The Palaeobotanist 66(2017): 17–36
0031–0174/2017

The Glossopteris flora of Manuguru Area, Godavari Graben, Telangana, India

RAJNI TEWARI*, ARUN JOSHI AND DEEPA AGNIHOTRI

Birbal Sahni Institute of Palaeosciences, 53 University Road, Lucknow 226 007, India.
**Corresponding author: rajni_tewari@bsip.res.in*

(Received 09 March, 2017; revised version accepted 10 April, 2017)

ABSTRACT

Tewari R, Joshi A & Agnihotri D 2017. The Glossopteris flora of Manuguru Area, Godavari Graben, Telangana, India. The Palaeobotanist 66(1): 17–36.

First comprehensive record of the Glossopteris flora from the Barakar Formation of the Prakasham Khani open cast mines II and IV of Manuguru Area, Godavari Graben, comprising detailed systematic analyses of the plant fossils is provided. The assemblage is well preserved and represented by pteridophytes and gymnosperms. Pteridophytes comprise *Phyllotheca australis* and equisetalean axes of the order Equisetales, whereas, gymnosperms include *Gangamopteris cyclopteroides* and seventeen species of *Glossopteris–Glossopteris angustifolia, G. arberi, G. communis, G. cordatifolia, G. damudica, G. gigas, G. indica, G. lanceolatus, G. longicaulis, G. mohudaensis*, *G. musaefolia, G. oldhamii, G. pseudocommunis, G. rhabdotaenioides, G. stenoneura, G. taenioides* and *G. tenuifolia* belonging to the order Glossopteridales and several leaves of *Noeggerathiopsis hislopi* besides *Cordaites* sp. of Cordaitales. Northern genus *Cordaites* is recorded for the first time from the area and substantiates earlier records from the Lower Gondwana horizons of India. The present study adds to the knowledge of the Glossopteris flora of India, especially that of the Godavari Graben from where the plant fossil records are scanty. The floral assemblage compares fairly well with those recorded from the Barakar Formation of other Lower Gondwana basins of peninsular India.

Key–words—Glossopteris flora, Early Permian, Barakar Formation, Prakasham Khani OCM, Manuguru area, Godavari Graben, Telangana.

भारत में तेलंगाना की गोदावरी द्रोणिका के मनुगुरू क्षेत्र की ग्लोसोप्टेरिस वनस्पति–जात

रजनी तिवारी, अरूण जोशी एवं दीपा अग्निहोत्री

सारांश

पादप जीवाश्मों के विस्तृत क्रमबद्ध विश्लेषण सन्निहित मनुगुरू क्षेत्र, गोदावरी द्रोणिका की प्रकाशम खनि विवृत द्वितीय व चतुर्थ खानों की बराकार शैलसमूह से प्राप्त ग्लोसोप्टेरिस वनस्पति–जात का प्रथम व्यापक अभिलेख प्रस्तुत किया गया है। समुच्चय सुपरिरक्षित है तथा प्टेरिडोफाइटों व अनावृतबीजियों से रूपायित है। टेरिडोफाइट *फायल्लोथेका ऑस्ट्रेलिस* और इक्वीसीटालीज कोटि के इक्वीसीटालीन अक्ष सन्निहित, जबकि अनावृतबीजी *गंगामॉप्टेरिस सायक्लोप्टेरॉड्स* तथा *ग्लोसोप्टेरीडेलीज* कोटि की *ग्लोसोप्टेरिस अंगुष्टिफोलिया, जी. अर्बेरी, जी. कम्युनिस, जी. कार्डेटीफोलिया, जी. डमुडिका, जी. जाइगस, जी. इंडिका, जी. लेन्सियोलेटस, जी. लॉगीकॉलिस, जी. मॉहुडेन्सिस, जी. म्यूज़िफोलिया, जी. ओल्डहमयाई, जी. स्युडोकम्युनिस, जी. रेब्डोटेनियॉइड्स, जी. स्टेनोन्युरा, जी. टेनिऑइड्स, जी. टेनुईफोलिया – ग्लोसोप्टेरिस* की सत्तरह जाति तथा कार्डेटेलीज की *कार्डेटीज* जाति के अलावा *नोएग्गेराथिऑप्सिस हिस्लोपियाई* की विविध पत्तियॉं हैं। क्षेत्र से पहली बार उत्तरी *कॉर्डाइटीज* अभिलिखित किया गया है तथा भारत के अधो गोंडवाना क्षितिजों से मिले पहले अभिलेख को पुख्ता करता है। मौजूदा अध्ययन–विषय भारत की ग्लोसोप्टेरिस वनस्पतिजात के ज्ञान में इज़ाफ़ा करता है, खासतौर से गोदावरी द्रोणिका जहां पादप अभिलेख अल्प हैं। प्रायद्वीपीय भारत में अन्य अधो गोंडवाना द्रोणियों के बराकार शैलसमूह से यह समुच्चय पूर्णतः तुलना करता है।

सूचक शब्द—ग्लोसोप्टेरिस वनस्पतिजात, प्रारंभिक पर्मियन, बराकार शैलसमूह, प्रकाश्म खनि ओ सी एम, मनुगुरू क्षेत्र, गोदावरी द्रोणी, तेलंगाना।

INTRODUCTION

STUDIES on Glossopteris flora of India have been carried out from different Lower Gondwana basins namely Damodar, Wardha, Satpura, Mahanadi, South Rewa and Rajmahal (Lakhanpal *et al.*, 1976; Chandra & Tewari, 1991; Maheshwari & Bajpai, 1992; Bajpai & Singh, 1994; Singh & Maheshwari, 2000; Tewari, 2007, 2008; Srivastava & Agnihotri, 2010; Singh *et al.*, 2011, 2012). However, reports of megafossils from the Godavari Graben are sporadic. Earlier records by King (1881) and Lakshminarayana and Murty (1990) include the genera *Phyllotheca, Glossopteris*, *Vertebraria* and *Araucarioxylon* but without any description. Tewari and Jha (2006), for the first time provided systematic descriptions of plant megafossils from bore core 726 of Manuguru Area and recorded equisetalean axes and other taxa like *Gangamopteris* sp., *Glossopteris indica, G. subtilis, G. sastrii, Glossopteris* sp., *G. tenuinervis* and *Glossopteris* sp. from the Barakar Formation and *Noeggerathiopsis hislopi, Glossopteris communis* and *G. stenoneura* from the Raniganj Formation. Later Joshi *et al.* (2015) recorded *Vertebraria indica* from the Barakar Formation of the Goutham Khani

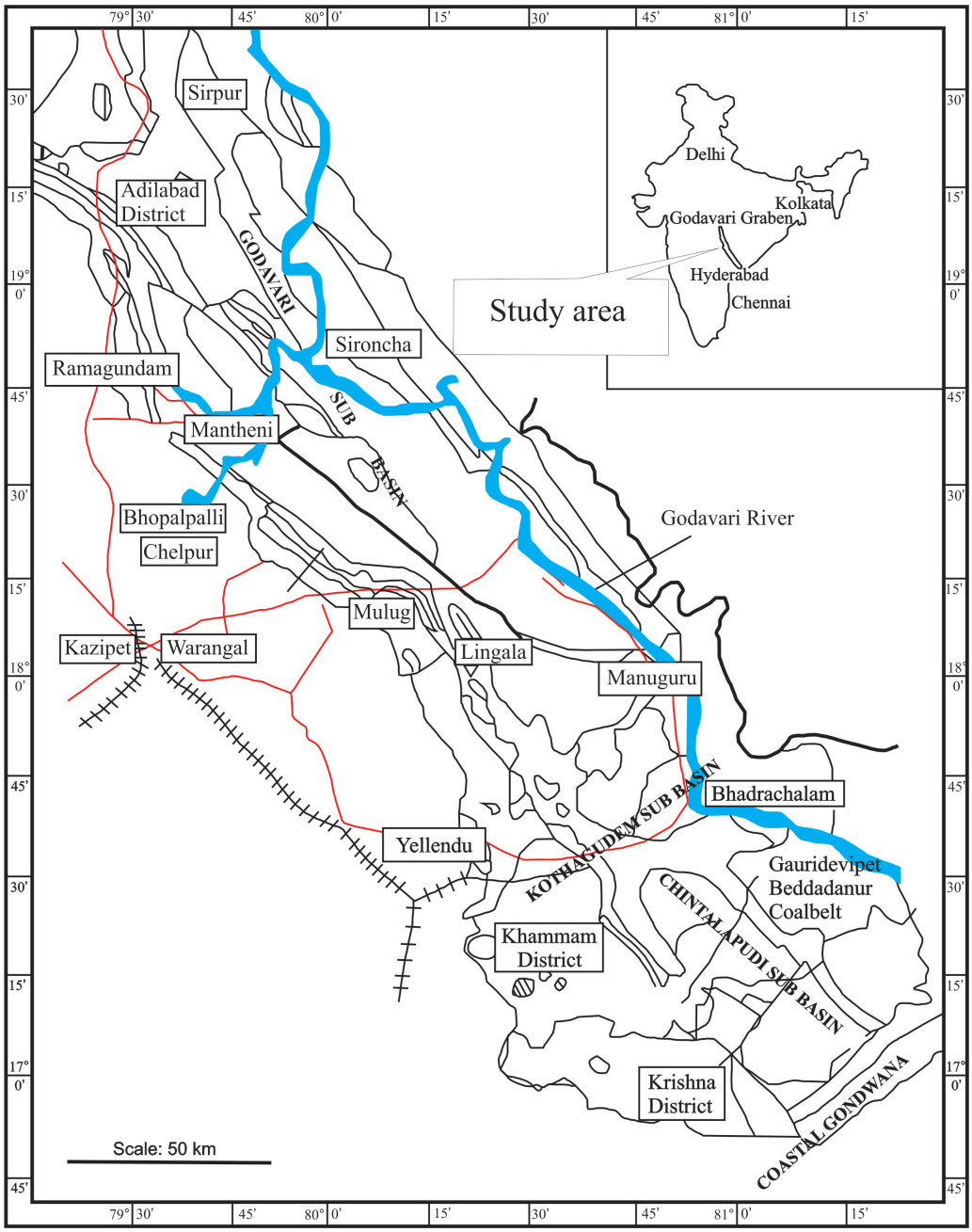

Fig. 1—Map of Godavari Graben showing sub–basins (modified from Jha & Aggarwal, 2012).

open cast mine, Kothagudem Area, Godavari Graben. Except for *Glossopteris indica,* all the other plant taxa, namely, *Phyllotheca australis, Glossopteris angustifolia, G. arberi, G. communis, G. cordatifolia, G. damudica, G. gigas, G. lanceolatus, G. longicaulis, G. mohudaensis*, *G. musaefolia, G. oldhamii, G. pseudocommunis, G. rhabdotaenioides, G. taenioides, G. tenuifolia, Noeggerathiopsis hislopi* and *Cordaites* sp. are new records from the Barakar Formation of Godavari Graben and substantiate the existing information on Glossopteris flora from this area.

GEOLOGY OF THE AREA

Pranhita–Godavari Basin, a NNW–SSE trending basin deposit, covering an area of 17000 sq km (latitudes 16°38' N and 19°32' N and longitudes 79°12' E and 81°39' E) rests on Precambrian platform and follows the course of Pranhita and Godavari rivers over a strike length of 470 km. On the basis of the tectonic setting and lithic fill, the Pranhita–Godavari Basin is subdivided into Godavari, Kothagudem, Chintalapudi and Krishna–Godavari coastal sub–basins (Fig. 1). 350 km long south eastern sector lying in the districts of Adilabad, Karimnagar, Warangal and Khammam of Telangana State is referred to as the Godavari Valley Coalfield. The continuity of coal seams is broken and missing at places due to faulting, and therefore, different coal bearing areas are generally treated as different coal belts. Manuguru–Cherla is one such coal belt, located in the south eastern part of the Godavari Valley Coalfield. Prakasham Khani open cast mines II and IV are included in this belt. The river Godavari divides the area into Cherla sector in the north and Manuguru sector in the south. The coal belt is located on the west of river Godavari and extends over a strike length of about 13 km from its bank on the north–east to Bugga in the south west. A complete sequence of Lower Gondwana formations is exposed in this coal belt. The stratigraphic succession in the Manuguru Area is given in Table 1 (after SCCL, 2011).

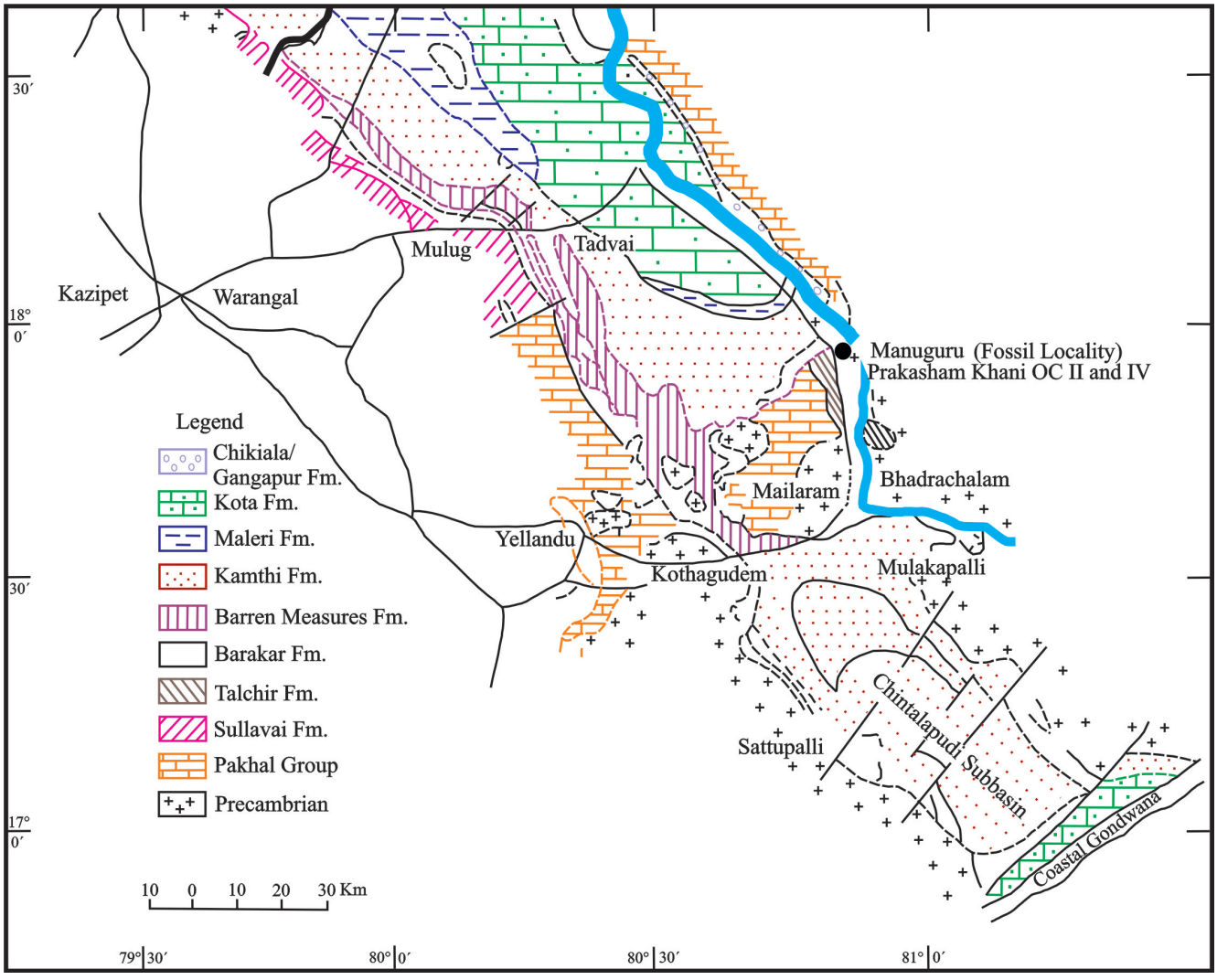

Fig.2—Location map of study area.

Geological Age	Group	Formation	General Lithology	Thickness (m)
-	-	-	Soil cover & alluvium	-
		Kamthi	Coarse to pebbly, ferruginous sand stones with clays/and few thin coal seams/bands.	250 m+
P E R M I A N	Lr. G O N D W A N A	Barakar	Medium to coarse grained feldspathic sandstones, shales/clays and regionally persistent coal seams.	300 m+
		Talchir	Boulder bed, pebble beds, green sand stone, greenish shales, etc.	130 m+
		…….Unconformity……..		
Pre-Cambrian	Pakhal		Shales, Quartzites, dolomites, etc.	

Table 1—Lithostratigraphic succession of the Manuguru–Cherla Coalbelt (after SCCL–2011).

MATERIALS AND METHOD

There are ten coal seams in the Prakasham Khani OCM namely, I Seam, H1 Seam, H2 Seam, B3 Seam, H3 Seam, H4T Seam, Thick Seam, Index Seam, Split Seam 1 and Split Seam 2 in descending order. The plant fossils were collected from the Thick Seam (Barakar Formation) of the Prakasham Khani open cast mines II and IV lying between north latitudes 17°56'29" and 17°59'12" and east longitudes 80°46'13" and 80°49'11" (Figs 2, 3a, 3b), near the Manuguru Village, a Mandal headquarter in Khammam District of Telangana. The Thick Seam overlies the Index Seam and is overlain by the H4T Seam. It is 16.69 m thick in OCM II and 7.13 m thick in OCM IV. The specimens were photographed and systematically analysed for morphotaxonomical study. Various morphological characters like shape of leaf, nature of apex, base, margin, midrib and venation pattern have been considered. Lawrence (1955), Melville (1969) and Chandra and Surange (1979) have been followed for exact description. The specimens were studied with the help of a hand lens and low power binocular microscope Leica DFC 290 under incident light for morphotaxonomical characters. On the basis of taxonomical differences, the specimens were categorized under different species. All the specimens are deposited in the repository of the Birbal Sahni Institute of Palaeosciences (Statement No. 1423), Lucknow, India.

SYSTEMATICS

Order—EQUISETALES

Genus—PHYLLOTHECA Brongniart, 1828

Type species—***Phyllotheca australis*** Brongniart, 1828

Phyllotheca australis Brongniart, 1828

(Pl. 1.1−4)

Description—Two specimens preserved on the same shale sample show axes and well preserved complete and incomplete leaves attached in a whorl at nodes. A few leaves lie scattered on the shale. The axes of the specimens measure 2.1−2.8 cm in length and 1−2 mm in width with well preserved nodes and internodes; ridges and furrows are seen in one of the specimens (40857B). In the other specimen (40857A), though the nodes and internodes are distinct, ridges and furrows are faint. Internodes are 0.9−1 cm long and nodes are 0.3 mm wide. Ridges are about 0.4 mm apart and apparently continuous across the nodes. About 8−16 leaves radiate out from the rim of a cup−like structure formed by the fusion of bases of the leaves at nodes. The cup is 1−2 mm wide.

PLATE 1
(Scale bar = 1 cm)

1–4. *Phyllotheca australis* Brongniart, 1828.
1. BSIP Specimen No. 40857A.
2. One of the leaves of Specimen No. 40857A enlarged to show an acuminate apex (indicated by an arrow).
3. BSIP Specimen No. 40857B.
4. Leaves from specimen in 3 enlarged to show striations perpendicular to midrib.

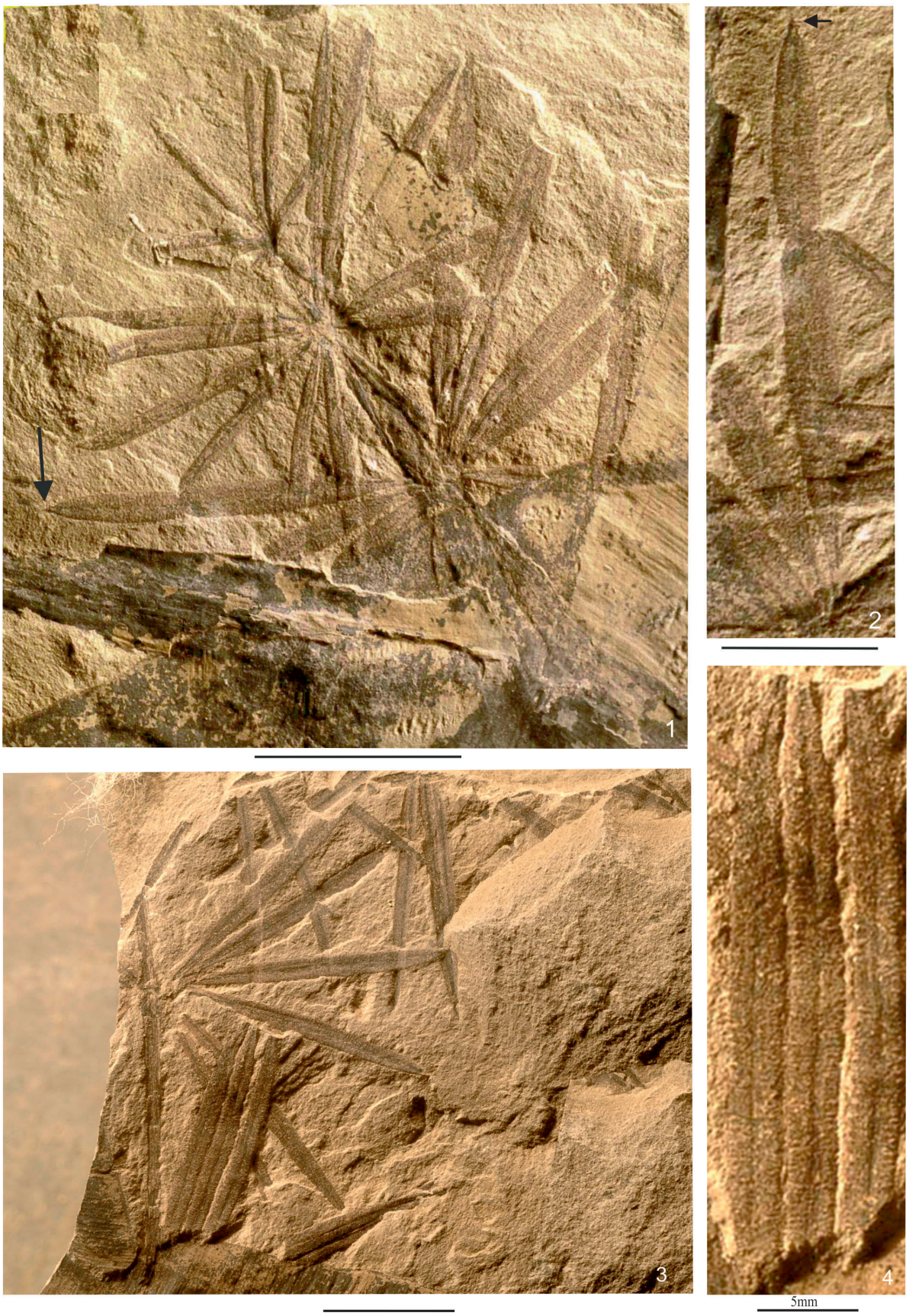

PLATE 1

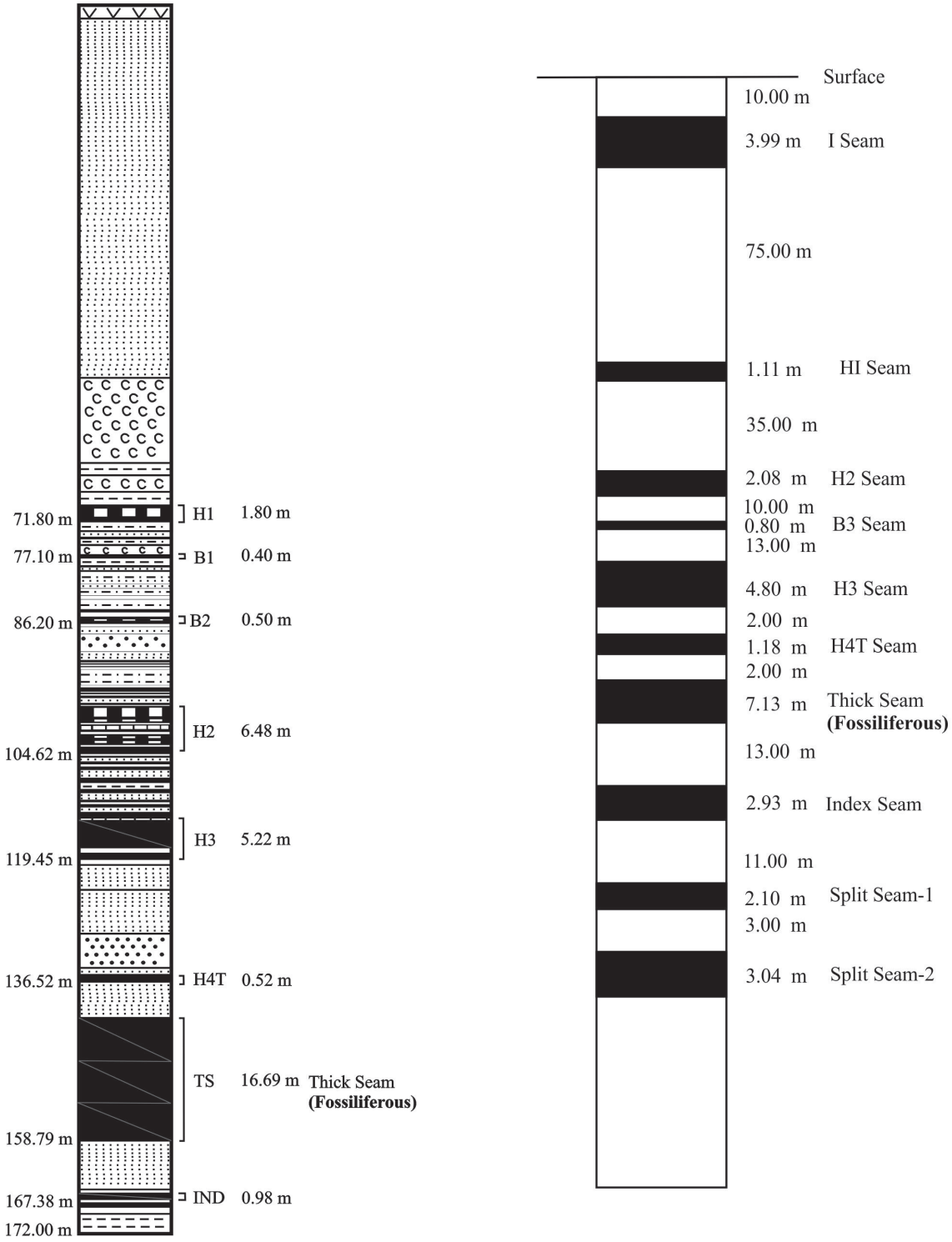

Fig. 3a & b—Lithologs of Prakasham Khani OCP II and IV.

PLATE 2

(Scale bar = 1 cm)

1. Equisetalean axes. BSIP Specimen No. 40858.
2, 3. *Gangamopteris cyclopteroides* Feistmantel, 1879, BSIP Specimen nos. 40859, 40860.
4. *Glossopteris angustifolia* Brongniart, 1828, BSIP Specimen No. 40867.
5, 6. *Glossopteris arberi* Srivastava, 1956, BSIP Specimen nos. 40863, 40861.

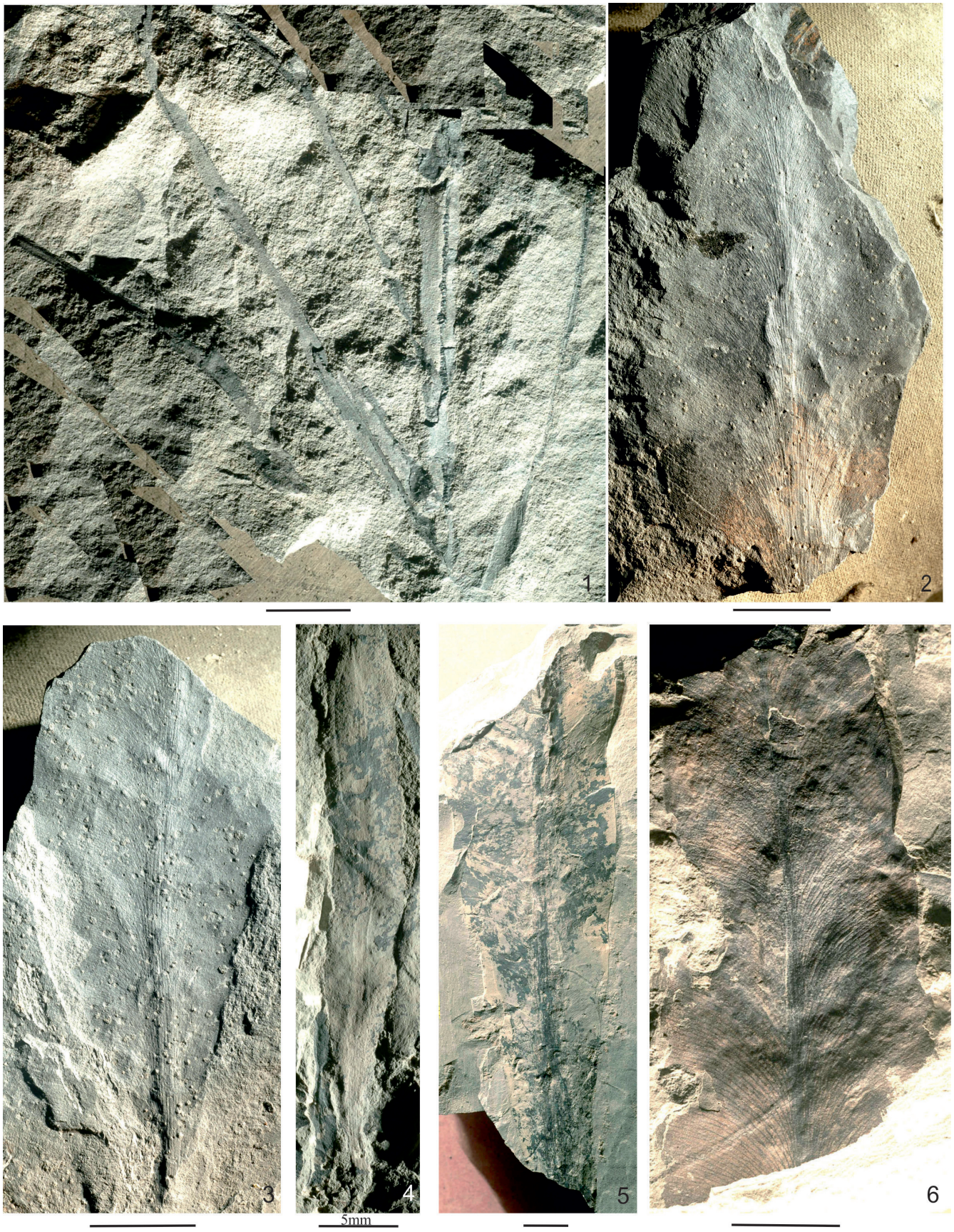

PLATE 2

Leaves are acicular, linear, needle−like with an acuminate apex, measure 1−2 cm in length and 1−2 mm in width, and are arranged in a whorl. Each leaf shows a distinct, persistent, 0.2−0.3 mm wide midvein extending up to the tip (indicated by arrow in Pl. 1.2). Numerous striations, placed perpendicular to the midvein are present on leaves (Pl. 1.4). Rare cross connections are present.

Remarks—The present specimens closely resemble the specimens described as *Phyllotheca indica* (Bunbury, 1861, Pl. 3, figs 6−9, Pl. 4, figs 1, 2; Pant & Kidwai, 1968, Pl. 30, figs 10–15, text–figs 1 A−C, 2 A−D, 3 A−D; Chandra & Rigby, 1981, Pl. 1, fig.1; Srivastava, 1992, Pl. 1, fig. 1) in having similar leaf sheath and leaf morphology. However, *Phyllotheca indica* was merged by Maheshwari (1968) with *Phyllotheca australis* on the basis of similarity of diagnostic characters. The specimens described here are also similar to those described by Maheshwari (1968, Pl. 1, figs. 1−4) in general leaf morphology and leaf cups except for the absence of axes. Further, the striations of leaves are not recorded by Maheshwari. The leaves of the present specimens are also comparable with *Phyllotheca westensis* described by Anderson and Anderson (1985, Pl. 41, figs.13, 14) in having pointed tips. However, midvein is absent in leaves of *P. westensis*.

Number of specimens—Two.

Equisetalean axes

(Pl. 2.1)

Description—There are eight leafless axes in the collection. The length of the axes varies from 5.5 to 17 cm and width varies from 0.9 to 1.6 cm. The impressions of the axes do not show nodes. However, ridges and furrow can be seen on the axes. The ridges are 8−12 in number and are 0.9 to 1 mm apart from each other.

Number of specimens—Eight.

Order—GLOSSOPTERIDALES

Genus—GANGAMOPTERIS McCoy, 1875

Type species—*Gangamopteris angustifolia* McCoy, 1875

Gangamopteris cyclopteroides Feistmantel, 1879

(Pl. 2.2, 3)

Description—There are three incomplete specimens in the present collection. Leaves are asymmetrical, basal portions contracted, measure 12 cm long and 5.5 cm broad at widest part, apices and bases are not present, margin entire and midrib absent. Median region of leaves occupied by thick sub–parallel veins in the basal portion. During upward course these veins diverge to form secondary veins. Lateral veins emerge at angles of about 5°−12° from the base and arch backwards to meet margin. Margin not distinct, therefore, it is difficult to measure the exact angle at which the veins meet the margin. Veins dichotomize and anastomose to form linear, oblong and polygonal meshes in middle part ranging from 4−6 mm in length and 0.6−1 mm in breadth. However, meshes are linear, narrow and 6−8 mm long and 0.5−0.8 mm broad towards margin. The vein density is 12−16 per cm in the middle portion of leaves and 16−20 per cm near margin. Some gall−like structures can be seen over the leaf surface which might be due to insect activity.

Remarks—Gangamopteris cyclopteroides is the most common species of the genus *Gangamopteris* McCoy 1875. Present specimens resemble *G. cyclopteroides* described by Feistmantel (1879, Pl. 7, figs 1, 2, Pl. 8, Pl. 9, figs 1, 2, 3, 4, 6, Pl. 10, fig. 3, Pl. 11, figs 2, 3, 4, Pl. 12, figs 2, 3, Pl. 13, figs 1, 5, Pl. 26, fig. 1, Pl. 27, figs 1, 2, 3, 1a, 1b), Tewari and Srivastava (2000a, Pl. 1, fig. 5), Maithy *et al*. (2006, Pl. 1, fig. 2) and Singh *et al*. (2006b, Pl. 2, fig. 2) in venation pattern.

Number of specimens—Three.

Genus—GLOSSOPTERIS Brongniart, 1828

Type species—*Glossopteris browniana* Brongniart, 1828

Glossopteris angustifolia Brongniart, 1828

(Pl. 2.4)

Description—One incomplete leaf impression is present in the collection. Leaf is narrow, linear, measures 8.3 cm in length and 1.4 cm in width, extreme apex and base are not preserved, margin entire. Midrib is distinct, striate and 1.7 mm wide at the base. Secondary veins arise at angles of about 42º−45º from the midrib, after dichotomization and anastomoses form narrow, elongate, hexagonal, 2−3.5 cm long and 0.5−0.7 cm broad meshes throughout the lamina.

Remarks—The present specimen resembles *Glossopteris angustifolia* described by Chandra and Surange (1979; Pl. 3, fig. 6, Pl. 13, fig. 5, Pl. 18, figs 7, 11, Pl. 42, fig. 2) and

PLATE 3
(Scale bar = 1 cm)

1. *Glossopteris communis* Feistmantel, 1876, BSIP Specimen No. 40862.
2. *Glossopteris cordatifolia* Feistmantel, 1879, BSIP Specimen No. 40857C.
3. *Glossopteris damudica* Feistmantel, 1890, BSIP Specimen No. 40864.
4, 5. *Glossopteris gigas* Pant and Singh, 1971, BSIP Specimen nos. 40865A, 40865B.

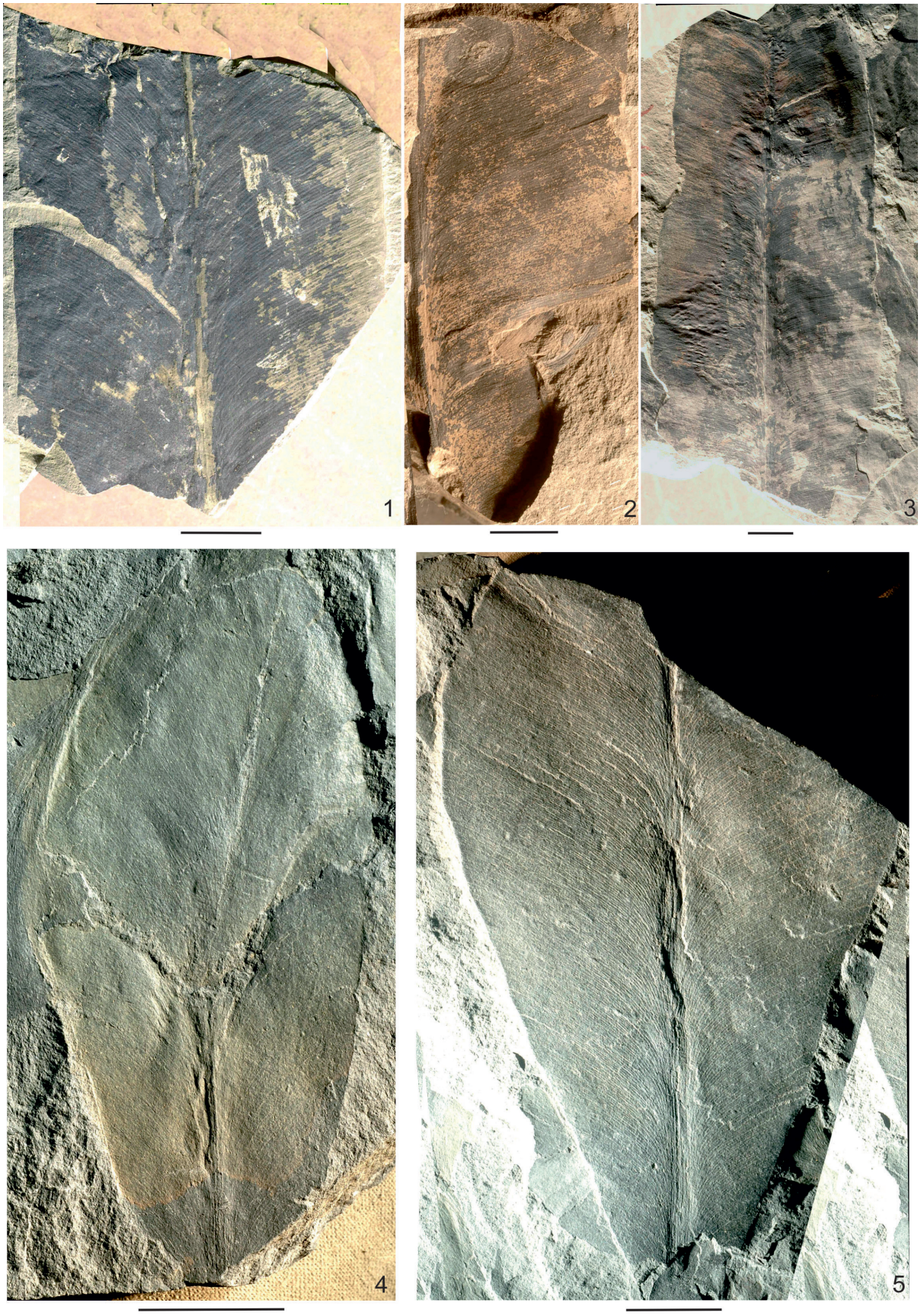

PLATE 3

Feistmantel (1881; Pl. 27, figs 6, 8, 9, 11, 12, 13, Pl .34, fig. 3; 1886; Pl. 5, fig. 5) from the Raniganj Formation of Raniganj Coalfield, West Bengal in having narrow, linear shape and distinct midrib with narrow, elongate, hexagonal meshes.

Number of specimen—One.

Glossopteris arberi Srivastava, 1956

(Pl. 2.5, 6)

Description—There are three incomplete specimens present in the collection. Leaves measure 8.2−12 cm in length and 1.3−4.5 cm in width, apices and bases are not preserved. The midrib is distinct and striate (with 3−4 striations at the base and 2−3 striations towards the apical part), 3 mm wide at base and 1 mm wide towards the apical part. The secondary veins arise from midrib at acute angles of about 40°−45°, arch backwards and run parallel to meet the margin at angles of 60°−65°.Three to four meshes are formed between the midrib and the margin. Meshes are mostly of uniform size throughout the lamina, arcuate near the midrib and trapezoid elsewhere, elongate and narrow, 3−4 mm long and 0.7−1 mm broad. The vein density is 16−18 per cm near midrib and 18−22 per cm near the margin.

Remarks—The present specimens resemble *Glossopteris arberi* (Srivastava, 1956, Pl. 9, figs 57, 58; Chandra & Surange, 1979, Pl. 7, figs 4−7, Pl. 18, fig. 6) in venation pattern.

Number of specimens—Three.

Glossopteris communis Feistmantel, 1876

(Pl. 3.1)

Description—All the specimens are incomplete. Leaves preserved as impressions, measure 1.8−7 cm in length and 2.2−4.5 cm in width at their widest part which is the middle portion of the preserved specimens. Apices and bases are not preserved, margin is entire. Midrib is broad, distinct, striate and 3−4 mm wide. The secondary veins arise at angles of about 42°−45° from the midrib and after successive dichotomies and anastomoses, form short and broad hexagonal, 3−4 mm long and 0.3−0.7 mm broad meshes near the midrib, and long and narrow meshes 5−7 mm long and 0.2−0.4 mm broad near the margin. The secondary veins meet the margin at angles of about 65°−70°. The vein density is 16−20 per cm near the midrib and 24−26 per cm near the margin.

Remarks—Leaves are identical to *G. communis* (Feistmantel, 1876, Pl. 21, fig. 5; Feistmantel, 1879, Pl. 17, figs 1, 2; Feistmantel, 1882, Pl. 21, figs 13, 14; Chandra & Surange, 1979, Pl. 1, figs 2, 3) in venation pattern.

Number of specimens—Thirty one.

Glossopteris cordatifolia Feistmantel, 1890

(Pl. 3.2)

Description—There is only one incomplete leaf impression in the collection. The leaf is simple and broad, 6.9 cm long and 3.8 cm broad at its widest part which is the middle portion of the specimen. Apical and basal portions not preserved, margin not distinct, midrib strong, distinct, elevated with striations (3−4) and 2−3 mm broad. Secondary veins arise at angles of about 45°−47° from the midrib, curve slightly to reach the margin at angles of about 80°−85°. The secondary veins dichotomise and anastomose to form broad, elongate, deltoid meshes near midrib, and narrower and longer meshes near the margin. Cross–connections are frequent. Meshes are 2−3 mm long and 0.5−1 mm broad near the midrib and 4−5 mm long and 0.4−0.7 mm broad near the margin. The vein density is 14−20 per cm near midrib and 24−30 per cm near the margin.

Remarks—Present specimen resembles *Glossopteris cordatifolia (=feistmantelii,* please see Rigby, 2013 for nomenclature) described by Rigby (1964, Pl. 1), Feistmantel (1882, Pl. 20, fig. 1), Banerjee (1978, Pl. 4, fig. 7), Chandra and Surange (1979, Pl. 5, fig. 3, Pl. 38, fig. 2), Singh *et al*. (1982, Pl. 9, fig. 57, text–fig. 11), Prasad *et al*. (1987, Pl. 4, fig. 16) and Tewari (2007, Pl. 9, fig. 2) in having distinct midrib and similar venation pattern.

Glossopteris damudica Feistmantel, 1879

(Pl. 3.3)

Description—Three incomplete leaf impressions are present in the collection. Leaves measure 6.5−11.5 cm in length and 3.5−5 cm in width at their widest which is the middle part. Leaves elliptical in shape with entire margin, apices and bases are not preserved. Midrib distinct, striate

PLATE 4

(Scale bar = 1 cm)

1, 2. *Glossopteris indica* Schimper, 1869, BSIP Specimen nos. 40868, 40866 .

3. *Glossopteris lanceolatus* Pant & Singh, 1971, BSIP Specimen No. 40869.

4, 5. *Glossopteris longicaulis* Feistmantel, 1879, BSIP Specimen nos. 40870, 40871.

6. *Glossopteris mohudaensis* Chandra and Surange, 1979, BSIP Specimen No. 40872.

7. *Glossopteris musaefolia* Bunbury, 1861, BSIP Specimen No. 40873.

8. *Glossopteris oldhamii* Pant & Singh, 1974, BSIP Specimen No. 40876A.

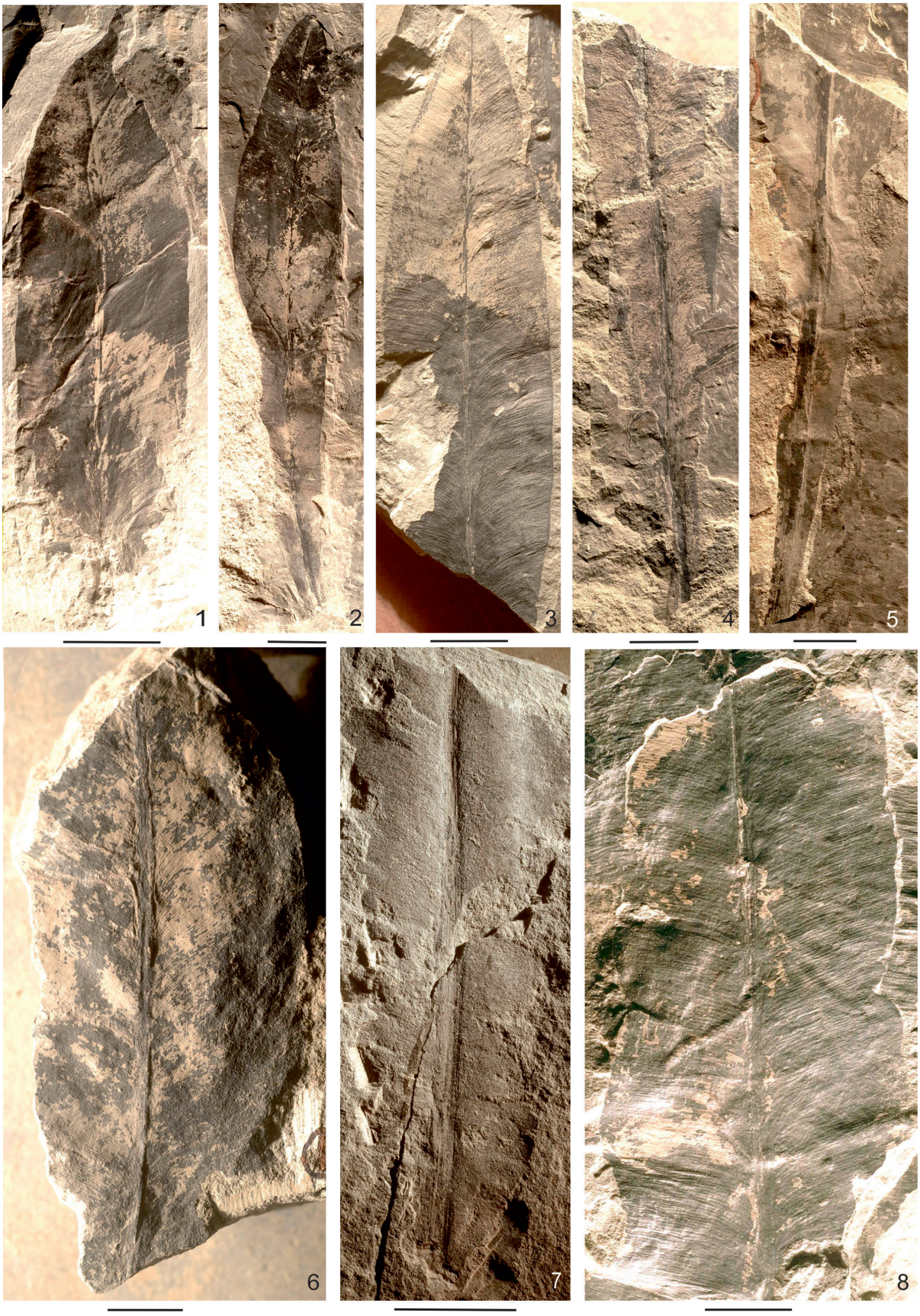

PLATE 4

(2−3 striations) and 2−3 mm broad. Secondary veins arise at angles of 40°−45° from the midrib, arch and meet the margin at angles of about 65°−75°. Meshes are hexagonal in shape, broad and long near midrib (4−5 mm long and 0.5−1 mm broad) and small and narrower near the margin (1.5−2 mm long and 0.2−0.6 mm broad). The vein density is 14−16 per cm near midrib and 20−22 per cm near the margin.

Remarks—Present specimens resemble *Glossopteris damudica* (Feistmantel, 1881, Pl. 20, fig. 2, Pl. 31, figs 1−3, Pl. 32, fig.1; Chandra & Surange, 1979, Pl. 6, fig. 5; Tewari *et al*., 2012, figs 6 C, D) in presence of broad midrib and polygonal meshes.

Number of specimens—Three.

Glossopteris gigas Pant & Singh, 1971

(Pl. 3.4, 5)

Description—There are nine leaves in the collection. Leaves range from 6−20 cm in length and 4−10.3 cm in width at their widest which is generally the middle portion of the leaves. Apex and base are not preserved in any of the specimens, margin entire. Midrib is broad, persistent, striate, measures 3−5 mm wide in lower part and 2−4 mm wide in the upper part of the specimens. The secondary veins arise at angles of about 45°−50° from the midrib and after a short distance, arch and meet the margin at angles of about 75°−85°. During their course, the veins dichotomise and anastomose to form narrow elongate, hexagonal meshes, which measure 3−4 mm in length and 0.5−1 mm in width in well preserved leaves. The vein density is 14−18 per cm near midrib and 16−20 per cm towards the margin.

Remarks—The specimens are similar to *Glossopteris gigas* described by Pant and Singh (1971, Pl. 3, figs 10, 14, text–fig. 2B), Chandra and Surange (1979, Pl. 12, fig. 1, Pl. 16, fig. 6, Pl. 25, fig. 1) and Tewari (2007, Pl. 2, fig. 3, Pl. 3, fig. 2) in general shape, midrib and venation pattern.

Number of specimens—Nine.

Glossopteris indica Schimper, 1869

(Pl. 4.1, 2)

Description—There are twenty six specimens of this species in the collection. Leaves lanceolate in shape with entire margin. Apex is acute and preserved in nine specimens. Base is absent in all the specimens. Leaves measure 6.8−15.2 cm in length and 2.5−3.6 cm in width at their widest part which is the middle portion. Midrib is distinct, persistent, elevated, striate (having 3−4 deep striations) and measures 1−2 mm in width. The secondary veins arise at angles of about 40°−45° from the midrib and after successive dichotomies and anastomoses form polygonal, short and broad meshes near the midrib and narrow–elongate meshes near the margin. The secondary veins meet the margin at angles of about 65°−75°. Meshes measure 2−3 mm long and 0.3−0.5 mm broad near the midrib and 2−3.5 mm long and 0.2−0.4 mm broad near the margin. The vein density is 14−20 per cm near midrib and 18−26 per cm near the margin.

Remarks—Leaves are identical to *Glossopteris indica* (Chandra & Surange, 1979, Pl. 5, fig. 1, Pl. 10, fig. 4, Pl. 15, fig. 11, Pl. 28, fig. 1, Pl. 29, fig. 1; Tewari & Srivastava, 2000a, Pl. 1, fig. 4; Tewari, 2008, Pl. 4, fig. 4) in shape, nature of midrib and venation pattern.

Number of specimens—Twenty six.

Glossopteris lanceolatus Pant & Singh, 1971

(Pl. 4.3)

Description—Upper half of the leaf is preserved. Leaf narrow, oblong in shape, measures 7.9 cm in length and 2.1 cm in width, apex acute, base absent and margin slightly undulating. Midrib striate, 0.7 mm wide and gradually tapers towards apex. Secondary veins arise at about 45° from midrib and after dichotomization and anastomoses, meet the margin at about 85°. Meshes are broad, elongate, 3.5−5 mm long and 0.5−0.6 mm broad near the midrib, and short and narrow, 2−2.5 mm long and 0.3−0.4 mm broad near the margin. Vein density is 17−21 per cm near the midrib and 25−32 per cm near the margin.

Remarks—Present leaf resembles *G. lanceolatus* described by Chandra and Surange (1979, Pl. 7, fig. 2, Pl. 19, fig. 2, Pl. 40, fig. 2) in similar shape and venation pattern.

PLATE 5

(Scale bar = 1 cm)

1. *Glossopteris oldhamii* Pant & Singh, 1974, BSIP Specimen No. 40876B.
2. *Glossopteris pseudocommunis* Pant & Gupta, 1968, BSIP Specimen No. 40874.
3. *Glossopteris rhabdotaenioides* Pant & Singh, 1971, BSIP Specimen Nos 40875A.
4. *Glossopteris stenoneura* Feistmantel, 1877, BSIP Specimen nos .40875B.
5. *Glossopteris taenioides* Feistmantel, 1882, BSIP Specimen No. 40877.
6–8. *Glossopteris tenuifolia* Pant & Gupta, 1968, BSIP Specimen nos. 40878A, 40878B, 40878C.

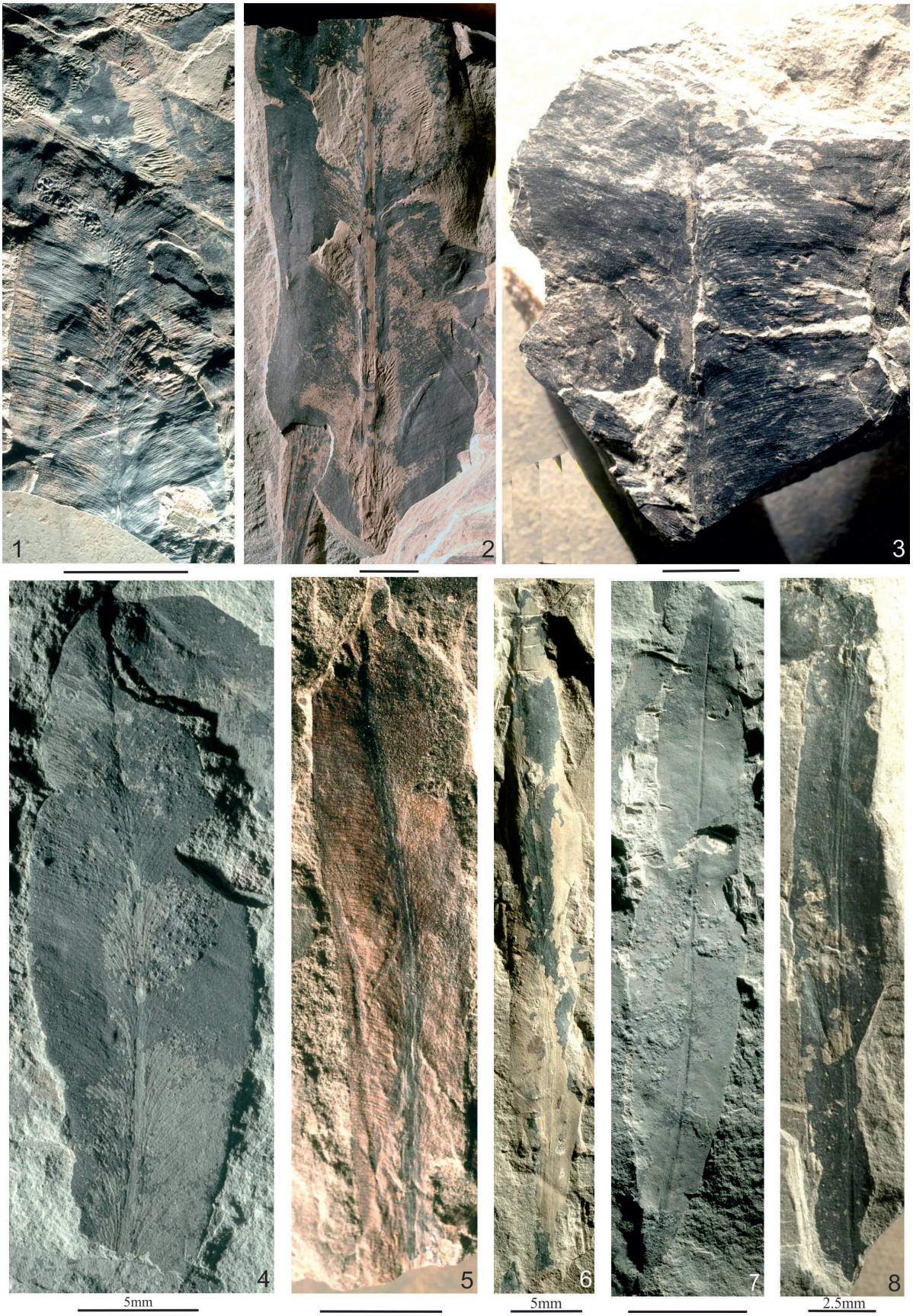

PLATE 5

Glossopteris longicaulis Feistmantel, 1879

(Pl. 4.4, 5)

Description—There are five incomplete leaf impressions in the collection, which measure 8−10 cm in length and 2−3.5 cm in width at their widest, margin entire, midrib strong, elevated and 3 mm broad. Leaves are characterized by long, narrow petiole, measuring about 1.5−1.8 cm in length. Secondary veins arise at angles of about 45°−50° from midrib. Meshes are polygonal in shape, short and broad, 2−3 mm long and 0.5−1 mm broad near midrib, long and narrow, 3−4 mm long and 0.5 mm broad near margin. The vein density is 11−13 per cm near midrib and 14−16 per cm near the margin.

Remarks—The present specimen resembles *Glossopteris longicaulis* (Feistmantel, 1880, Pl. 31, figs 1, 3; Chandra & Surange, 1979; Pl. 1, fig. 4, Pl. 15, fig. 13; Tewari & Srivastava, 2000b; Pl. 1, fig. 5; Tewari 2008, Pl. 4, fig. 8) in presence of petiole, nature of midrib and in venation pattern.

Number of specimens—Five.

Glossopteris mohudaensis Chandra & Surange, 1979

(Pl. 4.6)

Description—There is only one fragmentary leaf in the collection, that measures 7.8 cm in length and 3.8 cm in width at its widest part. Apex and base not preserved. Margin entire. Midrib thick, elevated, distinct, striate (with 2−3 striations). The secondary veins arise at angles of about 45°−60° from midrib and after dichotomising and anastomoses, form hexagonal, narrow, elongate, uniform and 2−3 mm long and 0.2−0.4 mm broad meshes throughout the lamina. The vein density is 18−22 per cm near midrib and 22−26 per cm near the margin.

Remarks—The present specimen is identical to *Glossopteris mohudaensis* (Chandra & Surange, 1979, Pl. 11, fig. 2, Pl. 18, fig. 14, Pl. 46, fig. 2; text–figs 39, B, 51 G) in presence of distinct, broad midrib and narrow–elongate hexagonal meshes. It also resembles *G. mohudaensis* described by Chandra and Prasad (1981, Pl. 3, fig. 24), Chandra and Singh (1992, Pl. 11, fig. 4) and Tewari (2008, Pl. 4, fig. 7) in having almost similar shape, midrib and the venation pattern.

Number of specimen—One.

Glossopteris musaefolia Bunbury, 1861

(Pl. 4.7)

Description—This species is represented by one leaf in the collection. The leaf measures 9 cm in length and 4.2 cm in width at its widest part which is the upper portion of the preserved leaf. Apex and base are not present, margin not entirely preserved. Midrib is strong, broad, distinct and striate (with 3−5 striations), 4 mm wide in preserved lower portion and 2.5 mm wide in the upper portion of the leaf. The secondary veins arise at angles of about 47°−50° from midrib, arch slightly backwards and then travel almost horizontally towards the margin. The veins dichotomise and anastomose to form narrow, elongate and hexagonal 3−6 mm long and 0.7−1 mm broad meshes throughout the lamina. The vein density is 16−18 per cm near the midrib and 16−20 per cm near the margin.

Remarks—The specimen is similar to *Glossopteris musaefolia* described by Bunbury (1861, Pl. 8, fig. 6), Chandra and Surange (1979, Pl. 18, fig. 13), Chandra and Prasad (1981, Pl. 2, fig. 14, Pl. 14, fig. 34, text–figs 3.N, O) and Tewari (2008, Pl. 3, fig. 3) in presence of a distinct, wide midrib and venation pattern.

Glossopteris oldhamii Pant & Singh, 1974

(Pl. 4.8; 5.1)

Description—Four incomplete leaf impressions are present in the collection. Leaves range from 8.9−13 cm in length and 3.2−5 cm in width, shape obovate, apices and bases not preserved, margin entire, midrib striate and 1 mm wide. Secondary veins arise at 40°−45° from the midrib, arch backwards and run straight upto the margin. During their course, secondary veins dichotomize and anastomose to form large, broad, 3.5−4.6 mm long and 0.4−0.5 mm broad meshes near the midrib and narrow, elongate, 6−7.5 mm long and 0.2−0.3 mm broad meshes near the margin. Vein density is 25−29 per cm near the midrib and 20−23 per cm near the margin.

Remarks—Present specimens are identical to *G. oldhamii* described by Chandra and Surange (1979, Pl. 8, fig. 3, Pl. 19, fig. 9, Pl. 37, fig. 1) in similar shape and venation pattern.

Glossopteris pseudocommunis Pant & Gupta, 1968

(Pl. 5.2)

Description—An incomplete specimen is present in the collection. Preserved portion measures 11.5 cm in length and 3.7 cm in width at its widest part. The midrib is distinct, flat, striate, pitted, 4 mm wide at the base and 2 mm wide towards

PLATE 6
(Scale bar = 1 cm)

1. *Cordaites* Unger, BSIP Specimen No. 40880
2, 3. *Noeggerathiopsis hislopi* Feistmantel, 1876, BSIP Specimen Nos 40881**,** 40879.

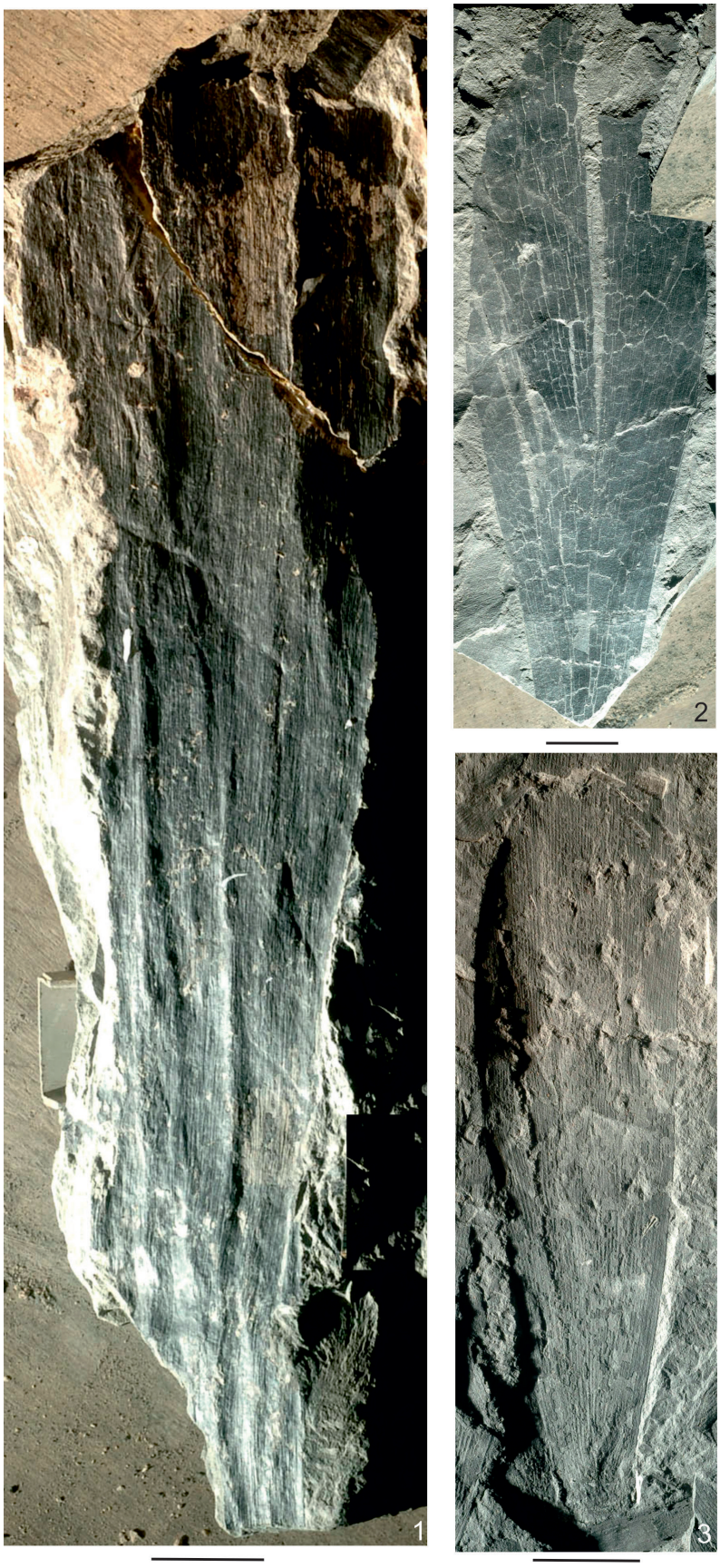

PLATE 6

the apical region. The secondary veins arise from midrib at acute angles (2°−7°), dichotomise, anastomose and arch backwards to meet margin at angles of about 60°−75°. The size of the meshes varies in different parts of the lamina. The shape of the meshes is arcuate near the midrib and mostly trapezoid elsewhere. The vein density is 14−20 per cm near the midrib and 20−33 per cm near the margin.

Remarks—The present specimen resembles *Glossopteris pseudocommunis* described by Maheshwari and Tewari (1992, Pl. 2, figs 1, 2, 6, 7, text–figs. 1 D, E) in shape and venation pattern.

Glossopteris rhabdotaenioides Pant & Singh, 1971

(Pl. 5.3)

Description—There are two fragmentary leaves in the collection measuring 5.2−5.8 cm in length and 3.8−4.2 cm in width at their widest part. Apex and base are not preserved. Margin not entirely preserved. Midrib is thick (2−3 mm), distinct, striate (with 2−3 striations). The secondary veins are perpendicular to the midrib and run straight to meet the margin. Meshes polygonal, elongate and uniform throughout the lamina, measure 3−5 mm in length and 0.2−0.5 mm in width. The vein density is 8−12 per cm near midrib and 16−18 per cm near the margin.

Remarks—The present specimens are identical to *Glossopteris rhabdotaenioides* described by Pant and Singh (1971, Pl. 7, figs 41−45, text–fig. 6, H), Chandra and Surange (1979, Pl. 9, fig. 5, Pl. 13, fig. 1, Pl. 18, fig. 6, Pl. 20, fig. 3, Pl. 33, fig. 1), Tewari and Rajanikanth (2001, Pl. 1, fig.1) and Tewari (2008, Pl. 3, fig. 6) in shape and venation pattern.

Number of specimens—Two.

Glossopteris stenoneura Feistmantel, 1882

(Pl. 5.4)

Description—Only one leaf impression is present in the collection. Leaf measures 5.3 cm in length and 1.8 cm in width, shape spathulate−oblanceolate, apex and base absent, margin entire, midrib flat, 1.5 mm wide in the basal part and 0.5 mm wide in the apical part, Secondary veins arise at 45° from the midrib and meet the margin at 65° after dichotomizing and anastomosing. Meshes are narrow, elongate, 4–5.5 mm long and 0.3–0.5 mm broad throughout the lamina. Vein density is 20–25 per cm.

Remarks—Present leaf is quite similar to *Glossopteris stenoneura* Feistmantel as described by Chandra and Surange (1979, Pl. 1, figs 7, 8, Pl. 15, fig. 8, Pl. 17, figs 1, 4), Srivastava and Tewari (2001, Pl. 2, fig. 2), Tewari and Srivastava (2000a, Pl. 1, fig. 3), Tewari and Srivastava (2000b, Pl. 1, fig. 2) and Tewari *et al.* (2012, figs 6Q, 6R) in shape and venation pattern.

Glossopteris taenioides Feistmantel, 1882

(Pl. 5.5)

Description—There are two incomplete specimens in the collection. Preserved portions of the specimens measure 5.5 to 6 cm in length and 1.1 to 1.4 cm in width in the middle part. The leaves are narrow, oblong, ribbon like, with an entire margin; apex is acute and base absent. The midrib is distinct, broad, striate lengthwise (with 3−4 striations at the base and 2−3 striations near the apex), 1 mm wide at base and 0.4 mm wide near the apex. The secondary veins arise from midrib at angles of about 50°−55° and after successive dichotomies, meet the margin at an angle of about 90°. Two to three meshes are present between the midrib and the margin. The shape of meshes is arcuate near the midrib and mostly trapezoid elsewhere. Meshes are short and broad, 2−3 mm long and 0.5−1 mm broad near midrib and narrow, 3−4 mm long and 0.3−0.5 mm broad near margin. The vein density is 18−20 per cm near midrib and 24−26 per cm near the margin.

Remarks—The present specimens resemble *Glossopteris taenioides* described by Feistmantel (1882, Pl. 21, fig. 4) and Chandra and Surange (1979, Pl. 4, fig. 6, Pl. 18, fig. 5; Pl. 43, fig. 3, text–figs 26 D, d) in narrow, oblong, ribbon–like shape, broad and strong midrib and venation pattern.

Number of specimens—Two.

Glossopteris tenuifolia Pant & Gupta, 1968

(Pl. 5.6−8)

Description—Four incomplete specimens are present in the collection, preserved portions measure 6 to 11.8 cm in length and 0.5−1.9 cm in width at their widest part. Leaves apparently linear in shape, apical and basal portions are not preserved, margin entire. Midrib broad, strong, elevated with striations (3−4 striations). The secondary veins arise at angles of about 40°−45°, slightly arch backwards and meet the margin at angles of about 70°−75° after dichotomizing and anastomosing, meshes narrow, elongate, hexagonal, 3−4 mm long and 0.5−1 mm broad near midrib and much narrower, 4−5 mm long and 0.3−0.5 mm broad near the margin. The vein density is 18−20 per cm near the midrib and 22−24 per cm near the margin.

Remarks—Present leaves are identical to *Glossopteris tenuifolia* (Pant & Gupta, 1968, Pl. 20, fig. 14, Pl. 21, fig. 15, text–fig. 2; Chandra & Surange, 1979, Pl. 6, figs 1, 2, Pl. 15, fig. 10, Pl. 17, fig. 10, Pl. 42, figs 1, 6; Tewari & Srivastava, 2000b, Pl. 1, fig. 5; Tewari, 2007, Pl. 2, figs 4, 5, Pl. 4, fig. 1; Tewari, 2008, Pl. 2, figs 5, 9, Pl. 3, fig. 4, Pl. 4, fig. 5; Tewari *et al.*, 2012, figs. 7 C, D) in shape and venation pattern.

Number of specimens—Four.

Name of taxa	Lower Gondwana basins of India					
	Damodar	Mahanadi	Wardha	Satpura	South Rewa	Rajmahal
†*Phyllotheca australis*	*					
Equisetalean axes	*	*	*	*	*	*
†*Gangamopteris cyclopteroides*	*	*	*	*	*	
Gangamopteris sp. (in Tewari & Jha 2006)						
†*Glossopteris angustifolia*	*	*	*	*	*	*
†*Glossopteris arberi*		*	*	*	*	
†*Glossopteris communis*	*	*	*	*	*	*
†*Glossopteris cordatifolia*		*			*	
†*Glossopteris damudica*	*	*	*	*	*	*
†*Glossopteris gigas*	*	*		*	*	
†*Glossopteris indica*	*	*	*	*	*	*
†*Glossopteris lanceolatus*		*				
†*Glossopteris longicaulis*	*	*	*	*		
†*Glossopteris mohudaensis*		*				
†*Glossopteris musaefolia*						
†*Glossopteris oldhamii*		*				*
†*Glossopteris pseudocommunis*	*					
†*Glossopteris rhabdotaenioides*	*					*
Glossopteris sastrii		*			*	
†*Glossopteris stenoneura*	*	*	*		*	
Glossopteris subtilis		*				
†*Glossopteris taenioides*		*			*	
†*Glossopteris tenuifolia*		*	*		*	
Glossopteris sp. cf. *tenuinervis*		*				
Glossopteris sp. (in Tewari & Jha 2006)						
Vertebraria indica	*	*		*	*	
†*Cordaites* sp.	*	*		*	*	
†*Noeggerathiopsis hislopi*	*	*	*	*	*	*

Table 2—Distribution of plant fossil taxa of Godavari Valley Coalfield in the Barakar Formation of other lower Gondwana basins of India.
† Present study

Order—CORDAITALES

Genus—CORDAITES Unger, 1850

Type species—*Cordaites borassifolius* (Sternberg) Unger, 1850

***Cordaites* sp.**

(Pl. 6.1)

Description—The only specimen present in the collection measures 23 cm in length and 4.7 cm in width at the widest which is the middle part of the leaf. Apex and extreme basal portion not preserved. Leaf is oblanceolate in shape with entire margin and shows distinct thick and thin veins. Thick veins are elevated, measure 0.5−1.5 mm in width and

dichotomize 1−2 times further upwards. Distance between two thick veins is 5−6 mm. In between the two thick veins about 3−4 thin veins are present.

Remarks—The genus *Cordaites* was instituted by Unger (1850). Basically, *Cordaites* is a northern hemisphere genus and is common in the flora of Angara, Eurameria and Cathaysia. *Cordaites* shows close resemblance with Gondwanan *Noeggerathiopsis in* presence of parallel dichotomizing veins. Seward (1917), Seward and Sahni (1920), Meyen (1969), Rigby *et al.* (1980) considered that both these genera were morphologically similar and transferred *Noeggerathiopsis* to *Cordaites.* Feistmantel (1879) and Zeiller (1902) for the first time, observed the differences between the two leaves with the presence of thick and thin veins in *Cordaites* and their absence in *Noeggerathiopsis*. Pant and Verma (1964) studied in detail the morphological and cuticular features of *Cordaites* and *Noeggerathiopsis* and found that leaves of *Cordaites* are generally larger in size with ovate or ribbon–like shape, presence of interstitial fibres in between thick veins and stomata arranged in regular rows, while, the leaves of *Noeggerathiopsis* are lanceolate–spathulate in shape with parallel dichotomizing veins and stomata arranged in one to many ill–defined longitudinal rows. Chandra and Srivastava (1991) recorded a large number of both the types of leaves from the Chirimiri Coalfield, Son Basin and instituted a new species, *i.e. Cordaites dumanii* for the leaves with distinct thick and thin veins. Later, Srivastava (1992) and Singh *et al.* (2007) recorded *Cordaites* in association with *Noeggerathiopsis*. The present specimen resembles closely with the genus *Cordaites* Unger 1850 in presence of thin veins in between distinct thick veins. It also shows close resemblance with *Cordaites* sp. described by Srivastava (1992; Pl. 4, figs 4−6) from the Barakar Formation, Raniganj Coalfield, West Bengal. However, it differs from *C. dumanii* described by Chandra and Srivastava (1991; Pl. 2, figs 1−3) from the Karharbari Formation of Chirimiri Coalfield, Son Basin, Madhaya Pradesh and specimens described by Singh *et al.* (2007; Pl. 3, fig. 4) from the Barakar Formation of Ib River Coalfield, Odisha in having more thin veins in between the thick veins. Additionally, the specimen described herein, differs in its large size.

GENUS—NOEGGERATHIOPSIS Feistmantel, 1876

Type species—***Noeggerathiopsis hislopi*** (Bunbury) Feistmantel, 1879

Noeggerathiopsis hislopi (Bunbury) Feistmantel, 1879

(Pl. 6.2, 3)

Description—Five leaves are present in the collection. They are spathulate in shape with obtusely rounded apex, narrow base and entire margin. The lamina is wider towards the upper part. Size of the leaves ranges from 4.3 to 14 cm in length and 1.4 to 1.8 cm in width at base and 1.6 to 3.8 cm in width near apex. Veins arise from base, run parallel for a very short distance of about 0.7 to 1 cm, divert at angles of about 5°−7° to meet the margin. The veins dichotomize 2−3 times to form secondary veins towards the upper part. Anastomoses of veins are absent. The vein density near the leaf base is 14−18 per cm and 14−16 per cm near the apex.

Remarks—The present leaves are identical to *Noeggerathiopsis hislopi* (Feistmantel, 1879, Pl. 19, fig. 5, Pl. 19, figs 1−6, Pl. 20, fig. 1; Maithy, 1965, Pl. 1, figs 1−3; Srivastava & Tewari, 2002, Pl. 1, figs 1−3) in spathulate shape and dichotomizing parallel veins.

Number of specimens—Five.

DISCUSSION

The Glossopteris flora is well known from almost all the major Lower Gondwana basins of India. However, plant fossil records from the Godavari Graben are so far, sporadic (Tewari & Jha, 2006 and references cited, therein). Tewari and Jha (2006) recorded fragmentary specimens of *Glossopteris indica, G. subtilis, G. sastrii, Glossopteris* sp. cf. *G. tenuinervis* and *Glossopteris* sp. from the bore core 726 of Manuguru Area belonging to the Barakar Formation. The present floral assemblage from the Barakar Formation of Manuguru Area, comprises the orders Equisetales (pteridophytes) and, Glossopteridales and Cordaitales (gymnosperms). Equisetales includes *Phyllotheca australis* and equisetalean axes. Glossopteridales dominates the assemblage and is represented by two species of *Gangamopteris–G. cyclopteroides* and *Gangamopteris* sp. and twenty one species of *Glossopteris* namely, *G. angustifolia*, *G. arberi*, *G. communis*, *G. cordatifolia*, *G. damudica*, *G. gigas, G. indica, G. lanceolatus, G. longicaulis, G. mohudaensis, G. musaefolia, G. oldhamii, G. pseudocommunis, G. rhabdotaenioides, G. sastrii, G. stenoneura, G. subtilis, G. taenioides, G. tenuifolia, Glossopteris* sp. cf. *tenuinervis* and *Glossopteris* sp., and *Vertebraria indica* (both earlier records and present study). Cordaitales is represented by *Cordaites* sp. and *Noeggerathiopsis hislopi*. Except for *Glossopteris indica* which was earlier recorded by Tewari and Jha (2006) along with *G. subtilis, G, sastrii, Glossopteris* sp. cf. *G. tenuinervis* and *Glossopteris* sp. from the Barakar Formation of Manuguru Area, all the taxa described here are new and substantiate the existing information on Glossopteris flora from the area. The floral assemblage as a whole is broadly comparable with those of the Barakar Formation of the Damodar (Srivastava, 1992; Srivastava & Tewari, 1996; Tewari & Srivastava, 1996), Mahanadi (Singh & Chandra, 1996; Singh *et al.*, 2006a, b, 2007; Goswami *et al.*, 2006), Son (Singh *et al.*, 2011; Saxena *et al.*, 2016), South Rewa (Agnihotri *et al.*, 2016), Wardha (Tewari *et al.*, 2012), Rajmahal (Maheshwari & Prakash, 1965) and Satpura (Srivastava & Agnihotri,

2009, 2013) basins of India (Table 2). In the present study, the assemblage is mainly dominated by the *Glossopteris* species. *Glossopteris musaefolia* is reported for the first time from the Barakar Formation. The earlier records of the species are from the late Permian beds of India. Other species like *Glossopteris cordatifolia*, *G. lanceolatus*, *G. oldhamii*, *G. pseudocommunis*, *G. rhabdotaenioides*, *G. sastrii* and *G. subtilis* show their rare occurrence in the Barakar Formation. The occurrence of these species indicates their appearance in the Barakar Formation and their continuation in the late Permian Raniganj and Kamthi formations where they are present in abundance. The dominance of *Glossopteris* leaves and complete absence of gymnospermous seeds (associated or dispersed) suggest that the flora is mainly comparable with that of the upper part of the Barakar Formation (Srivastava, 1997). First record of northern genus *Cordaites* from the area supports the occurrence of mixed flora in Gondwana.

Acknowledgements*—We thank Prof. Sunil Bajpai, Director, Birbal Sahni Institute of Palaeosciences (BSIP) for providing necessary facilities to carry out this research work and granting permission to publish the same (BSIP/RDCC/93/2016–17). Mr K. Joshuva Jaidev, GM, Exploration Division, Mr K. Ravi Shankar, General Manager (HRD) and Mr Gurumurthy, Singareni Collieries Company Ltd. Kothagudem are thanked for granting permission to visit the colliery and for providing necessary help during field trip. Sincere thanks are due to Dr Ashwini Kumar Srivastava, Former Scientist G and Dr Kamaljeet Singh, Scientist F of BSIP for critically reviewing the manuscript and helpful suggestions. We also thank Mr Shekhar, Senior Surveyor, Manuguru Area, Kothagudem, for helping in preparation of litholog and in plant fossil collection, Dr S. Suresh Kumar Pillai, Scientist C, for helping in collection of samples and Mr Pradeep Mohan, Technical Officer 'D', Birbal Sahni Institute of Palaeosciences for photography of the specimens.*

REFERENCES

Agnihotri D, Tewari R, Pillai SSK, Jasper A & Uhl D 2016. Early Permian Glossopteris flora from Sharda Open Cast Mine, Sohagpur Coalfield, Shahdol District, Madhya Pradesh. Palaeobotanist 65 (1): 97–107.

Anderson JM & Anderson HM 1985. Palaeoflora of southern Africa. Prodromus of South African megafloras Devonian to Lower Cretaceous. A.A. Balkema, Rotterdam.

Bajpai U & Singh KJ 1994. Indian Gondwana Annotated Synopsis III. Permian Megaplants—2, Birbal Sahni Institute of Palaeobotany, Lucknow, 82 pp.

Banerjee M 1978. Genus *Glossopteris* Brongniart and its stratigraphic significance in the Palaeozoic of India. Part 1–A Revisional study of some species of the genus *Glossopteris*. Bulletin of Botanical Society of India 32: 81–125.

Brongniart A 1828. Histoire des végétaux fossils ou recherché botaniques et géologiques sur les végétaux renfermés dans les diverse couches du globe. Prodomus d'une histoire des vegetaux fossils 1, Dufour & D' Ocagne, Paris, 488 pp.

Bunbury CJF 1861. Notes on a collection of fossil plants from Nagpur, central India. Quarterly Journal of Geological Society of London 17: 325–346.

Chandra S & Prasad MNV 1981. Fossil plants from the Kamthi Formation of Maharashtra and their biostratigraphic significance. Palaeobotanist 28/29: 99–121.

Chandra S & Rigby JF 1981. Lycopsid, Sphenopsids and Cycadaceous remains from the Lower Gondwana of Handapa, Orissa. Geophytology 11: 214–219.

Chandra S & Singh KJ 1992. The genus *Glossopteris* from the Late Permian beds of Handapa, Orissa, India. Review of Palaeobotany and Palynology 75: 183–218.

Chandra S & Srivastava AK 1991. Occurrence of Cordaitalean like foliage in the Lower Gondwana flora of India. Acta Palaeobotanica 31: 5–15.

Chandra S & Surange KR 1979. Revision of the Indian Species of *Glossopteris*. Monograph 2. Birbal Sahni Institute of Palaeobotany, Lucknow, 291pp.

Chandra S & Tewari R 1991. A Catalogue of Fossil Plants from India—B. Palaeozoic and Mesozoic Megafossils. Part 2, Birbal Sahni Institute of Palaeobotany, Lucknow, 81 pp.

Feistmantel O 1876. Notes on the age of some fossil floras in India—VII. Flora of the Jabalpur Group in South Rewah, near Jabalpur, and in the Satpura Basin. Records of the Geological Survey of India 9: 125–129.

Feistmantel O 1877. Notes on fossil floras in India XI. Note on plant fossils from Barakar District (Barakar Group). Records of Geological Survey of India 10: 73–74.

Feistmantel O 1879. The fossil flora of Lower Gondwana–The flora of Talchir–Karharbari beds. Memoirs of Geological Survey India Series 12(1): 1–48.

Feistmantel O 1880. The fossil flora of Gondwana System (Lower Gondwana). II. The flora of Damuda–Panchet Division. Memoirs of Geological Survey of India. Palaeotonlogia Indica 12(2): 1–77.

Feistmantel O 1881. The fossil flora of the Gondwana System. The flora of the Damuda–Panchet Division. Memoirs of the Geological Survey of India, Palaeontologia indica 12, 3(3): 78–149.

Feistmantel O 1882. The fossil flora of the Gondwana System in India—1. The fossil flora of the South Rewah Gondwana Basin. Memoirs of the Geological Survey of India, Palaeontologia indica 12, 3(4): 1–52.

Feistmantel O 1886. The fossil flora of the Gondwana System IV. The fossil flora of the some of the coalfields in western Bengal. Memoirs of Geological Survey of India. Palaeontologia indica 4(2): 1–71.

Feistmantel O 1890. Geological and palaeontological relations of the coal and plant–bearing beds of Palaeozoic and Mesozoic age in eastern Australia and Tasmania; with special reference to the fossil flora. Memoirs of the Geological Survey of New South Wales, Palaeontology 3, 1–185.

Goswami S, Singh KJ & Chandra S 2006. Palaeobotany of Gondwana basins of Orissa State, India: A bird's eye view. Journal of Asian Earth Sciences 28: 218–233.

Jha N & Aggarwal N 2012. Permian–Triassic palynostratigraphy in Mailaram area, Godavari Graben, Andhra Pradesh, India. Journal of Earth System Science 121: 1257–1285.

Joshi A, Tewari R, Agnihotri D, Pillai, SSK & Jain RK 2015. Occurrence of *Vertebraria indica* (Unger) Feistmantel, 1877–an evidence for coal–forming vegetation in Kothagudem area, Godavari Graben, Telangana. Current Science 108 (3): 330–333.

King W 1881. The geology of Pranhita–Godavari Valley. Memoirs of Geological Society of India 18: 150–311.

Lakhanpal RN, Maheshwari HK & Awasthi N 1976. A Catalogue of Indian Fossil Plants. Birbal Sahni Institute of Palaeobotany, Lucknow: 1–318.

Lakshminarayana G & Murty KS 1990. Stratigraphy of the Gondwana formations in the Chintalpudi sub–basin, Godavari Valley, Andhra Pradesh. Journal of Geological Society of India 36: 13–25.

Lawrence GHM 1955. An Introduction to Plant Taxonomy. The MacMillan Company, New York, 179 pp.

Maheshwari HK 1968. Studies in the Glossopteris flora of India 34. On a record of *Phyllotheca australis* Brongniart from Jharia Coalfield, Bihar. Palaeobotanist 16: 167–169.

Maheshwari HK & Bajpai U 1992. Ginkgophyte leaves from the Permian Gondwana of Rajmahal Basin. Palaeontographica B224: 131–149.

Maheshwari HK & Prakash G 1965. Studies in the Glossopteris flora of India 21. Plant megafossils from the Lower Gondwana exposures along Bansloi River in Rajmahal hills, Bihar. Palaeobotanist 13: 115–128.

Maheshwari HK & Tewari R 1992. Epidermal morphology of some Indian species of the genus *Glossopteris* Brongniart. Palaeobotanist 39: 338–380.

Maithy PK 1965. Studies in the Glossopteris flora of India 20. *Noeggerathiopsis* and allied remains from the Karharbari beds, Giridih Coalfield, India. Palaeobotanist 13: 94–100.

Maithy PK, Bindal CM, Bhushan SK, Sharma S, Banerji DC & Kumar G 2006. Lower Gondwana plant fossils from Arunachal Pradesh, Lesser Himalaya and their age. Journal of Geological Society of India 68: 316–326.

McCoy F 1875. Geological Survey of Victoria, Prodromus of the Palaeontology of Victoria, Decade II: 11–13.

Melville R 1969. Leaf venation patterns and the origin of the angiosperms. Nature 224: 121–125.

Meyen SV 1969. New data on the relationship between Angara and Gondwana Late Palaeozoic floras. Gondwana Stratigraphy IUGS Symposium Buenos Aires, 141–157.

Pant DD & Gupta KL 1968. Cuticular structure of some Indian Lower Gondwana species of *Glossopteris* Brongniart–Part 1. Palaeontographica 124 B: 45–81.

Pant DD & Kidwai P 1968. On the structure of stems and leaves of *Phyllotheca indica* Bunbury, and its affinities. Palaeontographica B121: 102–121.

Pant DD & Singh KB 1971. Cuticular structure of some Indian Lower Gondwana species of *Glossopteris* Brongniart Part III. Palaeontographica 135 B: 1–40.

Pant DD & Singh RS 1974. On the stem attachment of *Glossopteris* and *Gangamopteris* leaves. Part 2. Structural features. Palaeontographica 147 B: 42–73.

Pant DD & Verma BK 1964. The cuticular structure of *Noeggerathiopsis* Feistmantel and *Cordaites* Unger. Palaeontographica 115: 21–44.

Prasad B, Shukla VD & Maithy PK 1987. Megafossils of the Lower Gondwana succession in Pachhwara Coalfield, Bihar. Gondwana Geological Magazine 2: 17–29.

Rigby JF 1964. The Lower Gondwana flora of the Illawara coal measures, Wollongong, New South Wales, Australia. *22* International Geological Congress, India*,* Part–9: 17–5.

Rigby JF 2013. Priority of *Glossopteris cordatifolia* Feistmantel 1890 over *G. feistmantelii* Rigby 1964, occurring in the Permian of India. Palaeobotanist 62: 211–212.

Rigby JF, Maheshwari HK & Schopf JM 1980. Revision of Permian plants collected by J.D. Dana during 1839–1840 in Australia. Geological Survey of Queensland, 1–21.

Saxena A, Singh KJ, Shabbar H & Prakash A 2016. Macrofloral assemblage from the Early Permian Barakar Formation of Singrauli Coalfield, Son–Mahanadi Basin, India. Palaeobotanist 65: 139–150.

Schimper WP 1869. Traite´ de Pale´ontologie ve´ge´tale—1, J. b. Bailliere et Fils, Paris, 738 pp.

Seward AC 1917. Fossils plants 3. Cambridge University Press, Cambridge.

Seward AC & Sahni B 1920. Indian Gondwana Plants: A Revision. Memoirs of Geological Society of India, new series 7: 1–55.

Singh G, Maithy PK & Bose MN 1982. Upper Palaeozoic flora of Kashmir Himalaya. Palaeobotanist 30: 185–232.

Singh KJ & Chandra S 1996. Plant fossils from the exposures near Gopal Prasad Village, Talchir Coalfield, Orissa with remarks on the age of the bed. Geophytology 26: 69–75.

Singh KJ, Goswami S & Chandra S 2006a. Megafloral assemblage similar to Karharbari biozone from the Talchir Coalfield of Mahanadi Basin, Orissa. Journal of Geological Society of India 68: 277–287.

Singh KJ, Goswami S & Chandra S 2006b. The genus *Glossopteris* from the Lower Gondwana formations of Ib–River Coalfield, Orissa, India. Journal of Palaeontological Society of India 51: 81–107.

Singh KJ, Goswami S & Chandra S 2007. Occurrence of Cordaitales from Lower Gondwana sediments of Ib–River Coalfield, Orissa, India: An Indian scenario. Journal of Asian Earth Sciences 29: 666–684.

Singh KJ, Goswami S and Srivastava G 2011. Palaeodiversity in the genus *Glossopteris* from the Lower Gondwana rocks of the Korba Coalfield, Chhattisgarh State, India. Journal of the Palaeontological Society of India 56: 39–59.

Singh KJ, Saxena A & Goswami S 2012. Palaeobiodiversity of the Lower Gondwana rocks in the Korba Coalfield, Chhattisgarh, India and observations on the genus *Gangamopteris* McCoy. Palaeobotanist 61(1): 145–163.

Singh SM & Maheshwari HK 2000. On the species of genus *Glossopteris* from Barakar Formation of Karanpura and Bokaro coalfields, India. Palaeobotanist 49: 409–441.

Srivastava AK 1992. Plant fossil assemblages from the Barakar Formation of Raniganj Coalfield, India. Palaeobotanist 39: 281–302.

Srivastava AK 1997. Late Palaeozoic floral succession in India. Proceeding XIII, International Congress of Carboniferous and Permian. Krakow, Poland: 264–272.

Srivastava AK & Agnihotri D 2009. Palaeobotanical perspectives of Satpura Gondwana Basin, Madhya Pradesh. Earth System Sciences (Editors–Kumar A, Kushwaha RAS & Thakur Balesh) 2: 581–595.

Srivastava AK & Agnihotri D 2010. Upper Permian plant fossil assemblage of Bijori Formation: A case study of Glossopteris flora beyond the limit of Raniganj Formation. Journal of the Geological Society of India 76: 47–62.

Srivastava AK & Agnihotri D 2013. Coal seam correlation in an Indian Gondwana Coalfield. International Journal of Coal Geology 113: 88–96.

Srivastava AK & Tewari R 1996. Plant fossils from the Barakar Formation, Auranga Coalfield, Bihar. Geophytology 26: 83–88.

Srivastava AK & Tewari R 2001. Lower Gondwana plant fossils from Barren Measures of Jharia Coalfield, Bihar, India. Proceedings of National Seminar on recent advances in Geology of Coal and Lignite basins of India, Calcutta, 1997, GSI special publication 54: 127–134.

Srivastava AK & Tewari R 2002. Morphological and cuticular studies of Permain *Noeggerathiopsis*–leaves. Geophytology 32: 83–89.

Srivastava PN 1956. Studies in the Glossopteris flora of India–4. *Glossopteris*, *Gangamopteris* and *Palaeovittaria* from the Raniganj Coalfield. Palaeobotanist 5: 1–45.

Tewari R 2007. The Glossopteris flora from the Kamptee Coalfield, Wardha Basin, Maharashtra, India. Palaeontographica B 277: 43–64.

Tewari R 2008. The genus *Glossopteris* Brongniart from the Kamthi Formation of Camp IV area, Wardha Valley Coalfield, Wardha Basin, Maharashtra, India. Journal of Palaeontological Society of India 53: 19–30.

Tewari R & Jha N 2006. Occurrence of plant mega and microfossils of Barakar and Raniganj formations of Manuguru Area, Godavari Graben, Andhra Pradesh. Journal of Geological Society of India 67: 101–112.

Tewari R & Rajanikanth A 2001. Occurrence of Glossopteris flora, Pisdura Nand–Dongargaon sub–Basin. Palaeobotanist 50: 411–414.

Tewari R & Srivastava AK 1996. Plant fossils from the Barakar Formation, Jharia Coalfield, Bihar. Geophytology 25: 35–39.

Tewari R & Srivastava AK 2000a. Plant fossils assemblage from the Talchir Formation, Auranga Coalfield, Bihar, India. Palaeobotanist 49: 23–30.

Tewari R & Srivastava AK 2000b. Plant fossils from Bhareli Formation of Arunachal Pradesh, North–East Himalaya, India. Palaeobotanist 49: 209–217.

Tewari R, Pandita SK, Agnihotri D, Pillai SSK & Bernardes–De–Oliveira MEC 2012. An Early Permian Glossopteris flora from the Umrer Coalfield, Wardha Basin, Maharashtra, India. Alcheringa 36(3): 355–371.

Unger F 1850. Genera et species planetarium fossilium. Vienna: 1–627.

Zeiller R 1902. Observation sur quelques plantes fossiles des Lower Gondwanas. Memoirs of Geological Survey of India, Palaeontologia Indica 2: 1–40.