

A study on morphotaxonomy and distribution of glossopterid scale leaves from the Barakar Formation, South Karanpura Coalfield, Jharkhand, India

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The gymnosperms of order Glossopteridales are embodied by the naked fertile organs, which are usually attached to the vegetative leaves of glossopterids. The fossils of detached scale leaves are reported from the upper Barakar Formation (Kungurian) of South Karanpura Coalfield, Jharkhand, India. The assemblage consists of seven types of scale leaves (*Denkania* type, *Eretmonia* type, *Glossotheca* type, *Partha* type, *Plumsteadirostrobis* type, *Scirroma* type, *Venustostrobis* type). These detached scale leaves might have been attached to the axis in association with regular leaves. The article deals with the morpho-taxonomical descriptions and the distribution of the retrieved taxa in Lower Permian strata of Indian peninsula. This record of glossopterid scale leaves is the first of its kind from the Barakar Formation of South Karanpura Coalfield of the Indian Gondwana.

Keywords: Scale leaf, Lower Gondwana, Barakar Formation, Permian, South Karanpura

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INTRODUCTION

Scale leaves are often associated with *Glossopteris* leaves and are believed to perform the function of protector to the naked seed, which clearly indicate the gymnospermous behaviour of the glossopterid plants. The reconstruction of plants with scale leaves is a matter of challenge as in very rare cases, they are found attached to their parent elements. In particular, the scale leaves are small and are of subtle structures for which they got easily detached from the host bodies. They may be poorly preserved due to various taphonomic factors. However, the segregation of scale leaves into different genera is still matter of dispute as they exhibit minimal variations in their shape, size, apex, base and arrangement of seed scars on the receptacle.

The venation patterns in scale leaves are somewhat similar to that of *Glossopteris* leaf (Singh *et al.*, 2005; 2011; Goswami, 2002; 2006; 2007a,b). They have reticulated lateral veins, but typically lack midrib (Surange and Chandra, 1975; Chandra and Surange, 1976). The midribs of scale leaves are replaced by several robust persistent medial veins. They run straight towards the apex and but give off into secondary veins, especially in the expanded apical portion (Goswami *et al.*, 2006a, b, 2010, 2018, 2022). Individual species of scale leaves possess unique arrangement

anastomosing or dichotomising lateral veins which resulted in the formation of meshes. Scale leaves which bear the male or female reproductive elements are termed as fertile scales or fructifications (Goswami *et al.*, 2010).

The current article deals with the first report of diverse scale leaves from the Barakar Formation of South Karanpura Coalfield of the Indian Gondwana. Since, the scale leaves of the present study are found in detached condition and glossopterid fructifications are absent in the collection, these detached scale leaves are described as *Denkania* type, *Eretmonia* type, *Glossotheca* type, *Partha* type, *Plumsteadirostrobis* type, *Scirroma* type, *Venustostrobis* type (Srivastava and Agnihotri, 2012).

GEOLOGICAL SETTINGS

The South Karanpura Coalfield forms a semi-elliptical half-graben structure, which has occupied up to 37 km in EW and 9 km in NS to the western part of Damodar valley. In the north, the basin is surrounded by the southern limb of North Karanpura Coalfield while the older metamorphics of Ranchi Plateau bounds the basin from the south. The area preserves a complete sequence of Lower Gondwana sediments and

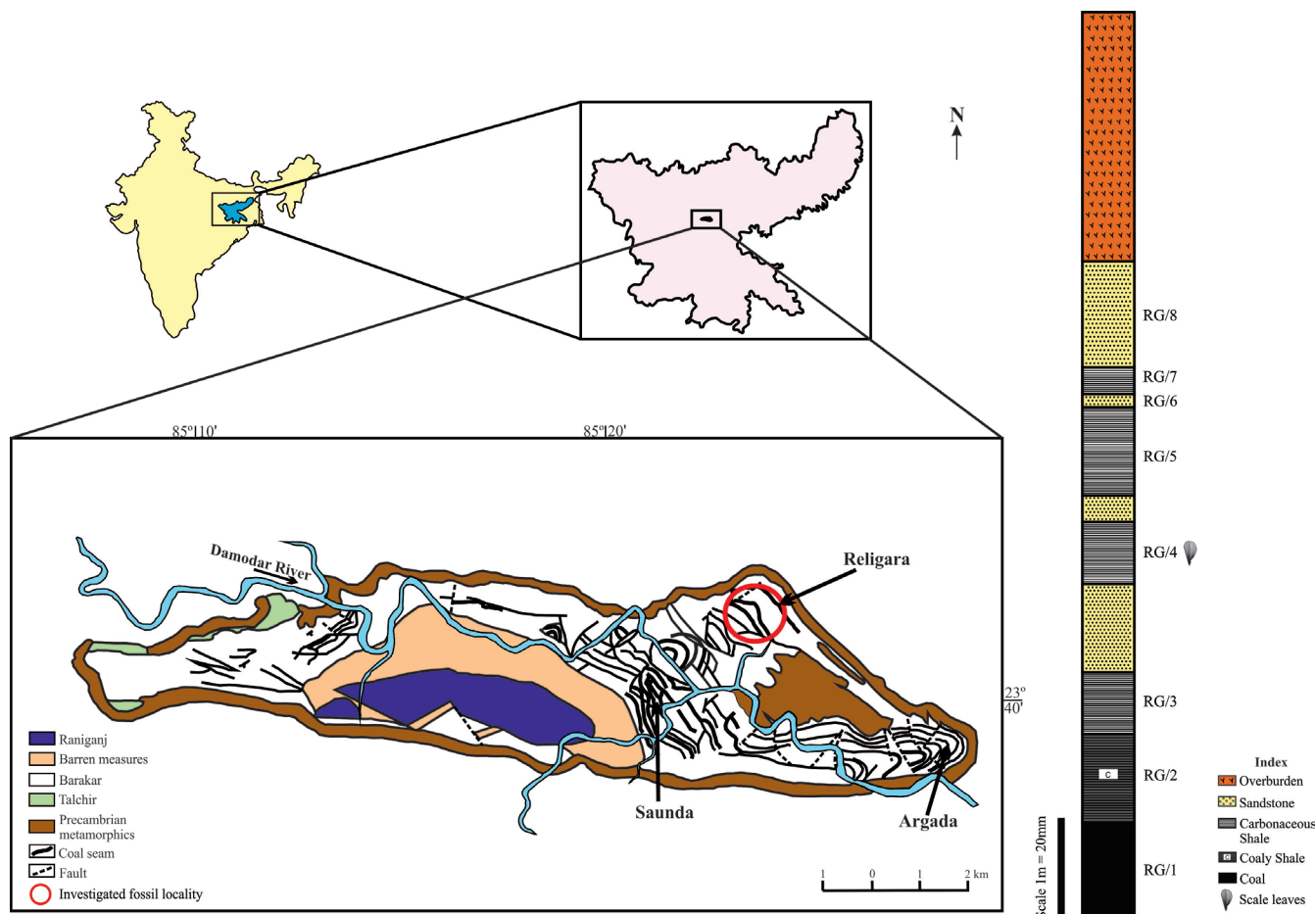


Figure 1. Geological map of South Karanpura Coalfield showing fossil locality and litho-column depicting fossil bearing horizon.

of scale leaves such as size, shape, apex, base and nature of veins were examined under the stereo-zoom Olympus microscope. The specimens are photographed with DSLR-5300 digital camera.

SYSTEMATICS

Scale leaves

Division Gymnospermophyta
 Order Glossopteridales
 Genus *Denkania* Chandra and Surange, 1971
 Type species *Denkania indica* Chandra and Surange, 1971

Denkania type
 (Pl. I, Fig. 1)

Description: This type is represented by a single petiolate scale leaf with length 3.7 cm and width 2 cm. The petiole itself is 2 cm long and 0.2 cm thick. Apex is acute and pointed. Base is acute cuneate. Leaf is narrow linear and broad at middle part of the lamina. Medial veins are

strong, broad, persistent and consists of 4 to 5 parallel veins; resembles midrib. Secondary veins are anastomosing and bifurcate to give rise small narrow meshes.

Comparison: This specimen resembles very well with the Holotype specimen of scale leaf of *Denkania indica* (Chandra and Surange, 1971) from Lower Kamthi (Raniganj) Formation of Handapa area, Odisha.

Distribution: Barakar and Lower Kamthi (Raniganj) formations of Indian Gondwana.

Specimen No.: RG-103.8.

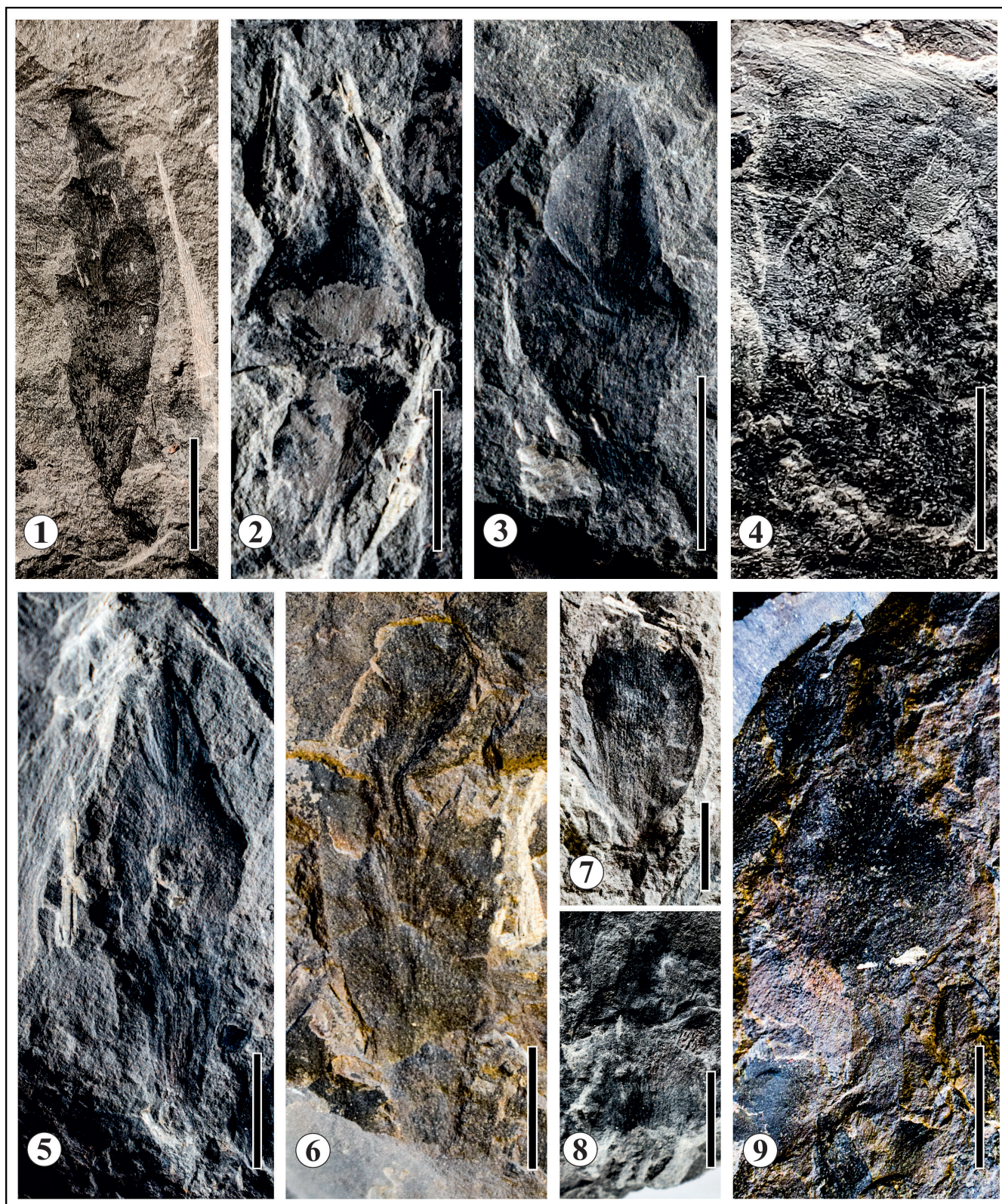
Genus *Eretmonia* duToit, 1932

Type Species *Eretmonia natalensis* du Toit, 1932

Eretmonia type (a)
 (Pl. I, Fig. 2)

Description: Total eight specimens are reported. None of them are complete. Apex is acute and stalks are not preserved. Scale leaves are lanceolate in shape ranging 1 cm to 2.7 cm in length and 0.6 cm to 1 cm in width. Central veins are straight and travel upwards with bifurcation towards the apical region. Lateral veins travel towards the margin with a gentle curve. Meshes are broad near the base and gradually become narrow towards apex.

Comparison: The specimens are well compared with the Holotype specimen of scale leaf of *Eretmonia emarginata*, established by Chandra and Surange (1977b) from the Lower Kamthi Formation of Talcher Coalfield.



EXPLANATION OF PLATE-I

Fig. 1. *Denkania* type (RG- 103.8), Fig. 2. *Eretmonia* type (a) (RG- 137.6), Fig. 3. *Eretmonia* type (b) (RG-89.2), Fig. 4. *Eretmonia* type (c) (RG- 117.2), Fig. 5. *Glossotheca* type (RG- 77.3), Fig. 6. *Partha* type (24.8), Fig. 7. *Plumsteadirostrobos* type (RG- 24.2), Fig. 8. *Scirroma* type (RG- 77.4), Fig. 9. *Venustostrobos* type (RG- 24.12). Scale bar 10 mm for all the specimens.

Table 3. Distribution of scale leaves recovered from investigated section in different Lower Gondwana formations of India.

Recovered taxa from studied area from Barakar Formation of South Karanpura Coalfield	Talchir	Karharbari	Barakar	Barren Measures	Raniganj (Lower Kamthi)	Bijori	Pali	Pachhware	Maitur	Hirapur	Parsora	Tiki	Maleri
Scale leaves													
<i>Denkania</i> type similar to scale leaf of <i>Denkania indica</i> fructification			+	*	+								
<i>Eretmonia</i> type (a) similar to scale leaf of <i>Eretmonia emarginata</i> fructification			+	*	+			+					
<i>Eretmonia</i> type (b) similar to scale leaf of <i>Eretmonia ovata</i> fructification			+	*	+			+					
<i>Eretmonia</i> type (c) similar to scale leaf of <i>Eretmonia utkalensis</i> fructification			+	*	+			+					
<i>Glossotheca</i> type similar to scale leaf of <i>Glossotheca orissiana</i> fructification			+	*	+								
<i>Partha</i> type similar to scale leaf of <i>Partha spatulata</i> fructification			+	*	+			+					
<i>Plumsteadioctrobus</i> type similar to scale leaf of <i>Plumsteadioctrobus pretiosus</i> fructification			+	*	+								
<i>Scirroma</i> type similar to scale leaf of <i>Scirroma ventilebra</i> fructification			+	*	+								
<i>Venustostrobus</i> type similar to scale leaf of <i>Venustostrobus indicus</i> fructification			+	*	+								

* Newly reported species from the Barakar Formation

Distribution: Barakar and Lower Kamthi formations of Indian Gondwana.

Specimen No.: RG-24.11, 26.4, 52.1, 52.2, 52.3, 83.7, 103.6, 137.6

Eretmonia type (b)
(Pl. I, Fig. 3)

Description: There are only three incomplete specimens in the present collection. Shape is ovate to obovate. Scale leaves are long and broad. Apices are acute with pointed thorn. Length ranges from 1.3 cm to 2.4 cm and width ranges from 0.7 cm to 1.5 cm.

Comparison: *Eretmonia ovata* was established by Surange and Chandra (1974) from the Lower Kamthi (Raniganj) Formation of Handapa, Odisha. The present specimens resemble well with the Holotype specimen of scale leaf of *Eretmonia ovata* (Surange and Chandra, 1974).

Distribution: Barakar and Lower Kamthi (Raniganj) formations of Indian Gondwana.

Specimen No.: RG-89.2, 114.4, 137.5.

Eretmonia type (c)
(Pl. I, Fig. 4)

Description: This type is represented by only one specimen with length 1.3 cm and width 0.8 cm. Scale leaf is rhomboid in shape with acute apex. The medial veins travel straight to the apical region and lateral veins gently arch out to the margin forming narrow meshes throughout the lamina.

Comparison: The specimen is similar to Holotype specimen of scale leaf of *Eretmonia utkalensis*, instituted by Surange and Maheshwari (1970) from the Lower Kamthi (Raniganj) Formation of Handapa, Odisha.

Distribution: Barakar and Lower Kamthi (Raniganj) formations of Indian Gondwana.

Specimen No.: RG-117.2.

Genus *Glossotheca* Surange and Maheshwari, 1970

Type species *Glossotheca utkalensis* Surange and Maheshwari, 1970

Glossotheca type
(Pl. I, Fig. 5)

Description: Shape of the scale leaf is elongate-lanceolate. It has stout, stretched out apex and base. Length is 4 cm and width is 1.5 cm. Medial veins are few, run straight upwards, become anastomose in apical portion. Lateral veins anastomose and diverge towards margin with elegant curves, form narrow elongate meshes.

Comparison: The specimen is similar to Holotype specimen of scale leaf of *Glossotheca orissiana*, instituted by Surange and Chandra (1972) from the Lower Kamthi (Raniganj) Formation of Handapa, Odisha. The specimen possesses very close elementary arrangements with *Glossotheca utkalensis*. The former is smaller in size.

Distribution: Barakar and Lower Kamthi (Raniganj) formations of Indian Gondwana.

Specimen No.: RG-77.3.

Genus *Partha* Surange and Chandra, 1973

Type species *Partha indica* Surange and Chandra, 1973)

Partha type
(Pl. I Fig. 6)

Description: This type is represented by five incomplete specimens. Shape is spatulate with obtuse apex and acute cuneate base. The length and width are 1.2 cm to 4 cm and

Table 4. Distribution of recovered scale leaves in various Gondwana basins of India.

Taxa of studied section from South Karanpura Coalfield	Ib-River	Talchir	Mand- Raigarh	Ramkola-Tatapani	Korba	Chirimiri	Singrauli	Hura	Pachwara	Jambad	Raniganj	Jharia	Bokaro	South Karanpura	North Karanpura	Deogarh	Auranga	Hatar	Daltonganj	Pench Valley	Umer	South Rewa
Scale leaves																						
<i>Denkania</i> type similar to scale leaf of <i>Denkania indica</i> fructification		+												+	*							
<i>Eretmonia</i> type (a) similar to scale leaf of <i>Eretmonia emarginata</i> fructification			+												+	*						
<i>Eretmonia</i> type (b) similar to scale leaf of <i>Eretmonia ovata</i> fructification		+	+												+	*						
<i>Eretmonia</i> type (c) similar to scale leaf of <i>Eretmonia utkalensis</i> fructification				+											+	*						
<i>Glossotheca</i> type similar to scale leaf of <i>Glossotheca orissiana</i> fructification				+											+	*						
<i>Partha</i> type similar to scale leaf of <i>Partha spatulata</i> fructification		+	+												+	*						
<i>Plumsteadistrobus</i> type similar to scale leaf of <i>Plumsteadistrobus pretiosus</i> fructification				+												+	*					
<i>Scirroma</i> type similar to scale leaf of <i>Scirroma ventilebra</i> fructification				+						+						+	*					
<i>Venustostrobus</i> type similar to scale leaf of <i>Venustostrobus indicus</i> fructification				+	+											+	*					

* Newly reported species from the investigated area

Information regarding the taxa reported from Ib River Basin is collected from unpublished Ph.D. thesis (Tripathy, 2021)

0.5 cm to 1.4 cm respectively. The medial veins are persistent and taper upwards to the apical region. Lateral veins are bifurcating and run to the margin with slight arcing.

Comparison: The specimen is similar to Holotype specimen of scale leaf of *Partha spatulata*, established by Surange and Chandra (1973) from the Lower Kamthi (Raniganj) Formation of Handapa, Odisha.

Distribution: Barakar and Lower Kamthi (Raniganj) formations of Indian Gondwana.

Specimen No.: RG-24.8, 24.10, 24.13, 77.7, 77.8.

Genus *Plumsteadistrobus* Chandra and Surange, 1977c

Type species *Plumsteadistrobus ellipticus* Chandra and Surange, 1977c

Plumsteadistrobus type
(Pl. I Fig. 7)

Description: In total three specimens are reported. Shape is elliptical oval. Apex is rounded, obtuse in one specimen. Base is acute cuneate. Margin is undulated. Length ranges from 2.6 cm to 3.8 cm and width ranges from 1.3 cm to 2.4 cm. Lateral veins travel to the margin with little curves.

Comparison: The present specimens resemble

very well with the Holotype specimen of scale leaf of *Plumsteadistrobus pretiosus*. *Plumsteadistrobus pretiosus* was instituted by Chandra and Surange (1977c) from the Raniganj Formation of Raniganj Coalfield.

Distribution: Barakar and Raniganj formations of Indian Gondwana.

Specimen No.: RG-24.2, 24.9, 52.5.

Genus *Scirroma* Chandra and Surange, 1977e

Type species *Scirroma angusta* Chandra and Surange, 1977e

Scirroma type
(Pl. I Fig. 8)

Description: Only one specimen represents the species. Length and width are 2 cm and 0.8 cm respectively. Apex and base are not well preserved. Medial veins are persistent and run straight to the apical region. Lateral veins travel to the margin with graceful curves. Meshes, formed by lateral veins are narrow in nature.

Comparison: The present specimens resemble very well with the Holotype specimen of scale leaf of *Scirroma ventilebra* (Chandra and Surange, 1977e) reported from the Raniganj Formation of Raniganj Coalfield.

Distribution: Barakar and Raniganj formations of Indian Gondwana.

Specimen No.: RG-77.4

Genus *Venustostrobus* Chandra and Surange, 1977a.

Type species *Venustostrobus diademus* Chandra and Surange, 1977a.

Venustostrobus type
(Pl. I, Fig. 9)

Description: There is only one specimen in the assemblage. Shape is orbicular. Apex and base are not preserved. Length and width are 2.3 cm and 1.5 cm respectively. The specimen is characterized by absence of midrib, strong mesh forming lateral veins arch out to the margin with graceful curves. Meshes are short and broad near basal portion whereas they become narrow towards apical region.

Comparison: The present specimens resemble very well with the Holotype specimen of scale leaf of *Venustostrobus indicus* (Chandra and Surange, 1977d) recovered from Raniganj Formation of Raniganj Coalfield.

Distribution: Barakar and Raniganj formations of Indian Gondwana.

Specimen No.: RG-24.7, 65.4, 67.6, 24.12.

DISCUSSION

In total nine types and twenty-seven specimens of scale leaves have been reported from the studied upper Barakar Formation (Kungurian) Exposure of Religara colliery of South Karanpura Coalfield. These are *Denkania* type, *Eretmonia* type (a), *Eretmonia* type (b), *Eretmonia* type (c), *Glossotheca* type, *Partha* type, *Plumsteadirostrobos* type, *Scirroma* type, *Venustostrobus* type having similar morphology with scale leaves of *Denkania indica*, *Eretmonia emarginata*, *E. ovata*, *E. utkalensis*, *Glossotheca orissiana*, *Partha spatulata*, *Plumsteadirostrobos*, *Scirroma ventilebra* and *Venustostrobus indicus* fructifications respectively.

Venustostrobus has been considered a junior synonym of *Scutum* (Rigby, 1978), whereas *Plumsteadirostrobos* has been considered a junior synonym of *Plumstedia* (Rigby, 1978; McLoughlin and Prevec 2019). However, *Plumstedia* has not yet been recognised and *Venustostrobus* has not been found erroneous in Indian Gondwana. Thus, our impression materials of Damodar Master Basin (South Karanpura Basin) are compared with scale leaf of *Plumsteadirostrobos pretiosus* fructification instituted by Chandra and Surange (1977c) and that of *Venustostrobus indicus* fructification erected by Chandra and Surange (1977a) and are described in the

present study as *Plumsteadirostrobos* type and *Venustostrobus* type scale leaves respectively. It is pertinent to mention here that holotype specimens of *Plumsteadirostrobos pretiosus* and *Venustostrobus indicus* are from same Damodar Master Basin (Raniganj Coalfield).

The studied scale leaves are well preserved in fine-grained carbonaceous layer in form of compressions and impressions. The floras are found detached and possess similar venation with that of glossopterid vegetative leaves. Most of these scale leaves are recorded from Talcher Basin, excluding scale leaf of *Plumsteadirostrobos pretiosus* (Goswami *et al.*, 2022). Nevertheless, earlier all these scale leaves have been recorded from Lower Kamthi/Raniganj Formation of Indian Gondwana. The present report of these fossils from the Barakar Formation expanded their range from late Artinskian to Changhsingian age. The distributions of documented scale leaves in different Lower Gondwana formations and various Gondwana basins of India are presented in Table 3 and Table 4 respectively. All these scale leaves are recorded for the first time from the Barakar Formation of South Karanpura Coalfield of the Indian Gondwana.

CONCLUSIONS

A variety of sterile diverse scale leaves are recorded in dispersed condition. Based on these morphological features; scale leaves are classified into nine types and compared with the respective scale leaves of different fructification genera in the present study.

Usually, convex or concave structured fructifications are accompanied by scale leaves in form of cupules, ovules or sporangia (Lacey *et al.*, 1975; Surange and Chandra, 1975; Chandra and Surange, 1976; Banerjee, 1979; Goswami *et al.*, 2010; Pant, 1958; Pant and Chauhan, 2000). In the recent study, the dispersed scale leaves are devoid of reproductive organs (ovules or sporangia). Hence, it can be concluded that rather than being a reproductive organ, scale leaves perform as external protectors of glossopterid vegetative buds.

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