

First record of late Palaeozoic Euramerian calamitalean foliage shoot *Annularia* Sternberg in the Late Early Permian (Barakar Formation) *Glossopteris* floral assemblage of Peninsular Indian Lower Gondwana

A number of equisetalean branch system with foliage shoots are recorded from the Peninsular Lower Gondwana sediments of India. The specimens are from the Late Early Permian (Barakar Formation) sediments of Saharjuri Basin, Jharkhand, an easterly basin of Peninsular India (Figure 1 a, b). Well-preserved foliage shoots emerge from the branch system (Figure 2 a-c), spread out on horizontal, thin shale layer. The specimens show up to third-order branching; minor branches come out alternately from moderately thick, articulated 0.9–3.2 mm branches, shorter branches originate from nodes with leaves in whorls; nodal and internodal regions distinct; ridges and furrows alternate in the successive whorls; number of ridges varies from 6 to 9 in the internodal regions of branches of different widths, each node bears oblong to obovate 3–9.2 × 1–1.7 mm leaves; 6 to 11 leaves of variable length occur in a verticel. Leaf length does not exceed the internodal length of the axis. Leaves free from each

other up to the point of attachment with the stem axis and form an almost round to elliptic distinct ring or disc at the nodal region. Each leaf has a tapering narrow base, widest at the middle part and bluntly acute apex terminated by a small mucronate tip; a single median vein runs along the entire length of the lamina, vein width almost one-fourth of the lamina width at the median part. Leaf margin entire. The morphocharacteristic features of the leafy shoots resemble those of the Euramerian genus *Annularia* Sternberg¹.

The leafy shoots are compared with the various species of *Annularia* described by several workers^{2–5}. The present specimens show some resemblance with the species of *A. stellata* (Schlothiem) Wood, *A. crassiscula* Halle, *A. radiata* (Brongn.) Sternberg and *A. spicata* (Gutb.) Schimp. The closest resemblance is observed with *A. crassiscula*. Differences in the shape and size of the lamina, number of leaves in a whorl, arrangement of the leaves at

nodes, and apex of lamina distinguish the present specimens from other species of *Annularia*. As such, the present *Annularia* leafy shoots in the *Glossopteris* floral assemblage are identified as *A. crassiscula* Halle (Boureau)³, which is a plant of the Euramerian flora. The collected specimens of *A. crassiscula* (nos ScTd. 450, ScTd. 498, ScTd. 499) are preserved in the Palaeobotany–Palynology Repository, Department of Botany, University of Calcutta, Kolkata.

A. crassiscula is different from the equisetalean plants of Lower Gondwana, viz. *Barakaria* Seward & Sahni, and *Bengalia* Maheshwari, Singh & Bajpai in leaf shape, size and in the absence of nodal disc, *Raniganjia* Rigby, in its laterally fused leaves almost up to three-fourth length to form a prominent sheath, cup or funnel-like leaf sheath in *Phyllothea* Brongn. With narrow lanceolate leaves and *Stelotheca*. (= *Lelstotheca* Maheshwari) with strap-shaped leaves, and phyllotaxy and conver-

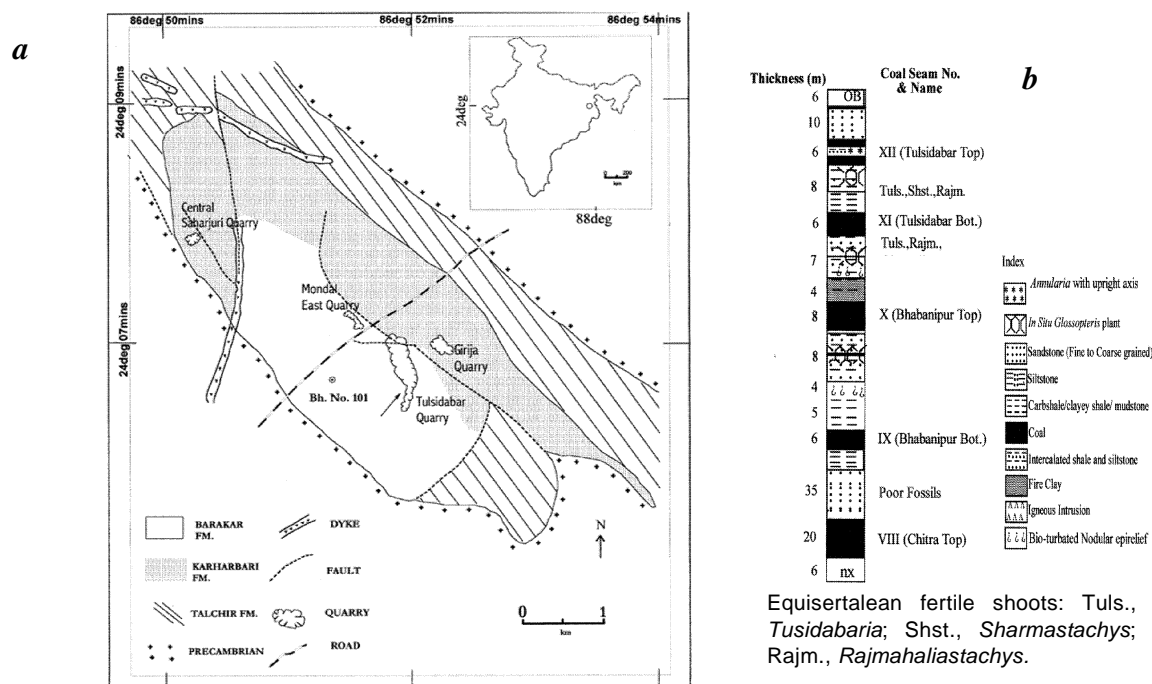


Figure 1. a, Geological map of Saharjuri Basin showing study area (after Niyogi²⁰, Datta *et al.*²¹ and Pareek *et al.*²²). b, Lithology of Tulsidabar quarry showing the section exposed and fossil locations.

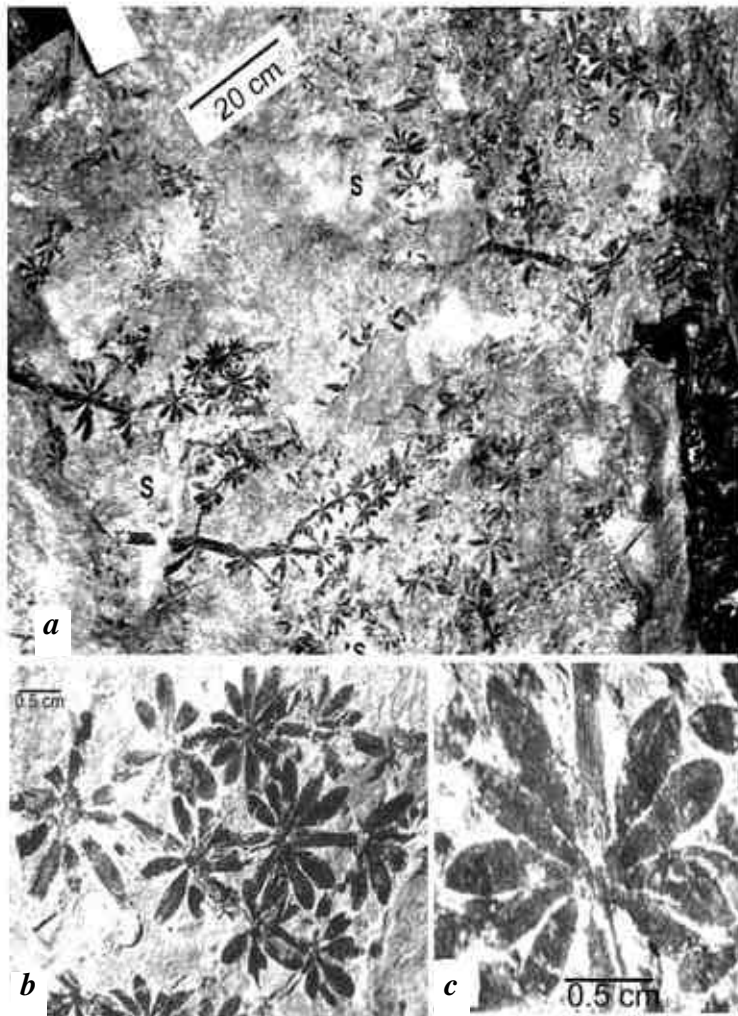


Figure 2. *a*, Rock surface showing the well-preserved leafy shoots of *Annularia crassiscula*. Specimen number ScTd 450. *b*, Portion of the leafy shoot enlarged to show the branching pattern and whorls of leaves. *c*, One of the leaf whorls enlarged to show the unequal leaves and nodal disc.



Figure 3. Distribution of *Annularia* spp. in different floristic provinces during Early Permian (after Cleal and Thomas¹⁴).

gent, multi-nerved leaves of *Schizoneura* Schimp. & Moug. The Mesozoic genus *Equisetites* Sternb. shows some similarities with our specimen in the alternate arrangement of ridge and furrow and almost free leaf segments, but the number of leaves

in a whorl, absence of variation in size of leaves in the same whorl, narrow-lanceolate shape of lamina and absence of nodal disc in *Equisetites* are different from the present specimen. The multi-nerved, forked veins, lobed, obovate-to-wedge-

shaped leaves of sphenophyllalean members, viz. *Sphenophyllum* Koenig and *Trizygia* Royle are distinctly different from the uni-nerved *Annularia* Sternb. leaves. Earlier, leafless equisetalean fertile shoots *Rajmahaliastachys* Banerjee & D'Rozario⁶, bractless fertile organ *Tulsidabaria* Banerjee *et al.*⁷, and a unique genus *Sharmastachys* Banerjee & D'Rozario⁶ were described from the same horizon of the basin.

Annularia foliage shoots and the equisetalean fertile shoots^{6,7} occur in an assemblage of *in situ* upright *Glossopteris* plants on *Vertebraria* roots⁴, diverse *Glossopteris* species, few *Gangamopteris* species, the *Glossopteris* seedlings, *Deogharia* Banerjee⁹, and some unique plants, viz. *Saharjuria*, and *Chitraphyllum*, *Santhalitheca* Banerjee¹⁰. The non-trizygoid *Sphenophyllum* leafy shoots, another Euramerian genus, are also encountered frequently along with *Annularia* in the assemblage.

Earlier reports of the fertile Sphenopsid genera, viz. *Rajmahaliastachys elongata*⁶, *Tulsidabaria indica*^{6,7} the unique genus *Sharmastachys*⁶, *Giridia* Pant *et al.*¹¹ from India, and *Gondwanostachys* Meyen¹² from Australia reveal that diverse sphenopsids were represented in the Lower Gondwana forests. Morphological characters of *R. elongata*⁶ are closely comparable to the fertile Sphenopsid genus *Palaeostachya* of Euramerian flora.

Annularia is a significant articulate taxon of the Permo-Carboniferous Euramerian equatorial floral province. The genus is reported from the Early Permian Gondwana sediments of extra-Peninsular India in the *Glossopteris*, *Gangamopteris*, *Phyllothea*, marine microplankton, and bryozoan assemblage¹³. The record of *Annularia* in the Early Permian sediments of north-western extra-Peninsular Gondwana rocks and in the eastern Indian Saharjuri basin thus indicates that the components of the Late Palaeozoic Euramerian flora invaded the northwestern extra-Peninsular Gondwana forests and their migration continued up to the Gondwana forest of Saharjuri basin in the eastern Indian Peninsular region during Late Early Permian (Figure 3).

The species of the Euramerian equatorial taxon *Annularia* are documented in the Permian Angara, Kuznetsk¹⁴ and Cathaysian North China, South China¹⁵ floral assemblages. Similarly, the Gondwana deposits of Argentina, Brazil and South Africa (Nothoafroamerica) have

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records of *Annularia*^{14,16,17}. The genus is known to occur in the Permo-Carboniferous rocks of Australia¹⁸ and Antarctica¹⁹. Records of *Annularia* in all the Lower Gondwana continents, western extra-Peninsular Gondwana deposits and the present luxuriant leafy shoots from eastern Indian Peninsular Gondwana sediments thus suggest that trans-migration of *Annularia* did occur between the different floristic provinces of Late Palaeozoic time, situated in different palaeolatitudes (Figure 3). Banerjee¹⁷ analysed the Permo-Carboniferous floral assemblages of Lower Gondwana continents, highlighting the rich representation of equatorial, tropical elements of northern hemisphere Carboniferous forests. The present record of *Annularia* in the *Glossopteris* floral assemblage of Indian Lower Gondwana is yet another evidence of representation of equatorial, tropical element of northern hemisphere Carboniferous forests in the Permian forests of the southern hemisphere.

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