Journal of the Palaeontological Society of India
Volume 66(1), June 30, 2021: 23-34

ISSN 0552-9360

Diversity of the Genus *Gangamopteris* McCoy in the Early Permian Sequences of Singrauli Coalfield, Son-Mahanadi Basin, India

Anju Saxena[1*], Suyash Gupta[1,2], Kamal Jeet Singh[1*], Srikanta Murthy[1], Anand Prakash[3] & P.K. Singh[2]

JPSI

The form genus *Gangamopteris*, with reticulate venation and midrib less lamina, is an important constituent of the *Glossopteris* flora and widely distributed in Indian Lower Gondwana sediments. Stratigraphically, its occurrence is generally restricted to the lower Permian sequences namely Talchir, Karharbari and Lower Barakar formations. Barring the sporadic occurrences of this genus in the Upper Barakar Formation, it is altogether absent from the Barren Measures Formation, however, a few occurrences of *Gangamopteris* have again been recognised in the Upper Permian Raniganj Formation. A diverse Glossopterid assemblage has been recorded from the coal bearing sequence of Block-B colliery, Singrauli Coalfield, belonging to the Barakar Formation. The assemblage includes *Gangamopteris*, *Glossopteris*, seeds and equisetalean axes. The genus *Gangamopteris* comprising five species, viz. *G. angustifolia, G. cyclopteroides, G. karharbariensis, G. major* and *Gangamopteris* sp. has been systematically described and discussed in the present study. *Gangamopteris cyclopteroides* has the maximum occurrence followed by *Gangamopteris* sp., *G. major, G. angustifolia* and *G. karharbariensis*. The leaves of all the *Gangamopteris* species are quite large and broad that pretend the existence of low light or the shady conditions in and around the vegetated area. The diverse occurrence of *Gangamopteris* in recovered plant assemblage indicates an Early Permian (Artinskian) age to the studied coal bearing sequence of Block-B colliery. A complete account depicting all the stratigraphical occurrences of various *Gangamopteris* species in Indian Gondwana has been provided.

Keywords: Macroflora, Glossopterid, *Gangamopteris*, Barakar Formation, Singrauli Coalfield, Son–Mahanadi Basin.

ARTICLE HISTORY

Manuscript Received: 28/05/2020
Manuscript Accepted: 25/02/2021

*[1]Birbal Sahni Institute of Palaeosciences, 53 University Road, Lucknow 226007, India; [2]Centre of Advanced Studies in Geology, University of Lucknow, Lucknow 226007, India; [3]Department of Geology, Banaras Hindu University, Varanasi 221005, India. [*]Corresponding author's e-mail: *anju_saxena@bsip.res.in*

INTRODUCTION

The Permian sediments in the Gondwana sequences of peninsular India are the major storehouse of the coal deposits. These coal basins had been extensively developed in the four major basins namely, Son-Mahanadi, Damodar, Satpura, and Wardha-Godavari (Fig. 1A). The sedimentary successions from the beginning of Early Permian up to the Jurassic/Cretaceous periods are very well exposed in these basins. A large number of studies pertaining to the palaeobotanical context have been carried out from these basins documenting and discussing various aspects of the Glossopteris flora. The genus *Gangamopteris* is an important element of the Glossopteris flora. McCoy (1875) instituted the genus *Gangamopteris* for a *Glossopteris* type of leaf without midrib which were earlier described by him (1847) under the name *Cyclopteris* ?*angustifolia* (Chandra, 1974). The chief character which distinguishes *Gangamopteris* from *Glossopteris* is the absence of definite midrib, the median portion being usually traversed by a group of almost parallel, anastomosing veins and a greater uniformity in their meshes. The original diagnosis of the genus was given by McCoy (1860) which was later modified by Feistmantel (1879), Arber (1905), Maithy (1965a) and Pant and Singh (1968). Although, the leaves of *Glossopteris* and *Gangamopteris* are easily distinguishable on the basis of median regions as the former possesses a distinct midrib while the latter has parallel running strands in place of a distinct midrib. However, many a times it becomes quite difficult to differentiate between these two forms as both show a number of parallel running strands in the median region. But, it has been noticed that in *Gangamopteris* the parallel running strands are joined together by oblique cross connections whereas *Glossopteris* is always devoid of such interconnections in the median veins. After running independently, the veins diverge out towards margins to form meshes after undergoing anastomosing and dichotomization (Srivastava, 1977; Pant and Singh, 1968, 1974; Srivastava and Agnihotri, 2010).

Like *Glossopteris*, it is also widely distributed in the Permian rocks of different Gondwana countries. The *Gangamopteris* has wide horizontal distribution in the Early Permian sequences of Indian Gondwana. However, it is more abundant than *Glossopteris* in the lower Permian sequences

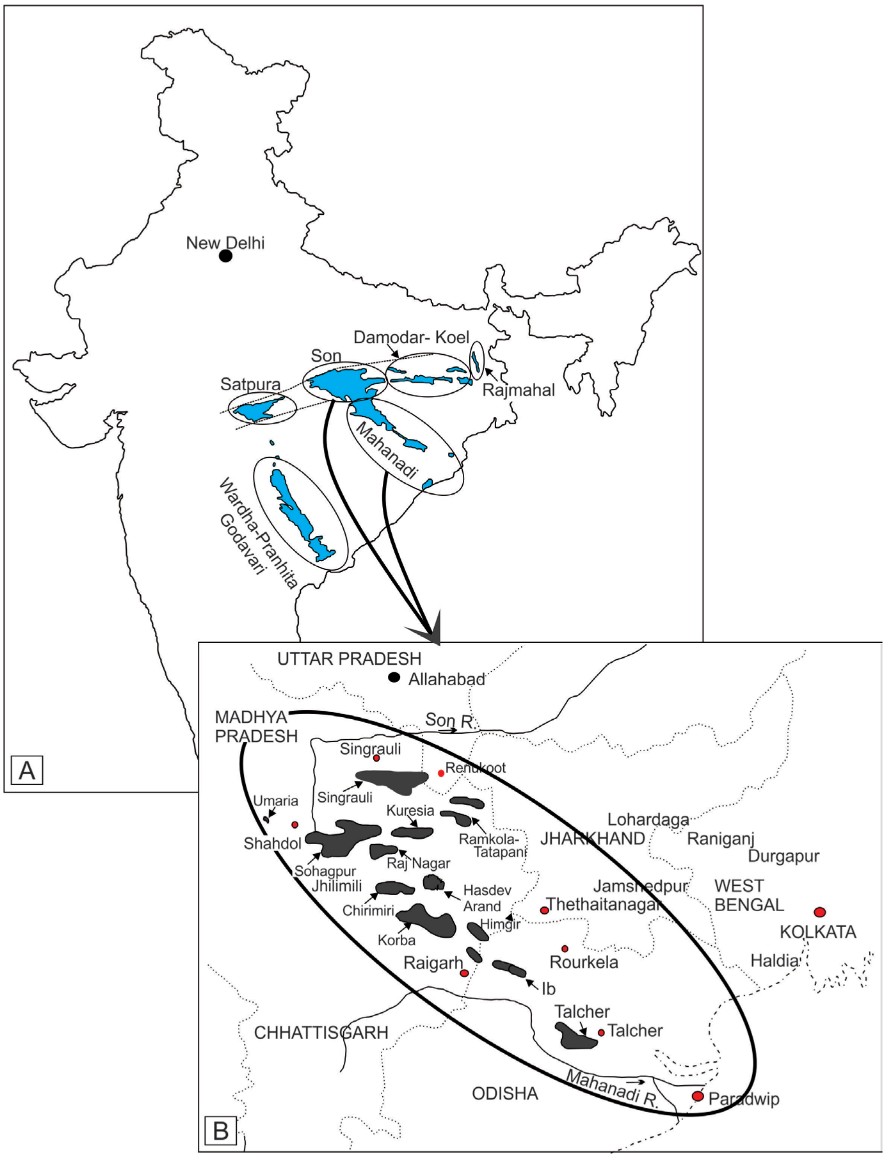


Fig. 1. (A). Coal-bearing Gondwana sedimentary basins of peninsular India (after Mukhopadhyay *et al*., 2010). (B). Depiction of distribution of important coalfields in Son-Mahanadi Basin. The coalfields positions are drawn on the base map of India and are not to scale.

namely Talchir, Karharbari and Lower Barakar formations. Except the few sporadic occurrences of this genus in the Upper Barakar Formation, it is altogether absent from the Barren Measures Formation, however rare occurrences of *Gangamopteris* have again been noticed in the Upper Permian Raniganj Formation.

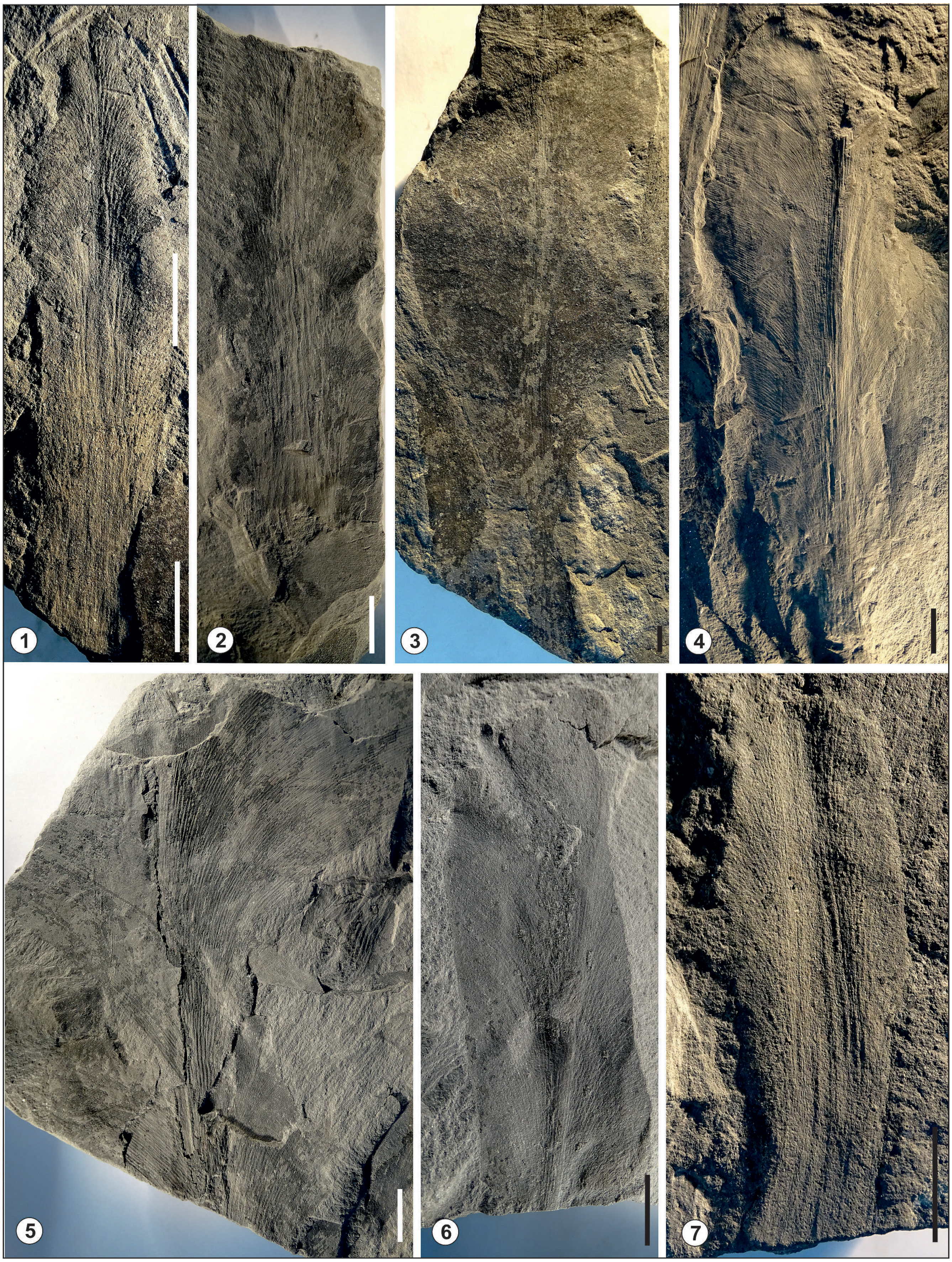
The Singrauli Coalfield is a part of the extensively distributed Lower Gondwana sequences in the northernmost boundary of the Son–Mahanadi Master Basin that stretches from east coast to the centre of Peninsular India. This coalfield embodies the last deposits of the Gondwana sedimentation. Therefore, no sediments of Gondwana period occur beyond this coalfield area in the northern part of Peninsular India.

In comparison to the extensive macrofloral studies carried out from the coal bearing sequences of the other coalfields/areas of Son-Mahanadi Basin such as Korba, Tatapani-Ramkola, Mand-Raigarh, Chirimiri, Sohagpur, Talcher and Ib River (Fig. 1B); the Singrauli Coalfield has not been studied in detail (Biswas, 1955; Ganguly, 1959; Chandra and Srivastava, 1982, 1991; Srivastava and Chandra, 1992; Goswami and Singh, 2010; Singh *et al*., 2006 a, b, c; 2011, 2012; Agnihotri *et al*., 2016; Goswami *et al*.,

EXPLANATION OF PLATE I →

1. *Gangamopteris angustifolia* McCoy, BSIP Museum Specimen No. 41651; 2. *Gangamopteris angustifolia* McCoy, BSIP Museum Specimen No. 41652A; 3. *Gangamopteris cyclopteroides*, Feistmantel, BSIP Museum Specimen No. 41652A; 4. *Gangamopteris cyclopteroides*, Feistmantel, BSIP Museum Specimen No. 41652B; 5. *Gangamopteris* sp., BSIP Museum Specimen No 41655; 6. *Gangamopteris major* Feistmantel, BSIP Museum Specimen No. 41653; 7. *Gangamopteris karharbariensis* Maithy, 1965 BSIP Museum Specimen No. 41654. (Scale bar is 5 mm for all the specimens)

Plate I



2018; Saxena *et al*., 2018). Except for a few early reports in which glossopterid megaplants are recorded from the Talchir and Barakar sediments carried out about five decades ago (Lele, 1966; Lele *et al.,* 1968), the coal-bearing sequences of this coalfield have never been taken up for investigations. Recently, well preserved, diversified mega and miofloral assemblages of Glossopterid remains recovered from the Raniganj Formation of Jhingurdah Colliery (Singh and Saxena, 2015; Singh *et al*., 2016), Barakar Formations of Bina Colliery (Saxena *et al*., 2016; Singh *et al*., 2017), Block-B and Nigahi collieries (Saxena *et al*., 2019) of Singrauli Coalfield have been studied in detail. Megafloral assemblage pertaining to the genus *Glossopteris* procured from the coal bearing sequences of the Block-B colliery has already been discussed in detail (Saxena *et al*., 2019). A number of palynological studies are available from this coalfield (Trivedi, 1950; Bhardwaj and Sinha, 1969a, b; Tiwari, 1969, 1971; Tiwari and Srivastava, 1984; Vijaya *et al.*, 2012).

Recently, a diversified Glossopterid assemblage comprising mainly of *Gangamopteris*, *Glossopteris*, seeds and equisetalean axes has been procured from the coal bearing sequence of the Barakar Formation of Block-B colliery. The present paper deals with the systematic studies of the genus *Gangamopteris* recorded herein. Attempts have also been made to discuss and correlate *Gangamopteris* diversity of Singrauli Coalfield with other coalfields of Son-Mahanadi Basin. A complete account depicting all the stratigraphical occurrences of various *Gangamopteris* species in Indian Gondwana has also been provided.

GEOLOGICAL SETTING

The Singrauli Coalfield 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 falls in Singrauli District of Madhya Pradesh State. The north eastern part of the coalfield sits on plateau with an altitude of 500 m above msl. The Singrauli Coalfield is divided into two parts: the Moher sub-basin lies in the Sidhi District of Madhya Pradesh and a small part lies in the Sonbhadra District of Uttar Pradesh. Singrauli main Basin lies in the western and southern parts of the coalfield and is largely unexplored.

The coalfield is structurally divided into two tectono–sedimentary sub–basins: (i) Singrauli main sub–basin to the west and (ii), the Moher sub–basin on the north–eastern side. However, these two sub–basins are not precisely delineated as all the Lower Gondwana formations are successively exposed in both the basins. The sediments of Permian age belonging to Talchir, Barakar, Barren Measures and Raniganj formations are extensively exposed in the Moher sub–basin. Sediments of Panchet (Pali) and Mahadeva (Parsora) formations belonging to Triassic age 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. The coal reserves in the Moher sub-basin covering an area of around 220 sq km, is about 9000 million tonnes, out of which 2,724 million tonnes are proved reserves. 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. Of these, the coal of the Jhingurdah Colliery belongs to Raniganj Formation (with thickest coal seam (134 m) in India) and rest other belong to the Barakar Formation. The Barakar Formation has three coal seams, lowermost Turra seam, middle Purewa Bottom and the uppermost Purewa Top (Fig. 2). Below Turra, a thin seam, namely Kota also exists that is in the Karharbari Formation. The stratigraphic sequence met within the Singrauli Coalfield is given in Table 1.

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

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

MATERIALS AND METHODS

The fossil specimens described in the present communication is a part of the megafossil assemblage comprising *Glossopteris, Gangamopteris*, stems and roots

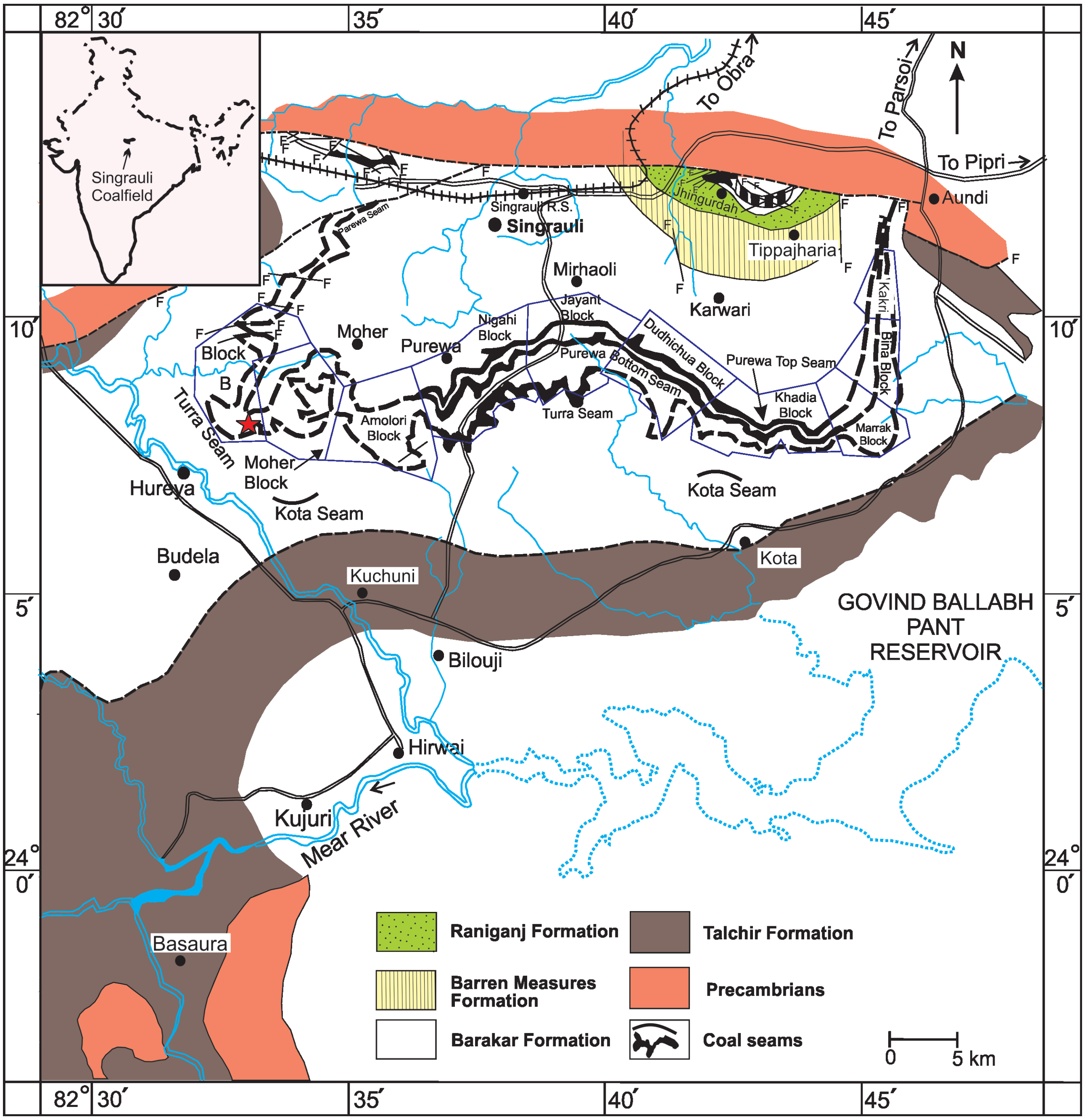


Fig. 2. Location Map of the Singrauli Coalfield showing the different collieries and position of Block-B colliery (modified after Raja Rao, 1983).

collected from the sedimentary sequences of Barakar Formation of the lower most seam, i.e. the Turra seam of Block-B colliery, Singrauli Coalfield. The generalized litholog depicting the coal, shale and sandstone horizons occurring in Turra Seam is given in Fig. 3. The log is based on the bore-core data of the Turra coal seam. In this paper, 23 megafossil specimens belonging to the genus *Gangamopteris* are described and discussed in detail. The specimens are preserved as impressions on grey shale and siltstone units of the coal-bearing sequence. They are measured and photographed to record the morphological characters using low power Leica microscope and Sony HX 400 digital camera. For the identification and species determination, different kinds of external 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 consideration. The details of the sequence yielding megafossil specimens are given in Fig. 4 and some of the specimens are shown in Plate I. The occurrence of different species of *Gangamopteris* is given in Table 2 and their salient morphological characters are provided in Table -3.

All the figured specimens are deposited in the repository of Birbal Sahni Institute of Palaeosciences, Lucknow vide statement number 1508 and museum specimen numbers 41651 to 41655.

Table 2. Distribution of *Gangamopteris* species occurring in Singrauli Coalfield and their respective representation in other Gondwana coalfields/basins.

Gondwana Coalfields/ Basins →	**1. Talcher**	**2. Mand-Raigarh**	**3. Tatapani - Ramkola**	**4. Korba**	**5. Chirimiri**	**6. Singrauli**	**7. Hutar**	**8. Pachwara**	**9. Raniganj**	**10. Jharia**	**11.Karanpura**	**12. Bokaro**	**13. Deogarh**	**14. Auranga**	**15. Hura/Bansloi**	**16. Daltonganj**	**17. Pali**	**18. Umaria**	**19.Girdih**	**20. Mohpani**	**21. Pench Valley**	**22. Kanhan Valley**	**23. Pathakhera**	**24. Umrer**	**25. Nand**	**26. Kamptee**	**27. Arunachal**	**28. Kashmir**
Gangamopteris (5 spp.)																												
Gangamopteris angustifolia	+	+	+	+		+			?	+			+	+			+	+	+	+								+
G. cyclopteroides	+	+		+	+	+	+	?	+	+	+		+	+	+	+	+	+	+	+	+	+	+	+	+		+	+
G. karharbariensis					+	+													+									
G. major	+				+	+			+		+			+			+		+	+	+	+	+					+
Gangamopteris sp.	+	+	+	+	+	+			+	+	+		+	+		+	+	+	+	+	+		+		+		+	+

Table 3. Salient morphological characters for species differentiation among the *Gangamopteris* species occurring in Singrauli Coalfield.

G. angustifolia	***G. cyclopteroides***	***G. karharbariensis***	***G. major***
Small leaves, linear-lanceolate shape, margin subparallel, asymmetrical, acute apex and tapering base. Few subparallel veins in median region, meshes uniform throughout the lamina.	Medium to large size, linear-lanceolate shape with gradually tapering base and obovate-acute apex, median region occupied with about 5-8 subparallel strong veins. Maximum width at half of the leaf length, meshes relatively broader near the margin.	Medium sized leaves, lanceolate shape, apex bluntly pointed, median region characterized by few weak subparallel running veins, meshes are of nearly uniform size.	Medium-large leaves, Spathulate-rhomboidal shape, broad obtuse apex and narrow tapering base. Maximum width above half length of the lamina. Median region occupied with ill defined obscure subparallel running veins.

SYSTEMATICS

Division **GYMNOSPERMOPHYTA**
Order **GLOSSOPTERIDALES**
Genus ***Gangamopteris* McCoy, 1875**
Type Species ***Gangamopteris angustifolia*** McCoy, 1875

Gangamopteris angustifolia McCoy, 1875
(Pl. I. Figs. 1, 2)

Synonymy

1847- *Cyclopteris* (?) *angustifolia* McCoy vol. XX, tab. 19, figs. 3, 3a.

1875 – *Gangamopteris angustifolia* McCoy p. 11, Pls. XII, fig. 1, XIII, fig. 2.

1879- *Gangamopteris angustifolia* Feistmantel p. 16, Pl. IX, fig. 5

Material: One specimen, incomplete preserved as impression with patchy carbonized crusts, preservation degree is good.

Description: The preserved leaf is 8.8 cm in length and 3.1 cm in width. The leaf seems to be narrow, small, linear and lanceolate in shape. Apex, base and margin of the leaf are not preserved. The median portion is occupied by 7-8 veins running sub-parallel from base to apex. These sub-parallel running veins form lateral veins that emanate at about 30°-40° and arch outwards. They dichotomise and anastomose to form elongate, narrow and linear meshes throughout the lamina.

Remarks: The present leaf resembles in its morphological character with specimens of *Gangamopteris angustifolia* described by McCoy, 1875 (Pl. XII, fig. 1; Pl. XIII, fig. 2 and (Feistmantel 1879, Pl. IX, fig. 5; 1881, Pl. XXX, fig. 10). However, McCoy earlier described it as *Cyclopteris* (?) *angustifolia* in 1847, which was later described as *Gangamopteris angustifolia* by himself in 1875 and later by Feistmantel in 1879. The specimen is also in accordance with specimens as described and discussed by later workers- Maithy, 1965a (Pl. 2, figs. 9, 10), Chandra and Srivastava 1982 (Pl. 2, fig. 14), Singh *et al*. 2006b (Pl. 2, fig. 4) and Srivastava *et al*. 2012 (Pl. 1, fig. b) in lanceolate shape, small size, venation pattern and absence of definite midrib.

Gangamopteris cyclopteroides Feistmantel, 1876
(Pl. I. Figs. 3, 4)

1869 - *Noeggerathia obovata* Carruthers

1876- *Gangamopteris cyclopteroides* Feistmantel

1879- *Gangamopteris cyclopteroides* var. *subauriculata* Feistmantel, Pl. X, figs. 1, 1a.

-*Gangamopteris cyclopteroides* var. *areolata* Feistmantel, Pl. X, fig. 2. Pg. 14, Pl. XVI, fig. 4.

-*Gangamopteris cyclopteroides* var. *attenuata* Feistmantel, p. 14, Pl. XI, fig. 1, Pl. XII, fig. 1.

- *Gangamopteris cyclopteroides* Feistmantel, Pl. X, fig. 3; p. 12, Pl. XI, figs. 2, 3, and 4; p. 12, Pl. XII, figs 2 and 3.

1905- *Gangamopteris clarkeana* (Feistmantel) Arber, p. 108

1905- *Gangamopteris hugesi* (Feistmantel) Arber, p. 108

1908- *Noeggerathia obovata* (Carruthers)White

1908- *Noeggerathia obovata* (Carruthers) Seward

1954- *Gangamopteris obovata* var. *major* Dolianiti

1965- *Gangamopteris cyclopteroides*

Material: 14 incomplete specimens in collection of which 2 are near complete. Preserved mostly as impression with thin patchy carbonized layers at places. Preservation degree is moderate to good.

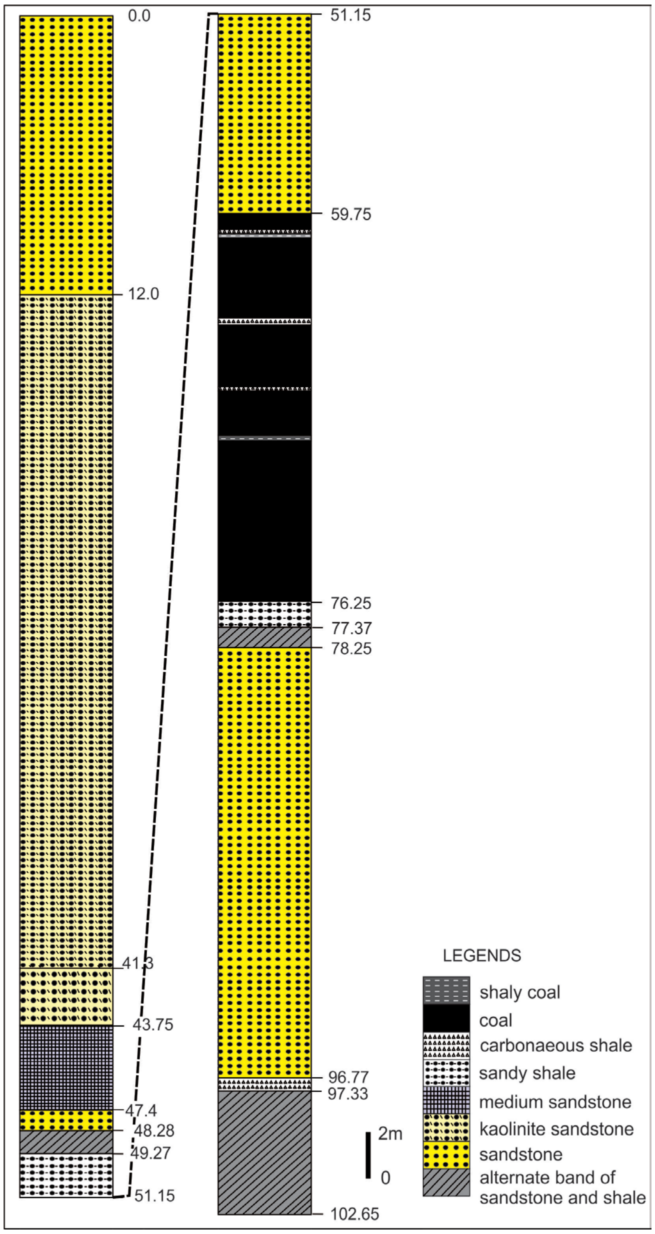


Fig. 3. Generalized litholog of the Turra Seam in Block-B showing the various horizons of coal, shale and sandstones. The log is based on the bore-core data of Turra seam provided by authorities of Block-B colliery, Singrauli Coalfield.

Description: Preserved leaves are ovate with tapered end at the basal portions and the upper portions, comparatively broader. Leaves vary in size from 5.2 cm to 18.9 cm in length and from 2.9 cm to 7.6 cm in width. The veins emanate from the base; medial portion is occupied by 3-7 parallel running interconnected strands, forming elongate meshes. Secondary veins appear to be emanated from the base and progressively spread out at an acute angle to the margins. Lateral veins form polygonal meshes after dichotomisation and anastomosis. Meshes are 3.5-5.5 mm long and 0.5-1.0 mm wide near the median portion whereas meshes, near the margin, are 2.4-3.9 mm long and 0.2-0.5 mm wide. Vein density is low near the middle part and comparatively higher near the margin.

Remarks: Specimens closely resemble in their

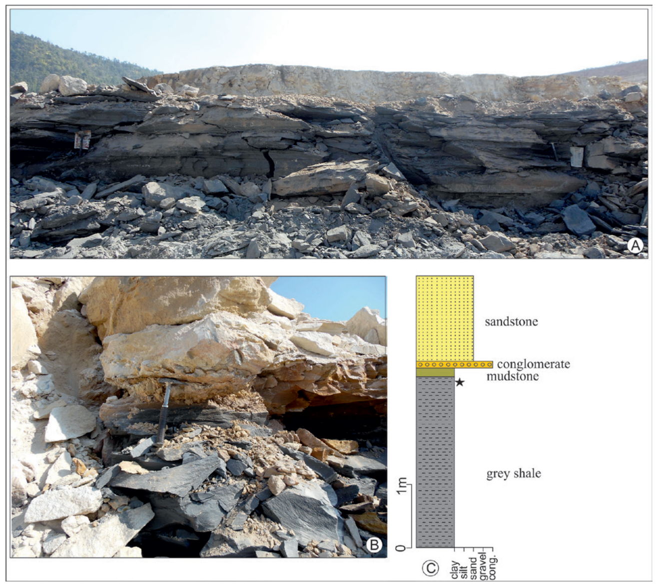


Fig. 4. (A) Field photograph of a part of the Turra Seam, Block B colliery, showing a coal bearing sequence. (B) Closer view of the section depicting horizon yielding megafossil assemblage (C) Litholog of the section of Turra Seam yielding megafossil assemblage (* indicate fossil bearing horizon).

general shape and venation pattern with the specimens of *Gangamopteris cyclopteroides* described by Feistmantel, 1879 (Pl. IX, figs 2, 4; Pl. X, fig. 3; Pl. XXVI, fig. 1). Feistmantel erected this species in 1876, but the illustrations about the holotype specimen and other specimens with pertinent photographs and drawings were provided in 1879. On the basis of minor differences in apex and base characteristics, he instituted four varieties of *G. cyclopteroides* (Pl. X, Fig. 1; Pl. XIII, Fig. 2, Pl. XV, Figs. 1,2 and 3) namely, *G cyclopteroides* var. *auriculata*. *G. cyclopteroides* var. *subauriculata* (proportionally greater length and narrow base); *G. cyclopteroides* var. *aerolata* (neat broad polygonal meshes); *G. cyclopteroides* var. attenuata (leaf little larger and much narrow towards the base). Later on, in 1881, he erected three more varieties (Table -4). However, Arber (1905) did not recognized above varieties because of indistinguishable morphological characteristics from the typical *G. cyclopteroides*. Subsequent workers have also not agreed with the concept of varieties of *G. cyclopteroides* and regarded all of them as the same species belonging to *G. cyclopteroides*. Preference to use *G. cyclopteroides* over *G. obovata* has been a matter of considerable debate. Some authors had considered *G. obovata* as synonymous to *G. cyclopteroides* (White, 1908; Dolianiti, 1954; Archangelsky, 1958. In the subsequent works, *G. obovata* has been considered as a distinct species (Maithy, 1965a). Fernández and Césari (2019), while working on the leaf whorl and phyllotaxy of *Gangamopteris* McCoy recovered from the Bajo de Véliz Formation, San Luis Province, Argentina, has discussed in detail about the controversies pertaining to *G. cyclopteroides* and *G. obovata*. Tybusch *et al*. (2016) have proposed to distinguish *G. cyclopteroides* from *G. obovata* "by the absence (in the Brazilian species) or presence (in the Indian species) of straight sharp subparallel veins in the middle region of the lamina from the base to the apical region of the leaf, just below the apex". Fernández and Césari

Table 4. Stratigraphical distribution of *Gangamopteris* species in Indian Lower Gondwana formations (modified after Singh *et al*., 2012).

S. No.	**Formation →** ***Gangamopteris* species**	**Talchir**	**Karharbari**	**Barakar**	**Barren Measures**	**Raniganj**
1.	*Gangamopteris angustifolia* McCoy 1875	+	+	+		
2.	*G. anthrophyoides* Feistmantel 1880					+
3.	*G. buriadica* Feistmantel 1879	+	+	+		
4.	*G. chatterjei* Bhattacharyya 1963			+		
5.	*G. clarkeana* Feistmantel 1879	+	+	+		
6.	*G. cyclopteroides* Feistmantel 1876	+	+	+		?
7.	*G. cyclopteroides* var. *acuminata* Feistmantel 1881	+				
8.	*G. cyclopteroides* var. *areolata* Feistmantel 1879	+	+			
9.	*G. cyclopteroides* var. *attenuata* Feistmantel 1879	+	+			
10.	*G. cyclopteroides* var. *auriculata* Feistmantel 1879		+			
11.	*G. cyclopteroides* var. *cordatifolia* Feistmantel 1881	+				
12.	*G. cyclopteroides* var. *crassinervis* Feistmantel 1881	+				
13.	*G. cyclopteroides* var. *subauriculata* Feistmantel 1879	+	+	+		
14.	*G. fibrosa* Maithy 1965	+	+	+		
15.	*G. flexuosa* Srivastava 1956					+
26.	*G. gondwanensis* Maithy 1965		+	+		
17.	*G. hispida* Pant and Singh 1968		+	+		
18.	*G. hughesii* Feistmantel 1876			+		
19.	*G. indica* Srivastava 1956					+
20.	*G. intermedia* Maithy 1965	+	+	+		
21.	*G. karharbariensis* Maithy 1965	+	+	+		
22.	*G. kashmirensis* Seward 1905		+	+		
23.	*G. maheshwarii* Bajpai 1990			+		
24.	*G. major* Feistmantel 1879	+	+	+		
25.	*G. media* Pant and Singh 1968		+			
26.	*G. mucronata* Maithy 1965	+	+	+		
27.	*G. oblanceolata* Maithy 1970		+			
28.	*G. obliqua* McCoy 1875	+	+	+		
29.	*G. obtusifolia* Pant and Singh 1968		+	+		
30.	*G. papillosa* Pant and Singh 1968		+			
31.	*G. rajaensis* Srivastava 1992			+		
32.	*G. spatulata* McCoy 1875	+	+	?		
33.	*G. srivastavae* Maithy 1968		+			
34.	*G. sethiaensis* Srivastava and Agnihotri 2010			+		
35.	*G. satpuraensis* Srivastava and Agnihotri 2010			+		
36.	*G. whittiana* Feistmantel 1876			+		+
37.	*Gangamopteris* sp.	+	+	+		
	Total number of taxa	18	24	23	0	4

(2019) have suggested that the presence, or not, of a cluster of central veins along the lamina, the shape of the leaves and the proportion of meshes may be useful characters to distinguish these similar species.

G. cyclopteroides is the most ubiquitous species of this genus in its stratigraphic occurrences in Indian Gondwana, hence there is great degree of variations in its morphological characters. Therefore, present specimens are compared with those specimens, which are in close accordance with the diagnosis as given by Fiestmentel. The presence specimens are also similar to the specimens illustrated by Maithy, 1965a (Pl. 1, figs 1-3), Pant and Singh, 1968 (Pl. 27, fig. 1), Srivastava, 1977 (Pl. 1, fig. 1), Chandra and Srivastava 1982 (Pl. 1, fig. 1), Singh *et al*., 2005 (Pl. 2, fig. 2), 2006a (Pl. 2, fig. 2), 2006b (Pl. 2, fig. 1), 2012 (Pl. 1, fig. 1-4; Pl. 2, fig. 2, 3), Srivastava *et al*. (2012; Pl. 1, fig. b).

Gangamopteris major Feistmantel, 1879
(Pl. I. Fig. 6)

1879- *Gangamopteris major* Feistmantel, p.15, Pl. XIV, fig. 3; Pl. XVI, figs. 1, 2 and 5.

1905- *Gangamopteris cyclopteroides* var. *major* Arber

Material: 2 incomplete specimens in collection, preserved as impressions. Degree of preservation is good.

Description: This species is represented by two incomplete leaves in the collection. The shape of the specimens is narrow-elongate to spatulate, margin entire; apices and bases are not preserved. The leaves range from 6.3 cm to 10.7 cm in length and 2.3 cm to 3.3 cm in width. There are 3-5 subparallel strands in the median region and secondary veins fan out at acute angles from these subparallel veins of the median region. The meshes formed by dichotomisation and anastomosis are linear elongate and more or less equal in size.

Remarks: The specimens resemble in possessing elongate shape, linear-narrow meshes and 3-5 subparallel veins with *G. major* described by Feistmantel (1879; Pl. 14, fig. 14, Pl. 16, Figs. 1-2) from Karharbari Formation of Giridih Coalfield. The leaves also show resemblance with *G. major* described by Feistmantel (1886; Pl. 5A, fig. 9, Pl. 11A, fig. 9) from Rikba beds of Karanpura Coalfield. Fiestemntal established this taxon in 1879, later on, Arber (1905) considered this as a variety of *Gangamopteris cyclopteroides* and regarded it as *G. cyclopteroides* var. *major*, although Arber himself rejected the idea of Feistmentel erecting the other varieties of *G. cyclopteroides*. Subsequently, Maithy in 1965a, retained the same under a separate taxon *G. major* discarding the merger by Arber as a variety of *G. cyclopteroides*. The present specimens are in morphological accordance with specimens illustrated by Maithy (1965a; Pl. 1, fig. 7) from Karharbari Formation of Giridih Coalfield. The leaves are also comparable with *Gangamopteris major* described by Chandra and Srivastava (1982; Pl. 1, Fig. 5 and Pl. 2, Fig. 12), Chandra *et al*. (1992; Pl. 1, fig. 2 and Pl. 3, fig. 2), from Talchir Formation of Chandas Nala section of Anuppur area, Shahdol District; Tewari and Srivastava (2000; Pl. 1, fig.2) described from Talchir Formation, Auranga Coalfield, Singh *et al*. (2006b; Pl. 1, fig. 3) and Srivastava *et al*. (2012; Pl. 1, fig. d) in shape and venation pattern.

Gangamopteris karharbariensis Maithy, 1965a
(Pl. I. Fig. 7)

Type species: *Gangamopteris karharbariensis*

Material: One incomplete specimen in collection, preserved as impression. Degree of preservation is good.

Description: The length of the preserved leaf is 4.8 cm

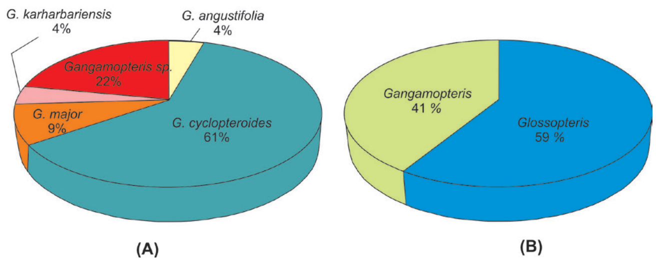


Fig. 5. (A) Relative frequency distribution of *Gangamopteris* species in the Block-B colliery. (B) Overall relative distribution of the two most dominant genera *Glossopteris* and *Gangamopteris* in Block-B colliery.

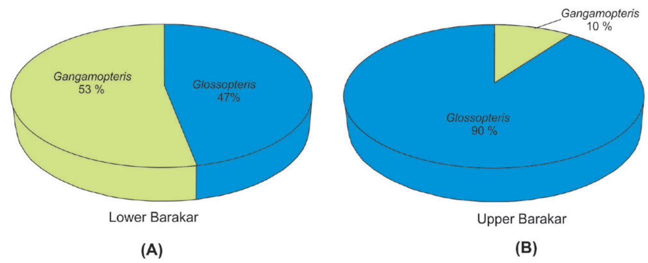


Fig. 6. (A) Percentage frequency distribution of the species of *Gangamopteris* and *Glossopteris* in the Barakr Formation of central India (A) Lower Barakar Formation. (B) Upper Barakar Formation (after Srivastava and Agnihotri, 2010).

and width 1.5 cm at its widest portion. The specimen has entire margin, linear to lanceolate in shape, apex as well as base is not preserved. 3-4 subparallel veins occupy the median portion. Lateral veins emerge from the median strands at an acute angle, forming narrow elongate meshes all through the lamina.

Remarks: The species was erected by Maithy (1965a) vide holotype specimen number 31381/424, BSIP repository. The preserved leaf shows close resemblance in its venation pattern with *G. karharbariensis* described by Maithy (1965a; Pl. 2, fig. 11-13) from Karharbari Formation, Giridih Coalfield. The leaf is also similar with *G. karharbariensis* in its venation pattern and shape described by Chandra and Srivastava (1982; Pl. 2, Fig.13) from Talchir and coal bearing formation of South Rewa Gondwana Basin, Tewari and Srivastava (2000a; Pl. 2, fig. 4) from Talchir Formation, Auranga Coalfield, Bihar and Srivastava *et al*. (2012; Pl. 1, fig. c) from Lower Gondwana of Mohpani Coalfield, Satpura Basin, Madhya Pradesh.

Gangamopteris sp.
(Pl. I. Fig. 5)

Material: 5 incomplete specimens in the collection, all are preserved as impressions. Degree of preservation is moderate to poor.

Description: The leaves range in size from 6.3 cm – 10.7 cm in length and from 2.3 cm -3.3 cm in width. Veins emerge from the basal part, and median portion is occupied by 3-7 parallel running thick median strands. Due to incomplete and poor preservation the species rank is not assigned.

DISCUSSION

The genus *Gangamopteris* is an important constituent of the Glossopteris flora and has been recorded mostly from the Early Permian sequences of all the five major sedimentary basins of India. The study of genus *Gangamopteris* for its systematic, stratigraphical and palaeogeographical context is of utmost significance as it is the commonest occurring element of Gondwana flora which inhabited the land during the early Permian after the deglaciation. It provides the strong bearing not only for understanding the evolution and subsequent proliferation of Gondwana floral elements during the Permian but also their palaeoecological preferences. In the present paper, attempts have been made to discuss the salient characteristics of *Gangamopteris* species occurring in Singrauli Coalfield, evolutionary significance, its relative distribution within the Brakar sediments and its comparable geographical distribution in other Gondwana basins of India.

In India, stratigraphically, its occurrence is generally restricted to the lower Permian sequences namely Talchir, Karharbari and Lower Barakar formations. In the Talchir and Karharbari formations, it is more abundant than *Glossopteris.* Barring the sporadic occurrences of this genus in the Upper Barakar Formation, it is altogether absent from the Barren Measures Formation, however, a few occurrences of *Gangamopteris* have again been reported in the Upper Permian Raniganj Formation.

Large number of plant fossils are recovered from the coal bearing Barakar Formation (Turra Seam) of Block-B colliery, of which 23 specimens belong to the genus *Gangamopteris,* represented by five species viz., *Gangamopteris angustifolia, G. cyclopteroides, G. karharbariensis, G. major* and *Gangamopteris* sp. *Gangamopteris cyclopteroides* has the maximum occurrence (14 specimens) followed by *Gangamopteris* sp., *G. major, G. angustifolia* and *G. karharbariensis,* represented by one specimen each. The occurrence of *Gangamopteris* is relatively poor in comparison to that of *Glossopteris*. The relative percentage frequency distribution of each of the *Gangamopteris* species is shown in Fig. 5A and its relative abundance as a genus with respect to the genus *Glossopteris* in Block-B colliery is shown in Fig. 5B. Interestingly, all the species reported herein are quite large in size specially the leaves of *G. cyclopteroides* that range from 5.2 to 18.9 cm in length. Such large sizes of the leaves pretend the shady conditions where the plants are generally unable to get the direct sun light. Similar observations were made on the basis of large size of the *Glossopteris* leaves recovered from the same horizon of present colliery (Saxena *et al*., 2019). The megafloral assemblage comprises of four genera (*Euryphyllum, Paracalamites, Gangamopteris* and *Glossopteris*) and 17 species. The genus *Glossopteris* has the maximum abundance in the assemblage and is represented by 10 species, amongst which taxon *Glossopteris gigas* dominates over other species (Saxena *et al*., 2019). *Glossopteris gigas*, as the specific name itself suggests is of fairly size.

The genus *Gangamopteris* has also been recorded previously from the Turra seam of Bina Colliery, Singrauli Coalfield (Saxena *et al*., 2016) as *G. cyclopteroides* species. From this coalfield, *Gangamopteris cyclopteroides, Gangamopteris* cf. *G. major* and *Gangamopteris* sp. have also been earlier reported from the Talchir Formation

(Lele, 1966); and *Gangamopteris* cf. *G. angustifolia*, and *G. cyclopteroides* from the Barakar Formation (Lele *et al*., 1968). The relative stratigraphic distribution of *Gangamopteris* species occurring in the Singrauli coalfield and their representation in other Indian Gondwana coalfields/ basin is given in Table 2.

The distribution of *Gangamopteris* leaves in the Lower Gondwana sequences indicates their good representation in the early part of Permian (Table 4). They are recorded from upper Talchir sequence of South Rewa Gondwana Basin and North Karanpura Coalfield, Karharbari beds of Giridih, Auranga, Nand and Talcher coalfields (Feistmantel, 1879; Maithy, 1965a,b; Srivastava, 1977; Singh *et al*., 2005, 2006a,b) and Lower Barakar flora of Raniganj, Deogarh, Pench Valley, Mohpani, Ib-River, Korba and Singrauli coalfields, (Feistmantel, 1881; Srivastava, 1992; Srivastava and Agnihotri, 2010; Srivastava *et al*., 2012; Bajpai, 1990; Singh *et al*., 2006a, b, 2012, 2017). Occurrence of *Gangamopteris* in association with the genera *Noeggerathiopsis*, *Cordaites*, *Buriadia, Botrychiopsis*, *Ottokaria*, *Euryphyllum,* and *Rubidgea* generally indicate the existence of Karharbari Formation (Banerjee, 1987). The absence of these associated genera barring *Glossopteris* in the Block B assemblage rules out these beds belonging to Karharbari Formation. The palynoassemblage recovered from Block B colliery (Saxena *et al*., 2019) also confirms these beds to be of Lower Barakar Formation, not the Karharbari Formation.

This genus has rare occurrences in the upper Permian sediments, only few species have been reported from the Raniganj Formation namely, *G. anthrophyoides* (Feistmantel 1880), *G. cyclopteroides* (Feistmantel, 1876), *G. flexuosa* (Srivastava, 1956), *G. whittiana* (Feistmantel, 1876), *G. indica* (Srivastava, 1956). Srivastava and Agnihotri (2010) described sixteen species of *Gangamopteris* from Barakar Formation of Pench Valley Coalfield in Satpura Gondwana Basin. They have synthesized the data pertaining to the genera *Gangamopteris* and *Glossopteris* in different Lower Gondwana formations of India and found that *Gangamopteris* dominated over *Glossopteris* in Talchir Formation with a percentage ratio of 75% : 25%. However, towards Karharbari, lower Barakar and upper Barakar the dominance of *Gangamopteris* diminished in favour of *Glossopteris* as is evidenced by the following percentage ratios (58% : 42% in Karharbari, 53% : 47% in lower Barakar and 10%: 90% in upper Barakar) as discussed by Srivastava and Agnihotri (2010) and shown in figure 6. The stratigraphical occurrences of various *Gangamopteris* species occurring in Indian Lower Gondwana formations have been provided in Table 4. It is evident from the data gathered and shown in present study that, there are more or less equal and comparable occurrences of *Gangamopteris* and *Glossopteris* in the lower Barakar sequences, whereas the frequency as well as species diversity of *Gangamopteris* sharply decline in upper Barakar sequences. Further, while dealing with the evolutionary perspective of the genus *Gangamopteris* and its species (*G. clarkeana, G. major and G. cyclopteroides*) Srivastava and Agnihotri (2010, fig. 12 A) have considered the coalescence of median veins after straightening have given rise to the mid rib like conditions in *Glossopteris.*

CONCLUDING REMARKS

The distribution of genus *Gangamopteris* in Indian Lower Gondwana sediments particularly in the Early Permian sequences is far and wide. In the Indian records, it is the most characteristic element of the pioneer flora inhabiting the land after the Carboniferous deglaciation. The other common co-occurring elements are *Noeggerathiopsis* and *Glossopteris*. Among the hitherto recorded Permian flora of Singrauli coalfield, the present record of *Gangamopteris* is rich in terms of diversity and abundance and suggests an Early Permian (Artinskian) age to studied strata. Five species (*G. angustifolia, G. cyclopteroides, G. karharbariensis, G. major* and *Gangamopteris* sp.) have been recorded. Moreover, the size of the leaves are quite big as compared to the size of the same species recorded from the other coalfields of Son Basin, indicate prevalence of shady conditions in the growing area. The available floral records of the diversity of *Glossopteris* and *Gangamopteris* in the studied coalfield reveal the gradual diminishing occurrences of *Gangampoteris* form the early Permian to late Permian.

ACKNOWLEDGEMENTS

The authors are thankful to the Director, Birbal Sahni Institute of Palaeosciences, for providing necessary facilities and permission (BSIP/ RDCC/62/2018-19) to carry out this work. The help rendered by Mr. Husain Shabbar for preparation of figures is also acknowledged. We also extend our thanks to Mr. T.K. Nag, CMD and Mr. Niranjan Das, Director (Technical/ Project and Planning), Singrauli Coalfield and to the CGM and GM of Block-B Colliery of this Coalfield for their help in providing bore-core data and permission to collect the plant fossils from colliery. Authors are also grateful to Prof. M. E. Popa and an anonymous reviewers for their comments and suggestions to improve the manuscript.

REFERENCES

Agnihotri, D., Tewari, R., Pillai, S.S.K., Jasper, A. and Uhl. D. 2016. Early Permian Glossopteris flora from the Sharda Open Cast Mine, Sohagpur Coafield, Shahdol District, Madhya Pradesh. Palaeobotanist, 65: 97-107.

Arber, E.A.N. 1905. Catalogue of the fossil plants of the Glossopteris flora in the Department of Geology. British Museum (Natural History), The Glossopteris Flora. London.

Archengelsky, S. 1958. Estudio Geologica Palaeontologica del Bajo de la Leona (Santa Cruz). De. Acta geologis Lillana. 2: 5-153.

Bajpai, U. 1990. Floristics, age and stratigraphic position of fossiliferous band in Chitra mine area, Saharjuri outlier, Deogarh Coalfield, Bihar. Palaeobotanist, 37: 306–315.

Banerjee, M. 1987. Karharbari: a formation or biozone. Palaeobotanist, 36: 37-50.

Bharadwaj, D.C. and Sinha, V. 1969a. Some new miospores from Lower Gondwana Coals. In: (Eds. Santapau, H. et al) J. Sen Memorial Volume, Botanical Society Bengal, Calcutta. p. 7-16.

Bharadwaj, D.C. and Sinha, V. 1969b. Sporological succession and age of Jhingurdah Seam, Singrauli Coalfield, M.P. India. Palaeobotanist, 17: 275-287.

Biswas, B.D. 1955. Geology of the Kurasia Coalfield around Chirimiri area, South Rewa Gondwana Basin. Quarterly Journal Geology Mineralogy Metallurgical Society of India, 27: 39-65.

Carruthers, W. 1869. Coal Plants from Brazil. III. On the plant remainsfrom the Brazilian Coal Beds with remarks on the genus Flemingites. Geological Magazine. 6: 151–156.

Chandra, S. 1974. Glossopteris and allied genera - morphological studies. In: Surange KR, Lakhanpal RN and Bharadwaj DC (Editors) — Aspects and appraisal. Birbal Sahni Institute of Palaeobotany Publication: 126-143.

Chandra, S. and Srivastava, A. K. 1982. Plant fossils from the Talchir and the coal bearing formations of South Rewa Gondwana Basin, India and their biostratigraphical significance. Palaeobotanist, 30: 143-167.

Chandra, S. and Srivastava, A. K. 1991. Occurrence of Cordaitalean like foliage in the Lower Gondwana flora of India. Acta Palaeobotanica, 31: 5- 15.

Chandra, S., Srivastava, A. K. and Singh, K. J. 1992. Lower Plant fossils from India and early developmental history of the Glossopteris flora. Acta Palaeobotanica, 32: 5-19.

Dolianiti, E. 1954. A Flora do Gondwana Inferior em Santa Catarina. 4: o gênero Vertebraria. Div. Geol. Mineral.: Notas Preliminares e Estudos. 81: 1–5.

Feistmantel, O. 1876. Note on the Gondwana age of some fossil floras in India. Records of the Geological Survey of India, 9 (2, 3): 27- 62, 63-114.

Feistmantel, O. 1879. The fossil flora of the Lower Gondwanas-1. The flora of the Talchir- Karharbari beds. Memoirs of the Geological Survey of India, Palaeontologia Indica Series, 123: 1-48.

Feistmantel, O. 1880. The fossil flora of the Gondwana System (Lower Gondwanas)–2. The flora of the Damuda and Panchet Divisions (1st part). Memoir Geological Survey of India–Palaeontologia Indica Series, 12: 1–77.

Feistmantel, O. 1881. The fossil flora of the Gondwana System-3 (Lower Gondwanas) -3. The flora of the Damuda and Panchet divisions. Memoirs of the Geological Survey of India, Palaeontologia Indica Series, 12, 3: 78-149.

Feistmantel, O. 1886. The fossil flora of the Gondwana system. The fossil flora of some coalfields in Western Bengal. Palaeontologia Indica Series 12, 4(2): 1-71.

Fernández, J.A. and Césari, S.N. 2019. Leafy branches of *Gangamopteris* from the Gzhelian–Asselian of western most Gondwana. Comptes Rendus Palevol. 18: 913-924.

Ganguly, S. 1959. Palaeontological study of Lower Gondwana rocks including the coal seams around Chirimiri of Surguja District, Madhya Pradesh. Quarterly Journal Geology Mineralogy Metallurgical Society of India, 31: 155-166.

Goswami, S., Saxena, A., Singh, K. J., Chandra, S. and Cleal, C. J. 2018. An appraisal of the Permian palaeobiodiversity and geology of the Ib-River Basin, eastern coastal area, India. Journal of Asian Earth Sciences, 157: 283–301.

Goswami, S. and Singh, K. J. 2010. Occurrence of gymnosperms from Lower Gondwana formations of Ib-River Coalfield, Orissa, India with a clue on the palaeoecology and the palaeoenvironment of the area. Journal of Palaeontological Society of India, 55: 121-135.

Lele, K. M. 1966. Studies in the Talchir flora of India-4. Quest for the early traces and subsequent development of the Glossopteris flora in the Talchir Stage. Symposium on floristics and stratigraphy of Gondwanaland, Birbal Sahni Institute of Palaeobotany, Lucknow, pp. 85-97.

Lele, K. M., Swarup, P. and Singh, J. N. 1968. Occurrence of Plant fossils in the Lower Gondwana succession of Singrauli Coalfield, U.P. Journal of the Palaeontological Society of India, 11: 8-17.

Maithy, P. K. 1965a. Studies in the Glossopteris flora of India- 26. Glossopteridale remains from the Karharbari beds, Giridih Coalfield, India. Palaeobotanist, 13: 248-263.

Maithy, P. K. 1965b. Studies in the Glossopteris flora of India-20. *Noeggerathiopsis* and allied remains from the Karharbari beds, Giridih Coalfield, Bihar. Palaeobotanist, 13: 89-103.

McCoy, F. 1847. On the fossil Botany and Zoology of rocks associated with the coal of Australia. Annual Magazine of Natural History Museum, 20 (1). pp. 145, 226-298.

McCoy, F. 1860. A commentary on ‘‘A communication made by the Rev. W. B. Clarke” and C. Transaction of Royal Society, Victoria 5, 98.

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

Mukhopadhyay, G., Mukhopadhyay, S. K., Roy Chowdhury, M. and Parani, P. K., 2010. Stratigraphic correlation between Gondwana basins of India. Journal of the Geological Society of India, 76: 251-266.

Pant, D. D. and Singh, K. B. 1968. On the genus *Gangamopteris* McCoy. Palaeontographica, 124B: 83-101.

Pant, D. D. and Singh, R. S. 1974. On the stem attachment of *Glossopteris* and Gangamopteris leaves. Part-2. Structural features. Palaeontographica, 147 B: 42-73.

Raja, Rao, C. S. 1983. Coalfields of India Vol. III; Coal resources of Madhya Pradesh, Jammu and Kashmir. Bulletins of Geological Survey of India, Series A 45: 75-80.

Saxena, A., Singh, K. J., Cleal, C. J., Goswami, S., Chandra, S. and Shabbar, H. 2018. Development of Glossopteris flora and its end Permian Demise in Tatapani Ramkola Coalfield, Son-Mahanadi Basin, India. Geological Journal, DOI: 10.1002/gj.3307.

Saxena, A., Singh, K.J., Murthy, S., Anand Prakash and Singh P.K. 2019. Early Permian floral diversity deduced from the Barakar Formation of Singrauli Coalfield, Son-Mahanadi Basin, India. Journal of the Palaeontological Society of India, 64(2): 169-183.

Saxena, A., Singh, K. J., Shabbar, H. and Prakash, A. 2016. Macrofloral Assemblage from the Early Permian Barakar Formation of Singrauli Coalfield, Son-Mahanadi Basin, India. Palaeobotanist, 65: 139-150.

Seward, A.C. 1908. Fossil Flora of Cape Colony. Annals of South Africa Museum. 4: 83–90.

Singh, K. J., Chandra, A. and Chandra, S. 2005. Evaluation of earliest Permian flora of India and its equivalents in other Gondwana continents. Palaeobotanist, 54: 107-113.

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

Singh, K. J., Goswami, S. and Chandra, S. 2006b. First report of genus *Gangamopteris* from Gondwana sediments of Ib-River Coalfield, Orissa. Journal of the Geological Society of India, 68: 893-905.

Singh, K. J., Goswami, S. and Chandra, S. 2006c. The genus *Glossopteris* from lower Gondwana formations of Ib-River Coalfield, Orissa, India. Journal of the Palaeontological Society of India, 51: 81-107.

Singh, K. J., Goswami, S. and Singh, 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: 45-64.

Singh, K. J. and Saxena, A. 2015. End Permian (Lopingian) floral diversity in Singrauli Coalfield: evidences from Jhingurdah Colliery, Son-Mahanadi Basin, India. Journal of the Paleontological Society of India, 60: 97-112.

Singh, K. J., Saxena, A. and Goswami, S. 2012. Palaeobiodiversity of the Lower Gondwana rocks in the Korba Coalfield, Chhattisgarh, India and observations on the genus *Gangamopteris* McCoy. Palaeobotanist, 61: 145-163.

Singh, K. J., Saxena, A. and Goswami, S. 2016. In-situ occurrence of *Vertebraria* roots in the Raniganj Formation of Singrauli Coalfield and its palaeoecological significance. Current Science, 110: 299-301.

Singh, K. J., Murthy, S., Saxena, A. and Shabbar, H. 2017. Permian macro and miofloral diversity, palynodating and palaeoclimate implications deduced from the coal-bearing sequences of Singrauli Coalfield, Son-Mahanadi Basin, Central India. Journal of the Earth System Science, 126: 25-41.

Srivastava, A. K. 1977. Palaeobotanical evidence for the presence of Karharbari Stage in the Auranga Coalfield, Bihar: Megaflora. Palaeobotanist, 23: 206-219.

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

Srivastava, A. K. and Agnihotri, D. 2010. Morphological consequence of *Gangamopteris* McCoy in Glossopteris flora. Journal of Asian Earth Sciences, 39: 760-769.

Srivastava, A. K. and Chandra, S. 1992. A new leaf from the Lower Gondwana beds of Chrimiri coalfield, Madhya Pradesh, India. Proceedings of National Academy of Sciences, India. 62(B), III: 487-489.

Srivastava, A. K., Saxena, A. and Agnihotri, D. 2012. Morphological and stratigraphical significance of Lower Gondwana plant fossils of Mohpani Coalfield, Satpura Gondwana Basin, Madhya Pradesh. Journal of the Geological Society of India, 80: 676-684.

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

Tewari, R. and Srivastava, A. K. 2000. Plant fossil assemblages from the Talchir Formation, Auranga Coalfield, Bihar, India. Palaeobotanist, 49: 23-30.

Tiwari, R. S. 1969. Sporological succession in Purewa Seam, Singrauli Coalfield, M.P. J. Sen Memorial volume, Botanical Society of Bengal, Calcutta, pp 93-100.

Tiwari, R. S. 1971. Sporological succession in Kota and Turra seams, Singrauli Coalfield, (M.P.), India. Palaeobotanist, 18(3): 264-269.

Tiwari, R. S. and Srivatsava, S. C. 1984. Palynological dating of Jhingurdah Seam, Singrauli Coalfield: A reappraisal. Palaeobotanist, 31: 263-269.

Trivedi, B. S. 1950. Megaspores from Lower Gondwana of Singrauli Coalfield District Mirzapur. Current Science, 19: 126.

Tybusch, G.P., Iannuzzi, R., Bernardes-de-Oliveira, M.E.C. and da Cunha Lopes, R., 2016. Revaluation of the Glossopterids from the Lower Permian ofCambaí Grande Outcrop, Paraná Basin, RS. Geologia USP. Série Cientí-fica. 16: 41–51.

Vijaya., Tripathi, A., Roy, A. and Mitra, S. 2012. Palynostratigraphy and age correlation of subsurface strata within the sub-basins in Singrauli Gondwana Basin, India. Journal of Earth System Science, 121(4): 1071-1092.

White, D. 1908. Fossil Flora of the Coal Measures of Brazil. In: White, I.C.(Ed.), Comissão de Estudos das Minas de Carvão de Pedra do Brasil. Relatório Final, pp. 558–568.