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The genus *Euryphyllum* Feistmantel revisited– Occurrence and diversity in Indian Gondwana

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ABSTRACT

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Two species of the genus *Euryphyllum*, viz. *E. whittianum* and *E. elongatum* are described from the Barakar Formation (late Early Permian / late Artinskian to Kungurian) of the Gevra colliery located in the Korba Coalfield, Son-Mahanadi Basin, central India. The paper incorporates the previous and recently published Indian records on *Euryphyllum* concerning morphology, cuticular studies and the affinities. The critical investigations of the holotype and the duplicate specimens of various species of *Euryphyllum* demonstrate that asymmetry of the leaves that used to be an important character for generic delineation, could not be considered as a distinguishing feature for this genus. The abundance of papillae in the epidermal cells in *E. maithyi* reported from the Karharbari Formation, their marked decrease in *E. whittianum* in the Barakar Formation and their complete absence in the species of the Raniganj Formation, namely *E. nautiyalii* can be related with variable climatic conditions. These observations further strengthen the viewpoint that climate was cool and dry during Early Permian which changed to warm and humid during Late Permian. The study also advocates independent generic status of *Euryphyllum* among akin genera, such as *Noeggerathiopsis* and *Rubidgea* based on regularity in the arching pattern in the lateral veins.

Key–words—Son-Mahanadi Basin, Barakar Formation, Gevra colliery, *Euryphyllum*.

यूरीफिल्लम फीस्टमेंटल वंश का पुनःपरिदर्शन-भारतीय गोंडवाना में प्राप्ति तथा विविधता

अंजू सक्सेना, कमल जीत सिंह एवं श्रीरूप गोस्वामी

सारांश

कोरवा कोयला क्षेत्र, सोन-महानदी द्रोणी, मध्य भारत में स्थित जेवरा कोयलाखदान के बराकर शैलसमूह (विलंबित प्रारंभिक पर्मियन/विलंबित अर्टिन्सकियन) से प्राप्त *यूरीफिल्लम* वंश की दो जातियां अर्थात *व्हिट्टीएनम* और *ई. इलांगेटम* वर्णित की गई हैं। शोध-पत्र *यूरीफिल्लम* संबंधी आकृतिविज्ञान, त्वचा अध्ययन एवं बंधुताओं पर पहले का और हाल ही में प्रकाशित अभिलेखों को समाविष्ट करता है। *यूरीफिल्लम* की विविध जातियों के नाम प्ररुप व दूसरे प्रतिदर्शों के क्रांतिक अन्वेषण प्रदर्शित करता है कि जातीय निरुपण हेतु पत्तियों की असममिति जो महत्वपूर्ण लक्षण प्रयुक्त हुआ है, इस वंश के लिए विशिष्ट लक्षण के रुप में विचारा नहीं गया। करहरबाड़ी शैलसमूह से अभिलिखित *ई. मेथयी* की अधिचर्म कोशिकाओं में अंकुरक की बहुलता, बराकर शैलसमूह के *ई. व्हिट्टीएनम* में उनके चिह्नित ह्वास तथा रानीगंज शैलसमूह की जातियों नामतः *ई. नौटियालयाई* में उनकी पूर्णरुपेण अविद्यमानता परिवर्तनीय जलवायवी स्थितियों से संबंधित हो सकती हैं। ये प्रेक्षण इस दृष्टिकोण को और संपुष्ट करते हैं कि प्रारंभिक पर्मियन के दौरान जलवायु शीत एवं शुष्क थी जो विलंबित पर्मियन के दौरान कोष्ण एवं आर्द्र में परिणित हो गई। अध्ययन पार्श्व शिराओं में आद्य प्रतिरुप में नियमितता के आधार पर जैसे कि *नोएग्गेराऑप्सिस* एवं *रुबिडजिया* सदृश वंश में *यूरीफिल्लम* की स्वतंत्र जातीय स्थिति को भी संपुष्ट करता है।

संकेत-शब्द—सोन-महानदी द्रोणी, बराकर शैलसमूह, जेवरा कोयलाखदान, *यूरीफिल्लम*।

INTRODUCTION

THE Korba Coalfield, located in the Korba and Bilaspur districts of Chhattisgarh State, occupies the south-central part of the Son-Mahanadi Basin and is one of the major coalfields of South Eastern Coalfield Limited (Fig. 1). This coalfield comprising five open cast mines namely Gevra, Dipika, Manikpur, Kusmunda and Laxman spreading over

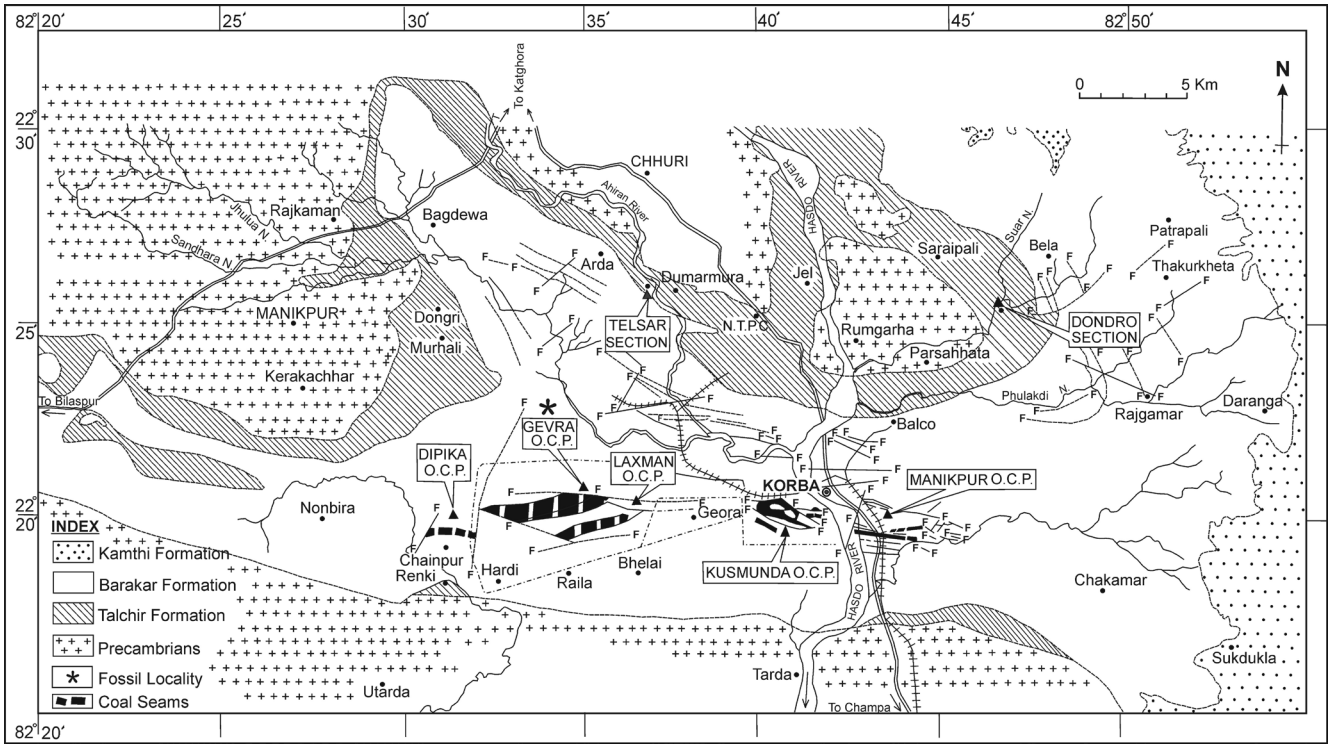


Fig. 1—Geological map of Korba Coalfield, Chhattisgarh, showing different collieries (After Raja Rao, 1983).

530 sq. kms, is regarded as one of the biggest coal producing units in India (total geological coal reserves around 10115 million tonnes). A huge macrofloral assemblage belonging to the Barakar Formation has been recovered recently from the above mentioned collieries (Singh *et al*., 2007, 2011, 2012).

The diverse plant assemblage of the Korba Coalfield can be grouped in three orders namely, Glossopteridales,

1. *Sakoarota polyangiata* (equisetalean stems)
2. *Noeggerathiopsis hislopi*
3. *Cordaites* sp.
4. *Euryphyllum whittianum*
5. *E. elongatum*
6. *Rubidgea obovata*
7. *Gangamopteris cyclopteroides*
8. *G. cyclopteroides* var. *subauriculata*
9. *G. angustifolia*
10. *G. clarkeana*
11. *G. rajaensis*
12. *Gangamopteris* sp.
13. *Glossopteris intermittens*
14. *G. stenoneura*
15. *G. arberi*
16. *G. raniganjensis*
17. *G. spatulata*
18. *G. gigas*
19. *G. sastrii*
20. *G. nimishea*
21. *G. maculata*
22. *G. barakarensis*
23. *G. taenioides*
24. *G. syaldiensis*
25. *G. emarginata*
26. *G. stricta*
27. *G. communis*
28. *G. indica*
29. *G. browniana*
30. *G. pantii*
31. *G. karanpurensis*
32. *G. major*
33. *G. feistmantelii*
34. *G. euryneura*
35. *Glossopteris* sp.
36. *Dictyopteridium sporiferum*
37. Scale leaves of *Eretmonia ovoides*
38. Scale leaves of *Lidgettonia mucronata*
39. Scale leaves of *Venustostrobus* sp.
40. Scale leaves of *Plumsteadiostrobus* sp.
41. *Vertebraria indica*
42. Stem casts / stem twigs

Table 1—A list of complete megafossil assemblage recovered from various collieries, i.e. Gevra, Dipika, Manikpur, Kusmunda and Laxman, Korba Coalfield.

Cordaitales and Equisetales, comprising 39 species belonging to 13 genera (Table 1). Among these, the order Glossopteridales shows maximum diversity with 34 taxa of which *Glossopteris* is the most abundant genus (38.09%) with 22 species, followed by the genera *Vertebraria*, *Dictyopteridium*/ scale leaves of fertile organs, *Gangamopteris* (5 species) and *Rubidgea.* The cordaitalean elements are represented by *Cordaites* sp., *Noeggerathiopsis* and *Euryphyllum*. *Sakoarota* (equisetalean stems) also exhibit their copious occurrence (11.32%) in the assemblage. The groups Lycopodiales, Sphenophyllales, Filicales, Ginkgoales, Cycadales and Coniferales are completely missing in this area which shows that the area might not be adequately cool and humid to facilitate the growth of these shade loving under-story plants.

There are number of leaf genera in the *Glossopteris* flora which possess certain common generic characters. The leaves of *Noeggerathiopsis* Feistmantel 1879, *Euryphyllum* Feistmantel 1879 and *Rubidgea* Tate 1867 look quite similar as they all are devoid of a distinct midrib and their veins also do not anastomose to form reticulations or meshes, they simply fork and thus have simple dichotomous venation. *Rubidgea* is certainly a distinct genus as it has densely clustered median veins like those of *Gangamopteris* but its secondary veins do not form reticulations. *Noeggerathiopsis* comes very close to *Euryphyllum* as it also possesses erect, dichotomous, subparallel veins throughout the lamina, however the secondary veins in the former run straight and in the later they arch out towards the margin. *Euryphyllum* also has somewhat closer sub-parallel veins along the median axis of the lamina as compared to the distantly placed veins in *Noeggerathiopsis*.

Feistmantel (1879) erected the genus *Euryphyllum* for a pair of ovate-spathulate or rhomboidal-ovate asymmetrical leaves having narrow tapering bases and obtuse apices reported from the Karharbari Formation (Artinskian) of the Giridih Coalfield, Jharkhand State. The two leaves seem to be attached on one side of a partially preserved stem/axis and possessed dichotomous, sub-parallel veins in the middle region and more or less arched veins towards the margin (Feistmantel, 1879; pl. 21, fig. 1, re-produced as Pl. 1) in the present paper). Feistmantel pointed out that the upper leaf is directly attached to the stem while the lower one is not in direct connection, still it is in such a position that cannot rule out its association with the stem. He also suggested the oblong- ovate mark in the lower portion of the stem to be a place where a leaf was attached. Taking into consideration the attachment pattern of the two leaves on the stem and the presence of the attachment mark, Feistmantel (1879) indicated the arrangement of the leaves on the stem to be spiral which is generally the characteristic of conifers. Feistmantel instituted the type species of this genus as *E. whittianum* after Mr. I.J. Whitty, the then superintendent of the Karharbari colliery who discovered this unique flora. It was based on the morphology alone as the specimen had only the impressions of the leaves.

After the erection of *E. whittianum* from the Giridih Coalfield in 1879, this type species was reported by many workers in subsequent years. Maithy (1965) figured two specimens of this species from the Karharbari sediments in Giridih Coalfield and reported only the morphological features. Both the specimens show asymmetrical leaves. Srivastava (1977) reported incomplete leaves of *E. whittianum* from the Karharbari Formation in the Auranga Coalfield. Well preserved compression specimens of the type species were described by Chandra and Singh (1996) from the Karharbari Formation of Talcher Coalfield in Odisha State. All the three specimens of Chandra and Singh (1996) had well preserved cuticles, however the authors did not report any cuticular features in this paper. While describing *E. whittianum* from Barakar Formation of the West Bokaro Coalfield and South Karanpura Coalfield, Singh (2000) reported the cuticles of this species. Recently, Singh *et al.* (2007) reported the biggest ever collection (45 specimens) of *E. whittianum* from the Barakar sediments of Ib-River Coalfield, Odisha. In the present study this species is being described from the Barakar Formation of Korba Coalfield.

Maithy (1970) described a new species of *Euryphyllum*, i.e. *E. obovatum*, represented by a symmetrical leaf (pl. 1, fig. 3) from the Karharbari sediments of the Giridih Coalfield. Cuticular features of this species are not yet known. The third species of this genus, namely *E. elongatum*, represented by asymmetrical, narrow, oblong leaves (pl. 4, fig. 1) was reported by Srivastava (1992) from the Barakar Formation of Raniganj Coalfield, West Bengal. Recently, Agnihotri (2011) and Srivastava and Agnihotri (2013) reported *E. elongatum* from Pench Valley and Mohpani coalfields, Madhya Pradesh. Chandra and Singh (1996) reported the cuticular features of *Euryphyllum maithyi* from the Karharbari Formation of the Talcher Coalfield, Odisha (pl. 1, figs 1, 5; pl. 2, figs 1-3). *E. maithyi* was again reported from the Barakar beds of the Ib-River Coalfield (pl. 2, fig. 1; pl. 3, figs 2, 6) by Singh *et al.* (2007). Pant and Chauhan (2000) instituted the fifth species, namely *E. nautiyalii* from the Raniganj Formation of the Raniganj Coalfield, West Bengal (pl. 1, figs A-E; pl. 2, figs A-E) on the basis of morphological and cuticular details.

The present study deals with the systematic description of *Euryphyllum* comprising two species, namely *E. whittianum* and *E. elongatum*. The complete assemblage of the Korba Coalfield is given in Table 1. The holotype and the duplicate specimens of various Indian species of *Euryphyllum* have been critically re-examined to infer information regarding their morphological and cuticular details (Table 2). The distribution of *Euryphyllum* in different formations of Indian Lower Gondwana has been provided in Table 3 whereas, Table 4 provides data regarding its distribution in various localities. The paper also incorporates the previous and recently published records of the genus *Euryphyllum* from all the Indian Lower Gondwana basins to provide an updated account on

***Euryphyllum* species**	**Shape of leaf**	**Nature of Lamina/ Margin**	**Apex**	**Base**	**Venation**	**Concen-tration of veins /cm²**	**Cuticle**	**Distribution**	**Reported by**
Euryphyllum whittianum, Feistmantel 1879	Ovate to spathulate or rhomboid to ovate	Asymmetrical, margin entire	Obtuse or obtusely pointed	Narrow, contracted	Veins strong, radiating from the base at very acute angle with dichotomy, sub-parallel in median region, arched towards margin in lateral portion at an angle of 15º-25º.	20-24	Leaves amphistomatic, stomatal density low on upper surface, stomata distributed in linear rows between veins, subsidiary cells papillate, papillae overhanging the stomatal pit, guard cells sunken	**Karharbari Fm**.- Buriadih colliery, Giridih Coalfield, Auranga Coalfield, Jharkhand; South Balanda colliery, Talcher Coalfield, Odisha. **Barakar Fm.**- Sarubera colliery, West Bokaro Coalfield, Gidi-A colliery, South Karanpura Coalfield, Jharkhand, Jurabaga & Lajkura collieries, Ib River Coalfield, Odisha; *Gevra colliery, Korba Coalfield, Chhattisgarh.	Feistmantel, 1879; Maithy, 1965; Srivastava, 1977; Chandra and Singh, 1996. Singh, 2000; Singh *et al.*, 2007; *Saxena *et al.* 2013.
Euryphyllum obovatum, Maithy 1970	Spathulate	Symmetrical, curvature of margin smooth	Broadly obtuse/ Rounded	Narrow, tapering and truncated	Sub-parallel veins emerging from base, dichotomous, closely spaced, sub-parallel in median portion, divergent, arched towards margin in lateral portion.	15-20	Not known	**Karharbari Fm.-** Srirampur colliery, Giridih Coalfield, Jharkhand	Maithy, 1970.
Euryphyllum elongatum, Srivastava 1992	Narrow to oblong	Asymmetrical, margin entire	Obtuse to acute	Contracted	Median region occupied by 3-6 straight parallel running strands, lateral veins emerge from base, arch towards the margin at an angle of 20º-30º, dichotomize 2-3 times during their course.	14-18	Not known	**Barakar Fm.-** Raja colliery, Raniganj Coalfield, West Bengal; Thisgora, Mathani, Naheria collieries, Pench Valley Coalfield; Sitarewa River Section, Mohpani Coalfield, Madhya Pradesh, *Gevra colliery, Korba Coalfield, Chhattisgarh	Srivastava, 1992; Agnihotri, 2011; Srivastava and Agnihotri, 2013; *Saxena *et al.* 2013.
Euryphyllum maithyi, Chandra and Singh 1996	Oval to obovate	Slightly asymmetrical, margin entire	Obtuse	Incomplete, appears to be cuneate	Dichotomous sub-parallel veins emerging from base, central veins almost straight, veins in lateral portions divergent and arched towards margin to meet it at about 20º-25º.	15-25	Leaf amphistomatic, stomata haplocheilic, monocyclic, evenly distributed between the veins, cells of upper & lower epidermis straight walled, elongated, narrow and cells between vein region are with median papilla; subsidiary cells papillate, hanging or covering stomatal pore, stomatal pore highly cutinized.	**Karharbari Fm**.- South Balanda colliery, Talcher Coalfield, Odisha. **Barakar Fm**. Jurabaga & Lajkura collieries, Ib River Coalfield, Odisha.	Chandra and Singh, 1996. Singh *et al.* 2007.
Euryphyllum nautiyalii, Pant and Chauhan 2000	Spathulate	Symmetrical, Lamina lobed,	Not known	Narrow, prolonged base	Veins run parallel to subparallel, crowded along median axis, elsewhere sparsely arranged, dichotomizing and arched towards margin at an angle of 25º-30º to median axis.	20-25	Leaves hypostomatic, stomata haplocheilic, monocyclic, longitudinally oriented, cells and subsidiary cells non papillate, average stomatal frequency 28/mm²	**Raniganj Fm.-** Kuardih colliery, Raniganj Coalfield, West Bengal.	Pant and Chauhan, 2000.

Table 2—Morphological and epidermal characteristics of Indian *Euryphyllum* species (*indicates present contribution).

PLATE 1

Euryphyllum whittianum Feistmantel, 1879. Type specimen of *E. whittianum* described by Feistmantel (1879, pl. 21, fig. 1) from the Buriadih colliery, Karharbari Coalfield and reproduced as such in this plate. The specimen shows a pair of ovate-spathulate asymmetrical leaves having narrow tapering bases and obtuse apices. Oblong-ovate marks can be seen in the lower portion of the stem that might be attachment places for the leaves.

Euryphyllum (5 taxa)	Talchir Fm. (Asselian-Sakmarian)	Karharbari Fm. (Artinskian)	Barakar Fm. (Artinskian to Kungurian)	Barren Measures = Kulti Fm. (Guadalupian)	Raniganj Fm. (Lopingian)
E. whittianum Feistmantel 1879		+	+		
E. obovatum Maithy 1970		+			
E. elongatum Srivastava 1992			+		
E. maithyi Chandra & Singh 1996		+	+		
E. nautiyalii Pant & Chauhan 2000					+

Table 3—Distribution of *Euryphyllum* in different formations of Indian Lower Gondwana.

Gondwana Coalfields ⟶ / ***Euryphyllum* species**	**1. Ib-River**	**2. Talcher**	**3. Mand-Raigarh**	**4. Tatapani-Ramkola**	**5. Korba**	**6. Chirimiri**	**7. Singrauli**	**8. Hura**	**9. Pachwara**	**10. Raniganj**	**11. Jharia**	**12. Karanpura**	**13. Bokaro**	**14. Deogarh**	**15. Auranga**	**16. Hutar**	**17. Daltonganj**	**18. Pali**	**19. Umaria**	**20. Giridih**	**21. Mohpani**	**22. Pench Valley**	**23. Kashmir**	**24. Arunachal Pradesh**
E. whittianum	+	+			*+							+	+		+					+				
E. obovatum																				+				
E. elongatum					*+					+											+	+		
E. maithyi	+	+																						
E. nautiyalii										+														

Table 4—Distribution of *Euryphyllum* in various Indian Gondwana coalfields /localities (*Indicates present contribution).

its morphological and cuticular aspects including the status of the genus and its affinities.

GEOLOGICAL SETTING

The Korba Coalfield is a part of the extensively distributed Lower Gondwana formations in the Mahanadi Valley Basin that extends over an area of 530 sq km. It lies in between the drainage areas of the Son and the Mahanadi rivers. The Barakar sediments of the Korba Coalfield are continuous with those of the Mand-Raigarh Basin in the east, whereas, towards the north a vast stretch of Talchir sediments connects this coalfield with the Hasdo-Arand Basin. A narrow strip of Barakar rocks also connects the Korba field with Hasdo-Arand towards the east. Therefore, the Korba, Hasdo-Arand and Mand-Raigarh areas form a master basin in the upper reaches of the Mahanadi Valley. The Korba Coalfield, situated in the Korba and Bilaspur districts of Chhattisgarh State, is elongated in an east-west direction, and is 64 km long and 4.8 to 16 km wide (Fig. 1). It is bounded by latitudes 22°15' and 22°30' and longitudes 82°15' and 82°55' (Raja Rao, 1983).

The Korba Coalfield was named by W.T. Blanford in the year 1870 and was first systematically examined by Lala Hiralal during 1886-87 (in Raja Rao, 1983). The Lower Gondwana rocks in this coalfield have been divided into three formations, i.e. Talchir, Barakar and the Kamthi (Fig. 2). The sediments of the Talchir Formation are well exposed in Suar Rivulet near Dondro Village in the eastern part and in the Ahiran Rivulet near Telsar Village in the north-central part of the coalfield, but were barren of any plant megafossil. Similarly, the Kamthi sediments exposed in the eastern side of this coalfield near Sukdukla and Daranga villages were found to be unfossiliferous. The stratigraphic sequence met within the Korba Coalfield is given in Fig. 2.

MATERIAL AND METHODS

The material described in this communication is a part (4 leaves of *Euryphyllum*) of a large collection of macro fos-

Age	Formation		Lithology (Thickness)
Recent	Alluvium		
Late Permian to Early Triassic	Kamthi		Conglomerates, sandstones, minor shales
Early Permian	Barakar	Upper Member	Sandstones, shales and thick coal seams inter-bedded with carbonaceous shale (350 m)
		Middle Member	Sandstones and conglomerate (300 m)
		Lower Member	Sandstones, shales and Ghordewa groups of seams (160 to 250 m)
	Talchir		Diamictites, greenish sandstones, olive green coloured needle shales, rhythmites, varves and black shale (200 m)
----------Unconformity----------			
Precambrian			Gneisses, migmatites, granites, etc.

Fig. 2—Geological succession of the Korba Coalfield area, Chhattisgarh (after Raja Rao 1983).

sils (512 specimens) recovered from five open-cast mines, namely Gevra, Dipika, Manikpur, Kusmunda and Laxman in the Korba Coalfield, Mahanadi Basin. The specimens of *Euryphyllum* have been found only in the Gevra colliery (Fig. 3) and are preserved as impressions on fine grained grey to blackish carbonaceous shales belonging to the Barakar Formation. Although, one of the leaves had faintly preserved carbon, it could not yield cuticles. Various macromophological characters of the specimens such as shape of the leaf, nature of apex and base, midrib, type of meshes and the venation pattern were taken into account for the identification of the taxa. We followed the terminology and the methodology as given by Chandra and Surange (1979) for the description of various species of the genus *Euryphyllum*. The specimens are measured and photographed to record the morphological characters using low power Leica Microscope and Nikon Digital Camera. All the megafossil specimens described in this paper are deposited in the repository of Birbal Sahni Institute of Palaeobotany, Lucknow vide statement no. 1345 and Museum Specimen Nos. 40129-40132.

SYSTEMATICS

Division—CONIFEROPHYTA

Class—PINOPSIDA

Order—CORDAITALES

Genus—EURYPHYLLUM Feistmantel, 1879

Type species—*Euryphyllum whittianum* Feistmantel, 1879

Euryphyllum whittianum Feistmantel, 1879

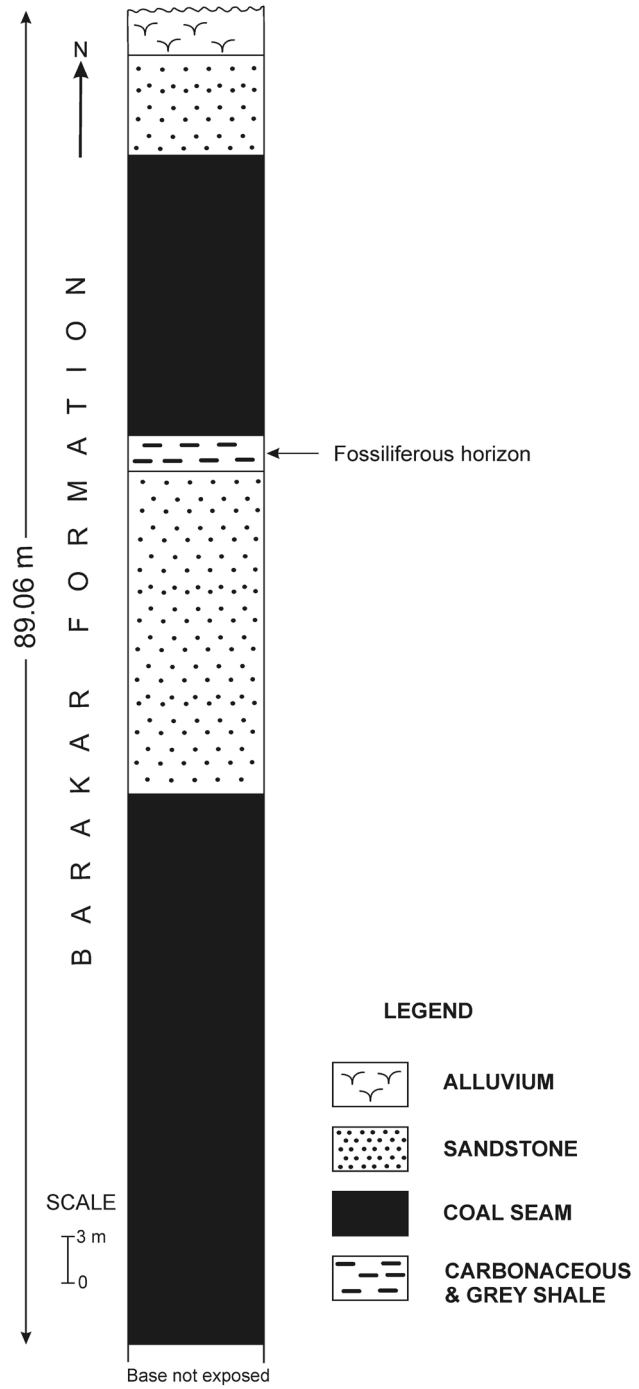
(Pl. 2.4, 5)

Synonym

1879 *Euryphyllum whittianum* Feistmantel, pl. 21, figs 1, 1a
1894 *Noeggerathiopsis hislopi* var. *euryphylloides* Kurtz, pl. 4, fig. 3
1905 *Noeggerathiopsis whittiana* Arber, p. 186-187
1920 *Euryphyllum whittianum* Seward & Sahni, p. 8
1922 *Noeggerathiopsis hislopi* var. *typica* Kurtz, pl. 3, figs 30, 32, 34, 37
1922 *N. hislopi* var. *subcuneformis* Kurtz, pl. 4, figs 37, 38
1922 *N. hislopi* var. *cuneformis* Kurtz, pl. 4, figs 42, 42a
1965 *Euryphyllum whittianum* Maithy, pl. 1, figs 9, 10.
1977 *E. whittianum* Srivastava, pl. 1, fig. 4
1996 *E. whittianum* Chandra & Singh, pl. 1, figs 2-4; pl. 2, fig. 4
2000 *E. whittianum* Singh, pl. 1, figs 1-3; pl. 3, figs 3, 4
2007 *E. whittianum* Singh, Goswami & Chandra, pl. 1, figs 2, 5; pl. 2, figs 2, 3, 6, 7

Description—This species is represented by two incomplete specimens in our collection. Leaves are simple, asymmetrical having ovate-spathulate shape with entire margin. Apex, preserved in one specimen, is obtusely pointed. Base not preserved. The preserved leaves are 5.6 cm and 3.2 cm long, 1.7 cm and 1 cm wide, respectively. Four to six strong veins emerge from the base of the leaf at very acute angle, which run sub-parallel in the median region but arch towards the margin in the lateral portion of the lamina and meet it at an angle of 15-20º to the median line. Veins dichotomize without forming meshes. Their average concentration is 14-20/cm^2 in the middle of the lamina.

Comparison and remarks—The present specimens closely resemble with the holotype of *Euryphyllum whittianum* (Feistmantel, 1879; pl. 21, fig. 1) in having ovate-spathulate shape, asymmetry of the lamina and the venation pattern. They also exhibit similarity with the specimens described by



Maithy {1965, pl. 1, figs 9 (Specimen No. 31414/426) & 10 (Specimen No. 20451)} in having asymmetrical lamina and venation. The specimens also bear resemblance to the leaves of *E. whittianum* reported by Srivastava (1977, pl. 1, fig. 4, Specimen No. 13/1393); Chandra and Singh (1996; pl. 1, figs 2, 3; and also with compression specimen pl. 2, fig. 4, Specimen No. 36868); Singh (2000, pl. 1, figs 1-3) and Singh *et al.* (2007, pl. 1, figs 2, 5; pl. 2, figs 2, 3, 6, 7) in the morphological details. *E. whittianum* differs from the other four species of *Euryphyllum* in minor characters. *E. obovatum* has broadly symmetrical leaf, obtuse apex and a long base with high density of veins. The leaves of *E. elongatum* are narrow-oblong, asymmetrical and have 3–6 straight parallel running strands in the median region besides arched lateral veins. *E. maithyi* has ovate-obovate leaves with wider lamina in the upper part. *E. nautiyalii* has very long leaves (22 cm) and lobed lamina with prolonged narrow base.

Locality—Gevra colliery, Barakar Formation

Distribution—*Euryphyllum whittianum* occurs in the Karharbari Formation of Giridih and Auranga coalfields of Jharkhand State (Damodar-Koel Basin); Talcher Coalfield of Odisha State (Mahanadi Basin) and from the Barakar Formation of West Bokaro, South Karanpura coalfields of Jharkhand (Damodar-Koel Basin) and Ib-River Coalfield, Odisha State, Korba Coalfield, Chhattisgarh State (Mahanadi Basin) in the Indian Gondwana.

Euryphyllum elongatum Srivastava, 1992

(Pl. 2.1-3, 6)

Synonym
1992 *Euryphyllum elongatum* Srivastava; pl. 4, fig. 1
2011 *E. elongatum* Agnihotri; pl. 5, figs A-D
2013 *E. elongatum* Srivastava & Agnihotri; p: 94

Description—There are only two specimens in our collection, of which one is almost complete (Specimen No. 40131), preserved with narrow tapering petiole. Leaves seem to be asymmetrical, narrow oblong in shape. Apices not com-

Fig. 3—Litholog of the Gevra OCP, Korba Coalfield.

PLATE 2

1. *Euryphyllum elongatum* Srivastava 1992. Showing an asymmetrical narrow oblong leaf, preserved with narrow tapering petiole. Apex appears to be obtusely pointed, base narrow contracted. BSIP Museum No. 40131, Scale Bar 5 mm, Barakar Formation, Gevra Colliery.
2. *Euryphyllum elongatum* Srivastava 1992. Enlargement of the apical portion of the leaf in fig. 1 showing arching of lateral veins.
3. *Euryphyllum elongatum* Srivastava 1992. Enlargement of the lower portion of the leaf in fig. 1 showing narrow tapering petiole and arching of the veins.
4. *Euryphyllum whittianum* Feistmantel, 1879. Showing ovate-spathulate leaf, lamina preserved in the middle portion, veins arch towards the margins in the lateral portion. BSIP Museum No. 40129, Scale Bar 5 mm, Barakar Formation, Gevra colliery.
5. *Euryphyllum whittianum* Feistmantel, 1879. Showing ovate-spathulate leaf having obtusely pointed apex. BSIP Museum No. 40130, Scale Bar 5 mm, Barakar Formation, Gevra Colliery.
6. *Euryphyllum elongatum* Srivastava 1992. Showing only the middle portion of the leaf with laterally arched veins. BSIP Museum No. 40132, Scale Bar 5 mm, Barakar Formation, Gevra Colliery.

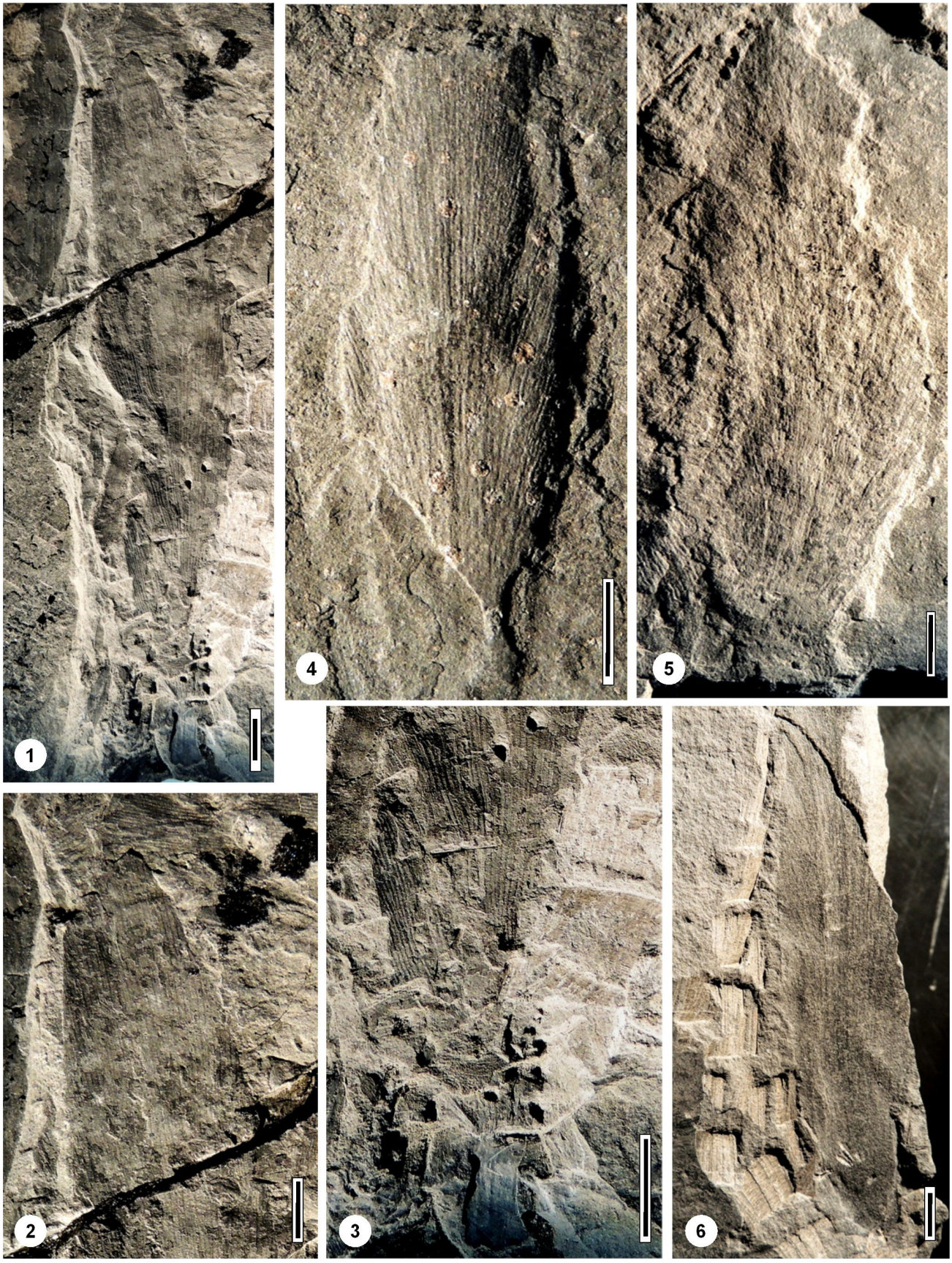


PLATE 2

pletely preserved in either of the leaves; however, in one of the specimens it appears to be obtusely pointed. Base appears to be narrow, contracted. The preserved specimens are 7.9 cm and 7.8 cm long and 1.7 cm and 1.8 cm wide respectively. The average concentration of veins ranges from 14-20/cm^2. Veins run almost straight in the median part, dichotomize 2-3 times during their course, slightly arch towards the margin, meeting it at angle of 20-30º.

Comparison and remarks—The present specimens closely resemble with the holotype of *Euryphyllum elongatum* (Srivastava, 1992; pl. 4, fig. 1, Specimen No. 36610) in having narrow oblong shape and venation pattern. The specimens are also similar with the specimens of this species described by Agnihotri (2011, pl. 5, figs A-D) from Mohpani and Pench Valley coalfields, Madhya Pradesh in having similar shape and overall venation pattern.

Locality—Gevra colliery, Barakar Formation.

Distribution—Euryphyllum elongatum is known from Barakar Formation of Raniganj Coalfield, West Bengal State (Damodar-Koel Basin), Pench Valley and Mohpani coalfields, Madhya Pradesh State (Satpura Gondwana Basin) and Korba Coalfield, Chhattisgarh State (Mahanadi Basin) in Indian Gondwana.

DISCUSSION, AFFINITIES AND CONCLUSION

The occurrence of *Euryphyllum whittianum* and *E. elongatum*, representing two specimens each in the Korba Coalfield, is the first record of this genus from the northern and central parts of Son-Mahanadi Master Basin. There are only two records of *Euryphyllum* from the eastern part of the Son-Mahanadi Basin, i.e. from the Talcher Coalfield (Chandra & Singh, 1996) and from the Ib-River Coalfield (Singh *et al.,* 2007). The biggest Gondwana basin, the Son-Mahanadi Basin thus has only three records of *Euryphyllum*. The Permian sediments of Pranhita-Godavari Basin are completely devoid of this typical genus. There is only one record of *Euryphyllum* from the Satpura Basin (Agnihotri, 2011; Srivastava & Agnihotri, 2013). The genus *Euryphyllum* has been found to occur at many places in the Damodar-Koel Valley basins (Giridih Coalfield– Feistmantel, 1879; Maithy, 1965, 1970; Auranga Coalfield– Srivastava, 1977; Raniganj Coalfield– Srivastava, 1992; Pant & Chauhan, 2000; West Bokaro Coalfield and South Karanpura Coalfield– Singh, 2000).

The Lower Gondwana sediments are exposed in various parts of the extra-peninsular regions like Kashmir (Nishatbagh Formation, Mamal Formation), Kumaon (Kuling Shale), Bhutan and Darjeeling (Diuri and Damuda beds), Sikkim and Arunachal Pradesh (Lichi and Bhareli formations). Although, some of the elements of Karharbari and Barakar formations (*Gangamopteris, Cordaites, Noeggerathiopsis, Glossopteris, Psygmophyllum,* etc.) are reported from these localities; the genus *Euryphyllum* is so far not reported from these above mentioned extra-peninsular Gondwana localities. Not only the genus *Euryphyllum* but the other key elements of Karharbari Formation such as *Botrychiopsis*, *Rubidgea*, *Buriadia* and *Ottokaria* are also missing in all these localities. This clearly indicates that the climate during the deposition of these extra-peninsular localities was comparatively warmer as compared to the colder climate prevailing during the deposition of Karharbari sediments in the peninsular India that favoured the growth of these elements (Lele, 1976).

Among the five species of *Euryphyllum* described from the Indian Lower Gondwana, *E. nautiyalii* has the biggest lamina (22 cm long) followed by *E. whittianum* (7 to 17 cm), *E. obovatum* (5.6 cm), *E. maithyi* (6.2 to 14 cm) and *E. elongatum* (6.6 to 7.9 cm). Three species, namely *E. maithyi, E. whittianum* and *E. nautiyalii* are preserved with cuticles whereas the specimens of *E. elongatum* and *E. obovatum* are impressions. Chandra and Singh (1996) reported the epidermal features of *E. maithyi*. Barring *E. nautiyalii* that has leaves with lobed margin, all four species have smooth and entire margined lamina. The leaves of *E. maithyi* and *E. whittianum* described by Chandra and Singh (1996) and Singh (2000) from the Karharbari and Barakar formations respectively, have amphistomatic lamina, whereas, the lamina of *E. nautiyalii* reported from the Raniganj Formation is hypostomatic. All the cells (including subsidiary and guard cells) of both the surfaces in *E. maithyi* have a single median papilla whereas only the subsidiary cells are papillate in *E. whittianum*. The papillae are completely absent in *E. nautiyalii* which belong to the Raniganj Formation. The abundance of papillae in the epidermal cells in *E. maithyi* reported from the Karharbari Formation, their marked decrease in *E. whittianum* in the Barakar Formation and their complete absence in *E. nautiyalii* of the Raniganj Formation can be related with variable climatic conditions. Based on the detailed studies in Talcher Coalfield, Goswami and Singh (2013) envisaged palaeoclimatic and palaeovegetational interpretations for the deposition of different formations of Lower Gondwana. Accordingly, the climate was cool and dry during Early Permian Karharbari Formation and warm and humid during the subsequent Barakar and the Late Permian Raniganj formations.

The critical investigations of the holotype and the duplicate specimens of various species of *Euryphyllum* demonstrate that asymmetry of the leaves that used to be an important character for generic delineation, could not be considered as a distinguishing feature for this genus. This is supported by Maithy (1970) who reported *E. obovatum* as more or less (±) symmetrical leaf. Similar observations were made by Singh *et al*. (2007) who studied 53 specimens of *Euryphyllum* (45 specimens of *E. whittianum* and 8 specimens of *E. maithyi*) and noted that more than half of the specimens posses symmetrical lamina.

Most of the specimens reported under various species of *Euryphyllum* are preserved as single leaf, however, the type

specimens of *E. whittianum* and *E. nautiyalii* provide some indirect clues regarding the phyllotaxy in this genus. Feistmantel suggested the spiral arrangement for the leaves of *Euryphyllum whittianum* attached on a piece of stem (Feistmantel, 1879; pl. 21, fig. 1; reproduced as Pl.1 in the present study), whereas, in the holotype of *E. nautiyalii,* nine leaves are arranged in a whorl (Pant & Chauhan, 2000; pl. 1, figs A, B).

Dana (1849) preferred to place some of the *Euryphyllum* looking specimens from Australia under *Noeggerathiopsis prisca.* Similarly, the specimens described by Kurtz (1894, 1922) from Argentina under *N. hislopi* var. *euryphylloides* (1894, pl. 4, fig. 3), *N. hislopi* var. *typica* (1922, pl. 3, figs 30, 32, 34, 37), *N. hislopi* var. *subcuneformis* (1922, pl. 4, figs 37, 38) and *N. hislopi* var. *cuneformis* (1922, pl. 4, figs 42, 42a) have almost similar venation pattern as that of *Euryphyllum*.

Feistmantel (1879) included *Euryphyllum* in the family Coniferae but also recognized its possible relationship with *Noeggerathiopsis*. Zeiller (1902) and Seward and Sahni (1920) placed it in the order Cordaitales. Chandra and Singh (1996) also supported this view and argued that these plants might have grown in the colder climate prevailing in the Early Permian as they are always found preserved in this age (Karharbari and Barakar formations).

Arber (1905) opined that arching of the lateral veins towards the margin of the leaves was not sufficient to establish *Euryphyllum* as a separate genus. He considered *Euryphyllum* to be a broad form of *Noeggerathiopsis* and placed it under *N. whittiana*. However, Zeiller (1902), Seward and Sahni (1920), Maithy (1965, 1970), Plumstead (1975), Srivastava (1977), Pant (1982), Srivastava (1992), Chandra and Singh (1996), Singh (2000), Singh *et al.,* (2007), Agnihotri (2011) and Srivastava and Agnihotri (2013) have supported Feistmantel (1879) in the separation of *Euryphyllum* and *Noeggerathiopsis* as the leaves of the former are asymmetrical in shape and possess arched lateral veins whereas, the leaves of latter are symmetrical and have straight veins. In our opinion, the asymmetry in the leaves of *Euryphyllum* is not a regular feature as is shown by the fact that the leaves of *E. obovatum* and *E. nautiyalii* have symmetrical lamina. Similarly out of 53 specimens of *Euryphyllum* described as *E. whittianum* and *E. maithyi* from the Ib-River Coalfield (Singh *et al.,* 2007) more than half have symmetrical leaves. This shows that the main distinguishing character of *Euryphyllum* is the venation pattern. This regularity in the arching pattern in the lateral veins in *Euryphyllum* advocates its independent generic status among akin genera, namely *Noeggerathiopsis* and *Rubidgea*.

Maithy (1970) included *Euryphyllum* in Glossopteridales along with *Noeggerathiopsis*. Chandra (1974) suggested *Euryphyllum* to be allied to the genus *Glossopteris*. Pant (1982) included *Euryphyllum* in Glossopteridales along with the genera *Glossopteris*, *Gangamopteris*, *Belemnopteris*, *Palaeovittaria*, *Rubidgea*, *Rhabdotaenia* and *Pteronilssonia*. However, he included the genus *Noeggerathiopsis* in the order Noeggerathiopsidales. The epidermal details of *Euryphyllum nautiyalii* (Pant & Chauhan, 2000) are comparable to those of *Palaeovittaria raniganjensis*.

The study concludes that asymmetry of the leaves as the distinguishing feature of genus *Euryphyllum* no longer remains the criterion to identify this genus; rather arching of the side veins without dichotomy serves the main basis of morphological identification. In comparison to the other genera, the occurrence of this genus is remarkably low in Indian Gondwana.

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