

# On the species of genus *Glossopteris* from Barakar Formation of Karanpura and Bokaro coalfields, India

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## ABSTRACT

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The assemblage of fossil plants of Barakar Formation from North Karanpura, South Karanpura and West Bokaro Coalfields contain thirty-two species of the genus *Glossopteris*. Among these three species are new, twenty-one species are recorded for the first time from the Barakar Formation of South Karanpura, nine species from North Karanpura and eight species from West Bokaro group of coalfields. The range of variation within species have been observed by taking more than one specimens as complex, from different collieries of these three coalfields. The comparison, diagnosis and range of distribution of species in context of other coalfields have also been given.

In the present study, the speciation of genus *Glossopteris* is based on morphography and cuticular features. Here, morphographical characters have been critically analysed in order to find a reasonable basis for precise specific delimitations. Morphographical circumscriptions are further verified by characters of the cuticle wherever available but only as associated or supportive characters.

**Key-words**— Exomorphology, Venations, Cuticles, Species, Lower Gondwana.

भारत के करनपुरा एवं बोकारो कोयला क्षेत्रों के बराकर शैलसमूह से प्राप्त ग्लॉसोप्टेरिस वंश की प्रजातियों का विवेचन

शिवमोहन सिंह एवं हरिकृष्ण माहेश्वरी

सारांश

उत्तरी करनपुरा, दक्षिणी करनपुरा एवं पश्चिमी बोकारो कोयला क्षेत्रों में बराकर शैलसमूह के पादपाश्म समुच्चय में ग्लॉसोप्टेरिस वंश की बत्तीस प्रजातियाँ विद्यमान हैं। इनमें से तीन प्रजातियाँ नयी हैं, इक्कीस प्रजातियाँ दक्षिणी करनपुरा के बराकर शैलसमूह से पहली बार प्राप्त की गयी हैं, नौ प्रजातियाँ उत्तरी करनपुरा तथा 8 प्रजातियाँ पश्चिमी बोकारो समूह के कोयला क्षेत्रों से प्राप्त की गयी हैं। इन कोयला क्षेत्रों की विभिन्न कोयला खदानों से संकुल के रूप में एक से अधिक प्रादशों को लेकर प्रजातियों के अन्दर परवर्ती परास प्रेक्षित की गयी है। अन्य कोयला क्षेत्रों के सन्दर्भ में प्रजातियों के वितरण की परास तथा सापेक्ष निदान को भी प्रस्तुत शोध पत्र में वर्णित किया गया है।

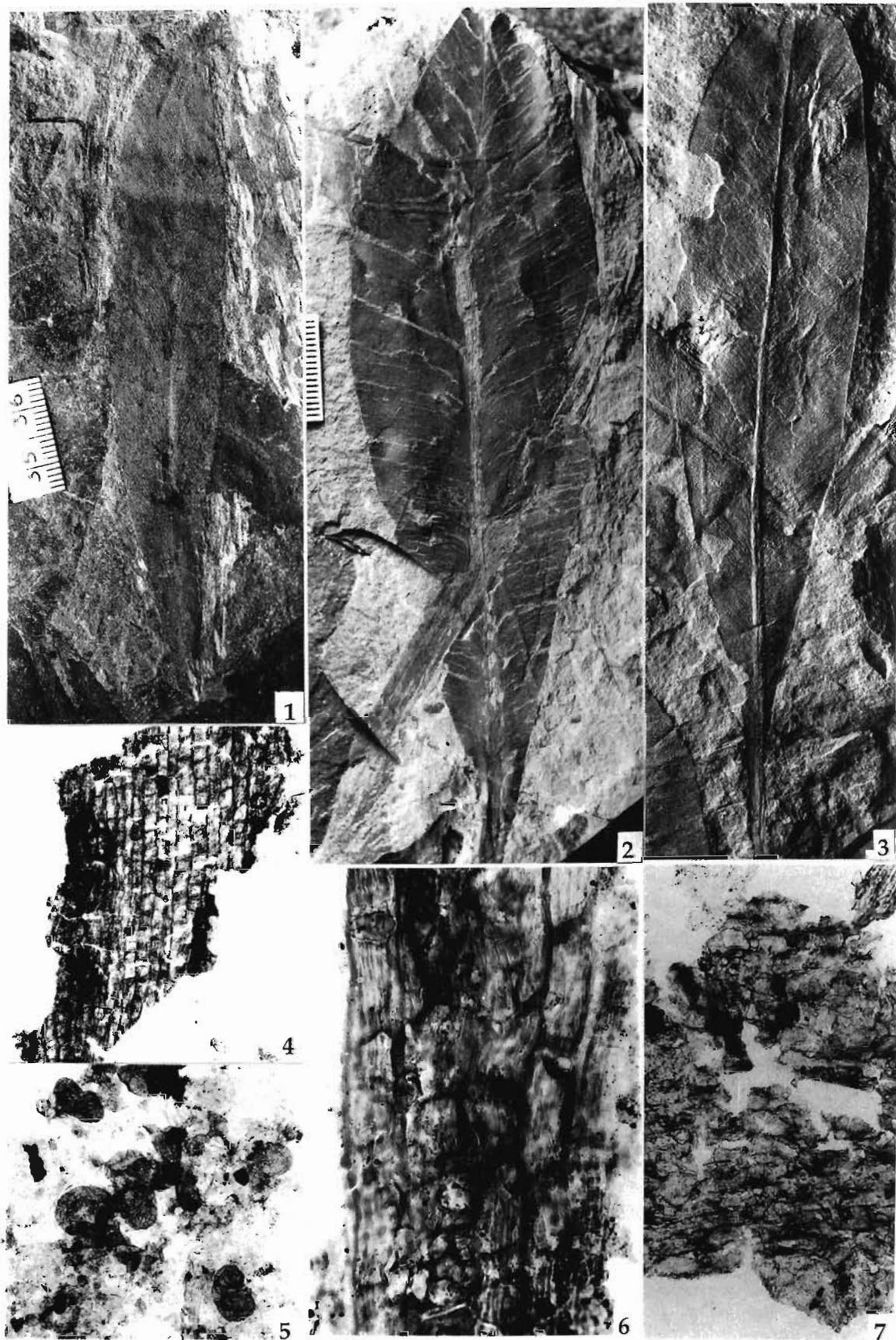


PLATE 1

वर्तमान अध्ययन में ग्लोसोप्टेरिस वंश का जाति उद्भवन संरचना विज्ञान तथा उपचर्मय अभिलक्षणों पर आधारित है. संक्षिप्त विशिष्ट परिसीमन हेतु औचित्यपरक आधार ज्ञात करने हेतु संरचनात्मक अभिलक्षणों का समीक्षात्मक विश्लेषण किया गया है. उपलब्धता के अनुसार उपचर्मों के अभिलक्षणों द्वारा संरचनात्मक परिमितों को अभिप्राणित किया गया है, किन्तु इन्हें सहयोगी अभिलक्षणों अथवा सहभागी के रूप में ही प्रमाणित किया गया है.

संकेत शब्द—बाह्यसंरचनाविज्ञान, शिरा, उपचर्म, प्रजाति, अधो गोण्डवाना.

## INTRODUCTION

*GLOSSOPTERIS* Brongniart (1828) is the most abundant fossil in the Permian floras of the southern hemisphere, that comprised of Australia, Antarctica, Africa, South America, and India, and possibly also the Arabian peninsula. The genus is of tongue-shaped fossil leaves which have a robust to flat midrib, secondary veins dichotomise and anastomose.

Feismantel (1881), and Banerjee (1958) described two species of the genus *Glossopteris*, viz., *G. communis* and *G. indica* from Barakar Formation of North Karanpura Coalfields. Kulkarni (1971) described 12 species, viz., *G. angustifolia*, *G. barakarensis*, *G. browniana*, *G. communis*, *G. damudica*, *G. decipiens*, *G. fusa*, *G. indica*, *G. karanpuraensis*, *G. linearis*, *G. spathulocordata* and *G. stricta* from South Karanpura Coalfield. Ghosh (1962) recorded *G. ampla* and *G. indica* from West Bokaro Coalfield. Maheshwari (1992) mentioned the presence of *G. angustifolia* and *G. stricta* from West Bokaro Coalfield. Thus the above mentioned authors have studied only 13 species of this genus from Barakar Formation of North Karanpura, South Karanpura and West Bokaro Coalfields. However the leaves of the genus appeared to require further study and this has been carried out and as a result we have been able to contribute additional 19 species of *Glossopteris* to the Barakar flora of these coalfields. The cuticular studies based taxonomy of *Glossopteris* species in these coalfields was not attempted by any of the earlier workers. This has been taken as an additional parameter for determining the species. Thus this study attempts to revise, update and enlarge the database of the species of *Glossopteris* and thus wider the parameters of the determination of species to make them more reliable. The revised, updated and enlarged database of Karanpura and West Bokaro Coalfields include : *G. angustifolia*, *G. arberi*, *G. barakarensis*, *G. browniana*, *G. communis*, *G. clarkei*, *G. danae*, *G. decipiens*, *G.*

*emarginata*, *G. euryneura*, *G. elongata*, *G. indica*, *G. intermittens*, *G. intermedia*, *G. karanpuraensis*, *G. linearis*, *G. longifolia*, *G. major*, *G. obscura*, *G. obovata* sp. nov., *G. oldhamii*, *G. pseudostricta* sp. nov., *G. pseudotortuosa* sp. nov., *G. raniganjensis*, *G. shailae*, *G. stenoneura*, *G. tanaeopteroides*, *G. tenuinervis*, *G. tortuosa*, *G. vulgaris*, *G. waltonii* and *G. zeilleri*.

## MATERIAL AND METHODS

The specimens of various species of the genus *Glossopteris* have been collected from shales associated with different coal seams dumped in campuses of different collieries of Karanpura and Bokaro group of Coalfields. The specimens are preserved mostly as impressions, sometimes as compressions with preserved cuticles. The shales are grey to carbonaceous. The specimens were collected from Talchir and Barakar (including Karharbai) Formations. The method used for the present study included cleaning and sorting of specimens, study of surface topography, cuticular preparations, and photography. All the specimens studied are deposited in the repository section of Birbal Sahni Institute of Palaeobotany, Lucknow.

For the preparation of cuticles a few drops of cellulose acetate solution (cellulose flakes + acetone) was placed over a small areas of midrib and laminar regions of the leaves chosen for study with the help of a thin glass rod or a needle. The cellulose acetate peel when dry, was lifted with the help of a needle and a pair of tweezers and oxidised in concentrated  $\text{HNO}_3$  in small petridish. When the crust turned brown, it was washed several times with water so as to remove completely the acid. The washed crust was then cleared with 5% KOH solution, the upper and lower cuticles separate out. The cuticle was then washed and mounted in canada balsam with polyvinyl alcohol.

## PLATE I

1. *Glossopteris angustifolia* Brongniart 1831, Specimen no. BSIP-38823 (7/4994), Barakar Formation, Bhurkunda "Sangum" Colliery, South Karanpura Coalfield, Bihar. x nat. size.
2. *Glossopteris arberi* Srivastava 1957, Specimen no. BSIP-38824 (37/4578), Barakar Formation, Sirka Colliery, South Karanpura Coalfield, Bihar. x nat. size.
3. *Glossopteris barakarensis* Kulkarni 1971, Specimen no. BSIP-38825 (9/5004), Barakar Formation, Jharkhand Colliery, West Bokaro Coalfield, Hazaribagh, Bihar. x nat. size.
- 4, 6, 7. Cuticle of *Glossopteris arberi*, Specimen no. BSIP-38824 (37/4578). 4 x 100, 6 x 400, 7 x 200.
5. Cuticle of *Glossopteris arberi*, Specimen no. (46/4578). x 200.

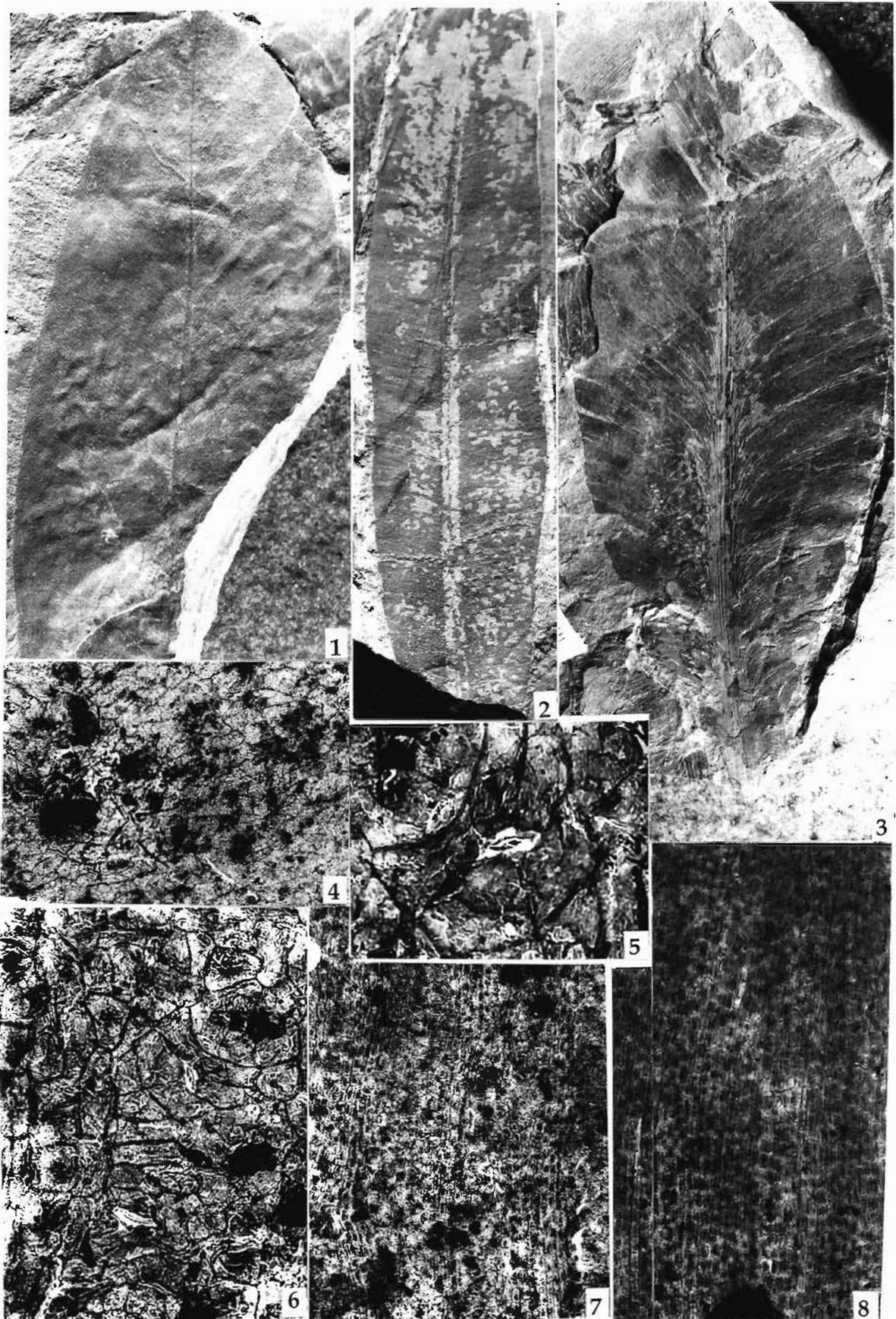


PLATE 2

The plant fossils were photographed on ORWO, FortePan 34 ISO 160 23 DIN (3.25" x 4.25" quarter size) cut films and cuticles were exposed in 35 mm microfilm Agfa Ortho 25 ISO and Ilford Pan F.

## SYSTEMATICS

### GYMNOSPERMS

**Genus—GLOSSOPTERIS** Brongniart (1928)

**GLOSSOPTERIS cf. ANGUSTIFOLIA** Brongniart 1831

Pl. 1-1

*Specimen nos.*—BSIP-38823 (7/4994), 29/4738.

*Locality*—Bhurkunda- "Sangum" and Sirka Collieries, South Karanpura Coalfield.

*Horizon*—Barakar Formation.

*Description*—Shape linear-lanceolate, length 9.5-12.5 cm, width 1.8-2 cm, apex acute, base cuneate, margin entire, midrib distinct, flat, faintly, striated, angle of origin of veins 15°-20° no. of veins/cm. (a) near the midrib 8-10, (b) near the margin 20-22. Secondary veins come out from the midrib at very acute angles, gradually arch outwards meeting the margin at an angle of 45°-60°. Veins dichotomise and anastomose forming elongate-polygonal meshes. Usually two to three meshes are formed in the course of a vein, cuticle not recovered.

*Remarks*—Our specimens resemble the narrow basal parts of leaves called *Glossopteris angustifolia* by Brongniart 1831. *G. angustifolia* superficially resembles some of the species instituted later, e.g., *G. tenuifolia* Pant & Gupta, *G. vulgaris* Pant & Gupta, *G. zeilleri* Pant & Gupta, *G. recurva* Pant & Singh and *G. nakkarea* Chandra & Surange, in size, general form and the venation pattern. *G. angustifolia* is a smaller fragment of a leaf in which the meshes are comparatively broader. *G. tenuifolia* is larger leaf, linear-lorate in shape, with acute apex and narrow elongate meshes. *G. zeilleri* is almost of the same size as *G. angustifolia* but the shape, midrib, and venation pattern are different. *G. nakkarea* is small frond, lorate in shape, with acute apex, thin midrib and veins are denser and shorter near the margin than near the

midrib. *G. recurva* has also a similar leaf, petiolate, lorate in shape, but with retuse apex, and narrow elongate meshes.

There has been some confusion about the taxonomic position of *G. angustifolia*. Seward (1897) included it as a variety of *Glossopteris browniana*, while Feistmantel (1880) and Zeiller (1902) kept it as a distinct species. Arber (1905) regarded the leaves of *G. angustifolia* to be narrower leaves of *G. indica* though he maintained both the species as separate. Plumstead (1952) thinks these to be similar to *G. browniana*. But the cuticular studies of African leaves called *G. indica* (Zeiller, 1896), a leaf fragment called *G. angustifolia* (Sahni, 1923) and *G. browniana* (Srivastava, 1957) show that the epidermal characters of all the three species are without comparison with holotype quite distinct and different and as such their distinct specific ranks should be maintained but their nomenclature requires confirmations. In India, '*G. angustifolia*' is known to occur in all the Gondwana formations, from the Karharbari to the Panchet (Maheshwari, 1992).

*Diagnosis* (based on Rigby, Maheshwari & Schopf, 1980)—Leaves narrow, linear-lanceolate, up to 12 cm long and 2 cm broad with broadly acute apex and lamina gradually contracting towards the base; midrib distinct but flat, gives off secondary veins at acute angles (15°-20°), which gradually arch outwards meeting the margin at an angle of 45°-60°; secondary veins dichotomise and anastomose forming elongate-polygonal meshes, usually two to three (or four) meshes in the course of a vein.

**GLOSSOPTERIS sp. cf. G. ARBERI** Srivastava 1957

Pl. 1-2, 4-7

*Specimen nos.*—24/4578, 30/4578, 33/4578, BSIP-38824 (37/4578), 41/4578, 46/4578, 47/4578.

*Locality*—Sirka Colliery; South Karanpura Coalfield.

*Horizon*—Barakar Formation, shales associated with Nadioli Seam.

*Description*—Shape lanceolate, length 11-16 cm, width 3.6-4.7 cm L/W ratio 4:1, apex acute, base contracted; basal as well as petiolar regions are not preserved in larger leaf of this species, the smaller leaf apparently shows a petiole.



## PLATE 2

1. *Glossopteris browniana* Brongniart 1828. Specimen no. BSIP-38826, Barakar Formation, Dakra Colliery, North Karanpura Coalfield, Hazaribagh, Bihar. x nat. size.
2. *Glossopteris clarkei* Feistmantel 1878. Specimen no. BSIP-38827, Barakar Formation, Gidi-C Colliery, South Karanpura Coalfield, Bihar. x nat. size.
3. *Glossopteris communis* Feistmantel 1876. Specimen no. BSIP-38828, Barakar Formation, Sirka Colliery, South Karanpura Coalfield, Hazaribagh, Bihar. x nat. size.
4. Cuticle of *Glossopteris browniana*, Specimen no. 3/4578. x 100.
5. Lower cuticle of *Glossopteris communis* showing a haplocheilic stoma with an open stomatal slit and a ring of subsidiary cells. Specimen no. BSIP-38829 (1/4579). x 200
6. Cuticle of *Glossopteris communis*, showing irregular distribution of stomata. Specimen no. BSIP-38829 (1/4579). x 200.
7. Cuticle of *Glossopteris communis*, showing vein and intervein areas. Specimen no. BSIP-38829 (1/4579). x 40.
8. Upper Cuticle of *Glossopteris communis*. Specimen no. BSIP-38829 (1/4579). x 40.

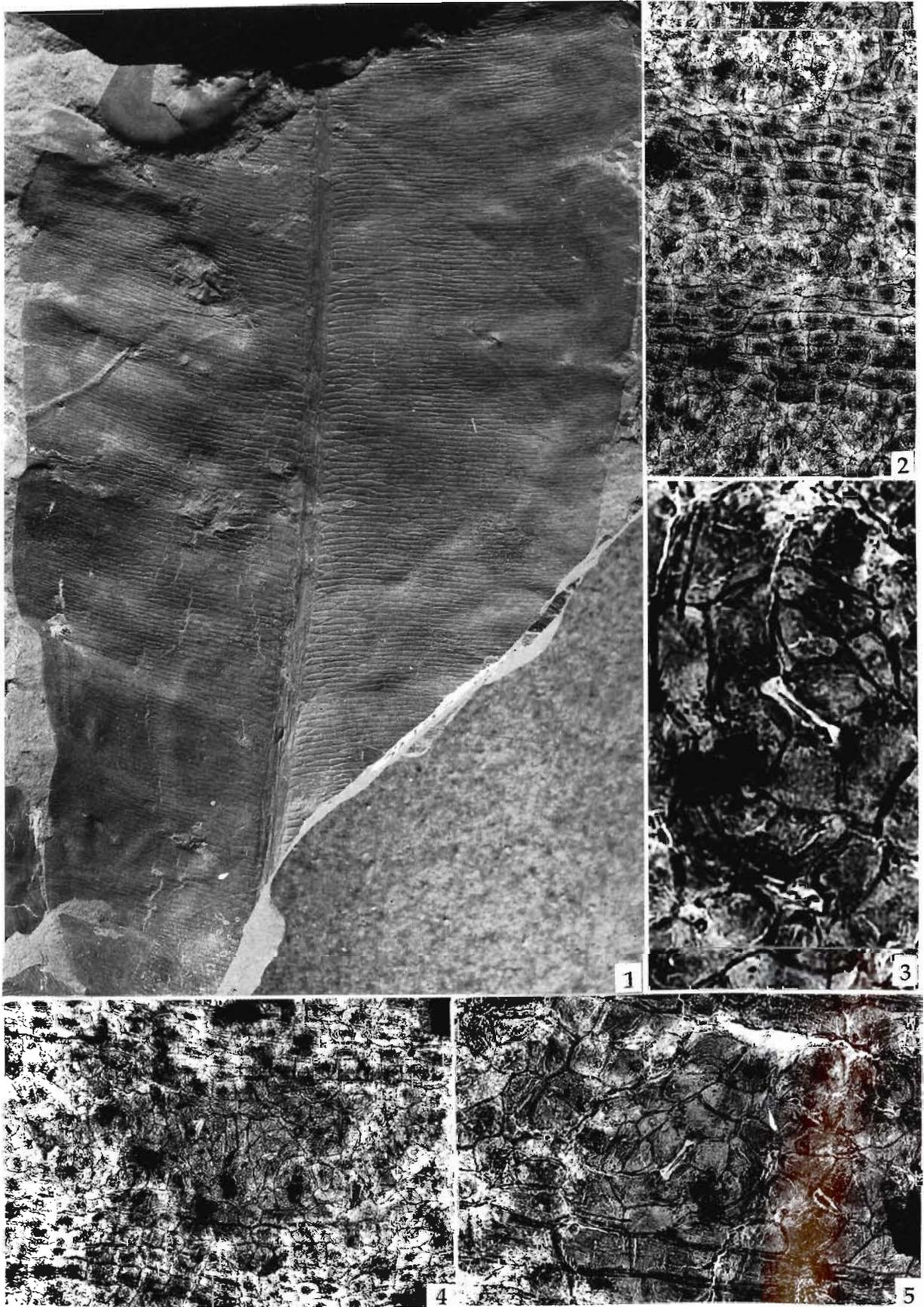


PLATE 3

Margin entire, midrib distinct, flat, wider near the base (0.2 cm), longitudinally striated, angle of origin of veins 15°-25°, no. of veins/cm. (a) near the midrib 9-10, (b) near the margin 18-20, shape of meshes long and narrow, veins arise at an acute angles, arching forwards near the midrib and then gradually bending towards the margin, reaching at an oblique angle. Lateral veins dichotomise and anastomose. Veins few near the midrib and dense near the margin, only small pieces of cuticle could be recovered; all the pieces are just hyaline masses and do not show any cellular outlines. Sometimes pollen are found attached on the cuticle.

*Comparison*—Our specimens show close resemblance with *Glossopteris arberi* Srivastava 1957. As satisfactory data are not available on the cuticular features in our specimens, these are referred to *G. cf. arberi*.

*Remarks*—*Glossopteris cf. arberi* seemingly resembles *Glossopteris stricta* Bunbury and *Glossopteris indica* Schimper. It differs from *G. stricta* in having long and narrow meshes which do not show any appreciable variation in their size. The leaves referred to *G. indica* by Schimper (1869) are very variable in shape and size, and it is difficult to distinguish the fronds of *G. arberi* from them on external characters alone. In venation also the leaves of *G. arberi* approach very close to *G. indica* but since they show different epidermal structures they can not be placed under leaves called *G. indica* by Zeiller (1902). The cuticle of *G. indica* has thick-walled, short, rectangular cells (Zeiller, 1902) while cuticle of *G. arberi* (Srivastava, 1957) is thin with elongate rectangular cells, showing thin and sinuous lateral and anticlinal walls. Further the epidermal cells on the lower surface of *G. arberi* are papillate. In Zeiller *G. indica*, the stomata are sunken, arranged in rows, showing longitudinal orientation while in *G. arberi*, the stomata are not sunken and they show irregular orientation and distribution.

*Diagnosis* (after Srivastava, 1957)—Leaves lanceolate in shape, variable in size, sometimes more than 20 cm long. Midrib stout, persisting up to apex, with longitudinally running parallel striations. Secondary veins arise at an acute angle from the midrib, arch, gradually bend towards the margin, reaching it an oblique angle, dichotomise and anastomose to form long, narrow, oblong, polygonal meshes.

Cuticle thin, epidermal cells elongate, rectangular with sinuous and toothed (zigzag) anticlinal walls; surface walls of

cells of lower epidermis papillate. Epidermis hypostomatic, stomata irregularly distributed and oriented, stomatal apparatus haplocheilic, monocyclic with two guard cells which are slightly thickened at the outer margin and at the poles.

### **GLOSSOPTERIS cf. BARAKARENSIS Kulkarni 1971**

Pl. 1-3

*Specimen nos.*—BSIP-38825 (9/5004), 18/5004.

*Locality*—Jharkhand Colliery, West Bokaro Coalfield.

*Horizon*—Barakar Formation.

*Description*—Shape narrow-elliptical, length 9.4-22 cm, width 2.3-3.5 cm, apex acute, base cuneate (in one of the specimens the petiole is concealed below the lamina of a neighbouring leaf, margin entire, midrib distinct, stout, wider near the base, angle of origin of veins 80°-85°, nos. of veins/cm (a) near the midrib 12-13, (b) near the margin 20-22, meshes small, narrow and elongated, lateral veins arise from the midrib, curve downwards and then again upwards near the margins. Meshes are smaller near the margin and slightly wider and bigger near the midrib, cuticle not recovered.

*Comparison*—Our specimens show closest resemblance with *Glossopteris barakarensis* Kulkarni 1971 originally reported from the South Karanpura Coalfield. *Glossopteris barakarensis* is comparable with *G. tenuinervis*, *G. lanceolatus*, *G. karharbariensis* Chandra & Surange and *G. saksenae* Chandra & Surange. *Glossopteris tenuinervis* is a longer leaf, leaves of the two species are of different shape; venation is also more open in *Glossopteris barakarensis*. The leaf of *G. lanceolatus* is much longer and the midrib is narrow. Its shape, base, and apex are also distinct. The venation of *Glossopteris karharbariensis* is somewhat similar, but the leaf is very narrow with a distinct apex. The venation pattern is quite different in *Glossopteris saksenae*.

*Diagnosis* (based on Kulkarni, 1971)—Leaf small, broad, shape oblanceolate, or narrow-elliptic, length/width ratio 3:1, apex obtuse or acute, base acute-cuneate. Midrib comparatively very broad in lower region, tapers rapidly above the middle region. Petiolate, lateral veins arise at an angle of 80°-85° take a gentle curve onwards and then again upwards near the margins. Meshes smaller and narrower near the margin than near the midrib and in the middle of the lamina.



### PLATE 3

- 1 *Glossopteris danae* Maheshwari & Tewari 1992, Specimen no. BSIP-38830 (35/5004), Barakar Formation, Jharkhand Colliery, West Bokaro Coalfield, Bihar. x nat. size.
- 2, 4. Stomatiferous cuticle of *Glossopteris communis*, the stomata are confined to the intercostal areas, cells over the veins are rectanguloid and arranged end-to-end. Specimen no. BSIP-38829 (1/4579). x 100.
3. Cuticle of *Glossopteris communis*, showing a stomatal apparatus with dumbbell-shaped stomata and a ring of subsidiary cells, Specimen no. BSIP-38829 (1/4579). x 400.
5. Cuticle of hypostomatic surface, stomata irregularly distributed and oriented, Specimen no. BSIP-38829 (1/4579). x 200.

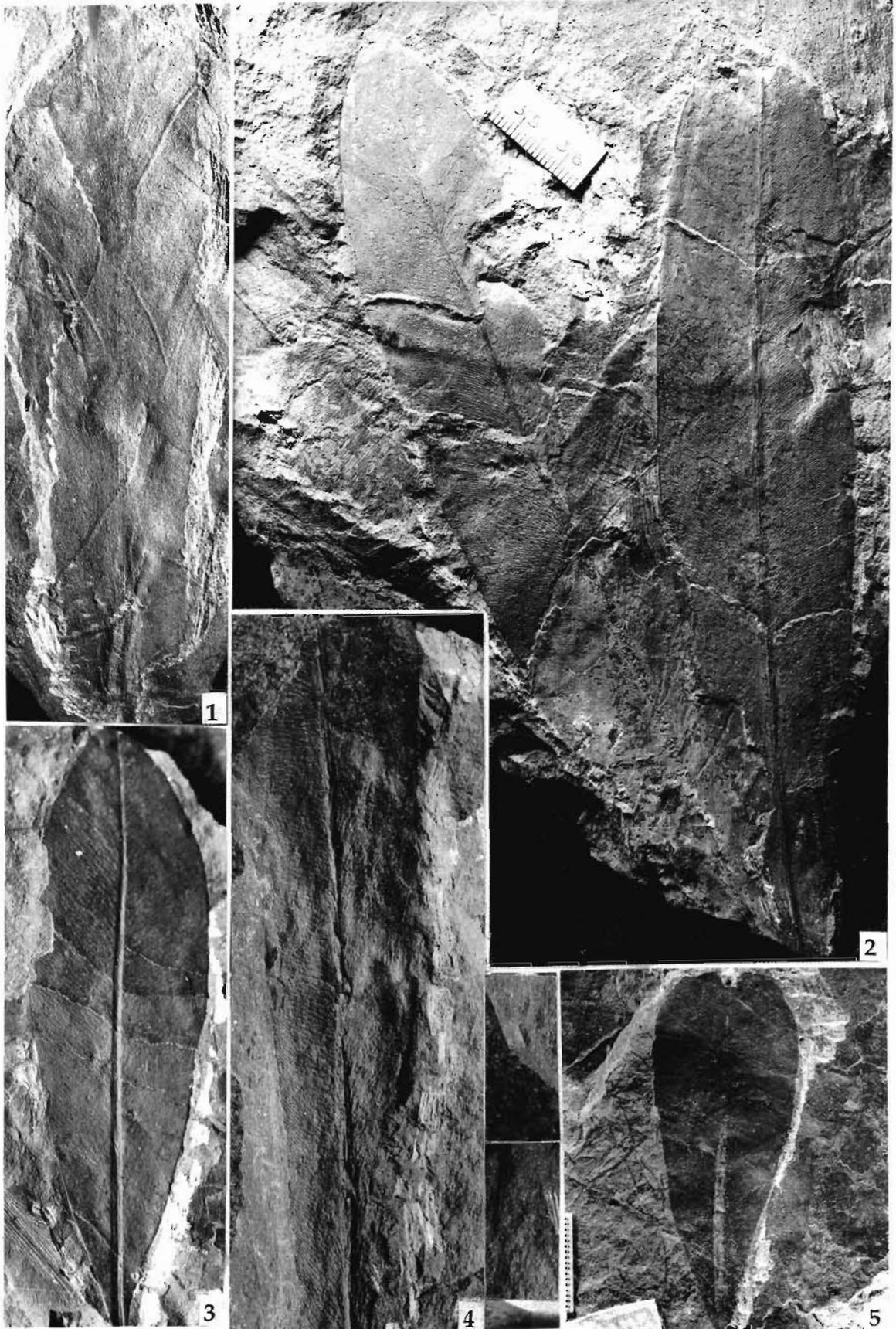


PLATE 4

**GLOSSOPTERIS cf. BROWNIANA** Brongniart 1828

Pl. 2:1, 4

*Specimen nos.*—BSIP-38826 (3A/4554), 3/4578.*Localities*—Dakra Colliery, North Karanpura Coalfield, and Sirka Colliery, South Karanpura Coalfield, respectively.*Horizon*—Barakar Formation.

*Description*—Shape spathulate-ovate, length 9-11 cm, width 2.3-5 cm, apex obtuse, base narrow tapering (3/4578), margin entire, midrib distinct, flat, angle of origin of veins 20°-45°, nos. of veins/cm. (a) near the midrib 10-13, (b) near the margin 17-20, secondary veins arise at acute angles from the midrib, arch gracefully near it; their remaining course through the lamina is more or less straight. Veins dichotomise and anastomose to form elongate-polygonal or polygonal areolae or meshes, almost equal in size throughout the lamina. Sometimes venation varies greatly even in different parts of the same leaf with accompanying variation in the size of the meshes. Only one specimen (no. 3/4578) has yielded small pieces of cuticle. On the non-stomatiferous surface, the cells over the veins are elongate-rectangular, arranged end-to-end in linear rows; cells in between the veins are irregularly polygonal. The stomatiferous cuticle is very thin, virtually without any cellular outlines. However, it does show spindle-shaped to dumbbell-shaped stomata. The stomata are irregularly oriented, the guard cells are slightly thickened, stomatal pore is a narrow slit. Under differential interference contrast, faint outlines of cell walls are seen. The cells probably were similar to those on non-stomatiferous surface. Cells over the midrib are very thick, straight-walled, rectangular and arranged end-to-end.

*Comparison*—Our specimens show close resemblance to *Glossopteris browniana* Brongniart 1828 in venation pattern and other accessory characters. This species often regarded as similar to *G. indica* and *G. angustifolia* differs from the former in character of the meshes near the midrib which are trigonal and broad; otherwise the meshes are narrow and elongate. In *G. browniana* meshes are uniform throughout. Cuticular studies by Srivastava (1957) of leaves which he identified with this species without reference the Holotypes according to him showed that all these species are distinct.

*Diagnosis* (after Rigby, Maheshwari & Schopf, 1980)—Leaves simple, spathulate-ovate, with an obtuse apex and

tapering base. Midrib, although sometimes flat and inconspicuous, usually distinct and strong. Often irregularly ribbed; Secondary veins arched, arising at an acute angle (20°-45°) and then dichotomising and anastomosing to form broad elongate, polygonal meshes near the midrib, and narrow elongate meshes towards the margin. In some specimens, the areolar meshes are almost equal throughout. Width and length of meshes varies in different specimens. In some, the number of meshes formed is comparatively small, the veins dichotomising only one to three times or occasionally not at all.

**GLOSSOPTERIS cf. CLARKEI** Feistmantel 1878

Pl. 2:2

*Specimen nos.*—10/4752, 11/4752, BSIP-38827 (cp. 9/4752) and 2/4756.*Locality*—Gidi-C Colliery, South Karanpura Coalfield; Ray Colliery, North Karanpura Coalfield.*Horizon*—Barakar Formation, Argada Seam.

*Description*—Shape linear-lanceolate, length 8.3-16 cm, width 3.4-2 cm, apex obtuse, base narrow tapering, margin entire, midrib distinct, flat, striated lengthwise, angle of origin of veins 40°-45°, no. of veins/cm (a) near the midrib 12-36, (b) near the margin 26-50. Secondary veins arise from the midrib, arch and pass on almost at right angles to the margin. Veins dichotomise only once or twice, anastomoses are rare. The whole venation pattern superficially resembles that of the leaf of *Taeniopteris*. Meshes are oblong, narrow, becoming slightly narrow and smaller in size towards the margin, cuticle not recovered.

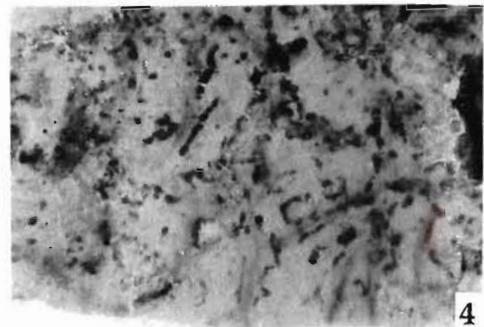
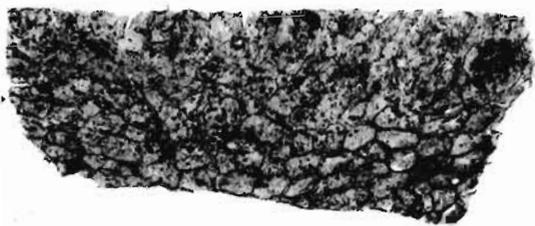
*Comparison*—The specimens show closest resemblance to Australian species *Glossopteris clarkei* which superficially resembles *G. taeniopteroides* Feistmantel and *G. jonesii* Rigby. Rigby *et al.* (1980) consider *G. jonesii* as a junior synonym of *G. taeniopteroides*.

*Diagnosis* (based on Rigby *et al.*, 1980)—The leaf is more or less ovate or linear, elliptical, 9-17 cm long and 3-4 cm broad; midrib is distinct, 2-3.8 mm wide at the base. Secondary veins arise from the midrib at an angle of about 45° then arch and pass on almost at right angles to the margin. Vein dichotomise only once or twice, anastomoses are rare. Stomata on both the surfaces and arranged irregularly.



## PLATE 4

- Glossopteris decipiens* Feistmantel 1879. Specimen no. BSIP-38831 (4/4743), Barakar Formation, Ara Colliery, West Bokaro Coalfield, Bihar. x nat. size.
- Glossopteris emarginata* Maheshwari & Prakash 1965, Specimen no. BSIP-38832 (4/4998), Barakar Formation, shales associated with Naditoli Seam, Sirka Colliery, South Karanpura Coalfield, Bihar. x nat. size.
- Glossopteris elongata* Dana 1849. Specimen no. BSIP-38833 (26/5004), Barakar Formation, Jharkhand Colliery, West Bokaro Coalfield, Bihar. x nat. size.
- Glossopteris tortuosa* Zeiller 1902, Specimen no. BSIP-38834 (16/4738), Barakar Formation, Naditoli Seam, Sirka Colliery, South Karanpura Coalfield, Bihar. x nat. size.
- Glossopteris obovata* sp. nov., Specimen no. BSIP-38835 (33/4753), Barakar Formation, Religara Colliery, South Karanpura Coalfield, Bihar. x nat. size.



3  
PLATE 5

**GLOSSOPTERIS cf. COMMUNIS** Feistmantel 1876

Pl. 2-3,5-8; Pl. 3-2-5

*Specimen nos.*—BSIP-38828(34/4578), 37/4578 (cp. 33/4578), BSIP-38829 (1/4579) (cp. 1/4579), 4/4752, 1/4753, 16/4753, 38/4753, 8/4754, 10/4754, 3/4755, 6/4997, 7/4997, 23/4997, 5/4998, 12/4998, 31/5004, 5/5007A, (counter part 7/5007), 17/5007A, 24/5007A.

*Localities*—Jharkhand Colliery, West Bokaro Coalfield; Dakra and K.D. Heslong Collieries, North Karanpura Coalfield; Gidi-A, Gidi-C, Religara, Sirka and Urimari Collieries, South Karanpura Coalfield.

*Horizon*—Barakar Formation.

*Description*—Shape oblanceolate, length 13-19.5 cm, width 4-1-7.5 cm, apex acute, base cuneate, narrow, tapering; probably petiolate, margin entire, midrib distinct, stout but flat, reaching up to the apex, faint striations longitudinally all over the midrib, angle of origin of veins 15°-20°, no. of veins/cm. (a) near the midrib 11-22, (b) near the margin 25-32. Secondary veins arise from the midrib at very acute angles, arch backwards and pass out on to the margin in graceful curves. Veins run almost parallel to each other, dichotomise several times and anastomose to form long and narrow meshes. Specimen no. 1/4579 has yielded very well preserved cuticles of both the surfaces. The leaf is hypostomatic. The cuticle of the non-stomatiferous surface shows cells over the veins as well as of the intercostal areas. The cells over the veins generally are elongate-polygonal to rectangular. Those in the mesh areas are comparatively small and polygonal. Almost all the cells have a dense central region. The cuticle of the stomatiferous surface is virtually similar except for being relatively thin. The dense central region of the cells is more pronounced on this surface. The stomata are haplocheilic, irregularly distributed and oriented. The stomatal apparatus is monocyclic, 4-6 polygonal subsidiary cells surround the stomata. The subsidiary cells are papillate, the papillae slightly overhanging the stomatal pore. The cells over the midrib are thick-walled, longish-rectangular and arranged end-to-end.

*Comparison*—Our specimens show close resemblance with *Glossopteris communis* Feistmantel 1876. Three other species, viz., *G. major* Pant & Gupta, *G. gigas* Pant & Gupta and *G. raniganjensis* Chandra & Surange resemble *G. communis* in venation pattern, but all the three leaves are

different from it in size and shape. *G. gigas* is very broad leaf, elliptic in shape whereas *G. major* is oblanceolate, lamina narrowing abruptly in the basal region. *G. raniganjensis* is large, narrow elliptic leaf with acute apex. *G. communis* is similar to *G. pseudocommunis* Pant & Gupta in morphography but differs in cuticular details, *G. pseudocommunis* being amphistomatic. Sometimes *G. communis* has been confused with *G. indica*; however, in the latter the meshes just near the midrib are comparatively small and trigonal then elsewhere on the lamina. In the former, the meshes are of uniform shape all over the lamina.

*Remarks*—Srivastava (1957) described cuticular features of a *G. communis* type of leaf. On the basis of cuticular preservation of one of Feistmantel's *G. communis* specimen, Pant and Gupta (1968) proposed *G. pseudocommunis* for Srivastava's *G. communis* specimen. Maheshwari and Tewari (1992) pointed that cuticles recovered by Pant and Gupta were fragmentary and inconclusive, whereas the cuticle of *G. pseudocommunis* is quite distinctive. This specimen resembles *Glossopteris communis* Feistmantel. According to "Law of priority" it is better to retain the species of Feistmantel, i.e., *G. communis* for all above species having typical *communis*-type of venation pattern. Pant (1958) suggested that leaves with similar pattern show dissimilar cuticles hence they can not be regarded as identical. The diagnosis should include exomorphic characters of leaf including base mid part and base as well as structure features like cuticle, fibers etc. Maheshwari and Tewari (1992) opined that "presence or absence of crust (cuticle) 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 which show *communis*-type of morphography, irrespective of the preservation of carbonified crust, should be included under *G. communis*.

*Diagnosis*—Simple leaf, oblong-lanceolate in shape, acute apex, narrow tapering base, continuous margin, Midrib distinct; flat; with continuous striations lengthwise, apparently persist up to the apical region, wider near the base. Veins arise from the midrib at acute angles (15°-20°), dichotomise and anastomose, and curve outwards to meet the margin, concentration of veins 11-22 near the midrib and 25-32 near the margin. Leaf hypostomatic, cells elongate, polygonal to rectangular; stomata monocyclic, haplocheilic.

← **PLATE 5**

- Glossopteris euryneura* Maheshwari 1965. Specimen no. BSIP-38816-B (2/4578), Barakar Formation, Naditoli Seam, Sirka Colliery, South Karanpura Coalfield, Bihar. x nat. size.
- Glossopteris indica* Schimper 1869, Specimen no. BSIP-38836-A (1/4578), Barakar Formation, shales associated with Naditoli Seam, Sirka Colliery, South Karanpura Coalfield, Bihar. x nat. size.
- Cuticle of nonstomatiferous surface of *Glossopteris indica* showing cells over the veins and in the intercostal areas, Specimen no. BSIP-38836A (1/4578). x 100.
- A few cells from the nonstomatiferous cuticle of *Glossopteris indica* showing degradation of lateral and surface walls, Specimen no. BSIP-38836A (1/4578). x 400.

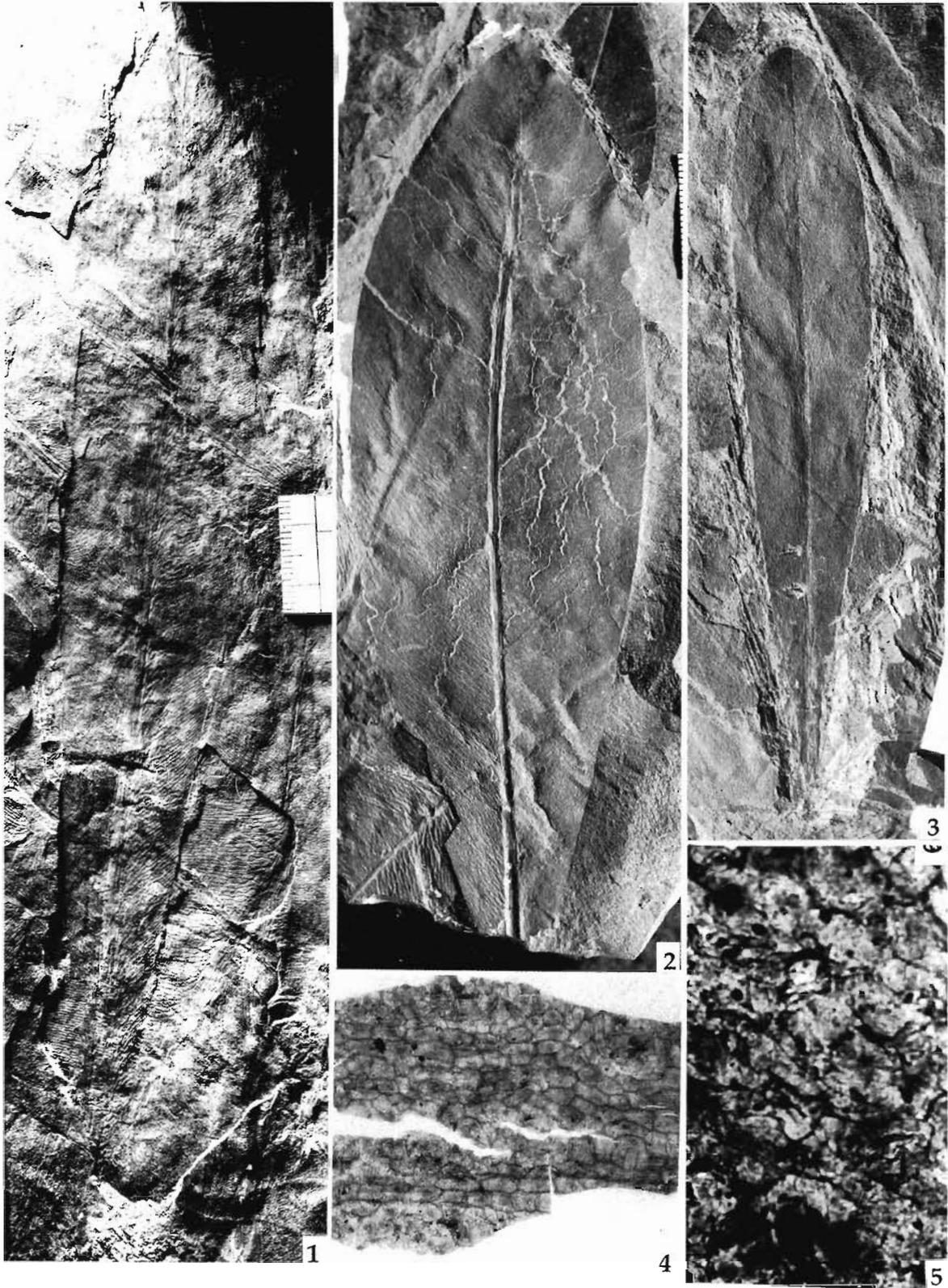


PLATE - 6

**GLOSSOPTERIS cf. DANAE** Maheshwari & Tewari 1992

Pl. 3-1

*Specimen nos.*—25/4998, BSIP-38830(35/5004).*Locality*—Sirka Colliery, South Karanpura Coalfield; Jharkhand Colliery, West Bokaro Coalfield.*Horizon*—Barakar Formation.

*Description*—Shape not known, length 16-27 cm, width 9-10 cm, apex not preserved, base narrow tapering (specimen no. 25/4998), margin entire, midrib prominent, elevated, striated lengthwise, wider near the base (0.3-0.4 cm), angle of origin of veins 1°-3°, no. of veins/cm. (a) near the midrib 7-10, (b) near the margin 14-18. Meshes are short, broad, triangular or polygonal, apparently deltoid or sometimes arcuate near midrib and mostly trapezoidal, elongate. Veins arise at acute angles to the midrib, dichotomise and anastomose to form broad meshes near the midrib and narrow towards the margin, cuticle not recovered.

*Comparison*—Our specimens compare with *G. rhabdotaenoides* Pant & Singh 1971, *G. damudica* Feistmantel 1881 (in Pant & Singh, 1971), *G. ampla* Dana (in Rigby, Maheshwari & Schopf, 1980), *G. taeniopteroides* Feistmantel (in Banerjee & Ghosh, 1970) and *G. danae* Maheshwari & Tewari 1992 in venation pattern but differ from most of them in either the course of veins or shape of meshes. *G. rhabdotaenoides* has broad, polygonal, elongate meshes which are shorter near midrib and the lateral veins meet the margin at approximately 65°. *G. ampla* differs by showing long and narrow meshes which are narrowest near the margin. *G. taeniopteroides* shows narrow, elongate, polygonal meshes. The lateral veins in this species run closely parallel to each other and meet the margins at approximately 90°. The specimens are similar to those of *G. danae* in most of the characters.

*Diagnosis* (after Maheshwari & Tewari, 1992)—Shape and length unknown, apex broad, emarginate, base unknown; margin entire; midrib distinct, persistent, striated length wise, thin towards apex, lateral veins arise from the midrib at very acute angles (1°-3°), dichotomies usually of gamma type, cross-connections between veins usually of zeta type; meshes short, broad, trigonal, apparently deltoid, angled or sometimes

arcuate near the midrib and mostly trapezoidal, elongate, narrow elsewhere.

**GLOSSOPTERIS cf. DECIPIENS** Feistmantel 1879

Pl. 4-1

*Specimen nos.*—BSIP-38831 (4/4743), 11/4754, 4/4997, 15/4997, 43/5007A.*Localities*—Ara Colliery, West Bokaro Coalfield. Dakara Colliery, North Karanpura Coalfield, and Gidi A and Urimari Collieries, South Karanpura Coalfield.*Horizon*—Barakar Formation.

*Description*—Shape spatulate, length up to 13.2 cm, width up to 3.8 cm, apex obtuse, base narrow tapering, margin entire, midrib evanescent, angle of origin of veins 35°-45°, no. of veins/cm. (a) near the midrib 17-18, (b) near the margin 34-40. The secondary veins come out from the midrib at an acute angles, and arch out in graceful curves to the margins. Secondary veins dichotomise and anastomose to form narrow-oblong meshes, cuticle not recovered.

*Comparison and Remarks*—Our specimens resemble closely those of *Glossopteris decipiens* Feistmantel 1879. In general character of secondary venation, Arber (1905) regarded *G. decipiens* to be closely similar to *G. indica*. The species is, however, distinguished by the fact that the midrib is evanescent and does not extend for more than two-thirds of length of the leaf. It also differs in having a truncated base, the lateral angles of which are slightly auriculate. As Feistmantel has pointed out, this species probably represents a transitional type between the genera *Glossopteris* and *Gangamopteris*. A somewhat similar leaf with well-preserved cuticle has been described as *Glossopteris shailae* (Bajpai, 1987).

*Diagnosis* (based on Arber, 1905)—Leaf narrow-spatulate; base narrow, tapering or truncate; apex broad, rounded or acuminate; margin entire; midrib evanescent, hardly extending for more than two-thirds of the length of the leaf, breaking up above into radiating and anastomosing secondary veins. Secondary veins arise at an acute angle, forming narrow oblong meshes.

**GLOSSOPTERIS cf. ELONGATA** Dana 1849

Pl. 4-3

**PLATE 6**

1. *Glossopteris intermedia* Feistmantel 1880, ex Maheshwari 1965, Specimen no. BSIP-38837 (18/4738), Barakar Formation, Sirka Colliery, shales associated with Naditoli Seam, South Karanpura Coalfield, Bihar. x nat. size.
2. *Glossopteris karanpuraensis* Kulkarni 1971, Specimen no. BSIP-38838 (4/5004), Barakar Formation, Jharkhand Colliery, West Bokaro Coalfield, Bihar. x nat. size.
3. *Glossopteris intermittens* Feistmantel 1881, Specimen no. BSIP-38839 (1/4743), Barakar Formation, Ara Colliery, West Bokaro Coalfield, Bihar. x nat. size.
4. Cuticle of non-stomatiferous surface of *Glossopteris indica* showing cells over the veins and in the intercostal areas, Specimen no. BSIP-38836A (1/4578). x 100.
5. Cuticle of *Glossopteris indica*, possibly showing a couple of stomata, Specimen no. BSIP-38836A (1/4578). x 400.



PLATE 7

*Specimen nos.*—1/5004 (cp 3/5004), BSIP 38833(26/5004).

*Locality*—Jharkhand Colliery, West Bokaro Coalfield.

*Horizon*—Barakar Formation.

*Description*—Shape oblanceolate, length 4.7-10 cm, width 1.1-2.8 cm, apex obtuse, base cuneate, margin entire, midrib prominent, striated, elevated, wider near the base, tapering and reaching towards apex, angle of origin of veins 45°-52°, no. of veins/cm. (a) near the midrib 8-9, (b) near the margin 16-17. Secondary veins come out of the midrib at acute angles, are arched near the midrib, dichotomise and anastomose forming broadly polygonal meshes, not much longer than broad and of almost equal size throughout the lamina, cuticle not recovered.

*Comparison and Remarks*—Our specimens show close resemblance to *Glossopteris elongata* Dana 1849. Feistmantel (1881, p. 103) erected the species *Glossopteris retifera* for leaves which Rigby, Maheshwari and Schopf (1980) consider identical with the lectotype for *G. elongata*. The remarkable similarity between Feistmantel's (1889, pl. 4, fig. 3) South African example of *G. retifera* and Dana's type for *G. elongata* was noted by Etheridge (1901, p. 71). Arber (1905, p. 48) opined that *G. elongata* may be the basal portion of a leaf of *G. browniana*, though he did agree that it more closely compares with *G. retifera*. Rigby, Maheshwari and Schopf (1980) re-examined the lecto-type of *G. elongata* (Specimen no. 1358A, Geological Survey of Queensland, Brisbane, Australia) which shows that in its broadly polygonal and almost equal-sized meshes it lies within the circumscription of *G. retifera* and differs from *G. browniana*. Therefore Rigby, Maheshwari and Schopf (1980) suggested that *G. elongata* has priority predating *G. retifera*.

*Diagnosis*—(based on Dana, 1849 and Rigby, Maheshwari & Schopf, 1980)—Leaves narrow elongate, lanceolate (?), attenuate below; midrib rather stout, very distinct; veins make an angle of 60° or more with the midrib, elegantly reticulate, meshes short, average length 3 mm, and 9 or 10 in breadth to 1.2 cm.

**GLOSSOPTERIS cf. EMARGINATA** Maheshwari & Prakash 1965

Pl. 4.2

*Specimen no.*—BSIP-38832 (4/4998).

*Locality*—Sirka Colliery, South Karanpura Coalfield.

*Horizon*—Barakar Formation, shales associated with Naditoli Seam.

*Description*—Shape linear-oblong, length 17 cm, width 3.4 cm, apex obtuse, Base tapering, margin entire, midrib distinct, stout, irregularly ribbed, angle of origin of veins 40°-45°, no. of veins/cm. (a) near the midrib 18-20, (b) near the margin 24-28. Secondary veins arise from the midrib at acute angles and after a gentle arch pass to the margin. The veins dichotomise and anastomose to form elongate-polygonal meshes which are slightly narrower near the margins, cuticle not recovered.

*Comparison*—Our specimens show close resemblance with *Glossopteris emarginata* Maheshwari & Prakash 1965. The venation of *G. emarginata* is comparable with some forms of *G. browniana* Brongniart. The leaves of *G. browniana* are, however, mostly spathulate, oval-linear, linear and venation in apical portion is different in the leaves. The meshes are uniform throughout the lamina while in *G. emarginata* the meshes are slightly wider elongate near the midrib and narrower towards the margin.

*Diagnosis* (after Maheshwari and Prakash 1965)—Leaf oblong with emarginate apex; midrib distinct and stout, persists up to the apex. Secondary veins are acute, arched, dichotomise and anastomose; meshes elongate polygonal. In apical part the secondary veins bend towards the midrib, run almost parallel to the leaf margins and finish in the margin of the apical portion.

**GLOSSOPTERIS cf. EURYNEURA** Maheshwari 1965

Pl. 5.1

*Specimen nos.*—BSIP-38816-B (2/4578), 3/4578.

*Locality*—Sirka Colliery, South Karanpura Coalfield.

*Horizon*—Barakar Formation, shales associated with Naditoli Seam.

*Description*—Shape strap-shaped, length 9-18 cm, width 2.7-5.5 cm, apex not preserved, base narrow-tapering, margin entire, midrib strong, elevated, angle of origin of veins 30°-35°, no. of veins/cm. (a) near the midrib 4-5, (b) near the margin 12-18. Secondary veins arise from the midrib at broad angles and traverse straight to the margins, almost at right angles to the midrib. The secondary veins are sinuous, dichotomise only once or twice. Anastomosing of the secondary veins is very rare, only 1-3 elongate and wide meshes being formed, cuticle not recovered.



**PLATE 7**

- |    |  |    |  |
|----|--|----|--|
| 1  | <i>Glossopteris major</i> Pant and Singh 1971, Specimen no. BSIP-38840 (4/4746), Barakar Formation, Jharkhand Colliery, West Bokaro Coalfield, Bihar. x nat. size. | 3. | <i>Glossopteris linearis</i> McCoy 1847, Specimen no. BSIP-38842 (22/5005), Barakar Formation, Sarubera Colliery, West Bokaro Coalfield, Bihar. x nat. size.                               |
| 2. | <i>Glossopteris shailae</i> Bajpai 1987, Specimen no. BSIP-38841 (10/5007A), Barakar Formation, Gidi-A Colliery, South Karanpura Coalfield, Bihar. x nat. size.    | 4. | <i>Glossopteris longifolia</i> Pant and Singh 1971, Specimen no. BSIP-38843 (26/4998-A1), Barakar Formation, Naditoli Seam, Sirka Colliery, South Karanpura Coalfield, Bihar. x nat. size. |

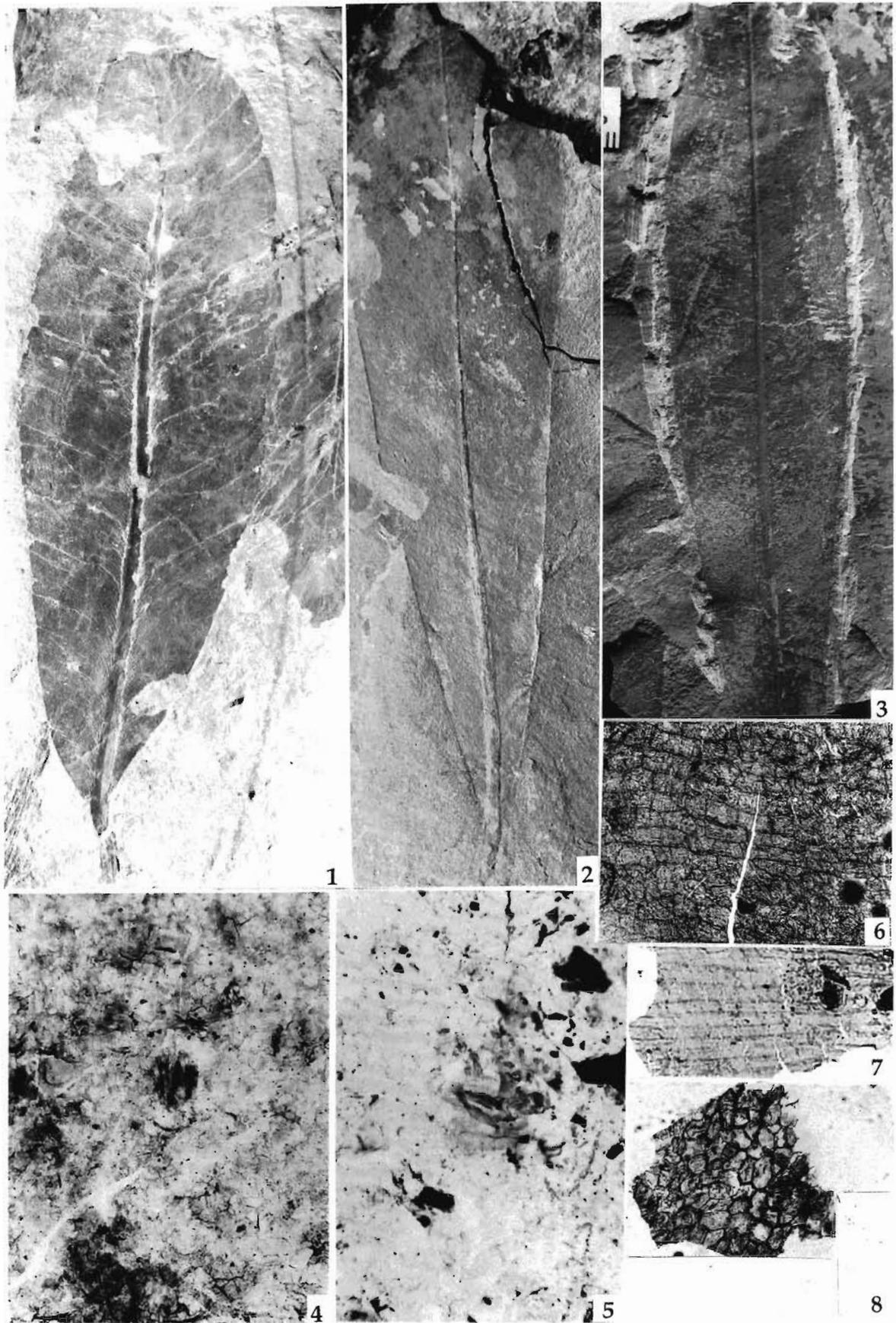


PLATE 8

*Comparison*—Our specimens show closest resemblance with *Glossopteris euryneura* Maheshwari 1965. This species resembles a *Taeniopteris* leaf, *G. damudica* and *G. taeniopteroides*. In *Taeniopteris*, however, the secondary veins do not anastomose. In *G. damudica* the anastomosing of the secondary veins is frequent and the meshes near the midrib are broader and shorter than those at the margins. *G. taeniopteroides* is distinguished by its much closer venation.

*Diagnosis* (after Maheshwari 1965)—Leaf simple, strap-shaped, apex not known definitely, lamina gradually contracting towards the base; midrib distinct and broad; secondary veins arise at broad angles, run straight to the margins, fork once or twice; anastomoses are rare near the midrib, more frequent at the margins, meshes broad and elongate.

### GLOSSOPTERIS INDICA Schimper 1869

Pl. 5·2-4; Pl. 6·4, 5

*Specimen nos.*—BSIP-38836A (1/4578), 2/5007B, 5/5004.

*Locality*—Sirka and Gidi-C Collieries, South Karanpura Coalfield; Jharkhand Colliery, West Bokaro Coalfield.

*Horizon*—Barakar Formation.

*Description*—Shape oval-lanceolate, length 11-26 cm, width 4·2-6·4 cm, apex acute, base cuneate, margin entire, midrib distinct, flat, 0·3 cm broad at base, gradually tapering towards apex, angle of origin of veins 30°-40°, no. of veins/cm. (a) near the midrib 5-10, (b) near the margin 21-30. Secondary veins pass out at acute angles from midrib, then curve sharply, passing on obliquely to the margin. The first dichotomy takes place quite near the midrib. Veins dichotomise and anastomose to form one or two series of short, broad, at times almost triangular, meshes near the midrib and narrow-elongate meshes away from the midrib. Cuticle of both the surfaces has been recovered from specimen number 1/4578, but cellular details are seen only on one surface, which probably is non-stomatiferous. Here veins and mesh areas are clearly marked by the shape and arrangement of cells. Cells over the veins are relatively long and arranged more or less end-to-end. Cuticle of the other surface is generally hyaline, cellular details are represented by broken cell walls only.

However, a couple of better preserved pieces show a cellular pattern which is similar to that of the other surface. Here a few stomata are seen. Subsidiary cells are 4-6 in number but do not form a decipherable ring. The stomatal pore is a narrow slit.

*Comparison*—Our specimens show close resemblance with *Glossopteris indica* Schimper 1869. The chief characters which distinguish *G. indica* from other species are the large, lanceolate, acute leaves with their close sub-parallel secondary venation and transversely elongate areoles. *Glossopteris arberi* Srivastava is also a strap-shaped, oblong-lorate leaf and has uniformly open venation with elongate meshes; the cuticle, however, is characteristically different (Srivastava, 1957). There are some other species that morphographically resemble *G. indica* but have a different cuticular pattern.

*Diagnosis* {based on Schimper (1869); Pant (1958); Rigby, Maheshwari & Schopf, 1980}—Simple leaf, oval-lanceolate in shape, apex acute, base cuneate or narrow-tapering, margin entire; midrib distinct, flat, 0·3 mm broad in basal region, gradually tapering towards the apical region. Secondary veins arise from the midrib at acute angles, curve sharply, passing on obliquely to the margin, meeting it at angle of 55°-60°. The first dichotomy takes place quite near the midrib. The veins dichotomise four to five times and anastomose to form one or two series of short, broad, at times almost triangular meshes near the midrib and narrow-elongate meshes away from the midrib.

### GLOSSOPTERIS cf. INTERMEDIA (Feistmantel 1881)

emend. Maheshwari 1965

Pl. 6-1

*Specimen nos.*—4/4738, 5/4738, BSIP-38837 (18/4738).

*Locality*—Sirka Colliery, South Karanpura Coalfield.

*Horizon*—Barakar Formation, shales associated with Naditoli Seam.

*Description*—Shape narrow ob-lanceolate, length 18-24·2 cm, width 3·1-4·6 cm, apex acute, base narrow tapering, margin entire, midrib distinct, elevated, angle of origin of veins acute, no. of veins/cm. (a) near the midrib 8-12, (b) near the margin 14-18, veins arise from the midrib at acute angles,



## PLATE 8

1. *Glossopteris obscura* Pant and Singh 1971, Specimen no. BSIP-38816-A (2/4578), Barakar Formation, Shales associated with Naditoli Seam, Sirka Colliery, South Karanpura Coalfield, Bihar. x nat. size.
2. *Glossopteris oldhamii* Pant and Singh 1974, Specimen no. BSIP-38844 (13/5007A), Barakar Formation, Gidi-A Colliery, South Karanpura Coalfield, Bihar. x nat. size.
3. *Glossopteris tenuinervis* Pant and Gupta 1971, Specimen no. BSIP-38845 (11/4752), Barakar Formation, Gidi-A Colliery, South Karanpura Coalfield, Bihar. x nat. size.
4. Cuticle of *Glossopteris obscura*, showing a single stoma, and indistinct cell walls, Specimen no. BSIP-38816-A (2/4578). x 400.
5. Cuticle of *Glossopteris karanpuraensis*, probably of the stomatiferous surface, showing barely discernible lateral cell walls, and spindle shaped stomata, Specimen no. BSIP-38836B (1/4578C<sub>1</sub>) x 400.
6. 8. Cuticle of *Glossopteris longifolia* Feistmantel 1880, Specimen no. BSIP-38843 (26/4998). x 1
7. Cuticle of *Glossopteris longifolia* showing cells over the veins, Specimen no. BSIP-38843 (26/4998). x 100.

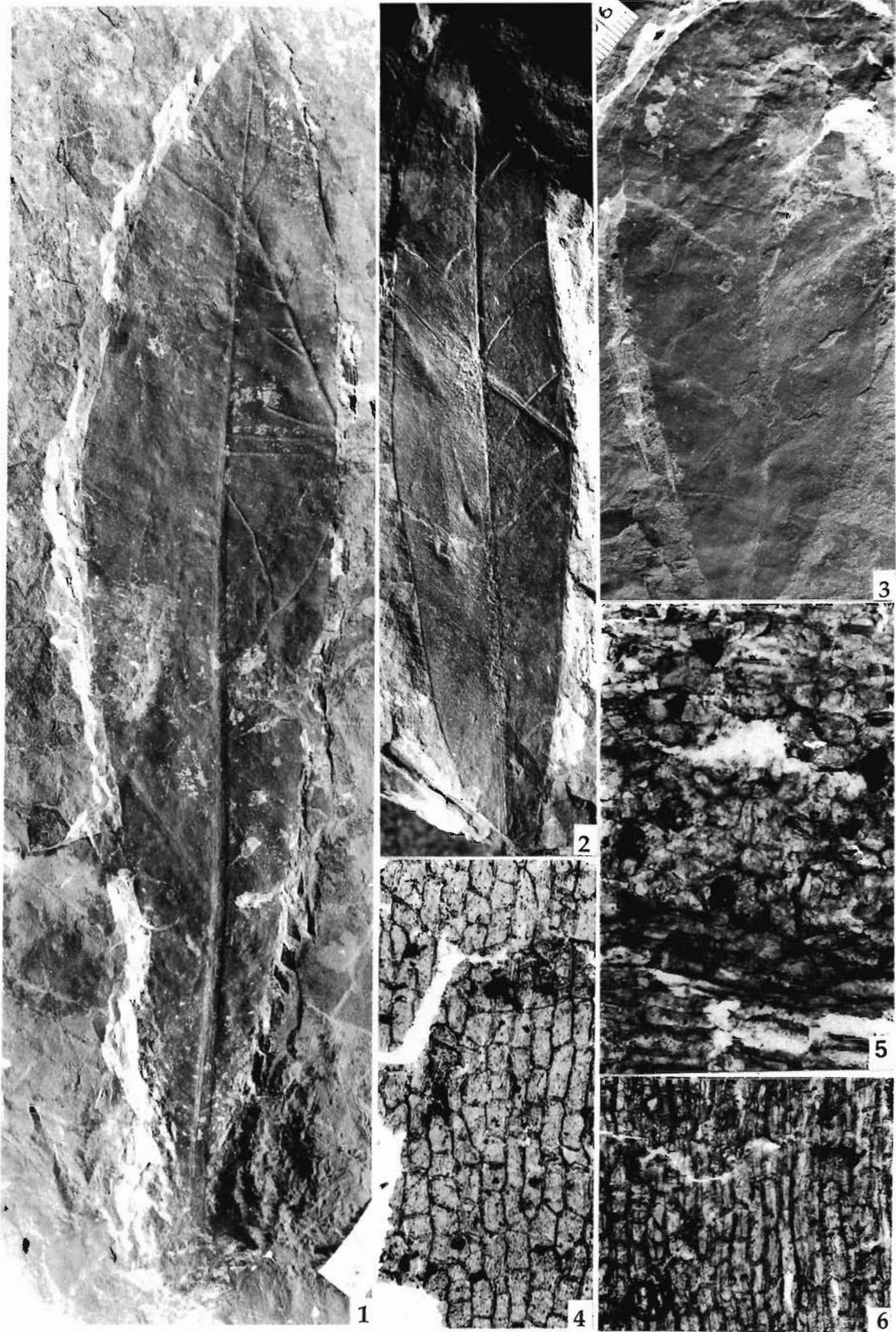


PLATE 9

dichotomise and anastomose to form oblong-polygonal meshes, cuticle not recovered.

*Comparison*—Our specimens resemble those of *Glossopteris intermedia* Feistmantel figured by Maheshwari (1965). Leaves of *Glossopteris browniana* are spatulate in shape as compared with linear-lanceolate or lanceolate spatulate shape of *Glossopteris intermedia*. In *G. browniana* the meshes are of intermediate size and become narrower towards the margins. In *G. intermedia* the secondary veins are comparatively more oblique, meshes are comparatively broader and almost equal size throughout. In the openness of the veins *G. intermedia* comes close to *G. conspicua* but in the latter species the meshes are very wide.

*Diagnosis* (after Maheshwari, 1965)—“Leaves linear-lanceolate or lanceolate-spatulate gradually contracting towards the base into a stalk; apex broadly acute or obtuse; leaves 5-6 times longer than broad; midrib stout, longitudinally striated, continues almost to the apex resolving into finer veins just below the apex; secondary veins arise at acute angles from the midrib and after a gentle arch pass straight to the margins, parallel to one another, dichotomising and anastomosing to form long and oblong-polygonal meshes of almost equal size throughout”.

#### **GLOSSOPTERIS cf. INTERMITTENS** Feistmantel 1881

Pl. 6-3

*Specimen no*—BSIP-38839 (1/4743).

*Locality*—Ara Colliery, West Bokaro Coalfield.

*Horizon*—Barakar Formation.

*Description*—Shape ob-lanceolate, length 15 cm, width 2.4 cm at the widest, apex acute, base probably cuneate, margin entire, midrib distinct, flat, continuous up to the apex, 2 mm broad at the base, angle of origin of veins 40°-45°, no. of veins/cm (a) near the midrib 12-14, (b) near the margin 18-22. Secondary veins arise at very acute angles, after gradually curving, pass on obliquely towards the margin. Veins dichotomise and anastomose to form elongate-narrow meshes, cuticle not recovered.

*Comparison*—Our specimen is morphologically similar to a specimen figured by Chandra and Surange (1979, pl. 3, fig. 5) as *Glossopteris intermittens*. This species is close to *G.*

*browniana* and *G. zeilleri*. It differs from *G. browniana* in which the anastomoses are much more frequent, and the meshes formed are comparatively broad and more polygonal. It resembles *G. zeilleri* in external features but differs in cuticular details.

*Diagnosis* (based on Feistmantel, 1881)—Leaves spatulate or ob-lanceolate in shape, gradually tapering base, rounded or acute apex. Midrib distinct, continuous up to apex. Secondary veins pass out some what thickish and with a slight curve from the midrib at an angle of about 45°, then continue straightway to the margin. Most of the veins dichotomise close to the midrib and form anastomoses here and there.

#### **GLOSSOPTERIS KARANPURAENSIS** Kulkarni 1971

Pl. 6-2; Pl. 8-5

*Specimen nos.*—BSIP-38836-B (1/4578), 18/4753, 22/4753; 7/4994; BSIP-38838 (4/5004), 21/5004A, 21/5004B, 21/5004C, 21/5004D.

*Locality*—Sirka Colliery, Religara Colliery, Bhurkunda-Sangum Colliery, South Karanpura Coalfield; Jharkhand Colliery, West Bokaro Coalfield.

*Horizon*—Barakar Formation.

*Description*—Shape ob-lanceolate, length 15-27 cm, width 3.9-5.6 cm at the middle, apex acute, base cuneate, petiolate, margin entire, midrib prominent, elevated, striated lengthwise, wide at base (2.5 mm) tapering at the apex, angle of origin of veins 36°-44°, no. of veins/cm. (a) near the midrib 10-14, (b) near the margin 17-25. Lateral veins emerge from the midrib at acute angles, take a slightly outward curve, and after successive dichotomies and anastomoses approach the margin at an angle 67°-80°. The vein dichotomies are usually of gamma and lambda type, meshes vary considerably in size and shape in different parts of the leaf, being deltoid, plano-convex, biconvex, usually trapezoidal or broad, elongate, hexagonal or pentagonal, cuticle recovered only from specimen no. 1/4578. The cuticle of both the surfaces is badly preserved. Only very faint outlines of cell walls are seen, particularly over the veins. The stomata are irregularly distributed and oriented; stomata are elliptical in shape with thickenings at both the polar ends.

### ← PLATE 9

- Glossopteris pseudostricta* sp. nov., Specimen no. BSIP-38813 (26/4753), Barakar Formation, Religara Colliery, South Karanpura Coalfield, Bihar. x nat. size.
- Glossopteris waltonii* Pant and Gupta 1968, Specimen no. BSIP-38847 (6/4746), Barakar Formation, Jharkhand Colliery, West Bokaro Coalfield, Bihar. x nat. size.
- Glossopteris stenoneura* Feistmantel 1877, Specimen no. BSIP-38848 (21/4753), Barakar Formation, Religara Colliery, South Karanpura Coalfield, Bihar. x nat. size.
- Cells of nonstomatiferous Cuticle of *Glossopteris shailae* Bajpai 1987, Specimen no. BSIP-38841 (10/5007A). x 100.
- Cuticle of stomatiferous surface of *Glossopteris shailae* showing cells over the veins and in the intercostal areas, Specimen no. BSIP-38841 (10/5007A). x 200.
- Cuticle of the midrib portion of *Glossopteris shailae*, note thick walled rectanguloid cells arranged end- to- end, Specimen no. BSIP-38841 (10/5007A). x 100.

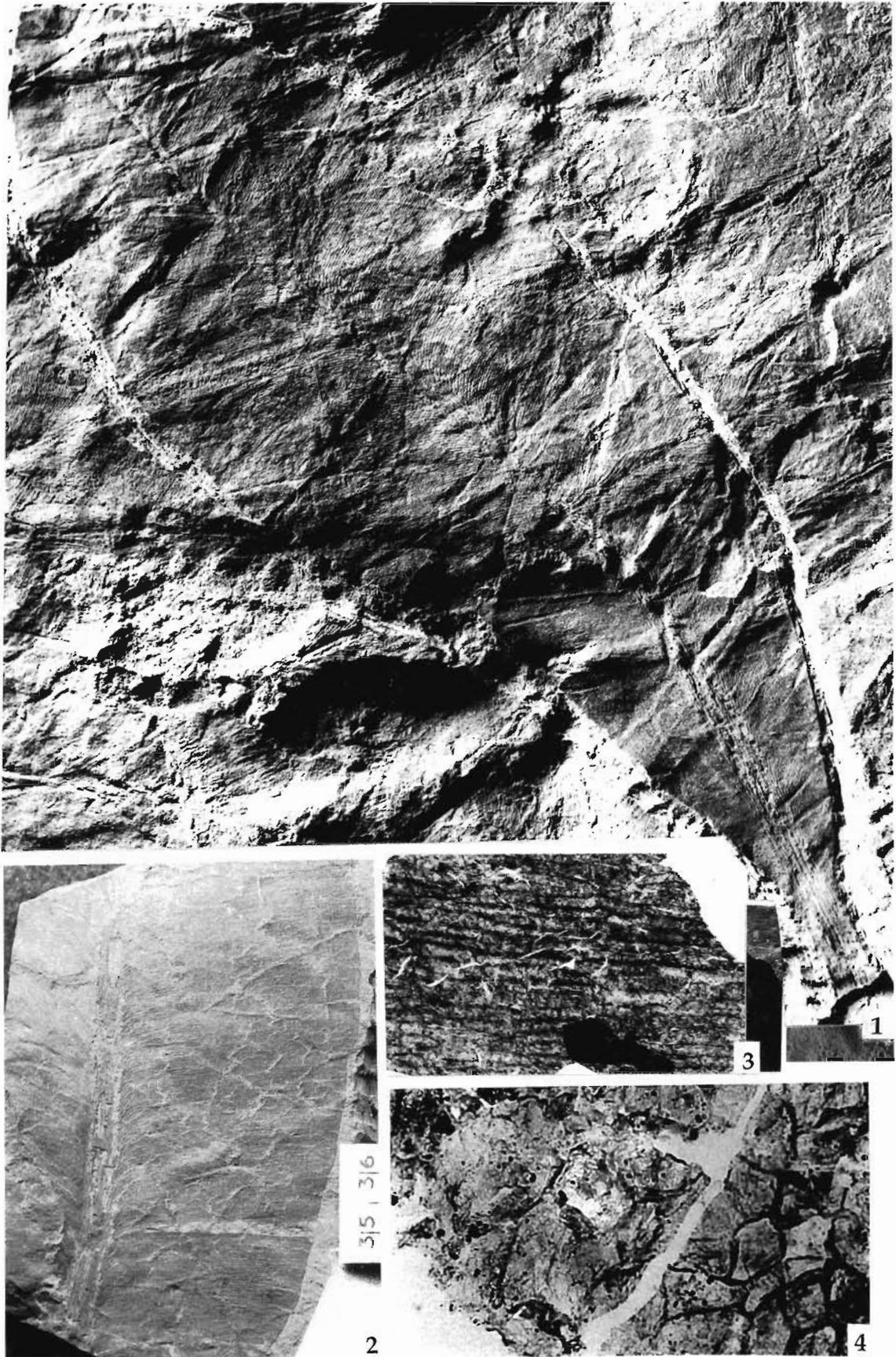


PLATE 10

*Comparison*—Our specimens show close resemblance with *Glossopteris karanpuraensis* Kulkarni 1971. *Glossopteris karanpuraensis* is comparable to *G. damudica* (= *G. danae*), *G. oldhamii* and *G. rhabdotaenoides*. *G. danae* is a very broad leaf with different shape; meshes are smaller. *G. oldhamii* is a smaller leaf and its shape is different, meshes are very broad throughout the lamina. *G. rhabdotaenoides* is a very broad leaf and the shape is different, meshes are broad, elongate and perpendicular to the midrib.

*Diagnosis* (based on Kulkarni, 1971)—Leaf large, ob-lanceolate or narrow-elliptic, apex acute, base cuneate, petiolate, midrib thick, elevated, striated, veins arise at 36°-45°, arching upwards, meshes large mostly deltoid, plano-convex, biconvex, hexagonal or pentagonal.

### GLOSSOPTERIS cf. LINEARIS McCoy 1847

Pl. 7-3

*Specimen nos.*—20/4745, 2/4756, cp.3/4756, BSIP-38842 (22/5005).

*Locality*—Saruber Colliery, West Bokaro Coalfield; Ray Colliery, North Karanpura Coalfield.

*Horizon*—Barakar Formation.

*Description*—Shape linear-lanceolate, length 9-26 cm, width 2.2-2.8 cm, apex acute, base cuneate, margin entire, midrib prominent, striated and persists right up to the apex, angle of origin of veins 15°-20°, angle near margin 63°-69°, no. of veins/cm (a) near the midrib 15-20. (b) near the margin 28-30, veins arise from the midrib at acute angles, arching backwards. The veins dichotomise and anastomose; dichotomies usually are of open gamma type. Size of meshes varies in different parts of the leaf, meshes are elongate-polygonal, slightly narrower towards the margin, only hyaline pieces of cuticle could be recovered from specimen number 2/4756. All the pieces are covered with pollen. Faint cellular outlines indicate presence of polygonal cells.

*Comparison*—Our specimens show close resemblance with *Glossopteris linearis* McCoy 1847. McCoy compared this species with the Indian form *Glossopteris angustifolia*. Though shape of *G. angustifolia* and *G. linearis* is almost similar, yet in the former species the apex is acute while in latter species the apex is obtuse or slightly notched; the meshes in *G. angustifolia* are comparatively narrow. Arber (1905) considered *G. linearis* to be a narrow leaf type referable to *G. browniana*. According to Maheshwari (1965) leaves of *G.*

*browniana* are comparatively large and spatulate, suboval or oval-lanceolate in shape while those of *G. linearis* are linear in shape. Meshes in *G. linearis* though of *G. browniana* type are comparatively narrower and smaller.

*Diagnosis*—Simple leaf, linear-lanceolate in shape, apex acute, base cuneate, midrib prominent, striated. Veins arise from the midrib at acute angles, veins dichotomise and anastomose to form elongate-polygonal meshes.

### GLOSSOPTERIS cf. LONGIFOLIA Pant & Singh 1971

Pl. 7-4

*Specimen no.*—BSIP-38843 (26/4998 A-1).

*Locality*—Sirka Colliery, South Karanpura Coalfield.

*Horizon*—Barakar Formation, shales associated with Naditoli Seam.

*Description*—Shape linear-lorate, length 27.5 cm, width 5 cm, apex not preserved, base not preserved, probably cuneate, margin entire, midrib distinct, flat, striated lengthwise, wider near the base, angle of origin of veins 40°-45°, no. of veins/cm (a) near the midrib 17-18, (b) near the margin 25-28, veins arise from the midrib at an acute angle, arch, dichotomise and anastomoses several times. Meshes near the midrib are short, longer between midrib and margins and again short near margin. The carbonified crust broke into very small pieces on maceration. On both the surfaces vein and mesh areas are delineated by the shape of cells. The stomata are usually present only in one row and are oriented obliquely. Subsidiary cells are 5-6 in number and form a ring (monocyclic stomatal apparatus). Some of the pieces show differential preservation.

*Comparison*—Our specimens show close similarity with the leaves of *Glossopteris longifolia* Pant & Singh 1971. The shape and venation of leaves of *G. longifolia* are similar to those of *G. nautiyalii*. The cuticles of both the species show sinuous-walled, elongated cells, however, the upper cuticle of midrib in *G. longifolia* does not show any stomata, whereas that of *G. nautiyalii* has clearly demarcated stomatiferous and non-stomatiferous areas.

*Diagnosis* (based on Pant & Singh, 1971)—Leaves lanceolate, apex acute, base cuneate, midrib continuing up to apex showing longitudinal strands. Veins arise at small angles, arch out and reach up to the margin. Concentration of veins near the midrib is 15-17/cm. and 18-25 near the margin.



## PLATE 10

1. *Glossopteris raniganjensis* Chandra & Surange 1979. Specimen no. BSIP-38849 (13/4998), Barakar Formation. Shales associated with Naditoli Seam, Sirka Colliery, South Karanpura Coalfield, Bihar. x nat. size.
2. *Glossopteris taeniopteroides* Feistmantel 1890, Specimen no. BSIP-38850 (3/4578), Barakar Formation, Shales associated with Naditoli

3. Cuticle of midrib region in *Glossopteris taeniopteroides*. Specimen no. BSIP-38850 (3/4578). x 100.
4. Cuticle of lower surface of *Glossopteris taeniopteroides*. Specimen no. BSIP-38850 (3/4578). x 100.

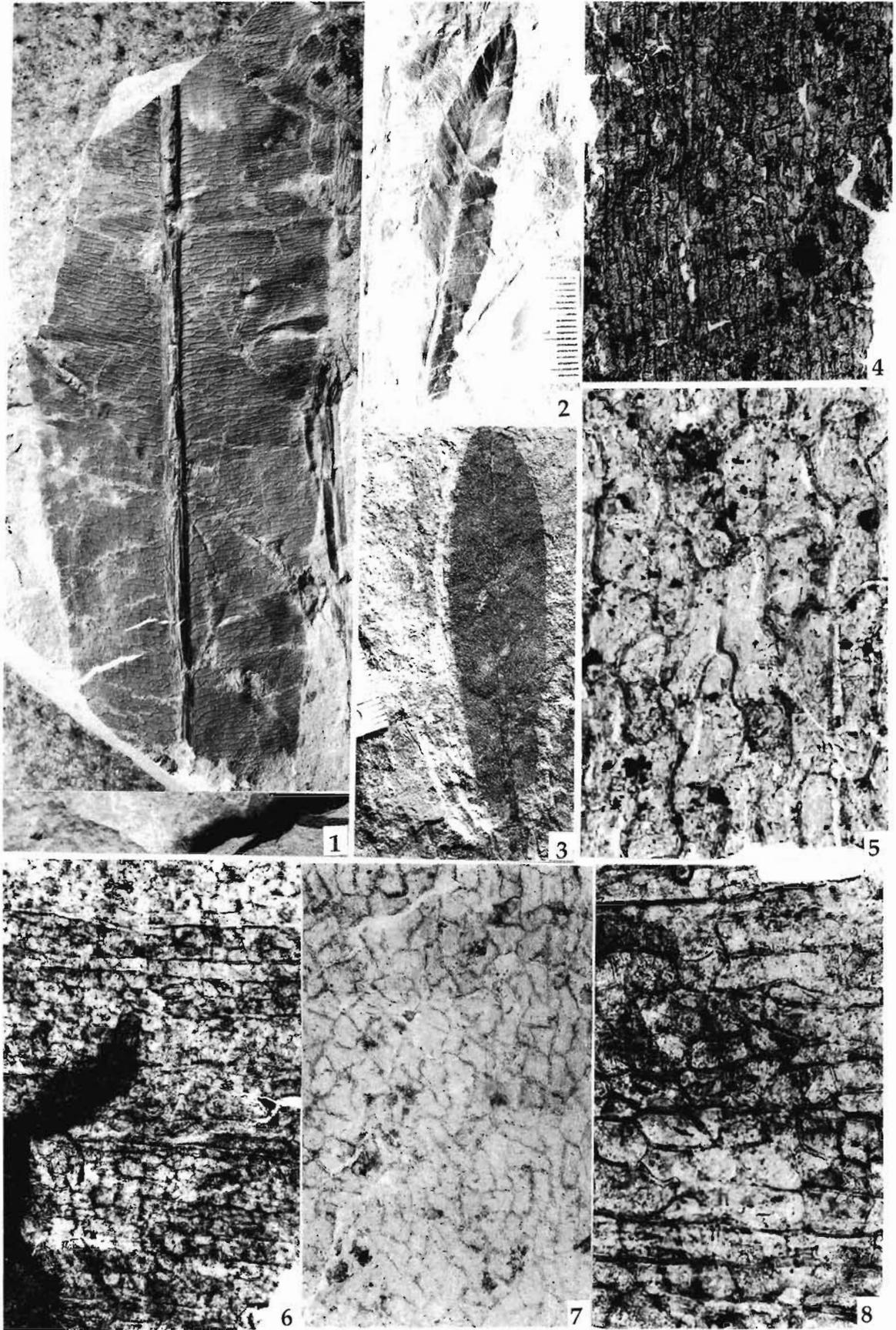


PLATE 11

Meshes are short near the midrib and relatively long between midrib and margin.

Leaves are hypostomatic. Upper cuticle of the lamina is differentiated into mesh and vein areas; cells over lamina usually tend to be arranged in rows parallel to veins. Cuticle over midrib thicker, showing rectanguloid cells arranged in linear rows. In lower cuticle of lamina surface walls of some epidermal cells over meshes and some or all subsidiary cells around a stoma papillate. Stomata monocyclic, irregularly distributed.

### **GLOSSOPTERIS cf. MAJOR** Pant & Singh 1971

Pl. 7-1

*Specimen nos.*—26/4998-B, 1/4752, BSIP-38840(4/4746).

*Locality*—Sirka and Gidi-C Collieries, South Karanpura Coalfield; Jharkhand Colliery, West Bokaro Coalfield.

*Horizon*—Barakar Formation, shales associated with Naditoli Seam.

*Description*—Shape ob-lanceolate, spatulate, length 11-29 cm, width 3.5-8 cm, apex obtuse, base acute, margin entire, midrib prominent, flat, striated, 6 mm wide at the base, reaching up to the apex, angle of origin of veins 15°-20°, no. of veins/cm (a) near the midrib 8-12, (b) near the margin 25-26. Veins arch towards the margin, dichotomise and anastomose, meshes elongate and narrow, cuticle not recovered.

*Comparison*—Our specimens resemble *Glossopteris major* Pant & Singh 1971 which in venation pattern closely resembles *G. communis* and in shape is like *G. spatulata*. However, all three species differ in combination of morphographical characters.

*Diagnosis* (after Pant & Singh, 1971)—Leaves spatulate, broadest region of the lamina near apex, apex obtuse or acute, base gradually tapering. Margin entire or lobed. Midrib persisting up to apex, with parallel running strands. Veins leaving midrib at angles of about 10°, intersecting margins in basal region at an angle of 70°, angle of intersection of margin by veins gradually smaller towards apex. Concentration of veins near margins 15-25/cm; concentration of veins as a rule lower near the midrib than that in corresponding part near margin. Meshes shorter in basal region, longer in middle

region, and again shorter in apical region, 5 mm long. Leaves hypostomatic.

### **GLOSSOPTERIS OBOVATA** sp. nov. <sup>†</sup>

Pl. 4-5

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

1992 *Glossopteris pandurata* Pant & Gupta 1971 Maheshwari & Tewari, *Palaeobotanist* 39:339, pl. 1, figs 3, 4, text-fig. 1 c.

*Specimen nos.*—21/4578, 7/4752A, 8/4753, BSIP-38835 (33/4753), 1/4757, 9/5007A.

*Locality*—Ray Colliery, North Karanpura Coalfield; Religara, Sirka, Gidi-A and Gidi-C Collieries, South Karanpura Coalfield.

*Horizon*—Barakar Formation.

*Holotype*—Specimen no. BSIP 36451A, shales associated with coal seam, Barakar Formation, Early Permian; Churulia OCP, Raniganj Coalfield, West Bengal.

*Description*—Shape obovate, length 7.5-9 cm, width 4-2 cm, apex obtuse, base rounded, margin entire, midrib distinct but flat, angle of origin of veins acute, no. of veins/cm (a) near the midrib 11-12, (b) near the margin 23-28, lateral veins emerge from the midrib at acute angles, gracefully curve outwards to meet the margin, veins dichotomise and anastomose. Vein dichotomies usually of gamma type, meshes usually arcuate near midrib, cuticle not recovered.

*Comparison*—*Glossopteris obovata* sp. nov. can be compared with *G. pandurata*, *G. spatulata*, *G. angusta*, *G. emarginata* and *G. retusa*; all the species have retuse apex. *G. pandurata* has strong midrib reaching up to apex and venation is close.

*Diagnosis*—Leaf simple, obovate in shape, apex broad obtuse having a notch, base narrow tapering, margin entire, midrib stout, distinct up to ¾ length or up to apex of lamina. Veins arise at acute angles, dichotomise and anastomose to form narrow meshes. Venation is of close type.

### **GLOSSOPTERIS cf. OBSCURA** Pant & Singh 1971

Pl. 8-1



## PLATE 11

1. *Glossopteris pseudotortuosa* sp. nov., Specimen no. BSIP-38851 (10/4578), Barakar Formation, Shales associated with Naditoli Seam, Sirka Colliery, South Karanpura Coalfield, Bihar. x nat. size.
2. *Glossopteris vulgaris* Pant & Gupta 1968, Specimen no. BSIP-38852 (16/4578), Barakar Formation, Shales associated with Naditoli Seam, Sirka Colliery, South Karanpura Coalfield, Bihar. x nat. size.
3. *Glossopteris zeileri* Pant & Gupta 1968, Specimen no. BSIP-38853 (2/4994), Barakar Formation, Bhurkunda Colliery, South Karanpura Coalfield, Bihar. x nat. size.
4. Cuticle of over the midrib region of *Glossopteris vulgaris*, Specimen no. BSIP-38854 (22/5007A). x 100.
5. Cuticle of *Glossopteris vulgaris* from stomatiferous surface, Specimen no. BSIP-38854 (22/5007A).
- 6, 7, 8. Cuticle of *Glossopteris pseudotortuosa*, Specimen no. BSIP-38815 (7/4578), 6 x 100, 7 x 100, 8 x 200.

*Specimen nos.*—BSIP 38816-A (2/4578), 2/4754, 21/5007A.

*Locality*—Gidi-A and Sirka Collieries, South Karanpura Coalfield; Dakara Colliery, North Karanpura Coalfield.

*Horizon*—Barakar Formation.

*Description*—Shape narrow obovate, length 10.5–12 cm, width 3.5–5 cm, L/W ratio 4:1, apex obtuse, base petiolate, preserved size 1.2 cm long, 0.3 cm wide, margin entire, midrib prominent, raised, 0.2 cm wide near base, having faint striations lengthwise, angle of origin of veins 20°–25°, no. of veins/cm (a) near the midrib 12–18, (b) near the margin 24–30, lateral veins arise from the midrib at acute angles, arch backwards, curve outwards near the margin, dichotomise and anastomose to form meshes that are longer than broad; comparatively broad and short near the midrib, narrow and long towards the margin, cuticle of both the surfaces is badly preserved and has become hyaline in specimen number 2/4578. Hardly any cell walls are seen. However, one of the surfaces shows irregularly arranged and distributed stomata.

*Comparison*—Our specimens show close resemblance with *Glossopteris obscura* Pant & Singh 1971 in external morphology. Cuticular data from our specimens is too meagre to be of any comparative value. Its shape is comparable with that of *G. bengalensis* which has broad meshes but differs from it in having non-papillate subsidiary cells.

*Diagnosis* (based on Pant & Singh, 1971)—Leaf simple, apex obtuse, base narrow-tapering, wide in middle region; margin entire; midrib striated lengthwise. Veins crossing lamina at an angle of 45° with midrib but arising at smaller angles and almost immediately curving outwards, concentration of veins 12/cm near the midrib, slightly higher towards the margin. Leaf hypostomatic. Upper cuticle shows no differentiation of mesh and vein areas, lower cuticle is obscure.

#### GLOSSOPTERIS cf. OLDHAMII Pant & Singh 1974

Pl. 8:2

*Specimen no.*—BSIP 38844 (13/5007 A) (cp. 11/5007A).

*Locality*—Gidi A Colliery, South Karanpura Coalfield.

*Horizon*—Barakar Formation, shales associated with Argada Seam.

*Description*—Shape ob-lanceolate, length 16 cm, width 4.7 cm, apex probably obtuse, base cuneate, petiolate, petiole 2.7 cm long, 3 mm wide, midrib distinct, elevated, wider near base, tapering towards apex, angle of origin of veins 30°–40°, no. of veins/cm (a) near the midrib 10–11, (b) near the margin 22–25, veins arise from the midrib at an acute angle, arch backwards and travel straight towards the margin; veins dichotomise and anastomose to form wide, long meshes near the midrib which are narrower and smaller towards the margin, cuticle not recovered.

*Comparison*—Our specimens show close resemblance with *Glossopteris oldhamii* Pant & Singh 1974. This species can also be compared with *G. browniana* and *G. cordata*. *G. browniana* is a smaller leaf and the apex is different. Veins pass out from the midrib at acute angles and the meshes near the margin are not as short. The leaf of *G. cordata* has cordate base and its shape is quite different.

*Diagnosis* (after Pant & Singh, 1974)—Leaves spatulate, petiolate, apex obtuse, margin entire, midrib prominent, striated. Lateral veins emerge at an angle of 30°–74°, arching backwards, concentration of veins 10–20 per cm, meshes long and polygonal. Upper cuticle without stomata, cells over the veins and mesh areas differentiated. Stomata on lower surface irregularly oriented, monocyclic.

#### GLOSSOPTERIS PSEUDOSTRICTA sp. nov.

Pl. 9:1

*Specimen nos.*—28/4738, 12/4752, 6/4752, BSIP-38813 (26/4753), 20/4998.

*Locality*—BSIP Gidi-C, Religara and Sirka Collieries, South Karanpura Coalfield.

*Holotype*—BSIP Specimen no. 26/4753, Barakar Formation, Early Permian; Religara Colliery, South Karanpura Coalfield, Bihar.

*Description*—Shape narrow elliptic, length 12–26.6 cm, width 5.4–7 cm, apex acute, base cuneate, petiolate, margin entire, midrib strong, elevated, striated, running up to the apex, angle of origin of veins 85°–87°, no. of veins/cm (a) near the midrib 17–20, (b) near the margin 20–45, lateral veins arise at right angles to the midrib, arching little near it, dichotomise and anastomose a few times, and then travel straight horizontally to the margin. Density of veins greater near the margin. Meshes broad near the midrib and then become very narrow and long, cuticle not recovered.

*Comparison*—*Glossopteris pseudostricta* differs from *G. stricta* Bunbury 1861 in being an oval-lanceolate leaf with very fine and dense venation; concentration of veins per cm is relatively much more than in the latter species. The species also compares with *G. indica* Schimper and *G. communis* Feistmantel. However, *G. indica* has wider and bigger meshes near the midrib and narrow elongate meshes near the margin. *G. communis* has fine almost equidistant veins throughout the lamina.

*Diagnosis*—Simple leaf, lanceolate in shape, acute apex, cuneate base, probably petiolate, entire margin; midrib strong, striated; lateral veins arise at acute angles, dichotomise and anastomose to form very narrow-elongate meshes. Veins are fine, up to 45 per cm near the margin.

#### GLOSSOPTERIS PSEUDOTORTUOSA sp. nov.

Pl. 11:1, 6–8

1992 *Glossopteris rhabdotaenoides* Pant & Singh 1971: Maheshwari & Tewari, *Palaeobotanist* 39(3) : 347, pl. 3, figs 1, 4, 6, text-fig. 3A-E.

*Specimen nos.*—BSIP-38851(10/4578) (cp 11/4578), 19/4578 (cp 7/4578), 2/4578, 20/5004, 30/5004.

*Locality*—Sirka Colliery, South Karanpura Coalfield; Jharkhand Colliery, West Bokaro Coalfield.

*Horizon*—Barakar Formation, shales associated with Naditoli Seam.

*Holotype*—BSIP Specimen no. 10/4578, Barakar Formation, shales associated with Naditoli Seam, Early Permian; Sirka Colliery, South Karanpura Coalfield, Bihar.

*Description*—Shape lanceolate, length 13-17 cm, width 2-4.5 cm, apex acute (in Specimen no. 30/5004), base cuneate (in specimen no. 30/5004), petiolate (in specimen no. 20/5004), margin entire, midrib distinct, stout, striated, wider near base, angle of origin of veins 30°-40°, no. of veins/cm. (a) near the midrib 9-15, (b) near the margin 14-22, lateral veins emerge from the midrib at acute angles, thereafter run straight

Glossopteris Species	North Karanpura Coalfields				South Karanpura Coalfields					West Bokaro Coalfields										
	D a k a r a	K. D. H E S L O N G	R a y	K a r k a t a	S i r k a	R e l i g a r a	G i d i - A & C	B h u r k u n d a	S a u n d a	U r i m a r i	J h a r k h a n d	P u n d i	K u j u	K e d l a	T a p i n	S a r u b e r a	A r a	T o p a	G h a t o	P i n d r a
<i>Glossopteris arberi</i>					+															
<i>G. angustifolia</i>					+			+												
<i>G. browniana</i>	+				+															
<i>G. barakarensis</i>											+									
<i>G. clarkei</i>			+				+													
<i>G. communis</i>	+	+			+	+	+		+	+	+		+					+	+	+
<i>G. danae</i>					+						+									
<i>G. decipiens</i>	+						+			+							+			
<i>G. elongata</i>											+									
<i>G. emarginata</i>					+															
<i>G. euryneura</i>					+															
<i>G. indica</i>	+	+			+	+	+			+				+	+					
<i>G. intermedia</i>					+															
<i>G. intermittens</i>					+						+						+			
<i>G. karanpuraensis</i>					+	+		+	+	+										
<i>G. linearis</i>			+							+						+				
<i>G. longifolia</i>					+															
<i>G. major</i>					+		+	+		+										
<i>G. oldhami</i>							+													
<i>G. obscura</i>	+				+		+													
<i>G. obovata</i> sp.nov.			+		+	+	+													
<i>G. pseudotortuosa</i> sp.nov.			+		+	+	+			+										
<i>G. pseudostricta</i> sp.nov.					+	+	+			+										
<i>G. shailae</i>					+	+														
<i>G. stenoneura</i>	+				+															
<i>G. raniganjensis</i>					+															
<i>G. tenuinervis</i>					+		+													
<i>G. tortuosa</i>					+															
<i>G. taeniopteroides</i>					+															
<i>G. vulgaris</i>					+		+			+										
<i>G. waltonii</i>			+	+	+			+		+		+							+	
<i>G. zeilleri</i>								+												

Fig. 1—Colliery-wise distribution of *Glossopteris* species.

and almost parallel to each other. After successive dichotomies and anastomoses the veins approach the margin approximately at right angles. 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. Meshes are mostly deltoid or rarely arcuate near the midrib and commonly pentagonal or elongate pentagonal elsewhere, cuticle of the only non-stomatiferous surface has been recovered from specimen no. 10/4578. The cuticle is very delicate and shows faint outlines of irregularly polygonal cells of the mesh areas. Cells over the veins are similar but more regularly arranged. Cell walls are broadly wavy.

*Comparison*—*Glossopteris pseudotortuosa* is comparable to *G. tortuosa* Zeiller (1902–3) in gross morphology. However, in details of venation, the differences between the two species are quite apparent. *G. tortuosa* has characteristic tortuosa-type venation pattern where the veins take a sinuous course towards the margin. *G. danae*, a somewhat similar species, has a venation pattern comprising broad, polygonal elongate meshes which are shorter near midrib and the lateral veins meet the margin at approximately 90°. In *G. rhabdotaenoides* the meshes are uniform in size, run at right angles from the midrib.

*Diagnosis*—Leaf simple, lanceolate, apex acute, base cuneate, petiolate; midrib striated, stout; lateral veins arise at acute angles, dichotomise and anastomose to form elongate-polygonal meshes; veins approach the margin at right angles. Cuticle shows irregularly polygonal cells in mesh areas while cells are arranged end-to-end in linear rows in vein areas.

**GLOSSOPTERIS cf. RANIGANJENSIS** Chandra & Surange 1979

Pl. 10·1

*Specimen no.*—BSIP 38849 (13/4998).

*Locality*—Sirka Colliery, South Karanpura Coalfield.

*Horizon*—Barakar Formation.

*Description*—Shape oval-lanceolate, length 26·5 cm, width 6·8 cm, L/W ratio 4:1, apex acute, base cuneate, probably petiolate, margin entire, midrib flat, wide at basal region, tapering towards the apex, angle of origin of veins 40°–45°, no. of veins/cm (a) near the midrib 13–14, (b) near the margin 26–28, veins arise at acute angle and reaches up to the margin in sweeping arch; veins thin, dichotomise and anastomoses to form long, narrow, elongate meshes, cuticle not recovered.

*Comparison*—The specimens show close resemblance with *Glossopteris raniganjensis* Chandra & Surange 1979. The venation pattern of *G. raniganjensis* resembles that of *G. communis*, *G. major*, *G. gigas* and *G. stenoneura* but all of these look quite different from each other in shape and size. *G. major* is an ob-lanceolate leaf with obtuse apex and lobed margin. *G. gigas* is a broad elliptical leaf with obtuse apex. *G. communis* is a comparatively small frond with almost similar

narrow elliptic shape, but apex is obtuse. *G. stenoneura* is a very small, ob-lanceolate leaf and its thin midrib dissolves into secondary veins.

*Diagnosis* (after Chandra & Surange, 1979)—Leaf large, longer than broad, shape narrow elliptic; length/width ratio 4:1, apex acute; midrib very wide, almost occupying three-fourths of width in basalmost region, gradually tapering upwards, veins thin, dense, arise at an angle of less than 45° and pass out to the margin in sweeping arcs; meshes very long, narrow; cross connections absent.

**GLOSSOPTERIS cf. SHAILAE** Bajpai 1987

Pl. 7·2, Pl. 9·4–6

*Specimen nos.*—20/4753, 26/5007, BSIP-38841 (10/5007A), 28/5007 A.

*Locality*—Religara and Gidi-A Collieries, South Karanpura Coalfield.

*Horizon*—Barakar Formation, Argada Seam.

*Description*—Shape spatulate-ovate, length 7·5–8 cm, width 1·8–2·3 cm, apex probably obtuse, base narrow-tapering, margin entire, midrib inconspicuous, largely evanescent, angle of origin of veins 20°–35°, no. of veins/cm (a) near the midrib 10–12, (b) near the margin 18–21, the vein dichotomies are of gamma type, anastomoses are of lambda type; meshes are narrow-elongate. The cuticle of the nonstomatiferous surface shows cells over the veins and in the intercostal areas. Cuticle of the midrib portion shows thick-walled, rectanguloid cells arranged end-to-end.

*Comparison*—Our specimens show closest resemblance with *Glossopteris shilae* Bajpai 1987.

*Diagnosis* (based on Bajpai, 1987)—Leaf simple, lanceolate to broad-lanceolate, apex obtuse or broadly rounded, base attenuate, margin entire; midrib evanescent in upper part with number of circular depression all over, angle of emergence of secondary veins 20°–23°, vein dichotomies of gamma type, anastomoses of lambda type. Epidermis hypostomatic, upper cuticle relatively thick, stomata irregularly distributed and oriented.

**GLOSSOPTERIS cf. STENONEURA** Feistmantel 1877

Pl. 9·3

*Specimen nos.*—BSIP-38848 (21/4753), 5-A/4754.

*Locality*—Religara Colliery, South Karanpura Coalfield; Dakara Colliery, North Karanpura Coalfield.

*Horizon*—Barakar Formation.

*Description*—Shape ob-lanceolate, length 8–10 cm, width 3·5–4·3 cm, apex obtuse, base cuneate, midrib thin, slightly broader near base, reaching up to 3/4<sup>th</sup> of lamina, margin entire, angle of origin of veins 40°–45°, no. of veins/cm (a) near the midrib 16–18, (b) near the margin 22–24, venation *communis* type, i.e., veins arise at acute angles, dichotomise and

anastomose to form narrow-elongate meshes throughout the lamina, cuticle not recovered.

*Comparison*—Our specimens show resemblance with *Glossopteris stenoneura* Feistmantel ex Banerji, Maheshwari & Bose 1976.

*Diagnosis* (After Banerji, Maheshwari & Bose, 1976)—Leaves small, spatulate to oblong-spatulate in shape. Midrib distinct for most part, becoming evanescent just near apex; secondary veins arising at acute angles and running towards margin with a slightly wavy, forming narrow-elongate meshes of  $\pm$  equal size through out the lamina.

**GLOSSOPTERIS cf. TAENIOPTEROIDES** Feistmantel  
1890

Pl. 10-2-4

*Specimen nos.*—BSIP 38850 (3A/4578), A/4578.

*Locality*—Sirka Colliery, South Karanpura Coalfield.

*Horizon*—Barakar Formation, shales associated with Nadioli Seam.

*Description*—Shape probably obovate, length 14 cm, width 6 cm, apex not preserved, base not preserved. margin entire, midrib distinct, flat, striated lengthwise, angle of origin of veins  $85^{\circ}$ - $90^{\circ}$ , no. of veins/cm (a) near the midrib 29-32, (b) near the margin 6-38, secondary veins, arising at nearly right angles from the midrib give the appearance of a *Taeniopteris* but more or less parallel secondary veins dichotomise and anastomose to form oblong, narrow elongate meshes of almost equal width throughout, cuticle of only one surface could be recovered. The cells are rectangular, have straight lateral and end walls and multipapillate surface walls.

*Comparison*—Our specimens show close resemblance with *Glossopteris taeniopteroides* Feistmantel 1890. The venation of this species resembles that of *Taeniopteris feddenii* which, however, does not show anastomosing of secondary veins. It also resembles *G. damudica* in straight and close

<i>Glossopteris</i> Species	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
<i>Glossopteris angustifolia</i>			+		+	+		+			+		+		+		+
<i>G. arberi</i>					+												
<i>G. browniana</i>		+	+		+	+		+			+		+				+
<i>G. barakarensis</i>			+		+	+		+									
<i>G. clarkei</i>					+	+											
<i>G. communis</i>	+	+	+		+	+		+			+	+	+		+	+	+
<i>G. danae</i> (= <i>G. damudica</i> )		+	+		+	+		+	+		+		+			+	+
<i>G. decipiens</i>					+												+
<i>G. elongata</i>		+			+			+									
<i>G. emarginata</i>		+	+		+	+											
<i>G. euryneura</i>			+		+												
<i>G. indica</i>		+	+	+	+	+		+	+		+	+			+		+
<i>G. intermedia</i>					+	+											+
<i>G. intermittens</i>			+		+	+											
<i>G. karanpuraensis</i>		+			+	+											
<i>G. linearis</i>					+	+		+									
<i>G. longifolia</i>			+		+												
<i>G. major</i>			+		+	+											
<i>G. obscura</i>			+		+	+											
<i>G. obovata</i> sp. nov.					+	+											
<i>G. oldhamii</i>			+		+												
<i>G. pseudostricta</i> sp. nov.					+	+											
<i>G. pseudotortuosa</i> sp. nov.					+	+											
<i>G. raniganjensis</i>			+		+												
<i>G. shailae</i>			+		+												
<i>G. stenoneura</i>			+		+												
<i>G. taeniopteroides</i>		+			+								cf				
<i>G. tenuinervis</i>					+												
<i>G. tortuosa</i>			+		+			+									
<i>G. vulgaris</i>			+		+												
<i>G. waltonii</i>			+		+												
<i>G. zeilleri</i>					+												

Fig. 2—Showing the distribution of the *Glossopteris* species in different coalfields of the Barakar Formation (+\* indicates new contribution). 1. Hura; 2. Pachhwara; 3. Raniganj; 4. Jharia; 5. Karanpura; 6. Bokaro; 7. Deogarh; 8. Auranga; 9. Hutar; 10. Daltonganj; 11. Ramkola; 12. Singrauli; 13. Pali; 14. Umaria; 15. Chirimiri; 16. Talcher; 17. Kashmir.

venation but here the meshes near midrib are much shorter and broader than those near the margin, while in the present leaf the meshes do not differ much in width from one another. On the basis of cuticular study Srivastava (1957) differentiated *G. taeniopteroides* from *G. indica* and *G. damudica* (= *G. ampla*).

*Diagnosis* (based on Srivastava, 1957 and Maheshwari, 1965)—Leaf oval-spathulate in shape; midrib distinct, longitudinally-striated, secondary veins arise from the midrib at acute angles but immediately thereafter take a sharp bend and follow a course at right angles to the midrib; veins dichotomise a few times and anastomose to form narrow-elongate meshes of almost equal breadth throughout. The cuticle is thin and the arrangement of veins and meshes is not very marked. Stomata are confined to one surface of the leaf. The cuticle of upper surface is slightly thicker than lower. Stomata are haplocheilic and irregularly oriented.

#### GLOSSOPTERIS cf. TENUINERVIS Pant & Gupta 1971

Pl. 8·3

*Specimen no.*—9/4752 BSIP-38845 (cp. 11/4752).

*Locality*—Gidi-C Colliery; South Karanpura Coalfield.

*Horizon*—Barakar Formation, shales associated with Argada Seam.

*Description*—Shape linear-lanceolate, length 16 cm, width 3·2 cm, apex not preserved, base probably narrow tapering, margin entire, midrib distinct, flat, longitudinally striated, angle of origin of veins 40°-45°, no. of veins/cm (a) near the midrib 30-36, (b) near the margin 40-50, veins arise from the midrib, arching backwards, dichotomise and anastomose to form short, narrow-long, wide near midrib and long near the margin.

*Comparison*—Our specimens show close resemblance with *Glossopteris tenuinervis* Pant & Gupta 1971. This species resembles *G. ghusikensis* in venation pattern but differs in presence of shining threads running along veins and in its cuticular features.

*Diagnosis* (based on Pant & Gupta, 1971)—Leaf simple, apex slightly emarginate, margin entire, midrib distinct, wider near base, lateral veins arise at acute angle of 45°-60°, dichotomise and anastomose to form short and long narrow meshes. Leaf is hypostomatic.

#### GLOSSOPTERIS cf. TORTUOSA Zeiller 1902

Pl. 4·4

*Specimen no.*—BSIP-38834 (16/4738).

*Locality*—Sirka Colliery, South Karanpura Coalfield.

*Horizon*—Barakar Formation, shales associated with Nadioli Seam.

*Description*—Shape lanceolate, length 15 cm, width 3 cm, L/W ratio 5:1, apex not preserved, base not known, margin

entire, midrib distinct, elevated and 0·2 cm at the base, angle of origin of veins 45°-50°, no. of veins/cm (a) near the midrib 6-7, (b) near the margin 16-17, the secondary veins are dichotomous and anastomosing. Veins take a sinuous course towards the margin. Arber (1905) mentioned that the secondary veins form two series of large polygonal meshes near the midrib followed by narrower meshes but Maheshwari (1965) opined that it is not always the case, the broader meshes may be in 1-3 or more series and then start becoming narrower.

*Comparison*—Our specimens show close resemblance with *Glossopteris tortuosa* Zeiller 1902. Arber (1905) believed *Glossopteris tortuosa* to be comparable with *G. damudica* but maintained its separate identity. While Walton (1929) considered it to be an intermediate type between *G. browniana* and *G. retifera*. However, in *G. tortuosa* the meshes near the midrib are much broader than those near the margin while in *G. retifera* meshes are of almost equal size throughout the lamina. Surange and Maheshwari (1962; text-fig. 9) figured a whorled cluster of *G. tortuosa* leaves surrounding an axis of *Vertebraria*.

*Diagnosis* (based on Arber, 1905)—Leaf of medium size, contracting gradually towards the base; midrib strong, elevated, with longitudinal striations, secondary veins thick, spreading irregularly, sinuate, forming on each side of the midrib two series of large, polygonal meshes, the succeeding meshes being narrower, more elongate, polygonal or trapezoidal.

#### GLOSSOPTERIS VULGARIS Pant & Gupta 1968

Pl. 11·2, 4, 5

*Specimen nos.*—BSIP-38852 (16/4578, 35/4578), BSIP-38854 (22/5007A).

*Locality*—Sirka and Gidi-A Colliery, South Karanpura Coalfield.

*Horizon*—Barakar Formation.

*Description*—Shape lanceolate, length 6·8-11 cm, width 1·2-2·2 cm, apex acute, base tapering, margin entire, midrib longitudinally ribbed, angle of origin of veins 30°-40°, no. of veins/cm (a) near the midrib 9-10, (b) near the margin 21-22, veins arise at acute angles from midrib, arch backwards and continue straight to the margin, dichotomising and anastomosing to form narrow-elongate meshes, the carbonified crust did not yield well-preserved cuticles. Cuticle of one of the surfaces (?nonstomatiferous) is relatively thick and shows outlines of irregularly longish polygonal cells arranged in false rows. The cells near the margin are much narrower. The cuticle of the other surface is thin, the cells over the veins are longish, polygonal whereas in the mesh areas, the cell outlines indicate irregular polygonal cells. No stoma has been observed. The cells over the median region are very thick-walled, longish, rectangular and arranged end-to-end in linear rows. The cells over the veins are similar except that their walls are

comparatively less thick. The cells in the intercostal areas are polygonal.

*Comparison*—The specimens show a very close resemblance to *Glossopteris vulgaris*, a species that can also be compared with *G. decipiens*, *G. zeilleri* and *G. tenuifolia*. *G. decipiens* possesses a midrib that is evanescent in the upper part and a venation that is relatively less dense. *G. zeilleri* has different shape and apex, and the midrib is also evanescent. *G. tenuifolia* is broader than *G. vulgaris* and has distinct shape and broad venation.

*Diagnosis* (based on Pant & Gupta, 1968)—Leaf lanceolate, broadest in the middle, gradually tapering towards apex and base, apex acute or obtusely pointed; margin entire; midrib persistent from base to apex; striated; lateral veins arising at acute angles from the midrib, arching backwards, and continuing at angle of 30°-50° with midrib; concentration of veins 14-24 per cm near the midrib and 22-36 per cm near the margin, meshes are long and wide. Leaf is amphistomatic.

#### GLOSSOPTERIS cf. WALTONII Pant & Gupta 1968

Pl. 9-2

*Specimen nos.*—26/4578, 3/4739, BSIP-38847 (6/4746), 13/4746, 7/4748, 2/4756, 3/4756 (cp.13/4756), 2/4994, 21/5004.

*Locality*—Bhurkunda-Sangum and Sirka Collieries, South Karanpura Coalfield; Ray Colliery, North Karanpura

Coalfield; Ghato, Jharkhand and Kuju Collieries, West Bokaro Coalfield.

*Horizon*—Barakar Formation.

*Description*—Shape linear lanceolate or spatulate, length 6.8-17.5 cm, width 1.2-3.5 cm, apex acute or rounded, base narrow tapering, margin entire, midrib prominent, stout, longitudinally striated, reaching up to the apex, angle of origin of veins 30°-40°, no. of veins/cm. (a) near the midrib 11-16, (b) near the margin 22-28, lateral veins arise from the midrib forming arch with midrib and then travel straight to the margin dichotomising and anastomosing to form long, narrow-elongate meshes, cuticle not recovered.

*Comparison*—The specimens have a close similarity with *Glossopteris waltonii* Pant & Gupta 1968 in overall features.

*Diagnosis* (based on Pant & Gupta, 1968) —Leaves spatulate to linear-lanceolate, gradually tapering towards base, apex obtusely pointed or rounded, margin entire; midrib wide in basal region, tapering upwards, having longitudinal striations; lateral veins arising from the midrib at very acute angles, arching backwards from the midrib and thereafter continuing almost straight at angles of 45°-60° with midrib. Meshes long, narrow. Leaf hypostomatic.

#### GLOSSOPTERIS cf. ZEILLERI Pant & Gupta 1968

Pl. 11-3

*Specimen no.*—BSIP-38853 (2/4994).

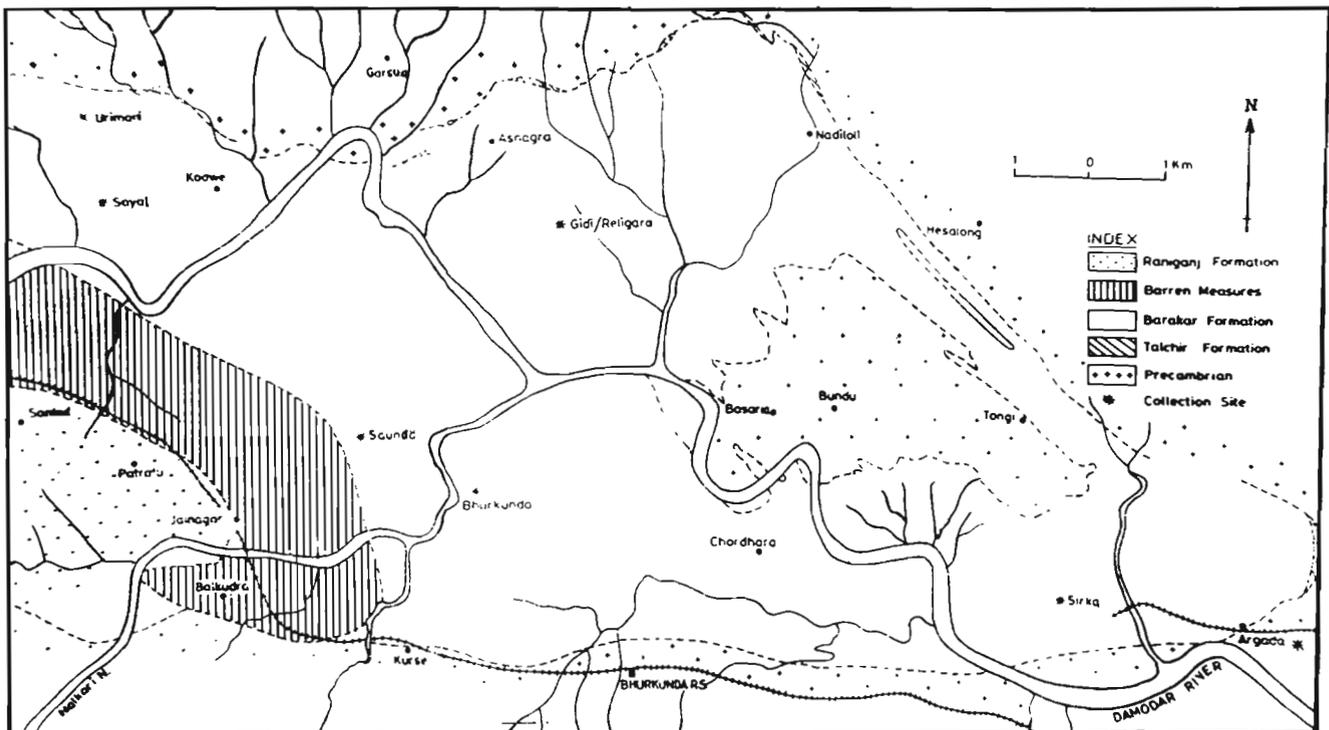


Fig. 3—A part of Geological map of South Karanpura Coalfield.

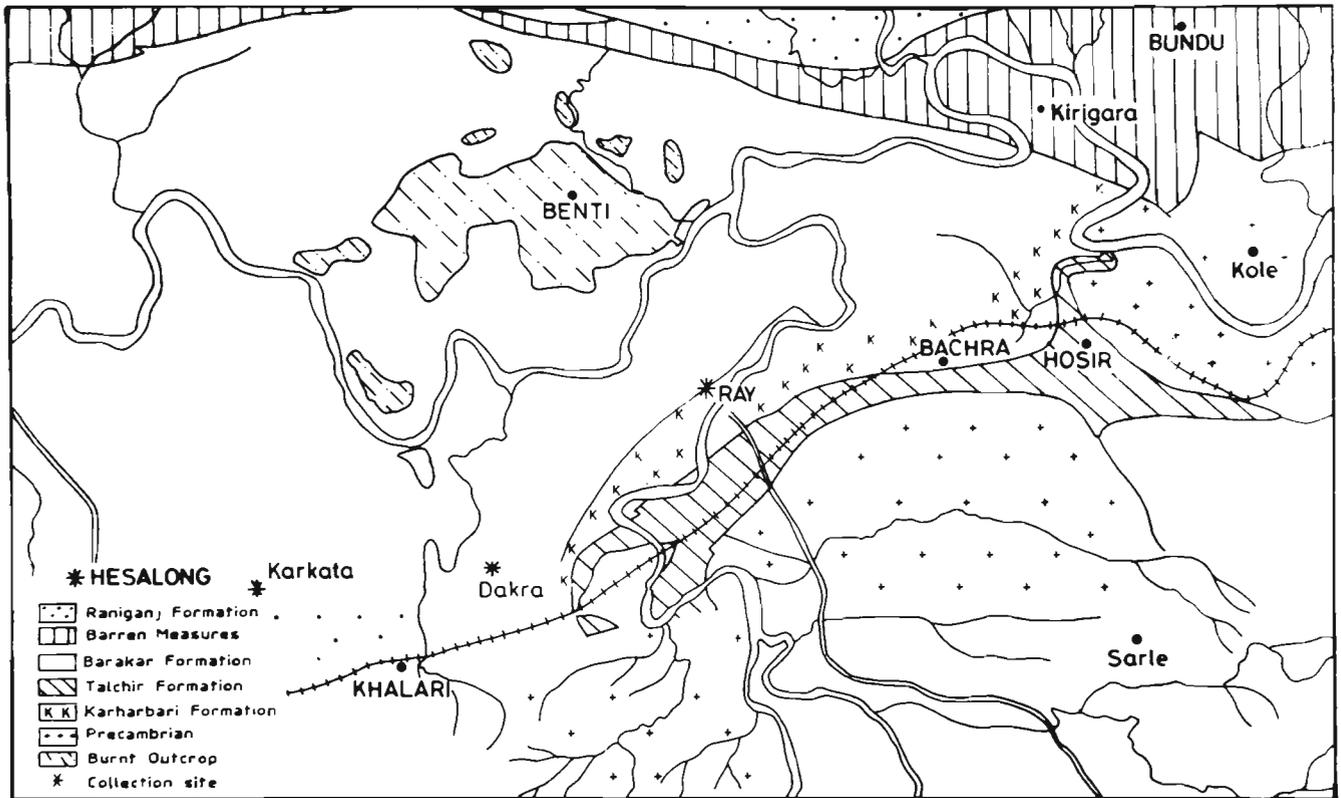


Fig. 4—Geological map of Ray-Bachra area. North Karanpura Coalfield.

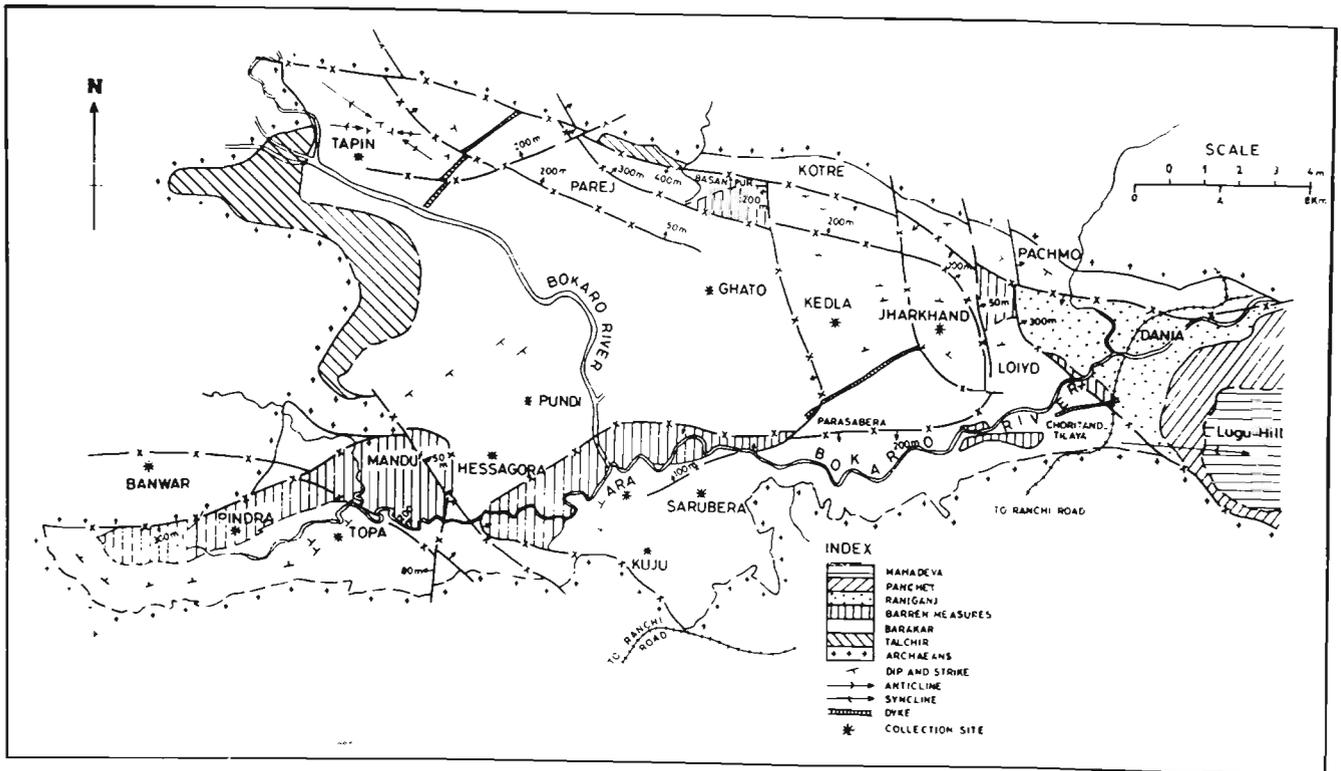


Fig. 5—Geological map of West Bokaro Coalfield.

*Locality*—Bhurkunda-Sangum Colliery, South Karanpura Coalfield.

*Horizon*—Barakar Formation, shales associated with Sangum Seam.

*Description*—Shape narrow ob-lanceolate, length 8 cm, width 2.8 cm, apex obtuse, base cuneate, margin entire, midrib distinct, angle of origin of veins 30°-35°, no. of veins/cm (a) near the midrib 17-18, (b) near the margin 28-30, veins arise from the midrib at acute angle, dichotomise and anastomose, cuticle not recovered.

*Comparison*—Our specimens resemble *Glossopteris zeilleri* Pant & Gupta 1968. In its external characters *G. zeilleri* resembles the leaves of *G. intermittens* Feistmantel and the narrower spatulate leaves of *G. varia* Pant & Gupta but their cuticles differ. In *G. intermittens* cell walls are always straight and thick whereas the cell walls of both the cuticles of *G. zeilleri* are undulate to sinuous and thin.

*Diagnosis* (based on Pant & Gupta, 1968)—Leaf spatulate, apex rounded, margin entire, base tapering, midrib showing longitudinal strands at base, tapering upwards; lateral veins arise at very acute angles from the midrib, slightly arching backwards, meshes wide near the midrib. Leaf hypostomatic.

## DISCUSSION AND CONCLUSIONS

In Karanpura and Bokaro groups of coalfields, most of the coal is found in the Barakar (including the Karharbari) Formation. Of all the formations of the Early Permian (i.e., Talchir, "Karharbari" and Barakar) of India, the fossil flora of Barakar Formation is richest in number of genera and in species. The assemblage of fossil plants of Early Permian age from North Karanpura (Fig. 4), South Karanpura (Fig. 3) and West Bokaro (Fig. 5) Coalfields consists mainly of *Glossopteris* leaves; associated with the leaves of *Neomariopteris*, *Gangamopteris*, *Palaeovittaria*, *Pantophyllum* (= *Noeggerathiopsis*), *Euryphyllum* and *Kawizophyllum*, axes & roots of *Vertebraria*, equisetalean axes, *Cordaicarpus*-type seeds, and the fructifications *Gonophylloides*, *Scutum* and *Ottokaria*. In present paper the species of most abundant element of the assemblage, the genus *Glossopteris* has been described. In the North Karanpura, South Karanpura and West Bokaro Coalfields the distribution of the plant fossils is not the same everywhere. In those localities where *Vertebraria* is dominant, other fossils are not found in appreciable number.

Specific differentiation in *Glossopteris* is difficult due to close similarities in their appearances. Most of the work published in the past was based on either morphological features (size, shape, base, apex) or cuticular features and in this way a large number of *Glossopteris* species have been created. In present study both the features where ever available, together have been taken as reliable parameters during identification and speciation. Large number of closely related

species have been minimised by making the species complexes (e.g., *G. arberi*..... *G. zeilleri*) (Thesis Shiv Mohan Singh, 1998). Species complexes can be compared to the mountainous terrain where the major hills are named. In fact the method of naming the peaks is akin to the way we name the species. The names of the hills for instance are not referred to the peaks alone but to the whole domain of the hill. A small shoulder or a sub peak on the major peak belong to the major hill and any two hills can be clearly separated only if there is distinct valley between them.

Arber suggested that as the classification of *Glossopteris* is an artificial one it would be better to maintain comparatively few species by grouping together those species which differ in one or two characters but are not sufficiently dissimilar in the aggregate of their characters. He also doubted the usefulness of creating varieties or sub-species and in this connection he is amply supported by Edwards (1928, p. 325) who says "..... I think that the custom of applying varietal names to isolated fossil leaf impressions is to be deprecated.... The use of trinomial nomenclature does not appear to add to the convenience of this artificial classification." While the tendency to create varieties or sub-species is to be deprecated it is equally true that a genus, howsoever artificial has to be critically resolved into various specific components, whatever their number. Seward (1897) has very rightly observed that "while endeavouring to avoid dangerous and unscientific practice of needlessly multiplying specific names, we must be careful to bear in mind the possibility of carrying too far the system of linking together distinct types by a long series of intermediate forms." Arber was infact more interested in reducing the number of species by linking together, which resulted in a conglomeration of many distinct types under fewer names which sometimes became so unwieldy as to be of no stratigraphical value. His *Glossopteris browniana* may particularly be cited as an example where different and distinct forms were huddled together, e.g., *G. parallela*, *G. linearis*, *G. taeniopteroides*, etc.

Further researches have, however, shown the unsatisfactory nature of Arber's broadbased specific circumscriptions. They go a long way in supporting Feistmantel's "liberal" circumscription of the species. It is interesting to note that so far almost none of the species delimited by Feistmantel have been contradicted by cuticular studies or on fructification evidence. In fact some of Feistmantel's species need even further delimitation as is evident from the works of Srivastava (1957), Pant (1958) and Høeg & Bose (1960) on the epidermal structures and of Plumstead (1956) on the fructifications. As an example may be cited the *G. indica* type of leaf which has been found to possess many different types of epidermal structures, e.g., *G. indica*, *G. communis*, *G. jamottei*, *G. arberi*, *G. hispida* and *G. fibrosa*. Here it is not meant to say that the above species are morphologically indistinguishable from the typical *G.*

*indica* leaf. However, this distinction between these species can only be accomplished when we leave aside Arber's "broad-based" system and take into account all the important morphographical characters whether gross or minute. However Pant (1958) suggested that the identifications of species where the specific name is preceded by Cf e.g., *Glossopteris cf angustifolia* should be regarded as tentative, since proper identification of a species required first hand comparison with the Holotype and if cuticle and other structural details be available by comparison with them. Identifications based on fragments of leaves where base, apex and middle region have not seen and whose cuticles are not available should only be regarded as tentative and hence Cf. Specific name. There is lot of confusion already prevailing and a strict code must be evolved for identifications of species. Where are required characters are not present from base to apex and cuticles of different parts should only go as Cf. specific name. Moreover comparison with Holotype is also important. Maheshwari (1965) mentioned that *G. brownii* also seems to be a complex species as is evident from the different types of fructifications borne by such leaves. Singh *et al.* 1999a & b studied the taxonomic problems of *Berberis lycium* complex. They supported that the cuticular studies are as an additional parameter to distinguish the infra-specific variations within closely related taxa.

It seems that these leaves had a generalized pattern. Hence it is important that take into account all recognisable characters - whether gross or minute - and they should be critically analysed in various ways in order to find a more reasonable and precise basis for specific delimitations. Morphographic circumscriptions can be further verified by other evidences such as cuticular, if and when they are available.

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