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A Record on Gangamopteris from the Lower Gondwana Sediments of Nagpur Maharashtra, India

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Abstract: *: A well-preserved megafossil leaf of Gangamopteris is described from the Lower Kamthi Formation, exposed at the New Bhanegaon Opencast Coal Mine (Lat. 21.267077ºN Long. 79.13871ºE), Kamptee Coalfield, Nagpur District, Maharashtra, India. The fossil-bearing sediments represent an important phase of the Late Permian–Early Triassic Gondwana succession. The most significant diagnostic feature of the specimen is the complete absence of a true midrib, which supports its assignment to Gangamopteris. The leaf possesses an elongate–lanceolate lamina with closely spaced, repeatedly anastomosing veins forming a distinct reticulate venation pattern. The veins form predominantly polygonal to elongated meshes. These morphological features are characteristic of Gangamopteris, a significant component of the Glossopteridales flora of the Indian Gondwana succession. Based on comparative morphological analysis, the specimen is proposed as a new species, Gangamopteris bhanegaonensis sp. nov. The specific epithet refers to the Bhanegaon locality from which the specimen was recovered. The occurrence of this taxon adds to the known diversity and geographical distribution of Gangamopteris in the Kamptee Coalfield and contributes to the palaeobotanical understanding of the Glossopteridales flora of the Lower Gondwana succession of central India.*

Keywords: Gangamopteris, Glossopteridales, Lower Kamthi Formation, Kamptee Coalfield, New Bhanegaon, Nagpur, Maharashtra, India.

I. INTRODUCTION

The Lower Gondwana formations of India are renowned for their diverse associations of fossil flora, predominantly dominated by the order Glossopteridales. The plant megafossils occurring as significant elements in these formations provide valuable information about the Early Permian paleoclimate, paleoecology and phytogeography of Gondwanaland. The genus *Gangamopteris* McCoy was originally reported by McCoy (1847) from New South Wales, Australia and classified under the name Cyclopteris, representing a foliage type of plants having netted venation without true midrib. Subsequently in 1860, he examined a large number of specimens from Bachhus-Marsh Sandstone, Victoria and named them *Gangmopteris augustifolia*. Presently, *Gangamopteris* has been widely reported from practically all the components of Gondwanaland viz., Australia, Antarctica, Argentina, Brazil, India, Madagascar and South Africa, McCoy (1847), Feistmantel (1876, 1879, 1890), Dolianiti (1954), Srivastava (1956), Maithy (1965, 1966, 1981), Maheshwari & Prakash (1965), Pant & Singh (1968), Kulkarni (1971), Chandra & Srivastava (1982), Bajpai (1990), Srivastava (1992), Singh (2000), Tewari & Srivastava (2000), Singh, Goswami and Chandra (2006 b). Leaves belonging to *Gangamopteris* are represented as one of the dominant components of Glossopteris flora during Early Permian of Gondwanan sequences (Srivastava & Agnihotri, 2010). Though widespread horizontally, *Gangamopteris* appears to have narrow vertical distribution thus proving to be of diagnostic significance. In the Indian subcontinent,

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this genus appeared first during the early Talchir period (Early Sakmarian), recorded near tillite deposits indicating adaptation to local ice-free micro-habitats (Surange & Lele, 1956). With the relaxation of the glacial regime during the late Talchir, *Gangamopteris* diversified to a great extent and up to eighteen species have been recorded from the Talchir Formation, ranging from small curled or folded leaves to fully expanded foliar laminas. Morphologically, *Gangamopteris* differs from its sister genus Glossopteris mainly in lack of a distinct central midrib, the venation of the former consisting of sub-parallel, anastomosing veins radiating out from a basal median group. Surange and Srivastava (1956) have pointed out that discrimination between *Gangamopteris* and *Glossopteris* on the basis only of presence or absence of a midrib can encounter difficulties especially when the crowded median veins simulate the appearance of a midrib, thus emphasizing the need for cuticular evidence. Singh (2002) has studied the taxonomy of *Gangamopteris* again considering the patterns of vein-mesh and epidermal characters for species identification.

A substantial body of chronological literature provides details about the biostratigraphic, palaeoecological and taxonomic progress about the genus. Singh *et al.* (2006) reported the first occurrence of *Gangamopteris* from the Ib-River Coalfield (Orissa) and showed that it was co-existence with the earliest *Glossopteris* species in Karharbari/Barakar strata, thereby extending its palaeogeographical range. Soon after, Bauer (2009) described the Permian glacio-fluvial sediments and *Glossopteris–Gangamopteris* plant megafossils from Heimefrontfjella, Antarctica, which demonstrated the existence of shared terrestrial ecosystems and continuous floristic connectivity between the Gondwana high latitudes. Tewari and Pillai (2011) studied India's Late Palaeozoic floras and highlighted the importance of *Gangamopteris* as a pioneer taxon, which was most abundant and diverse in the Talchir and Karharbari Formations, reaching a peak before being overtaken by the *Glossopteris* species. Singh *et al.* (2012) further studied the Barakar Formation macroflora in the Korba Coalfield (Chhattisgarh) and identified six species of *Gangamopteris*. They also remarked that the association of *Gangamopteris* along with *Rubidgea* and *Noeggerathiopsis* defined a Karharbari horizon (Early Permian/Artinskian age). Taxonomic and structural studies continued to flourish around the globe and the region in recent times. Tybusch *et al.* (2016), while redescribing the glossopterid flora from Lower Permian sequences in the Paraná Basin (Brazil) provided valuable insights into the critical taxonomic differences between closely related species like *G. obovata* and *G. cyclopteroides*. In westernmost Gondwana (Argentina), Fernández and Césari (2019) documented an outstanding record of *Gangamopteris* leafy branches showing helical phyllotaxis along the long axis of the branches, refining the growth models, thus confirming the arborescent habit in the Gzhelian–Asselian transition. More recently, Joshi and Priya (2021) cited *Gangamopteris rajaensis* from the carbonaceous shale-coal sequences of the Rajmahal Basin (Jharkhand) and confirmed the presence of diagnostic characters like the midrib-less reticulate venation. Saxena *et al.* (2021) described the morphotaxonomy and structural diversity of the *Gangamopteris* species from the Singrauli Coalfield, highlighting the distinctive character of midrib-less venation as markers and illustrating how the variations in the morphology reflect the localised post-glacial micro-climate. Extending this micro-floristic understanding of the region, Hatzade and Meshram (2025) have cited a distinct set of midrib-baring Glossopteris species from the Permotriassic beds of the adjacent Singhori Mines. Subsequently, Hatzade and Meshram (2026) expanded the floral record of the New Bhanegaon Gondwana region by describing three additional species of Glossopteris from the same geographical horizons.

The Kamptee Coalfield of the Pranhita-Godavari basin of Maharashtra exposes thick Permian deposits which often yield well-preserved plant impressions. This paper documents a foliar specimen recovered from the New Bhanegaon Open Cast Coal Mine in the Nagpur district, Maharashtra. The primary objective of this study is to analyze the structural venation patterns of the specimen, evaluate its taxonomic assignment within *Gangamopteris* based on key diagnostic features (specifically the absence of a true midrib) and contribute further observations to the Lower Gondwana paleobotanical record of the area.

II. MATERIAL AND METHODS

The fossil material described in the present study consists of a single, well-preserved megafossil leaf impression recovered during field investigations at the New Bhanegaon locality (Lat. 21.267077ºN Long. 79.13871ºE), Kamptee

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Coalfield, Nagpur District, Maharashtra, India in 2026. New Bhanegaon is located 16 km north of Nagpur city. The fossil horizons are exposed in natural drainage cuts and at rural excavations, where the lower clastic horizons of the Kamthi Formation are exposed. Stratigraphically, this sequence constitutes an important lithostratigraphic component of the Lower Gondwana.

Fig. 1–2. Geological exposure at Bhanegaon, Maharashtra, India, showing the investigated fossiliferous locality and field investigation with sample collection from the exposed strata

III. DESCRIPTION

The specimen comprises a nearly complete, well-preserved carbonaceous *Gangamopteris* leaf impression preserved on a fine-grained, dark-grey shale matrix (Plate 1, Fig. 1; Text Fig. 1). Leaf simple, sessile and megaphyllous. The leaf measures about 9.1 cm long and 5.0 cm broad, with a length-to-breadth ratio is 1.82:1. The lamina is broad and elongate, apparently oblong to lanceolate in shape, with the basal and apical ends poorly preserved. The laminal margin is apparently entire, unlobed and it tapers gradually into the broadly rounded base.

The apex is obtusely rounded. There is no prominent biological midrib along the longitudinal axis (Plate 1, Fig. 1; Text Fig. 1). Instead, this central area features a flat, un-mineralized median zone, confirming that the apparent line is a preservation artifact resulting from differential compaction or the selective decay of primary vascular tissue prior to fossilization. Branching directly from this median zone. Secondary veins emerge at acute angles (35°- 40°), the lateral venation is highly reticulate, forming a closed network composed of distinct narrow and polygonal meshes (Text Fig. 2). The areoles are predominantly polygonal to elongated and become comparatively finer towards the margins. The central region also shows several closely spaced, subparallel venational strands.

The combination of a broad lamina, absence of a distinct true midrib, radiating lateral venation, and dense anastomosing reticulate venation is highly consistent with the genus *Gangamopteris*.

Shape of lamina: Lamina broad, elongate, apparently oblong to lanceolate

Apex of lamina: Obtusely rounded

Margin: An entire and unlobed margin.

Midrib: A distinct primary vascular midrib is absent along the longitudinal axis of the lamina. The median region is represented by a relatively flat, undifferentiated zone from which the lateral veins arise and radiate toward the margins. No continuous, structurally distinct midrib is observed in the preserved specimen.

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Secondary Veins and Meshes: Secondary veins emerge at acute angles (35°- 40°), the lateral venation is highly reticulate, forming a closed network composed of distinct narrow and polygonal meshes.

IV. DISCUSSION AND COMPARISION:

The present specimen resembles several species of *Gangamopteris* described by McCoy and Feistmantel in that it has an elongate lamina, entire margin, lacks a distinct true midrib, and has a reticulate venation produced by dichotomizing and anastomosing veins. Of previously described taxa, *Gangamopteris angustifolia* McCoy (1875), originally described as *Cyclopteris* (?) *angustifolia* McCoy (1847), may be similar in possessing an elongate to lanceolate lamina, lacking a definite midrib, and having reticulate venation. However, *G. angustifolia* generally has a considerably narrower lamina with relatively narrow, linear and elongated meshes whereas the present specimen has a broader lamina measuring approximately 9.1 × 5.0 cm and possesses polygonal to elongated meshes with distinct spatial differentiation of areoles.

The present specimen also resembles *Gangamopteris cyclopteroides* Feistmantel (1876) in the absence of a distinct midrib and in the development of radiating, dichotomizing and anastomosing veins forming polygonal to elongated meshes. However, *G. cyclopteroides* is generally characterized by a median region occupied by several distinct, sub-parallel veins, from which the lateral veins arise and diverge towards the margins. In the present specimen a continuous and structurally distinct median vein system is not developed; instead, the median region forms an undifferentiated zone from which the lateral veins radiate. Further, present specimen differs in having a broad elongate lamina and distinctly differentiated areoles.

In comparison with *Gangamopteris major* Feistmantel (1879), the present specimen possesses an elongate lamina, lacking a true midrib and exhibiting anastomosing venation. While, *G. major* is generally characterized by a narrower, linear-lanceolate to elongate lamina with relatively uniform, narrow elongated meshes, the present specimen exhibits a broader lamina with marked spatial differentiation of the areoles, which become progressively narrower and more elongated towards the laminal margin.

Gangamopteris buriadica Feistmantel (1879) differs from the present specimen by the more or less spatulate to ovate-oblong lamina outline and the different basal configuration. Similarly, *G. clarkeana* Feistmantel (1879) differs from the present one by the in its characteristic laminal shape and venation pattern.

Gangamopteris hughesii Feistmantel (1876) is also different from the present specimen on the basis of differences in laminal shape and venation pattern.

The present specimen resembles in many respects the glossopterid flora reported from the Early Permian of India by Singh (2000). In the present specimen, however, there is a complete absence of true midrib, with lateral veins radiating from the median region, and forming dense, anastomosing polygonal to elongated meshes, affording it a close resemblance to *Gangamopteris* and distinguishing it from the midrib bearing *Glossopteris* leaves. It closely resembles the *Gangamopteris* described from the Lower Gondwana succession by earlier workers. The absence of a distinct midrib, radiating lateral veins, and reticulate anastomosing venation are diagnostic features of the genus (Singh (2000); Tewari & Srivastava, 2000; Singh *et al*., 2006; Srivastava & Agnihotri, 2010). Singh *et al.* (2006) have reported that various species of *Gangamopteris* differ from each other in lamina shape and vein angles in the Ib-River Coalfield. Similar variation has also been observed by Singh (2002), Tewari *et al.* (2012) and Saxena *et al.* (2021). However, the present specimen differs from all earlier reported species of the genus in having broadly oblong–lanceolate lamina, an obtusely rounded apex, lateral veins that depart nearly at 35–40° angles from the midrib, and progressively narrowing polygonal to elongate meshes towards the margin. A similar report on *Gangamopteris rajaensis* was reported by Joshi and Priya (2021). This species is characterized by the lack of a distinct midrib, acute lateral veins, and reticulate anastomosing venation. The present specimen agrees with this species in the absence of a distinct midrib and reticulate venation but differs in having a much larger and broader lamina (9.1 × 5.0 cm in size), obtusely rounded apex and broadly polygonal to elongate meshes compared to *G. rajaensis*.

Thus, although the present specimen shares the major *Gangamopteris* characters of the midrib-less lamina and the reticulate, anastomosing venation pattern with some of the previously known species, it can be differentiated from the

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other species by the following characters: broad elongate lamina (9.1 × 5.0 cm), laminal proportions (L/B ratio ca. 1.82:1), obtusely rounded apex, absence of a distinct median vein system, secondary veins departing at an angle of ca. 35–40°, polygonal to elongate meshes, and distinct spatial differentiation of areoles. In all the previously described species of *Gangamopteris*, the leaves are more or less ovate to obovate in shape, with acute to acuminate apex, and possess a prominent median vein system. Moreover, the secondary veins in the previously known species diverge at a more acute angle (45–60°), and the meshes are mostly rhomboidal, with less prominent spatial differentiation of areoles. The combination of the characters mentioned above differentiates the present specimen from the previously known species of *Gangamopteris*. Hence, it is proposed as *Gangamopteris bhanegaonensis* sp. nov. The species name is given after the place of its occurrence, viz., New Bhanegaon, Nagpur District, Maharashtra, India.

Diagnosis:

Gangamopteris bhanegaonensis sp. nov.

Leaf simple, sessile, megaphyllous, preserved dimensions approximately 9.1 cm in length and 5.0 cm in breadth, elongate oblong-lanceolate with an entire margin and obtusely rounded apex. True primary midrib absent; longitudinal axis represented by a flat median zone. Secondary veins emerge from the median zone at 35º- 40º forming a closed, anastomosing network. Meshes spatially differentiated, transitioning from open-polygonal near the center to narrow, elongated-polygonal at the margins.

Holotype: R.T.H./Gangmopteris-1/ Deposited at Department of Botany, RTMNU, Nagpur University, Nagpur.
Locality: New Bhanegaon, Opencast Coal Mine Dist. Nagpur India.
Horizon: Lower Gondwana of India.
Age: ? Permotriassic

V. ACKNOWLEDGEMENT

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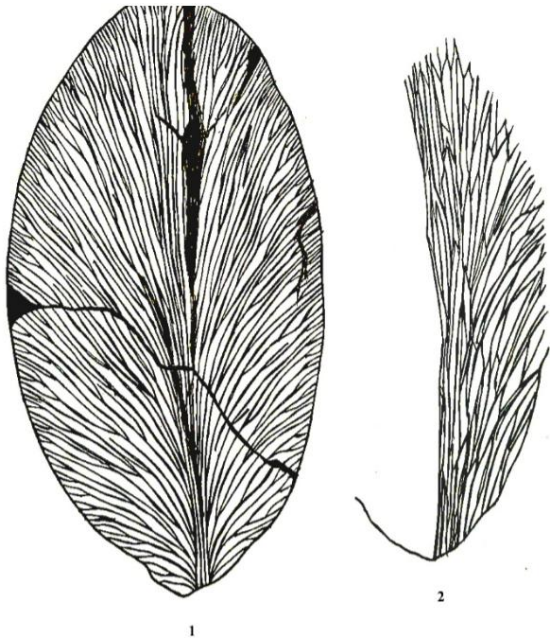

Explanation of Plate 1, Fig.1:
Gangamopteris bhanegaonensissp. nov. from the Lower Kamthi Formation of the New Bhanegaon Opencast Coal Mine, Nagpur District, Maharashtra, India. Well-preserved carbonaceous leaf impression showing the elongate lamina, absence of a true midrib and dichotomizing and

Explanation of Text Figs. 1 – 2:
Gangamopteris bhanegaonensissp. nov.
Fig. 1: Leaf illustrating the absence of a distinct midrib and the secondary veins arch outward, continuously bifurcating and anastomosing to form a characteristic polygonal mesh (areole) network across the lamina.
Fig. 2: Detailed view of the venation pattern

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