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Macrofloral assemblage from the Early Permian Barakar Formation of Singrauli Coalfield, Son–Mahanadi Basin, India

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ABSTRACT

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A well preserved macroflora belonging to early Permian (Artinskian) Lower Barakar Formation has been reported for the first time from the Bina Colliery in Singrauli Coalfield, Son–Mahanadi Basin. The floral assemblage mostly represented by leaves belong to two orders Glossopteridales and Cordaitales and three genera, namely *Gangamopteris*, *Glossopteris* and cf. *Noeggerathiopsis*. Many ill–preserved impressions representing scale leaves, seeds, fertile structures, branching axes/roots and stem casts have also been found in this assemblage. The macroflora is completely devoid of the groups Lycopodiales, Sphenophyllales, Filicales, Pinales, Ginkgoales, Equisetales and Cycadales. Their absence signifies that vegetated area might not be adequately cool and humid to facilitate the growth of these shade loving plants.

Key–words—Macroflora, Glossopterid, Barakar Formation, Singrauli Coalfield, Son–Mahanadi Basin.

सिंगरौली कोयला क्षेत्र, सोन–महानदी द्रोणी, भारत के प्रारंभिक पर्मियन बराकार शैलसमूह से प्राप्त दीर्घपादप समुच्चय

अंजु सक्सेना, कमलजीत सिंह, हुसैन शब्बर एवं आनंद प्रकाश

सारांश

सिंगरौली कोयला क्षेत्र, सोन–महानदी द्रोणी में बीना कोयला–खदान से प्राप्त प्रारंभिक पर्मियन (अर्टिन्सकियन) अधो बराकार शैलसमूह की एक सुपरिरक्षित दीर्घ पादप समूह को पहली बार प्रस्तुत किया गया है। पादप समुदाय मुख्यतः दो समूहों ग्लॉसॉप्टेरीडेल्स व कार्डेटल्सज की पत्तियों व तना संचकाश्म जो तीन वंश नामतः *गैंगमॉप्टेरिस* एवं *नोएग्गेराथिऑप्सिस* से रूपायित है। इनके अतिरिक्त, इस समुच्चय में बहुत से खराब ढ़ंग से परिरक्षित शल्क–पत्रों, बीजों, उर्वर संरचनाएं, शाखित अक्षों/जड़ों व तना संचकाश्म के संपीडाश्म भी मिले हैं। दीर्घ पादप समूह में लायकोपोडिएल्स, स्फीनोफायल्लेल्स, फिलिकेल्स, पाईनेल्स, गिंगोएल्स, इक्वीसीटेल्स एवं सायकेडेल्स समूह पूर्णतः अनुपस्थित है। उनकी अनुपस्थिति द्योतक है कि वनस्पति आवृत क्षेत्र इन छाया प्रिय पादपों की सुगम वृद्धि के लिए पर्याप्त रूप से शीत एवं आर्द्र नहीं रहा होगा।

सूचक शब्द—दीर्घ पादप समूह, ग्लॉसॉप्टेरीड, बराकार शैलसमूह, सिंगरौली कोयला क्षेत्र, सोन–महानदी द्रोणी।

INTRODUCTION

THE Singrauli Coalfield lies in the north–western part of Son–Mahanadi Master Basin and spreads in the states of Uttar Pradesh and Madhya Pradesh. The coalfield has ten opencast collieries of which coal–bearing sequences of nine collieries (Dudhichua, Jayant, Kakri, Bina, Krishnashilla, Amlohri, Khadia, Block B and Nigahi) belong to the Barakar

Formation whereas Jhingurdah Colliery is in Raniganj Formation. All the nine collieries of Barakar Formation have three coal seams, i.e. the lowermost Turra Seam, middle Purewa Bottom and the uppermost Purewa Top.

The coalfield has been investigated for its palynological and petrological aspects in the past by many workers (Trivedi, 1950; Bhardwaj & Sinha, 1969a, b; Pareek, 1969, 1970; Sinha, 1969, 1972; Tiwari, 1969, 1971; Tiwari & Srivastava, 1984; Tiwari & Ram–Awatar, 1989; Mishra & Singh, 1990; Singh & Mishra, 1991; Vijaya *et al.*, 2012; Singh & Singh, 2014; Saxena *et al.*, 2015). However, it has not been investigated thoroughly for the megafloral studies. Barring the initial investigations by Lele, 1966 and Lele *et al.*, 1968 who reported the glossopterid mega plantfossils in the Talchir and Barakar sediments exposed in the eastern part of the coalfield, and a recent study from the Raniganj Formation of the Jhingurdah Colliery (Singh & Saxena, 2015) no other megafloral studies have been carried out so far. However, the famous Nidpur beds (non–coal bearing strata) belonging to Panchet Formation (Pali Formation) of early Triassic Period, and exposed in the

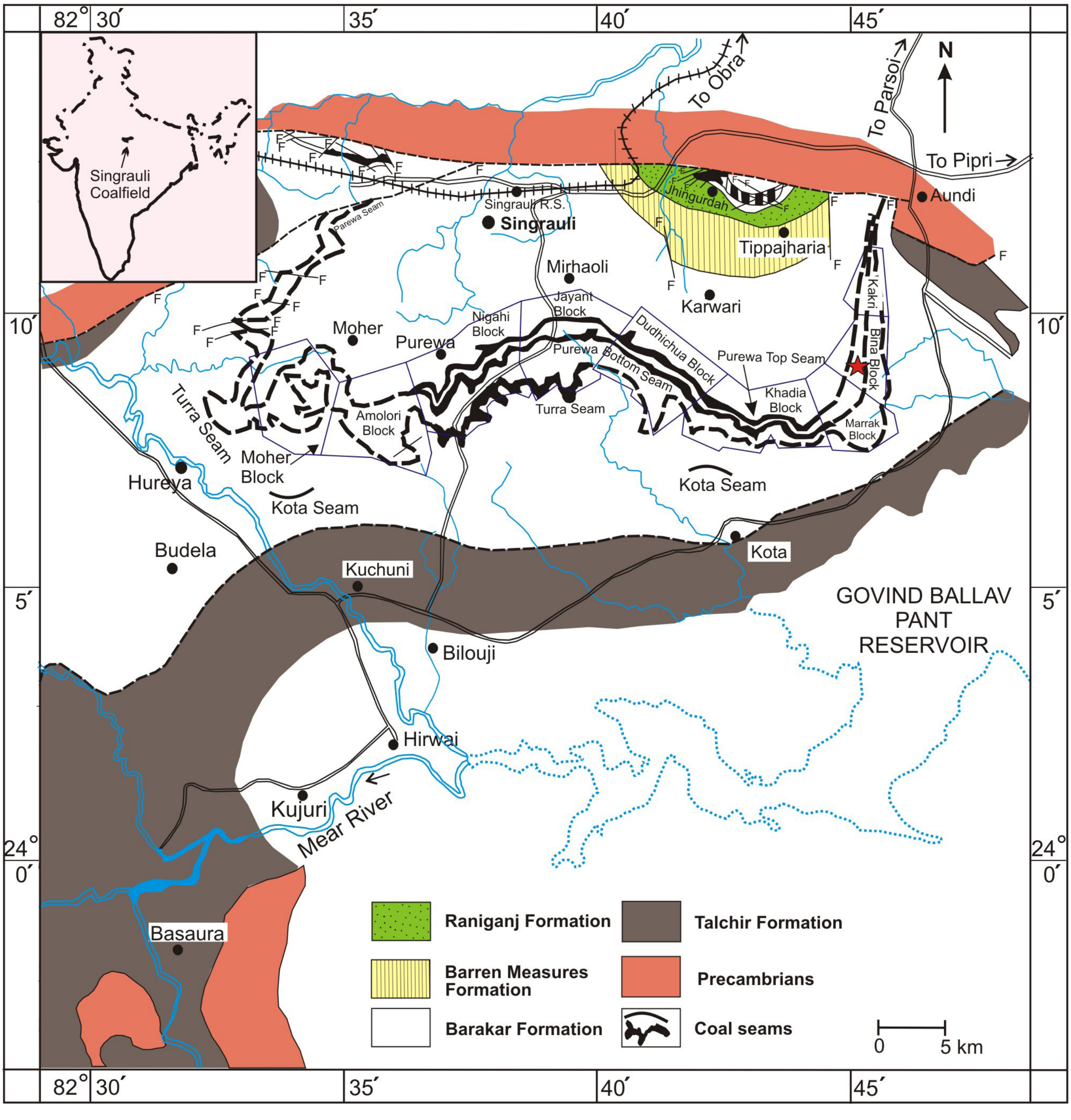

Fig. 1— Location Map of the Singrauli Coalfield showing Bina Colliery (after Raja Rao, 1983).

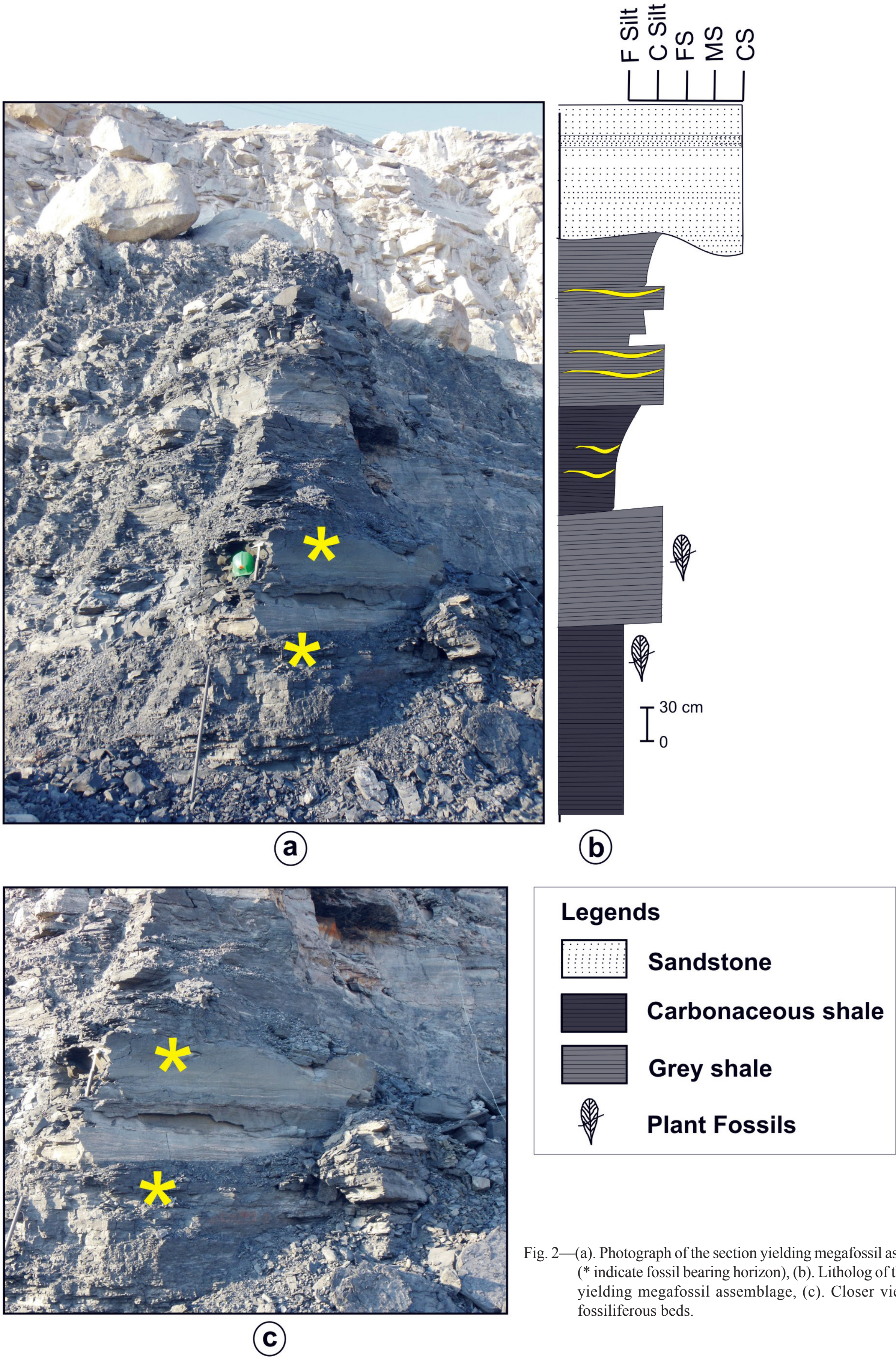

Fig. 2—(a). Photograph of the section yielding megafossil assemblage (* indicate fossil bearing horizon), (b). Litholog of the section yielding megafossil assemblage, (c). Closer view of the fossiliferous beds.

Age	Formation / Group	Thickness	General Lithology
Recent			Alluvium
Cretaceous	Basic intrusive		Dolerite dykes and sills
Late Triassic	Parsora (Mahadeva)	500 m +	Medium– to coarse–grained ferruginous quartzose sandstone
Early Triassic	Pali (Panchet)	700 m +	Greenish yellow to reddish yellow, medium– to coarse–grained sandstone with variegated siltstone and clay
Late Permian	Raniganj	215–400 m	Fine– to medium–grained dirty to buff coloured subarkosic to feldspathic wacke with alternation of thin lamination of grey and carbonaceous shale along with impersistent coal seams
Middle Permian	Barren Measures	110–300 m	Dark brown to brownish yellow to greenish grey, medium– to coarse–grained flaggy sandstone with thin grey clay bands in between
Early Permian	Barakar	325–550 m	Dirty white fine– to coarse–grained sub–arkosic to arkosic sandstone along with siltstone, shale, carbonaceous shale and coal seams
Early Permian	Talchir	75–230 m	Dark greenish grey to grey shale, fine–grained sandstone diamictite, siltstone pebbly sandstone and boulder bed
——Unconformity——			
Precambrian	Mahakoshal		Granite, gneiss, quartzite, phyllite, schist and pegmatite

Table 1— General stratigraphic succession of Singrauli Coalfield (after GSI unpublished report, in Vijaya *et al.* 2012).

west of Singrauli main sub–basin are the most explored and studied rocks in terms of macrofossil studies in this Coalfield (Bhowmik & Das, 2008, 2012; Bhowmik & Parveen, 2008, 2009, 2012; Bose & Srivastava, 1970, 1971, 1972, 1973; Chandra & Maheshwari 1988; Pant & Basu, 1973, 1977, 1978, 1979; Srivastava, 1969, 1971, 1974, 1979, 1988).

The present paper deals with the systematic studies of glossopterid assemblage recovered from the coal bearing sequence of Purewa Bottom seam of the Barakar Formation of Bina Colliery. The complete megafossil assemblage comprises of three genera, namely *Gangamopteris*, *Glossopteris* and cf. *Noeggerathiopsis*. Among these, the genus *Glossopteris* dominates with 8 species, namely *Glossopteris browniana*, *G.* cf. *G. cordatifolia, G. gigas, G. leptoneura, G. Nakkarea, G. pantii, G. recurva* and *G. tenuifolia,* whereas, the remaining genera are represented by one species each.

GEOLOGICAL SETTING

The Singrauli Coalfield (Fig. 1) lies at the northernmost boundary of the Son–Mahanadi Master Basin that stretches from east coast to the centre of Peninsular India. This coalfield embodies the last deposits of the Gondwana sedimentation. Therefore, no sediments of Gondwana period occur beyond this coalfield area in the northern part of Peninsular India. It lies between the latitudes 23º47′ and 24º12′ and longitudes 81º48′ and 82º52′ and is located in the drainage area of Son and Rihand rivers. The total geographical area of this coalfield is around 2200 sq km, approximately 80 sq km comes in Sonbhadra District of Uttar Pradesh State and rest fall in Singrauli District of Madhya Pradesh State.

The coalfield is structurally divided into two tectono–sedimentary sub–basins: (i) Moher sub–basin on the north–eastern side and (ii) the Singrauli main sub–basin to the west. There is no clear cut demarcation between these two

PLATE 1

(Scale bar 5 mm for all the figures) →

1. *Glossopteris browniana* Brongniart, BSIP Museum Specimen No. 40888.
2. *Glossopteris leptoneura* Bunbury, BSIP Museum Specimen No. 40894.
3. *Glossopteris nakkarea*, Chandra & Surange, BSIP Museum Specimen No. 40887.
4. *Glossopteris tenuifolia* Pant & Gupta, BSIP Museum Specimen No 40889.
5. *Glossopteris* cf. *G. cordatifolia* Feistmantel, BSIP Museum Specimen No. 40894.
6. *Glossopteris gigas* Pant & Singh, BSIP Museum Specimen No. 40885.
7. *Gangamopteris cyclopteroides* BSIP Museum Specimen No. 40889

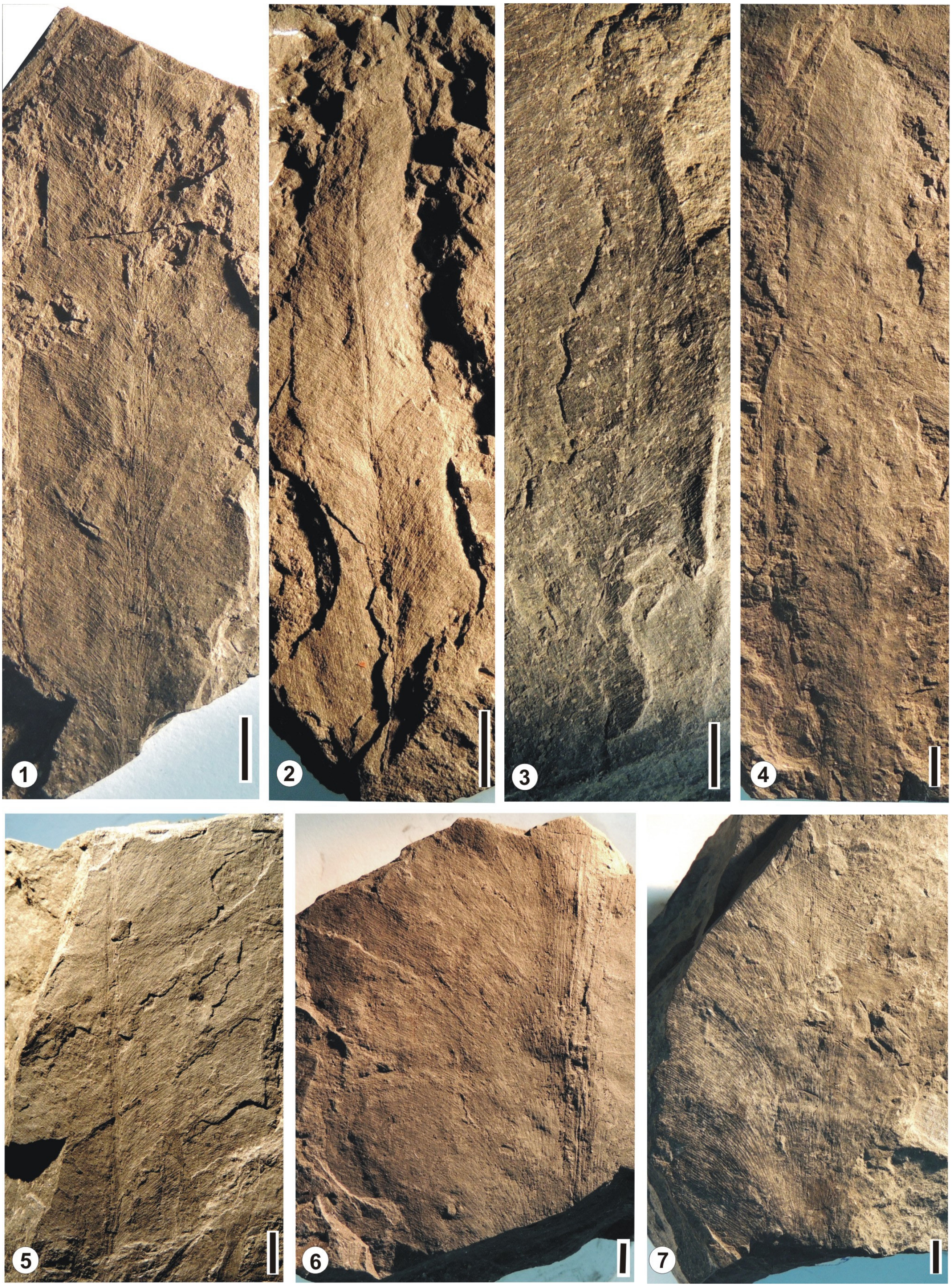

PLATE 1

sub–basins because all the Lower Gondwana formations are exposed uninterruptedly in these sub–basins. The sediments of Permian representing Talchir, Barakar, Barren Measures and Raniganj formations are extensively exposed in the Moher sub–basin whereas, the Triassic sediments belonging to Panchet (Pali) and Mahadeva (Parsora) formations are mainly confined to the Singrauli main sub–basin. The only difference between both the sub–basins lies in the amount of coal reserves found in them. All the ten working opencast mines of Singrauli Coalfield, viz. Dudhichua, Jayant, Kakri, Bina, Krishnashilla, Amlohri, Khadia, Block B, Nigahi and Jhingurdah come under Moher sub basin. First nine collieries are in Barakar Formation and have three coal seams, i.e. the lowermost Turra Seam, middle Purewa Bottom and the uppermost Purewa Top. Below Turra, a thin seam, namely Kota also exists that is in Karharbari Formation. Jhingurdah Colliery is in Raniganj Formation and has the thickest coal seam (134 m) in India. It also has the deepest basinal area among all other collieries of this coalfield. The stratigraphic sequence met within the Singrauli Coalfield is given in Table 1.

MATERIAL AND METHODS

The specimens described in this paper include megafossils collected from the Purewa Botton Seam of the Bina Colliery, Singrauli Coalfield. The fossils are recovered from the shale unit of the coal bearing sequence. The litholog of the section along with photograph is given in Fig. 2. The assemblage includes impressions of leaves, roots, seeds and undetermined thin branching axes and stem casts. Different morphological features such as shape of the leaf, nature of apex and base, midrib, type of meshes and the venation pattern have been taken into account for the identification of the leaves. Around 47 specimens are studied and many of them have been identified upto genus and species level (Table 2). The methodology as given by Chandra and Surange (1979) has been adopted for the description of various species of the genus *Glossopteris*. They are measured and photographed to record the morphological characters using low power Leica microscope and Nikon 35 mm digital camera.

Repository—All the megafossil specimens documented in this paper are deposited in the repository of the Birbal Sahni Institute of Palaeobotany (BSIP), Lucknow vide Statement No. 1424 and Museum Specimen Nos. 40884–40894.

Gangamopteris sp.
Glossopteris browniana
Glossopteris cf. *cordatifolia*
Glossopteris gigas
Glossopteris leptoneura
Glossopteris nakkarea
Glossopteris pantii
Glossopteris recurva
Glossopteris tenuifolia
Glossopteris sp.
cf. *Noeggerathiopsis* sp.
Rooting structures
Stem casts
Stem axes (impression)
Bifurcating/ branching axes
Seed
Scale leaf
Fertile structures
Ruptured /Assorted meshes

Table 2—A list of complete macrofloral assemblage collected from the Barakar Formation of the Bina Colliery, Singrauli Coalfield.

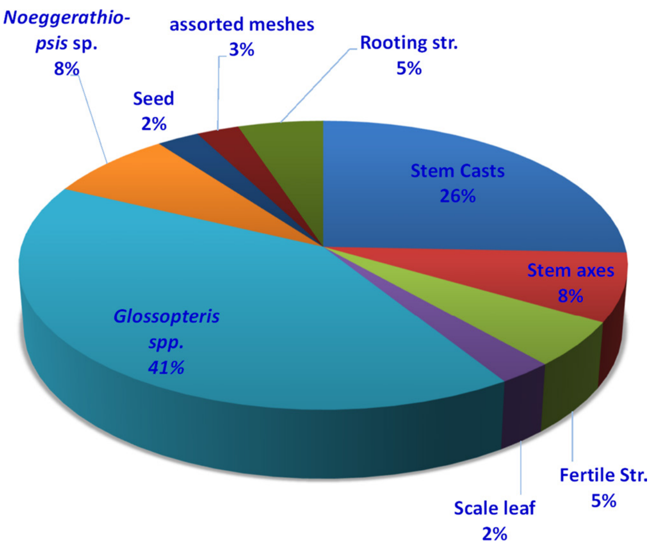

Fig. 3—Relative percentages of various genera and *Glossopteris* species from Barakar Formation of Bina C olliery

PLATE 2

(Scale bar 5 mm for all the figures)

→

1. *Glossopteris nakkarea* Pant & Gupta, BSIP Museum Specimen No. 40894.
2. *Glossopteris recurva*, Pant & Singh, BSIP Museum Specimen No. 40886
3. *Glossopteris pantii* Chandra & Surange, BSIP Museum Specimen No. 40884.
4. cf. *Noeggerathiopsis* sp. Feistmantel, BSIP Museum Specimen No. 40890.

5, 6. Branching axes, BSIP Museum Specimen No s. 40892 and 40893.

7, 8. Stem casts, BSIP Museum Specimen No. 40891.

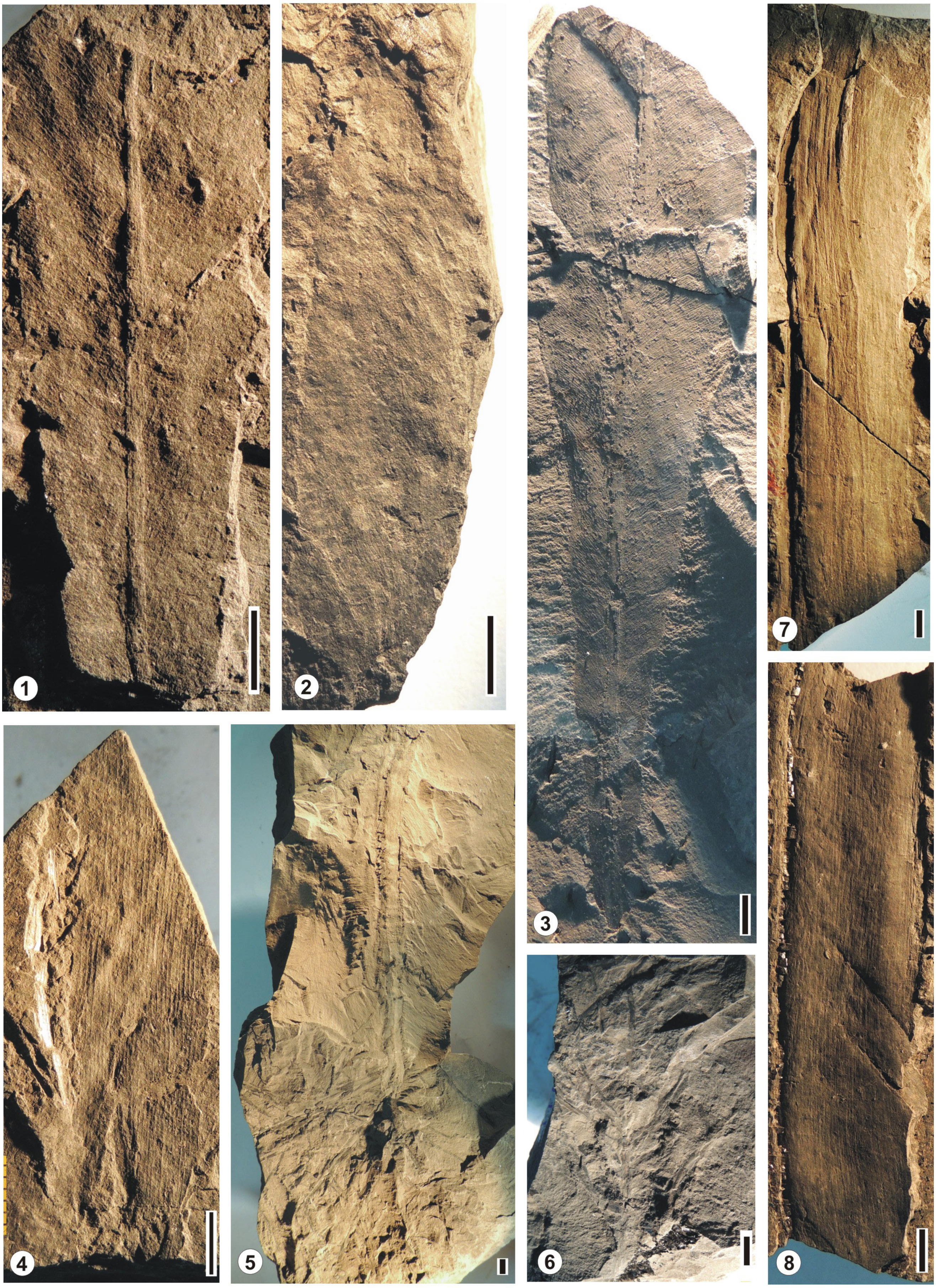

PLATE 2

OBSERVATIONS AND SYSTEMATICS

Division—GYMNOSPERMOPHYTA

Order—GLOSSOPTERIDALES

Genus—GANGAMOPTERIS McCoy, 1875

Gangamopteris cyclopteroides Feistmantel, 1876

(Pl. 1.7)

Description—One incomplete leaf impression, measures 7 cm in length and 4.6 cm in width. Half lamina is about 2.6 cm wide. Leaf appears to be elliptical in shape with entire margin. Apex and base are not preserved. Median portion of the leaf is occupied by 5–8 parallel, interconnected veins forming elongate meshes. Secondary veins seem to be arisen from the base and gradually fan out at acute angle towards the margin. They dichotomize and anastomose to form polygonal meshes. Meshes are 3.5 to 6 mm long and 0.6 to 1.0 mm wide near the median region, whereas near the margin meshes are narrower and more elongated. Vein density is 15–20 veins/cm^2 near the median region and 20–28 veins/cm^2 near margin.

Comparison and remarks—Owing to the absence of a well–defined midrib; having subparallel running veins in the median region; elliptical–spatulate shape, the specimen closely resembles with the taxon *Gangamopteris cyclopteroides* Feistmantel, as described by Feistmantel (1879; Pl. 7, Fig. 2, Pl. 10, Fig. 2; Pl. 11, Figs 2, 3, 4, Pl. 12, Figs 2, 3, Pl. 13, Fig. 1, Pl. 16, Fig. 1, Pl. 17, Figs 1, 2, 3) from Talchir and Karharbari formations of Karanpura and Mohpani coalfields. The present specimen is also comparable with the specimen described by Singh *et al*. (2006a; Pl. 1, Fig. 2; Pl. 2, Figs 2, 3) from Karharbari Formation of Mahanadi Basin and Singh *et al*. (2006b; Pl. 2, Fig. 1) from the Barakar Formation of Ib River Coalfield and as described by Srivastava *et al*. (2012, Pl. 1, Fig. b) from Mohpani Coalfeild.

Genus—GLOSSOPTERIS Brongniart, 1828

Glossopteris browniana Brongniart, 1828

(Pl. 1.1.)

Description—This species is represented by a single nearly complete specimen as part and counterpart. Preserved leaf measures about 5.7 cm in length and 1.9 cm in width and is narrow oblanceolate in shape, with entire margin and distinct midrib. Apex and base not preserved. Midrib is 1.0–1.2 mm thick and striate. Secondary veins emerge at 42–50º, arch backwards and meet the margin at about the same angle, dichotomize and anastomose forming broad, elongate, polygonal meshes near the midrib and relatively narrower meshes near the margin.

Comparison and remarks—The leaf is comparable with the type specimen of *G. browniana* Brongniart (1828, Pl. 62, Fig. 1) and also compares closely with figured specimens of Feistmantel (1890, Pl. 16, Figs 3, 4; Pl. 17, Figs 3, 4, 5) in the general shape of the leaf and the venation pattern. The specimen also resembles closely with the specimens of *G. browniana* as described by Singh *et al.* (2006b, Pl. 4, Fig. 6) from Ib River Coalfield and (2011; Pl. 5, Fig. 2) from the Korba Coalfield, Tewari *et al.* (2012; Fig. 5 G–J) from Umrer Coalfield and Singh and Saxena (2015, Pl. 1, Figs 5, 6) from the Singrauli Coalfield.

Glossopteris* cf. *G. cordatifolia Feistmantel, 1890 (*G. feistmanteli* Rigby, 1964)

(Pl. 1.5)

Description—One incomplete specimen and only middle part of the lamina is preserved, measures 6.3 cm in length and 3.1 cm in width at its widest part. Half of the lamina is nearly 2.1 cm broad, midrib prominent and persistent, striate, secondary veins arise about 45º and travel straight to the margins, meshes elongate and uniform.

Comparison and remarks—The present specimen is comparable with the Lectotype of *Glossopteris cordatifolia* (No. GSI 5478), Feistmantel, 1890, page 37, Pl. 20, Fig. 1) which was originally described as *G. cordata* sp. nov. by Feistmantel himself in 1882. Later, the specimen was renamed as the name *G. feistmanteli* nom. nov. by Rigby in 1964 after re–examining it and assigned the name *G. feistmanteli* as *G. cordata* was already given to some other species. Rigby (2013, p. 211) revised this ambiguity as per nomenclature norms and has given priority to *G. cordatifolia* over *G. feistmanteli*. Hence, the specimens described as *G. feistmanteli* in Indian records are compared herein as *G. cordatifolia*. The present specimen is also in accordance with the restoration of *G. feistmanteli* given by Chandra and Surange (1979, Pl. 10, Fig. 3; Pl. 16, Fig. 10; Pl. 19, Fig. 1; Pl. 38, Fig. 2) in overall shape and venation pattern, with Singh and Chandra (2000, Pl. 1, Fig. 3) and also with Singh *et al.*, 2011 (Pl. 1, Figs 2, 4).

Glossopteris gigas Pant and Singh, 1971

(Pl. 1.6)

Description—The species is represented by one incomplete specimen as part and counterpart in the collection. The leaf measures about 6 cm in length and 5.3 cm in width; appears to be large and very broad. On one side of the midrib, lamina is nearly 4.2 cm broad. Apex and base not preserved. Midrib 2.3 thick gradually tapering towards the apex. Margin entire, lateral veins emerge at about 40–45º, arch a little outwards and then pass to the margin in gentle curves, meshes long and narrow.

Comparison and remarks—The specimen is comparable with the Holotype of *G. gigas* Pant & Singh (1971, Pl. 3, Fig. 14, specimen no. 3034A) in shape of the leaf and venation pattern. It is also in accordance with *G. gigas* as figured by Chandra and Singh (1992, Pl. 6, Fig. 1) and Singh *et al.* (2011, Pl. 6, Figs 2, 4).

Glossopteris leptoneura Bunbury, 1861

(Pl. 1.2)

Description—One almost complete specimen, measuring 4.7 cm in length and about 1 cm in width. Leaf is long and narrow, shape linear–lanceolate, margin entire. Apex acute and base appears to be narrow and tapering downwards. Midrib prominent and persistent in the lower middle part and faint in upper part; secondary veins arise at acute angle, slightly curved backwards to meet margin at an angle of 35–40º; after dichotomization and anastomose, secondary veins form elongate, narrow, oblong–polygonal meshes which are slightly broader near midrib, smaller and narrower near margin.

Comparison and remarks—The preserved specimen is closely comparable with the specimens of *Glossopteris leptoneura* described by Bunbury (1861, Pl. 9, Figs 1–4), Chandra and Singh (1992, Pl. 1, Figs 2, 4 and Pl. 2, Figs 2, 3) and Tewari (2008, Pl. 2, Fig. 4) in its overall shape and venation pattern.

Glossopteris nakkarea Chandra and Surange, 1979

(Pls 1.3, 2.1)

Description—Two specimens in the collection, of which one is almost complete (Pl. 1.3); the preserved leaves measure 4.1 to 5.8 cm in length and 1.2 to 1.3 cm in width. The complete leaf is narrow, relatively small, linear–lorate in shape. Apex is acute, base tapering, acute–cunetae; midrib narrow, persistent; lateral veins arise about 45º and meet margins at almost same angle without any arching. Meshes narrow, elongate, straight, denser and shorter towards margin; venation dense.

Comparison and remarks—In its appearance and venation pattern of the preserved part, the specimens are comparable with the Holotype of *Glossopteris nakkarea* as described by Chandra and Surange (1979, Pl. 47, Fig. 2 vide Specimen No. 34063, BSIP.

Glossopteris pantii Chandra and Surange, 1979

(Pl. 2.3)

Description—This species is represented by two incomplete specimens of which one is nearly complete that measures about 11.6 cm in length and 2.5 cm in width. Leaf is long, linear narrow at the base and broader towards the upper part. Base is narrow and tapering. Midrib broad, thick in the basal part and gradually thinning towards the apex. Lateral veins arise at an angle of 42–45º, run straight to the margin to meet it at 75–80º. Meshes narrow and almost uniform from midrib to more than half of the lamina, become narrower at the margins.

Comparison and remarks—The leaves are comparable with the Holotype specimen of *Glossopteris pantii* (Chandra & Surange 1979, Pl. 14, Fig. 1, Specimen No. BSIP 35281) in their shape and venation pattern. Present specimens also resemble with the specimens as described by Singh *et al*. (2011, Pl. 5, Fig. 3).

Glossopteris recurva Pant and Singh, 1974

(Pl. 2.2)

Description—One incomplete specimen, measures 4.5 cm in length and 1.9 cm in width. Leaf small, with entire margin. Shape appears to be oblong–lorate, only one side of the lamina is preserved. Apex and base not preserved. Lateral veins arise from the midrib at an angle of less than 45º and then arch out to the margin. Veins thin, meshes narrow, elongate and almost of equal size.

Comparison and remarks—The leaf closely resembles with the Holotype specimen of *G. recurva* Pant and Singh (1974, Pl. 31, Fig. 61) and specimen of this taxon as Chandra and Surange (1979, Pl. 42, Fig. 4).

Glossopteris tenuifolia Pant and Gupta, 1968

(Pl. 1.4)

Description—One nearly complete specimen with part and counter–part in the collection. The leaf measures about 10.9 cm in length and 2.0 cm in width at its widest part. Leaf, medium, narrow, oblanceolate in shape; apex obtusely pointed, base attenuate; midrib narrow (1–2 mm thick), striated, continue upto the apex; secondary veins emerge at 10–20º, arch slightly, run straight upto the margins at 35–45º, dichotomize and anastomose to form very long narrow polygonal meshes; vein density is high.

Comparison and remarks—Leaf is comparable with the Holotype specimen of *G. tenuifolia* described by Pant & Gupta (1968, Pl. 21, Fig. 15) and also with the specimen reported by Chandra and Surange (1979, Pl. 6, Fig.1; Pl. 15, Fig. 10; Pl. 17, Fig. 10; Pl. 42, Figs 1, 6) in shape, length: width ratio and venation pattern. Leaf also shows resemblance with *G. tenuifolia* as described by Chandra and Singh (1992, Pl. 4 Fig. 1; Pl. 5, Figs 1, 2), Singh and Chandra (2000, Pl. 3, Figs

2, 3), Singh *et al.* (2006, Pl. 1, Fig. 4), Tewari (2008, Pl. 2, Figs 5, 9; Pl. 3 Fig. 4; Pl. 4, Fig. 5), Tewari *et al.* (2012, Fig. 7c, d) and Singh and Saxena (2015, Pl. 1, Fig. 2, Pl. 2, Figs 1, 2, Pl. 4, Fig. 4).

Glossopteris sp.

There are three incomplete specimens in the assemblage which are not well preserved and fragmentary in nature, therefore difficult to be identified at species level. However, on the basis of presence of definite midrib and reticulate venation pattern these are identified as the *Glossopteris* leaves.

Division—CONIFEROPHYTA

Class—PINOPSIDA

Order—CORDAITALES

Genus—cf. NOEGGERATHIOPSIS Feistmantel, 1879

cf. _Noeggerathiopsis_ sp.

(Pl. 2.4)

Description—This genus is represented by three incomplete specimens. The near complete specimen measures 4.1 cm in length and 1.1 cm in width at its widest part. Leaves are simple, symmetrical, shape spathulate to ovate, apex not preserved, base narrow–elongate, simple veins of uniform thickness throughout the lamina, a number of parallel veins arise from base and bifurcate frequently during upward course, side veins show slight arching near margin. The angle of divergence between adjacent veins is less than 5°.

Comparison and remarks—Having spatulate to ovate shape and characteristic venation pattern, these specimens are closely comparable with the specimens of the genus *Noeggerathiopsis* as described by Feistmantel 1879 (Pl. 1, Figs 3, 6; Pl. 3, Figs 1, 3).

STEM CASTS

(Pl. 2.7, 2.8)

There are 10 specimens of stem casts in the present collection. The length of the specimens ranges from 5.0 to 10.8 cm and width from 1.6 to 2.4 cm. A number of longitudinal striations are seen on the surface with no definite pattern. They are preserved as impressions.

In addition to the above described macrofloral remains, few fertile structures, scale leaf, many branching axes (Pl. 2.5, 2.6) and rooting structures are also recorded in the assemblage. But due to fragmentary nature, ill preservation and lack of definite authentic structures these are not given any generic or specific status.

DISCUSSION

Carbonaceous and grey shale facies associated with coal–bearing horizons in Bina Colliery have been thoroughly searched and investigated to collect the megafossils; however, only a small number of specimens could be found preserved in these facies. The occurrence of megafossils in Bina Colliery is remarkably very less (only 47 specimens) as compared to their enormous presence in the Jhingurdah Colliery of the same coalfield (Saxena & Singh, 2015) and in various other collieries of different coalfields, viz. Talcher (Saxena *et al.*, 2014), Ib–River (Singh *et al.*, 2006b), Korba (Singh *et al.*, 2011), etc. of Son–Mahanadi Basin. Further, none of the megafossils is preserved with cuticle, depicting the complete oxidation of the carbon content of the preserved fossils at least in these facies.

The Bina macroflora is dominated by the order Glossopteridales (Fig. 3) and the genus *Glossopteris* dominates with 8 species (41%). The orders Lycopodiales, Sphenophyllales, Equisetales, Filicales (all Pteridophytes), Ginkgoales, Cycadales and Pinales are completely missing in this colliery demonstrating that the vegetated area might not be adequately cool and humid to facilitate the growth of these shade loving plants.

However, the presence of pteridophytes in the area can be envisaged as evident by the occurrence of a large number of naked, spore tetrads from the Turra Seam (Lower Barakar Formation) of Bina Colliery. These spore tetrads are assignable to the dispersed microspore genera *Indotriradites*, *Microbaculispora* and *Microfoveolatispora* are the first record of tetrads from any Artinskian strata in the world. There is no evidence of any kind of sporangia or related plant parts in the present investigation that could ascertain the affinity of these tetrads, however the presence of a trilete mark in the spores of the tetrads demonstrates their alliance at least with the pteridophyte group. The Turra Coal Seam is the lowermost seam and its deposition predates the deposition of Purewa Bottom Seam (middle seam), the fact provides an indirect evidence for the presence of pteridophytes during Artinskian, and megaremains of them could not be preserved.

Almost all the specimens in the collection are fragmentary and ill–preserved. This indicates that the vegetal matter might have travelled for a long distance before their final deposition in the basin amidst a low energy depositional environment indicated by the presence of fine–grained carbonaceous shale of the Barakar Formation.

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