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Comprehensive Record of Megafossils from the Rajmahal Basin, Jharkhand, India

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Abstract

The study provides the first comprehensive record of the plant megafossils mainly Glossopteris flora from the Barakar Formation, Rajmahal Open Cast Mine, Rajmahal Basin, Jharkhand. The assemblage is composed of pteridophytes and gymnosperms. The pteridophytes comprise Equisetalean axes (order Equisetales), whereas, gymnosperms include nine species of Glossopteris including *Glossopteris communis*, *G. damudica*, *G. gigas*, *G. indica*, *G. lanceolatus*, *G. longicaulis*, *G. oldhamii*, *G. taenioides*, *G. tenuifolia* along with *Vertebraria indica* and *Noeggerathiopsis hislopi*. The present investigation adds to the knowledge of the Glossopteris flora of India, especially that of the Rajmahal Basin from where the plant fossil records are sporadic. The area is a treasure for palaeobotanical studies as evinced by different fossil localities. However, the localities are degraded by mining activities performed by private companies and hence systematic investigation for such vegetation is vital to create a palaeobotanical database before their complete degradation. The floral assemblage compares with earlier known assemblages, recorded from the Barakar Formation of other Lower Gondwana basins of peninsular India.

Keywords

Glossopteris Flora, Barakar Formation, Rajmahal Basin, Gondwana

1. Introduction

The Rajmahal Basin covers a large area of Bengal Basin, north Bengal and Purnea Basin. The Basin comprises five coalfields namely Brahmani, Mahuagarhi, Pachwara, Chuperbhita and Hura [1] Megafossils are recorded from different Gondwana basins of India namely Damodar, Mahanadi, Satpura, South Rewa, Wardha, and Godavari basins [2]-[12] but records of these from Rajmahal Basin

are scare [13] [14] [15] [16]. No detailed systematic study of megafossils mainly the Glossopteris flora from early Permian has been published so far in the last twenty-five years from Rajmahal Basin. The flora is mainly superintended for the formation of such large reservoirs of coal in the Basin, witnessed by about 10.5 million tons of it from its different coalfields. Hence, it is very necessary to study such coal forming vegetation and its distribution in the other lower Gondwana basins of India. In the present communication, an attempt has been made to study the plant megafossil mainly the Glossopteris flora recovered from the Rajmahal colliery, Rajmahal Basin, Jharkhand India (**Figure 1**).

2. Geology of the Area

The Lower Gondwana exposures are found in the North-South direction of the Rajmahal Basin. The Rajmahal traps capped Rajmahal hills have receded considerably towards the east in the areas towards the north near Ganges, exposing large areas of the coal-bearing Barakar Formation beneath. The Barakars have been identified to be lying with a depositional contact with the Archeans, which lie towards the west. In addition to these lithostratigraphic units, Talchir (underlying the Barakar) and Dubrajpur (underlying the Rajmahal traps) have been exposed in the Basin [**Figure 1(a)** & **Figure 1(b)**]. The northern part of Hura Coalfield is constituted by Rajmahal Open Cast Mine. The general stratigraphic sequence within the block is given in **Table 1** (after Eastern Coalfields Limited, India).

3. Material and Methods

Samples were collected from thick carbonaceous shale, Barakar Formation, Rajmahal OCP, Coal Mine Zone-57, Rajmahal Basin (**Figure 1**), lies 24˚01'12" to 25˚01'15" North latitude and 87˚24'52" to 87˚25'00" East longitudes. Impressions of the specimens were studied for their morphotaxonomy with a hand lens and binocular microscope Olympus 20i H under incident light. Taxonomical differences were different leaf shapes, apex, base, margin, midrib and venation patterns. Relevant literature namely [17] [18] [19] have been consideration for their identification and systematic description. Different species have been recognized on account of taxonomical differences. All the specimens have been deposited in the Botany Department, SGRR (P.G.) College, Dehradun.

4. Result and Discussion

Systematics

Division—Pteridophytes

Order—Equisetales

Equisetalean axes

[**Plates 1(a)-(c)**]

Description—Seven leafless specimens are in the collection. Their length ranges from 3 to 10 cm and width varies from 0.8 to 4 cm. No nodes are visible in the specimens. However, ridges and furrows can be seen on the axes. 8 - 12 ridges are present and are at a 0.4 to 1.2 mm gap apart from each other.

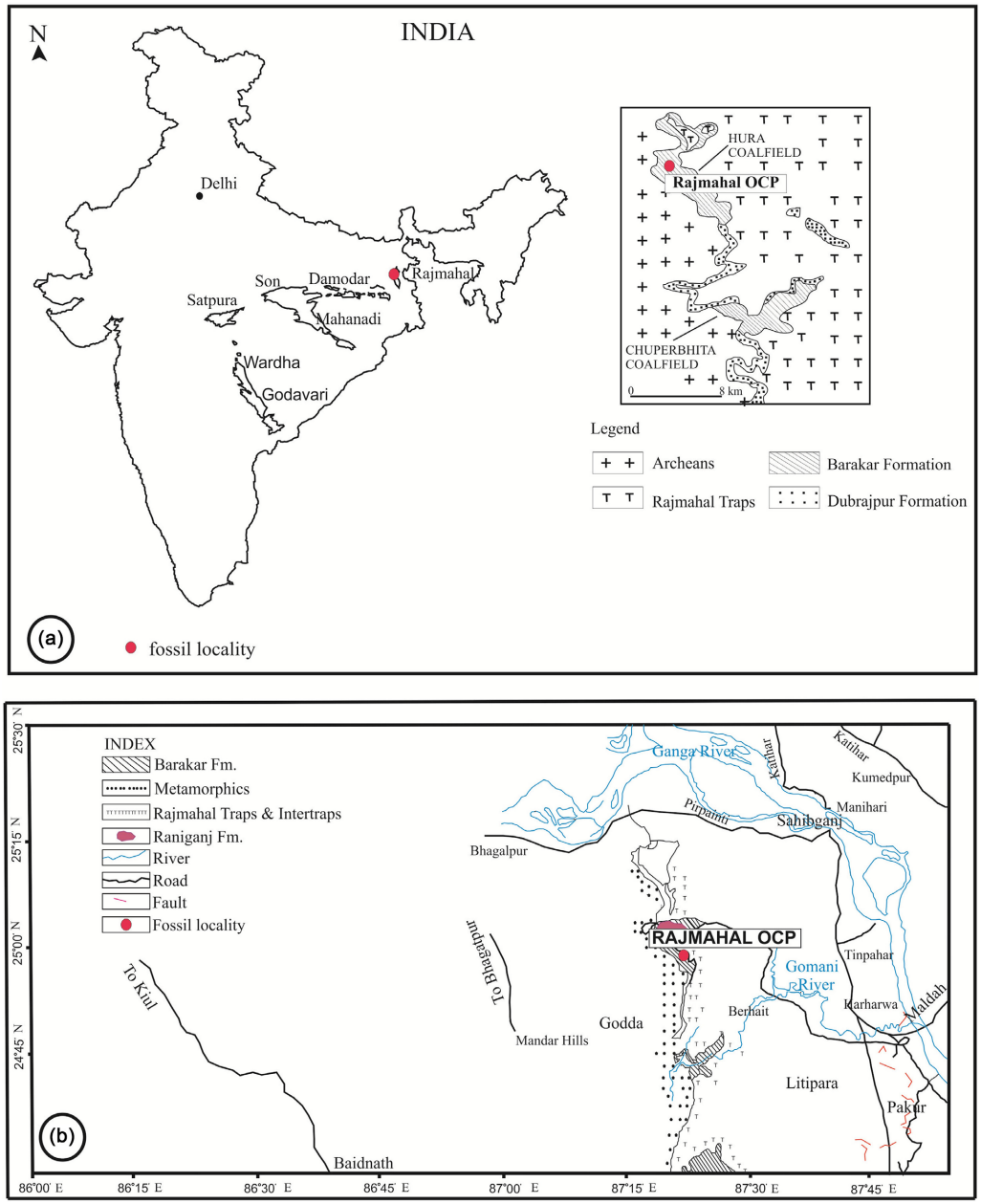

Figure 1. (a) Map showing fossil locality; (b) Geological map of the study area (after Joshi, 2020).

Table 1. General stratigraphy of the Rajmahal Open Cast Mine, Rajmahal Basin Jharkhand, India (after Eastern Coalfields Limited, India).

STRATIGRAPHIC SEQUENCE OF RAJMAHAL OPEN CAST MINE			
GROUP	FORMATION	LITHOLOGY	THICKNESS RANGE (m)
Recent to Sub-Recent	Alluvium	-------Unconformity-------	0 - 15
Upper Gondwana	Rajmahal Traps	Rajmahal volcanic and intertrappean sandstone and shale ------Unconformity--------	50

Continued

Lower Gondwana	Barakar	Coarse to medium grained sandstone with shale and coal	25 - 350
		Coarse arkosic sandstone, pebbly at places	15 - 150
	Talchir	Sandstones and shales tillites --------Unconformity------- Granite genesis, hornblende Schists and pigmatites	10 - 20

Division—Gymnosperm

Order—Glossopteridales

Genus—*Glossopteris* [20]

Type species—*Glossopteris browniana* [20]

Glossopteris communis [21]

[**Plate 1(d)**, **Plate 1(e)**]

Description—There are twelve specimens in the collection. All the specimens are incomplete. Leaves preserved as impressions, measure 3 -11 cm in length and 2 - 7.2 cm in width at their widest part which is the middle portion of the preserved specimens. Apices are not preserved while the base is tapering in one specimen, the margin is entire. Broad striate midrib is about 3.2 - 4.7 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, 4 - 5 mm long and 0.3 - 0.9 mm broad meshes near the midrib, and long and narrow meshes 4 - 6 mm long and 0.1 - 0.5 mm broad near the margin. The vein density is 15 - 17 per cm near the midrib and 22 - 27 per cm near the margin.

Remarks—Leaves are identical to *G. communis* [22] pl. 21, fig. 5; [23] pl. 17, figs. 1-2; [24] pl. 21, figs 13-14; [19] pl. 1, figs 2-3; [11] pl. 3, fig. 1 in venation pattern.

Glossopteris damudica [23]

[**Plate 1(f)**]

Description—Two incomplete leaf impressions are present in the collection. Leaves measure 6 - 9 cm in length and 5 - 5.6 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 (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). 12 - 16 veins per cm present near midrib and 17 - 22 per cm near at margin.

Remarks—Present specimens are similar to *Glossopteris damudica* [23] pl. 20, fig. 2, pl. 31, figs. 1-3, pl. 32, fig. 1; [19] pl. 6, fig. 5; [9] figs 6 C, D; [11] pl. 3, fig. 3 in presence of broad midrib and polygonal meshes.

Glossopteris gigas [25]

[**Plate 1(g)**]

Description—There are three leaves in the collection. Leaves range from 4 - 16.6 cm in length and 5 - 10 cm in width at their widest which is generally the middle portion of the leaves. Absence of the apex and base, however, margin entire. Broad striate midrib about 2.5 - 5.2 mm wide at the lower part while 1.7 - 3 mm wide at the upper part. 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˚. Hexagonal meshes about 3 - 4 mm long and 0.5 - 1 mm broad are found in the specimens. The vein density is 14 - 16 per cm near midrib and 18 - 20 per cm towards the margin.

Remark—The specimens are similar to *Glossopteris gigas* described by [25] pl. 3, figs 10, 14, text-fig. 2B), [19] pl. 12, fig. 1, pl. 16, fig. 6, pl. 25, fig. 1, [26] pl. 2, fig. 3, pl. 3, fig. 2 and [11] pl. 3, figs 4-5 in general shape, midrib and venation pattern.

Glossopteris indica [27]

[**Plate 1(h)**, **Plate 1(i)**; **Plate 2(a)**]

Description—Fourteen specimens are in the collection. Leaves are lanceolate in shape with an entire margin. Acute apex is present in well preserved specimens. Leaves are 7 - 23 cm long and 3 - 5.2 cm broad at their widest part. Distinct, persistent and striate midrib with 3 - 5 deep striations and 1 - 3 mm wide present in the specimens. 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 arise at an angle of 67˚ - 73˚. Meshes are 1 - 4 mm in length and 0.2 - 0.4 mm in width near midrib and 2.2 - 3.7 mm lengthwise and 0.3 - 0.5 mm in breath at the margin. 16 - 20 veins per cm are present near midrib and 18 - 26 per cm near the margin.

Remarks—Specimens are alike *Glossopteris indica* [19] pl. 5, fig. 1, pl. 10, fig. 4, pl. 15, fig. 11, pl. 28, fig. 1, pl. 29, fig. 1; [26] pl. 1, fig. 4; [27] pl. 4, fig. 4 and [11] pl. 4, figs. 1-2 in shape, nature of midrib and venation pattern.

Glossopteris lanceolatus [25]

[**Plate 2(b)**, **Plate 2(c)**]

Description—There are three leaf specimens in the collection. Leaves narrow, oblong in shape, measures 7 - 12.2 cm in length and 3 - 4 cm in width, apex acute, base absent and margin slightly undulating. 0.7 mm broad striate midrib is present and gradually gets tapers towards apex. Secondary veins arise at about 45˚ from midrib and after dichotomization and anastomoses, meet the margin at about 85˚. Meshes broad, elongate, 3.5 - 5 mm in length and 0.5 - 0.6 mm wide are present near the midrib while narrow about 2 - 2.5 mm long and 0.3 - 0.4 mm broad near the margin. 17 - 22 veins per cm are present near midrib and 24 - 31 per cm near the margin.

Remarks—Present specimens are similar with *G. lanceolatus* delineated by [19] pl. 7, fig. 2, pl. 19, fig. 2, pl. 40, fig. 2 and [11] pl. 4, fig. 3 in similar shape and venation pattern.

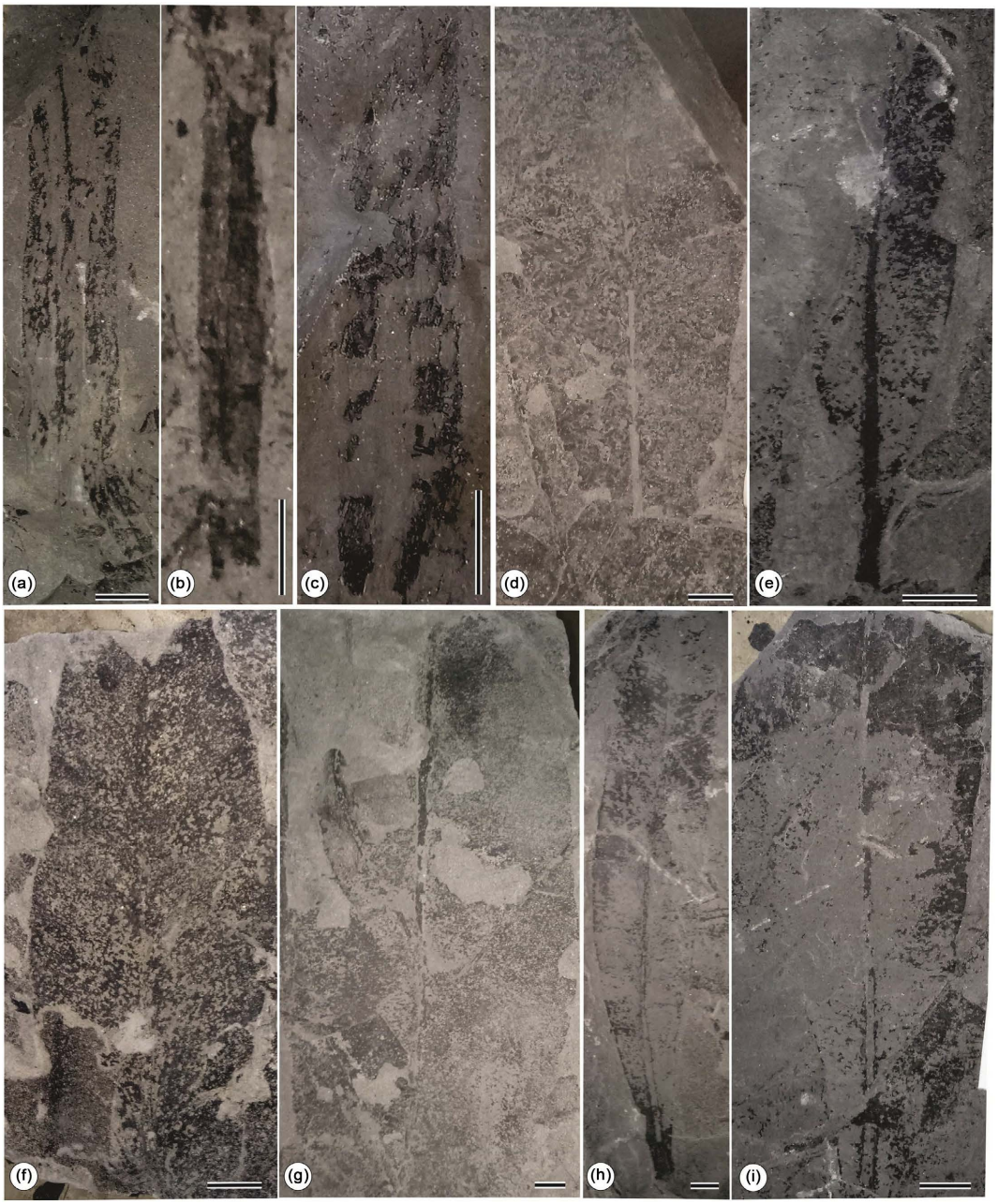

Plate 1. Scale bar = 1 cm. (a)-(c): Equisetalean axes, specimens nos. RJ 1/2017, RJ 2/2019 and RJ 3/2019. (d) (e): *Glossopteris communis*, specimens nos. RJ 4/2019 and RJ 5/2019. (f). *Glossopteris damudica*, specimen no. RJ 6/2019. (g): *Glossopteris gigas*, specimen no. RJ 7/2019. (h) (i): *Glossopteris indica*, specimens nos. RJ 8/2019 and RJ 9/2019.

Glossopteris longicaulis [23]

[**Plate 2(d)**]

Description—There are five incomplete leaf impressions in the collection, which measure 8 - 12 cm in length and 3 - 4.5 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 - 2 cm in length. Secondary veins angle of arise is about 47˚ - 52˚ 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 13 - 15 per cm near midrib and 16 - 18 per cm near the margin.

Remarks—The present specimen bear resemblance to *Glossopteris longicaulis* [24] pl. 31, figs 1-3; [19] pl. 1, fig. 4, pl. 15, fig. 13; [30] pl. 1, fig. 5; [27] pl. 4, fig. 8 and [11] pl. 4, figs 4-5 [26] in presence of petiole, nature of midrib and in venation pattern.

Glossopteris oldhamii [31]

[**Plate 2(e)**, **Plate 2(f)**]

Description—Two incomplete leaf impressions are present in the collection. Leaves are 7.1 - 7.3 cm lengthwise and 3.7 - 4.5 cm widthwise. Acute apices and bases are absent. Secondary veins angle is 42˚ - 47˚ from the midrib, arch backwards and run straight upto the margin. Meshes are borad near midrib and narrower towards the margin with 3.3 - 4.7 mm in length and 0.5 - 0.7 mm in near midrib while, 6.2 - 7.7 mm in length and 0.3 - 0.4 mm in width towards margin. Vein density is 22 - 27 per cm near the midrib and 19 - 24 per cm near the margin.

Remarks—Present specimens are identical to *G. oldhamii* described by [19] pl. 8, fig. 3, pl. 19, fig. 9, pl. 37, fig. 1, [11] pl. 4, fig. 8, pl. 5, fig. 1 in similar shape and venation pattern.

Glossopteris taenioides [23]

(**Plate 2(g)**; **Plate 3(a)**)

Description—There are three incomplete specimens in the collection. Preserved portions of the specimens measure 3.1 to 4 cm in length and 0.5 to 1 cm in width in the middle part. Ribbon like leaves have an entire margin, acute apex and base absent. There is distinct, broad and striate midrib of about 1.1 mm wide at lower and 0.5 mm broad at the apex present in the specimens. 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˚. The shape of meshes is arcuate near the midrib and mostly trapezoid elsewhere. Short and broad meshes are present, they are 2.2 - 3.4 mm in length and 0.3 - 1.2 mm in width towards midrib and narrow about 3.1 - 4.3 mm long and 0.4 - 0.6 mm broad near margin. The vein density is 16 - 20 per cm near midrib and 22 - 26 per cm near the margin.

Remarks—The present specimens are resemble with *Glossopteris taenioides* described by [23] pl. 21, fig. 4; [19] pl. 4, fig. 6, pl. 18, fig. 5, pl. 43, fig. 3, text–figs 26 D, d and [11] pl. 5, fig. 5 in narrow, oblong, ribbon–like shape, broad and strong midrib and venation pattern.

Glossopteris tenuifolia [32]

[**Plate 3(b)**, **Plate 3(c)**]

Description—Four incomplete specimens are present in the collection, preserved portions measure 7 - 9.4 cm in length and 1.2 - 1.5 cm in width at their widest part. Leaves are linear in shape with entire margin, apex and base are not preserved. Midrib broad, strong, elevated with striations (3 - 4 striations). The secondary veins arise at angles of about 40˚ - 45˚, slightly arch backwards and

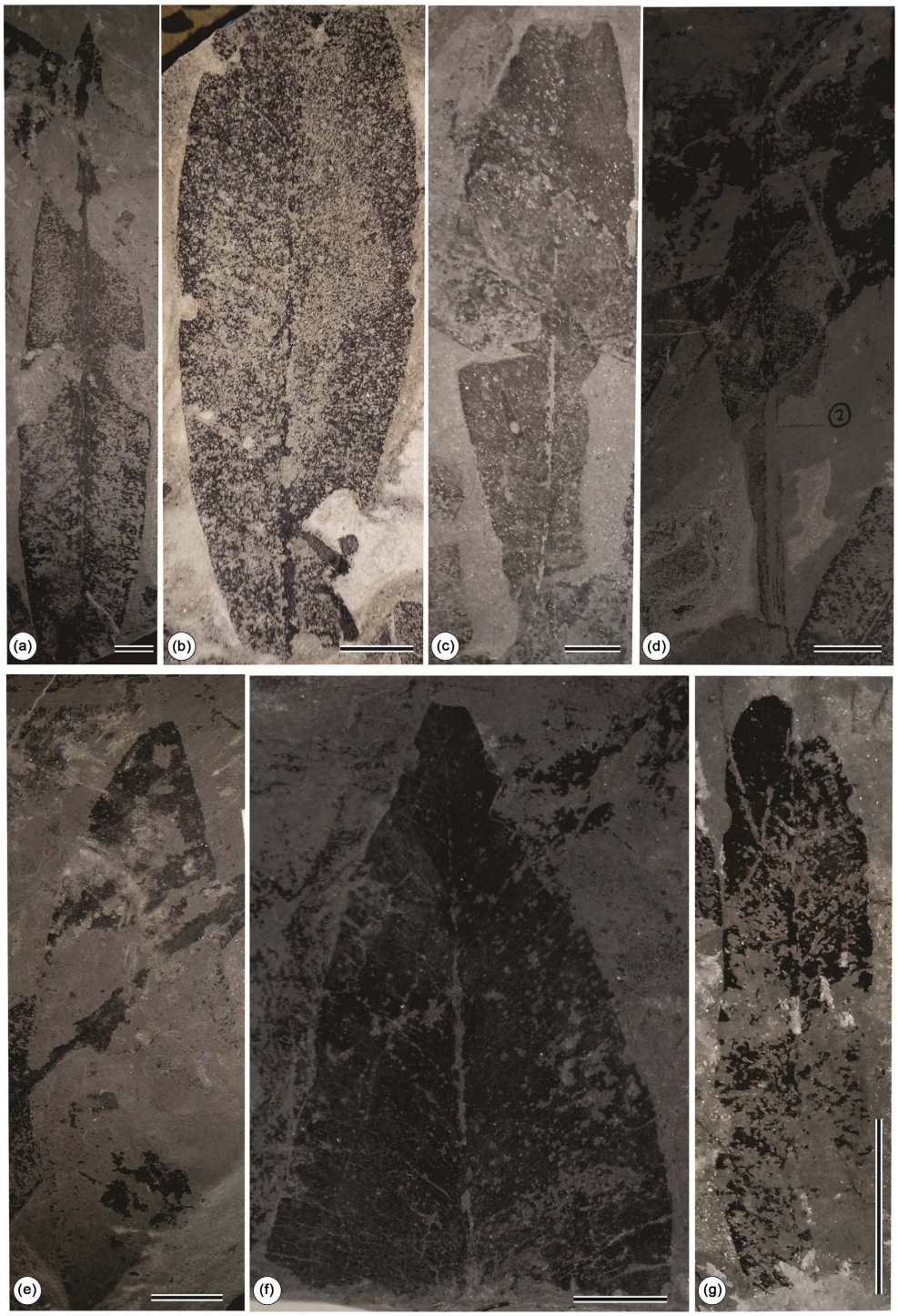

Plate 2. Scale bar = 1 cm. (a) *Glossopteris indica*, specimen no. RJ 10/2019. (b) (c): *Glossopteris lanceolatus*, specimens nos. RJ 11/2019 and RJ 12/2019. (d): *Glossopteris longicaulis*, specimen no. RJ 13/2019. (e) (f): *Glossopteris oldhamii*, specimens nos. RJ 14/2019 and RJ 15/2019. (g): *Glossopteris taneioides*, specimen no. RJ 16/2019.

meet the margin at angles of about 70˚ - 75˚ after dichotomizing and anastomosing, meshes narrow, elongate and hexagonal in shape. The vein density is 19 - 22 per cm near the midrib and 23 - 25 per cm near the margin.

Remarks—Present leaves are identical to *Glossopteris tenuifolia* [32] pl. 20, fig. 14, pl. 21, fig. 15, text-fig. 2; [19] pl. 6, figs. 1-2, pl. 15, fig. 10, pl. 17, fig. 10, pl. 42, figs. 1, 6; [30] pl. 1, fig. 5; [26] pl. 2, figs 4-5, pl. 4, fig. 1; [29] pl. 2, figs 5, 9, pl. 3, fig. 4, pl. 4, fig. 5; [9] figs 7 C, D; [11] pl. 5, figs. 6-8) in shape and venation pattern.

Genus— *Vertebraria* [33]

Type species— ***Vertebraria australis* [33]**

Vertebraria indica

[**Plate 3(d)**]

Description—There are seventeen incomplete horizontally preserved unbranched specimens in the collection. Their size ranges from 2 - 15 cm in length and 0.5 - 3.5 cm in width. Axes consist of 4 to 12 rectangular areas, arranged in linear rows. These rectangular areas are not of equal size and a longitudinal median ridge is present in between the rows of rectangular area. These rectangular areas are separated by a median groove which is 1.4 - 4 mm broad.

Remarks—The specimens compare in their morphological features with *Vertebraria indica* [36] pl. 1, figs 3, 4 and 9; [5] fig. 1 a, b; [37] fig. 3 a-d; [6] fig. 3 e-g; [1] pl. 1, figs. 3-5.

Genus—*Noeggerathiopsis* [21]

Type species—*Noeggerathiopsis hislopi* [22]

Noeggerathiopsis hislopi [22]

[**Plate 3(e)**]

Description—Two leaves are present in the collection. The leaf is broad at the upper end. Size of the leaves ranges from 4 to 15 cm in length and 0.4 to 1.8 cm in width at base and 1.6 to 2.4 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 primary veins dichotomize toward upper part to form secondary veins. The vein density near the leaf base is 10 - 12 per cm and 12 - 16 per cm near the apex.

Remarks—The present specimen bear resemblance to *Noeggerathiopsis hislopi* [22] pl. 19, fig. 5, pl. 19, figs 1-6, pl. 20, fig. 1; [38] pl. 1, figs 1-3; [39] pl. 1, figs. 1-3; [11] pl. 6, figs 2, 3 in dichotomizing parallel veins.

5. Conclusion

The present study reveals that the area is rich in Glossopteris flora as about nine species of *Glossopteris* recovered along with Equisetalean axes, *Vertebraria indica* and *Noeggerathiopsis hislopi.* Out of nine species of *Glossopteris* (**Table 2**), five species (namely *Glossopteris gigas*, *G. lanceolatus*, *G. longicaulis*, *G. taenioides* and *G. tenuifolia*) are first time documented here from the Basin, especially from Coal Mine Zone-57, Rajmahal colliery, Jharkhand. The occurrence of *Vertebraria indica* in abundance represents its autochthonous deposition and flushing environment better suited for the growth and development of the flora within the vicinity [1] [36]. The occurrence of both wide and narrow leaves specimens endorse a phase of transition from Lower to Upper Barakar. Besides, it is

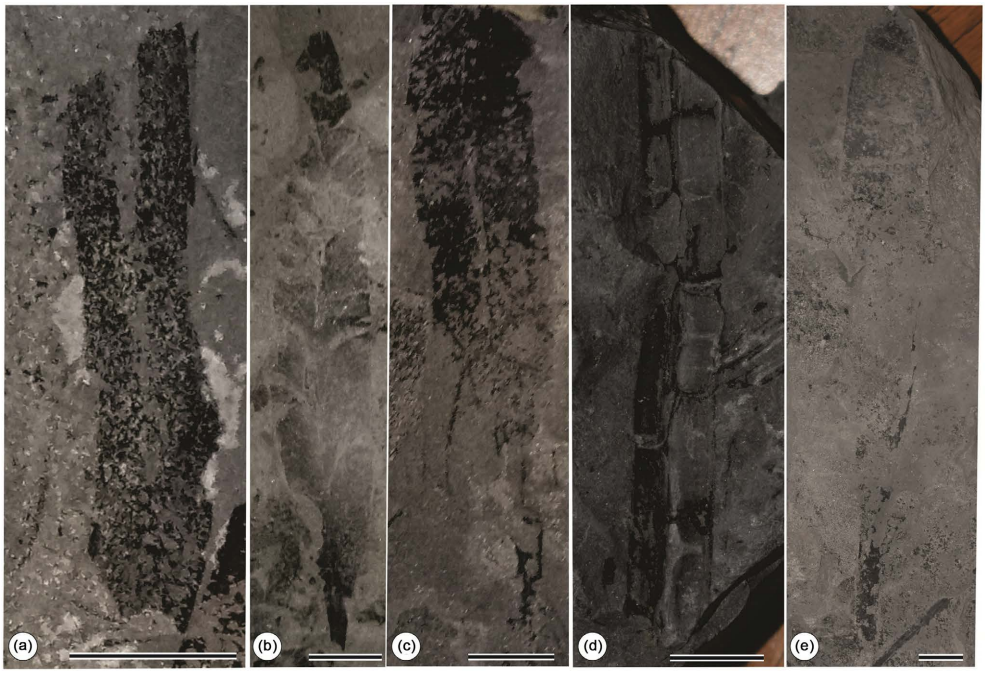

Plate 3. Scale bar = 1 cm. (a) *Glossopteris taenioides*, specimen no. RJ 17/2019; (b) (c): *Glossopteris tenuifolia*, specimens nos. RJ 18/2019 and RJ 19/2019; (d): *Vertebraria indica*, specimen no. RJ 20/2019; (e): *Noeggerathiopsis hislpoi*, specimen no. RJ 21/2019.

Table 2. Distribution of plant fossil taxa (present study) of Rajmahal Open Cast Mine in the Barakar Formation of other lower Gondwana basins of India.

Name of Taxa	Lower Gondwana basins of India					
	Damodar	Mahanadi	Wardha	Satpura	South Rewa	Godavari Graben
Equisetalean axes	+	+	+	+	+	+
Glossopteris communis	+	+	+	+	+	+
Glossopteris damudica	+	+	+	+	+	+
**Glossopteris gigas*	+	+	-	+	+	+
Glossopteris indica	+	+	+	+	+	+
**Glossopteris lanceolatus*	-	+	-	-	-	+
**Glossopteris longicaulis*	+	+	+	+	-	+
Glossopteris oldhamii	-	+	-	-	-	+
**Glossopteris taenioides*	-	+	-	-	+	+
**Glossopteris tenuifolia*	-	+	+	-	+	+
Vertebraria indica	+	+	-	+	+	+
Noeggerathiopsis hislopi	+	+	+	+	+	+

*New records from the Area.

representing large floral diversity within the vicinity during their deposition and advocates for favourable environmental conditions for the development of such luxuriant Glossopteris vegetation [40] [41] [42] [43]. The floral assemblage

represents dense coal forming vegetation, responsible for the formation of large coal reservoirs in the area. The study helps to record a new palaeobotanical database of such coal forming vegetation before its devastation due to unplanned mining activities. As the government of Jharkhand has given mining leases to private companies, these companies are running in an unplanned manner. Therefore more efforts are needed to study such coal forming vegetation and its distribution for the generation of new palaeobotanical records from the area. The record will surely be helpful to understand the diversity of plants and palaeoenvironment precisely during the deposition of the Barakar Formation in the area.

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Conflicts of Interest

Author states that there is no conflict of interest.

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