

Gondwana Fossil Flora from Lower Gondwana Kamptee Basin, Nagpur, Maharashtra, India

Kawale Janvi R.¹ and Meshram Sanjay M.²

¹Department of Botany, Rashtrasant Tukadoji Maharaj Nagpur University, Nagpur

²Department of Botany, Manoharabhai Patel College Art, Commerce and Science, Sakoli Dist. Bhandara

¹janvikawale20@gmail.com, ²sanjaymeshram83@rediffmail.com

Abstract: A well-preserved Gondwana leaf was collected from Bhanegaon Open Cast Coal Mine, Kamptee Basin (Lat.21.26729°N and Long.79.138812°E) in Nagpur Dist. Maharashtra, India. The present study reports a fossil leaf from a previously unexplored locality near the Kanhan River. The present fossil leaf is elongate relatively long and narrow, with a distinct median midrib and is preserved as an impression in fine clay shale. It is comparatively longer than the *Glossopteris* leaves reported earlier from the region. The good preservation of the specimen allows a clear comparison with previously reported *Glossopteris* leaves. The occurrence of this leaf indicates the presence of a diverse flora and suggests that the palaeovegetation of the region was diverse in nature. *Glossopteris* leaves are also found in abundance, mostly as impressions with or without carbon, in rocks associated with coal deposits across the continents of Gondwanaland. The present study focuses on the taxonomy, morphology and stratigraphic distribution of the fossil leaf, with emphasis on its morpho-taxonomic characteristics and occurrence within the Permian strata of the Indian subcontinent.

Keywords: *Glossopteris* flora, Kamptee Basin, Lower Gondwana, Bhanegaon, Nagpur.

I. INTRODUCTION

The lower Gondwana Group is of Late Carboniferous to Permian age (approximately 323-252 million years ago). It is characterized by the *Glossopteris* flora, which flourished during the interval when India, Africa, South America, Australia, Madagascar as well as Antarctica were united to form the southern supercontinent Gondwanaland. The Gondwana Supergroup is broadly divided into Lower, Middle, Upper Gondwana. The Lower Gondwana succession includes the Talchir Group and Damuda Group. The Damuda Group comprises the Karharbari, Barakar, Barren Measures and Raniganj formations. The coal-bearing strata of the Bhanegaon Open Cast Mine (Kamptee Coalfield) are correlated with the Early Permian.

There are lots of *Glossopteris* leaves reported from this various region and they show resemblance present reported specimen like, *Glossopteris taeniopteroides* (Feistmantel, 1878), *G. communis* (Feistmantel, 1879), *G. arberi* (Shrivastav, 1956), *G. euryneura* (Maheshwari, 1965), *G. gigas* & *G. spathulate* (Pant and Singh, 1971), *G. sastrii* (Pant & Singh, 1974), *G. indica*, *G. shailae* & *G. duocaudata* (Agashe, 1995), *G. vagyanii* (Bhowal & Meshram, 2010), *G. chhindaii* (Yadav, 2018), *Glossopteris shingorii* (Hatzade and Meshram, 2025), *Glossopteris bhanegaonii* (Hatzade and Meshram, 2026).

The present study is an additional contribution to the knowledge of Gondwana flora, particularly the genus *Glossopteris*. For many years species of *Glossopteris* primarily on the basis of external leaf morphology. It has been demonstrated that different specimens of *Glossopteris* can exhibit similar venation pattern and form but differ in their epidermal patterns. Therefore, investigators must consider cuticular structure along with external morphology to fully identify and characterize *Glossopteris* leaves Stewart and Rothwell (1993).

Earlier, the flora of Kamthi and Kanhan formations was studied by Bunbury (1861) and Feistmantel (1881). Bunbury (1861) described *Glossopteris browniana* var. *indica*, *G. browniana* var. *australasica*, *G. musaeifolia*, *G. leptoneura*,



G. stricta and *G. taeniopteridoides* (Feismantel, 1878). Feismantel (1881) described various plant fossils from Kamthi, including *Glossopteris communis*, *G. sticta*, *G. musaefolia*, *G. damudica*, *G. angestifolia*, *G. leptoneura* and *Gangmopteris hughesii*, from the Kamthi group of Wardha - Godavari valley. (Shrivastav, 1956) described the *G. arberi*, Maheshwari (1965) described the *G. euryneura* and *G. mohudaensis*, *G. bosei* was described by Surange and Chandra (1976). Pant (1987) suggested that the earliest members of *Glossopteris* flora and the Gondwana Ice Age appeared simultaneously. Prof. Pant remarks, "We can safely conclude that the pioneers of the *Glossopteris* flora had come into existence during the Gondwana Ice Age". This conclusion was supported by the occurrence of many vascular plants under similar condition in present-day India and other countries. Agashe (1995) described various plant fossils, *G. indica*, *G. shailae* and *G. duocaudata*.

Singh S.M. (2000) studied the taxonomy and diversity of the genus *Glossopteris* and Singh K.J. et al. (2006) also described the genus *Glossopteris*. Tewari R. (2008) studied the genus *Glossopteris* Brongniart from the Kamthi Formation of Camp IV area, Wardha Valley Coalfield. Bhowal et al. (2010) described a new species of *Glossopteris* from the Permo-Triassic beds of the Kamthi Stage, exposed near Kanhan and Satnavri in Nagpur District, India. The study was significant because it added to the taxonomic diversity of the Gondwana flora of Central India. Vagyan et al. (2011) worked on the *Glossopteris* leaves. McLoughlin (2012) studied *Glossopteris* providing insights into the architecture and relationships of this iconic Permian Gondwanan plant. Yadav et al. (2012) reported a new species, *Glossopteris acutensis*, from the Permo-Triassic beds of the Kamthi Stage at Satnavari, Nagpur District. The species was distinguished from other members of the genus by its acute apex which justified the new specific epithet.

Chatterjee et al. (2014) studied the new species of *Glossopteris* from the late Permian and Early Triassic of India. Gulbranson et al. (2014) studied the leaf habit of Late Permian *Glossopteris* trees from high-palaeolatitude forests. Chougule and Jadhav (2015) documented new additions to the *Glossopteris* flora from the Kamthi Formation of Maharashtra, India. Tewari et al. (2015) studied the *Glossopteris* flora of the Permian Weller Formation of Allan Hills, South Victoria Land, Antarctica with implications for palaeogeography, palaeoclimatology, and biostratigraphic correlation. Srivastava and Srivastava (2016) discussed *Glossopteridales* as an intricate group of plants. Naugolnykh and Uranbileg (2018) reported a new discovery of *Glossopteris* in southeastern Mongolia. Yadav (2018) reported a new species, *Glossopteris chhindaii*, from the Permo-Triassic beds of the Kamthi Stage, Perasia, Chhindwara District, India. Chopparapu et al. (2019) *Glossopteris* diversity of Flora from Barren Measures, Pranhita-Godavari Basin, India. Zhang Y. et al. (2022) Reported *Glossopteris* survived end-Permian mass extinction in North Hemisphere. Mario, G.F. Esperanca Junior et al. (2023) describe an efficient method for estimating vein density of *Glossopteris*. Sahoo et al. (2024) described the richest Late Permian floral diversities of *Glossopteris* flora. Schwendemann (2024) conducted a leaf economics analysis of high-latitude *Glossopteris* leaves using a technique to estimate leaf mass per area. Hatzade and Meshram (2025) reported a new species of *Glossopteris* from the Permo-Triassic beds of the Kamthi Stage, Shingori, Nagpur District, India. Hatzade and Meshram (2026) reported a three new species of *Glossopteris* from New Bhanegaon Gondwana Region Dist. Nagpur, Central India. The study highlights that the *Glossopteris* flora, dating about approximately 323-252 million years, from the Late Carboniferous to Permian age, thrived across Gondwanaland, which included India, Africa, South America, Australia, Madagascar as well as Antarctica.

Pillai et al. (2025) conducted palaeofloristic studies on the early Permian Barakar sediments of Singrauli Coalfield, Son Basin, India, using a multiproxy approach involving morphotaxonomy, palynology, and FTIR analysis. Patel and Goswami (2025) reported a well-diversified plant megafossil assemblage from the Lower Kamthi Formation, Talcher Basin, Odisha. The flora included representatives of Sphenophyllales (*Trizygia speciosa*), Filicales (*Neomariopteris hughesii*), Equisetales (*Schizoneura gondwanensis* and equisetaceous stems), Ginkgoales (*Rhipidopsis gondwanensis*), and particularly abundant *Glossopteridales*. Agnihotri et al. (2025) described *Satpuraphyllum furcatum* gen. et sp. nov. from the Middle Permian Barakar Formation of the Satpura Basin, India. The species is characterized by once to twice forked leaves with slender, entire-margined segments, amphistomatic nature, incompletely monocyclic to amphicyclic stomata, trichomes, papillae, and multicellular domal glands. Based on these features and associated reproductive structures, it was assigned to *Peltaspermiales*.



The rich diversity of the *Glossopteris* flora during the Lower Gondwana period has attracted considerable attention from researchers, and numerous specimens have been described based not only on their morphological characters but also on their cuticular features. In this context, the present fossil leaf from the Bhanegaon Open Cast Coal Mine, Kamptee Basin, Nagpur District, Maharashtra, India, adds an additional record to the *Glossopteris* flora of the region.

II. MATERIAL AND METHODS

The fossil specimen described in this study was collected during fieldwork conducted in 2026 from the Bhanegaon Open Cast Mine, Kamptee Basin, dist. Nagpur, Maharashtra, India (Lat. 21.26729°N and Long.79.138812°E), located approximately 12 km aurally and about 25 km by road from Kamptee. The specimen is preserved as a compression-impression of a leaf in fine clay shale. The specimen was photographed and systematically analysed for morphotaxonomic study. Various morphological features were carefully examined, including leaf shape, size, apex, base, margin, midrib, and venation pattern. An outline drawing was prepared to illustrate the diagnostic characters of the specimen.



Fig. 1-2. Field views of the Bhanegaon open cast mine, Kamptee Basin, Nagpur District, Maharashtra, showing extensive exposures of the sedimentary succession and mine benches.

III. DESCRIPTIONS

The preserved leaf is lanceolate, with an acute apex and entire margin (Plate 1, Figs: 1-9; Text Figs: 1-3). It measures about 21 cm in length and 5.3 cm in breadth. The midrib is very clear broad, gradually becoming narrower towards the apex. (Plate 1, Figs:1-3,6,7 and 9; Text Figs: 1-2) The secondary veins arise at angle of 30° to 35° and nearly parallel to each other, forming narrow, polygonal meshes of almost equal size. (Text Figs: 2-5)

Shape of lamina: Elongate to obtuse.

Apex of lamina: Acute.

Margin: Entire.

Midrib: Distinct and prominent, extending clearly for approximately 19 cm, after which it gradually becomes diffuse and merges with the fine secondary veins towards the apex.



IV. SECONDARY VEINS AND MESHES

The secondary veins arise from the midrib at an acute angle. In present specimen, the veins run straight for a short distance after emerging from the midrib, then curve and continue towards the margin. The secondary veins are nearly parallel to each other and show little branching. The shape of the meshes formed by anastomosing veins is also variable. The meshes narrow and polygonal (Plate 1, Figs: 1-9; Text Figs: 2-5).

V. COMPARISON AND DISCUSSION:

In *G. taeniopteroides* (Feistmantel, 1878) and *G. euryneura*, (Maheshwari, 1965), the secondary veins that arise from the midrib may be perpendicular and may form an acute angle, but in the present specimen condition leaf forming veins run straight, the length is 21 cm to 5.3 cm, the midrib is very clear, broad and narrow towards the apex. Secondary veins are bifurcate and arise at angle 30° to 35° and form narrow and polygonal meshes.

The specimen is different from *G. bosei* (Chandra and Surange, 1979), which is 4.5 cm long and 1 cm broad, oblanceolate in shape and the midrib is 1.5 cm width, but in the present specimen the leaf is lanceolate, acute apex, entire margin, 1-21 cm in length and 5.3 cm breadth thus it shows striking difference in shape, size and midrib with the specimen *G. bosei*. Thus, they cannot be compared with *G. bosei*.

Glossopteris nimishea Glossopteris sp. of. *G. nimishea* (Chandra & Surange, 1979), the leaf is elliptic in shape, measuring 7.3 cm in length and 2.4 cm in breadth. Apex is missing and base is broken. Margins are entire. Midrib is 2.5 mm broad, persistent and gradually attenuating towards apex. The secondary veins arise at an angle of 45°. They dichotomise and anastomose to form broad elongated meshes near the midrib and narrow elongated meshes near the margins, but present leaf is lanceolate with acute apex, entire margin, the secondary veins that arise from the midrib forms an acute angle of 30° to 35° and it measures about 21 x 5.3 cm in length and breadth.

Glossopteris vagyanii (Bhowal and Meshram, 2010). Leaf measured about 8 cm x 3.5 cm in length and breadth. Its short lanceolate, acute apex, entire margin, Midrib broad and narrow, leaf petiolate. The secondary veins arise at angle of 40° to 45° and forms elongated rhomboidal broad meshes of almost equal size. The present leaf closely resembles *G. vagyanii* in the general shape of lamina, acute apex, entire margin and anastomosing venation pattern forming polygonal meshes. However, the present specimen differs in having larger lamina, measuring approximately 21 cm length and 5.3 cm breadth and the angle divergence of the secondary veins, which arise at 30° to 35°. The present specimen also possesses a prominent midrib that is broad at the base and gradually narrow towards the apex, with polygonal anastomosing meshes.

Glossopteris vagyanii sp. nov., leaf measured about 11.5 cm x 2 cm in length and breadth. Its shaped lanceolate, spatulate apex, petiolate, entire margin, Midrib is fine and narrow, measured about 11.2 cm long. The secondary veins arise at acute angle of 35° to 45° and Secondary veins arise at forms shortly rhomboidal meshes of almost equals size, but present specimen is acute apex, petiolate, the midrib is very clear, broad and narrow towards the apex and it measures about 21 cm length and 5.3 cm breadth. Secondary veins are bifurcate and arise at acute angle of 30° to 35° and form narrow and polygonal meshes.

Glossopteris acutensis (Yadav et al., 2012), leaf lanceolate, longer than broad, L/B ratio 5:1, apex acute, base normal acute, midvein narrow tapering toward apex, venation is reticulate, lateral vein arises at an angle for 30° to 40° and anastomises to form long narrow meshes, but present leaf meshes narrow and polygonal. The secondary veins arise at angle of 30° to 35° and forms narrow and polygonal broad meshes of almost equal size. (Gulbranson et al., 2014), all specimens lack preserved primary vascular structure; therefore, they are classified only wood morphogenera. They show distinct growth rings. When compared with woods previously reported from Antarctica, the new specimens can be distinguished from *Megaporoxylon*, but present leaf is different on the basis of leaf morphology.

(Chougule and Jadhav, 2015), *Glossopteris longicaulis*, (Feistmantel, 1879), the specimen is ovate- lanceolate in shape, measuring 7 cm in length and 1.8 cm in breadth with long petiole. Apex is missing. Base is obtuse. Margins are entire. Petiole is 2 cm long, slightly swollen at the base. Midrib is distinct, longitudinally striated and 2 mm broad near the basal part. The secondary veins arise from the midrib at an acute angle of 50°. They dichotomise and anastomose to



form oblong polygonal meshes, but in present specimen the apex is acute, lanceolate, 21 cm in length and 5.3 cm in breadth, midrib is broad and narrow towards the apex, polygonal meshes. The secondary veins arise at acute angle of 30° to 35°.

Glossopteris chhindaii (Yadav, 2018), leaf spatulate, broad at the apex and narrow at the base, obtuse apex, midrib prominent and thick at base, L/B ration 2:1, secondary veins arises at an angle of 40° to 45° taking graceful curve runs towards the margin, secondary veins anastomises to form long narrow polygonal meshes of sizes 1 to 1.5 to 8.5 mm, but present leaf is lanceolate with acute apex, the secondary veins arise at acute angle of 30° to 35° and leaf measures about 21 x 5.3 cm in length and breadth.

(Zhang et al., 2022), fertile ultimate branch slender, attached by scale leaves and young branches with a whorl like arrangement; both ultimate and young branches showing the Vertebraria structure in both cross and longitudinal sections; Scale leaf simple, linear, petiolate, with an entire margin, cuneate base, and probably an obtuse apex; Midrib strong, persisting to the apex; Lateral veins bifurcating and anastomosing to form narrow, elongate reticulate meshes; Several cupules each with a strong and short pedicel attached to the abaxial midrib; Each cupule with six linear lobes; Seed broadly ovate, platyspermic, with wide furrows in the nucule. But present leaf is elongate to obtuse leaf lamina, entire margin, reticulate venation, petiolate, secondary veins are bifurcate and arise at angle 30° to 35° and form narrow and polygonal meshes.

(Mario, G.F. Esperança Júnior et al., 2023), describe an efficient method for estimating vein density of *Glossopteris* and McLoughlin (2012) studied *Glossopteris* insights into the architecture and relationships of an iconic Permian Gondwanan plant. Both the leaf morphology is totally distinct characteristics of external measurement of leaf.

(Sahoo et al., 2024), the rich diversity of the *Glossopteris* in the fine sediments, along with several petiolate leaves, infers a low-energy environment during the deposition. In the Talcher Basin during the Late Permian, a temperate forest thrived due to warm weather, high humidity, intense light, strong winds, and a temperate climate. One the basis of above characters of vegetation and present leaf morphology, it indicates, flora is very rich and dense, but the present leaf morphology is totally distinct characteristics of external measurement of leaf.

Satpuraphyllum furcatum (Agnihotri et al., 2025), variably apetiolate to long-petiolate *Satpuraphyllum* leaves with acute secondary veins that are straight or reflexed slightly near the margin. Pavement epidermal cells weakly differentiated between venial and interveinal areas, varying from polygonal and equidimensional to narrowly rectangular with transverse or oblique end walls. A normocytic stoma orientated and distributed irregularly or in loosely arranged pairs in which stomatal apparatuses share subsidiary or encircling cells. Subsidiary cells isodiametric polygonal, rhombic or trapezoid. Stomata with small guard cells sunken within a pit. Multicellular glands 200 mm in diameter arranged along lamina margin, incorporating 20–30 small square to polygonal cells raised into a low dome with an apical aperture, but the present leaf is lanceolate with an acute apex, entire margin, and reticulate venation. The secondary veins arise at an angle of 30° to 35° and form narrow, polygonal meshes. Therefore, the present leaf differs in its overall architecture, venation pattern, and systematic placement.

Glossopteris shingorii (Hatzade and Meshram, 2025), leaf measured about 8 cm x 3.5 cm in length and breadth. Its short lanceolate, acute apex, entire margin, Midrib broad and narrow, leaf petiolate. The secondary veins arise at angle of 42° to 47° and forms elongated rhomboidal broad meshes of almost equal size, but in present specimen leaf is different in size, the secondary veins arise at angle of 30° to 35° and forms narrow, polygonal meshes of almost equal size and it measures about 21 cm x 5.3 cm in length and breadth.

(Patel and Goswami, 2025), the *Glossopteridales* are particularly abundant, comprising *Glossopteris* (45 species), *Palaeovittaria kurzzi*, scale leaves, fructifications and stem casts. While a previous publication has addressed the other plant groups, this study focuses on the scale leaves and fertile parts. A total of 268 fossil impressions of *Glossopteris* fertile parts has been documented from the Lower Kamthi sediments. The assemblage includes 10 genera and 14 species, including *Denkania indica*, *Dictyopteridium feistmanteli*, *Eretmonia emarginata*, *E. hinjridaensis*, *E. ovata*, *E. utkalensis*, *Glossoschea immanis*, *G. orissiana*, *Jambadostrobos pretiosus*, *Partha spathulata*, *Plumsteadistrobos*



pretiosus, *Scirromaventi lebra*, *Scutum sahnii* and *Venustostrobus indicus*, but the present specimen is different in their overall architecture, their venation pattern and its systematic placements.

(Pillai et al., 2025), the genus *Glossopteris* is represented by thirteen species namely *G. arberii*, *G. communis*, *G. emarginata*, *G. gigas*, *G. indica*, *G. major*, *G. mohudaensis*, *G. nautiyalii*, *G. recurva*, *G. spatulata*, *G. stenoneura*, *G. tenuifolia* and *Glossopteris* sp. Most of these species have narrow to intermediate meshes which indicate prevalence of warm and humid climatic conditions with sufficient sunlight, but present leaf is different on the basis of leaf morphology with polygonal meshes.

Glossopteris bhanegaonii (Hatzade and Meshram, 2025), The leaf measured about 9 cm x 3 cm in length and breadth. Its shaped oval-lanceolate, spatulate apex, entire margin, petiolate and reticulate venation. The midrib is clear up to a length of 9 cm and later becomes diffused into fine secondary veins near the apex. The secondary veins arise at acute angle of 34° to 44°, after forming an acute angle with the midrib, the veins may run straight or take an arcuate and the meshes are mostly elongated, narrow and rectangular to polygonal, but the present specimen is elongate to obtuse shaped with acute apex as well as an angle 30° to 35° and leaf measured about 21 cm x 5.3 cm in length and breadth.

A comparison of the present specimen with previously reported specimens indicates a close resemblance to *Glossopteris* species such as *G. vageyanii* (Bhowal and Meshram, 2010). However, the present specimens differ from these taxa in certain morphological features, particularly in size and measurements. On the basis of these distinguishing characters, the specimens are described as a new species, *Glossopteris newbhanegaonii* sp.nov. The specific name is derived from the fossil locality, Bhanegaon.

VI. DIAGNOSIS

Glossopteris newbhanegaonii sp.nov.

The leaf is lanceolate, measuring approximately 21 cm in length and 5.3 cm in breadth. The lamina is elongate, with an acute apex and entire margin. The midrib is distinct and prominent, extending clearly for approximately 19 cm, after which it gradually becomes diffuse and merges with the fine secondary veins towards the apex. Secondary veins arise from the midrib at an acute angle 30° to 35°, are nearly parallel to each other and form narrow, polygonal meshes of almost equal in size.

Holotype: J.R.K./IG.L./ Deposited at Botany Department, RTMNU, Nagpur University, Nagpur.

Locality: Bhanegaon Coal Mine Dist. Nagpur India.

Horizon: Lower Gondwana of India.

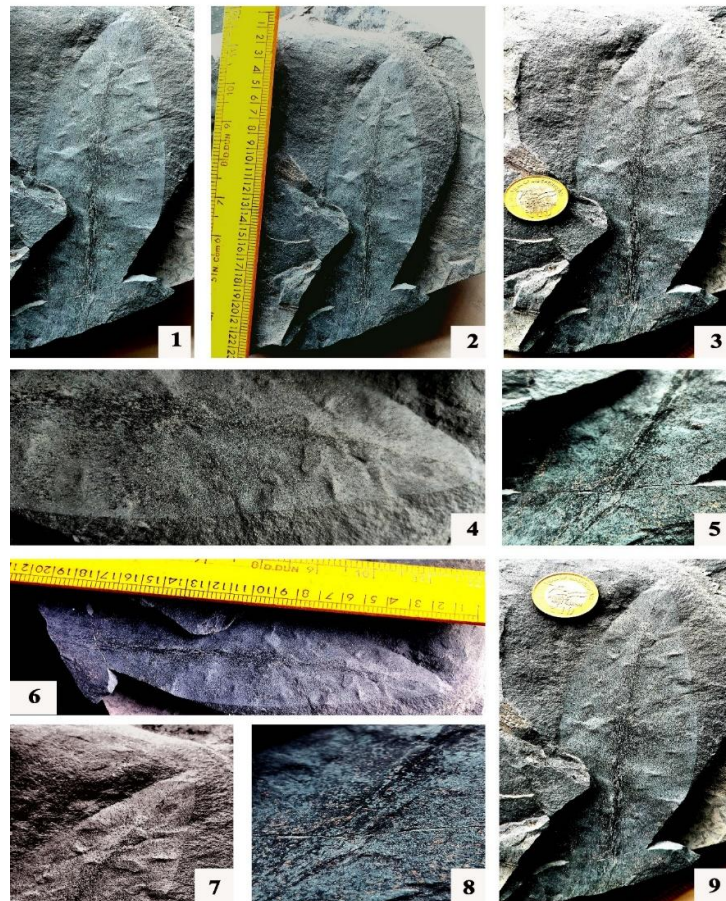
Age: ? PermoTriassic

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Plate 1, Figs. 1-9



Explanation of Plate 1, Figs. 1-9:

Glossopteris newbhanegaonii sp. nov.

Figs. 1-3: Complete leaf lamina in different views, showing the overall morphology and characteristic form of the leaf.

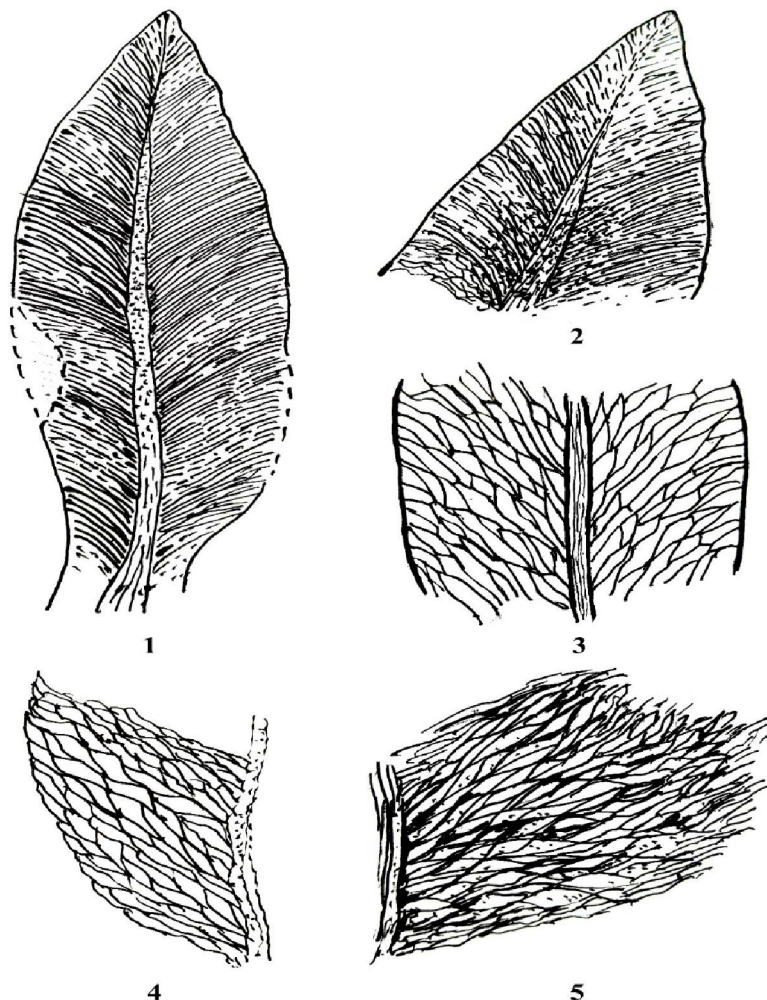
Figs. 4-6: Leaf impressions showing the prominent midrib and distinct venation pattern.

Figs. 7, 9: Apical region of the leaf showing the characteristic shape of the apex.

Fig. 8: Enlarged view of the prominent midrib.



Text Figs. 1-5



Explanation of Text figs. 1-5:

Glossopteris newbhanegaoii sp. nov.

Fig. 1: Complete leaf showing the characteristic morphology of *Glossopteris*.

Fig. 2: Leaf apex showing the smooth, entire margin.

Fig. 3: Enlarged view of the prominent structure midrib.

Fig. 4-5: Leaf venation showing the characteristic anastomosing pattern and polygonal meshes.

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