

# STUDIES IN THE GLOSSOPTERIS FLORA OF INDIA —

## 11. SOME OBSERVATIONS ON *VERTEBRARIA* FROM THE LOWER GONDWANAS OF INDIA

K. R. SURANGE & HARI K. MAHESHWARI  
Birbal Sahni Institute of Palaeobotany, Lucknow

### ABSTRACT

Recently a large collection of *Vertebrarias* was made from Barakar and Raniganj Stages of the Lower Gondwanas. The specimens were studied for anatomical structures by the "Dry Pull" method. One specimen from the Raniganj Stage shows anatomy different from that of *V. indica* and hence has been referred to a new species *V. raniganjensis*. The collection also includes an axis cast with a small middle part not belonging to the xylem and which looks like a pith. As pith is not known in other species of *Vertebraria*, it has been given a new specific name *V. myelonis*. A specimen doubtfully referred to *Ctenis* by Srivastava (1954) has been found on reinvestigation to be a new species of *Glossopteris* — *G. srivastavaei*. The anatomy of the midrib of *G. srivastavaei* and *V. raniganjensis* is almost similar. It is probable that *G. srivastavaei* was one of the leaves borne on an axis of *V. raniganjensis*.

### INTRODUCTION

THE genus *Vertebraria* was instituted by Royle in 1833. Its morphology and relationships were further discussed by Feistmantel (1879, 1880), Arber (1902, 1905), Seward (1910), Etheridge (1894, 1904), Oldham (1897), Zeiller (1896) and others. The anatomy of the axis was first described by Walton and Wilson (1932) and later by Pant (1956) and Sen (1958). These axes have been variously regarded as roots or rhizomes of some members of the *Glossopteris* flora because of their frequent occurrence in the Permo-Carboniferous strata. In India *Vertebraria* is found right from the Talchir Stage up to the Panchet series. Surprisingly enough from all these strata, as well as from the Gondwana rocks of other continents only one species of *Vertebraria* was known so far.

The material for the present study was collected from Barakar and Raniganj Stages of the Lower Gondwanas of India. Out of a total of 32 specimens of *Vertebraria* examined, 23 are from the Barakar Stage and 9 from the Raniganj Stage. None of the specimens collected from the Barakar Stage gave any valuable information, except regard-

ing the external features. A few axes from Raniganj, however, yielded peels which were examined for anatomy. One specimen from the same stage was a cast and gave some more information regarding its structure.

### 1. *VERTEBRARIA RANIGANJENSIS* SP. NOV.

The species *Vertebraria indica* was instituted by Royle on the basis of its external characters alone. Other specimens of *Vertebraria* found later were also included in the same species as they had similar morphological features. Walton and Wilson (1932) and later Pant (1956) and Sen (1958) studied its anatomy in detail but they also described their specimens under *V. indica*. Recently some specimens of *Vertebraria* were collected from East Raniganj Coalfield, Bengal. One of them, which is a fusinized axis, yielded very good peels while others were not so encouraging. The anatomy of the fusinized axis shows some important anatomical differences from that of *V. indica* and hence has been described here as a new species.

### Description

The specimen (PL. 1, FIG. 1) on the basis of external features can be placed in *Vertebraria indica*. Dry Durofix pulls were prepared by smearing portions of the axis by the adhesive cement. The peels were pulled off when dry and were mounted in Canada balsam.

The pulls show only radial view of the wood. The secondary xylem is composed of compactly arranged tracheids. The radial walls of the tracheids have variously disposed bordered pits. The pits are multiseriate, opposite and are arranged in horizontal rows, often six occurring at the same level (PL. 1, FIG. 2). However, more than often the pits are arranged irregularly (PL. 1, FIG. 3). They may be arranged in groups of 2-9, the

groups being sometimes of stellate shape. In the same tracheid both regular and irregular arrangement of the pits may occur side by side. The pits are contiguous and flattened often acquiring an oval shape. When uniseriate, however, the pits are wide apart and more circular. The pit pore is oval or sometimes only a small slit and the apertures on the two sides are crossed (PL. 1, FIG. 4). The number of pits in a tracheid varies greatly. Some tracheids have compactly arranged pits all over their radial surface while in others as few as one pit could be seen. When unpitted portion of such a tracheid is seen, it looks like a thin-walled unpitted element (PL. 1, FIG. 5) which may be suspected of being a part of the phloem. Xylem rays, if not common, are also not scarce as in *V. indica*. They are usually 1-5 cells high, rarely up to 8 cells high (PL. 1, FIG. 6). At places the xylem rays span both the normally pitted tracheids and the apparently unpitted elements (PL. 1, FIG. 5). Number of pits in the cross-field is 7-9 (PL. 1, FIG. 7). The pits in the cross-field are bordered with an oval pore. There are certain fields where no pits are seen. Such fields were also observed by Sen (1958) who compared them with closed windows. It seems that the absence of pits in these fields is simply because of a bad preparation or bad preservation, otherwise the pits should be present there. Some tracheids have large pits without any distinguishable border. They probably represent the transitional stages between the scalariform thickening and pitting. At one place scalariform elements were observed which probably are parts of the primary xylem.

The layers of parenchymatous tissue reported by Walton and Wilson (1932), Pant (1956), and Sen (1958) are conspicuous by their absence in this specimen. The pith, the phloem and the tissues external to xylem could not be detected. Peels were also studied from the transverse facet of the vertically preserved axis. They showed structures similar to those seen in peels from the rectangular blocks or the ridges.

#### Comparison

Walton and Wilson (1932) reported four different types of tissues in *Vertebraria indica* and their observations were later corroborated by the studies of Pant (1956) and Sen (1958). In their specimens as well as in the present

specimen the pits on the radial walls of the tracheids are bordered and multiseriate. In *V. indica* the pits tend to be arranged in horizontal rows and are 2-3 seriate while in *V. raniganjensis* the pitting is more irregular and at places as many as six pits may be found in the same horizontal row. The xylem rays in *V. indica* are scarce while in our specimen, if they are not very common, are also not scarce. In *V. raniganjensis* the rays are up to 8 cells high with 7-9 pits in the cross-field, while in *V. indica* the rays are comparatively lower with a larger number of pits in the cross-field. The most important difference between the two species, however, lies in the absence of broad parenchymatous cells in *V. raniganjensis*.

#### *Vertebraria raniganjensis* sp. nov.

*Diagnosis*—Radial pits bordered, opposite, multiseriate, up to six in the same horizontal row, often in groups of 2-9, contiguous and flattened with pit pores of the two sides crossed. Xylem rays 1-8 cells high. Number of pits in the cross-field 7-9. Thin-walled broad parenchymatous cells absent.

*Type Specimen No.* — 31837/433, B.S.I.P. Collection.

*Horizon* — Raniganj Stage.

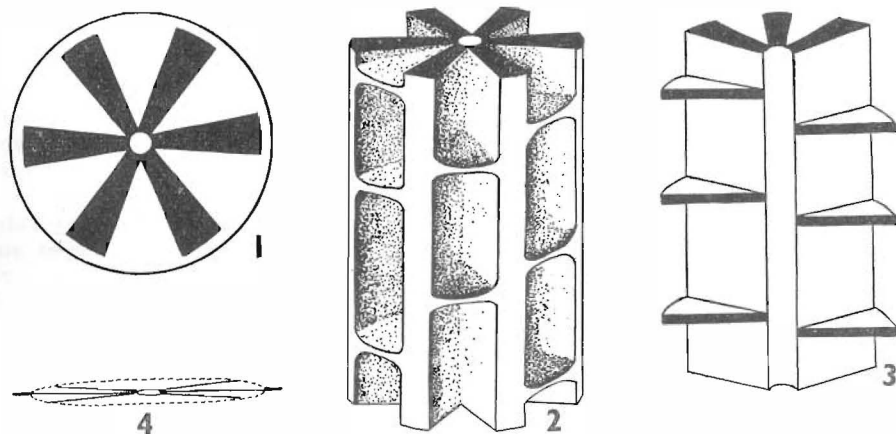
*Age* — Upper Permian.

*Locality* — East Raniganj Coalfield, Bengal.

#### 2. *VERTEBRARIA MYELONIS* SP. NOV.

The specimen is of large size measuring 22 cm. in length and 6 cm. in width (PL. 1, FIG. 8). The axis consists of two longitudinal series of rectangular blocks separated by a broad space which at places is as wide as 6 mm. Below the upper series of blocks is another similar series. Between the upper and lower series of rectangular blocks and also in the transverse grooves separating the adjacent blocks, a thin film of carbonaceous matter is present. The rectangular blocks are striated longitudinally and are 6-28 mm. high. They are thin near the centre and gradually become thicker towards the periphery (4.4-5 mm.). From the position of the central space it seems that it does not represent a portion of the xylem, but most probably the central space represents the pith of the axis which is not preserved. So far *Vertebraria* was supposed to lack pith.

On one side, just where the blocks end, there is present a 4-mm. wide impression



TEXT-FIGS. 1-4 — Reconstruction of *Vertebraria* axis as modified after Walton and Wilson. 1, cross-section of the axis showing 6 xylem wedges radiating from a central pith. 2, longitudinal view of the axis showing transverse septa interconnecting the radiating xylem wedges. 3, a vertical section through the axis exposing the pith. 4, cross-section of the compressed axis.

which perhaps represents tissues external to xylem.

From the study of this axis cast it seems that the axis was originally cylindrical with a pith in the centre and 5-8 groups of vascular bundles around it (TEXT-FIG. 1). The vascular bundles were separated by air spaces, or some soft tissue, but at the same time were interconnected by means of transverse septa (TEXT-FIGS. 2, 3). Pant (1956) has tried to explain the features of *Vertebraria* in the light of Walton's theory of compression. It seems probable that during the process of preservation the soft tissues, if present, between the vascular bundles were first disintegrated and their place was taken up by mud. The vascular bundles were next to undergo a change and they were reduced to mere films of carbonaceous matter under the weight of sediments above (TEXT-FIG. 4). At the same time the mud also compressed and was reduced to the present thickness. The downward pressure caused the mud to expand laterally resulting in the compression of the transverse septa. In the same way the vertical preservation of the axis can be explained.

Due to the presence of a pith in this specimen it is proposed to give it a new name *Vertebraria myclonis* sp. nov.

*Vertebraria myclonis* sp. nov.

*Diagnosis* — Elongate, flattened and simple casts composed of two longitudinally disposed

series of almost rectangular blocks; the longitudinal series separated by a wide space representing the pith and the rectangular blocks separated by transverse grooves.

*Type Specimen No.* — 31836/432, B.S.I.P. Collection.

*Horizon* — Raniganj Stage.

*Age* — Upper Permian.

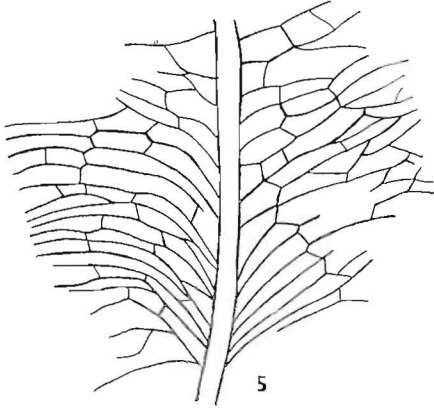
*Locality* — Mukherji's Jyoti Janaki quarry, East Raniganj Coalfield, Bengal.

3. *GLOSSOPTERIS SRIVASTAVAI* SP. NOV.  
AND ITS RELATION WITH  
*VERTEBRARIA RANIGANJENSIS*

? *Ctenis* Srivastava (1954)

*The Palaeobotanist* 3: 70-78

Srivastava (1954) referred an incomplete leaf impression from the Raniganj Coalfield, Bengal, to the genus *Ctenis* putting a quarry mark before the genus. He described the leaf to be "... a pinnate type of frond. The impression shows veins coming out of strong rachis at acute angles. They bifurcate near the rachis and then join either by forking or cross bars". While re-examining the type specimen (PL. 1, FIG. 9; TEXT-FIG. 5) we found that the leaf was actually a simple one with net-like venation and a strong midrib as in *Glossopteris*. On comparison with the known species of *Glossopteris* we found, however, that it did not completely agree with any one of them. Its epidermal



TEXT-FIG. 5 — *Glossopteris srivastavai* sp. nov., a line drawing of the photograph represented in Pl. 1, Fig. 9, to show venation.  $\times$  Nat. size.

characters are also different and, therefore, it is proposed to describe it here under a new specific name *Glossopteris srivastavai*.

***Glossopteris srivastavai* sp. nov.**

**Diagnosis** — Fronds probably large in size with a strong midrib and thin lamina. Base and apex not known. Lamina more than 6 cm. broad. Midrib distinct, very strong, with parallel longitudinal striations and nearly 2.5 mm. in width. Secondary veins

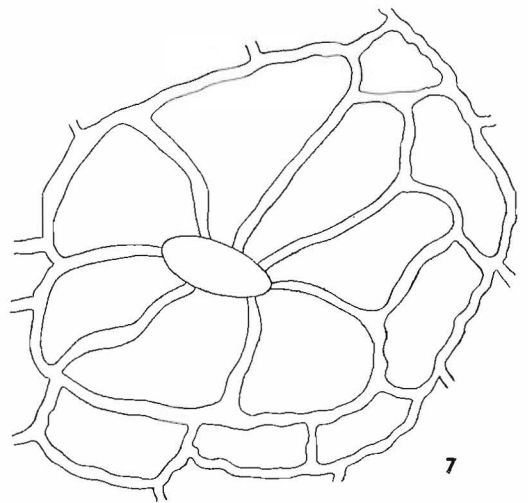
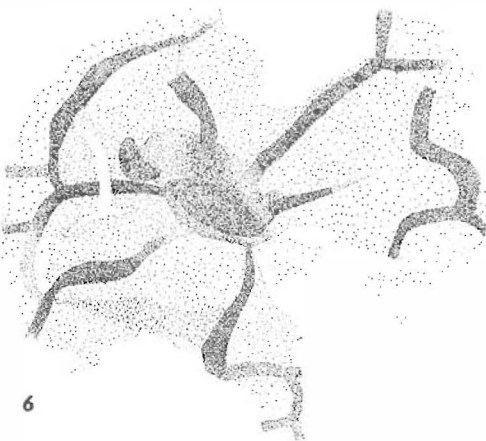
arising at acute angles from the midrib, 1.4-5 mm. apart; form large, open, oblong meshes of unequal size. Stomata present only on the lower surface of the leaf. The cells of the upper epidermis much longer than broad, having thick, slightly curved or straight walls. The cells of lower epidermis of irregular shape, with comparatively less thick sinuous walls. About 6-7 subsidiary cells surround the oval to linear stomatal opening (TEXT-FIGS. 6, 7).

**Type Specimen No.** — 9403, B.S.I.P. Collection.

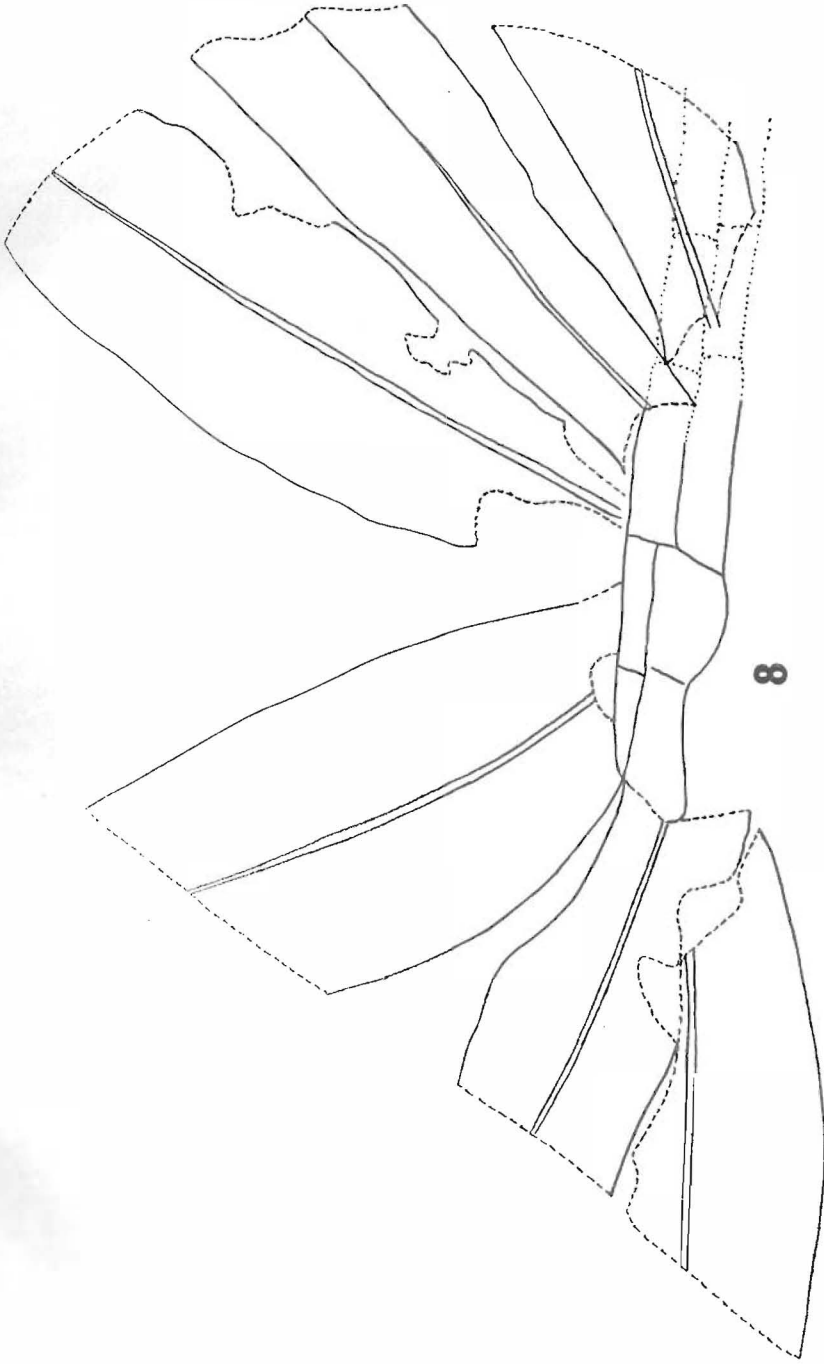
**Horizon** — Raniganj Stage.

**Locality** — East Raniganj Coalfield, Bengal.

**Comparison** — From the rocks of the Lower Gondwanas only a few leaves with large meshes are known. They are *Gangamopteris whittiana* Feist., *Glossopteris retifera* Feist., *Glossopteris conspicua* Feist., and *Glossopteris sahnii* Srivastava. *Gangamopteris whittiana* belongs to a different genus characterized by the absence of midrib. Our specimen is distinct from *Glossopteris retifera* in having meshes much longer than broad and of unequal size, while in the latter they are not much longer than broad and are of equal size throughout the lamina. *G. srivastavai* differs from *G. conspicua* in having comparatively larger meshes of unequal size. In the case of *G. sahnii* the secondary veins arise from the midrib at nearly acute angles and form comparatively larger meshes of almost



TEXT-FIGS. 6, 7 — 6, *Glossopteris srivastavai* sp. nov., a single stoma from the lower epidermis.  $\times 500$ . 7, a line drawing showing reconstruction of the subsidiary cells of the stoma in Text-fig. 6.  $\times 500$ .



TEXT-FIG. 8 — 6 leaves of *Glossopteris tortuosa* arranged round an axis of *Vertebraria*.  $\times$  Nat. size.

equal size while this is not the case in *G. srivastavai*.

In *Glossopteris srivastavai* the cells of the lower epidermis have sinuous walls. This type of cell wall in the lower epidermis is known to occur in *Glossopteris angustifolia* Feist., *G. retifera*, *G. sahnii*, *G. colpodes* Pant, *G. hispida* Pant and *G. arberi* Srivastava. In *Glossopteris angustifolia* cells of both the surfaces have sinuous walls, those of lower epidermis are rectangular in shape and the number of subsidiary cells is 4-6, while in our species only the lower epidermis has cells with sinuous walls and they are of irregular shape. The number of subsidiary cells in *G. srivastavai* is 6-7. Morphologically too, they are distinct. *G. angustifolia* is a small leaf with narrow meshes while *G. srivastavai* is probably very big and has large meshes.

In the case of *G. retifera* both the epidermis have thin and sinuous-walled cells as against *G. srivastavai* which has comparatively thicker cuticle and the cells of only the lower surface have sinuous walls. Furthermore, the stomata of *G. retifera* are comparatively smaller in size.

Cuticle of *G. sahnii* is badly preserved, the cells of the epidermis are irregular, thin with sinuous walls and the two epidermis are not known separately.

As regards *G. arberi* the epidermal cells are thin-walled, elongated, rectangular with thin and sinuous or toothed-walls, whereas the cuticle of *G. srivastavai* is thick with only one surface having cells with sinuous walls and irregular in shape.

Besides marked difference in external form of *G. srivastavai* and those of *G. colpodes* and *G. hispida*, the epidermal characters of these species also differ markedly from each other. *G. srivastavai*, therefore, is a distinct species from all the known species of *Glossopteris*.

#### ANATOMY OF THE MIDRIB OF *G. SRIVASTAVAI*

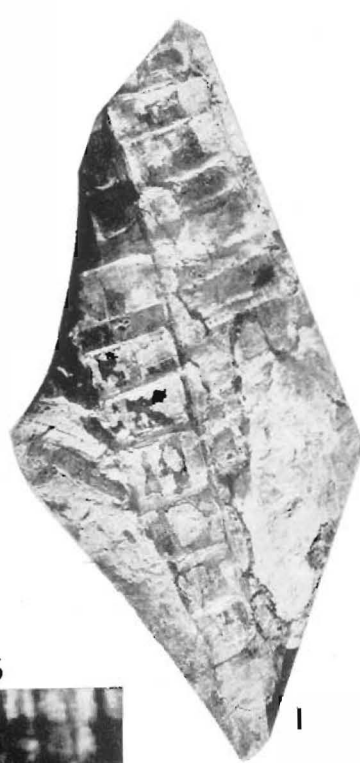
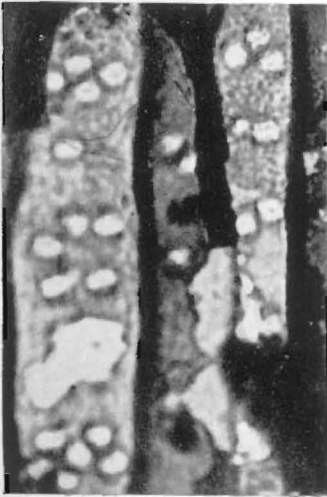
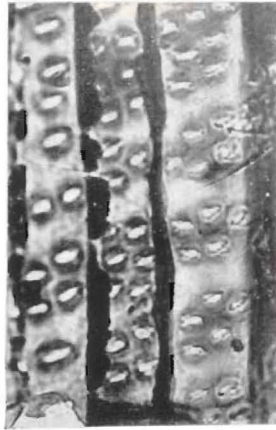
The midrib of *G. srivastavai* is very strong and thick. Srivastava (1954) studied the anatomy of the midrib from peel transfers, which strongly resembles the anatomy of *Vertebraria raniganjensis*. Both, the midrib of the leaf and the *Vertebraria* axis, show multiseriate, oppositely placed and grouped bordered pits on the radial walls of the tracheids. In both cases the pits more often are arranged in irregular or sometimes

stellate groups. In shape and size also the pits in the two cases are almost identical. Unpitted elements as observed in *V. raniganjensis* are also found in this midrib. Little is, however, known about the xylem rays and pits in the cross-field in the midrib of *G. srivastavai*, the only ray observed so far being two cells high. The anatomical structure of the midrib, though it shows certain resemblances with *V. indica* Royle, yet is different from it in regard to radial pitting and the absence of the parenchymatous cells in the midrib of *G. srivastavai*.

*Discussion* — Many a time in the past it had been suggested that *Vertebraria* is a rhizome which bore *Glossopteris* type of leaves. Zeiller (1896) was first to suggest this, then Oldham (1897) independently discovered a connection between *Vertebraria indica* and *Glossopteris*. Arber (1902) also noted continuity between *Glossopteris* and *Vertebraria* in a specimen from the Clarke collection. In 1910 Seward described *G. browniana* leaves attached to an axis of doubtful nature. Views supporting a connection between *Vertebraria* and *Glossopteris* were also expressed by Koidzumi (1933), Plumstead (1958) and Dolianiti (1954). Dolianiti described a *Vertebraria* axis with four pairs of leaves attached to it. But it may be said that from time to time opposite views have also been expressed. Etheridge (1904) denied any connection between *Vertebraria* and *Glossopteris*. Thomas (1952) described whorled leaves of *G. browniana* attached to an axis quite unlike that of *Vertebraria*. This, of course, is to be expected, for we now know that *Glossopteris* is not a single genus but a complex consisting of at least six different genera (SURANGE & SRIVASTAVA, 1956).

Recently from the East Raniganj coalfield a shale was collected which shows six *Glossopteris tortuosa* leaves arranged round an axis of *Vertebraria* (TEXT-FIG. 8). Though there is no actual organic connection between the leaves and the axis, yet the mode of preservation is such that one is tempted to believe that the leaves might have been actually attached on the axis.

In any case, on account of close similarity in the anatomical features of the midrib of *Glossopteris srivastavai* and the stem, *Vertebraria raniganjensis*, both occurring in the same coalfield, it becomes tempting to conclude that *V. raniganjensis* bore leaves of *G. srivastavai* type.



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## EXPLANATION OF PLATE I

*Vertebraria raniganjensis* sp. nov.

1. The fusinized axis of *Vertebraria raniganjensis*. ×  $\frac{1}{2}$ .
2. A part of secondary xylem in radial section showing 6-seriate pitting. × 500.
3. Tracheids in radial view showing grouped pits. × 500.
4. A part of the secondary xylem showing crossed apertures of the radial pits. × 500.
5. A part of the secondary xylem showing xylem rays spanning both the normally pitted tracheids and the unpitted elements. × 175.

6. An eight cell-high xylem ray in radial view. × 175.
7. Radial longitudinal view showing pits in the crossfield. × 500.

*Vertebraria myelonis* sp. nov.

8. The axis cast showing pith surrounded by the rectangular blocks. ×  $\frac{3}{2}$ .

*Glossopteris srivastavai* sp. nov.

9. Leaf of *Glossopteris srivastavai*. × *Nat. size*.