STUDIES IN THE GLOSSOPTERIS FLORA OF INDIA — 26. GLOSSOPTERIDALES FROM THE KARHARBARI BEDS, GIRIDIH COALFIELD, INDIA

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ABSTRACT

Glossopteridalean remains, viz., *Gangamopteris*, *Glossopteris* and *Vertebraria* are described from the Karharbari beds, Giridih Coalfield. Five species of *Gangamopteris* and one species of *Vertebraria* are new.

INTRODUCTION

GLOSSOPTERIDALES from the Lower Gondwanas of India were earlier described by Brongniart (1828) from Ranigunj, near Rajmahal. Royle (1833) described from the Raniganj stage of the Raniganj coalfield. Later McClelland (1850), Bunbury (1861), Feistmantel (1879, 1882, 1886) and Zeiller (1902) described a large number of Glossopteridalean remains from the Lower Gondwanas of India. In recent years Srivastava (1956), Pant (1958), Surange & Lele (1956), Surange & Maheshwari (1962), Saksena (1963), Maithy (1965a) and Maheshwari (1965a & b) added a few more records to our knowledge. These records have been assigned to the following genera:

Glossopteris
Gangamopteris
Palaeovittaria
Rhabdotaenia
Rubidgea
Vertebraria

Of the Indian Glossopteridalean remains, Sahni (1923), for the first time described the cuticular structure of *Glossopteris angustifolia*. Srivastava (1956) described the cuticular structure of 14 species of *Glossopteris*, 6 species of *Gangamopteris* and 1 species of *Palaeovittaria*. On the basis of this study, Surange & Srivastava (1956) proposed a classification for the Glossopteridean leaves. In recent years cuticular structure of Glossopteridalean remains have been described by Pant (1958) and Surange & Maheshwari (1962).

The anatomy of the Indian *Vertebraria*, the only known axis belonging to Glossopteridales has been described by Sen (1958), Surange & Maheshwari (1962) and Pant (1960).

The Glossopteridalean fructifications have been described by Zeiller (1902), Sen (1955), Srivastava (1952), Surange (1957), Varma (1963) and Maheshwari (1965b).

MATERIAL AND METHOD

The material described below comes from the Karharbari stage, Giridih coalfield (for localities *see* MAITHY, 1965 b). The material consists of impressions and compressions of leaves and stems. Some of the leaves have a carbonized crust which during the course of acid treatment for obtaining cuticle crumples into small pieces. However, in some favourable cases a study of the crust under incident light helped to obtain some information about the epidermal characters.

DESCRIPTION

Gangamopteris McCoy

The genus *Gangamopteris* was instituted by McCoy in 1861 for the fronds earlier described in 1847 from Australia under *Cyclopteris angustifolia*. Feistmantel (1879, 1882) described a number of species of *Gangamopteris* from the Lower Gondwana Coalfields of India. In recent years the cuticular structure (SRIVASTAVA, 1956; HØEG & BOSE, 1960) and the fructifications (PLUMSTEAD; 1956, 1958 a) have been described. In view of the above addition to our knowledge, the genus *Gangamopteris*, is redefined as below:

"Fronds simple, entire, symmetrical or asymmetrical; linear, lanceolate, elliptical, spathulate or ovate in shape; apex broadly rounded, obtuse, acute, acuminate or mucronate, base petiolate, contracted or cordate. Midrib absent; median region occupied by subparallel veins with anastomoses of elongate or hexagonal outline. Secondary veins arising from median veins by repeated

dichotomy, arched, bifurcating and anastomosing to form network."

"Cuticle differentiated into two surfaces, stomata present on one or both the surfaces, stomatal apparatus haplocheilic, monocyclic or dicyclic, distribution and orientation of stomata irregular to regular, papillae present or absent."

"Fructification consisting of two halves, ? bisexual, ? cupular, attached to ? median region by long pedicel."

So far about twenty two species of *Gangamopteris* are known from the Lower Gondwana formations, of which about twelve are known from India. The identification of species is based chiefly upon external characters. However, in recent years the cuticular structure has been described for six species of *Gangamopteris* by Srivastava (1956) and one species by Høeg and Bose (1960). It is obvious that the cuticular structure of leaves is better suited for delimiting the species than their external features alone. In recent years the evidences of the cuticular studies of Glossopteridalean remains have exhibited that leaves with a similar external morphology, may have different type of epidermal structures, for example *Glossopteris indica* Schimper has three type of cuticles, viz., *G. indica* Zeiller (1896), *G. arberii* Srivastava (1956) and *G. jamotii* Høeg & Bose (1960). Similarly, the studies have also pointed that leaves with different morphological characters, may possess cuticles with similar epidermal structures. Thus, these homogenous type of leaf with heterogeneous character raises the problem for the identification of species, especially, when *Gangamopteris* leaves are found commonly preserved in the form of impressions only. These impressions occur in such a large number that one cannot neglect their study. Thus, the problem is what should be done ? For the present, the most suitable course will be to describe the leaves without cuticle and those with a cuticle under two distinct specific names. In the former the circumscription would be entirely based on the external characters as has been done so far. In the latter the cuticular structure would form the main basis for specific delimitation. Although, this method of approach might result a nomenclatural duplication, but it will nevertheless resolve much confusion existing between the cuticular and the non-cuticular forms.

Most of the leaves collected from the Giridih coalfield are preserved as impressions and a few as compressions. Repeated attempts were made to recover a cuticle from those compressions but they did not yield any. However, in a few cases the study of the epidermal characters was possible by studying the imprints of cells and stomata under strong incident light. Such informations, when found sufficient, has been utilized in the institution of new species. In most cases, however, the specific determination have been based upon external characters. A critical examination of a large number of impressions was carried out to assess the relative merits of the various characters in each case. The study has shown that certain characters, such as the shape of the leaf, its apex and base and the venation can be used with advantage for specific delimitation. This became particularly evident in the case of *G. clarkeana*, *G. major*, *G. spathulata* and *G. obliqua*, all of which were formerly merged under *G. cyclopteroides* by Arber (1905).

Gangamopteris cyclopteroides Feistmantel

Pl. 1, Figs. 1-3

Description — About 70 specimens referable to this species are in my collection. Most of the leaves are incomplete with the middle part preserved. Leaves show a great size range, estimated maximum width is about 18 cm. The most complete leaf in the collection (Pl. 1, Fig. 1) measures 13·2 cm. × 3·5 cm. and is lanceolate in shape. Commonly the specimens have obtuse apex and narrow tapering base. The median region is occupied by a group of subparallel veins (Pl. 1, Fig. 2), which are usually prominent at the base. From these emerge arched secondary veins, forming long and broad meshes towards the median region and narrow meshes towards the margin. The size of the meshes varies according to the size of the leaves.

There are a few small leaves (Pl. 1, Fig. 3) in the collection which are more linear in shape but their venation agree with the bigger specimens of *G. cyclopteroides*. These may be the juvenile leaves of *G. cyclopteroides*.

Comparison and Discussion — A survey of literature shows that *G. cyclopteroides* Feistmantel (1879) is rather a broadly based species, and some of the forms which have

been placed in it appear to be beyond reasonable limits of variation permissible to this species. The typical leaf of *G. cyclopteroides* according to Feistmantel is characterized by lanceolate shape, symmetrical or slightly asymmetrical; tapering base, margin entire; midrib absent, median region occupied by subparallel veins, from these median veins arise the secondary veins, form broader and longer meshes towards centre and smaller and narrower towards the margin. In the present study due care has been taken and only those specimens which are typical or fairly near the typical forms of *G. cyclopteroides* Feistmantel has been assigned to it.

The present specimens from the Giridih coalfield agree in their form and venation with *G. cyclopteroides* Feistmantel (1879, PL. 10, FIG. 1; PL. 12, FIG. 12).

In past, some authors (WHITE, 1908; ARCHANGELSKY 1958; DOLIANITI, 1954) have considered *Gangamopteris obovata* (Carr.) White and *G. cyclopteroides* as synonymous. Therefore, on the basis of priority the former name was used. But from the recent morphological studies of leaves, it seems desirable to keep both of them separately. Because from the examination of the diagram of the type specimen of *G. obovata* Carruthers it appears that the leaf is oval-spathulate in shape with rounded apex; besides the venation is ill preserved and is more arching. It may be added that the fructification described as *Ottokaria transvaalensis* by Plumstead (1956) is said to be borne on a leaf of *G. cyclopteroides* type.

Gangamopteris gondwanensis sp. nov.

Pl. 1, Figs. 4-6, Text-figs. 1, 2

Diagnosis — Leaves lanceolate, apex obtuse, base tapering, margin entire, median region is occupied by few subparallel veins; from these emerge arched secondary veins forming long and broad meshes towards the median region and narrow meshes towards the margin. Epidermis can be distinguished on the two surfaces of the leaf, one is stomatiferous and the other is non-stomatiferous. Cells over the veins are elongate rectangular and arranged end to end. Cells of the mesh area are squarish or polygonal. Stomata present only on one surface, irregularly orientated and distributed, haplocheilic and monocyclic. Subsidiary cells are 5-6 in number and are like the ordinary epidermal cells.

Holotype — 31341/424, Birbal Sahni Institute of Palaeobotany, Lucknow.

Locality — Central pit, Srirampur Colliery, Giridih coalfield.

Horizon — Karharbari stage.

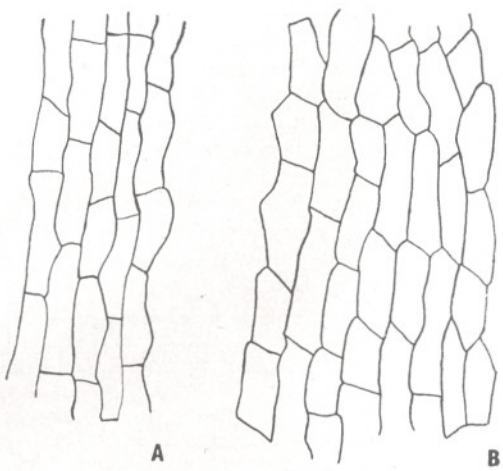
Age — Lower Permian.

Description — Almost all the specimens in the collection are incomplete. The one figured in Pl. 1, Fig. 4 is the middle part of the leaf, measuring 7·2 cm. in length and 4 cm. broad. The median region is occupied by few subparallel veins. From these arched secondary veins arise and they form elongate rectangular meshes of bigger size towards the median region.

Epidermal Structure — These specimens from the Giridih coalfield bearing the crust do not yield any cuticle under chemical treatment. But under certain favourable cases a crust bearing the imprints of epidermal cells was preserved on the specimen and its counterpart, which enabled the study of both the epidermal surfaces under incident light. The epidermis is distinguishable into two, non-stomatiferous and stomatiferous representing two sides of the leaf. The non-stomatiferous surface shows distinct arrangement of cells over the veins and over the meshes. The cells over the veins are narrow, 2-3 cells wide, long, rectangular, arranged end to end and measure 160×28 μ. The areas of the meshes are wider, with some epidermal cells which are usually rectangular, trapezoid (occasionally polygonal), placed end to end and 128×40 μ in size (PL. 1, FIG. 5; TEXT-FIG. 1A, B).

On the stomatiferous surface, the epidermal cells over the meshes are different in shape and size from those on the veins. The cells over the veins are 2-3 cells wide, elongate, rectangular, arragned end to end, 120×28 μ and devoid of stomata (PL. 1, FIG. 6).

The mesh areas show the presence of stomata-like structures scattered in between comparatively smaller and less regular epidermal cells, measuring 100×24 μ. The stomata are haplocheilic, irregular in distribution and orientation. Stomatal apparatus shows monocyclic condition (PL. 1, FIG. 6; TEXT-FIG. 2A, B). Each stoma measures nearly 64 μ in length. Guard cells and stomatal opening are not very distinct. Subsidiary cells are 6 in number and resemble ordinary epidermal cells.



TEXT-FIG. 1A, B — *Gangamopteris gondwanensis* sp. nov., Cells of the non-stomatiferous surface from the mesh area. × 200.

Comparison and discussion — The specimens of *G. cyclopteroides* from the Karharbari beds exhibiting epidermal characters are described under a new specific name, because the cuticle of the type specimen has not so far been described. The cuticles of *G.* cf. *cyclopteroides* described by Srivastava from the Raniganj stage of India and *G. cyclopteroides* by Høeg & Bose (1960) from the Permocarboniferous of Belgian Congo are comparable to the present specimens.

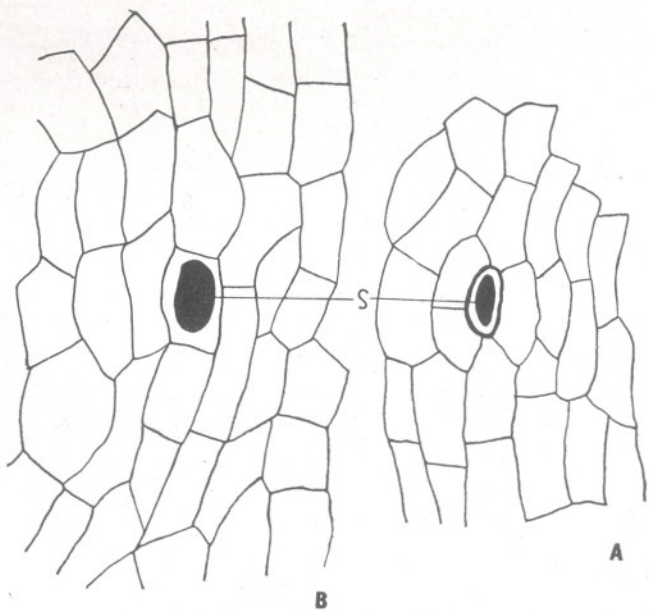
Gangamopteris major Feistmantel

Pl. 1, Fig. 7

1905 — *Gangamopteris cyclopteroides* var. *major* Arber

Description — The collection includes a few specimens of this species. The one figured (PL. 1, FIG. 7) is 8×3·2 cm., symmetrical, rhomboidal, with narrow tapering base and bluntly pointed apex. The base is very narrow in comparison to the middle part of the leaf. The median portion of the leaf is occupied by a few subparallel veins giving rise to arched secondary veins. The meshes are narrow, elongate and somewhat broader near the median portion of the frond.

Comparison and Discussion — Feistmantel (1879 : 15) created the species *G. major* which was subsequently merged by Arber (1905) with *G. cyclopteroides* as one of its variety.



TEXT-FIG. 2A, B — *Gangamopteris gondwanensis* sp. nov. Stomata(s) and Cells of the stomatiferous surface. × 200.

An examination of the present forms not only suggests a close comparison with *G. major* of Feistmantel but also reveals clear differences from *G. cyclopteroides*. These differences, which are stated below incline me to retain *G. major* as a separate species:

G. cyclopteroides Feistm.	*G. major* Feistm.
1. Linear-lanceolate shape	1. Rhomboidal shape
2. Gradually tapering base	2. Narrow tapering base
3. Maximum width at 1/2 length of the leaf	3. Maximum width above 1/2 length of the leaf
4. Median veins clear	4. Median veins ill-defined (obscure, diffused)

The present specimens closely agrees in its shape and venation with those of Feistmantel (1879, PL. 14, FIG. 3; PL. 16, FIGS. 1, 2). Feistmantel's specimen of *G. cyclopteroides* (1879, PL. 16, FIG. 5) as one can judge from the figure is indistinguishable from *G. major*.

Gangamopteris ? *major*

Pl. 2, Fig. 8

Description — The collection includes a few forms, most of them are incomplete and the apex is mostly not preserved. Leaves spathulate shape, tapering base and broad obtuse apex; median region occupied by subparallel veins which give rise to arched secondary veins. Secondary veins form elongate meshes, somewhat broader towards the median region.

Comparison and Discussion — The present specimens agree closely with Feistmantel's specimen (1879) figured in Pl. 26, Fig. 2. Feistmantel attributed it to *G. major* due to its close agreement in venation. However, it differs from typical *G. major* in its distinct spathulate shape and broad obtuse apex, and presumably seems to be a distinct species. The Karharbari specimens are, however, too few in number to establish a distinct species. The best course is, therefore, to place the specimens doubtfully under *G. major*.

Gangamopteris angustifolia McCoy

Pl. 2, Figs. 9, 10

1847 — *Cyclopteris* (?) *angustifolia* McCoy

Description — Only few leaves are in the collection. Carbonized impressions of small incomplete leaves, ranging in size from 4 to 7 cm. in length and 1·2 to 1·5 cm. in breadth. Leaves linear-lanceolate, margins subparallel, asymmetrical with tapering base and acute apex. The median region is occupied by a few subparallel veins which give rise to secondary veins at acute angle. The meshes are elongate hexagonal, formed by cross connections and uniform in size throughout the lamina.

Comparison and Discussion — The present specimens agree in their shape and venation with the description and drawings of the McCoy (1875, PL. 12, FIG. 1) and Feistmantel (1879, PL. 9, FIG. 5). The specimen described by Surange & Lele (1956, PL. 1, FIG. 6) from the Talchirs of South Rewah Gondwana Basin probably represents a more lanceolate form and the veins are noticiably sparser than in the present case.

Gangamopteris karharbariensis sp. nov.

Pl. 2, Figs. 11-16; Text-figs. 3, 4

Diagnosis — Leaves lanceolate, apex bluntly pointed, narrowing towards the base, median region is occupied by few weak sub-parallel veins, which give rise to arched secondary veins at acute angles; they form narrow elongate meshes of nearly uniform size. Epidermis can be distinguished on two surfaces of the leaf, one is stomatiferous and the other is non-stomatiferous. Cells over the veins are elongate-rectangular and arranged end to end. Cells in the mesh area are squarish or polygonal. Stomata present on only one surface, irregularly orientated and distributed, haplocheilic and dicyclic. Subsidiary cells are 5-6 in number and are like the ordinary epidermal cells.

Holotype — 31381/424, Birbal Sahni Institute of Palaeobotany, Lucknow.

Locality — Central pit, Srirampur colliery, Giridih coalfield.

Horizon — Karharbari stage.

Age — Lower Permian.

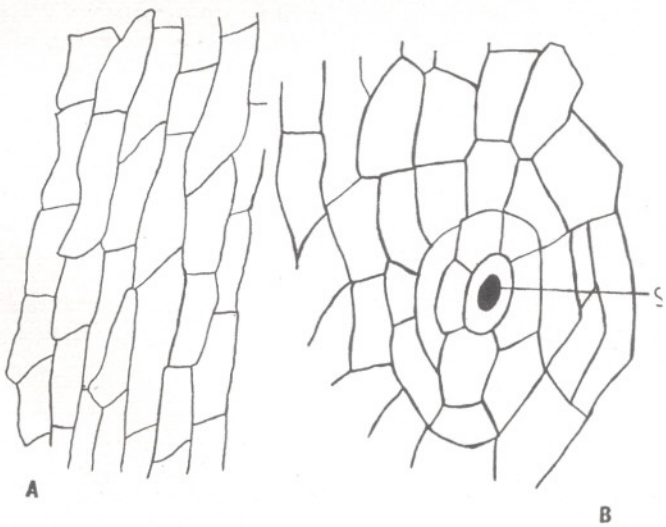
Description — Only ten specimens are in the collection and all of them are incomplete. All the specimens have similar epidermal structure. The specimen in Pl. 2, Fig. 11 is 7·8 cm. long and 2·8 cm. broad at the widest part. The apical part is incomplete, however, from the converging nature of two margins one can imagine that the apex is bluntly pointed. The specimen in Pl. 2, Fig. 13 is of the median portion of leaf measuring 8·8 cm. long and 2·4 cm. broad. Few distinct median subparallel veins occupy the median region of the leaf, about 3-4 in number, from which arched secondary veins arise forming elongate rectangular, polygonal or trapezoid meshes of uniform width (Pl. 6, Fig. 36). Veins are not very close.

Epidermal Structure — Under incident light the epidermis is clearly distinguishable. One surface is devoid of stomata. On the non-stomatiferous surface cells over the vein areas (Pl. 2, Fig. 14; Text-fig. 3A) are narrow, two cells wide, elongate, rectangular and arranged end to end. Cells of the mesh areas are comparatively smaller and broader, usually rectangular and arranged end to end.

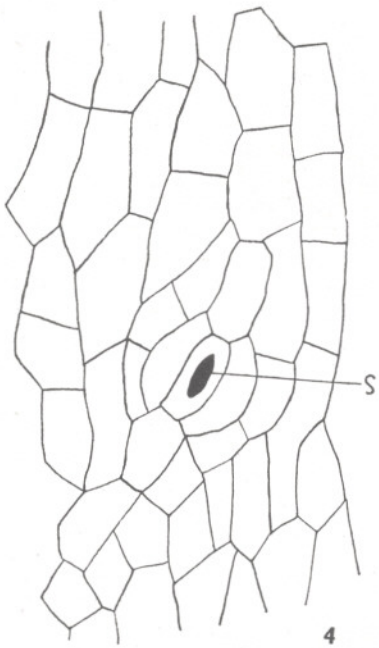
On the stomatiferous surface the cells of the (Pl. 2, Figs. 15, 16) veins are narrow, only two cells wide and shows rectangular cells placed end to end. Cells of the mesh areas are polygonal, rectangular or trapezoid, arranged irregularly and measure 80-112μ × 32-40μ. Certain cells appear to bear some marks but it is difficult to say whether they are papillae. Stomata haplocheilic, irregularly distributed and orientated, measuring 40-50μ × 25-30μ. Stomatal apparatus shows partially dicyclic condition (Pl. 8, Figs. 15, 16; Text-figs. 3B, 4). Guard cells are faintly seen. Generally 5 subsidiary cells surround the stoma and are like the ordinary epidermal cells.

Comparison and Discussion — The present species shows its closest agreement in venation to *G. kashmirensis* Seward (1907, Pl. 13, Fig. 2) but is easily distinguished by the absence of prominent median subparallel veins, which is the characteristic feature of *G. kashmirensis*. Beside this the cuticular structure of *G. kashmirensis* is so far not known. *G. cyclopteroides* Feistmantel differs in the presence of meshes which are broader towards the centre and narrower towards the margin. *G. angustifolia* McCoy is a comparatively more linear type of leaf and the veins are closer and the epidermal structure is also unknown.

In the dicyclic condition of the stomata, the present specimen compares with *Gangamopteris* cf. *hughesi* Feistm. (Srivastava,



Text-fig. 3 — *Gangamopteris karharbariensis* sp. nov. A. Cells of the non-stomatiferous surface. × 200. B. Stomata(s) and cells of the stomatiferous surface. × 200.



TEXT-FIG. 4 — *Gangamopteris karharbariensis* sp. nov. A stomata(s) showing partially dicyclic condition and cells of the stomatiferous surface. × 200.

1956; PL. 12, FIGS. 78, 79). But in *G.* cf. *hughesi* the stomata are arranged in linear rows, whereas in the present specimen stomata are irregularly distributed. Thus, the present specimen is not comparable with any of the known species of *Gangamopteris*; hence a new specific name is proposed for it, viz., *Gangamopteris karharbariensis*.

Gangamopteris mucronata sp. nov.

Pl. 3, Figs. 17-19

Diagnosis — Leaves simple, elliptical in shape, apex pointed mucronate, base tapering; median subparallel veins arise from the base, in the basal region they are prominent and become evanescent towards the apex; secondary veins arise at acute angle, ± arched, dichotomize frequently, closely placed and form very narrow elongate meshes of uniform size.

Holotype — 20542, Birbal Sahni Institute of Palaeobotany, Lucknow.

Locality — Central pit, Srirampur colliery, Giridih coalfield.

Horizon — Karharbari stage.

Age — Lower Permian.

Description — There are twenty specimens in the collection, but unfortunately most of them are incomplete. The holotype (PL. 3, FIG. 17) measures 23 cm. in length and 5 cm. wide from the median region on one side. The leaf is elliptical in outline with a acute mucronate apex. The base in all the specimens is incomplete, however, from the curving tendency of both the margins it appears to be tapering. The margin is entire. Median subparallel veins are prominent near the basal region and become evanescent as they pass forward towards the apical portion of the leaf. The median subparallel veins occupy about 0·4 cm. wide area in the middle portion of the leaf. The median subparallel veins occupy about 0·4 cm. wide area in the middle portion of the leaf. The median veins are 4-6 in number. The secondary veins (PL. 3, FIG. 19) arise at acute angle and they are fairly arched as they pass forward. Secondary veins are closely placed. There being about 20 veins per cm. Meshes are very narrow and elongate.

Comparison and Discussion—*G. mucronata* closely compares with *G. mosesi* Dolianiti (1954), in its mucronate apex, but the latter differs in having linear-lanceolate shape. *G. cyclopteroides* var. *acuminata* Feistmantel (1886) is distinguished by the presence of acute apex and persistent median subparallel veins up to apex. *G. whittiana* Feistmantel (1882) differs by the presence of broad polygonal meshes of uniform size.

Gangamopteris obliqua McCoy

Pl. 3. Fig. 20

1905 — *Gangamopteris cyclopteroides* Arber *partim*

Description — Only ten specimens are in the collection. Leaf obovate, base tapering with broadly pointed apex, margin entire. A thin coaly carbonized crust is preserved at some places. The leaf is 4 cm. long and 2·5 cm. broad. Arched flexuous secondary veins arise from the median portion of the frond but do not join to form a group of subparallel veins in the median region as is seen in other species of *Gangamopteris*, e.g. *G. cyclopteroides*. The meshes are polygonal,

coalescent and comparatively bigger towards the centre than towards the margin.

Comparison and Discussion — The specimens agree with the drawing of the Feistmantel (1881, PL. 2, FIG. 5). This species was placed by Arber (1905) under *Gangamopteris cyclopteroides* Feistmantel. But on examining the figures it appears to me that *G. obliqua* should be retained as a distinct species on the basis of its flexuous veins polygonal meshes and lack of discernible subparallel veins in the median region.

Gangamopteris clarkeana Feistmantel

Pl. 4, Fig. 25

1905 — *Gangamopteris cyclopteroides* Arber *partim.*

Description — Only a few specimens are in the collection. Leaves vary in size, 3-8 cm. × 1·5-4·5 cm.; obovate, entire, symmetrical, apex broadly obtuse, narrowing towards the base. Midrib absent, veins radiate out from the base, somewhat thick and distant, bifurcate and form oblong meshes. Leaves are broadest at the apex.

Comparison and Discussion — The present specimens serve to record *G. clarkeana* for the first time from India. They compare with Feistmantel's drawing of *G. clarkeana* (FEISTM. 1890, PL. 20, FIG. 3) in shape and venation. The species *G. clarkeana* was merged with *G. cyclopteroides* by Arber (1905:108). But on examining the figures and the present fronds it appears to me that *G. clarkeana* should be retained as separate species on the basis of its obovate shape, broadly rounded apex and oblong meshes. Walkom's specimen of *G. cyclopteroides* (1922, PL. 4, FIG. 20), as far as one can judge from the figure, also bears striking resemblance to Feistmantel's figure and with the present specimens of *Gangamopteris clarkeana*. Feistmantel's *G. cyclopteroides* (1886, PL. XII A, FIG. 17) from Talchirs of Auranga coalfield resembles *G. clarkeana* in its apex and venation and seems to be allied. *Gangamopteris* cf. *clarkeana* described by Plumstead (1963) does not agree with the type specimen of Feistmantel, but it is spathulate in shape and has a acute apex. The specimen of Plumstead comes more closer to *G. spathulata* McCoy (1875) in its shape and venation. The specimen attributed to *G. obovata* var. *major* by Dolianiti (PL. 2, FIG. 1) agrees to the present form in shape. However, it is comparatively much bigger in size.

Gangamopteris intermedia sp. nov.

Pls. 3, 4, Figs. 21-24; Text-fig. 5

Diagnosis — Leaf simple, ovate in outline, apex obtuse, broadly rounded, base narrow, contracted to a point, margin entire; midrib or median subparallel running veins absent; the median region is occupied by hexagonal meshes, and from them secondary veins arch out, forming hexagonal meshes, which are longer and broader near median region and narrow and short towards margin. Veins are fairly open.

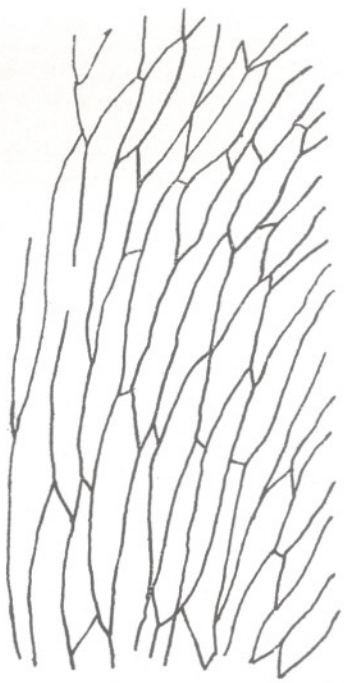
Holotype — 19941, Birbal Sahni Institute of Palaeobotany, Lucknow.

Isotypes—31317/424 and 33007/499, Birbal Sahni Institute of Palaeobotany, Lucknow.

Locality — Central pit, Srirampur colliery, Giridih coalfield.

Horizon — Karharbari stage.

Age — Lower Permian.



TEXT-FIG. 5 — *Gangamopteris intermedia* sp. nov. A portion of the leaf enlarged to show the venation. × 4.

Description — There are ten specimens in the collection. The holotype (PL. 3, FIG. 21) measures 3·8 cm. in length and 2·4 cm. broad. The leaf is ovate in shape with obtuse apex. The other specimen in Pl. 4, Fig. 23 is incomplete, measures 6× 4·5 cm., the apex of the leaf is broadly obtuse. The specimen in Pl. 3, Fig. 22 is incomplete and the apical portion is missing, it shows distinctly contracted base. The margin of the leaves is entire. The median region is occupied by elongate hexagonal meshes and from them secondary veins arch out. They form hexagonal meshes of bigger size towards median region (PL. 4, FIG. 24). The meshes are fairly open and about 4-5 meshes are present from the median region to the margin.

Comparison and Discussion — The present specimens compare with *Gangamopteris clarkeana* Feistmantel (1890) in the presence of a broad obtuse apex; but the present species is distinguished by the presence of clear hexagonal meshes over the lamina as well as in the median region. *G. obliqua* McCoy differs by the presence of acute apex and ± flexuous veins. *G. castellanosii* Archangelsky (1958) differs by the presence of median subparallel veins and narrow elongate meshes towards the margin. In venation it compares with *Gangamopteris whittiana* Feistmantel (1881), and *Gangamopteris conspicua* Feistmantel (1890) but both of them possess a distinct acute apices.

The specimens assigned to *G. cyclopteroides* Feistmantel (1886, PL. VIIIA, FIG. 6; PL. XIII A, FIG. 4) appear to agree in shape and venation with the present form, but differs in the presence of median subparallel veins. The present specimen does not compare with the known species of *Gangamopteris* and appears to be a distinct type. Hence, a new specific name is proposed.

Gangamopteris fibrosa sp. nov.

Pl 4, Figs. 26-28

Diagnosis — Lanceolate leaf, apex obtuse, tapering base; margin entire. Median subparallel veins distinct, secondary veins radiate out at acute angle, anastomoses rare, meshes elongate-rectangular in shape, flexuous fibres like structure present in between the meshes.

Holotype — 31390/425, Birbal Sahni Institute of Palaeobotany, Lucknow.

Locality — Jogtiabad pit, Karharbari colliery, Giridih coalfield.

Horizon — Karharbari stage.

Age — Lower Permian.

Description — Only two specimens are in the collection. The most complete specimen (PL. 4, FIG. 26) is 10·5×1·5 cm. Leaf narrow lanceolate, with obtuse apex and tapering base. The median region is occupied by subparallel veins from which secondary veins radiate out at acute angle. They dichotomize repeatedly and follow a flexuous course. After each dichotomy the two veins run in a subparallel manner for considerable distance, anastomosing rarely. Only few elongate meshes are formed near the median region. The characteristic feature of the leaf is the presence of subparallel, flexuous, elongate fibres in between the secondary veins (PL. 4, FIG. 28). The fibres may anastomose in themselves or may join any of the adjacent secondary veins. The fibres are not seen to cross the main meshes. The presence of these fibres imparts striated appearance to the frond.

Comparison and Discussion — None of the known species of *Gangamopteris* show the presence of elongate fibres in between the secondary veins. Similar structures are known in *Glossopteris hispida* Pant (1958), *Glossopteris fibrosa* Pant (1958), *Glossopteris* sp. Maheshwari (1965a) and *Rhabdotaenia fibrosa* Pant and Verma (1963). The present leaves are therefore a distinct type and hence have been described as a new species of the genus *Gangamopteris*.

Glossopteris **Brongniart**

Glossopteris indica Schimper

Pl. 5, Fig. 30

Description — The leaves are fairly common in the assemblage, but all of them are incomplete. The one figured (PL. 5, FIG. 30) is 14·5 cm. long and 3·2 cm. broad at the widest part. The midrib is distinct, tapering towards the apex. From the midrib secondary veins arise at acute angle forming shorter and broader meshes towards the midrib and narrow elongate meshes towards the margin. The margin is entire.

Comparison and Discussion — The specimens from the Karharbari beds are

comparable to the figures of Feistmantel (1881, PL. 24 A, FIG. 1) and Zeiller (1902, PL. 1, FIGS. 1-5). The cuticle of *G. indica* is known (ZEILLER, 1898) but the present specimens did not yield any cuticle for their confirmation.

Glossopteris communis Feistmantel

Pl. 5, Fig. 31

Description — This species is fairly common in the assemblage. The leaves are characterized by their lanceolate form, bluntly acute apex and tapering base. The median region is occupied by a distinct midrib. The secondary veins arise at acute angle from the midrib and form very narrow and elongate meshes. The veins are closely set. A nearly complete specimen in Pl. 5, Fig. 31 is 9·8 cm. long and 2·8 cm. broad.

Comparison and Discussion — The morphological distinction between *G. communis* and *G. indica* as originally proposed by Feistmantel (1879) has now been supported by the cuticular studies of Srivastava (1956). Although, some specimens in the present collection show some carbonized crust, yet it was not possible to make a cuticular preparation from them. However, the venation strongly favours the assignment of these leaves to *G. communis*. In recent years the fructification attached to *G. communis* has been described by Sen (1955) viz., *Lanceolatus communis* from the Raniganj stage of the Jharia coalfield.

Glossopteris longicaulis Feistmantel

Pl: 4, Fig. 29

Description — There are about ten incomplete specimens in the collection. The one figured here is an impression showing the basal part, measuring $9{\cdot}5 \times 2{\cdot}4$ cm. The margin of the lamina gradually converges downwards and then forms a long narrow petiole, which measure $5 \times 0{\cdot}5$ cm. The midrib is distinct in the lower part of frond but vanishes towards the apical region into a groove. Secondary nerves arise at sub-acute angle forming broad oblong meshes.

Comparison and Discussion — The present specimens closely agree in their venation and shape with *Glossopteris longicaulis* Feistmantel (1879, PL. 21, FIGS. 1, 3). So far this species was known only from the Karharbari stage but recently Srivastava (1956) and Maheshwari (1965a) recorded it from the Raniganj Stage. Plumstead (1958) described a fructification belonging to this species, viz., *Pluma longicaulis* from the Ecca series of S. Africa.

Glossopteris angustifolia Brongniart

Pl. 5, Fig, 33

Description — Only few specimens are in the collection. The one figured here is 7·5 cm. long and 1·5 cm. broad, narrow linear in shape with gradually contracting base. Midrib well marked, persistent up to apex. Secondary nerves oblique, $\pm$ arched near the midrib forming very narrow, elongate polygonal meshes.

Comparison and Discussion — The specimens from the Karharbari beds agree well with those of Feistmantel (1881, PL. 27 A, FIGS. 11, 13). So far this species was known only from the Damuda division of India, it is recorded for the first time from the Karharbari stage.

Glossopteris spathulo-cordata Feistmantel

Pl. 5, Fig. 34

Description — Only six specimens are in the collection. The one figured in Pl. 5, Fig. 34 is 7 cm. long and 2·2 cm. broad. Leaf ovate with emarginate apex and narrow tapering base. A distinct midrib is present. Secondary nerves arise at acute angle forming narrow elongate meshes of equal size.

Comparison and Discussion — The specimens from the Karharbari beds agree well with the Australian forms of *G. spathulo-cordata* Feistmantel (1890, PL. 20 FIGS. 7, 8) in shape. However, the meshes in the latter are somewhat open. This species was so far not known from India.

Glossopteris browniana Brongniart

Pl, 5, Fig. 32

Description — Only few specimens are in the collection. The one figured (PL. 5, FIG. 32) is 4·5 cm. in length and 2·8 cm. broad. A distinct midrib is present. From this arch out secondary veins forming poly-

gonal meshes which are somewhat broader and longer towards midrib and shorter and narrower towards the margin. The margin is entire.

Comparison and Discussion — The specimens from the Karharbari beds agree well with those of Feistmantel (1881, PL. XXIXA, FIG. 3). Plumstead described the fructification, viz., *Scutum leslium* from the South Africa attached to *G. browniana*. So far this species was known only from the Damudas of India, it is for the first time recorded from the Karharbari stage of the Giridih coalfield.

Vertebraria Royle

Vertebraria gondwanensis sp. nov.

Pl. 5, Figs. 35-39; Text-figs. 6, 7

Diagnosis — Radial and tangential wall of the tracheids are pitted. Pits on the radial wall 1-4 seriate (commonly uniseriate and biseriate); bordered, alternate, subopposite or opposite; contiguous or separate with an elleptic or crossed aperture; sometimes pits are in groups of 2 or 3; tangential wall pits only one seriate, contiguous or separate; xylem rays 1-3 cells high; cross-field pits 4-7. Broad thin-walled cells present.

Holotype — 33015/503, Birbal Sahni Institute of Palaeobotany, Lucknow.

Locality — Jubille pit, Karharbari colliery; Giridih.

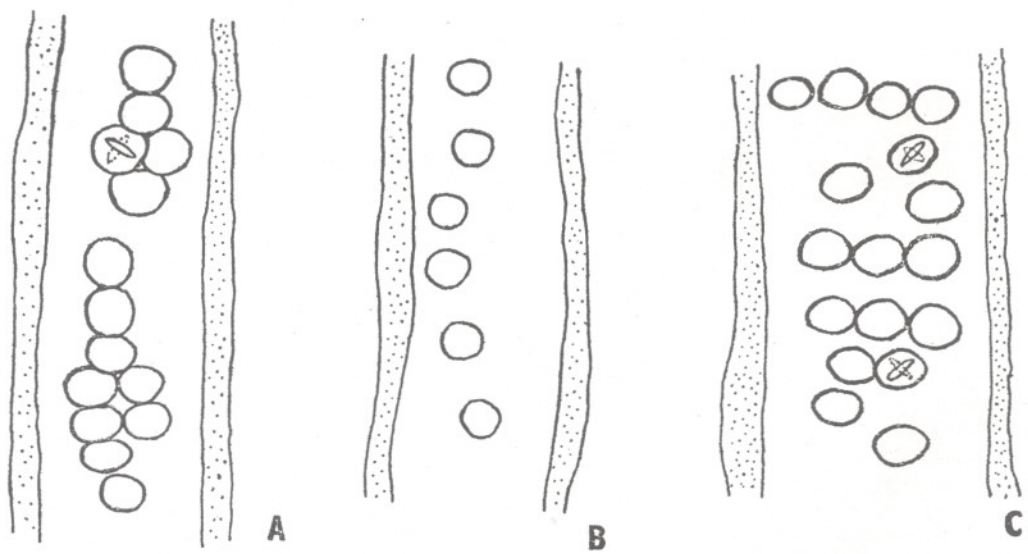
Horizon — Karharbari Stage.

Age — Lower Permian.

Description — The specimens are unbranched, variable in size and flattened in the plane of bedding. The specimen in Pl. 5, Fig. 35 measures 5 × 4 cm., shows two rows of rectangular blocks separated by a ridge. The transverse partitions may be in the form of ridges or furrows. The partitions of one row of blocks may be alternate to opposite with respect to those of the adjacent row.

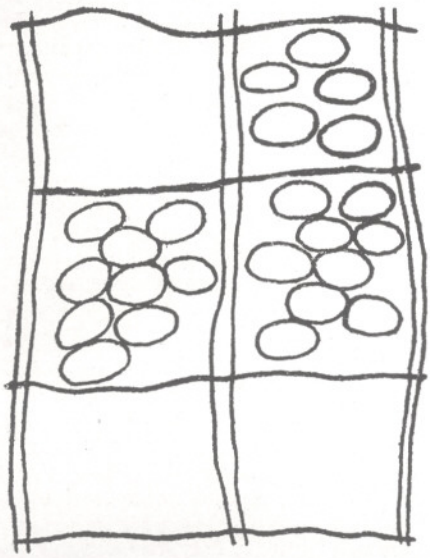
Cellulose peels from the surface of the *Vertebraria* axes reveal the following details of the secondary xylem:

The peels show commonly the radial view of the tracheids. Tracheids are pitted, uniseriate to tetraseriate, but more commonly uniseriate or biseriate. Uniseriate pits are commonly contiguous placed in a row, sometimes separately placed and arranged alternately (TEXT-FIG. 6, B). Biseriate pits are commonly alternate or sometimes opposite, contiguous or separate (PL. 5, FIG. 36; TEXT-FIG. 6, A). Triseriate and tetraseriate pits are opposite or alternate and commonly contiguous (TEXT-FIG. 6, C). Sometimes pits



TEXT-FIG. 6A-C — *Vertebraria gondwanensis* sp. nov. showing the arrangement pits and pores on the radial wall of the tracheids. × 1000.

are arranged in separate groups of 2 or 3. Pits are circular to oval, bordered, with an elleptic pore or crossed apertures. The size of the pits varies from 7 to 8 μ×4 to 5 μ. The cross-field pits are circular to oval, contiguous and 4-7 in number (PL. 5, FIG. 37; TEXT-FIG. 7).



TEXT-FIG. 7 — *Vertebraria gondwanensis* sp. nov. Showing the arrangement of pits in the cross-field. × 1000.

Some peels show the tangential view of the axis. The medullary rays are uniseriate, commonly 1 cell or sometimes 2 or 3 cells high (PL. 5, FIG. 39). They are oval, simple and measures 50×25 μ. The tangential wall of the tracheids has commonly uniseriate, contiguous or separate pits.

Above the tracheids, some thin-walled rectangular cells are seen in the peels taken from deeper layers (PL. 5, FIG. 38). The cells are horizontally arranged in 2-3 rows and 3 to 4 rows longitudinally along the tracheids. The cells are of varying size. Walton & Wilson (1932) considered these cells to be parenchymatous, while Pant (1956) refers to them as phloem cells. In my opinion the view of Walton & Wilson (*l.c.*) seems more justifiable, because it is difficult to ascertain the nature of these cells in fossil state.

Comparison and Discussion — The anatomy of the *Vertebraria* axis has been described by Walton & Wilson (1932); Pant (1956), Sen (1958) and Surange & Maheshwari (1962). The anatomy of the axis described by Walton & Wilson, Pant and Sen shows an agreement in their anatomical characters, and the Karharbari specimen too agrees with them in all the characters. However, the anatomy of the axis described by Surange & Maheshwari (*l.c.*) from the Raniganj coalfield markedly differs from the above record by the absence of broad parenchymatous cells, absence of pits on the tangential walls, height of xylem rays and radial pitting characters. A new name was, therefore, proposed by them, viz., *V. raniganjensis*. Thus it is evident that even the axis of *Vertebraria*, resembling externally, may differ in their anatomical characters. Thus, in view of this the present Karharbari specimen and the specimens of Walton & Wilson, Pant are now removed from *V. indica* and transferred under a new specific name *V. gondwanensis*. Because the type species of *V. indica* was instituted by Royle (1833) on external characters alone and furthermore, the anatomy of the axis is not known.

The genus *Vertebraria* is one of the commonest Lower Gondwana fossils, being represented by at least 4 species. Of these *V. indica* and *V. gondwanensis* sp. nov. are widely known and occur in all the stages of Lower Gondwanas. The other two species are so far only known from the Raniganj beds. *Vertebraria* was believed to be a rhizome or stem of *Glossopteris* due to its frequent occurrence in association with that genus. This idea was supported by many palaeobotanists (SEWARD, 1910; ZEILLER, 1896-97; OLDHAM, 1897; EDWARDS in Darrah, 1939; KOIDZUMI, 1933) and several figures showing their organic connection have been published. Dolianiti (1954) has described and illustrated an axis, probably of a *Vertebraria* bearing 4 pairs of *Glossopteris* ?*browniana* leaves. Surange & Maheshwari (1962) have given a figure showing six *Glossopteris tortuosa* leaves arranged round an axis of *Vertebraria*, and despite any proof of organic connection the position of the leaves with reference to the axis tempts one to speculate that they were probably attached there. Pant (1958) figured some tracheids macerated from the midrib of *Glossopteris fibrosa* Pant showing *Vertebraria* type of pits. Surange & Maheshwari (*l.c.*) have pointed out the similarity in the anatomical structures

of the midrib of *Glossopteris srivastavae* and the axis of *Vertebraria raniganjensis* which strongly suggests that at least some of the *Glossopteris* leaves were borne on *Vertebraria* axis. However, from time to time a connection between *Glossopteris* and *Vertebraria* has been disputed. Thomas (1952) has figured two whorls of *Glossopteris* around an axis quite unlike *Vertebraria*, but as has been rightly pointed out by Surange & Maheshwari (*l.c.*), *Glossopteris* is not a single genus but a complex of many genera (SURANGE & SRIVASTAVA, 1956), and hence the axes of these genera might have been different or as pointed out by Pant (1960) that the apparent differences between the two type of stems could be explained by regarding the features of *Vertebraria* as representing stelar structure of stem and its real surface features having been lost during preservation. Plumstead (1958a) has gone to the extent to suggest that the axis described by Thomas might be the outer impression of a stem of which *Vertebraria* is only the vascular cylinder. Thus, most of the evidences seem to converge in favour of a connection between *Vertebraria* and some *Glossopteris* species.

In the past several interpretations have been put forward by several workers on the organization of the *Vertebraria* axis. Walton & Wilson (1932) and Pant (1956) proposed that the *Vertebraria* axis possessed radiating xylem plates which anastomosed here and there (*See* PANT, 1960, FIG. 1A) and the axis virtually had no pith and the space between the xylem plates were filled with parenchymatous cells. However, Sen (1958) insisted that the large parenchymatous cells reported by the above authors are recognizable only towards the peripheral region of the axis and the mud-filled rectangular blocks contain tracheids inside their rocky matrix. But Pant (1960, FIGS. 1F, 10) demonstrated in a vertically preserved axis that the parenchyma cells lie in between mud-filled wedges and along the sides of xylem plates and considered that the tracheids in Sen's material perhaps represented displaced xylem. Surange & Maheshwari (1962) have interpreted the presence of pith in *Vertebraria* which is represented by a central space in the species *V. myelonis* Surange & Maheshwari. The presence of the pith in *Vertebraria* has also been supported by Plumstead (1962). She had also put forth an diagramatic representation of the organization of *Vertebraria* axis, which agrees totally with that of earlier workers except for the following:

(a) central column communicating by means of large oval cavities with the rest of the axis.
(b) the outer cortex.

The above mentioned organization characters interpreted by Plumstead (1962) needs a clarification, because the evidences for these structures are very fragmentary and doubtful.

ACKNOWLEDGEMENTS

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EXPLANATION OF PLATES

PLATE 1

Gangamopteris cyclopteroides Feistmantel

1. A complete frond, showing obtuse apex and tapering base. × 1. Specimen No. 31295/424. Locality, Central pit.
2. An incomplete frond, showing distinct median subparallel veins and secondary veins. × 1. Specimen No. 33001/499. Locality, Central pit.
3. A small, narrow incomplete frond. × 1. Specimen No. 33002/499. Locality, Central pit.

Gangamopteris gondwanensis sp. nov.

4. An incomplete frond. × 1. Specimen No. 31341/424. Locality, Central pit.
5. Non-stomatiferous surface under direct incident light. × 200.
6. Stomatiferous surface under direct incident light showing stomata(s) and cells of the vein area and in between the vein area. × 200.

Gangamopteris major Feistmantel

7. A nearly complete frond showing acute apex and narrow tapering base. × 1. Specimen No. 31355/424. Locality, Central pit.

PLATE 2

Gangamopteris cf. ? *major*

8. An incomplete frond. × 1. Specimen No. 33003/499. Locality, Central pit.

Gangamopteris angustifolia McCoy

9. An incomplete linear frond with acute apex. × 1. Specimen No. 33004/499. Locality, Central pit.
10. Another incomplete frond. × 1. Specimen No. 33005/499. Locality, Central pit.

Gangamopteris karharbariensis sp. nov.

11. The holotype. × 1. Specimen No. 31381/424. Locality, Central pit.
12. Fig. 11 enlarged to show venation. × 4.
13. Another incomplete frond. × 1. Specimen No. 33006/499. Locality, Central pit.
14. Non-stomatiferous surface showing the epidermal cells under incident light. × 200.
15-16. Stomatiferous surface showing cells and stomata (S). × 200.

PLATE 3

Gangamopteris mucronata sp. nov.

17. The holotype. × 2/3. Specimen No. 20542. Locality, Central pit.
18. Another incomplete frond showing pointed acute apex. × 1. Specimen No. 31348/424. Locality, Central pit.
19. Fig. 18 enlarged to show venation. × 4.

Gangamopteris obliqua McCoy

20. A complete frond showing the characteristic venation, note the flexuous veins. × 1. Specimen No. 31373/424. Locality, Central pit.

Gangamopteris intermedia sp. nov.

21. An incomplete frond showing the basal region of the frond. × 1. Specimen No. 31317/424. Locality, Central pit.
22. The holotype, note in the median region hexagonal meshes. × 2. Specimen No. 19941. Locality, Central pit.

PLATE 4

23. *G. intermedia*, another specimen showing obtuse apex. × 1. Specimen No. 33007/499. Locality, Central pit.
24. The specimen in Fig. 23 enlarged to show venation characters. × 4.

Gangamopteris clarkeana Feistmantel

25. An incomplete frond showing broad obtuse apex. × 1. Specimen No. 33008/499. Locality, Central pit.

Gangamopteris fibrosa sp. nov.

26. A complete frond showing obtuse apex and tapering base. × 1. Specimen No. 31390/425. Locality, Jogtiabad pit.
27. Another incomplete frond. × 1. Specimen No. 33009/499. Locality, Central pit.
28. The frond in Fig. 27 enlarged to show arrangement of veins and fibres in between the veins. × 4.
29. *Glossopteris longicaulis*, an incomplete frond. × 1. Specimen No. 33070/504. Locality, Jogtiabad pit.

PLATE 5

Glossopteris indica Schimper

30. An incomplete frond, note a distinct midrib. × 1. Specimen No. 33010. Locality, Bengal Nagpur quarry.

Glossopteris communis Feistmantel

31. A complete frond. × 1. Specimen No. 33011. Locality, Bengal Nagpur quarry.

Glossopteris browniana Brongniart

32. An incomplete frond. × 1. Specimen No. 33012. Locality, Bengal Nagpur quarry.

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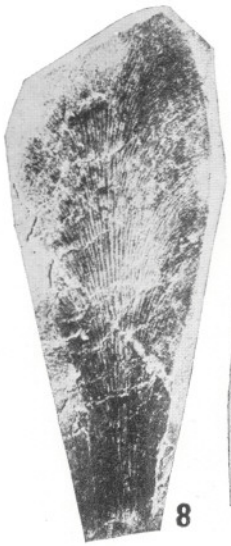

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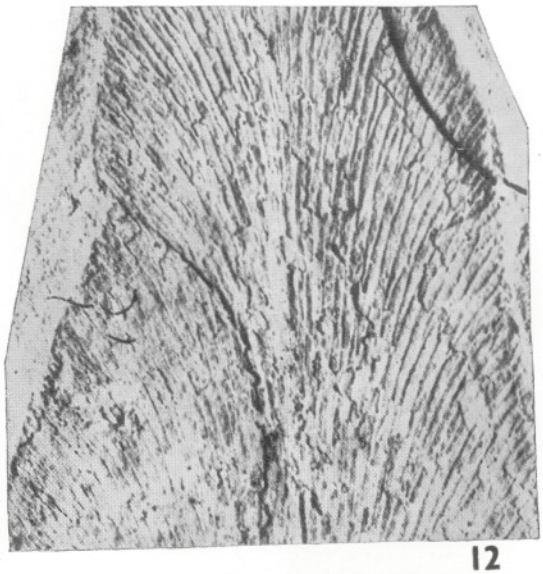

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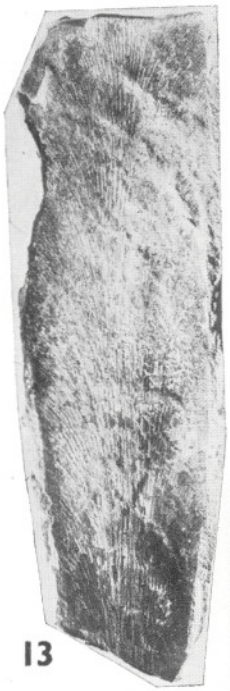

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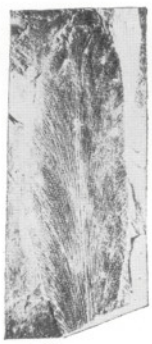

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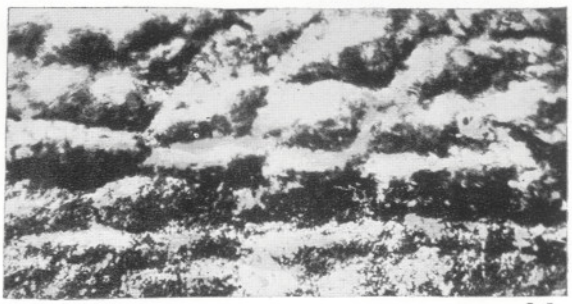

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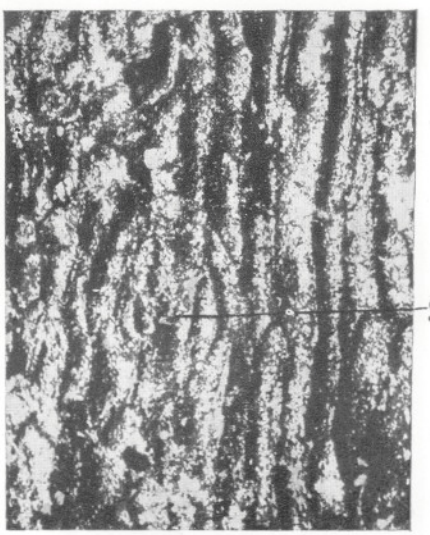

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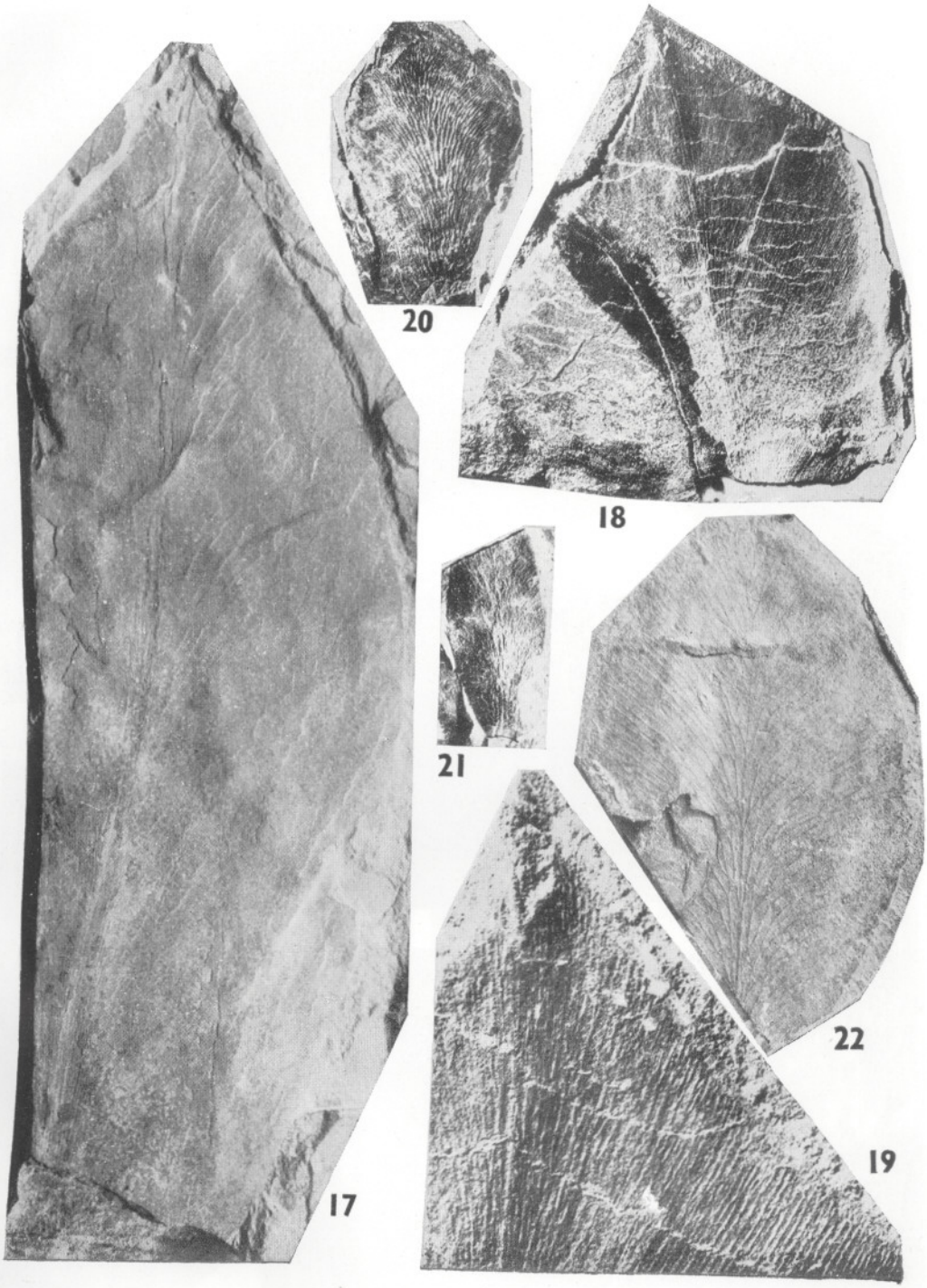
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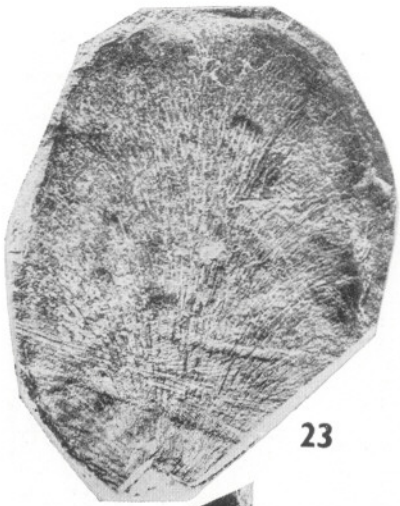

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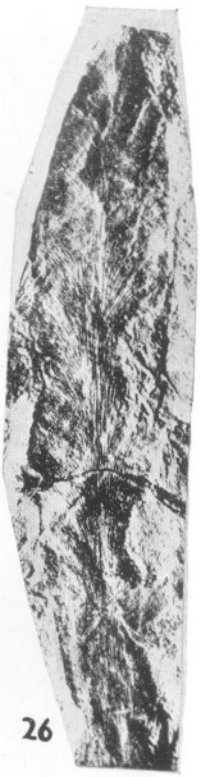

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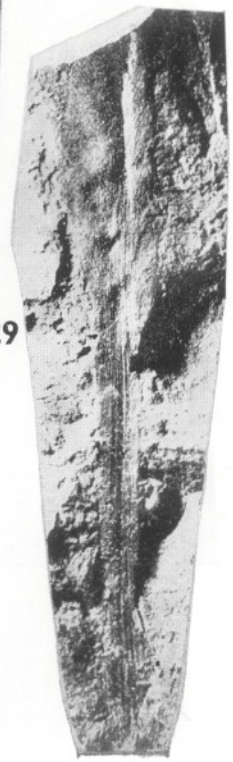

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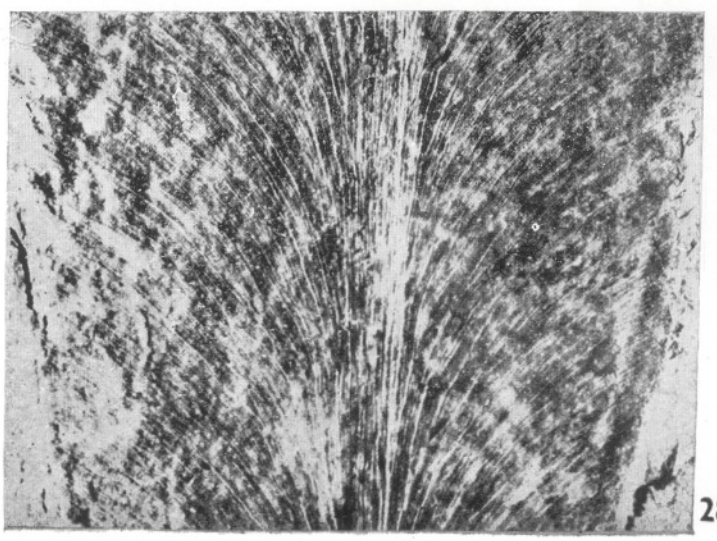

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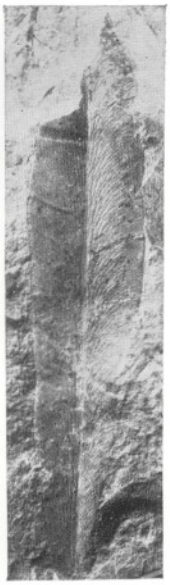

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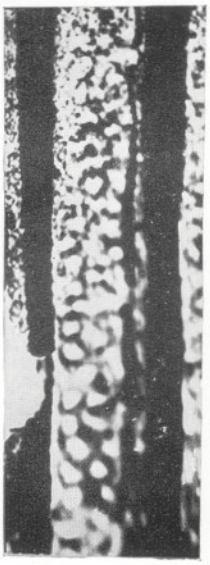

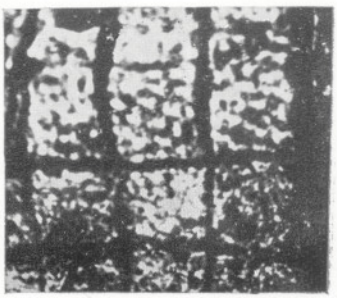

37

Glossopteris angustifolia Brongniart

33. An incomplete frond showing the basal region. × 1. Specimen No. 33013. Locality, Bengal Nagpur quarry.

Glossopteris cf. *spathulato-cordata* Feistmantel

34. A complete frond showing retuse apex. × 1. Specimen No. 33014. Locality, Bengal Nagpur quarry.

Vertebraria gondwanensis sp. nov.

35. An axis, the holotype. × 1. Specimen No. 33015/503. Locality, Jubille pit.

36. An tracheid showing radial pitting. × 250.

37. Tracheids in radial view showing pits in the cross-field. × 250.

38. Figure showing parenchymatous cells. × 100.

39. Tangential view showing 1-celled high medullary ray. × 100.