 μm long and 2-6 μm wide with 2 μm thick walls. Stomatal pores are 16-30 μm long and 4-6 μm wide. Stomatal index ranges from 5.79 to 6.97. Cells over the midrib portion are thick-walled (6-16 μm), 50-94 μm long, 40-50 μm wide, squarish to rectangular and arranged end-to-end in linear rows.

Comparison—*G. asansolensis* is comparable to *G. vulgaris* (Pant & Gupta, 1968), *G. nautiyalii, G. longifolia* and *G. cordiformis* (Pant & Singh, 1971). *G. vulgaris* resembles in having lanceolate shape, acute apex, entire margins, striated midrib and

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PLATE 4

Glossopteris asansolensis sp. nov.

1. Holotype. A complete lanceolate leaf with an acute apex, a narrow base and a well-preserved carbonified crust. BSIP Specimen no. 36460A. × 1.
7. Midrib cuticle from the holotype showing squarish, thick-walled cells arranged end-to-end in rows. BSIP Slide no. 36460A-2. × 100.

Glossopteris bunburyana sp. nov.

2. Holotype. Upper half of leaf showing an acute apex and patches of well-preserved coalified crust. BSIP Specimen no. 36460B. × 1.
3. A part of leaf in fig. 4 enlarged to show venation and trapezoidal meshes. × 2.
4. Impression of a leaf showing a narrow base and a flat, striated midrib with prominent pits. BSIP Specimen no. 36461. × 1.
5. A part of holotype enlarged to show venation. × 3.
6. Lower cuticle of lamina from the leaf in fig. 2 showing a stoma. BSIP Slide no. 36460B-1 × 400.
8. Lower cuticle of lamina from the leaf in fig. 2 showing elongate-rectangular cells over veins and irregular cells over meshes. BSIP Slide no. 36460B-2. × 100.
9. Upper cuticle of lamina from the leaf in fig. 2 showing narrow, rectangular cells over veins arranged end-to-end in rows and polygonal cells over meshes arranged irregularly. BSIP Slide no. 36460B-3 × 100.

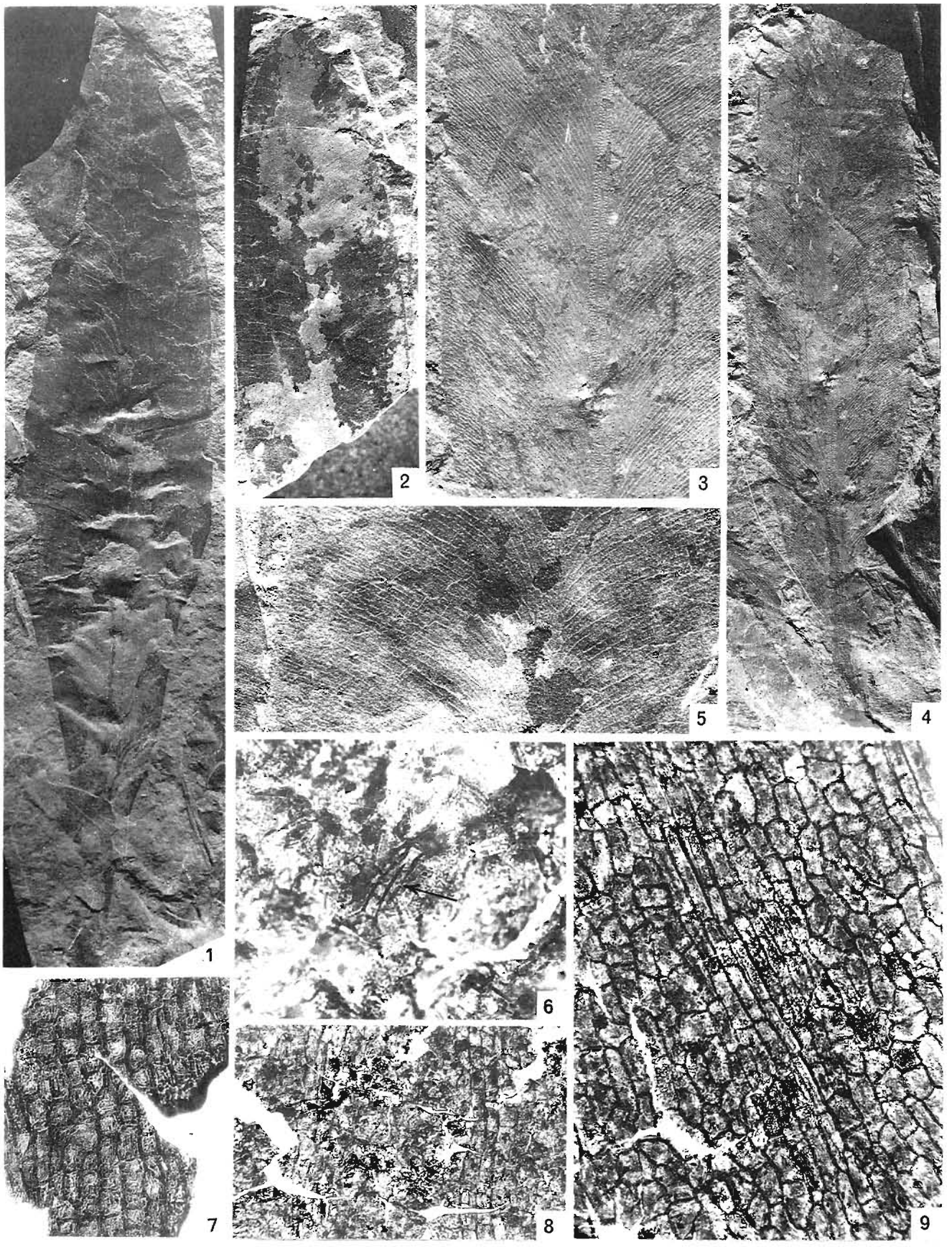
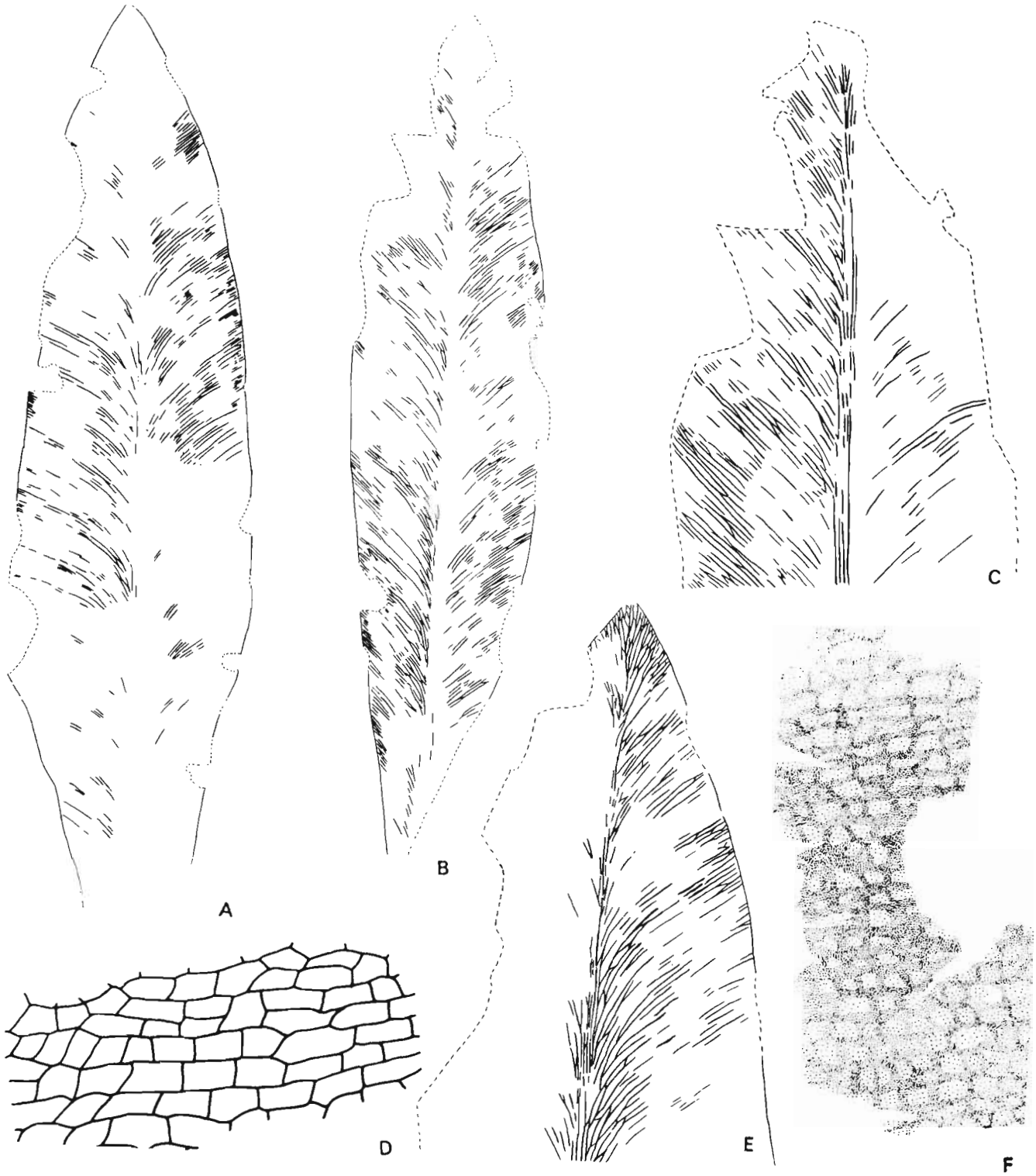


PLATE 4



Text-figure 5—*Glossopteris asansolensis* sp. nov.: **A,** leaf showing venation and a flat midrib with pits, Holotype, BSIP Specimen no. 36460A × 1; **B,** another leaf showing venation, BSIP Specimen no. 36459 × 1; **C,** apical portion of the same magnified to show venation, BSIP Specimen no. 36459 × 2; **D,** upper cuticle of lamina, BSIP Slide no. 36460A-3 × 100; **E,** apical portion of leaf in fig. A magnified to show venation, BSIP Specimen no. 36460A × 2; **F,** midrib cuticle, BSIP Slide no. 36460A-2 × 100.

identical venation pattern (Pant & Singh, 1971, pl. 24, fig. 34; pl. 25, fig. 37; text-fig. 16). However, the species differs in being amphistomatic, in having a single median papilla on the surface walls of cells of both upper and lower cuticle (Pant & Gupta, 1968, pl. 25, figs 35, 36; text-figs 12D, E, 13A) and in

having papillate subsidiary cells with papillae overhanging the guard cells (Pant & Gupta, 1968, pl. 25, fig. 39; text-fig. 13C). *G. nautiyalii* and *G. longifolia* differ from *G. asansolensis* in having sinuous lateral walls of cells of the upper cuticle (Pant & Singh, 1971, pl. 12, fig. 73; pl. 13, fig. 78; text-figs 10E, 11C) and in having papillate subsidiary cells with papillae overhanging guard cells on the lower surface (Pant & Singh, 1971, pl. 11, fig. 71; pl. 12, fig. 74; pl. 13, figs 79, 80; text-figs 10G, H, J; 11E, F; 12E, G). *G. longifolia* also differs in having some papillate epidermal cells on the lower surface. Incidentally, *G. longifolia* and *G. nautiyalii*, though similar in having identical shape, venation, sinuous walled cells and papillate subsidiary cells, differ in their midrib cuticle. Whereas, the upper cuticle of midrib in *G. longifolia* does not show any stomata, that of *G. nautiyalii* has clearly demarcated stomatiferous and non-stomatiferous areas like the median portion of a *Gangamopteris* leaf. *G. cordiformis* shows altogether different morphology by having cordate shape, auriculate base and lesser concentration of veins (9 per cm near midrib and 15 per cm near margin). The cuticle of both the species is also not exactly alike because *G. cordiformis* shows irregularly arranged cells over meshes of upper surface, some of which are irregular in shape having equal thickness (6 μm) of lateral walls of cells of midrib and lamina. *G. asansolensis* resembles *G. communis* in having dense veins but the latter differs in having amphistomatic cuticle and papillate subsidiary cells.

Glossopteris bunburyana sp. nov.

Pl. 4, figs 2-6, 8-9; Text-fig. 6A-E

Diagnosis—Leaves lanceolate in shape, apex acute, base attenuate, margins entire; midrib distinct, flat, striated lengthwise, prominent pits present in between striations, wider at base, gradually thinning towards apical region; lateral veins arise from midrib at acute angles, curve outwards, dichotomise, meet margins at open angles, veins 12 to 18 per cm near midrib, 24 to 37 per cm near margin, meshes narrow, elongate, arcuate near midrib, trapezoidal elsewhere.

Upper cuticle of lamina differentiated into vein and mesh areas, cells over veins rectangular, arranged end-to-end in longitudinal rows; cells over meshes polygonal, arranged irregularly; lateral walls straight; surface walls non-papillate; stomata absent; upper cuticle of midrib differentiated into striated and non-striated areas; cells over striations narrow, elongate, usually rectangular, arranged end-to-end in longitudinal rows; cells over non-striated areas

Text-figure 6—*Glossopteris bunburyana* sp. nov.: **A**, leaf showing venation and a flat, striated midrib with pits, BSIP Specimen no. 36461 × 1; **B**, a part of holotype magnified to show venation, BSIP Specimen no. 36460B × 2.

broader, rectangular, elongate-polygonal, arranged end-to-end in longitudinal rows; lateral walls thick, straight, surface walls non-papillate; stomata absent.

Lower cuticle of lamina differentiable into vein and mesh areas, cells over veins rectangular to polygonoid, arranged end-to-end in rows; cells over meshes polygonal to irregular in shape, arranged irregularly; lateral walls straight to undulate, surface walls non-papillate; meshes stomatiferous; stomata haplocheilic, monocyclic, irregularly distributed and oriented, subsidiary cells 8-9 in number, similar to other epidermal cells, guard cells normal, stomatal opening apparent as slit; lower cuticle of midrib differentiated into striated and non-striated areas like upper cuticle of midrib; cells over striations narrow, rectangular, arranged end-to-end in longitudinal rows; cells over non-striated areas irregular to polygonal in shape, arranged irregularly; lateral walls of cells straight; surface walls non-papillate; stomata absent.

Holotype—Specimen no. 36460B, slide nos. 36460B 1 to 3; Birbal Sahni Institute of Palaeobotany, Lucknow; Early Permian, Barakar Formation, Churulia area, Raniganj Coalfield.

Derivation of name—After Charles Bunbury.

Description—The specimens are incomplete and measure 7.6 to 13.3 cm in length and 3 to 3.1 cm in width at the widest, which probably is the middle region of the leaves. Leaves are lanceolate in shape with entire margins and acute apices. Midrib is distinct, flat, striated, 1-3 mm wide, gradually thinning towards apex. Prominent pits are present in between the striations. Lateral veins emerge from midrib at very acute angles (10°-23°), take a graceful outward curve and after successive dichotomies and anastomoses approach the margins at an angle between 65°-80° The number of veins varies from 12-18 per cm near the midrib to 24-37 near the margin. Vein dichotomies usually are of gamma and lambda types or rarely of psi type; the cross-connections between veins which form the meshes are usually of zeta type and occasionally of psi-lambda type. Shape of the meshes is usually arcuate, occasionally deltoid near the midrib and mostly trapezoidal elsewhere.

The carbonified crust during chemical treatment yielded good pieces of cuticle, showing salient features. Stomata are present only on the lower surface.

The upper cuticle of lamina is differentiable into vein and mesh areas through shape and arrangement of cells. Cells over the veins are rectangular, very rarely polygonal, arranged end-to-end in linear rows, 94-192 μm long, and 38-72 μm wide. The cells in mesh areas are polygonal in shape, 50-140 μm long and 46-84 μm wide. Lateral walls are 4-14 μm thick over veins and 4-10 μm thick over meshes, straight to slightly undulate. The surface walls are non-papillate.

The lower stomatiferous cuticle of lamina is also differentiable into vein and mesh areas in the same way as the upper cuticle. The cells over the veins are rectangular to polygonoid, arranged end-to-end in linear rows, 50-116 μm long and 26-44 μm wide. Lateral walls are straight to slightly undulating and 2-8 μm thick. The cells in the mesh areas are polygonal to irregular in shape, irregularly arranged, 32-54 μm long and 28-50 μm wide with 2-4 μm thick, undulate to slightly sinuous lateral walls and unspecialised surface walls. The stomata are anomocytic (haplocheilic) and are irregularly distributed and oriented measuring 24-50 μm in length and 6-30 μm in width. The stomatal apparatus is monocyclic and has 8-9 subsidiary cells. Guard cells are 24-50 μm in length and 4-6 μm in width with 2 μm thick walls. Stomatal pore is 22-28 μm long and 2-6 μm wide. Stomatal index varies from 4.10 to 5.08.

The upper cuticle of midrib is differentiated into striated and non-striated areas. Cells over

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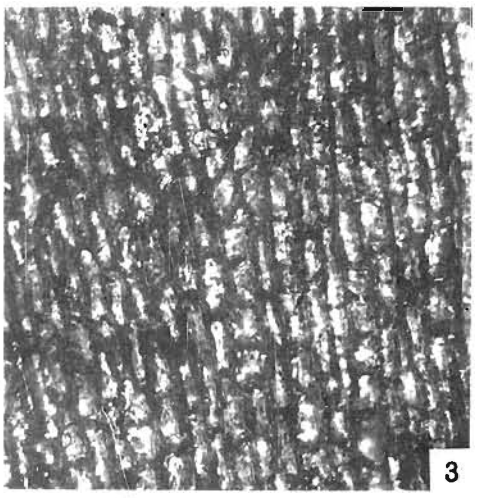
PLATE 5

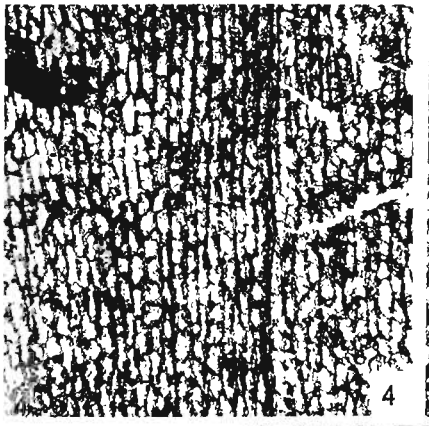
Glossopteris manjuiae sp. nov.

1. Holotype. Leaf-compression showing a narrow base and a flat, striated midrib with prominent pits. BSIP Specimen no. 36452C. × 1.
2. Lower cuticle of midrib from the leaf in fig. 1 showing striated and non-striated areas. BSIP Slide no. 36452C-2. × 50.
3. Upper cuticle of midrib from the leaf in fig. 1 showing thick-walled cells arranged in rows. BSIP Slide no. 36452C-1. × 100.
4. Upper cuticle of lamina from the leaf in fig. 1 showing differentiation of vein and mesh areas. BSIP Slide no. 36452C-1. × 50.
5. Lower cuticle of lamina from the leaf in fig. 1 showing vein and mesh areas. BSIP Slide no. 36452C-2. × 100.
6. Lower cuticle of lamina from the leaf in fig. 1 showing a stoma (marked by an arrow). BSIP Slide no. 36452C-2. × 400.
7. Lower cuticle of lamina from the leaf in fig. 1 showing bifurcation of veins. BSIP Slide no. 36452C-3. × 100.

Glossopteris schimperi sp. nov.

8. Holotype. A linear leaf compression with a flat midrib. BSIP Specimen no. 36455B. × 1.
9. Lower cuticle of midrib from the basal part of leaf in fig. 8 showing striated and non-striated areas, latter with conspicuous stomata. BSIP Slide no. 36455B-1. × 250.
10. Upper cuticle of midrib from the basal part of leaf in fig. 8 showing squarish, triangular, irregular and polygonal cells arranged end-to-end in rows. BSIP Slide no. 36455B-1. × 70.





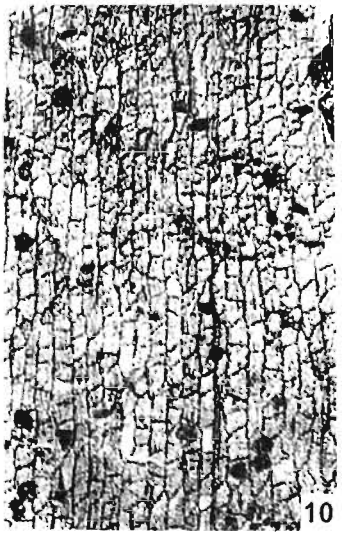


PLATE 5

striated areas are narrow, usually rectangular, occasionally trianguloid, arranged end-to-end in linear rows, 36-63 μm in length and 24-28 μm in width. In non-striated areas the cells are rectangular, elongate-polygonal, arranged end-to-end in linear rows, 47-76 μm in length and 30-38 μm in width. Lateral walls are 5-8 μm thick over striated areas and 5-9 μm thick over non-striated areas and straight to undulate.

The lower cuticle of midrib is non-stomatiferous and differentiated into striated and non-striated areas like the upper cuticle of midrib. Cells over the striated areas are narrow, rectangular and arranged end-to-end in linear rows. They measure 43-81 μm in length and 25-37 μm in width. The cells in the non-striated areas are irregular to polygonal in shape, arranged irregularly, 19-31 μm long and 14-25 μm wide. Lateral walls are straight both over striated and non-striated areas, sometimes slightly undulating; 6-12 μm thick over striated areas and 2-6 μm thick over non-striated areas.

Comparison—Glossopteris bunburyana compares with a number of species in either morphological or cuticular characteristics. In venation pattern, it compares with many species, of which *Glossopteris stenoneura* (Feistmantel, 1877, p. 74) is foremost. This species was later described as *Glossopteris communis* var. *stenoneura* by Feistmantel (1881, pl. 32A, fig. 3; pl. 33A, fig. 1; pl. 38A, fig. 5) and still later by Pant and Gupta (1968, p. 72) who also described the cuticle of type specimen (specimen no. 5269, GSI Museum, Calcutta). *G. communis* var. *stenoneura* is spathulate in shape and *G. bunburyana* is lanceolate, cuticle of former is very fragmentary and does not show differentiation of vein and mesh areas.

Srivastava (1956, pl. 3, figs 17, 18) had also described *Glossopteris communis* var. *stenoneura*; only the basal portions are present which continue into a stalk. The cuticle of the leaf described by Srivastava differs from that of the type specimen (Pant & Gupta, 1968, p. 72; pl. 26, fig. 47; text-fig. 14P, Q) and shows clearly defined vein and mesh areas on both the surfaces of lamina as well as presence of stomata on both the surfaces (amphistomatic). Therefore, Srivastava's leaf could be a new species but the specimen described by him is not traceable.

Banerji, Maheshwari and Bose (1976, p. 64; pl. 2, figs 16-18; text-figs 3A-D, 4A-B) separated var. *stenoneura* from *communis* and raised it to the specific rank. Chandra and Surange (1979) created a new species for the specimens of Feistmantel (1881, pl. 38A, fig. 5) and Banerji, Maheshwari and Bose (1976) and named it as *G. bosei* (Chandra & Surange, 1979, pl. 47, fig. 5). We consider *G. bosei* as a junior synonym of *G. stenoneura*.

G. bunburyana is comparable to *G. waltonii, G. harrisii* and *G. brongniartii* (Pant & Gupta, 1968, pl. 19, fig. 1; pl. 20, fig. 10; pl. 22, fig. 27, respectively; text-figs. 1A, B, C and 4, respectively) on the similarity in venation pattern. But, each of these leaves differs in one or two cuticular features.

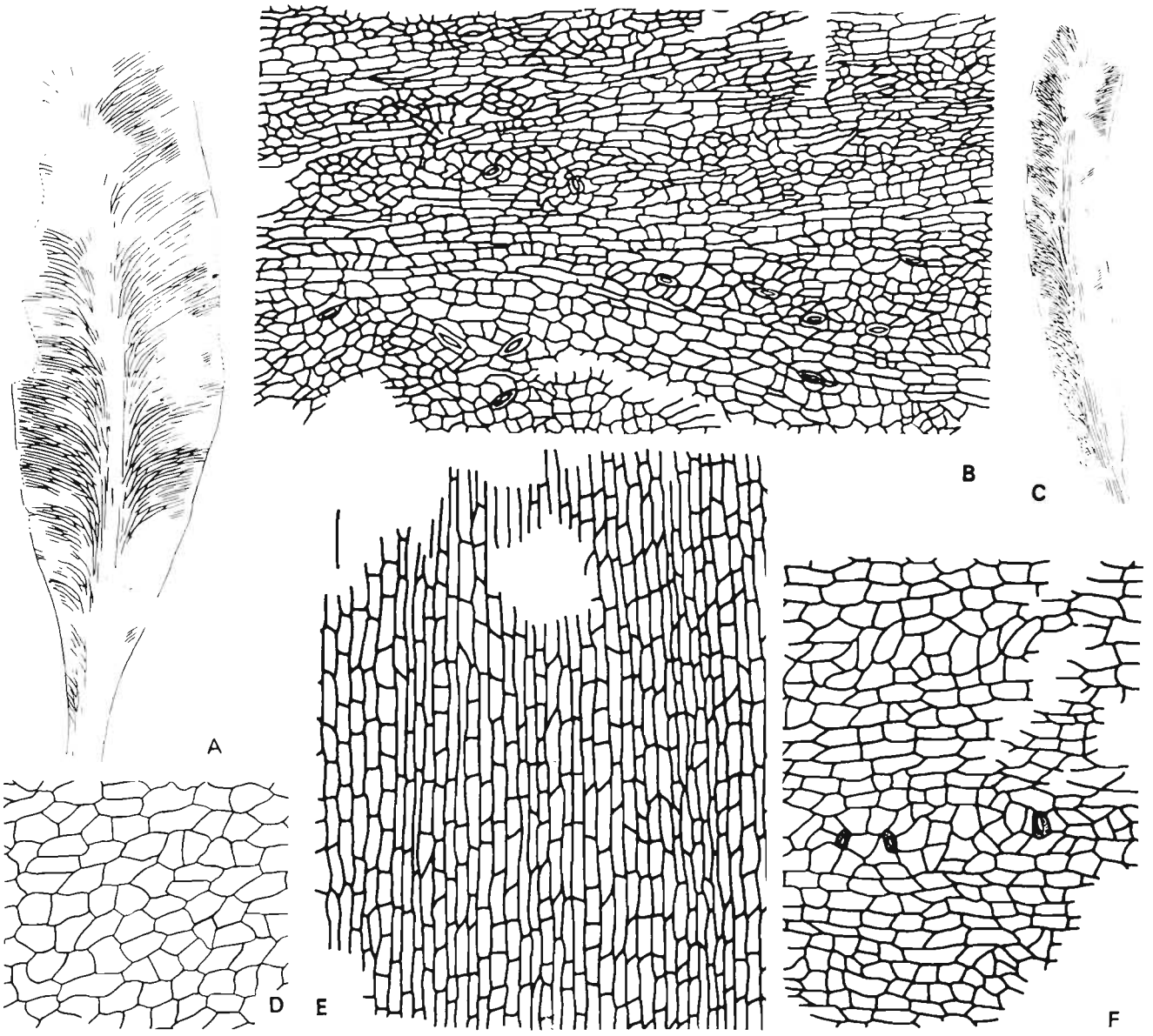
Glossopteris manjuiae sp. nov.

Pl. 5, figs 1-7; Text-fig. 7A-B

Diagnosis—Base attenuate, margins entire; midrib distinct, flat, striated lengthwise, prominent pits present in between striations; lateral veins arise from midrib at acute angles (15°-25°), dichotomise, meet margins at open angles, 7-11 per cm near midrib, 30-38 per cm near margin; meshes slightly shorter and broader near midrib than elsewhere, shape usually arcuate, rarely deltoid, angled near midrib, elsewhere usually trapezoidal, sometimes pentagonal.

Upper cuticle of lamina differentiated into vein and mesh areas, cells over veins narrow, rectangular, arranged end-to-end in longitudinal rows, cells over meshes broader, rectanguloid to polygonal, arranged either in rows or irregularly; lateral walls of cells straight, surface walls non-papillate; stomata absent; cuticle of midrib differentiated into striated and non-striated areas, cells over striations narrow, elongate, usually rectangular, rarely trianguloid in shape, arranged end-to-end in longitudinal rows, cells over non-striated areas broader, rectanguloid, polygonoid, squarish or trianguloid in shape, arranged end-to-end in longitudinal rows; lateral walls of cells very thick, straight, surface walls non-papillate; stomata absent. Lower cuticle of lamina differentiated into vein and mesh areas, veins show anastomoses, cells over veins rectangular, arranged end-to-end in longitudinal rows, cells over meshes polygonal to irregular, arranged irregularly, lateral walls straight to undulate, surface walls non-papillate; meshes stomatiferous; stomata anomocytic (haplocheilic), monocyclic, irregularly oriented, distributed in rows; subsidiary cells 4-7 in number, irregular in shape; lower cuticle of midrib differentiated into striated and non-striated areas, cells over striations elongate, rectangular, arranged end-to-end in longitudinal rows, cells over non-striated areas rectanguloid, irregular to polygonal in shape, arranged irregularly; lateral walls straight to undulate, surface walls non-papillate, stomata absent.

Holotype—Specimen no. 36452C, slide nos. 36452C-1 to 3; Birbal Sahni Institute of



Text-figure 7—A-B, *Glossopteris manjuiae* sp. nov.: **A,** leaf fragment showing venation, Holotype, BSIP Specimen no. 36452C × 1; **B,** lower cuticle of lamina showing bifurcation of veins, BSIP Slide no. 36452C-3 × 100; **C-F,** *Glossopteris schopfii* sp. nov.: **C,** leaf fragment showing venation and a flat, striated midrib, Holotype, BSIP Specimen no. 36462A × 1; **D,** upper cuticle of lamina showing polygonal cells, BSIP Specimen no. 36462A-2 × 100; **E,** midrib cuticle, BSIP Slide no. 36462A-1 × 100; **F,** lower cuticle of lamina showing vein and mesh areas and stomata, BSIP Slide no. 36462A-2 × 100.

Palaeobotany, Lucknow; Early Permian, Barakar Formation, Churulia area, Raniganj Coalfield.

Derivation of name—After Dr Ms Manju Banerjee.

Description—The specimen is incomplete, measures 11.6 cm in length and 3.1 cm in width with entire margin and attenuate base. Midrib is distinct, flat, striated lengthwise with prominent pits present in between the striations; 3 mm wide in the basal region and 1 mm wide further above. Lateral veins emerge from midrib at acute angles (15°-25°), take an outward curve and after successive dichotomies and anastomoses approach the margin at an angle between 62°-75°. The concentration of veins is 7(8.7) 11 per cm near the midrib and 30(33.7) 38 per cm near the margin. The vein dichotomies usually are of gamma and lambda types or rarely of psi type and the cross connections between the veins are usually of zeta type, occasionally of eta and psi-lambda types. Size of meshes varies in different parts of the leaf. The shape of meshes is usually arcuate, rarely deltoid and angled near the midrib and trapezoidal and pentagonal elsewhere.

The carbonified crust of the middle region of

leaf broke up into small fragments during chemical treatment. However, it has been possible to recover some good pieces of cuticle from the basal region of leaf which is probably hypostomatic.

The non-stomatiferous or upper cuticle of lamina is differentiable into vein and mesh areas. Cells over the veins are narrow, rectangular, arranged end-to-end in longitudinal rows, 56-81 μm in length and 19-37 μm in width. The cells in mesh areas are rectanguloid to polygonal in shape, 56-114 μm long and 31-62 μm wide. Lateral walls of cells, both over the veins and meshes are 6 μm thick and straight to slightly undulate; the surface walls are non-papillate.

The stomatiferous or lower cuticle of lamina is also differentiable into vein and mesh areas, in the same way as the non-stomatiferous surface. The veins show anastomoses. Cells over the veins are rectangular, elongate, arranged end-to-end in linear rows, 66-120 μm long and 30-38 μm wide. Lateral walls are usually straight to undulate, 2-8 μm thick. Cells over the meshes are polygonal to irregular, arranged irregularly and 30-50 μm long and 22-32 μm wide with undulate lateral walls which sometimes are straight. Surface walls are non-papillate in both the areas. Stomata are haplocheilic, irregularly oriented and distributed in the mesh areas, measure 20-34 μm in length and 6-18 μm in width. The stomatal apparatus is monocyclic and has 4-7 subsidiary cells which are irregular in shape, 8-40 μm long and 4-18 μm wide. Guard cells are 20-34 μm in length and 2-6 μm in width with 2 μm thick walls. The stomatal pore is 12-34 μm long and 2-4 μm wide. Stomatal index varies from 1.53 to 10.95.

The cuticles of midrib are differentiated into striated and non-striated areas. Cells over the striations are narrow, elongate, usually rectangular, rarely trianguloid and arranged end-to-end in almost linear rows measuring 82-180 μm in length and 14-38 μm in width. Cells over the non-striated areas are rectangular, polygonal, squarish or triangular in shape, 16-140 μm long and 28-46 μm wide, arranged end-to-end in linear rows. Walls of the cells are 6-20 μm thick over the striations and 4-10 μm thick over non-striated areas, straight to slightly undulate; the surface walls are non-papillate.

Comparison—*G. manjuiae* resembles *G. obscura* (Pant & Singh, 1971, pl. 8, fig. 46; text-fig. 7A) and *G. longifolia* (Pant & Singh, 1971, pl. 12, figs 25, 26; text-fig. 11A, B) in venation pattern. *G. manjuiae* also resembles *G. ghusikensis* (Pant & Gupta, 1971) and *G. bunburyana* in being hypostomatic, absence of papillae and in having straight lateral walls but differs in morphographic characters.

Glossopteris schopfii sp. nov.

Pl. 6, figs 1, 4-5, 7; Pl. 7, fig. 9; Text-fig. 7C-G

Diagnosis—Leaf linear in shape, apex not known, base narrow, margins entire; midrib distinct, flat, striated lengthwise; lateral veins arise from midrib at acute angles (10°-14°), take an outward curve, dichotomise, anastomose, meet margin at angle between 70°-75°, 11-16 per cm near midrib, 19-26 per cm near margin; meshes narrow, short, arcuate near midrib, trapezoidal elsewhere.

Upper cuticle of lamina differentiated into vein and mesh areas, cells over veins narrow, rectangular or elongate-polygonal, arranged end-to-end in longitudinal rows, cells over meshes polygonal, arranged irregularly, lateral walls of cells straight, surface walls non-papillate; stomata absent.

Lower cuticle of lamina differentiated into vein

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PLATE 6

Glossopteris schopfii sp. nov.

1. Holotype. Compression of a linear leaf with dense veins and a flat midrib. BSIP Specimen no. 36462A. × 1.
4. Upper cuticle of lamina from the leaf in fig. 1 showing polygonal cells of mesh area arranged irregularly. BSIP Slide no. 36462A-2. × 100.
5. Midrib cuticle from the leaf in fig. 1 showing narrow, elongate-rectangular cells arranged in rows. BSIP Slide no. 36462A-1. × 100.
7. Lower cuticle of lamina showing vein and mesh areas and stomata. BSIP Slide no. 36462A-2. × 400.

Glossopteris schimperi sp. nov.

2. Lower cuticle of lamina from the leaf in pl. 5, fig. 8 showing a stoma. BSIP Slide no. 36455B-2. × 600.
3. Lower cuticle of lamina from the leaf in pl. 5, fig. 8 showing veins, meshes and stomata. BSIP Slide no. 36455B-2. × 200.

Glossopteris kusumiae sp. nov.

6. Upper cuticle of midrib from the leaf in pl. 7, fig. 3, showing circular hair bases. BSIP Slide no. 36464-1. × 100.
8. Upper cuticle of lamina from the leaf in pl. 7, fig. 4 showing vein and mesh areas, latter with undulate-walled cells. BSIP Slide no. 36465-1. × 100.
9. Lower cuticle of lamina from the leaf in pl. 7, fig. 3, showing a stoma (the epidermal cell outlines are not marked), with subsidiary cells papillae overhanging the guard cells (outlines of subsidiary cells are not marked and subsidiary cells, instead, are represented by papillae). BSIP Slide no. 36464. × 400.

Glossopteris ednae sp. nov.

10. Lower cuticle of lamina from the leaf in pl. 7, fig. 1 showing stomata overhung by papillae and papillate surface walls. BSIP Slide no. 36463-1. × 400.

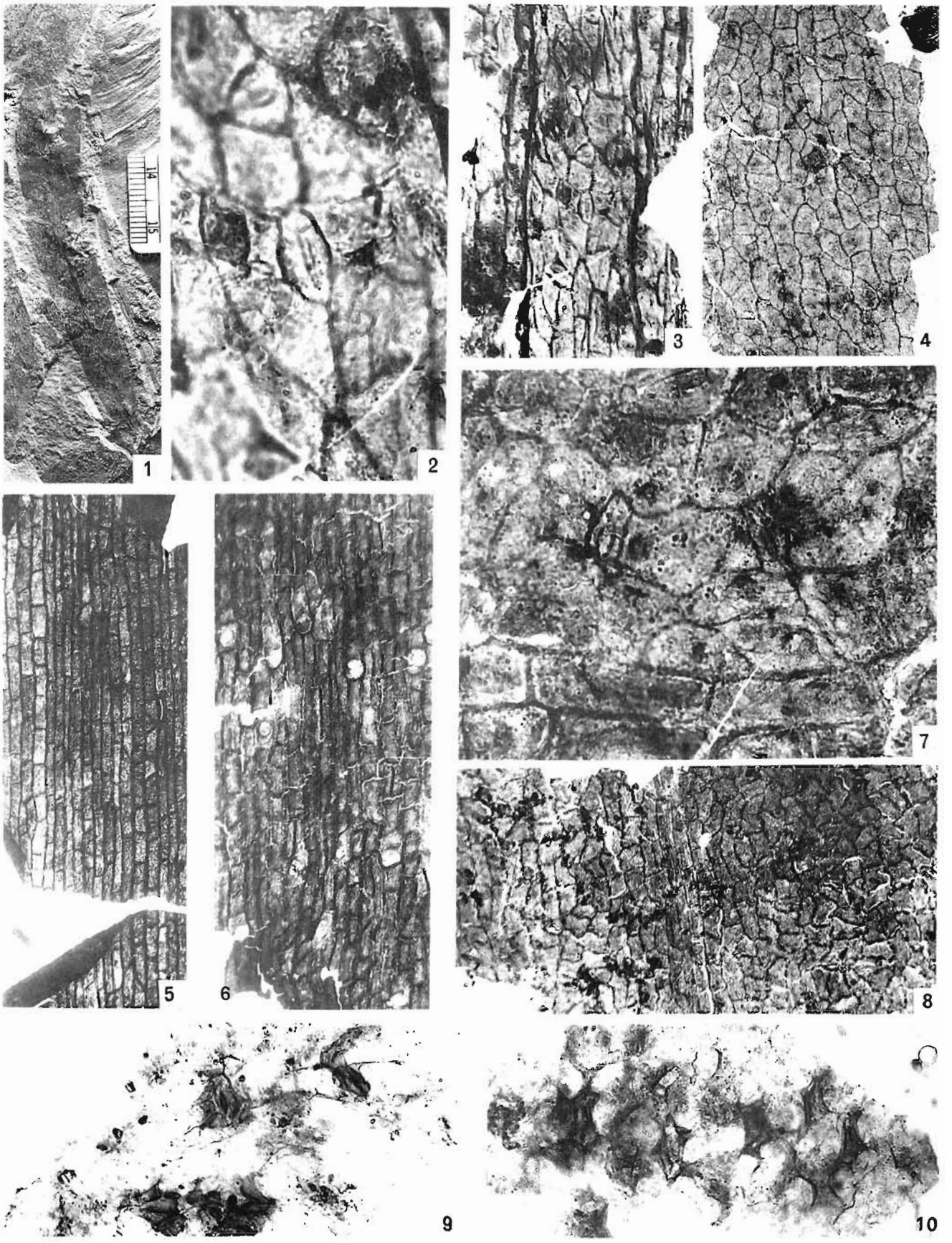


PLATE 6

and mesh areas, cells over veins narrow, rectangular, trianguloid, squarish, arranged end-to-end in longitudinal rows, cells over meshes polygonal, arranged irregularly; lateral walls straight, surface walls non-papillate; meshes stomatiferous, stomata haplocheilic, distributed in rows, oriented at right angles or obliquely or parallel to veins, stomatal apparatus monocyclic, subsidiary cells 5-6 in number, non-papillate; guard cells normal, stomatal opening visible as biconvex slit.

Holotype—Specimen no. 36462A, slide nos. 36462A-1, 2; Birbal Sahni Institute of Palaeobotany, Lucknow; Early Permian, Barakar Formation, Churulia area, Raniganj Coalfield.

Derivation of name—After late Professor James Morton Schopf.

Description—The specimen is incomplete, apical half and basalmost portion are not preserved. Overall shape of the leaf was probably linear with entire margins. Leaf gradually narrows down towards base. Midrib is distinct, flat and striated lengthwise. Lateral veins emerge from midrib at very acute angles (10°-14°), take an outward curve, and after successive dichotomies and anastomoses approach the margin at an angle between 70°-75°. The number of veins is 11(13.6) 16 per cm near midrib and 19(22.8) 26 per cm near the margin. Vein dichotomies usually are of gamma type and the cross-connections between the veins are of zeta type. Size of the meshes varies in different parts of the leaf, while the shape of the meshes is arcuate near the midrib and mostly trapezoidal elsewhere.

Non-stomatiferous cuticle of lamina is differentiable into vein and mesh areas; the cells over the veins are narrow and rectangular or elongately polygonal, arranged end-to-end in almost longitudinal rows. Cells in the mesh areas are polygonal in shape. Lateral walls of the cells are straight to slightly undulate. The surface walls are non-papillate.

The stomatiferous cuticle of lamina is also differentiable into vein and mesh areas. Stomata are haplocheilic, distributed in longitudinal rows along veins in the mesh areas and oriented either at right angles to the veins or placed obliquely or parallelly to them. Stomatal apparatus is monocyclic and has 5-6 subsidiary cells which are polygonal in shape like other epidermal cells of the mesh areas.

The cells over the midrib are usually rectangular, rarely triangular or irregular and arranged end-to-end in linear rows.

Comparison—G. schopfii is morphographically similar to *G. angustifolia* (Brongniart, 1828, pl. 63, fig. 11A) but differs in cuticular features (Sahni, 1923, pl. 17, figs 1-3); the latter species is characterised by (i) cells with sinuous lateral walls on both the surfaces of cuticle (the sinuosities, however, are less pronounced on the lower surface), and (ii) papillate subsidiary cells. *G. schopfii* is also comparable in venation pattern with *G. zeilleri, G. petiolata, G. vulgaris* and *G. varia* (Pant & Gupta, 1968, pl. 21, fig. 20; text-fig. 3; pl. 22, fig. 26; text-fig. 1D; pl. 25, fig. 37; text-fig. IE; pl. 26, fig. 44, text-fig. 5, respectively). However, they differ in cuticular features.

G. schopfii is comparable to the cuticles of *G. pseudocommunis* (Srivastava, 1956, pl. 2, fig. 13; pl. 3, figs 14, 15) and resembles in the shape and arrangement of cells on both the surfaces and in having identical stomata but the latter species differs anatomically in being amphistomatic and externally in shape and venation pattern (Srivastava, 1956, pl. 2, fig. 12). The cuticle of *G. intermittens* (Srivastava, 1956, pl. 7, figs 45, 46, 47) is also identical, though papillae have also been reported on the lower surface by Pant and Gupta (1968) the leaf differs in being spathulate.

Glossopteris schimperi sp. nov.

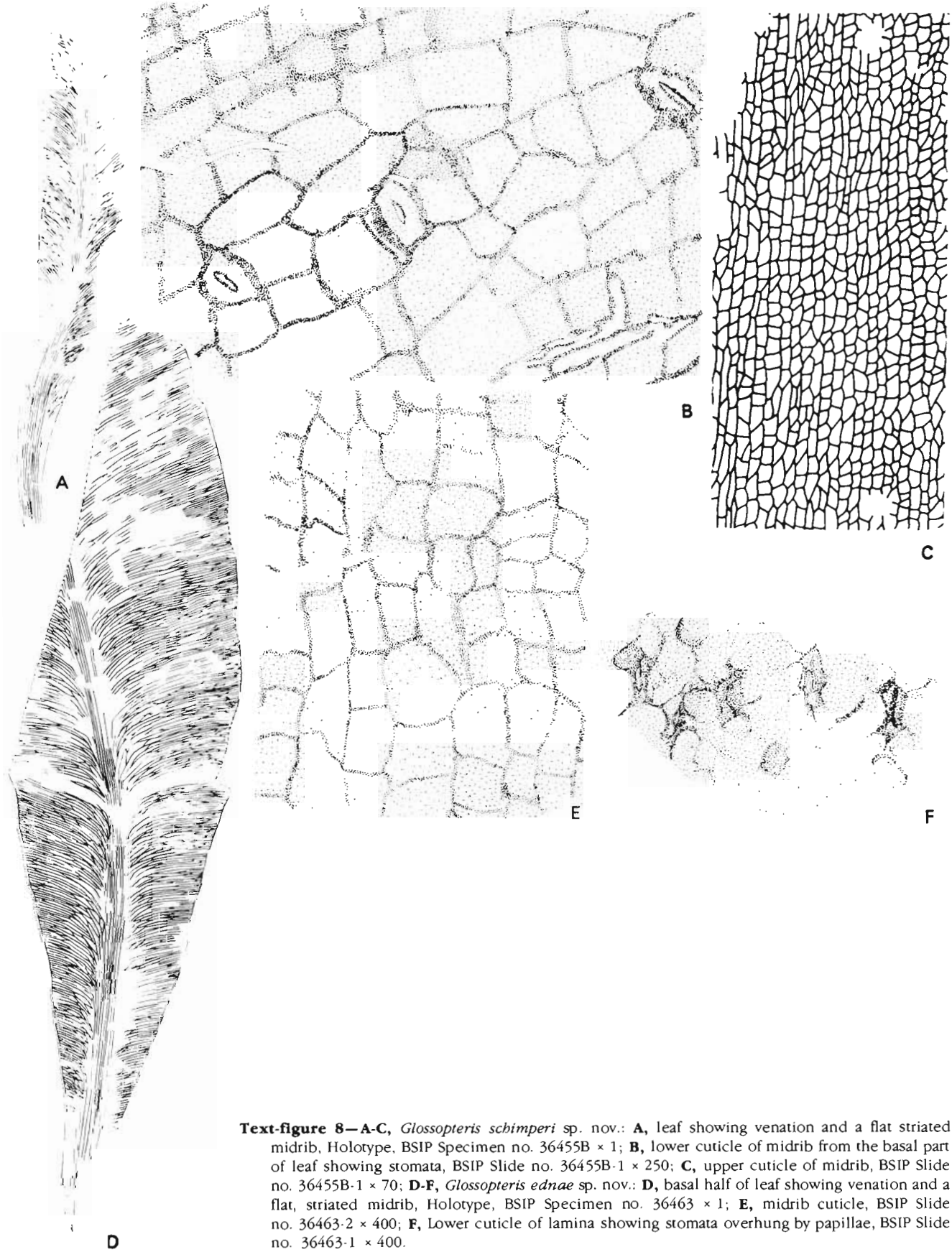
Pl. 5, figs 8-10; Pl. 6, figs 2, 3; Text-fig. 8A-C

Diagnosis—Leaf probably linear in shape; midrib prominent, flat, striated lengthwise; lateral veins arise from midrib at acute angles (10°-19°), meet margins at angle between 58°-70°, density 11-17 per cm near midrib, 28-36 per cm near margin; meshes narrow throughout leaf lamina; shape of meshes arcuate near midrib, trapezoidal elsewhere.

Upper cuticle of lamina differentiated into vein and mesh areas, cuticle of midrib differentiated into striated and non-striated areas, lateral walls of cells equally thick in both areas, surface walls non-papillate.

Lower cuticle of lamina differentiated into vein and mesh areas, lateral walls of cells 6 μm thick over veins, 2-4 μm thick over meshes, straight, surface walls non-papillate; meshes stomatiferous, stomata haplocheilic, irregularly distributed and oriented, stomatal apparatus monocyclic; subsidiary cells 5-6 in number, unspecialised; lower cuticle of midrib differentiated into striated and non-striated areas; latter stomatiferous; surface walls non-papillate; stomata haplocheilic, monocyclic, rectanguloid in shape, distributed in longitudinal rows in non-striated areas, oriented at right angles or lie slightly oblique to striations; subsidiary cells 5-6 in number, polygonal in shape with distinct, straight lateral walls, non-papillate surface walls, guard cells normal.

Holotype—Specimen no. 36455B, slide nos.



Text-figure 8—A-C, *Glossopteris schimperi* sp. nov.: **A,** leaf showing venation and a flat striated midrib, Holotype, BSIP Specimen no. 36455B × 1; **B,** lower cuticle of midrib from the basal part of leaf showing stomata, BSIP Slide no. 36455B-1 × 250; **C,** upper cuticle of midrib, BSIP Slide no. 36455B-1 × 70; **D-F,** *Glossopteris ednae* sp. nov.: **D,** basal half of leaf showing venation and a flat, striated midrib, Holotype, BSIP Specimen no. 36463 × 1; **E,** midrib cuticle, BSIP Slide no. 36463-2 × 400; **F,** Lower cuticle of lamina showing stomata overhung by papillae, BSIP Slide no. 36463-1 × 400.

36455B-1, 2; Birbal Sahni Institute of Palaeobotany, Lucknow; Early Permian, Barakar Formation, Churulia area, Raniganj Coalfield.

Derivation of name—After G. Schimper.

Description—The specimen is incomplete. The leaf was probably linear in shape with entire margin and a gradually tapering base. Midrib is prominent, flat, striated lengthwise and occupies almost whole of the basal portion. Lateral veins emerge from midrib at very acute angles (10°-19°), take an outward curve and after successive dichotomies and anastomoses approach the margin at an angle between 58°-70°. The vein dichotomies usually are of gamma type and the cross connections between the veins which form the meshes, are of eta type. Size of the meshes varies in different parts of leaf. Shape of meshes is arcuate near the midrib and mostly trapezoidal elsewhere.

The carbonified crust from the middle part of leaf broke up into small fragments during chemical treatment. However, the crust of the basal portion has yielded some good pieces of cuticle worth study, although these pieces are mostly from the median region. The leaf is probably hypostomatic.

The non-stomatiferous or upper cuticle of lamina is differentiable into vein and mesh areas. Surface walls are non-papillate.

The stomatiferous or the lower cuticle of lamina is also differentiable into vein and mesh areas. The cells over the veins are narrow, rectangular and arranged end-to-end in longitudinal rows, lateral walls are straight or slightly undulating. Cells in the mesh areas are elongate-polygonal, with straight to slightly arched lateral walls. Surface walls both over veins and meshes are non-papillate. Stomata are haplocheilic, irregularly distributed and oriented in mesh areas. Stomatal apparatus is monocyclic and has 5-6 subsidiary cells similar to the other epidermal cells.

Upper cuticle of midrib is non-stomatiferous and differentiable into striated and non-striated areas. Cells over the striations are elongate, rectangular, arranged end-to-end in longitudinal rows and have straight to slightly undulating lateral walls. The cells over non-striated areas are usually narrow, elongate and rectangular, sometimes squarish, triangular, polygonal or irregular in shape with straight lateral walls. Surface walls are non-papillate. The cells are arranged end-to-end in longitudinal rows.

The lower cuticle of the midrib is also differentiable into striated and non-striated areas. Non-striated areas are stomatiferous. The cells over the striations are narrow, elongate, rectangular and arranged end-to-end in longitudinal rows. Cells over non-striated areas are polygonal to irregular in shape. The stomata are haplocheilic, distributed in longitudinal rows in the non-striated areas and lie at right angles or slightly oblique to the striations. Stomatal apparatus is monocyclic and has 5-6 subsidiary cells, polygonal in shape, with straight lateral walls. Incidentally, whereas, the lateral walls of the other epidermal cells are indistinct, those of the subsidiary cells are straight and distinct.

Comparison—*G. schimperi* shows an altogether different type of cuticle which has not been described so far. Morphographically the species resembles *G. angustifolia* (Brongniart, 1828, pl. 63, fig. 1, 1A), *G. zeilleri, G. petiolata, G. vulgaris, G. varia* (Pant & Gupta, 1968, pl. 21, fig. 20; text-fig. 3; pl. 22, fig. 26; text-fig. 1D; pl. 25, fig. 37; text-fig. 1E and pl. 26, fig 44; text-fig. 5; respectively). In fact, the present species could have been identified as *G. angustifolia* except for the cuticle, which shows sinuous lateral walls and papillate subsidiary cells in *G. angustifolia* (Sahni, 1923, pl. 17, figs 1, 2, 3) and absence of both these features in *G. schimperi*. *G. schimperi* shows some similarity with the cuticle of

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PLATE 7

Glossopteris ednae sp. nov.

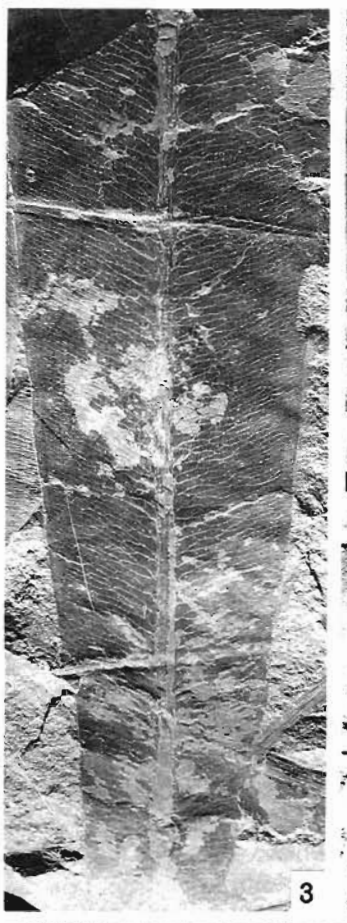
1. Holotype. Leaf-compression showing dense venation pattern, flat, striated, midrib and a narrow base. BSIP Specimen no. 36463. × 1.
6. A part of leaf in fig. 1 enlarged to show venation. × 2.

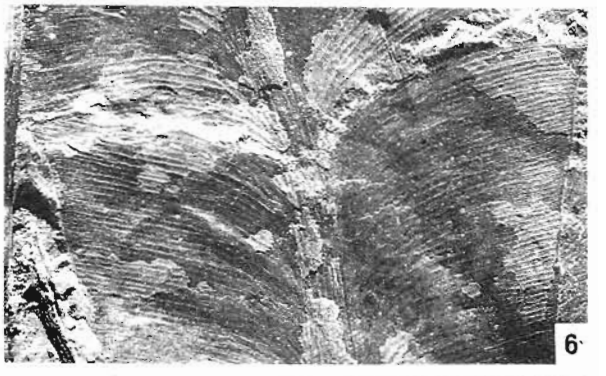
Glossopteris kusumiae sp. nov.

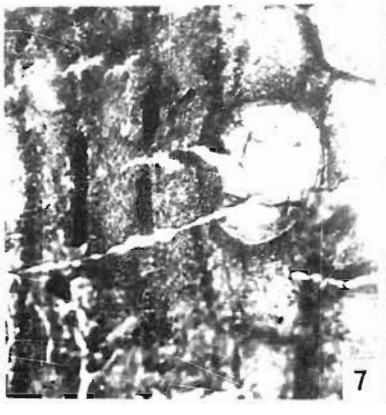
2. Impression of a leaf with strong midrib and patches of coalified crust. BSIP Specimen no. 36449B. × 1.
3. Holotype. Compression of a leaf showing broad, pentagonal meshes and striated, elevated, persistent midrib. BSIP Specimen no. 36464. × 1.
4. Compression of apical portion of a leaf showing acute apex, strong midrib and pentagonal meshes. BSIP Specimen no. 36465. × 1.
5. A part of leaf in fig. 4 enlarged to show venation and broad pentagonal meshes. × 2.
7. A part of midrib cuticle in pl. 6, fig. 6, enlarged to show a circular hair base. × 400.
8. Lower cuticle of lamina from the leaf in fig. 4, showing stomata, guard cells overhung by papillae. BSIP Slide no. 36465-2. × 400.

Glossopteris schopfii sp. nov.

9. Lower cuticle of lamina from the holotype (pl. 6, fig. 1) showing vein and mesh areas, latter with stomata. BSIP Slide no. 36462A-2. × 100.







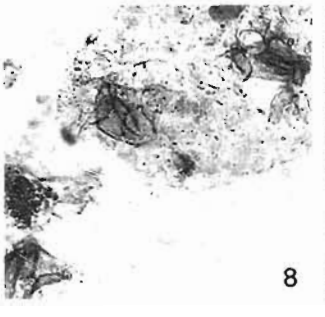


PLATE 7

G. formosa and *G. longicaulis* (as conceived by Srivastava 1956). Though, upper and lower surfaces of lamina of *G. formosa* show similarity with the cuticle of present species, cuticle of midrib differs by showing irregular cells. *G. formosa* also differs in venation pattern by showing broad, polygonal meshes of equal size throughout lamina. *G. schimperi* is also comparable in shape and venation pattern with *Lidgettonia inhluzanensis* (Anderson & Anderson, pl. 120, figs 2, 5, 8, 13, 15a, b, 16; pl. 122, fig. 16). However, the cuticle is not known from the latter species.

Glossopteris ednae sp. nov.

Pl. 6, fig. 10; Pl. 7, figs 1, 7; Text-fig. 8D-F

1980 *Glossopteris indica* Schimper: Rigby, Maheshwari & Schopf, *Geol. Surv. Qd Publ.* **376**, *Palaeont. Pap.* (47) : p. 14-16, figs 38, 39.

Diagnosis—Leaf base attenuate, margins entire; midrib distinct, flat, striated lengthwise, 4 mm wide; lateral veins arise from midrib at acute angles, curve outwards, dichotomise and anastomose, meet margin at angle between 70°-80°, 10-14 per cm near midrib, 27-38 per cm near margin, meshes narrow, elongate, short near midrib, longest between midrib and margin, shortest near margin, arcuate near midrib, trapezoidal elsewhere.

Cells of upper cuticle elongate, polygonal in shape; lateral walls of cells straight, surface walls non-papillate; stomata absent. Cells of lower cuticle polygonal in shape when visible; surface walls papillate, papillae rare, hollow, dome-shaped; stomata haplocheilic, irregularly distributed and oriented, stomatal apparatus monocyclic, subsidiary cells 5-6 in number, papillate, papillae overhanging guard cells.

Holotype—Specimen no. 36463, slide nos. 36463-1; Birbal Sahni Institute of Palaeobotany, Lucknow; Early Permian, Barakar Formation, Churulia area, Raniganj Coalfield.

Derivation of name—After Dr Ms Edna Plumstead.

Description—The specimen is incomplete, preserved portion 16.6 cm long and 4 cm wide with entire margin and a gradually tapering base. Midrib is distinct, flat, striated lengthwise. In between the striations, pits are present which, however, are not very prominent. Lateral veins emerge from midrib at acute angles (20°-30°), curve outwards and after successive dichotomies and anastomoses, approach the margin at an angle between 70°-80°. Vein dichotomies usually are of gamma type and the cross-connections between the veins, which form the meshes, are usually of zeta type or rarely of psi-lambda type. Size of meshes varies in different parts of the leaf. Shape of the meshes is usually arcuate, rarely deltoid and angled near the midrib and mostly trapezoidal elsewhere.

The carbonified crust, though looked good under incident light, broke up into small fragments during chemical treatment. Leaf is probably hypostomatic as cuticle of only one surface has stomata. The non-stomatiferous or upper cuticle of lamina is not marked into vein and mesh areas. The cells are elongate, polygonal in shape, lateral walls are straight to arched, surface walls are non-papillate.

The stomatiferous or lower cuticle of lamina is also not marked into vein and mesh areas. Cell outlines are indistinct mostly, but wherever visible, the cells are polygonal in shape with straight to slightly undulating lateral walls. Surface walls are papillate, papillae rare, hollow, dome-shaped. The stomata are haplocheilic, irregularly distributed and oriented. Stomatal apparatus is monocyclic and has 5-6 papillate subsidiary cells, papillae over-hanging the guard cells.

The cuticles from the midrib portion are differentiable into striated and non-striated areas, the cells over the striated areas are narrow, rectangular to squarish in shape and arranged end-to-end in almost linear rows. Cells over the non-striated areas are broad, polygonal, rectangular to squarish and are also arranged end-to-end in rows.

Comparison—G. ednae is comparable to a number of forms either morphographically or in cuticular features. In venation pattern, it resembles to a certain extent *G. indica* Schimper (Rigby, Maheshwari & Schopf, 1980, figs 40, 41), *G. communis* (Feistmantel, 1876, 1979-1882, 1886, 1890), *G. pseudocommunis* Pant & Gupta 1968 (Srivastava, 1956, pl. 2, fig. 12), *G. pseudocommunis* (pl. 2, figs 6, 7), *G. fibrosa, G. hispida* (Pant, 1958, text-figs 1C, D, E; 1F, respectively), *G. cordiformis* (Pant & Singh, 1971, pl. 4, fig. 20; text-fig. 3A, E) and *G. syaldiensis* (Chandra & Surange, 1979, pl. 2, fig. 1; pl. 15, fig. 5; pl. 43, fig. 4; text-fig. 40A, a_1, a_2). However, all these leaves differ from *G. ednae* in some or the other characters. For example, *G. indica* shows distinct short and broad, at times almost triangular meshes near the midrib and narrow, elongate meshes away from the midrib. Lateral veins in *G. indica* meet margin at an angle between 55°-60°. One of the leaves described by Rigby, Maheshwari and Schopf (1980, figs 38, 39) resembles the present species in morphology and has been merged here on this basis with *G. ednae*, although its cuticular characters are not known. *G.*

communis though, resembles the present species externally, yet differs from it in (i) absence of stomata on both the surfaces, (ii) absence of papillae, and (iii) presence of rectanguloid cells (Pant & Gupta, 1968, pl. 26, figs 48, 49; text-fig. 14 J-O). *G. syaldiensis* (Kulkarni's *G. stricta*, 1971, pl. 1, fig. 5) apparently simulates *G. ednae* in venation pattern but on closer observation of the holotype (*G. syaldiensis*), it was found that the veins are much finer, concentration of veins denser and meshes broader and shorter near the midrib than elsewhere. Incidentally, it is important to mention here that Kulkarni (1971) did not mention the specimen number of the leaf of *G. stricta* (pl. 1, fig. 5) and in 1979 when Chandra and Surange formed a new species *G. syaldiensis* by maintaining *G. stricta* of Kulkarni (1971) as holotype, they mentioned the number of this holotype as 34060 (p. 35). However, this particular specimen number does not belong to *G. syaldiensis* as was found during an attempt to study the type specimen. A thorough search of all the specimens which Kulkarni had described in the year 1971, was, therefore made and it was found that the actual specimen which contained *G. syaldiensis* was numbered as 34067. Therefore, it is proposed here that specimen number of holotype of *G. syaldiensis* should be considered as 34067 instead of 34060.

Glossopteris kusumiae sp. nov.

Pl. 6, figs 6, 8-9; Pl. 7, figs 2-5, 7-8; Text-figs 9A-F, 10A-C

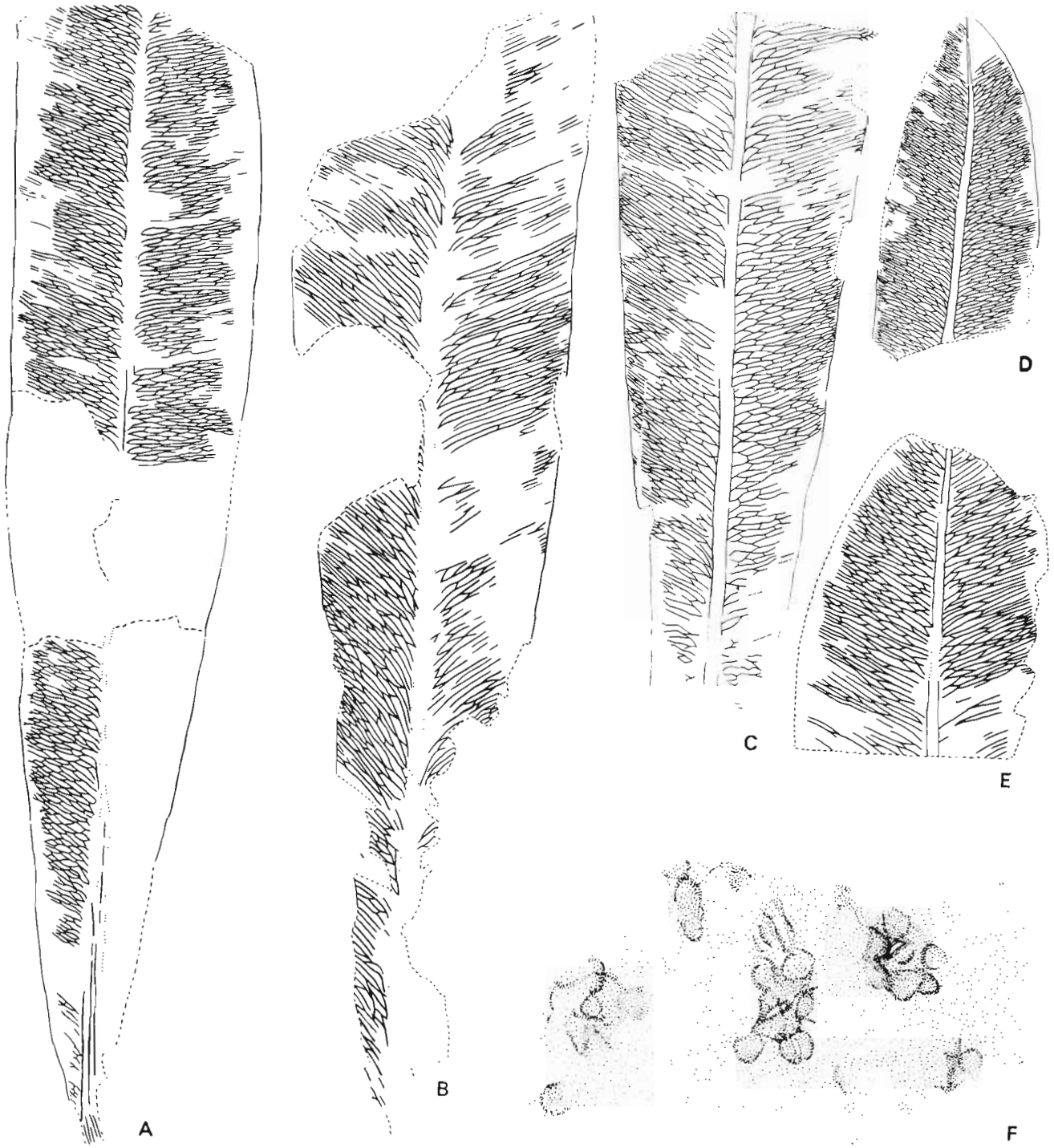
Diagnosis—Leaves oblanceolate in shape, apex acute, base attenuate, margins entire; midrib distinct, persistent, elevated, striated lengthwise, wide at base, narrow towards apex; lateral veins arise from midrib at acute angles (15°-45°), dichotomise, anastomose, meet margin at angle between 46°-60° in middle region of lamina; meshes broad, elongate, apparently deltoid, usually arcuate, rarely angled near midrib, pentagonal elsewhere, short and narrow near margins.

Upper cuticle of lamina differentiated into vein and mesh areas; upper cuticle of midrib not differentiated into striated and non-striated areas; cells narrow, rectangular, arranged end-to-end in longitudinal rows; lateral walls of cells straight, surface walls non-papillate, characterised by presence of circular hair bases. Lower cuticle of lamina stomatiferous; cell outlines indistinct; stomatal portions distinct; stomata haplocheilic, irregularly distributed and oriented, stomatal apparatus monocyclic; subsidiary cells represented by papillae, papillae 4-8 in number, overarching guard cells; cells of lower cuticle of midrib similar to upper cuticle of midrib, hair bases absent.

Holotype—Specimen no. 36464, slide nos. 36464-1, 2; Birbal Sahni Institute of Palaeobotany, Lucknow; Early Permian, Barakar Formation, Churulia area, Raniganj Coalfield.

Derivation of name—After Ms Kusum Lata Bharadwaj (nèe Gupta).

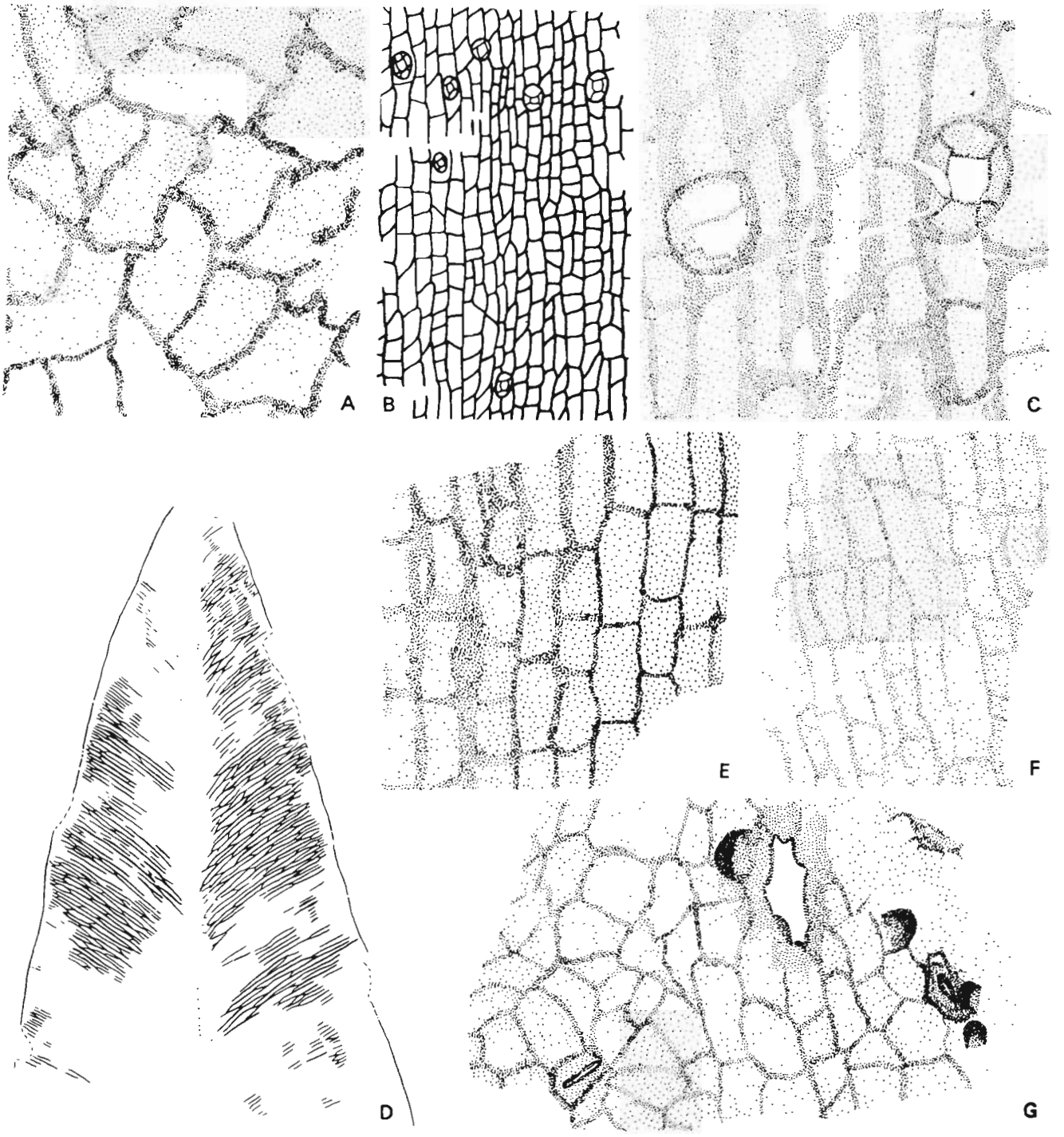
Description—The leaves are oblanceolate in shape with acute apex and attenuate base, 5.3-19 cm long and 3.2-5.5 cm wide at the widest, which probably is the middle region of leaf. The leaf has entire margins. Midrib is distinct, elevated, striated lengthwise, thinning towards the apex. The lateral veins emerge from the midrib at acute angles (15°-45°), emergence angle appearing 30°-60° where midrib crust has been peeled off), curve very slightly near the midrib, then run straight about a milimetre away from the midrib, and after successive dichotomies and anastomoses, approach the margin at an angle between 46°-75°. The number of veins varies from 7-20 per cm near the midrib and 15-34 per cm near the margin. The vein dichotomies usually are of gamma type, occasionally of lambda and psi types and the cross-connections between the veins which form the meshes are of zeta and eta types or rarely of chi type. Size of the meshes varies in different parts of the leaf (1.7-10.3 × 0.3-1.4), shape apparently deltoid, usually angled and arcuate near the midrib and mostly pentagonal elsewhere. The leaf is probably hypostomatic. Non-stomatiferous cuticle of the lamina is differentiable into vein and mesh areas, cells over the veins (22-152 × 6-54 μm) are narrow, rectangular and arranged end-to-end in almost linear rows, cells in the mesh areas (22-148 × 12-68 μm) are polygonal or irregular in shape, lateral walls of the cells are straight over the veins (2-12 μm) and undulate to straight over the meshes (2-10 μm). Surface walls are non-papillate. The differentiation into vein and mesh areas is not marked in the stomatiferous cuticle of the lamina. Moreover, the cells outlines are also very indistinct. The cells are distinctly marked only in one specimen, i.e., 36449B. In this specimen, the cells are quadrangular, polygonal, squarish to rectangular in shape (34-100 × 40-80 μm), with straight lateral walls (4-10 μm). Surface walls are non-papillate. The stomata (16-46 × 4-38 μm) are haplocheilic and irregularly distributed and oriented. The guard cells are 26-46 μm long and 4-12 μm wide with 2-4 μm thick walls. Stomatal apparatus is monocyclic and has 4-8 subsidiary cells represented by papillae (12-34 × 14-26 μm) overhanging the guard cells. Stomatal index varies from 2.77 to 11.76. A characteristic feature of midrib



Text-figure 9— *Glossopteris kusumiae* sp. nov.: **A,** lower half of a leaf fragment showing venation, BSIP Specimen no. 36449B × 1; **B,** another leaf fragment showing venation, BSIP Specimen no. 36466 × 1; **C,** leaf fragment showing pentagonal meshes, Holotype, BSIP Specimen no. 36464 × 1; **D,** apical portion of a leaf showing venation, BSIP Specimen no. 36465 × 1; **E,** leaf fragment showing venation, BSIP Specimen no. 36455C × 1; **F,** lower cuticle of lamina showing stomata overhung by papillae, BSIP Slide no. 36464-3 × 400.

cuticle is the frequent presence of circular hair bases, which are 40-64 μm in diameter and have 2-6 μm thick walls.

Comparison—*G. kusumiae* is comparable to *G. browniana* (Brongniart, 1828-1837, pl. 62), *G. elongata* (Feistmantel, 1881, pl. 28A, figs 1, 5, 6, 8, 9), *G. subtilis* (Pant & Gupta, 1971, text-fig. 2B, C; Chandra & Surange, 1979, pl. 3, fig. 7; pl. 14, fig. 3;



Text-figure 10—A-C, *Glossopteris kusumiae* sp. nov.: **A,** upper cuticle of lamina showing mesh area with undulate cell walls, BSIP Slide no. 36465-1 × 400; **B,** upper cuticle of midrib showing circular hair bases, BSIP Slide no. 36464-1 × 100; **C,** same magnified to show hair bases, BSIP Slide no. 36464-1 × 400; **D-G,** *Glossopteris roylei* sp. nov.: **D,** apical portion of a leaf magnified to show venation, Holotype, BSIP Specimen no. 36467 × 2; **E,** midrib cuticle, BSIP Slide no. 36467-1 × 400; **F,** upper cuticle of lamina, BSIP Slide no. 36467-2 × 400; **G,** lower cuticle of lamina showing stomata and an abnormal structure, BSIP Slide no. 36467-2 × 400.

pl. 17, fig. 2; pl. 22, fig. 12; pl. 37, fig. 2), *G. karanpuraensis* (Kulkarni, 1971, pl. 2, figs 11, 12), *G. maculata* and *G. sastrii* (Pant & Singh, 1974, pl. 25, figs 16-19; text-fig. 1A, B, C; pl. 27, figs 33-38; text-fig. 2A-D, respectively) in having broad, polygonal meshes. However, all these species differ either in cuticular features or in other morphographical characteristics. The leaf described

by Srivastava (1956) as *G. browniana* (the cuticle of which has also been described) belongs to some other species, because it is very unlike *G. browniana* (pl. 1, figs 1, 2) and shows an altogether different type of venation pattern. *G. elongata* is a small, obovate leaf with obtuse apex and though it shows broad, polygonal meshes as in *G. kusumiae*; the meshes are much broader than long, whereas, in *G. kusumiae* the meshes are longer than broad. The cuticle of *G. retifera* as reported by Srivastava (1956) differs by showing rectangular cells on the upper surface of lamina, which are arranged end-to-end in rows and have sinuous lateral walls. The lower cuticle of lamina of *G. retifera* differs in having non-papillate subsidiary cells. *G. karanpuraensis* (Kulkarni, 1971, pl. 2, figs 11, 12) resembles *G. kusumiae* in venation pattern and probably in shape. In fact, *G. kusumiae* could have easily been kept under *G. karanpuraensis* on the morphographical grounds except for the cuticle, which is not known in *G. karanpuraensis*.

There are only two species which resemble *G. kusumiae* in showing circular hair bases. They are *G. hispida* (Pant, 1958) and *G. tenuifolia* (Pant & Gupta, 1968, pl. 21, fig. 17; text-fig. 8D). *G. hispida* shows hair bases not only on the midrib cuticle but also on the cells of lower surface of lamina.

Glossopteris roylei sp. nov.

Pl. 8, figs 1-6; Pl. 9, fig. 2; Text-figs 10D-G, 11A-F, 12D-E

Diagnosis—Leaves lanceolate in shape, apex acute, base narrow, margins entire; midrib distinct, stout, elevated, striated lengthwise, persistent; lateral veins emerge from midrib at acute angles, faintly curve outwards, dichotomise, anastomose, meet margin at open angles, 11-19 per cm near midrib, 31-38 per cm near margins; meshes very narrow, elongate, arcuate near midrib, trapezoidal elsewhere.

Upper cuticle of lamina differentiated into vein and mesh areas; cells over veins elongate, rectangular, arranged end-to-end in longitudinal rows; cells over meshes rectanguloid to polygonal in shape, arranged end-to-end in longitudinal rows or irregularly; lateral walls of cells straight, thick, surface walls papillate, each cell showing single, hollow, rounded or dome-shaped papilla; stomata haplocheilic, distributed in either longitudinal rows or irregularly in mesh areas, lie at either right angles or oblique to veins, or distributed irregularly, stomatal apparatus monocyclic, subsidiary cells 6-7 in number, papillate, papillae overhanging guard cells.

Lower cuticle of lamina differentiated into vein and mesh areas, cells over veins elongate, rectangular, arranged end-to-end in longitudinal rows; cells over meshes polygonal in shape, arranged irregularly; lateral walls of cells straight, thin, surface walls papillate, each cell showing single, hollow, rounded or dome-shaped papilla; stomata abundant, anomocytic (haplocheilic), irregularly distributed and oriented, stomatal apparatus monocyclic, subsidiary cells like other epidermal cells, 5-8 in number, papillate, papillae overhanging guard cells.

Cuticle of midrib non-stomatiferous, undifferentiated into striated and non-striated areas, cells rectangular in shape, arranged end-to-end in longitudinal rows, lateral walls of cells straight, moderately thick; surface walls non-papillate.

Holotype—Specimen no. 36467, slide no. 36467-1; Birbal Sahni Institute of Palaeobotany Museum, Lucknow; Early Permian, Barakar Formation, Churulia area, Raniganj Coalfield.

Derivation of name—Named after J. F. Royle.

Description—The specimens are almost complete, overall shape of the leaves is lanceolate with entire margins and acute apices. Midrib is distinct, stout, elevated, faintly striated lengthwise, 2 mm wide throughout the length of the leaf and persists right up to the apex. Lateral veins emerge from midrib at acute angles (10°-20°) in the apical region (elsewhere, angle of emergence of veins is 14°-45°), take a slight outward curve and after successive dichotomies and anastomoses, approach the margin at an angle between 79°-82°. In

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PLATE 8

Glossopteris roylei sp. nov.

1. Holotype. Compression of an almost complete leaf showing dense venation and a persistent, stout, elevated midrib. BSIP Specimen no. 36467. × 1.
2. Compression of another leaf. BSIP Specimen no. 36462B. × 1.
3. Upper cuticle of lamina from the leaf in fig. 1 showing vein and mesh areas and a stoma encircled by a ring of subsidiary cells. BSIP Slide no. 36467-1. × 400.
4. Midrib cuticle from the leaf in fig. 1 showing elongate-rectangular cells arranged in rows. BSIP Slide no. 36467-1. × 400.
5. Lower cuticle of lamina from the leaf in fig. 2 showing papillate surface walls and a stoma with papillae overhanging the guard cells. BSIP Slide no. 36462B-1. × 400.
6. Lower cuticle of lamina from the leaf in fig. 2 showing a number of stomata with papillae overhanging the guard cells and each epidermal cell surface showing a single, rounded papilla. BSIP Slide no. 36462B-2. × 400.

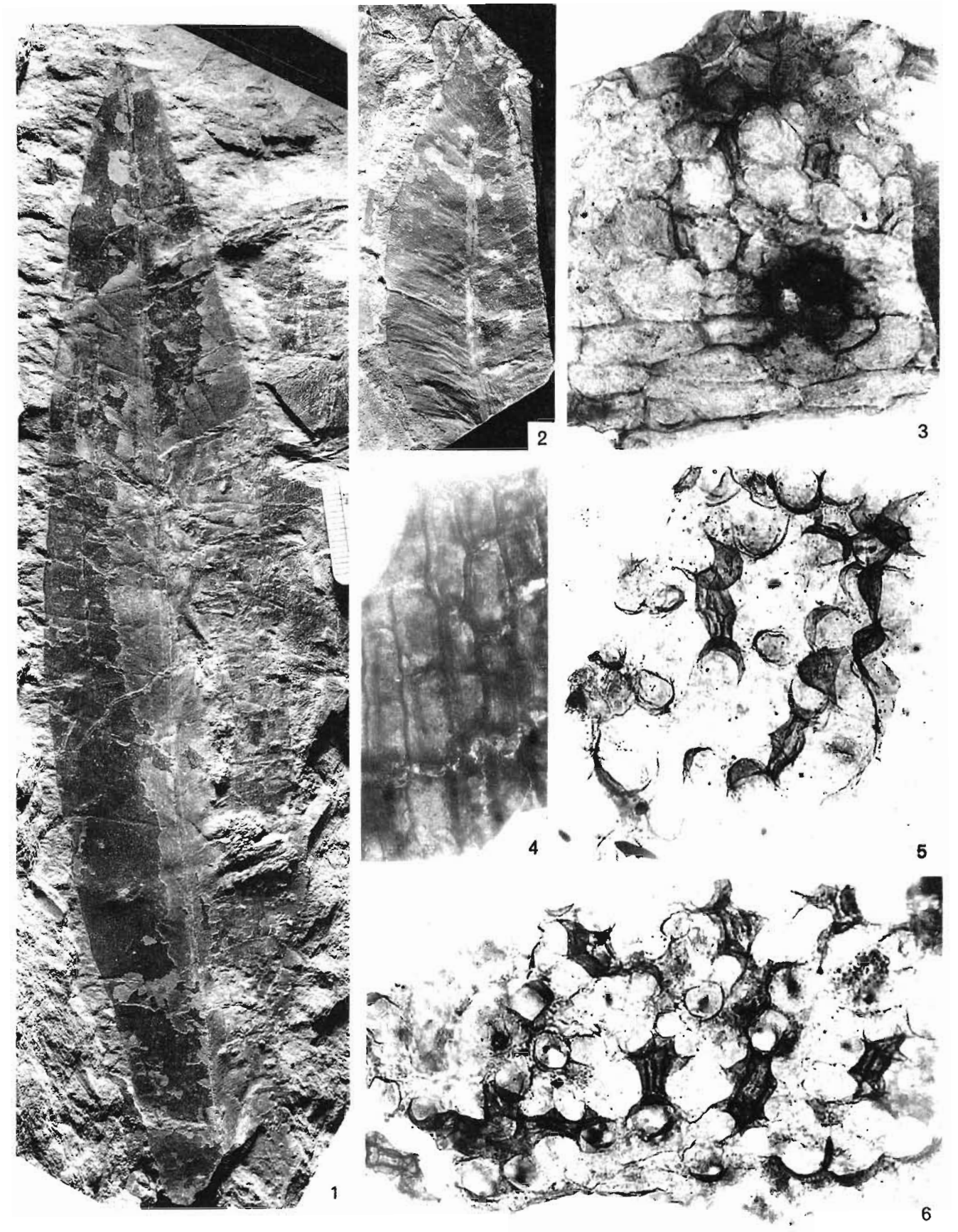


PLATE 8

specimen no. 36462B, the lateral veins reach margin at angles of 64°-73°. Number of veins varies from 11-19 per cm near the midrib to 31-38 per cm near the margin. The vein dichotomies usually are of gamma and lambda types and the cross-connections between the veins, which form the meshes are of zeta type or occasionally of psi-lambda type. Size of the meshes varies in different parts of leaf. Shape of the meshes is arcuate near the midrib and mostly trapezoidal elsewhere.

Leaf is amphistomatic as cuticle of both the surfaces have stomata. Upper cuticle of lamina is differentiable into vein and mesh areas. Cells over the veins are rectangular and arranged end-to-end in longitudinal rows. The cells in the mesh areas are rectanguloid to polygonal in shape. Lateral walls of cells are 2-10 μm thick over the veins, 4-10 μm thick over the meshes and straight or slightly arched. The surface walls are papillate, each cell showing a single, rounded or dome-shaped papilla. The stomata are few, haplocheilic, either irregularly oriented or lie at right angles or oblique to veins and distributed in longitudinal rows or irregularly in the mesh areas. Stomatal apparatus is monocyclic and has 6-7 subsidiary cells with dome-shaped papillae overhanging guard cells.

The lower cuticle of lamina is also differentiable into vein and mesh areas. Surface walls of the cells over the meshes are papillate, each cell showing a single, rounded or dome-shaped, hollow papilla. Stomata are haplocheilic and are irregularly distributed and oriented. Stomatal apparatus is monocyclic and has 5-8 subsidiary cells. The subsidiary cells are also papillate, as the other epidermal cells, with papillae overhanging the guard cells. Cuticle from the midrib portion is non-stomatiferous and does not show distinctive distribution of cells.

Comparison—Morphographically, *G. roylei* is comparable to *G. feistmantelii* Rigby (= *G. cordata* Feistmantel, 1886, pl. 20, fig. 1; Chandra & Surange, 1979, pl. 2, fig. 3; pl. 5, fig. 3; pl. 10, fig. 3; pl. 16, fig. 10; pl. 19, fig. 1), *G. indica* Schimper (Chandra & Surange, 1979, pl. 5, fig. 1; pl. 10, figs 2, 3) and *G. stricta* Bunbury (Chandra & Surange, 1979, pl. 5, fig. 4; pl. 32, fig. 1). *G. feistmantelii* resembles *G. roylei* in venation pattern. The base in *G. feistmantelii* has, however, been reported to be cordate, though the basal portion in illustrations of this species is broken and therefore, the nature of the base is not clear. Venation pattern, as reported by Feistmantel for *G. cordata* and later by Chandra and Surange for *G. feistmantelii* is different in the upper and lower portions of the species. Accordingly, in the upper portion, the lateral veins pass out at acute angles and form rather narrow meshes, slightly larger near the midrib. In the lower or basal portion, however, the direction of veins changes, that is, they pass out at less acute angles until in the basal lobes, they are radiating, i.e., changing from a slightly upwards direction to a horizontal and downwards direction, the meshes at the same time increasing in width, until in the basal lobes they become quite conspicuous, broad and polygonal. *G. feistmantelii* also seems to be a very confusing name, since *G. indica* Schimper (in Chandra & Surange, 1979, pl. 5, fig. 1) and *G. stricta* Bunbury (in Chandra & Surange, 1979, pl. 5, fig. 4) have similar venation pattern and therefore, all these three leaves appear to be forms of one taxonomic unit. Another specimen which resembles *G. roylei* has been figured in Plate 9, figure 2 and Text-figure 12 D-E. This leaf resembles *G. roylei* in venation pattern and probably also in shape. However, the cuticle of this specimen is fragmentary and shows only stomatal outlines; rest of the epidermal cells are not distinct.

→

PLATE 9

Glossopteris sp. cf. *G. leptoneura*

1. Impression of a lanceolate leaf showing an acute apex, a prominent midrib and dense venation pattern. BSIP Specimen no. 36469. × 1.
4. Upper cuticle of lamina (prepared from counter part of the leaf) from the leaf in fig. 1 showing a stoma. BSIP Slide no. 36469-1. × 400.
7. Lower cuticle of lamina from the leaf in fig. 1 showing stomata (marked by an arrow). BSIP Slide no. 36469-2. × 400.

Glossopteris roylei

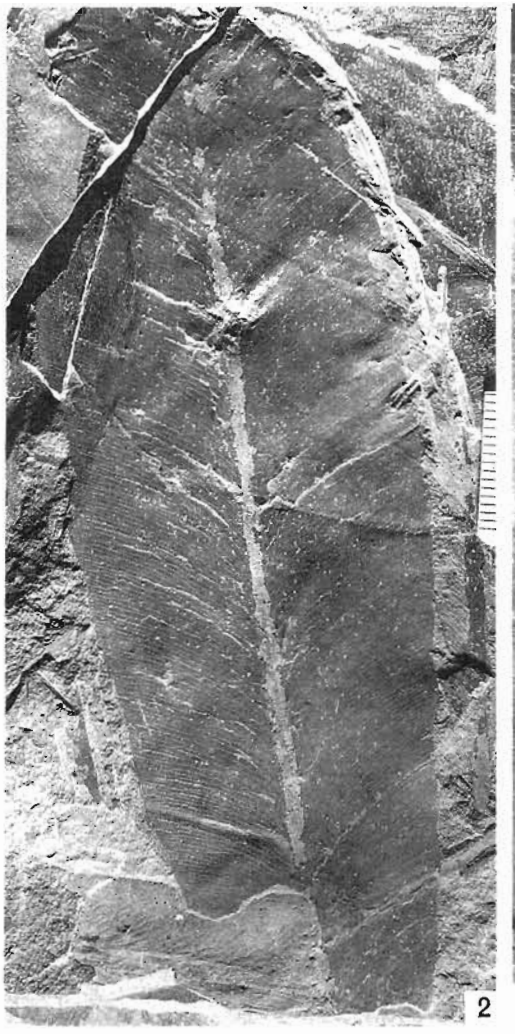
2. Compression of middle part of a leaf with a strong midrib and dense veins. BSIP Specimen no. 36468. × 1.

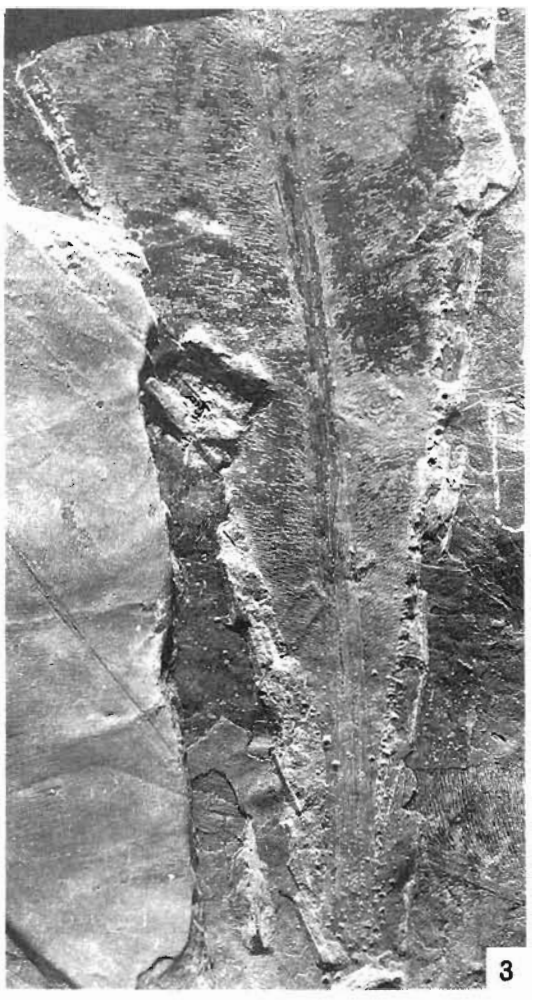
Glossopteris sp. b

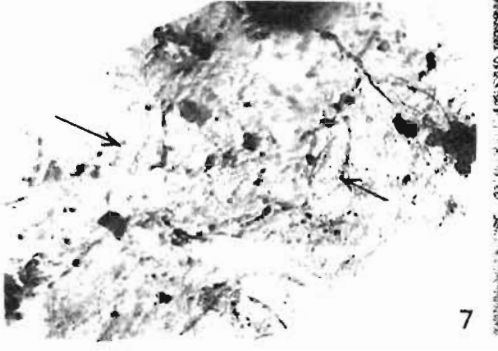
3. Compression of basal half of a leaf showing conspicuous venation pattern and a broad, striated, flat midrib. BSIP Specimen no. 36456B. × 1.
5. Lower cuticle of lamina from the leaf in fig. 3 showing papillate epidermal cells (the papillae are dome-shaped) and a stoma (marked by an arrow). BSIP Slide no. 36456B-1. × 400.

Glossopteris sp. a

6. Compression of a leaf with acute apex and dense veins. BSIP Specimen no. 36460C. × 1.
8. A part of leaf in fig. 6 enlarged to show venation and trapezoidal meshes. × 4.







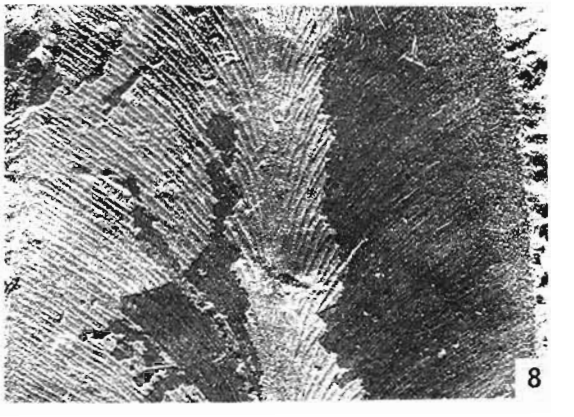
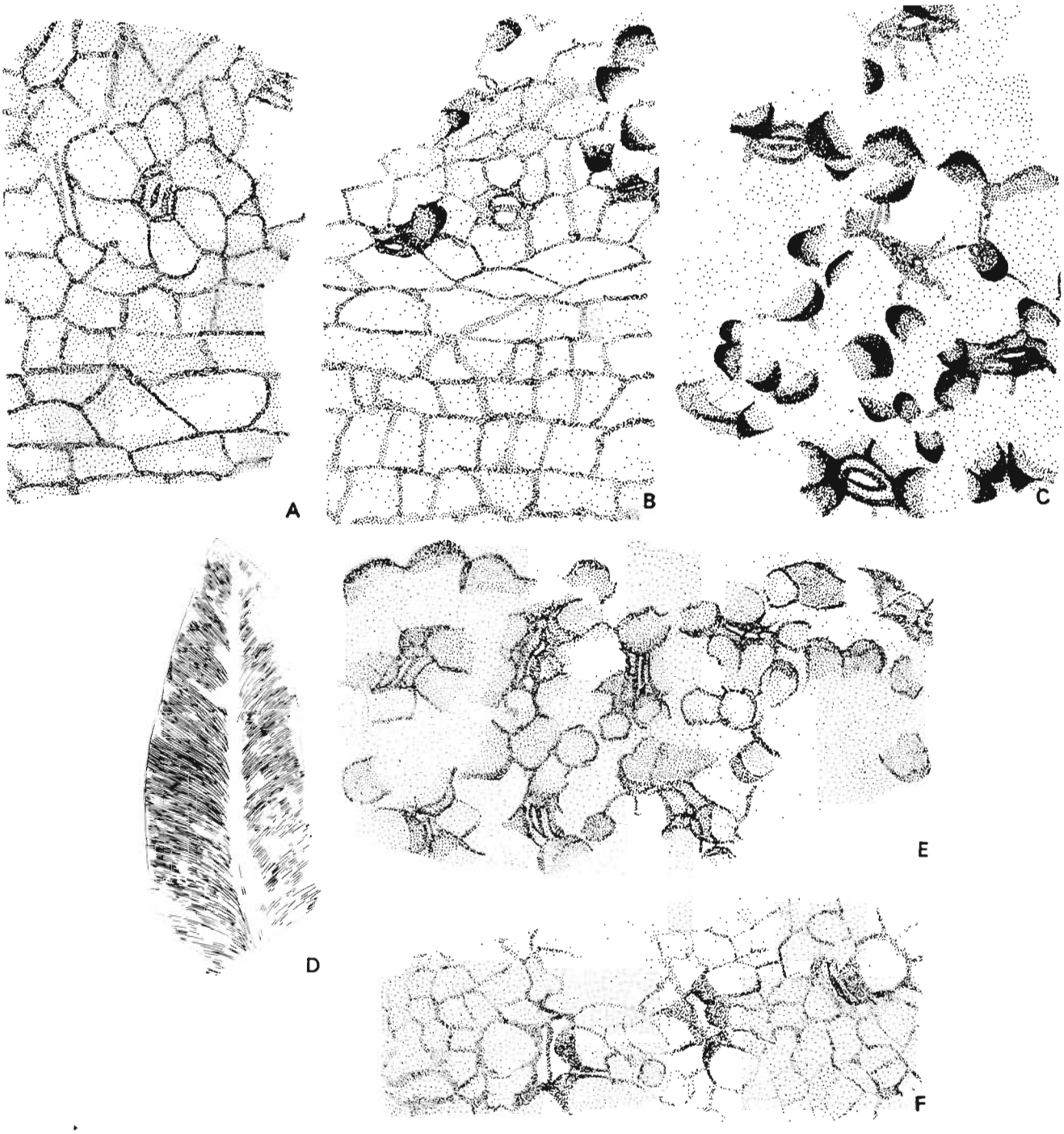


PLATE 9

Glossopteris sp. cf. *G. leptoneura* Bunbury 1861

Pl. 9, figs 1, 4, 7; Text-fig. 12A-C

Description—The specimen is almost complete and linear-lanceolate in shape with entire margin, acute apex and cuneate base; the basalmost portion, however, is not known. The midrib is prominent, elevated, striated and persists right up to the apex, although it is very thin in this region. The lateral veins emerge from midrib at acute angles (15°-20°)



Text-figure 11—*Glossopteris roylei* sp. nov.: **A,** upper cuticle of lamina showing vein and mesh areas and a stoma encircled by a ring of subsidiary cells, BSIP Slide no. 36467-1 × 400; **B,** lower cuticle of lamina showing vein and mesh areas and papillate surface walls, BSIP Slide no. 36467-2 × 400; **C,** lower cuticle of lamina showing distribution of stomata (overhung by papillae) and dome-shaped papillae on surface walls, BSIP Slide no. 36467-1 × 400; **D,** leaf fragment showing venation, BSIP Specimen no. 36462B × 1; **E,** lower cuticle of lamina showing stomata and papillae, BSIP Slide no. 36462B-2 × 400; **F,** upper cuticle of lamina showing stomata overarched by papillae, BSIP Slide no. 36462B-3 × 400.

and after successive dichotomies and anastomoses, approach the margin at an angle between 63°-69°. The vein dichotomies usually are of gamma type or occasionally of psi type; cross-connections between the veins, which form the meshes, are of zeta type. The size of the meshes varies in different parts of the leaf. The shape of the meshes is arcuate near midrib and mostly trapezoidal elsewhere.

The carbonified crust is not well-preserved over the midrib, and that of the laminar portion broke up into very small fragments during chemical treatment. However, it has been possible to recover some pieces of cuticle, although not good, showing some salient features.

The leaf is amphistomatic. The upper cuticle of lamina is differentiable into vein and mesh areas, cells over the veins are narrow, rectangular and arranged end-to-end in almost linear rows; cells in the mesh areas are rectanguloid to polygonal (commonly hexagonal) in shape and are basically arranged end-to-end in rows. Lateral walls are straight to undulate; the surface walls are non-papillate. Only one stoma could be seen which is haplocheilic and oriented parallel to the veins. Stomatal apparatus is monocyclic, partly amphicyclic and has 5 subsidiary cells similar to other epidermal cells.

The cells of lower cuticle are not very distinct, polygonal to irregular in shape, with very thin straight to undulate lateral walls and unspecialised surface walls. Stomata are haplocheilic; and irregularly distributed and oriented. The stomatal apparatus is monocyclic and has 5-7 polygonal subsidiary cells.

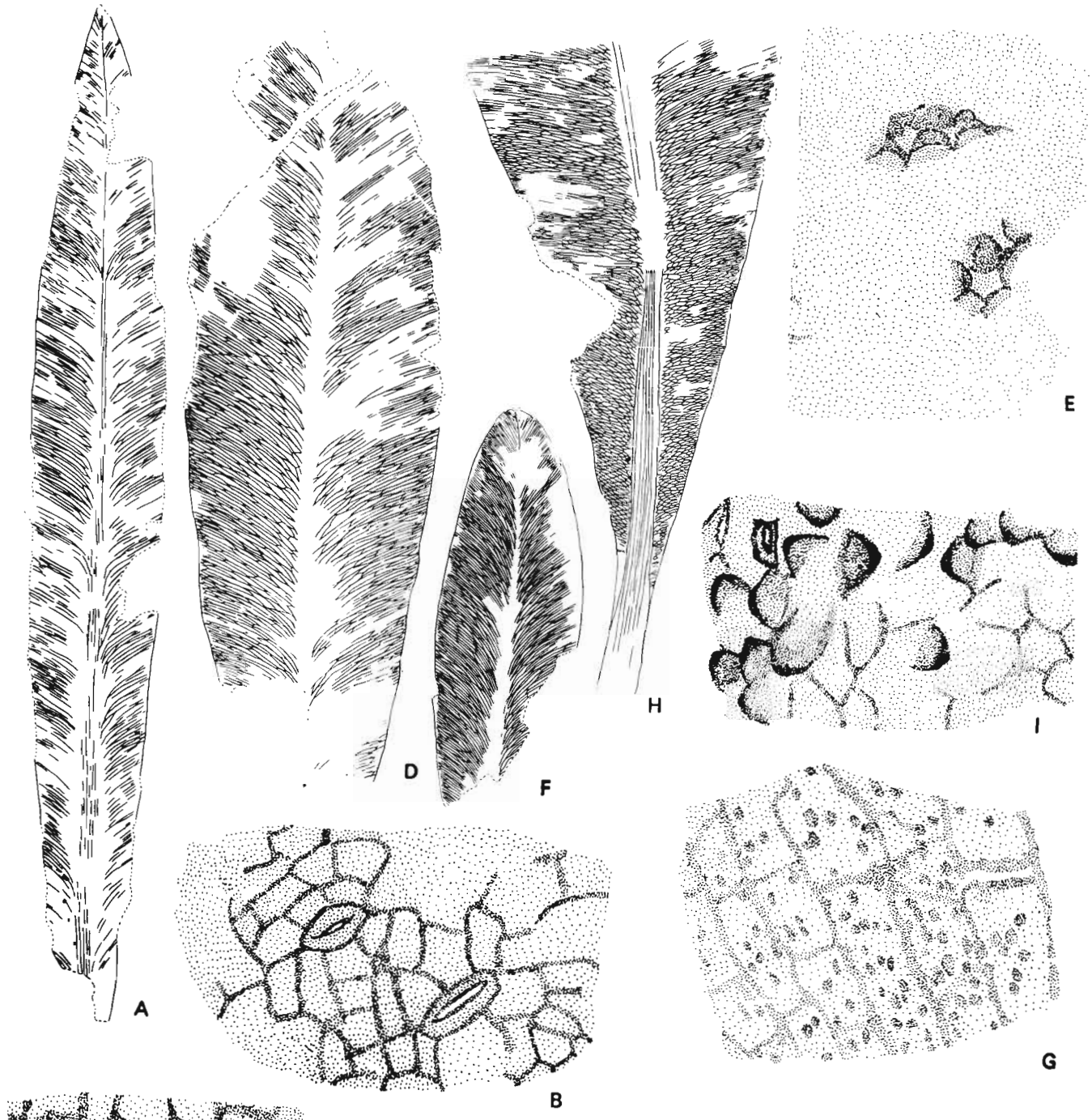
Remarks—The specimen resembles *G. leptoneura* (Bunbury, 1861, pl. 19, figs 1-4; Srivastava, 1977, pl. 2, fig. 10, text-fig 3A, B; 1979, pl. 3, fig. 14). *G. leptoneura,* according to Bunbury (1861, p. 330), is a very narrow leaf in proportion to its length, about 4-6 inches × 1/2 inch, with acute apex, base tapering very gradually into the foot stalk, the secondary vein being oblique, very fine and close, anastomosing repeatedly throughout their length, even near the margins. The present species fits accurately with this description of *G. leptoneura.* However, the cuticle is not reported in *G. leptoneura* of Bunbury. A leaf described as *G. leptoneura* by Bose, Banerji and Maithy (1977, pl. 1, fig. 12; text-fig. 6A) does not belong to *G. leptoneura* since it shows oblong, polygonal meshes. *G. linearis* McCoy (Maheshwari, 1965, pl. 1, fig. 8; text-fig. 5; Kulkarni, 1971, pl. 1, fig. 3) closely resembles *G.* sp. cf. *G. leptoneura* but differs in having petiolate base, slightly notched apex and elongate, polygonal meshes which are slightly narrower near the margin.

Glossopteris sp. a

Pl. 9, figs 6, 8; Text-fig. 12F-G

Description—The specimen is incomplete, leaf probably lanceolate in shape with a retuse apex. Midrib is prominent, flat, persistent, striated lengthwise; in the apical region the midrib becomes very thin and is represented only by a single strand. Lateral veins emerge from midrib at acute angles (18°-20°), and after successive dichotomies and anastomoses approach the margin at an angle between 50°-60°. Vein dichotomies usually are of gamma type and the cross-connections between the veins form meshes of zeta type. Size of the meshes varies in different parts of the leaf. The shape of meshes is arcuate near the midrib and mostly trapezoidal elsewhere. Leaf is probably hypostomatic as cuticle of only one surface has stomata. The non-stomatiferous cuticle of the lamina is not differentiable into vein and mesh areas. Cells are rectanguloid to polygonal, with straight to slightly undulating lateral walls and papillate surface walls; each cell showing a number of small, rounded papillae which are irregular in distribution. Stomatiferous cuticle of lamina is also not differentiable into vein and mesh areas. Cell outlines are very faint. The surface walls are papillate, each cell showing a single, hollow, dome-shaped papilla. The stomata are few, haplocheilic and irregularly distributed and oriented. The stomatal apparatus has 4-6 subsidiary cells represented by papillae overhanging the guard cells and thus covering them completely. The papillae of the subsidiary cells are similar to those of other epidermal cells. Cuticle of midrib portion is very faintly differentiated into striated and non-striated areas.

Remarks—The leaf resembles *G. angusta* (Pant & Gupta, 1971, pl. 21, fig. 33) in shape and venation. The slightly retuse apex may either be a preservational factor or the leaf is slightly broken at the apical point. Cuticle of *G. angusta* resembles in having numerous small papillae on cells of upper surface and in having obscure cells on lower surface with subsidiary cells being papillate and papillae overarching guard cells, but the lateral walls on both the surfaces are sinuous. Venation pattern of *G. waltonii* Pant & Gupta (1968, pl. 19, figs 2, 5; text-fig. 6B) resembles that of our specimen but differs in shape. *G. waltonii* was merged by Chandra and Surange (1979) with *G. arberi* (Srivastava, 1956, pl. 9, fig. 57) on the similarity of size, shape and venation pattern. Differences in cuticular features were considered as minor. However, there is one major difference which prevents the merger of the two species, and that is the absence of numerous



Text-figure 12—A-C, *Glossopteris* sp. cf. *G. leptoneura*: **A,** leaf-impression showing linear-lanceolate leaf with a persistent midrib and trapezoidal meshes, BSIP Specimen no. 36469 × 1; **B,** lower cuticle of lamina showing stomata, BSIP Slide no. 36469-2 × 400; **C,** upper cuticle of lamina showing a stoma, BSIP Slide no. 36469-1 × 400; **D-F,** *Glossopteris roylei*: **D,** leaf fragment showing venation, BSIP Specimen no. 36468 × 1; **E,** lower cuticle of lamina showing stomata, BSIP Slide no. 36468-1 × 400; **F-G,** *Glossopteris* sp. a; **F,** leaf fragment showing venation, BSIP Specimen no. 36460C × 1; **G,** upper cuticle of lamina, each cell showing numerous small papillae, BSIP Slide no. 36460C-1 × 400; **H-I,** *Glossopteris* sp. b: **H,** basal half of a leaf showing venation and a flat, broad, striated midrib, BSIP Specimen no. 36456B × 1; **I,** lower cuticle of lamina showing a stoma and dome-shaped papillae, BSIP Slide no. 36456B-1 × 400.

papillae on the upper surface of lamina in *G. arberi* (Srivastava, 1956, pl. 9, fig. 59). According to Srivastava (1956, p. 22) "Only lower epidermal cells are papillate." This difference was not mentioned by Pant and Gupta (1968) and since presence or absence of papillae is usually considered a characteristic feature in instituting a species, it is proposed here to retain separate identity of the two species. On the same grounds merger of *Gangamopteris flexuosa* with *Glossopteris spathulata* (Chandra & Surange, 1979, p. 58) is not accepted.

Glossopteris sp. b

Pl. 9, figs 3, 5; Text-fig. 12H-I

Description—The specimen is incomplete and hence overall shape of leaf is not known. The margin is entire and base attenuate. Midrib is distinct, strong, striated lengthwise; lateral veins emerge from midrib at acute angles (14°-30°), and after successive dichotomies and anastomoses approach the margin at an angle between 55°-60°. Vein dichotomies are usually of gamma type but psi, lambda and chi types of dichotomies are also frequently found. The cross-connections between the veins, which form the meshes, are usually of zeta and eta types or occasionally of psi-lambda type. Size of meshes varies in different parts of the leaf. The meshes formed near the midrib are of various types, viz., angled, arcuate and deltoid. Apart from these, very rarely the meshes also form hydroid islands near the midrib. Elsewhere, they are pentagonal, trapezoidal or polygonal.

Leaf is hypostomatic. The non-stomatiferous cuticle of lamina is differentiable into vein and mesh areas, cells over the veins are narrow, rectangular and arranged end-to-end in longitudinal rows, cells in the mesh areas are polygonal in shape and arranged irregularly. Lateral walls are straight, surface walls are non-papillate.

Stomatiferous cuticle is faintly differentiable into vein and mesh areas. Cell outlines of mesh areas are not distinct. Surface walls are papillate showing hollow, dome-shaped papillae.

Remarks—The specimen shows distinct type of meshes, viz., short, broad, pentagonal, apparently trianguloid. The meshes are mainly arcuate, angled or deltoid near midrib in the basal portion. Rarely, the meshes form hydroid islands near the midrib, i.e., four or more than four veins emerge from the apex of meshes. These islands are mainly found towards basal half of the leaf lamina. However, further upwards the meshes tend to become trapezoidal in shape. This type of venation pattern has not been reported so far in the *Glossopteris* species. The leaf may be compared to a certain extent with *G. browniana* Feistmantel (1881, pl. 27A, fig. 2).

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