SPHENOPHYLLUM, TRIZYGIA AND *GONDWANOPHYTON* FROM BARAKAR FORMATION OF RANIGANJ COALFIELD, WITH A REVISION OF LOWER GONDWANA SPHENOPHYLLALES

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ABSTRACT

Morphology of *Sphenophyllum*, *Trizygia* and *Gondwanophyton* collected from the Barakar Formation of the Churulia area, Raniganj Coalfield are discussed. The systematic positions of Lower Gondwana species of *Sphenophyllum* and *Trizygia* from India, Australia, South America and South Africa are reviewed. New species *Sphenophyllum archangelskyii*, *S. churulianum*, *S. waltonianum* and *Trizygia maithyiana* are proposed. A new mode of attachment of leaf to the axis is discovered for *Gondwanophyton*.

INTRODUCTION

A large number of plant fossils belonging to the genera *Glossopteris*, *Neomariopteris*, *Sphenophyllum*, *Trizygia*, and *Gondwanophyton* were collected from the carbonaceous shales exposed in a quarry, about 250 m east of the Churulia Railway Station in the north-eastern part of the Raniganj Coalfield, West Bengal. The specimens belong to the Barakar Formation (for geological details and locality map see BISWAS, 1966).

The geological succession met within the area is as follows :

	Sandstones and shales	
Barakar Series	Coarse gritty sandstones and shales with coal seams	—Churulia seam
		—Kasta seam
		—No. IV seam of Gee
	Fossiliferous carbonaceous shales and fire clays containing coal seam	—Churulia Basal
		—No. II seam of Gee
	Ferruginous sandstones	
	Pebbly sandstones and basal conglomerates	
	Unconformity——	
	Archaean Basement	

Type and figured specimens have been deposited in the Museum of Birbal Sahni Institute of Palaeobotany (BSIP). The present paper deals with the morphological aspects of *Sphenophyllum*, *Trizygia* and *Gondwanophyton*. Other Lower Gondwana species of *Sphenophyllum* and *Trizygia* are reviewed.

ASAMA (1970) separated the genera *Parasphenophyllum* and *Paratrizygia* from *Sphenophyllum* and *Trizygia*, respectively, because his new genera had venation which intersected the lateral margins as well as the apical margin of each leaf. However, the problem of such separation of taxa lies in the fact that in most species it is impossible to say where the lateral margin ends and the apical margin begins. The second feature used by ASAMA (1970) is subjective because it depends on the basis used to define the apical margin,

viz. curvature of the veins. The veins are obliged to curve if the ratio of leaf length to width is greater than about 2; otherwise they would become crowded towards the apex as in these genera the veins tend to intersect the margin at a high angle, almost perpendicularly. Because of the problem given above, we consider that the genera *Parasphenophyllum* and *Paratrizygia* have no basis on which they are to be retained.

Many authors, including WALTON (1929) and PANT AND MEHRA (1963), regard *Trizygia* as a junior synonym of *Sphenophyllum;* others regard them as distinct taxa (MAHESHWARI, 1968; MAITHY, 1978). In our openion, they may be separated quite readily by the symmetry of the leaf whorl and the uniformity/dissimilarity of leaves within individual whorls. *Sphenophyllum* has leaves of uniform size within each whorl and arranged with radial symmetry with respect to the axis. *Trizygia* has leaves arranged in three pairs, each of uniform size with the basal pair significantly smaller than the other pairs. Symmetry is planar, the plane passing between the basal pair of leaves and containing the axis.

A number of workers (WALTON, 1963; PANT & MEHRA, 1963; MAITHY, 1978) have stressed that when a leaf whorl, lying at an angle to the bedding planes of the enclosing sediments, is compressed, it become distorted from round to oval-shaped. This accounts for differences in leaf length sometimes observed in genera, such as *Annularia* and *Raniganjia.* Distortion is not easily noticed in whorls of *Triygia* where the leaves are asymmetrical in an undistorted whorl. We have observed that vein density is constant in undistorted whorls of *Sphenophyllum,* and that many whorls of *Trizygia* also have constant vein density. When a whorl of *Trizygia* is obviously distorted, the veins are more densely spaced on leaflets, which are distorted by narrowing (WALTON, 1929); we have taken this into consideration.

DESCRIPTION

Genus—**Sphenophyllum** Köenig, 1825

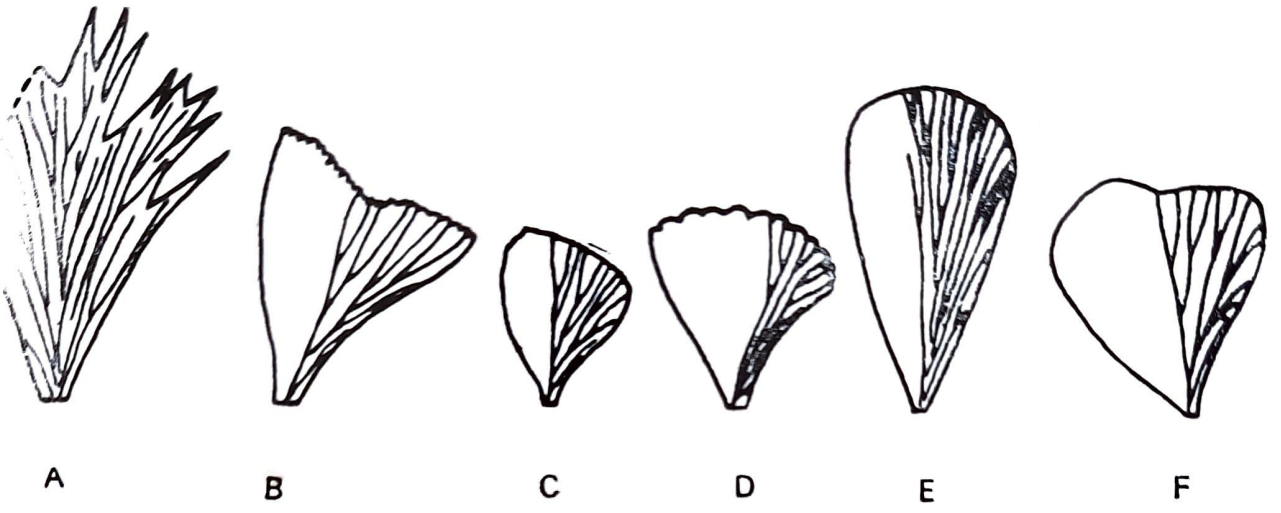
Sphenophyllum churulianum sp. nov.
Pl. 1, Figs. 1-3

Diagnosis—Six leaves arranged in a whorl, leaves equal in size and similar in shape; length-width ratio 3: 1; obovate, lanceolate to subtriangular in shape, apex obtuse, base acute cuneate, margin smooth; median vein distinct, emerged at base; veins arched, anastomoses absent.

Holotype—35970, BSIP Museum (Pl. 1, Fig. 1)
Locality—Churulia, East Raniganj Coalfield, West Bengal
Horizon—Barakar Formation (Lower Gondwana)
Age—Early Permian
Derivation of name—After the village Churulia, the type locality

Description—Eighteen specimens are present in the collection of which four show more or less complete whorls of leaves. Each whorl comprises six leaves of equal size and similar shape. The leaves are 2.0-3.8 cm long and 1.5 to 2.7 cm wide, obovate oblanceolate in shape. The apical and lateral margin of the leaves are smooth. Leaves of a whorl are attached only basally. A single vein emerges from the base which, after repeated dichotomy, gives rise to 20-25 veinlets. The course of veins is straight in the middle of the leaf and arched towards the margins.

Comparison—*Sphenophyllum churulianum* sp. nov. is comparable with *S. rhodesii* Rigby (1966), *S. obovatum* Sellards (1908) and *S. sakoense* Appert (1977). *S. rhodesii* has broadly ovate and smaller leaves with a less rounded apex. Length-width ratio in *S. churulianum* is 3 : 1 whereas in *S. rhodesii* it is 1 : 1. *S. obovatum* is distinct in having asymmetrical leaves. *S. sakoense* is different in showing remarkable reduction in size of one or two leaves in a whorl (Text-fig. 1).



Text-figs. 1A-E. Shape of leaves of different species of *Sphenophyllum*; A. *S. archangelskyii*, B. *S. crenulatum*, C. *S. rhodesii*, D. *S. waltonianum*, E. *S. churulianum*, F. *Trizygia maithyiana*

Sphenophyllum archangelskyii sp. nov.

1960. *Sphenophyllum thonii, in* Archangelsky p. 29-30 ; pl.5, fig. 3 ; pl. 6, fig. a-c ; pl. 7, fig. 1; pl. 8, fig 1; pl. 10, fig. 1.

Diagnosis—Six leaves similar in size and shape, arranged around a central point, elongate obovate in shape, apex broad, apical margin fringed, deeply incised, lateral margin smooth; single vein emerging at the base after repeated dichotomy form veins, anatomoses absent, one vein present in each fringe or notch.

Holotype—LIL 1077 in the collections of the Institute Miguel Lillo, Universidad Nacional del Tucuman, Argentina (ARCHANGELSKY, 1960, pl. 8, fig. 1)
Locality—Santa Cruz, Bajo de La Leona, Laguna Polina, Argentina (see ARCHANGELSKY, 1960, p. 30)
Horizon—La Golondrina Series (Lower Gondwana)
Age—Early Permian
Derivation of name—After Dr. S. Archangelsky for his valuable contribution towards the knowledge of the Glossopteris flora
Description—See ARCHANGELSKY, 1960, p. 29-30.

Comparison and Discussion—ARCHANGELSKY (1960) has identified some leaves of *Sphenophyllum* as *S. thonii* Mahrii (1868). However, the specimens differ from the original *S. thonii* by having a straighter apical fringe with significantly fewer lobes (about half the number) that do not extend as far along the lateral margins. The lobes or teeth are shorter and narrower in *S. thonii*.

S. spinulosum Yabe & Oishi (1928) has asymmetrical leaves. *S. incisum* Wagner (1964) has a smaller number of deeply incised teeth. *S. cornutum* Lesquereux (1870) has a triangular leaf with very few teeth. *S. neofimbriatum* (Halle) Boureau (1964) has

shorter teeth formed along almost the entire margin. *S. wankianum* Hurd-Moine (1965) has six leaves composed of three different pairs.

Sphenophyllum waltonianum sp. nov.

1929. *S. thonii* var. *minor* Sterzel *in* Walton, pl. A, figs. 3, 4, 8
1947. *S. thonii* Mahr., *in* Teixeira, pl. 8, fig. 2 ; pl. 9, fig. 1
1972. *S. thonii* Mahr, *in* Arrondo, pl. 1, fig. 1

Diagnosis—Six leaves similar in size and shape, arranged in a whorl, attached to a central point, obovate, apex broadly rounded, base contracted, apical margin toothed, lateral margin smooth; single vein at the base then repeatedly dichotomizing, anastomoses absent; each vein ending at the convex apex of a crenulation, the latter meeting at a sharp V-notch.

Holotype—V. 20764, British Museum (Natural History) (WALTON 1929, pl. A, fig. 4)
Locality—Wankie District, Southern Rhodesia
Horizon—Upper Wankie Sandstone
Age—Permian
Derivation of name—After Prof. J. Walton for his significant contribution towards the knowledge of Karoo flora
Description—See WALTON, 1929, p. 65

Comparison and Discussion—The forms described under *S. thonii* var. *minor* Sterzel (1958) by WALTON (1929) from the Wankie district of Southern Rhodesia, by TEIXEIRA (1947) as *S. thonii* from Mozambique, and by ARRONDO (1972) as *S. thonii* from Argentina are found to be distinct from *S. thonii*. They are placed under a new species, *S. waltonianum*.

The crenulations found along the apical margin of *S. waltonianum* are rare in species of *Sphenophyllum* where, if they occur, the apex is pointed and the notch is concave. It compares with *S. tenue* White (1900) but the leaf of *S. tenue* has sparse venation and a gently rounded apex. The apical margin of *S. waltonianum* is curved, whereas it is straight in *S. emarginatum* (Brongniart) Köenig (1825), *S. cuneifolium* (Sternberg) Zeiller (1880), and *S. majus* (Brann) Brann (1835). Teeth in *S. verticillatum* (Schlotheim) Brongniart (1828) are irregular and blunt.

Sphenophyllum crenulatum (Maithy) comb. nov.

Basionym—Parasphenophyllum crenulatum Maithy, 1978, *Palaeobotanist*, **25**, p. 274, pl .2, figs. 11, 12

Diagnosis—Whorls comprising six leaves of equal size, leaves spreading out at right angles to the stem; triangular in outline, petiolate base, obcordate apex, apical margin undulate, lateral margin entire; a distinct median vein emerging at the base of leaf which dichotomizing once each supplying one half of the leaf by repeated dichotomy; veins arching in the lateral portion and straight in the middle portion.
Holotype—10/1644, BSIP Museum
Locality—Pit No. 7, Damodar Colliery, East Raniganj, Coalfield, West Bengal.
Horizon—Raniganj Formation (Lower Gondwana)
Age—Late Permian

Description and Comparison—See MAITHY, 1978, p. 274

Discussion—Parasphenophyllum crenulatum Maithy (1978) has been transferred to *Sphenophyllum crenulatum* (Maithy) comb. nov. because we consider the genus *Parasphenophyllum* to be a junior synonym of *Sphenophyllum*, as discussed above.

Sphenophyllum rhodesii Rigby, 1966

Diagnosis—"Slender ribbed stem bearing whorls of six approximately equal-sized obcuneate leaves at enlarged nodes. Leaves almost as broad as long; distal margin entire slightly rounded, base contracted, non petiolate; leaves free. Venation repeatedly dichotomizing, arising from a single, stouter vein that enteres leaf base; some veins intersect the apparent lateral margin of leaves, whereas the majority intersect the apical margin. Leaf whorls separated by a distance of less than the whorl diameter. Fructification unknown" (After Rigby, 1966).

Holotype—WA 23684, Department of Geology, University of Western Australia
Locality—North Irwin River, No. 2 Coal Adit
Horizon—Irwin River Coal Measures
Age—Early Permian

Discussion—*S. rhodesii* was described by Rigby (1966) and two specimens were figured out of which one (pl. 33, fig.30) shows two whorls joined by a stem. Rigby omitted to mention that the whorls were at an angle to the surface of the specimen thus appearing to elliptical. The figure gives the impression that the whorls were not radially symmetrical, but as the whorls were at an angle to the plane of the photograph, some leaflets have been foreshortened. Maithy (1978) has based his reclassification of the species on the assumption that the photograph accurately showed the specimen; however, this is not so. In consequence, we revert to Rigby's original attribution to *Sphenophyllum* as the whorls are radially symmetrical.

Genus—**Trizygia** Royle, 1839

Trizygia speciosa Royle, 1839
Pl. 1, Fig. 4
Our specimens are typical.

Trizygia maithyiana sp. nov.

1947. *Sphenophyllum speciosum* Teixeira, pl. 11, fig. 3 ; pl. 12, figs. 1-2.
1978. *Paratrizygia rhodesii* Maithy, p. 274 ; pl. 2, fig. 10.

Diagnosis—Six leaves in a whorl arranged in 3 pairs, two lateral pairs larger in size than third pair; larger leaves obcuneate, broadly rounded with emarginate apex and contracted base, non-petiolate; smaller leaves similar to the larger ones in shape but having a non-emarginate apex, venation dichotomous arching towards margin, straight in the middle.

Holotype—103/1216 BSIP Museum (see Maithy, 1978; pl. 2, fig. 10).
Locality—Lower Nakari Seam, South Karanpura Coalfield
Horizon—Barakar Formation (Lower Gondwana)
Age—Early Permian
Derivation of name—After Dr. P. K. Maithy for his contribution towards the knowledge of Indian Lower Gondwana Palaeobotany.
Description—See Maithy, 1978, p. 274

Comparison and Discussion—The forms described under *Paratrizygia rhodesii* by Maithy (1978, pl. 2, fig. 10) and *Sphenophyllum speciosum* by Teixeira (1947) differ from *Trizygia speciosa.* Accordingly they have been placed under a new species, *Trizygia maithyiana* sp. nov., which differs from other species in having lateral leaves with an emarginate apex. *T. speciosa* Royle (1839) has two dissimilar pairs of narrow, asymmetrical,

obovate larger leaves, whereas in *T. maithyiana* sp.nov. the four leaves are symmetrical broadly obovate in shape with emarginate apex. The smaller leaves in *T. maithyiana* are proportionally larger about 2/3 the size of the larger leaves. *T. sinocoreanum* Asama (1970) lacks emarginate lateral leaves although its basal small leaves resemble those of *T. maithyiana* sp. nov.

Genus—**Gondwanophyton** Maithy, 1974
Pl. 1, Figs. 5, 6

The present specimens are comparable with the forms described by Maithy under *Gondwanophyton indicum* Maithy (1974).

Maithy (1974) has proposed a reconstruction for this genus where the leaves are non-petiolate and attached obliquely to the narrow axis by their truncate base and arranged alternately. The proposed attachment of leaves for *Gondwanophyton* is a modification of the original reconstruction. Our specimen (Pl. 1, Fig. 6) shows that the leaf-base is split into a V-shaped incision from which the venation arises. This suggests that the leaf was either sessile and stem clasping or petiolate. We prefer the petiolate explanation as if it were stem clasping, the stem would have to be angular with a lunate cross section which is highly improbable as the stem would be mechanically weak. We have no evidence for the arrangement of leaves on the stem.

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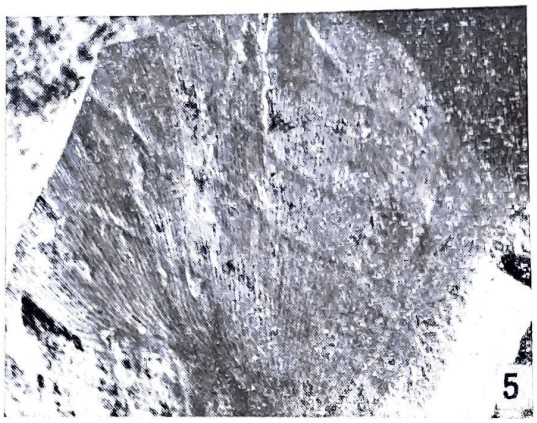
EXPLANATION OF PLATE

PLATE 1

1. *Sphenophyllum churulianum* sp. nov., Holotype, Specimen no. 35970; One complete whorl of the leaves. Nat. size.
2. *Sphenophyllum churulianum* sp. nov., Counter part of the holotype. Nat. size.
3. *Sphenophyllum churulianum* sp. nov., Photo shows the leaf arrangement around a central point. Specimen no. 35974, ×2
4. *Trizygia speciosa* Royle. Photo shows a whorl of leaves. Specimen no. 35973, ×2.
5. *Gondwanophyton indicum* Maithy, Photo shows one leaf attached with a broad base to axis. Specimen No. 35975, Nat. size.
6. *Gondwanophyton indicum* Maithy, Photo shows the clasping V-shaped notched attachment of the leaf, Specimen no. 35977, ×2.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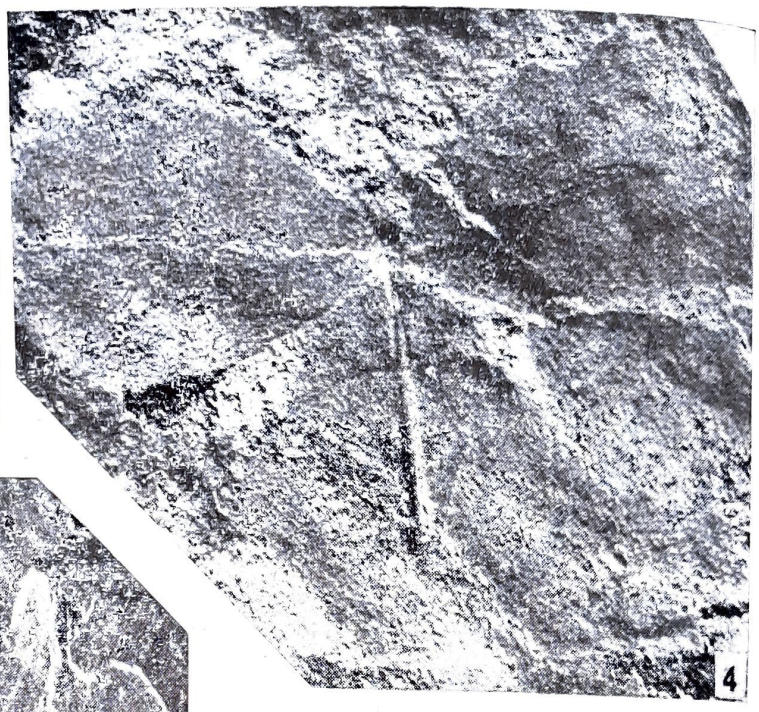
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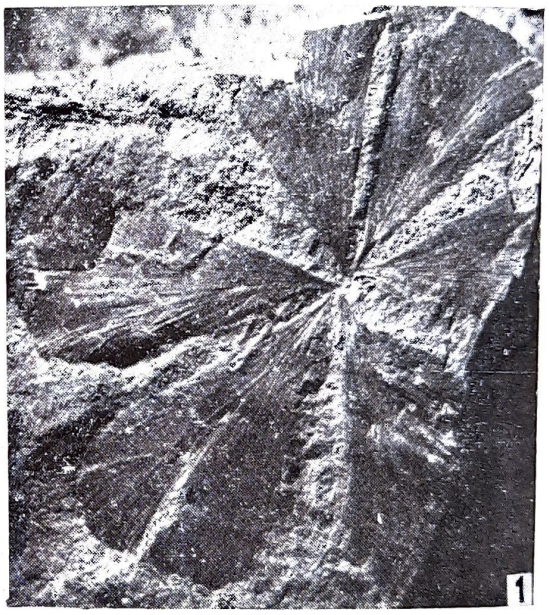
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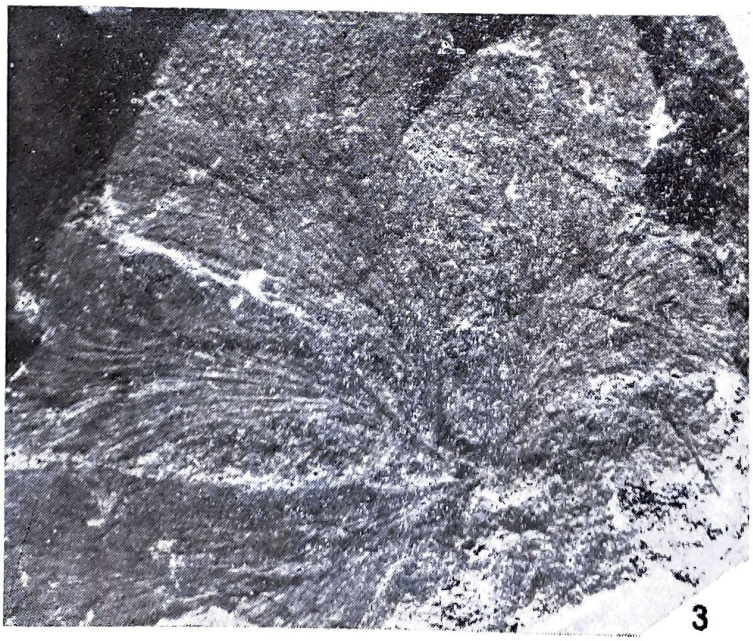
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