STUDIES IN THE GLOSSOPTERIS FLORA OF INDIA — 4. *GLOSSOPTERIS, GANGAMOPTERIS* AND *PALAEOVITTARIA* FROM THE RANIGANJ COALFIELD

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THE name *Glossopteris* was instituted by Brongniart for the large tongue-shaped leaves, which were dominant in the Lower Gondwana flora. So far about 40 species of this genus have been described by various authors. From India alone as many as 18 species are known, majority of which were described by Feistmantel. Since most of the species were founded before the cuticular technique was adopted by the palaeobotanists, species were created on the external characters alone, such as the shape, size and venation of the leaf. However, no two authors agree about the distinctive characters of any particular species and such examples are numerous in the literature. While Feistmantel gave new specific names to the leaves on very minor differences, Arber did not agree in multiplicity of the names. He, in fact, merged several of the *Glossopteris* species and reduced their number to 13 (ARBER, 1905, pp. 47, 48).

So far no serious attempts were made to study these leaves by cuticular methods, the only exceptions being that of Zeiller (1896) and Sahni (1923).

In the present work, cuticles of 14 Indian species of *Glossopteris* are described. *Glossopteris indica* (ZEILLER, 1896) and *Glossopteris angustifolia* (SAHNI, 1923) were repeated in order to find any new details. *Glossopteris angustifolia* did not reveal any new features worthy of note. The present study, therefore, confirms the observations of Professor Sahni. Leaves identified as *Glossopteris indica* from external characters did not yield cuticles similar to those described by Zeiller (1896), and hence,on the basis of different epidermal characters, these leaves have been separated from *Glossopteris indica* and described here under a new specific name, *Glossopteris arberi*.

As regards *Gangamopteris*, which is as widely distributed in the Permo-Carboniferous rocks of the Gondwanaland as *Glossopteris*, was instituted by McCoy in 1861. Earlier (1847) he had described a frond from New South Wales as *Cyclopteris*(?) *angustifolia* showing netted venation as in *Glossopteris*, but without a midrib. He referred this frond to (?)*Cyclopteris* with some hesitation, but at the same time thought that the difference in the venation is of generic importance. Later in 1861 he gave a new generic name, *Gangamopteris*, to these fronds. In India *Gangamopteris* is found more abundantly in the Talchir division and so far this genus has not been reported from the rocks younger in age than the Raniganj stage. The chief character in which *Gangamopteris* is supposed to differ from *Glossopteris* is the absence of a definite midrib. Instead, the median portion of the leaf is usually traversed by a group of almost parallel, anastomosing veins.

So far nearly 18 species of *Gangamopteris* have been described by various authors from different parts of the world. In the beginning McCoy himself described three species of *Gangamopteris* from Victoria. Later, Feistmantel created about nine more species from India, Australia and Tasmania. He also created several varieties within the species *Gangamopteris cyclopteroides*. Seward (1905) described one more species, *Gangamopteris kashmirensis* from India. Zalessky described about six species of *Gangamopteris* from Russia and Siberia. Arber (1905), however, thought that several of Feistmantel's species were indistinguishable from *Gangamopteris cyclopteroides*. So far epidermal structure of not even a single species of *Gangamopteris* is known.

In the following pages I have described cuticles of six species of *Gangamopteris* which are quite distinct from each other. Two of the specimens have been compared with *Gangamopteris cyclopteroides* and *Gangamopteris hughesi*. Two other specimens, which did not compare with any of the known species of *Gangamopteris* in the external as well as the cuticular characters, are described here under new specific names, *Gangamopteris indica* and *Gangamopteris flexuosa*. The remaining two specimens

which, although distinct from the other species of *Gangamopteris*, are very fragmentary and, therefore, they are described provisionally as *Gangamopteris* sp. A and (?)*Gangamopteris* sp. B.

Feistmantel (1876) instituted the third genus *Palaeovittaria* to describe certain leaves from the Raniganj coalfield which, according to him, showed resemblance with the fronds of the recent fern *Vittaria*. Only a single species of this genus is known. It was found first from the Raniganj group of the Damuda division, but later it has been recorded from the Rhaetic beds of Tonquin also. This genus is of uncertain systematic position. However, Feistmantel referred it to the family Taeniopteroideae.

The material for the present study was collected from the Raniganj coalfield, Bengal, and belongs to the Raniganj Stage. The specimens described here are compared with the type specimens of those species which are kept at the Geological Survey of India Museum, Calcutta. It is, therefore, presumed provisionally that the identifications of the species described below are correct.

A. GENUS *GLOSSOPTERIS* BRONGNIART

1. *Glossopteris browniana* Brongniart

Glossopteris browniana was instituted by Brongniart in 1828. Later on he distinguished two varieties within this species, *Glossopteris browniana* var. *indica* and *Glossopteris browniana* var. *australasica*. Schimper in 1869 raised the former to the specific rank, *Glossopteris indica* and the name *Glossopteris browniana* was retained for the leaves with open network and occurring more commonly in Australia.

Arber (1905, pp. 52-54) included under *Glossopteris browniana* the fronds of twelve *Glossopteris* species, described by various authors under different specific names. He thought that in view of the great variation met within the fronds of *Glossopteris browniana*, the above leaves did not warrant a separate specific designation.

There has been some confusion as regards the fronds of *Glossopteris browniana*, *Glossopteris indica* and *Glossopteris angustifolia*. As stated above, Schimper (1869) and Zeiller (1896) had already separated *Glossopteris indica* from *Glossopteris browniana*. Seward (1897) considered *Glossopteris angustifolia* as a variety of *Glossopteris browniana*, but Brongniart, Feistmantel and Zeiller maintained *Glossopteris angustifolia* as a separate species. On the other hand, Arber believed that the fronds of *Glossopteris angustifolia* were probably the narrower fronds, corresponding to *Glossopteris indica* (ARBER, 1905, p. 74). Plumstead (1952, p. 290) is inclined to believe that the leaves of *Glossopteris angustifolia* probably belong to *Glossopteris browniana*.

The present study of the cuticle of *Glossopteris browniana* and its comparison with the cuticles of *Glossopteris indica* described by Zeiller (1896), and *Glossopteris angustifolia* described by Sahni (1923) and confirmed by me shows that all the three fronds possess quite different and distinct epidermal characters. The present results, therefore, lend support to the idea of Schimper (1869) and Zeiller (1896) that the leaves of *Glossopteris indica* and *Glossopteris browniana* should be placed in separate species. It also supports the view of Brongniart, Zeiller and Feistmantel in maintaining *Glossopteris angustifolia* as a distinct species from both *Glossopteris browniana* and *Glossopteris indica*.

Leaf, Specimen No. 5633 — Leaf with carbonized crust well preserved, broken at the apical and the basal ends (PL. 1, FIG. 1). It appears to be broadest in the middle, tapering gradually towards both the ends. The midrib is stout, persisting, and with fine parallel striations, broader towards the base, measuring 3 mm. in width and tapering towards the apex. The incomplete impression of the leaf measures nearly 13 cm. in length and 4·5 cm. in breadth in the widest part. Secondary veins are slightly arched (PL. 1, FIG. 2) near the midrib, making a little more than 90° angle and reaching the margin at an open angle. The network is fairly open. The meshes are medium in size, elongate polygonal in shape and slightly larger and more distinct near the midrib than at the margins.

This specimen agrees with the descriptions and the figures of *Glossopteris browniana* given by Feistmantel (cf. FIGS. 1, 2 and FEISTMANTEL, 1881, Vol. III, Pt. 2, PL. 29A, FIG. 3). It compares in size and venation with a specimen of *Glossopteris browniana* numbered 5480 kept in the Geological Survey of India Museum at Calcutta.

Cuticle — The cuticles of both the surfaces are moderately thick, with network of the veins more prominent on the lower than the

upper surface. Stomata are present on both the surfaces but are very few in number on the upper surface.

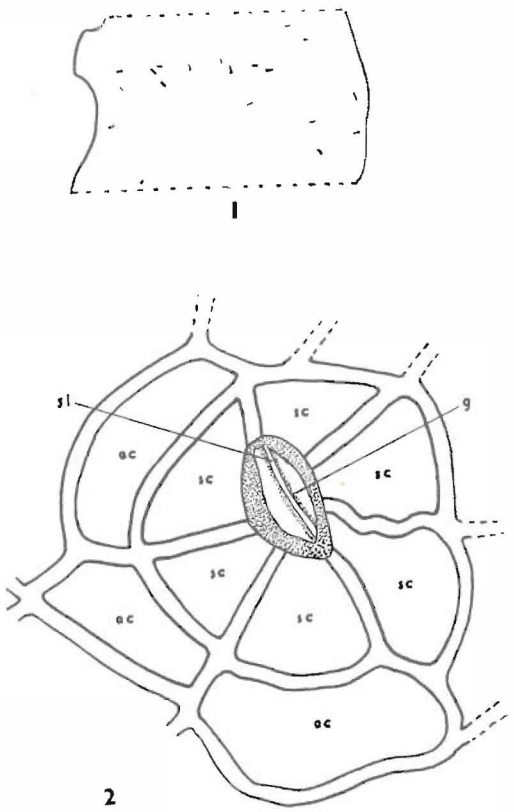
The cuticle of the upper surface (PL. 1, FIG. 4) shows the mesh areas bounded by narrow strips of elongated, rectangular cells covering the veins. The rectangular cells are arranged end to end and usually 2-3 times longer than broad. They are straight-walled and moderately thick. The cells of the mesh areas are 4 to 5-sided, straight-walled, moderately thick, irregular in shape and measure nearly 75×22 μ. In these areas sometimes a few stomata are found.

The cuticle of the lower surface (PL. 1, FIG. 5) is slightly thinner than the upper one. Here the mesh areas are more prominent on account of the presence of the stomata which are absent over the veins. The epidermal cells in the mesh areas are polygonal to irregular in shape, straight and thin-walled and measure about 64×30 μ. The cells over the veins are similar to those on the upper surface.

The stomata are haplocheilic, fairly crowded at some places but the distribution is not regular. They are also irregular in orientation (TEXT-FIG. 1). The adjacent stomata (PL. 1, FIG. 5) are sometimes contiguous. The stomatal apparatus is monocyclic but sometimes partly dicyclic. A stoma (PL. 1, FIG. 6; TEXT-FIG. 2) measures nearly 80 μ in diameter. The guard cells nearly 30 μ in length are slightly sunken and thickened. The thickening is seen round the stomatal opening also. Stomatal opening (pore), measuring nearly 21 μ in length, is seen as a slit in between the two guard cells. The subsidiary cells are polygonal and 5-7 in number, six being the most common number. Polar subsidiary cells probably vary in number from 2 to 4, and the rest are lateral.

Midrib — The upper cuticle of the midrib and the prominent secondary veins are very thick. The epidermal cells are more or less similar to those over the veins described above, but are more robust, thick-walled and dark brown in colour. The average thickness of the cell walls is 16 μ. These cells are devoid of stomata.

Leaf, Specimen No. 5639 — The specimen 5639 (PL. 1, FIG. 3) shows somewhat different nervation from the other two specimens, 5632 and 5633. The secondary veins in this specimen come out at a fairly acute angle from the midrib, forming quite broad



TEXT-FIGS. 1, 2 — *Glossopteris browniana*. 1, distribution and orientation of the stomata on the lower cuticle. × 32. 2, an enlarged drawing of the stoma. *g*, guard cells; *sl*, slit; *sc*, subsidiary cells; *ec*, encircling cells. These abbreviations are used in all the text-figs. × 542.

and open polygonal meshes of more or less uniform size throughout the lamina, whereas in the specimen 5633 the secondary veins come out at nearly right angles, forming meshes which are comparatively larger and broader near the midrib. This specimen compares closely with a specimen of *Glossopteris browniana* numbered 5257, kept at the Geological Survey of India Museum, Calcutta.

I first suspected that these two specimens belong to different species. But when I examined the cuticle of specimen 5639, it was strikingly similar to that of specimen 5633, except for the fact that a few lightly stained pieces of the upper cuticle showed some faint rounded marks on the surface of the

epidermal cells. The exact nature of these small marks is not clear. However, they are not a constant feature and appear to be rather apparent than real. The cuticles of the two specimens, therefore, show that although they differ from each other in a nervation and size, they belong to the same species.

In fact, Arber (cf. 1905, PL. II, FIGS. 1, 3) had already included both such types of leaves in *Glossopteris browniana*. These results further strengthen his view that *Glossopteris browniana* varies greatly in size, shape and the details of nervations.

Comparison — The controversy about the distinction between the fronds of *Glossopteris browniana*, *Glossopteris indica* and *Glossopteris angustifolia* has already been stated above. This controversy is almost set at rest when we compare the epidermal structures of the above-mentioned three species. Differences between the cuticles of *Glossopteris indica* and *Glossopteris angustifolia* have already been discussed by Sahni (1923, p. 278). They are not only of specific value but, according to Florin (1940, p. 6), the differences are also sufficiently great to be of generic value.

When the cuticles of *Glossopteris browniana* and *Glossopteris indica* as described by Zeiller are compared, it is seen that in the latter species the cuticle is very thick and the epidermal cells are short, rectangular, straight and thick-walled, whereas in *Glossopteris browniana* the cuticles are only moderately thick and the epidermal cells are elongately rectangular over the veins and polygonal to irregular in the meshes, straight and thin-walled. Again, in *Glossopteris indica* the stomata are sunken and arranged in linear rows with longitudinal orientation, whereas in *Glossopteris browniana* the stomata are present on both the surfaces, crowded and irregular in their distribution and orientation. We do not know the details of the stomatal apparatus in *Glossopteris indica*, but the differences pointed out above seem to be as great as between *Glossopteris indica* and *Glossopteris angustifolia*.

Similarly, a comparison between the cuticles of *Glossopteris browniana* and *Glossopteris angustifolia* reveals important differences. As opposed to *Glossopteris browniana* the upper cuticle of *Glossopteris angustifolia* does not show any marked arrangement of veins and meshes, the epidermal cells are sinuous and it is devoid of stomata. Moreover, in *Glossopteris browniana* the stomata are sometimes partly dicyclic, the subsidiary cells are non-papillate and the guard cells are thickened, whereas in *Glossopteris angustifolia*, the stomata are monocyclic, subsidiary cells papillate and the guard cells are thinly cutinized.

From cuticular studies, therefore, it appears that all the three species, *Glossopteris browniana*, *Glossopteris indica* and *Glossopteris angustifolia*, are quite distinct. If the differences between the cuticles of *Glossopteris indica* and *Glossopteris angustifolia* are to be regarded as of generic value, then the difference between *Glossopteris browniana* and *Glossopteris indica* and *Glossopteris angustifolia* should also be given the same importance.

2. *Glossopteris* cf. *divergens* Feistmantel

Feistmantel (1881, p. 104) based this species on two fragmentary specimens from Raniganj coalfield. Arber (1905, p. 89) also included this species in his catalogue of the Glossopteris flora but slightly modified the description given by Feistmantel. He laid great stress on the flexuous course of the secondary nerves as a distinctive character, which Feistmantel had not mentioned. However, Arber also pointed out that this feature may be due to an accident of preservation.

Leaf, Specimen No. 5634 — An incomplete impression (PL. 2, FIG. 7) of a leaf with well-preserved carbonized crust. It measures nearly 8 cm. in length and 2 cm. in breadth on one side of the midrib in the specimen. The leaf has a strong midrib, nearly 2·5 mm. wide. Secondary veins are very oblique and come out nearly at right angles to the midrib in the median portion of the frond, but slightly less obliquely towards the apical end. The course of the secondary nerves is sinuous as seen more clearly at the basal end of the specimen.

My specimen shows all the distinctive characters of *Glossopteris divergens*, although it differs in size of the secondary nerves and distances at which they arise on the midrib (cf. PL. 2, FIG. 7 and ARBER, 1905, FIG. 23, p. 89). On comparing my specimen with the type specimen of *Glossopteris divergens* numbered 5244 kept at the Geological Survey of India Museum, Calcutta, I found that the two specimens compare in size of the lamina, thickness of the midrib and nature of secondary venation but the secondary veins

in the G.S.I. specimen arise at a distance which is more than that in my specimen.

Cuticle — Cuticle obtained from this specimen shows a striking similarity with that of *Glossopteris browniana*. The cuticles are moderately thick. The stomata are confined to the meshes on both the surfaces.

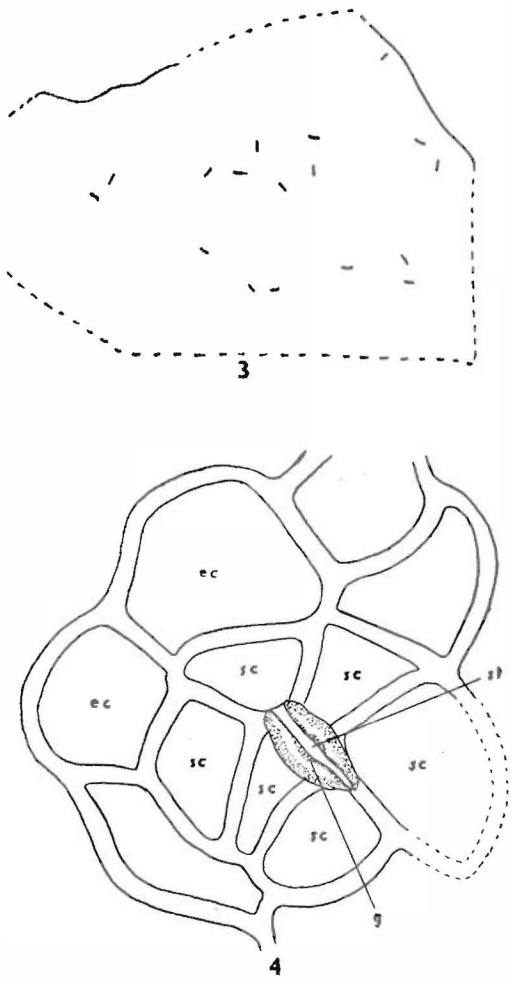
The upper cuticle (PL. 2, FIG. 9) is slightly thicker than the lower. The cells over the veins are rectangular, placed end to end, measuring nearly 80 × 30 μ. The cells in the areas of the meshes are irregular or elongately polygonal in shape, measuring nearly 72 × 20 μ. The walls of both the types of cells are moderately thick and straight. Stomata are very rare on this surface.

The lower cuticle (PL. 2, FIG. 10) is comparatively thinner and shows cells polygonal to irregular in shape in the mesh areas. The cells over the veins are similar to those on the upper surface. Stomata are present in large numbers.

Stomata are of the haplocheilic type. They are rather crowded but do not show any definite plan of distribution and are irregular in orientation (TEXT-FIG. 3). Adjacent stomata are sometimes contiguous. Stomatal apparatuses are monocyclic, sometimes perhaps partly dicyclic. A stoma (PL. 2, FIG. 11; TEXT-FIG. 4) measures nearly 80 μ. The guard cells measuring nearly 30 μ are slightly sunken and thickened. Subsidiary cells are polygonal, 5-6 in number, six being the most common number. A stoma with more than six subsidiary cells has not been observed in the pieces examined.

The cuticle of the upper and lower surfaces of the midrib shows epidermal cells which are short, squarish or rectangular in shape and are arranged end to end. The larger cells measure nearly 57 × 36 μ. The walls of these cells are fairly thick, measuring nearly 18 μ. These cells are devoid of stomata.

Comparisons — The cuticle of my specimen of *Glossopteris* cf. *divergens* is almost similar to that of *Glossopteris browniana* in shape, size and arrangement of epidermal cells in the lamina and the midrib, and in the orientation, distribution and structure of the stomata (cf. FIGS. 2 & 8; 4 & 9; 5 & 10; 6 & 11). The number of subsidiary cells in *Glossopteris browniana* are 5-7, but in *Glossopteris* cf. *divergens*, I did not get any stoma with more than 6 subsidiary cells. However, in both the most common number is six.



TEXT-FIGS. 3, 4 — *Glossopteris* cf. *divergens*. 3, distribution and orientation of the stomata on the lower cuticle. × 35. 4, an enlarged drawing of the stoma. × 517.

If my specimen belongs to *Glossopteris* cf. *divergens*, then it is obvious that this species should be merged with *Glossopteris browniana* on the basis of similarity in the epidermal characters.

3. *Glossopteris communis* Feistmantel

Feistmantel instituted this species in 1876 to describe certain larger and broader fronds, which he distinguished from *Glossopteris indica*. These leaves were characterized by the presence of crowded secondary veins,

forming longer and narrower meshes close to the midrib. Zeiller (1896) did not agree with Feistmantel, and he considered *Glossopteris communis* to be just a variation of *Glossopteris indica*. Arber also supported Zeiller and included the fronds of *Glossopteris communis* Feistmantel under *Glossopteris indica* Schimper (ARBER, 1905, p. 67).

The present study of the cuticles of *Glossopteris communis* and their comparison with those of *Glossopteris indica* as described by Zeiller shows that the two leaves possess distinct epidermal characters.

Leaf, Specimen No. 5650 — Impression of a leaf broken at the basal end and with well-preserved carbonized crust. The leaf has an acute apex and a distinct midrib. The midrib is broader in the basal part, thinning out towards the apical end and becoming very faint near the apex. The leaf as preserved in the specimen is nearly 12 cm. long and about 2·5 cm. broad at the widest part. The secondary veins (PL. 2, FIG. 12) come out at a fairly acute angle from the midrib. They are crowded and form very long and narrow meshes throughout the lamina.

This specimen agrees in shape and the details of venation with the figures given by Feistmantel (cf. FIGS. 16, 17 and FEISTMANTEL, 1881, Vol. III, Pt. 2, PL. 26A, FIG. 4). It compares with a specimen of *Glossopteris communis* numbered 5229, kept at the Geological Survey of India Museum, Calcutta, except in the breadth of the lamina which is slightly more in the G.S.I. specimen.

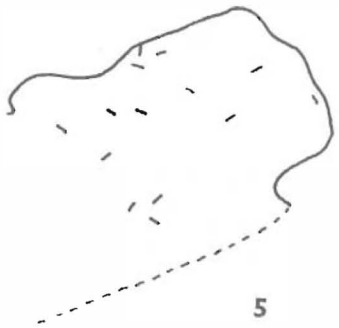
Cuticle — The cuticles are moderately thick and the stomata are present on both the surfaces. What strikes the eye at once is the close network of the veins, as revealed by the arrangement of the cells on both the surfaces.

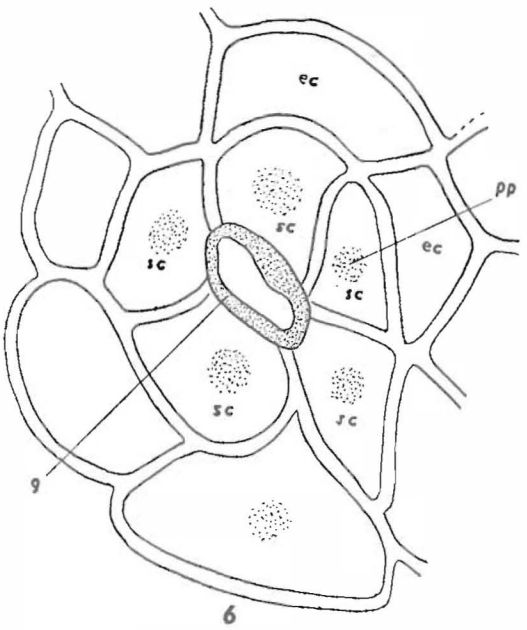
The epidermal cells on the upper side (PL. 2, FIG. 13) are rectangular or squarish over the veins and polygonal in the meshes. The cells over the veins measure about 87 × 28 μ. The veins are 2-3 cells wide and often show anastomosing. The cells in the mesh areas are polygonal or elongately polygonal, straight and thin-walled and measure about 65 μ. Few stomata are present.

The cells of the lower epidermis (PL. 3, FIG. 14) are similar to those on the upper-side, but the arrangement of the veins and the meshes is more distinct. Also the stomata are present in large numbers.

The stomata are of the haplocheilic type. On both the surfaces they are confined to the meshes. They are not evenly distributed but are often seen occurring in groups of four or five. Adjacent stomata are sometimes contiguous. The orientation of the stomata is irregular (TEXT-FIG. 5). The stomata are monocyclic, but sometimes they show dicyclic condition (PL. 3, FIG. 15).

A stoma (TEXT-FIG. 6) measures about 75 μ in diameter. The two guard cells,





TEXT-FIGS. 5, 6 — *Glossopteris communis*. 5, distribution and orientation of the stomata on the lower cuticle. × 52. 6, an enlarged drawing of the stoma. *pp*., papilla. × 639.

measuring about 40 μ in length, are thickened. Stomatal opening (pore), measuring nearly 18 μ in length, is sometimes seen as a slit in between the two guard cells. The subsidiary cells are polygonal, 4 to 7 in number, the most common number being five or six. In each subsidiary cell a dark, rounded, deeply stained mark is often seen, which may probably be a papilla (TEXT-FIG. 6).

The upper cuticle of the midrib (PL. 3, FIG. 16) shows long, narrow, rectangular cells, arranged end to end, measuring 72 × 28 μ. The walls of these cells are nearly 8 μ thick. They are devoid of stomata. The lower cuticle of the midrib shows arrangement of veins and meshes as in the lamina but the cells on the veins are slightly thick-walled.

Comparison — The conflicting opinion regarding the specific status of *Glossopteris communis* and *Glossopteris indica* is stated above. When the cuticles of both the species are compared, they appear to be separate and distinct.

In *Glossopteris indica* the cuticle is thick and epidermal cells short, rectangular, straight and thick-walled, whereas in *Glossopteris communis* the cuticles are moderately thick, showing well-marked anastomosing of the veins on both the surfaces and straight, thin-walled cells, elongately rectangular over the veins and polygonal in the meshes. Moreover, as opposed to the sunken, longitudinally oriented stomata of *Glossopteris indica* arranged in linear rows, the stomata in *Glossopteris communis* are not sunken and are present on both the surfaces, distributed in groups, showing irregular orientation. Details of the stomatal apparatus are not known in *Glossopteris indica*, but these differences are sufficiently great to distinguish *Glossopteris communis* from *Glossopteris indica*.

On the other hand, the cuticles of *Glossopteris communis* show certain similarities with the cuticles of *Glossopteris browniana*. The two species compare with each other in having moderately thick cuticles with prominent arrangement of veins and meshes and the presence of stomata on both the surfaces in the areas of the meshes. Besides, the stomata in both species show monocyclic to partly dicyclic condition and irregular orientation. Number of subsidiary cells in the two species range from 4 to 7. However, the two species differ from each other in the details of the shape and size of the epidermal cells and the structure and distribution of the stomata. In *Glossopteris browniana* the cells in the mesh areas are mostly irregular in shape and of large size, but in *Glossopteris communis* the cells in the mesh areas are always polygonal and slightly smaller than those in *Glossopteris browniana*. However, in *Glossopteris browniana* the stomata are irregularly distributed and their subsidiary cells are non-papillate, but in *Glossopteris communis* the stomata sometimes occur in groups and their subsidiary cells are papillate.

Thus, from the comparison of the cuticles of *Glossopteris communis* with *Glossopteris browniana*, it appears that the difference, although sufficient for specific separation of the two, is not as great as that between *Glossopteris communis* and *Glossopteris indica*. On the basis of the epidermal characters *Glossopteris communis* comes much closer to *Glossopteris browniana* than to *Glossopteris indica*.

4. *Glossopteris communis* var. *stenoneura*

Feistmantel (1877) described some leaves usually smaller in size, oval to spathulate in shape, with a stout midrib, which formed a stalk in the basal portion, under a new specific name, *Glossopteris stenoneura*. In 1880 he, however, included this species in *Glossopteris communis* as a variety, for in venation these leaves did not differ from the larger leaves of *Glossopteris communis*. Arber (1905, p. 67) did not think it worthwhile even to recognize it as a separate variety.

A study of the cuticle of this leaf shows that it is similar to that of *Glossopteris communis*.

The specimen is described below to show its similarity with *G. communis*.

Leaf, Specimen No. 8664 — An incomplete specimen of a leaf with badly preserved carbonized crust. The basal portion of the leaf is complete (PL. 3, FIG. 17) but the upper half is broken. The midrib in the basal portion forms a narrow stalk, but gradually becomes faint towards the apical end. The preserved portion of the leaf, including the stalk, measures nearly 6·5 cm. in length and 2 cm. in breadth. The stalk measures 1·5 cm. in length and 3 mm. in breadth. The secondary veins (PL. 3, FIG. 18) come out at a very acute angle from the midrib and form very long and narrow polygonal meshes similar to those in *Glossopteris communis*.

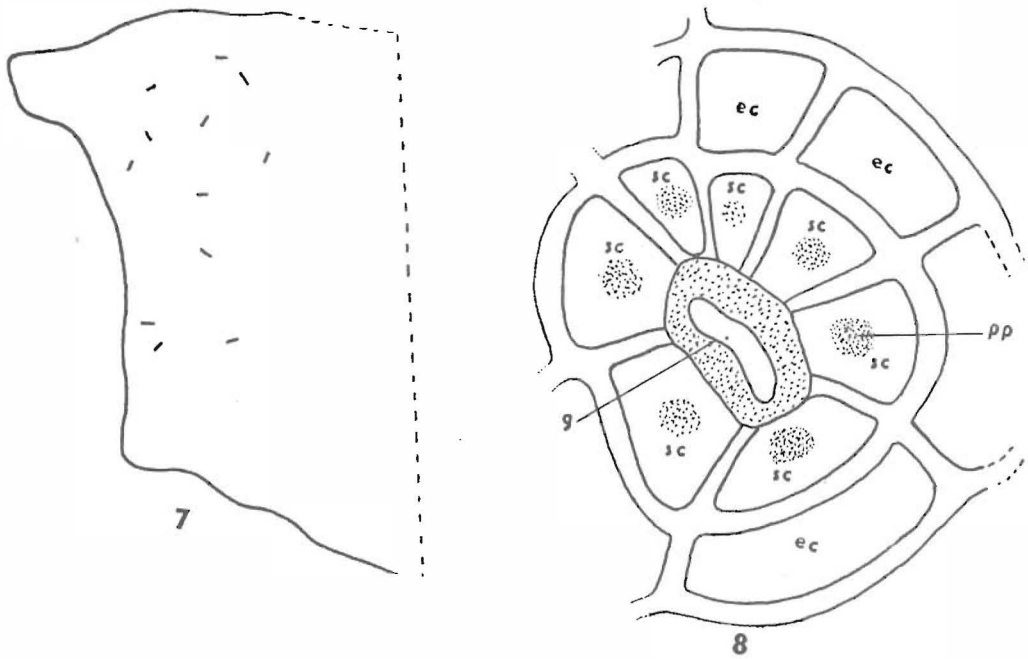
This leaf agrees with the description and the figures of *Glossopteris communis* var. *stenoneura* given by Feistmantel (cf. Fig. 17 and Feistmantel, 1881, Vol. III, Pt. 2, Pl. 38A, Fig. 5). It closely compares with a specimen of *Glossopteris communis* var. *stenoneura* numbered 5289 kept at the Geological Survey of India Museum, Calcutta. My specimen represents the lower portion of the frond.

Cuticle — The cuticles on both the surfaces are moderately thick as in *Glossopteris communis*. The arrangement of veins and meshes is more distinct on the lower surface. Stomata occur on both the surfaces, although they are much less in number on the upper side.

The epidermal cells of the upper cuticle (Pl. 3, Fig. 19) are rectangular or polygonal. The cells over the veins are thin-walled, rectangular, 2-3 cells wide and placed end to end. They are usually longer than broad, measuring 80-90 μ in length and 25-30 μ in breadth. In the areas of the meshes the cells are polygonal or elongately polygonal. Some of the longer cells measure nearly 70×32 μ. All the cells are thin and straight-walled. Stomata are sometimes seen in the mesh areas but are absent over the veins.

The epidermal cells on the lower surface (Pl. 3, Fig. 20) are similar to those on the upper side. Here the stomata are found in fairly good numbers and are confined to the areas of the meshes. The stomata are of the haplocheilic type, generally distributed in groups, showing irregular orientation (Text-fig. 7). Adjacent stomata are sometimes contiguous. Some stomata perhaps (Text-fig. 8) show partly dicyclic condition. A stoma measures nearly 75 μ in diameter. The two guard cells, nearly 30 μ in length, are thickened. They sometimes show a slit-like pore in the centre. Subsidiary cells are 5-7 in number. A stoma having less than five subsidiary cells has not been observed here. The subsidiary cells are polygonal in shape and in each (Text-fig. 8) is often seen a dark, rounded, deeply stained mark which appears to be a papilla.

Comparison — A comparison of these cuticles with those of *Glossopteris communis* shows that the two are almost identical in shape, size and arrangement of the epidermal



Text-figs. 7, 8 — *Glossopteris communis* var. *stenoneura*. 7, distribution and orientation of the stomata. × 72. 8, an enlarged drawing of the stoma. × 639.

cells, orientation and distribution of the stomata and the structure of the stomatal apparatuses.

It is, therefore, not necessary to maintain this as a separate variety of *Glossopteris communis*.

5. *Glossopteris conspicua* Feistmantel

Feistmantel instituted this species in 1881 to describe some fronds, spathulate or oval-lanceolate in shape with very large, open, elongate meshes of approximately equal size throughout the lamina. These leaves differ from *Glossopteris formosa*, which possess almost similar venation, in being bigger and broader in size. From *Glossopteris retifera* the leaves of *Glossopteris conspicua* differ in having transversely elongate and much longer than broad meshes. *Glossopteris conspicua* is reported from India, South Africa and New South Wales.

Leaf, Specimen No. 9368 — Incomplete impression of a leaf (locality Kalipahari area, Raniganj coalfield) with carbonized crust well preserved (Pl. 4, Fig. 21). The apical portion is more or less complete but the margins and the basal part is broken in the specimen. The leaf has an obtuse apex and a distinct midrib, which is stout in the basal region, nearly 2 mm. wide, thinning out towards the apex. The preserved portion of the leaf measures nearly 9 cm. in length and 3 cm. in breadth.

Secondary veins (Pl. 4, Fig. 22) come out at an acute angle from the midrib and form large, open, elongate meshes of equal size, nearly 1 cm. in length throughout the lamina. Meshes are oblong-polygonal, transversely elongate, much longer than broad.

This specimen agrees in venation with the description and the figures of *Glossopteris conspicua* given by Feistmantel (cf. Figs. 21, 22 and Feistmantel, 1881, Vol. III, Pt. 2, Pl. 28A, Fig. 9). In venation my specimen compares with two specimens of *Glossopteris conspicua* numbered 5247 and 5250, kept at the Geological Survey of India Museum, Calcutta.

Cuticle — The cuticles are quite thick on both the surfaces. The stomata are confined to the lower surface only. The arrangement of veins and meshes, as seen in some other species of *Glossopteris*, is not apparent.

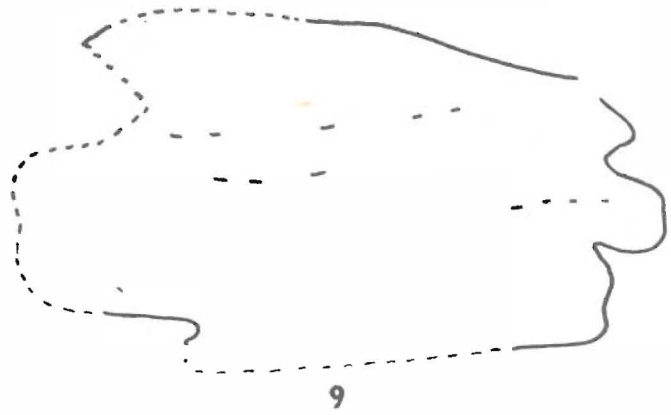
The epidermal cells of the upper surface are rectangular, much longer than broad, placed end to end. Some of the longer cells measure as much as 132 × 37 μ. The cells possess dark brown walls which are straight and very thick, sometimes with a narrow lumen.

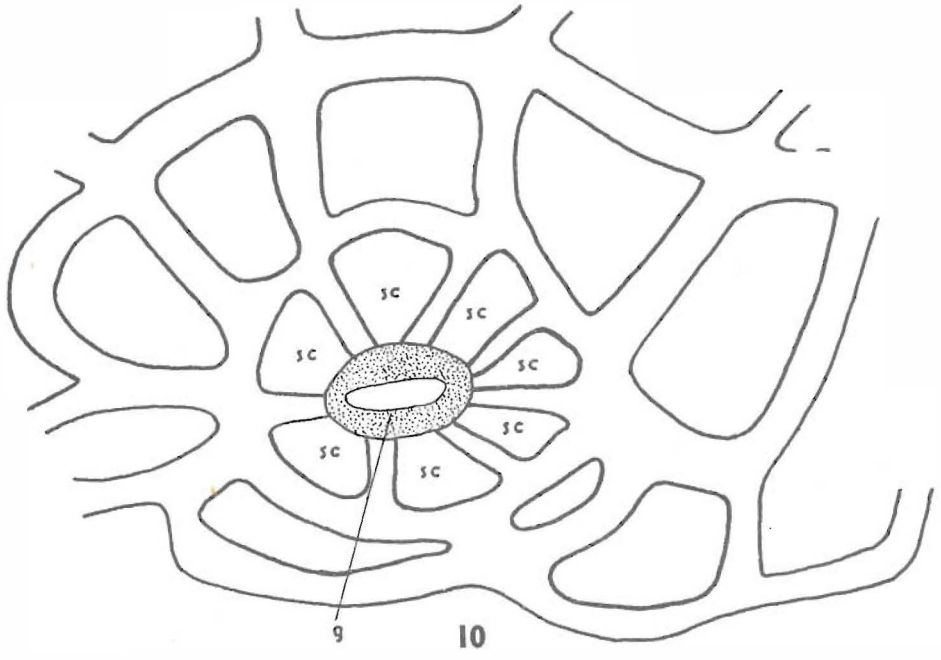
The cuticle of the lower surface (Pl. 4, Fig. 23) possesses squarish or polygonal cells which are isodiametric and smaller in size than the cells on the upper epidermis, measuring nearly 60 μ. The walls of these cells are straight and nearly as thick as those of the cells of the upper epidermis. But after a prolonged maceration the cell walls loose their thickness, presenting beautiful polygonal outlines (Pl. 4, Fig. 24). A faint idea about the arrangement of the veins in the lower cuticle is obtained at places by the presence of squarish cells placed end to end in narrow strips.

The stomata (Pl. 4, Fig. 25; Text-fig. 10) are not very apparent at the first glance. They are smaller in size, sunken and tend to merge with the other epidermal cells. The stomata are haplocheilic and occur among polygonal cells. They are distributed in linear rows and have longitudinal orientation (Text-fig. 9). The adjacent stomata are found 1-2 cells apart longitudinally and 3-4 cells apart transversely. The stomatal apparatus, measuring nearly 90 μ, shows monocyclic condition. The guard cells measure 25 μ in length. They are sunken and thickened. Stomatal opening is visible in between the two guard cells. The subsidiary cells vary from 5 to 7, six being the common number. They are polygonal in shape and much smaller in size than the other epidermal cells.

Comparison — The controversy as regards the specific identity of *Glossopteris conspicua* and *Glossopteris formosa* is stated on page 11. The cuticles of *Glossopteris conspicua* are, however, widely different from those of *Glossopteris formosa*. A detailed comparison of the cuticles of the two species is given on page 11.

Glossopteris conspicua shows some similarity with *Glossopteris indica* in the epidermal characters. In both the species the cuticles are thick, having very thick-walled epidermal cells. The stomata are also sunken and distributed in linear rows, showing longitudinal orientation. However, they differ from each other considerably in the shape and size of the epidermal cells. In *Glossopteris indica* the epidermal cells are short and rectangular in shape and the stomata occur in between these cells in longitudinal rows,





TEXT-FIGS. 9, 10 — *Glossopteris conspicua*. 9, distribution and orientation of the stomata. × 20. 10, an enlarged drawing of the stoma from the lower cuticle. × 650.

whereas in *Glossopteris conspicua* the epidermal cells are very long and rectangular, measuring about 132 × 37 μ on the upper surface and polygonal on the lower surface. Stomata are absent in the rectangular cells of the upper surface, but are present in the polygonal cells on the lower surface.

6. *Glossopteris formosa* Feistmantel

Feistmantel instituted this species in 1881, to describe some narrow, linear fronds with broad, oblong-polygonal meshes of uniform size throughout the lamina. Arber (1905, p. 88) believed *Glossopteris formosa* to be a narrow leaf type corresponding to *Glossop-*

teris retifera or *Glossopteris conspicua*. The present study of the cuticles of *Glossopteris formosa* shows that its epidermal characters are quite different from *Glossopteris conspicua* and *Glossopteris retifera*. *Glossopteris formosa* should, therefore, be retained as a distinct species.

More than a dozen specimens of this species were examined, out of which the cuticles have been studied from four specimens 9333, 9339, 5637 and 5639. The last-mentioned specimen has the broadest lamina of all the *Glossopteris formosa* leaves in my collection, measuring more than 2 cm. in breadth. It has also yielded identical cuticles. Feistmantel (1882, p. 36) described some broad leaves of *Glossopteris formosa* from South Rewa as a separate variety, namely, *major*, but Arber (1905, p. 87) included this in *Glossopteris formosa*. The result of the cuticular study of broad and narrow forms of *Glossopteris formosa* shows that they are identical and, therefore, it is not necessary to distinguish broader leaves of *Glossopteris formosa* from the rest.

Leaf, Specimen No. 5637 — Impression of a leaf (locality Samla area, Raniganj coalfield) with carbonized crust preserved. The apical portion is almost complete but the basal portion is broken (Pl. 4, Fig. 26). The leaf has an obtuse apex and a midrib persisting to the apex. The midrib shows parallel longitudinal striations and measures about 2 mm. in breadth in the basal region. The length of the preserved portion of the leaf is about 10 cm. and the breadth is 1·2 cm. Secondary veins (Pl. 4, Fig. 27) arise from the midrib at very acute angles, forming broad, open, polygonal meshes of almost equal size, throughout the lamina. The meshes measure approximately 1 cm. in length and 1 mm. in breadth.

This specimen agrees in form and venation, with the drawings and description of *Glossopteris formosa* given by Feistmantel (cf. Figs. 26, 27 and Feistmantel, 1881, Vol. III, Pt. 2, Pl. 39A, Figs. 5, 7). It compares with a specimen of *Glossopteris formosa* numbered 5294, kept at the Geological Survey of India Museum, Calcutta.

Cuticle — The cuticles of both the surfaces are moderately thick and show a distinct network of veins, enclosing the meshes. Stomata are present both on the lower and the upper sides.

The cuticle of the upper surface (Pl. 5, Fig. 29) is comparatively thicker than the lower one, but the veins showing frequent anastomosing are equally prominent. The veins are 2-3 cells wide and the cells are usually rectangular, narrow, much longer than broad, measuring 72 × 18 μ. These cells are arranged end to end and possess straight and moderately thick walls. The cells in the meshes are large, irregular or sometimes polygonal in shape. The walls of the cells are straight but slightly thinner than those of the cells over the veins. Stomata, which occur in fairly good numbers, are confined to the meshes and absent over the veins.

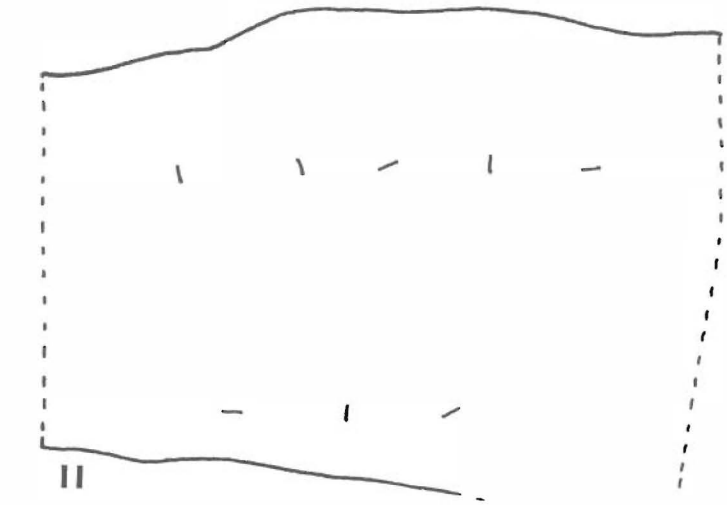
The cuticle of the lower surface (Pl. 5, Fig. 30) shows almost similar nature and arrangement of cells as on the upper surface. But it is slightly thinner and the stomata are present here in comparatively greater number than on the upper surface.

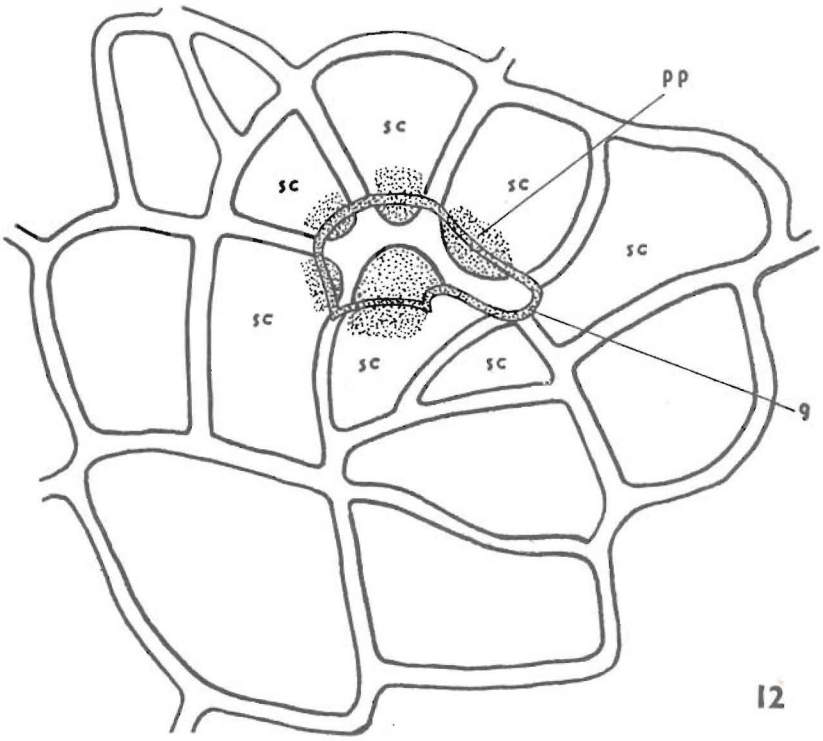
The stomata which are of the haplocheilic type occur in single or sometimes double linear rows within the mesh areas (Pl. 5, Fig. 30). Generally, the adjacent stomata are found 2-3 cells apart longitudinally, but at times they are found contiguous as well. They show irregular orientation (Text-fig. 11). The stomatal apparatuses show monocyclic or sometimes dicyclic condition, the subsidiary cells being completely or partly surrounded by a row of encircling cells. A stoma (Pl. 5, Fig. 31; Text-fig. 12) measures about 90 μ. The two guard cells, about 29 μ in length, are not very thickly cutinized. The subsidiary cells are papillate, polygonal, 4 to 7 in number, the more common number being either five or six. The papillae are seen overhanging the margins of the guard cells. In some stomata the pore is visible as a linear slit.

The cuticle of the upper surface of the midrib is very thick. It shows rectangular, elongated cells, arranged in rows. The cell walls are very thick, about 15 μ. Stomata are not found on this surface.

The cuticle of the lower surface of the midrib (Pl. 4, Fig. 28) is comparatively thinner. The cells over the veins are 5 to 6 cells wide, slightly thick-walled, squarish or rectangular and arranged end to end. They do not seem to anastomose. The cells in the meshes are polygonal. Stomata are present in the meshes but are very few in number.

Comparison — Some confusion prevails as regards the identity of *Glossopteris formosa*, *Glossopteris conspicua* and *Glossopteris retifera* (*see* p. 13).





TEXT-FIGS. 11, 12 — *Glossopteris formosa*. 11, distribution and orientation of the stomata. × 90. 12, an enlarged drawing of the stoma. *pp*., overhanging papillae. × 700.

A comparison of the fronds of *Glossopteris conspicua* with *Glossopteris formosa* shows that they differ externally only in their size, otherwise the form and venation is almost similar in both the species. However, the cuticles differ widely in the two

species. In *Glossopteris conspicua* the cuticles are very thick, with thick-walled epidermal cells of rectangular or polygonal shape, showing no signs of veins and meshes, but in *Glossopteris formosa* the cuticles are only moderately thick, showing well-marked network of veins and meshes. In *Glossopteris formosa* the cells are thin-walled, rectangular in shape over the veins and polygonal to irregular in the mesh areas. The cuticles of the two species further differ from each other in the structure and orientation of the stomata. In *Glossopteris conspicua* the stomata are monocyclic, sunken, with thickened guard cells, showing longitudinal orientation, whereas in *Glossopteris formosa* the stomata, showing irregular orientation, are sometimes partly dicyclic and not sunken. Moreover, their guard cells are not much thickened and the subsidiary cells possess papillae which hang over the guard cells.

On the other hand, the cuticles of *Glossopteris formosa* show a great deal of similarity with the cuticles of *Glossopteris browniana* and *Glossopteris communis*. The three species are similar in having moderately thick cuticles, showing distinct arrangement of veins and meshes, possessing stomata on both the surfaces, which are partly dicyclic and irregularly oriented. However, the three differ from one another in details. The differences between *Glossopteris browniana* and *Glossopteris communis* have already been discussed (p. 7). The cuticles of *Glossopteris formosa* differ from the other two species in possessing stomata in fairly large numbers on the upper surface, whereas they are very rare both in *Glossopteris browniana* and *Glossopteris communis*. Also, the stomata in *Glossopteris formosa* are arranged in linear rows as opposed to their irregular arrangement in groups in *Glossopteris browniana* and *Glossopteris communis*. Lastly, the stomata in *Glossopteris formosa* possess guard cells which are not much thickened but in the other two species the guard cells are thickened.

In external characters, especially the nervation, the leaves of *Glossopteris formosa* differ very widely from those of *Glossopteris communis* and *Glossopteris browniana*. But the general similarity of the epidermal characters between the three, in contrast to the differences in their external characters, is very interesting. On the other hand, the leaves of *Glossopteris formosa* and *Glossopteris conspicua* are very similar in external form and nervation but the differences between their cuticles are not only sufficiently great to separate them specifically, but also to warrant their inclusion in separate groups, perhaps of the generic rank.

7. *Glossopteris retifera* Feistmantel

This species was instituted by Feistmantel in 1880 for some fronds of medium size having broadly polygonal meshes of approximately equal size throughout the lamina. Unlike *Glossopteris conspicua* and *Glossopteris formosa*, the meshes in *Glossopteris retifera* are not much longer than broad. Arber (1905) included under this species the fronds of *Sagenopteris polyphylla* and (?)*Glossopteris tatei*, described by Feistmantel in 1876 and 1879 respectively. He also believed that *Dictyopteris* (*?simplex*) described by Tate in 1867 also compared with *Glossopteris retifera* in the nature of the meshes. Previously this species was reported only from India, but later it was found from several other countries like South Africa and Argentina.

The study of the cuticles of *Glossopteris retifera* and their comparison with the cuticles of *Glossopteris conspicua* and *Glossopteris formosa* shows that the cuticles of *Glossopteris retifera* are very distinct from the cuticles of the other two species, with which the leaves of *Glossopteris retifera* show some similarity in venation. *Glossopteris retifera* should, therefore, be retained as a separate species.

Leaf, Specimen No. 9357 — An incomplete impression representing the upper part of a leaf with poorly preserved carbonized crust (Pl. 5, Fig. 32). The leaf appears to be of medium size and lanceolate shape with acute apex. Midrib is broad towards the basal end, becoming thinner towards the apex. The preserved portion of the leaf measures 6 cm. in length and 2 cm. in breadth. Secondary veins (Pl. 5, Fig. 33) come out from the midrib at an acute angle. They are arched, forming open, broadly polygonal meshes of uniform size throughout the lamina. The meshes are not much longer than broad.

This specimen agrees with the description and figures of *Glossopteris retifera* given by Feistmantel (cf. Pl. 5, Figs. 32, 33 and Feistmantel, 1881, Vol. III, Pt. 2, Pl. 28A, Figs. 2, 7). It compares with a specimen of *Glossopteris retifera* numbered 5248, kept at the Geological Survey of India

Museum, Calcutta. Only the G.S.I. specimen has a slightly broader lamina.

Cuticle — This specimen did not yield well-preserved cuticles. However, a few pieces were obtained which revealed the following information.

The cuticles on both the surfaces of the lamina are rather thin and do not show the arrangement of the veins and meshes. Stomata are not very apparent. They are present on the lower surface only.

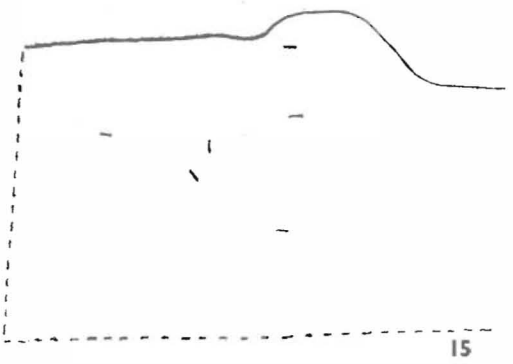
The cuticle of the upper surface (PL. 5, FIG. 34; TEXT-FIG. 13) is slightly thicker than that of the lower surface. It shows rectangular cells which are much longer than broad, measuring nearly 120 × 30 μ. These cells are arranged end to end in rows. The lateral walls of the cells are thin and sinuous. The dividing walls of the cells are not always straight, more commonly they are oblique. Stomata are not seen on this surface.

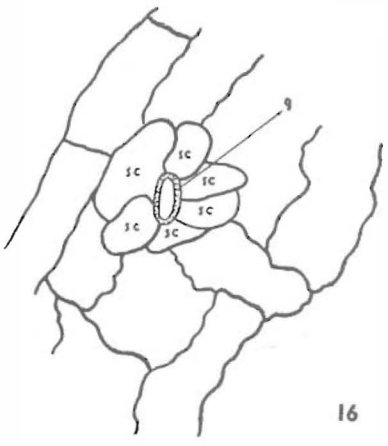
The cuticle of the lower surface (TEXT-FIG. 14) is comparatively thinner, but the epidermal cells are similar to those on the upper surface. The epidermal cells on this surface are, however, faintly marked and their walls are very thin. Stomata are present.

Stomata are of the haplocheilic type, they are irregular in distribution and orientation (TEXT-FIG. 15). The stomatal apparatuses show monocyclic condition. A stoma (PL. 5, FIG. 35; TEXT-FIG. 16) is very small in size, measuring nearly 36 μ. Two guard cells forming an elliptical area are only 16 μ long. They are thinly cutinized. Subsidiary cells are probably 6 in number, 2 polar and rest lateral. They are smaller in size than the neighbouring epidermal cells and irregular in shape with slightly sinuous walls.

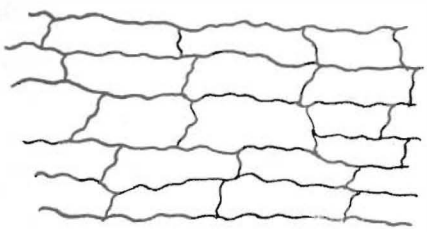
The cuticle over the midrib and the prominent secondary veins (PL. 5, FIG. 36) are nearly as thick as that of the upper surface of the lamina. The narrow epidermal cells are about 3 times longer than broad, measuring 108 × 36 μ. The walls of these cells are comparatively thicker and more or less straight.

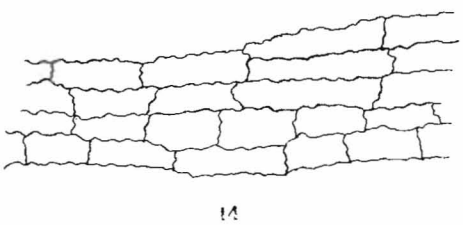
Comparison — The leaves of *Glossopteris retifera* were also thought to be similar to those of *Glossopteris formosa* on the basis of





TEXT-FIGS. 15, 16 — *Glossopteris retifera*. 15, distribution and orientation of the stomata. × 101. 16, an enlarged drawing of a stoma. × 540.





TEXT-FIGS. 13, 14 — *Glossopteris retifera*. 13, epidermal cells of the upper cuticle × 168. 14, epidermal cells of the lower cuticle. × 168.

external characters, especially the secondary nervation. But a comparison of their cuticles shows that the two are widely different from each other. In contrast to the moderately thick cuticles of *Glossopteris formosa* showing well-marked arrangement of veins and meshes, the cuticles in *Glossopteris retifera* are thin and do not show any arrangement of veins and meshes. In *Glossopteris formosa* the epidermal cells are straight-walled, rectangular or polygonal in shape and usually not much longer than broad, whereas in *Glossopteris retifera* all the epidermal cells have sinuous walls and are very long, narrow and rectangular. Moreover, the two cuticles differ in the structure and distribution of the stomata. In *Glossopteris formosa* we find the stomata occurring on both the surfaces, sometimes showing partly dicyclic condition, whereas in *Glossopteris retifera* the stomata are confined to the lower surface only and they show monocyclic condition.

From epidermal characters, therefore, these two species appear to be quite distinct.

8. *Glossopteris damudica* Feistmantel

This species was instituted by Feistmantel in 1887 to describe some very large and broad fronds showing pseudo-parallel venation. Arber (1905, pp. 78, 79) included this species, along with four others, in the Australian form, *Glossopteris ampla* Dana. He, however, pointed out that the Indian fronds of *Glossopteris damudica* differed from the Australian specimens in having more acute nervation, but did not attach any importance to this character.

I have described the cuticles of my specimen under the Feistmantel's name *Glossopteris damudica*, because I believe that the cuticular study of the leaves of *Glossopteris ampla* and its comparison with the cuticles of the Indian fronds should better solve this problem.

Leaf, Specimen No. 5639 — An incomplete impression of a long leaf with carbonized crust preserved at some places (Pl. 6, Fig. 37). The apical and the basal portions of the leaf are broken in the specimen. It shows contraction towards the basal region and broadens out towards the apical end. The leaf in the specimen measures nearly 20 cm. in length and 4·8 cm. in breadth in the widest part. It has a stout midrib, measuring nearly 3 mm. with parallel longitudinal striations. The midrib slightly thins out towards the apical end.

The secondary veins are arched near the midrib. They form one or two series of broad and short meshes close to the midrib and then subdivide into a number of close, almost parallel veins which are often oblique. The subparallel veins form extremely narrow elongate meshes throughout the whole lamina.

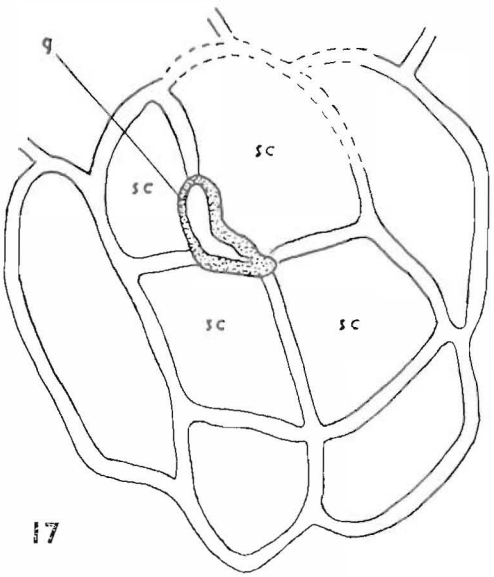
This specimen agrees with the description and drawings of *Glossopteris damudica*, given by Feistmantel (cf. Pl. 6, Fig. 37 and Feistmantel, 1881, Vol. III, Pt. 2, Pl. 31A, Fig. 1 and Pl. 40A, Fig. 6). It compares with a specimen of *Glossopteris damudica*, numbered 5623, kept at the Geological Survey of India Museum, Calcutta. However, the G.S.I. specimen is slightly broader than my frond.

Cuticle — The cuticles of the upper and the lower sides of the leaf are distinct because of their different thickness. Stomata are present only on the lower surface of the leaf.

The cuticle of the upper surface (Pl. 6, Figs. 38, 39) is very thick, with small squarish or polygonal cells, measuring about 19 μ. The walls of these cells are straight and thick. The areas of the veins and meshes are not marked. Stomata are absent on this surface.

The cuticle of the lower surface (Pl. 6, Figs. 40, 41) is much thinner than the cuticle of the upper side. The epidermal cells in the areas of the meshes are well marked from those in the areas over the veins. In the areas of the meshes the cells are large, polygonal, measuring about 66 μ in size. The cells over the veins occur in single or double rows, and are placed end to end. They are rectangular in shape, measuring nearly 51 × 22 μ. The walls of the cells, both in the areas of the meshes and the veins, are straight and thin. The stomata, which are of the haplocheilic type, occur in the areas of the meshes. In the cuticular pieces obtained from this specimen, they appear to be rather few in number and sparsely distributed. A stoma (Text-fig. 17) shows monocyclic condition. It measures about 62 μ. The guard cells which are slightly thickened measure nearly 22 μ in length. The stomatal opening is visible in the form of a slit in between the two guard cells. Subsidiary cells are probably 4-5 in number, they are slightly smaller than the other epidermal cells and are polygonal in shape.

The cuticle of the midrib is slightly thick showing long and narrow rectangular cells measuring 57 × 18 μ. The walls of these



TEXT-FIG. 17 — *Glossopteris damudica*. An enlarged drawing of a stoma from the lower cuticle. × 720.

cells are slightly thickened, measuring nearly 11 μ in thickness Stomata are not present in these cells

9. *Glossopteris intermittens* Feistmantel

Feistmantel instituted this species in 1881 to describe some fronds of medium size, having a rounded or broadly pointed apex and slightly contracted base. All the secondary veins in these fronds do not anastomose, but some of them are only forked. This species was recorded by Feistmantel only from the Barakar group of Lower Gondwanas. My specimen of *Glossopteris intermittens* comes from a slightly higher horizon, namely the Raniganj group.

Leaf, Specimen No. 8661 — An incomplete impression of a leaf (PL. 7, FIG. 42) with well-preserved carbonized crust. The apical portion of the leaf is complete, but the basal portion is broken in the specimen. The leaf has a broadly rounded apex and it shows contraction towards the basal region. The midrib is seen in the form of a groove in the part where the carbonized crust is preserved and it persists to the apex. The broken leaf in the specimen measures nearly 4 cm. in length and 2·3 cm. in breadth at the widest part.

Secondary veins (PL. 6, FIG. 42) arise from the midrib at an acute angle and curve towards the margin. Most of the veins dichotomize close to the midrib. They anastomose only here and there forming elongate narrow nets.

This specimen agrees with the description and the figures of *Glossopteris intermittens*, given by Feistmantel (cf. PLS. 6, 7, FIGS. 42, 43 and FEISTMANTEL, 1881, Vol. III, Pt. 2, PL. 33A, FIGS. 2, 4). It compares with a specimen of *Glossopteris intermittens* numbered 5270, kept at the Geological Survey of India Museum, Calcutta. My specimen represents the upper part of the frond.

Cuticle — The carbonized crust of this specimen was very brittle and it broke up into tiny pieces when put into the acid. It was found difficult to handle each piece separately. Hence the pieces were treated in bulk with alkali. The cuticular pieces which showed best preservation were picked out separately. Cuticles are moderately thick, showing the arrangement of veins and meshes on both the surfaces. Stomata are confined to one surface only, which, by analogy with the living land plants, may be taken as the lower (SAHNI, 1923, p. 278).

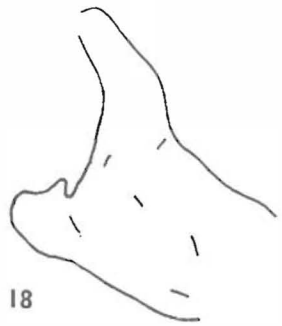
The cuticle of the upper surface (PL. 7, FIGS. 44, 45) is moderately thick showing two types of cells. The rectangular cells, arranged in rows, probably represent the areas over the veins. These cells measure about 108 × 36 μ. The walls of these cells are straight and about 11 μ thick. In the areas of the meshes, the epidermal cells are polygonal to irregular in shape and variable in size. Some of the large cells measure about 72 × 54 μ. The walls of these cells are also straight and thick, like those of the cells over the veins. The portions of the lateral walls of the epidermal cells are slightly drawn out where they meet the adjoining cells, giving them a characteristic appearance (PL. 7, FIG. 45), which I have seen only in one other species of *Glossopteris*, viz. *Glossopteris taeniopteroides* (cf. PL. 7, FIG. 45 and PL. 8, FIG. 51). Stomata are not found on this surface.

The cuticle of the lower surface (PL. 7, FIGS. 44, 46) is comparatively thinner. Here also the arrangement of veins and meshes is discernible as on the upper surface. The cells are of the same size and shape as on the upper surface, but they possess walls which are less thick. Stomata are confined to the

meshes. They are of the haplocheilic type, distributed in groups of six or more and sometimes contiguous. The orientation of the stomata is irregular (TEXT-FIG. 18).

Stomata (PL. 7, FIG. 47; TEXT-FIG. 19) measuring about 72 μ, show monocyclic condition. The two guard cells, which are about 43 μ in length, appear as dumble shaped in surface view. The thickenings of the guard cells are seen in the middle portion of the outer walls, round the stomatal opening and slightly at the poles. Such type of thickening of the guard cells is found in *Palaeovittaria kurzi* (PL. 7, FIGS. 46, 47 and PL. 14, FIGS. 94, 95). The thickening of the guard cells at the poles is seen rarely in *Glossopteris* species I have examined. This has been found only in *Glossopteris arberi* and probably in *Glossopteris sahnii* (cf. PL. 7, FIGS. 46, 47 and PL. 8, FIG. 55 and PL. 9, FIG. 61). Stomatal opening (pore) is seen as a linear slit, 22 μ in length. Subsidiary cells are polygonal in shape, 4-5 in number and five is the most common number.

The epidermal cells over the midrib and thicker veins are narrow, much longer than broad, measuring 54 × 18 μ. They are arranged end to end. Walls of these cells are fairly thick, nearly as thick as in the cells of the upper cuticles. Stomata are absent in these cells.



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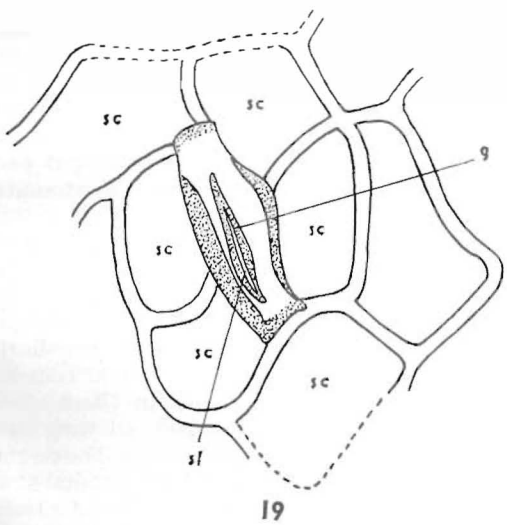

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TEXT-FIGS. 18, 19 — 18, *Glossopteris intermittens*. Distribution and orientation of the stomata. × 105. 19, an enlarged drawing of a stoma from the lower cuticle. × 540.

10. *Glossopteris taeniopteroides* Feistmantel

This species was instituted by Feistmantel in 1878 to describe some fronds from the Permo-Carboniferous rocks of New South Wales. These leaves are characterized by their secondary veins, which at the first glance give the appearance of *Taeniopteris*. Later on Tenison-Woods and Johnston also described this species in 1883 and 1885 respectively. Arber (1902) regarded this species as a smaller frond of *Glossopteris ampla* and later (1905, p. 63) included this under *Glossopteris indica* Schimp. This species has also been recorded from Brazil.

So far *Glossopteris taeniopteroides* had not been reported from India. My specimen, which comes from the Raniganj Stage of the Lower Gondwanas, is the first record of this species from India.

A study of the cuticle of this species shows that its epidermal structure is quite different from that of *Glossopteris indica* described by Zeiller (1896) and, therefore, the present study lends support to the idea of Feistmantel in maintaining this as a separate species.

Leaf, Specimen No. 8662 — An incomplete impression of a leaf with well-preserved carbonized crust (PL. 7, FIG. 48). The leaf is broken both at the apical and the basal ends in the specimen, giving no definite idea of its shape. It has a stout midrib which is longitudinally striated. The leaf in my specimen measures nearly 5·5 cm. in length and 3 cm. in breadth at the widest part.

Secondary veins, arising at nearly right angles from the midrib, give the appearance

of *Taeniopteris* at the first glance (PL. 7, FIG. 49). But more or less parallel secondary veins form oblong, narrow, obliquely acute meshes. The meshes become slightly narrow and smaller in size towards the margin.

My specimen differs in size from Feistmantel's Australian specimen of this species, but the venation which is so distinctive a character is very similar. Hence, I have placed it under *Glossopteris taeniopteroides* (cf. PL. 7, FIGS. 48, 49 and FEISTMANTEL, 1890, No. III, PL. 8, FIGS. 1 and 1A).

The only other specimen having such type of sub-parallel venation is *Glossopteris damudica*. But the cuticles of these two specimens are entirely different.

Cuticle — The cuticles are thin and the arrangement of veins and meshes is not very marked. Stomata are confined to one surface of the leaf, which is most probably the lower one.

The cuticle of the upper surface (PL. 8, FIG. 51) is slightly thicker than the lower one. Here the areas of the veins and meshes are distinguishable due to the different nature of the cells. The veins which are 2-3 cells wide have rectangular cells, longer than broad, measuring 93 × 40 μ. These cells are arranged end to end. In the areas of the meshes the cells are polygonal to irregular in shape, fairly large in size, about 75 × 54 μ. The portions of the lateral walls of the epidermal cells are slightly drawn out where they meet with the adjoining cells giving it a characteristic appearance. Similar characteristic appearance is presented by the epidermal cells in *Glossopteris intermittens* (cf. PL. 8, FIG. 51 and PL. 7, FIG. 45). The walls of the cells both in the meshes and over the veins are straight and moderately thick. Stomata are absent.

The cuticle of the lower surface (PL. 8, FIG. 50) is comparatively thinner than the upper surface. Here, except for a few cells surrounding the stomata, the rest of the cells are rectangular and much longer than broad, looking very much like those found over the veins in most of the other species of *Glossopteris*. These cells measuring about 72 × 22 μ are arranged end to end. The walls of the cells are straight and thin.

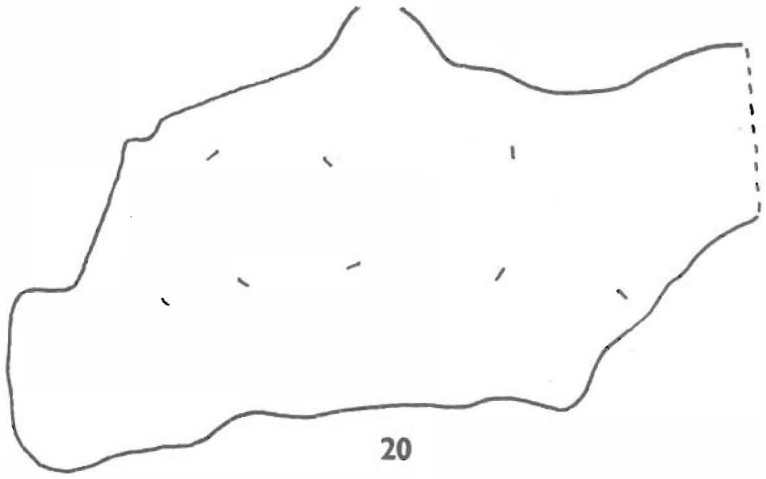
The stomata are haplocheilic. They are rather few in number, arranged in longitudinal rows separated by wide nonstomatiferous regions. Near the stomata (PL. 8, FIG. 50) the epidermal cells are polygonal or irregular in shape and smaller in size than the other cells. The orientation of the stomata (TEXT-FIG. 20) is irregular. A stoma (PL. 8, FIG. 52; TEXT-FIG. 21) shows monocyclic condition and measures about 90 μ. The guard cells about 30 μ in length are thickened at their outer margins. Stomatal opening is visible in a few stomata in between the guard cells. Subsidiary cells are polygonal in shape, 5-6 in number, six being the most common number.

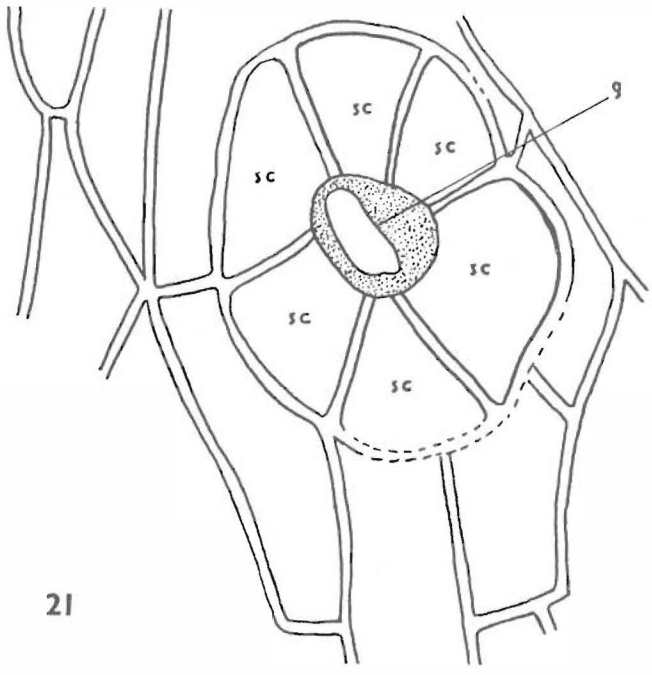
Comparison — There has been some confusion regarding the specific identity of *Glossopteris taeniopteroides*. Arber (1902, p. 8) thought it to be the smaller leaf of *Glossopteris ampla*. He (1905) included *Glossopteris damudica* also in *Glossopteris ampla*. The cuticles of *Glossopteris ampla* are not known, but if Arber is correct in including *Glossopteris damudica* in *Glossopteris ampla*, then a comparison of the cuticles of *Glossopteris damudica* and *Glossopteris taeniopteroides* shows that the two cannot belong to one species in spite of their similar venation.

In *Glossopteris damudica* the upper cuticles are thick, with small polygonal cells, showing no signs of veins and meshes; but in *Glossopteris taeniopteroides* the upper cuticles clearly show the arrangement of veins and meshes and their cells are large in size. As opposed to the upper cuticle, the lower cuticle of *Glossopteris damudica* shows the arrangement of veins and meshes clearly and here the epidermal cells are of two shapes, rectangular over the veins and polygonal in the meshes; but in *Glossopteris taeniopteroides* the lower cuticle does not show clear arrangement of veins and meshes and all the cells are more or less rectangular in shape, arranged end to end, except for a few near the stomata which are irregular in shape.

Later Arber (1905) included *Glossopteris taeniopteroides* under *Glossopteris indica*, but a comparison of the cuticles of these two species shows that they differ widely in epidermal characters. As opposed to the short, rectangular, thick-walled epidermal cells of *Glossopteris indica*, the cells in *Glossopteris taeniopteroides* are thin-walled, showing distinct arrangement of veins and meshes on the upper surface. Moreover, the stomata in *Glossopteris indica* are sunken and longitudinally oriented, while in *Glossopteris taeniopteroides* the stomata are not sunken and they show irregular orientation.

On the basis of the epidermal characters, therefore, it appears that *Glossopteris taeniop-*





TEXT-FIGS. 20, 21 — *Glossopteris taeniopteroides*. 20, distribution and orientation of the stomata. × 50. 21, an enlarged drawing of a stoma. × 740.

teroides is quite distinct from both *Glossopteris indica* and *Glossopteris damudica*, and it should be retained as a separate species.

11. *Glossopteris sahnii* sp. nov.

In 1954, while I was collecting fossils near the Raniganj area in the Raniganj coalfield, I found some pieces of shale bearing incomplete carbonized impressions of a large leaf. The impressions showed net-like venation and a distinct midrib. These characters of the leaf suggested its inclusion under the genus *Glossopteris*. On comparing these impressions with the known species of *Glossopteris*, I found that they did not agree completely with any one of them. As the

specimens are very characteristic and interesting, I am describing them here under a new specific name, *Glossopteris sahnii*. One of the specimens bearing the No. 8666 yielded some pieces of badly preserved cuticle.

Diagnosis — Fronds usually large in size. One of the incomplete specimen measures more than 20 cm. in length. Base and apex not preserved. Lamina very broad measuring 12 cm. or more. Midrib distinct, not very thick, with parallel longitudinal striations. Secondary veins arising at nearly right angles from the midrib, about 3 mm. apart, form large, open, oblong or rhomboidal meshes of almost uniform size from the midrib to the margin of the lamina.

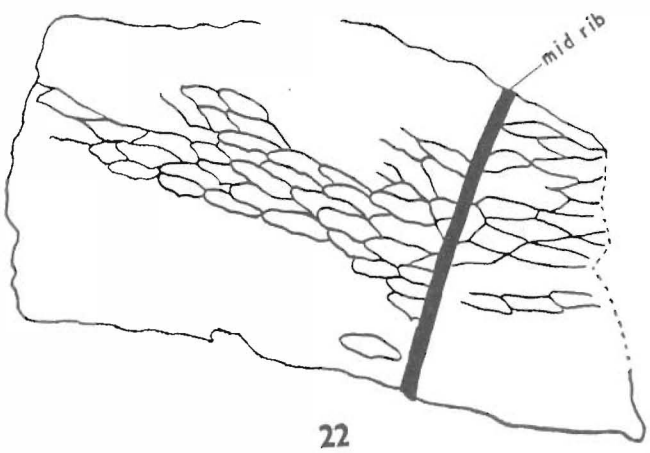
The cuticles are very thin, looking like transparent membranes. Outlines of the epidermal cells very faintly marked, walls sinuous, guard cells showing probably the polar thickenings also, besides those of the outer and the inner walls.

This new species is represented by three specimens bearing the numbers 8508, 8659, and 8666.

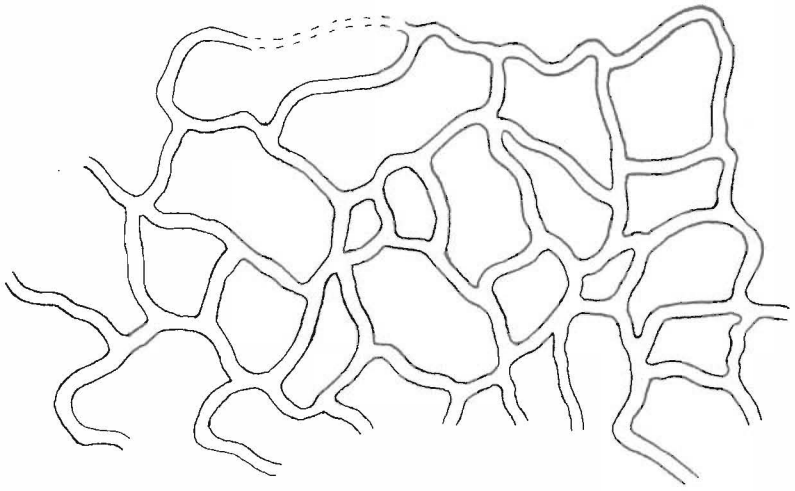
Leaf, Specimen No. 8666 (*Holotype*)— Incomplete impression of a leaf, with rather badly preserved carbonized crust (PL. 8, FIG. 53, TEXT-FIG. 22). No idea about the shape and size of the leaf can be obtained as the impression is incomplete. The impression shows a midrib, about 2 mm. wide and with parallel striations. In the specimen the leaf measures nearly 5·5 cm. in length and 6 cm. in breadth, from the midrib to the margin and so the leaf must have been at least 12 cm. broad in the complete specimen.

Secondary veins (PL. 8, FIG. 54) arising from the midrib at nearly right angles are placed about 3 mm. apart and form large, open oblong or rhomboidal meshes of almost equal size, right up to the margin of the leaf. The meshes measure nearly 1 cm. in length and 2-3 mm. in breadth.

Comparison — The larger fronds, having broad lamina with netted venation described from the Lower Gondwanas of India are those of *Gangamopteris cyclopteroides*, *Glossopteris damudica*, *Glossopteris browniana* and *Glossopteris communis*. The fronds of *Glossopteris sahnii* differ from the larger fronds of *Gangamopteris cyclopteroides* in possessing a distinct midrib, a character which is supposed to distinguish the genus *Glossopteris* from *Gangamopteris*. My specimen, however, compares with those of *Glossopteris damudica* Feistmantel in breadth of the lamina, but strikingly differs from it in the venation. The secondary veins in *Glossopteris damudica*, arising at right angles from the midrib, form one or two series of comparatively broad and short meshes and then subdivide into a number of close and almost parallel veins, often very oblique, forming extremely narrow elongate meshes. From *Glossopteris browniana* my specimen differs in the breadth of the lamina which is well over 12 cm., whereas the maximum breadth of the fronds in *Glossopteris browniana* recorded so far is only 6·5 cm. Further the venation of the two



TEXT-FIG. 22 — *Glossopteris sahnii* sp. nov. A line drawing of the photograph represented in Pl. 8, Fig. 53, to show the venation. × Nat. size.



23

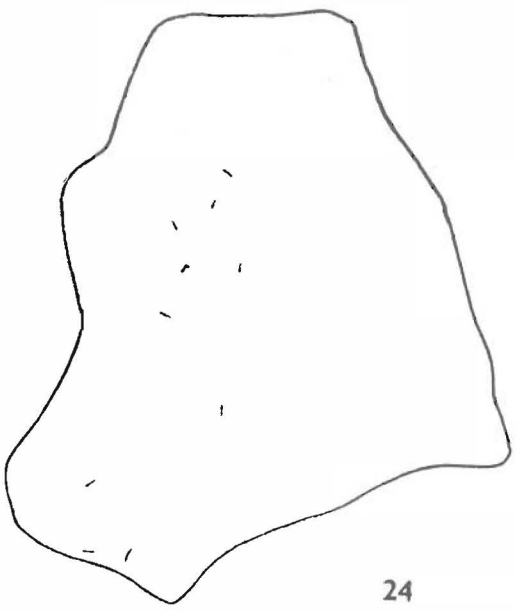
TEXT-FIG. 23 — *Glossopteris sahnii* sp. nov. Outlines of the epidermal cells. × 250.

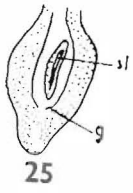
leaves differs considerably. From the larger fronds of *Glossopteris communis* my specimen differs very much in the venation. Secondary veins in *Glossopteris communis* form very long and narrow meshes, in contrast to the large, open, oblong or rhomboidal meshes of uniform size in *Glossopteris sahnii*.

The other larger fronds of *Glossopteris* besides those reported from the Lower Gondwanas of India are *Glossopteris ampla* Dana, *Glossopteris musaefolia* Bunbury, *Glossopteris cordata* (Dana) Feistmantel, *Glossopteris occidentales* White, *Glossopteris parallela* Feistmantel and *Glossopteris crassinervis* Harris. *Glossopteris musaefolia*, *Glossopteris cordata* and *Glossopteris damudica* have been merged together with *Glossopteris ampla* by Arber (1905). All of them are characterized by the same type of venation as exhibited in the fronds of *Glossopteris damudica* from which my specimen differs considerably. From *Glossopteris occidentales* the fronds of which are very long, sometimes as much as 40 cm., *Glossopteris sahnii* differs in having a broader lamina. In *Glossopteris parallela* the secondary veins arise at an angle of nearly 40° in the lower and 20° in the upper portion of the lamina, forming distinct oblong polygonal meshes which are narrower towards the margin. *Glossopteris sahnii* differs from it in having the secondary veins at nearly right angles to the midrib, forming meshes of uniform size throughout the lamina. *Glossopteris crassinervis* is a Mesozoic frond described by Harris from Greenland. According to Harris this leaf is unusually large in size measuring about 100 cm. in length and 20 cm. in breadth. *Glossopteris sahnii* differs from it, apart from its younger age, in being a smaller leaf. Further the meshes in *Glossopteris crassinervis* are longer, nearly 2 cm., close to the rachis, gradually decreasing in size till they become only 1-2 mm. in length near the margin of the leaf, whereas in *Glossopteris sahnii* the meshes remain uniform in size throughout the lamina. My specimen thus cannot be identified with any of the known *Glossopteris* species and, therefore, I have described it under a new specific name, *Glossopteris sahnii*.

Cuticle — The specimens of *Glossopteris sahnii* did not yield well-preserved cuticles and, therefore, the information obtained about the epidermal structure is far from complete. Big pieces of cuticles were obtained, but unfortunately they became transparent after alkali treatment, showing almost no cellular structure.

The cuticle of both the surfaces appears to be very thin. After staining for a prolonged time, a few pieces showed the cell outlines very faintly. The epidermal cells (TEXT-FIG. 23) are irregular in shape. They are usually longer than broad, possessing thin





TEXT-FIGS. 24, 25 — 24, *Glossopteris sahnii* sp. nov. distribution and orientation of the stomata. × 90. 25, an enlarged drawing of the guard cells of a stoma. × 792.

and sinuous walls. Well-preserved stomata have not been found in these cuticles. In some of the pieces which looked more or less transparent, the guard cells are seen preserved at a few places. The guard cells (PL. 8, FIG. 55; TEXT-FIG. 25) measure nearly 25 μ in length. The thickening of the guard cells is seen in the middle portion of the outer wall and round the stomatal opening and probably also at the poles. Stomatal opening is seen in the form of a linear slit. From the distribution of the guard cells, it appears that the stomata were sparse and irregular in their distribution and orientation (TEXT-FIG. 24).

The cuticle over the midrib (PL. 8, FIG. 56) is comparatively thicker than that of the lamina. It shows rectangular cells which are much longer than broad, placed end to end. Some of these cells measure about 128 × 25 μ. The walls of these cells are straight and thin.

12. *Glossopteris arberi* sp. nov.

I have included under this specific name those fronds which resemble *Glossopteris indica* in external appearance, especially the secondary nervation, but differ widely in epidermal characters. I have taken for comparison the epidermal characters of *Glossopteris indica* as described by Zeiller (1896). It appears that all the leaves, showing venation like that of *Glossopteris indica*, do not belong to a single species.

Diagnosis — Leaves linear, lanceolate in shape, variable in size, sometimes more than 20 cm. long. Midrib stout, persisting, with parallel striations. Secondary veins arise at an acute angle from the midrib, arched, gradually bending towards the margin, reaching it at an oblique angle. Secondary veins anastomose to form long, narrow, oblong, polygonal meshes which are nearly sub-parallel. The difference in size of the meshes at the midrib and the margins is not much.

Cuticles thin, epidermal cells elongate, rectangular with sinuous and toothed (zig-zag) walls. Only lower epidermal cells are papillate. Stomata irregularly distributed and oriented. Stomatal apparatuses haplocheilic, monocyclic with two guard cells which are slightly thickened at the outer margin and at the poles.

Leaf, Specimen No. 8484 (*Holotype*)— Impression of a long leaf, with shiny carbonized crust (PL. 9, FIG. 57). The leaf is broken at the apex and the base in the specimen. It appears to have a linear lanceolate shape as it shows contraction at both the ends. The leaf has a stout midrib which persists up to the apex. It is longitudinally striated. The broken leaf in the specimen measures nearly 20 cm. in length and 4·5 cm. in breadth at the widest part.

Secondary veins (PL. 9, FIG. 58) are crowded and sub-parallel. They come out at an acute angle, forming arches near the midrib and then gradually bending towards

the margin, reaching it at an oblique angle. The veins anastomose to form long and narrow meshes, which do not show any great variation in their size.

Comparison — The fronds of *Glossopteris arberi* show a great resemblance in external characters to the fronds of *Glossopteris stricta* and *Glossopteris indica*. It resembles *Glossopteris stricta* in size and linear lanceolate shape, but differs from that in having long and narrow meshes which do not show any appreciable variation in their size. On the other hand, in *Glossopteris stricta* the meshes near the midrib, which is more stout, are shorter and broader than the meshes at the margins. The fronds of *Glossopteris indica* are very variable in shape and size, and it is difficult to distinguish the fronds of *Glossopteris arberi* from them on the external characters alone. In their venation also the fronds of *Glossopteris arberi* approach very close to *Glossopteris indica* but since they show different epidermal structures they cannot be placed under *Glossopteris indica*.

Cuticle — Cuticle on both the surfaces is thin and the stomata are confined to the lower side. The cuticle of the upper surface (PL. 9, FIG. 59) shows epidermal cells which are more or less rectangular to irregular in shape, usually arranged end to end, 2-3 times longer than broad and measuring nearly 90 × 36 μ. Arrangement of veins and meshes is not seen on this surface. The walls of the cells are thin and highly sinuous and toothed. The cells are non-papillate and the stomata are absent.

The cuticle of the lower surface (PL. 9, FIG. 60) also does not show the veins and meshes. The epidermal cells are large, rectangular to irregular in shape, measuring about 90 × 54 μ. The walls of the cells are thin, sinuous and toothed. Each epidermal cell possesses a large rounded scar, which is probably the mark of the papilla. Stomata are present on this surface.

The stomata are of the haplocheilic type. They are irregularly distributed (PL. 9, FIG. 60) and occasionally the adjacent stomata are contiguous. The orientation of the stomata (TEXT-FIG. 26) is irregular. A stoma (PL. 9, FIG. 61: TEXT-FIG. 27), measuring about 111 μ, shows monocyclic condition. The two guard cells look like a linear dumble-shaped body. The guard cells are slightly thickened in the middle portion of the outer walls and very slightly at the poles. The stomatal opening (pore) is usually not visible. Subsidiary cells are papillate, irregular in shape, 4-6 in number and of almost the same size as the other epidermal cells.

The cuticle of the midrib and prominent secondary veins is thick. The epidermal cells are long, narrow, rectangular in shape, arranged end to end, measuring about 80 × 36 μ. The walls of these cells are thickened and sinuous, but the sinuosity is less marked. Stomata are absent.

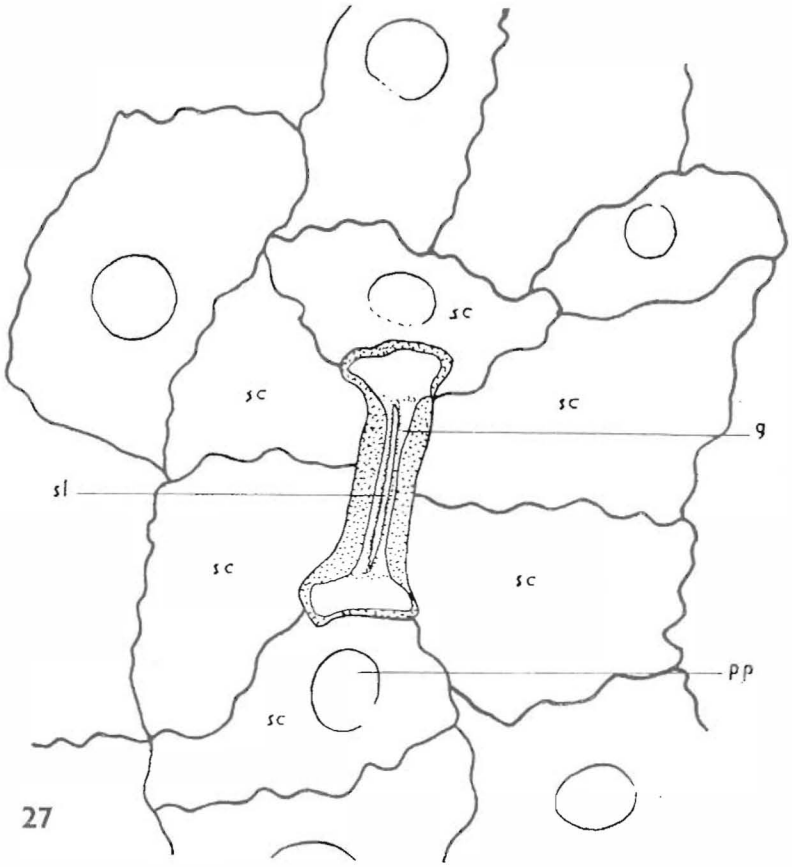
Comparison — Although the fronds of *Glossopteris arberi* and *Glossopteris indica* are very similar in appearance, yet their cuticles show very different epidermal characters. In contrast to the thick cuticles of *Glossopteris indica*, showing thick-walled, short, rectangular epidermal cells, the cuticle of *Glossopteris arberi* is thin with elongate, rectangular cells, showing thin and sinuous or toothed walls. Further, the epidermal cells on the lower surface of *Glossopteris arberi* are papillate. The two cuticles also differ from each other in the distribution, orientation and structure of the stomata. Whereas in *Glossopteris indica*, the stomata are sunken, arranged in rows, showing longitudinal orientation, the stomata in *Glossopteris arberi* are not sunken and they show irregular orientation and distribution.

On the other hand, the cuticle of *Glossopteris arberi* shows some similarity with the cuticle of *Glossopteris angustifolia*. In both the species the cuticles have epidermal cells with thin and sinuous walls and the stomata irregularly oriented. The guard cells are thinly cutinized and the subsidiary cells are papillate. However, *Glossopteris arberi* differs from *Glossopteris angustifolia* in the size and shape of the stomata. The guard cells in *Glossopteris angustifolia* are thinly cutinized and together they form a small elliptical area, but in *Glossopteris arberi* the two guard cells are much elongated and possess slightly thickened dorsal walls and at the poles also some thickening is visible. Moreover, in the lower cuticle of *Glossopteris arberi*, other epidermal cells besides the subsidiary cells are also papillate and their walls are more sinuous than those on the lower cuticle of *Glossopteris angustifolia*.

13. *Glossopteris longicaulis* Feistmantel

Feistmantel (1881, *Suppl.*, p. 81) described a leaf from Karharbari beds of the Lower Gondwanas under the specific name

26



TEXT-FIGS. 26, 27 — *Glossopteris arberi*. 26, orientation and distribution of stomata. × *Ca*. 63. an enlarged drawing of a stoma. × 730.

*Glossopteris longicaulis**. This leaf is characterized by a very long petiole and an impersistent midrib, which is very stout in the lower portion, but becomes indistinct in the upper portion of the frond. Arber (1905) included this species in his catalogue of the *Glossopteris* flora and he recognized the above two characters as the chief distinguishing features of this species.

I have found three specimens from a higher horizon, the Raniganj Stage of the Lower Gondwanas, which show great resemblance with the fronds of *Glossopteris longicaulis*,

*Thomas (1952, p. 438) gave the name *Glossopteris longicaulis* to a specimen which was previously described as *Sagenopteris longicaulis* by Du Toit from S. Africa. Since the name *Glossopteris longicaulis* has already been given to a leaf from Karharbari beds, India, by Feistmantel (1881), this name should not be used for Thomas's specimen on the basis of priority.

in possessing a petiole which is sufficiently long in one of the three specimens in my collection. The secondary veins in my fronds are also similar to those in *Glossopteris longicaulis*. But, unfortunately, in none of my specimens the upper portion of the leaf is preserved, and, therefore, the other character, that the midrib vanishes in the upper part of the leaf, could not be verified. However, my specimens are almost identical in other characters with *Glossopteris longicaulis*.

Leaf, Specimen No. 8439 — Impression of a broken leaf (PL. 10, FIG. 62) having carbonized crust preserved at some places. The upper portion of the leaf is broken, but the basal portion is preserved. It shows a broad, distinct midrib, about 3 mm. wide and which prolongs into a petiole. The leaf in the specimen measures nearly 7 cm. in length, excluding the petiole. It is about 2·5 cm. broad. The petiole, of which only a small portion is preserved in this specimen, measures nearly 2 cm. in length and 4 mm. in breadth. Secondary veins (PL. 10, FIG. 63) come out at an acute angle from the midrib. They anastomose to form rather broad, oblong meshes.

This specimen agrees in general shape, size and secondary venation with the description and figures of *Glossopteris longicaulis* given by Feistmantel (cf. FIG. 62 and FEISTMANTEL 1881, Vol. III, Pt. 1, *Suppl.*, pp. 53, 54, PL. 31, FIGS. 1-3). It closely compares with a specimen of *Glossopteris longicaulis* numbered 5086, kept at the Geological Survey of India Museum, Calcutta.

Cuticle — The cuticles on both the surfaces are rather thick, showing the network of veins and meshes. Stomata are present on the upper as well as the lower side of the leaf.

The cuticle of the upper surface (PL. 10, FIG. 64) is slightly thicker than the lower one. Arrangement of veins and meshes is seen clearly. The veins are wider, 4-6 cells wide, and the meshes are narrower. The epidermal cells over the veins are squarish or sometimes rectangular in shape, measuring nearly 54 μ. The cells in the meshes are smaller, polygonal to irregular in shape, measuring nearly 43 μ. Their cell walls are straight but thinner than the walls of the cells over the veins. Stomata occur in the areas of the meshes separated by bands of veins. The stomata are arranged in one or more linear rows. The adjacent stomata are sometimes contiguous. The orientation of the stomata (TEXT-FIG. 28) is irregular.

The cuticle of the lower surface is thinner than the upper one. It is also divided into stomatiferous and non-stomatiferous areas which are seen as bands 4-6 cells wide having long and narrow rectangular to irregular cells, measuring about 72 × 18 μ. These cells are arranged end to end and their walls are straight and slightly thick, measuring nearly 5 μ.

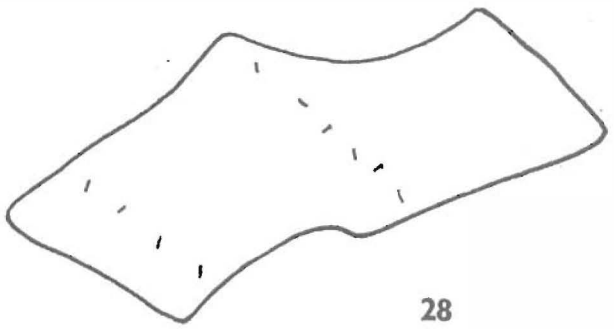
The stomatiferous areas or meshes are much wider, having polygonal to irregular epidermal cells, smaller in size than those over the veins. These cells measure nearly 43 μ. The walls of these cells are thin. Stomata are very crowded and they are irregularly distributed (TEXT-FIG. 29), as opposed to that of the upper surface.

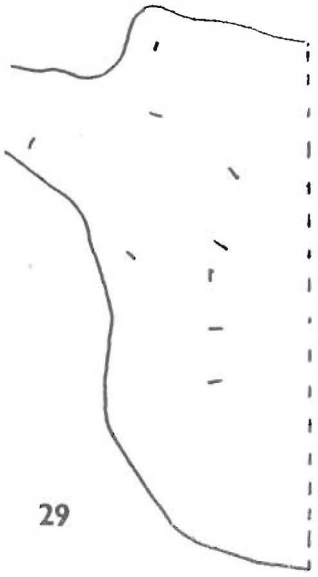
Stomata are of the haplocheilic type. The stomatal apparatuses show monocyclic or sometimes amphicyclic condition (PL. 10, FIG. 66; TEXT-FIG. 30), that is, the subsidiary cells are surrounded by more than one tier of encircling cells. The orientation of the stomata is irregular. A stoma measures nearly 75 μ. The two guard cells are about 40 μ long; they are slightly thickened. Stomatal opening is sometimes seen in the form of linear slit, round which also the guard cells are slightly thickened. Subsidiary cells are 5-7 in number, six being the most common number. In at least some stomata, two subsidiary cells are polar and the rest lateral. Subsidiary cells are smaller in size than the neighbouring epidermal cells and are generally polygonal in shape.

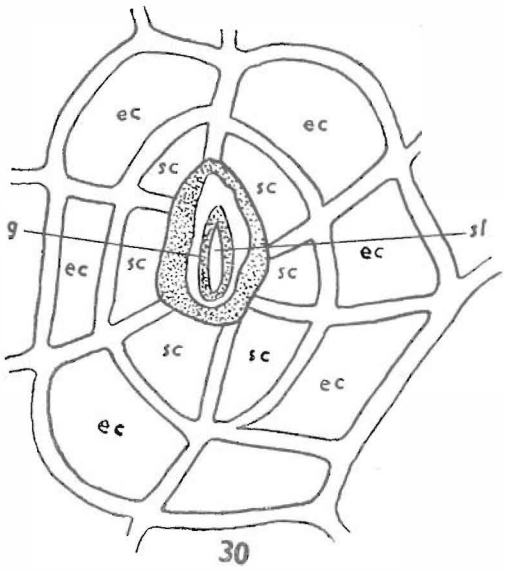
14. *Glossopteris taenioides* Feistmantel

This species was first described by Feistmantel (1882) from South Rewa Gondwana Basin. The species is characterized by a long and narrow ribbon-like leaf, with a broad and stout midrib. Arber (1905) included this species provisionally in *Glossopteris angustifolia*. Feistmantel compared this species with *Glossopteris wilkinsoni* from the New Castle beds in New South Wales, but he distinguished it from the Australian species by its more acute secondary nervation and in the number of meshes formed in a row. Feistmantel reported this species from Karharbari beds of South Rewa. I have collected this specimen from a higher horizon, the Raniganj Stage of the Raniganj coalfield in Bengal.

A comparison of the cuticles of *Glossopteris taenioides* with *Glossopteris angustifolia* shows







TEXT-FIGS. 28-30 — *Glossopteris longicaulis*. 28, distribution and orientation of the stomata on the upper cuticle. × 50. 29, distribution of the stomata on the lower cuticle. × 150. 30, an enlarged drawing of a stoma. × 720.

that the two are quite distinct from each other.

Leaf, Specimen No. 5645 — Carbonized impression of a very long and narrow ribbon like leaf (PL. 11, FIG. 67), broken both at the basal and the apical ends. The leaf in the specimen measures nearly 12 cm. in length and 1 cm. in breadth.. Midrib is fairly broad as compared to the narrow lamina; it occupies nearly one-fourth of the space of the lamina in the basal portion and persists throughout in the specimen. The midrib is longitudinally striated. Secondary veins (PL. 11, FIG. 68) pass out from the midrib at very acute angles, forming rather conspicuous, open nets. As the lamina on both the sides of the midrib is very narrow, not more than 2-3 meshes are formed by each secondary vein. From this specimen nothing definitely can be said about the base and the

TABLE 1 — DISTINGUISHING EPIDERMAL CHARACTERS OF *GLOSSOPTERIS* SPECIES

Name of the species	Differentiation between veins and meshes	Epidermal cells			Stomata			Guard cells
		Thick or thin straight or sinuous	Size and shape	Papillate or non-papillate	Stomata on both or one surface	Distribution and orientation	No. of subsidiary cells, papillate or non-papillate	
Glossopteris angustifolia	Up–not marked Lw–marked	Up–thin and very sinuous Lw–thin and less sinuous	Up–3 times longer than broad, rectangular Lw–rectangular and longer than broad at the veins and isodiametric in the meshes	Up–non-papillate Lw–non-papillate except near the stomata	Up–not present Lw–present	Dis– Ori–irregular	4-6, possess some scars	Together form an elliptical area, not thickened
Glossopteris indica	Not marked	Very thick and straight (epidermal cells of upper and lower surfaces not known separately)	Short and rectangular	Non-papillate	Not known	Dis–in linear rows Ori–longitudinal	Number not known Non-papillate	Thickened and sunken
Glossopteris browniana	Up–marked	Up–moderately thick and straight	Up–veins–rectangular, 80 × 30 μ; meshes–irregular, 4 to 5-sided, 75 × 22 μ	Up–non-papillate	Up–present	Dis–irregular	5-7, non-papillate	Slightly sunken and thickened
	Lw–marked	Lw–moderately thick and straight	Lw–veins–same as above; meshes–polygonal to irregular, 64 × 30 μ	Lw–non-papillate	Lw–present	Ori–irregular		
Glossopteris cf. *divergens*	Up–marked	Up–moderately thick and straight	Up–veins–rectangular, 80 × 30 μ; meshes–irregular, 4 to 5-sided, 75 × 20 μ	Up–non-papillate	Up–present	Dis–irregular	5-6, non-papillate	Slightly sunken and thickened
	Lw–marked	Lw–moderately thick and straight	Lw–veins–same as above; meshes–polygonal irregular	Lw–non-papillate	Lw–present	Ori–irregular		
Glossopteris communis	Up–marked showing anastomosing	Up–moderately thick and straight	Up–veins–rectangular or squarish, 87 × 28 μ; meshes–polygonal, 65 μ	Up–non-papillate	Up–present	Dis–irregular or in groups of four or five	4-7, papillate	Thickened
	Lw–marked showing anastomosing	Lw–moderately thick and straight	Lw–same as above	Lw–non-papillate	Lw–present	Ori–irregular		
Glossopteris communis var. *stenoneura*	Up–marked	Up–moderately thick and straight	Up–veins–rectangular, 80-90 × 25-30 μ; meshes–polygonal or elongately polygonal, 70 × 32 μ	Up–non-papillate	Up–present	Dis–irregular or in groups of four or five	4-7, papillate	Thickened
	Lw–marked	Lw–moderately thick and straight	Lw–same as above	Lw–non-papillate	Lw–present	Ori–irregular		
Glossopteris conspicua	Up–not marked Lw–not marked	Up–very thick and straight Lw–very thick and straight	Up–rectangular, 132 × 37 μ Lw–polygonal, 60 μ	Up–non-papillate Lw–non-papillate	Up–not present Lw–present	Dis–in linear rows Ori–longitudinal	5-7, non-papillate	Sunken and thickened
Glossopteris formosa	Up–marked showing anastomosing Lw–marked showing anastomosing	Up–moderately thick and straight Lw–moderately thick and straight	Up–veins–rectangular, 72 × 18 μ; meshes–polygonal or irregular, large Lw–same as above	Up–non-papillate Lw–non-papillate	Up–not present Lw–present	Dis–in linear rows Ori–irregular	4-7, papillate	Not much thickened but overhung by papillate
Glossopteris retifera	Up–not marked Lw–marked	Up–thin and sinuous Lw–faint, thin and sinuous	Up–rectangular, 120 × 30 μ Lw–same as above	Up–non-papillate Lw–non-papillate	Up–not present Lw–present	Dis–irregular Ori–irregular	6, non-papillate	Not thickened
Glossopteris damudica	Up–not marked Lw–marked	Up–thick and straight Lw–thin and straight	Up–polygonal, 19 μ Lw–veins–rectangular, 51 × 22 μ; meshes–polygonal, 68 μ	Up–non-papillate Lw–non-papillate	Up–not present Lw–present	Dis–not known Ori–not known	4-5, non-papillate	Slightly thickened
Glossopteris intermittens	Up–marked	Up–thick and straight	Up–veins–long, rectangular, 108 × 36 μ; meshes–polygonal or irregular, 72 × 54 μ	Up–non-papillate	Up–not present	Dis–in groups	4-5, non-papillate	Together form a dumble-shaped area in surface view, thickened
	Lw–marked	Lw–moderately thick and straight	Lw–same as above	Lw–non-papillate	Lw–present	Ori–irregular		
Glossopteris taeniopteroides	Up–marked	Up–slightly thick and straight	Up–veins–rectangular, 93 × 40 μ; meshes–polygonal or irregular, 75 × 54 μ	Up–non-papillate	Up–not present	Dis–in linear rows	5-6, non-papillate	Slightly thickened
	Lw–marked	Lw–thin and straight	Lw–rectangular, 72 × 22 μ	Lw–non-papillate	Lw–present	Ori–irregular		
Glossopteris taenioides	Up–marked	Up–slightly thick and straight	Up–veins–rectangular, 90 × 28 μ; meshes–irregular, four-sided, 54 μ	Up–non-papillate	Up–not present	Dis–irregular	5-6, non-papillate	Not thickened
	Lw–marked	Lw–faint, thin and straight	Lw–same as above	Lw–non-papillate	Lw–present	Ori–irregular		
Glossopteris longicaulis	Up–marked	Up–slightly thick and straight	Up–veins–squarish or rectangular, 54 μ; meshes–polygonal or irregular, 43 μ	Up–non-papillate	Up–not present	Dis–Up–in linear rows; Lw–irregular	5-7, non-papillate	Slightly thickened
	Lw–marked	Lw–slightly thick and straight	Lw–veins–rectangular or irregular, 72 × 18 μ; meshes–polygonal or irregular, 43 μ	Lw–non-papillate	Lw–present	Ori–irregular		
Glossopteris sahnii	Not known	Thin and sinuous (Upper and lower surfaces not known separately)	Epidermal cells irregular in shape, longer than broad	Non-papillate	Not known	Dis–irregular Ori–irregular	Not known	Thickened
Glossopteris arberi	Up–not marked Lw–not marked	Up–thin and sinuous Lw–thin and sinuous	Up–rectangular to irregular, 90 × 36 μ Lw–rectangular to irregular, 90 × 54 μ	Up–non-papillate Lw–papillate	Up–not present Lw–present	Dis–irregular Ori–irregular	4-6, papillate	Slightly thickened

Note — Up=for cuticle of the upper surface. Lw=for cuticle of the lower surface.

apex of the leaf, but it can safely be said that the leaf must have been fairly long.

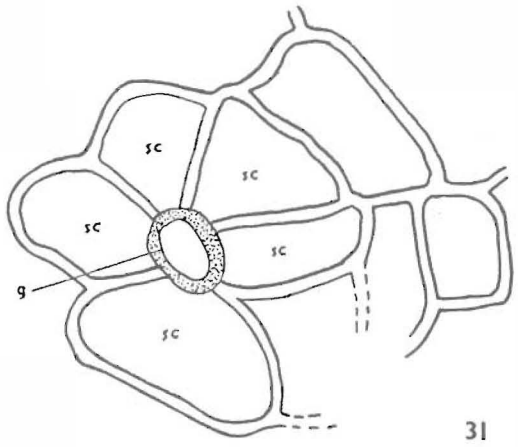
This leaf agrees with the description and figures of *Glossopteris taenioides* given by Feistmantel (FEISTMANTEL, 1882, Vol. IV, Pt. 1, pp. 36, 37, PL. 21, FIGS. 4, 9). It is seen that in Feistmantel's figures the secondary veins come out at a slightly less acute angle, but I think this is a minor difference. My specimen compares in breadth of the lamina, nature of the midrib and venation with a specimen of *Glossopteris taenioides* numbered 5490, kept at the museum of the Geological Survey of India, Calcutta.

Cuticle — The specimen has not yielded good cuticles. The carbonized crust on the impression is very thin. However, from a few pieces I have obtained, it is seen that the cuticles of the two surfaces are distinct from each other on account of their different thickness. Arrangement of veins and meshes is marked on both the surfaces. Stomata are present only on the lower surface.

The cuticles of the upper surface are slightly thicker. The areas of the meshes are separated by those over the veins. Over the veins the cells are long and narrow, 2-3 cells wide, rectangular in shape arranged end to end. An average cell measures about 90 × 28 μ. The areas of the meshes are broader; here also the cells are of four sides but they are not always rectangular and measure about 54 μ. The walls of these cells are straight and slightly thick.

The cuticle of the lower surface (PL. 11, FIG. 69) is comparatively thinner than that on the upper surface and the cell outlines are fairly marked. Here also the areas of the meshes are clearly demarcated from those of the veins. The cells over the veins are similar to those in the upper cuticle. In the meshes the cells are polygonal or sometimes irregular in shape. An average cell measures nearly 54 μ. Stomata are present on this surface, they are confined to the areas of the meshes.

The stomata are not very conspicuous, so that they are often missed. They are scattered fairly apart. A stoma (PL. 11, FIG. 70; TEXT-FIG. 31) measures about 72 μ. It shows monocyclic condition. Guard cells are not much thickened. The two guard cells together form an elliptical area measuring about 18 μ. The subsidiary cells are usually 5-6 in number. Sufficient number of stomata have not been found to throw light on the distribution and orientation.



TEXT-FIG. 31 — *Glossopteris taenioides*. An enlarged drawing of a stoma. × 621.

The cuticle of the midrib (PL. 11, FIG. 71) is thick. The epidermal cells are more or less rectangular in shape, arranged end to end. The walls of these cells are fairly thickened.

Comparison — Feistmantel (1882) described *Glossopteris taenioides* as a new species, but Arber (1905) thought it to be similar to *Glossopteris angustifolia* Brongniart and, therefore, he included it provisionally in *Glossopteris angustifolia*. A comparison of the epidermal characters of *Glossopteris taenioides* and *Glossopteris angustifolia* shows that the two leaves are quite distinct from each other. In *Glossopteris angustifolia* the epidermal cells on both the surfaces possess sinuous walls and there is no demarcation of the areas of the veins and the meshes in the cuticle of the upper surface. But in *Glossopteris taenioides* the epidermal cells possess straight walls and the areas of the meshes are marked clearly from those of the veins on both the surfaces. Further, in *Glossopteris angustifolia* the cuticles are thin on both the surfaces but in *Glossopteris taenioides* the cuticles of the upper surface are comparatively thicker. Lastly, the stomata in *Glossopteris angustifolia* possess papillate subsidiary cells but in *Glossopteris taenioides* the subsidiary cells are non-papillate.

On the basis of the epidermal characters, therefore, the two leaves appear to be quite distinct and warrant at least a different specific rank.

B. GENUS—*GANGAMOPTERIS* McCOY

1. *Gangamopteris* cf. *cyclopteroides* Feistmantel

Gangamopteris cyclopteroides was first described by Feistmantel in 1876. Arber (1905) thought that McCoy's species *Gangamopteris obliqua* and *Gangamopteris spatulata* are identical with *Gangamopteris cyclopteroides*. On grounds of priority, he wanted to change the name of *Gangamopteris cyclopteroides*, after either of the McCoy's species. But he deferred from doing so, because the name *Gangamopteris cyclopteroides* had become very widely known. He also included under this species the fronds described as *Gangamopteris clarkeana* and *Gangamopteris hughesi* by Feistmantel. He stated that the several varieties of *Gangamopteris cyclopteroides* described by Feistmantel were hardly worthy of distinction and represented minor variations of the same leaf (ARBER, 1905, p. 108).

The fronds of *Gangamopteris cyclopteroides* vary greatly in shape and size, but the venation remains remarkably constant in different fronds. The leaves usually possess a broadly rounded or obtuse apex and somewhat contracted base. Secondary nerves radiate out from the base, or form a few sub-parallel median nerves and form meshes usually longer and broader in the central portion of the frond and narrower towards the margin.

My specimen bearing the number 8458 closely resembles the fronds of *Gangamopteris cyclopteroides* in the secondary nervation and has yielded well-preserved cuticles. But, as it is fragmentary in nature, a detailed comparison is not possible. I am, therefore, describing it here provisionally as *Gangamopteris* cf. *cyclopteroides*.

Leaf, Specimen No. 8458 — Fragmentary impression of probably a large leaf having well preserved carbonized crust. No idea of the shape of the leaf can be had from the specimen. The broken leaf in the specimen measures nearly 3·5 cm. in length and 2·8 cm. in breadth. In the median portion of the frond are seen a few strong sub-parallel median nerves. Secondary nerves (PL. 11, FIG. 72) which radiate out from the basal portion, and also from some of the median veins, anastomose to form long and narrow meshes. The meshes are somewhat shorter and broader near the median veins, becoming longer and narrower, away from the central portion.

This specimen compares in the nature of the secondary veins and the meshes with the drawings of *Gangamopteris cyclopteroides* given by Feistmantel (cf. FIG. 76 and FEISTMANTEL, 1879, Vol. III, Pt. 1, PL. 9, FIG. 6).

Cuticle — The cuticles are moderately thick, showing distinct arrangement of veins and meshes on both the surfaces. Stomata are confined to the lower surface only.

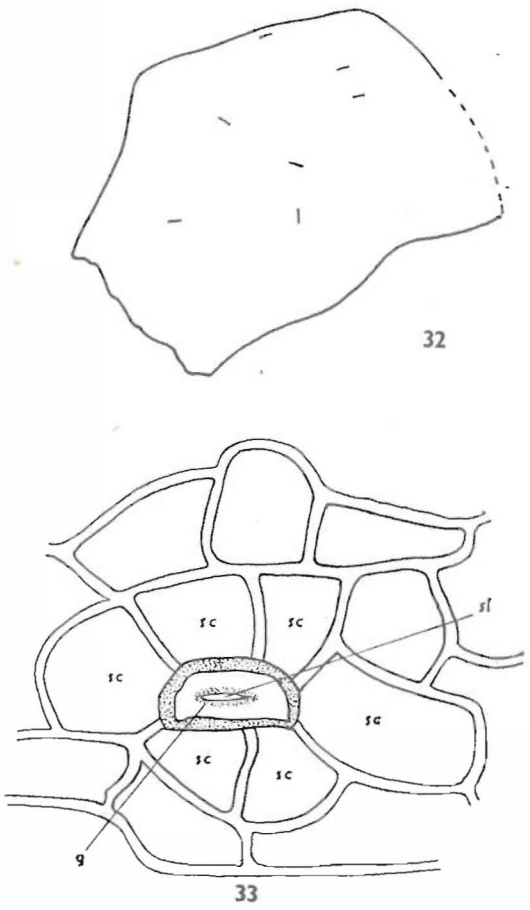
The cuticle of the upper surface (PL. 11, FIG. 73) is comparatively thicker and arrangement of veins and meshes is quite distinct. The areas representing the veins are narrow, 2-3 cells wide, having long and narrow epidermal cells which are rectangular in shape and arranged end to end. These cells measure nearly 162 × 36 μ. The areas of the meshes are wider, with epidermal cells usually rectangular or sometimes irregular in shape, but smaller in size than those over the veins and arranged end to end. These cells are also longer than broad, measuring about 90 × 46 μ. The walls of the cells both over the veins and in the meshes are straight and slightly thick, about 5 μ. On the surface of these cells are seen a large number of very small dark coloured marks. Exact nature of these marks is not clear. Stomata do not occur on this surface.

The cuticle of the lower surface (PL. 11, FIG. 74) is somewhat thinner. The areas of the meshes are demarcated from those of the veins. In the areas of the veins, which are 2-3 cells wide, the epidermal cells are long, rectangular in shape, arranged end to end. These cells measure nearly 90 × 28 μ. In the meshes the cells are smaller in size, usually four-sided, but not arranged end to end as seen over the veins. These cells measure nearly 50 μ. Stomata occur on this surface, they are fairly crowded and confined to the areas of the meshes only.

Stomata are of the haplocheilic type. They are irregular in distribution and orientation (TEXT-FIG. 32). Stomatal apparatus (PL. 12, FIG. 75; TEXT-FIG. 33) shows monocyclic condition. Adjacent stomata are contiguous. A stoma measures nearly 100 μ. The guard cells are about 40 μ in length; they are slightly thickened. Stomatal opening is seen as a linear slit, measuring 21 μ, in between the two guard cells. Subsidiary cells are usually 5-6 in number and are not much different from the other epidermal cells in shape and size.

2. *Gangamopteris* cf. *hughesi* Feistmantel

Feistmantel (1881) described some *Gangamopteris* leaves from the Raniganj group



TEXT-FIGS. 32, 33 — *Gangamopteris* cf. *cyclopteroides*. 32, distribution and orientation of stomata. × 107. 33, an enlarged drawing of a stoma. × 576.

under a new specific name *Gangamopteris hughesi*. This species, he thought, directly descended from *Gangamopteris cyclopteroides*. However, the fronds of this species differed from those of *Gangamopteris cyclopteroides* in being smaller in size. Moreover, the meshes in *Gangamopteris hughesi* are somewhat larger and equal in size throughout the lamina, whereas the meshes in *Gangamopteris cyclopteroides* are smaller but are larger towards the middle of the leaf, becoming closer and narrower towards the margin. Arber (1905) did not agree with Feistmantel and he thought these differences to be insufficient to warrant a separate specific rank and, therefore, he included these fronds under *Gangamopteris cyclopteroides*.

My specimens, which very much resemble *Gangamopteris hughesi* in characters of the midrib and secondary nervation, come from the same horizon as that of Feistmantel. One of these specimens has yielded well-preserved cuticles. But as *Gangamopteris hughesi* is not a very clearly defined species and my specimens are fragmentary in nature, I am provisionally describing them here as *Gangamopteris* cf. *hughesi*.

Leaf, Specimen No. 8662 — Incomplete impression of a small leaf, having well-preserved carbonized crust at some places (PL. 12, FIG. 76). The apical and the basal portions of the leaf are broken. The leaf shows gradual contraction towards the basal end. The broken leaf in the specimen measures nearly 5·5 cm. in length and 1·8 cm. in breadth at the widest part. The leaf has no midrib, but in the median portion of the frond a few sub-parallel median nerves are visible. From the median nerves, lateral nerves come out at acute angles, forming large polygonal meshes. These meshes are nearly equal in size throughout the preserved portion of the lamina.

This specimen agrees with the description and drawings of *Gangamopteris hughesi* given by Feistmantel (cf. FIG. 76 and FEISTMANTEL, 1881, Vol. III, Pt. 2, PL. 43A, FIGS. 6-8).

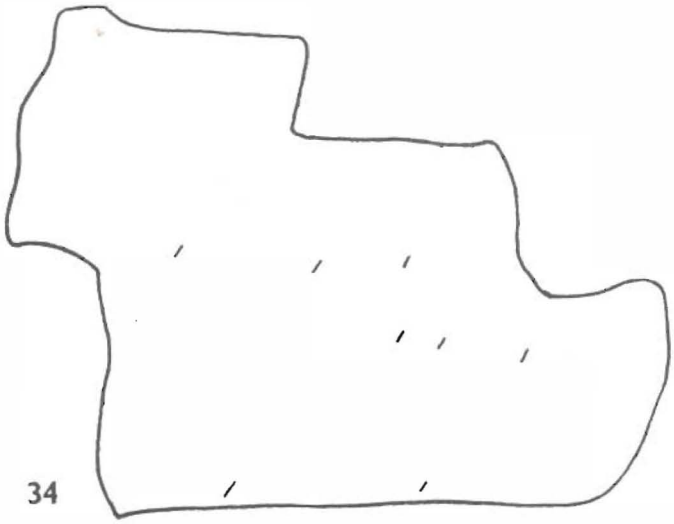
Cuticle — The cuticles of the two surfaces are distinct on account of their different thickness. Network of veins not very marked, but discernible on the upper surface. Stomata confined to one surface only, which probably is the lower one.

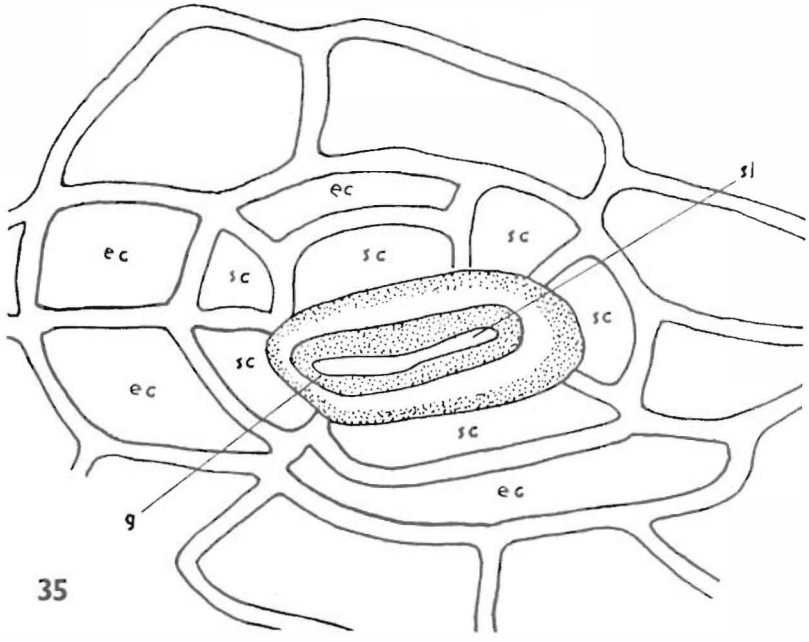
The cuticle of the upper surface (PL. 12, FIG. 77) is thin, showing two types of epidermal cells. Those over the veins are long and narrow, more or less rectangular in shape, measuring about 90 × 36 μ. The walls of these cells are slightly thick and straight to sinuous. The cells in the mesh areas are wider, rectangular or elongate-polygonal in shape, usually longer than broad, measuring nearly 80 × 50 μ. The cell walls are thin and sinuous. Stomata are not found on this surface.

The cuticle of the lower surface (PL. 12, FIG. 78) is much thicker than the upper one. Veins not marked, the epidermal cells are more broad than long, and mostly arranged end to end in tiers. The arrangement is very characteristic. The cells are four-sided, sometimes irregular in shape, usually small

in size, measuring nearly 44 μ. The cell walls are more or less thick, measuring nearly 7 μ. The lateral walls of these cells show a slight curvature.

Stomata are of the haplocheilic type. They occur in single, linear rows and are rather few in number. They show oblique orientation (TEXT-FIG. 34). The stomatal apparatus (PL. 12, FIG. 79; TEXT-FIG. 35) shows dicyclic condition, the subsidiary cells being wholly or partly surrounded by a row of encircling cells. A stoma measures nearly





TEXT-FIGS. 34, 35 — *Gangamopteris* cf. *hughesi*. 34, orientation and distribution of stomata. × 50. 35, an enlarged drawing of a stoma. × 720.

110 μ. The two guard cells, about 50 μ in length, are fairly thickened. Subsidiary cells are usually six in number and they show no specialization.

Comparison — *Gangamopteris hughesi* described as a separate species by Feistmantel in 1881 was included under *Gangamopteris cyclopteroides* by Arber (1905) on the grounds that the differences were not sufficient enough to warrant a specific rank. However, if my fronds described as *Gangamopteris* cf. *cyclopteroides* and *Gangamopteris* cf. *hughesi* belong to *Gangamopteris cyclopteroides* and *Gangamopteris hughesi* respectively, then a comparison of their cuticles shows that in epidermal structure the two species are strikingly different from each other. While in *Gangamopteris* cf. *hughesi* the cuticles of the upper surface are thin with sinuous cell walls, in *Gangamopteris* cf. *cyclopteroides* the cuticles of the upper surface are slightly thick with straight walls. The epidermal cells on the lower cuticle of *Gangamopteris* cf. *hughesi* look to be very different from those on the lower cuticle of *Gangamopteris* cf. *cyclopteroides*. Network of veins and meshes is distinctly marked in the lower cuticle of the latter species, but this arrangement is not discernible in the lower cuticle of the former species. Also the two species differ greatly in the distribution and orientation of the stomata. While in *Gangamopteris* cf. *cyclopteroides* the stomata are irregular in their distribution and orientation, in *Gangamopteris* cf. *hughesi* they are arranged in linear rows, showing oblique orientation. Further, the stomatal apparatus shows dicyclic condition in *Gangamopteris* cf. *hughesi*, but the condition is monocyclic in *Gangamopteris* cf. *cyclopteroides*.

The differences in the epidermal characters between the two species are almost as great as those between *Glossopteris indica* and *Glossopteris angustifolia*. They appear almost of generic value.

3. *Gangamopteris indica* sp. nov.

In my collection from the Raniganj coalfield, I had one carbonized impression of the basal portion of a long leaf, showing a very gradually tapering long and narrow base. The impression showed net-like venation but no midrib. These characters suggested its inclusion in the genus *Gangamopteris*. The gradually tapering long and narrow base suggested its inclusion in *Gangamopteris major*, but a careful examination of the specimen and its comparison with the fronds of the above species showed that it did not agree with them completely. Moreover, *Gangamopteris major* is known only from the Talchir division of the Lower Gondwanas and my specimen comes from a higher horizon, the Raniganj Stage of the Damuda division. A comparison of my frond with the other known species of *Gangamopteris* showed that it did not agree completely with any of the known species. As my specimen is very characteristic in its shape and has yielded well-preserved cuticles, I am describing it here under a new specific name, *Gangamopteris indica*.

Diagnosis — Fronds probably long, having a gradually tapering, very long and narrow base. Apex not known. Nerves few at the basal end, sub-parallel and straight. Median nerves very prominent, secondary nerves arise from the median nerves and from long and narrow meshes.

Cuticles rather thin, stomata present on both the surfaces. Upper cuticle possesses thin and sinuous walled rectangular cells, showing no arrangement of veins and meshes. The lower cuticle is slightly thicker than the upper one and shows distinct arrangement of veins and meshes. Stomata monocyclic or partly dicyclic, showing irregular distribution and orientation.

Leaf, Specimen No. 9402 — Impression of the basal portion of a leaf having carbonized crust preserved at some places (Pl. 12, Fig. 80). Apical portion of the leaf broken, basal portion very long and narrow tapering gradually. The broken leaf in the specimen measures about 13 cm. in length and 2·5 cm. in breadth at the broadest part. Midrib is absent, but a few prominent sub-parallel veins are seen in the median portion of the frond. The secondary nerves come out from the median veins laterally, forming long and narrow meshes.

Comparison — The fronds of *Gangamopteris* with long and narrow tapering bases are those of *Gangamopteris major* and *Gangamopteris buriadica* from the Lower Gondwana rocks of India, and McCoy's *Gangamopteris spatulata* from Australia. The first two species are known only from the Karharbari beds of the Talchir division and have not been reported from the higher Damuda division of the Lower Gondwanas. *Gangamopteris spatulata* was later merged by Arber (1905, p. 106) with *Gangamopteris cyclopteroides*.

My specimen differs from the fronds of *Gangamopteris buriadica* and *Gangamopteris major* in having a more long and narrow base, very prominent median veins and secondary veins coming out laterally from the median veins, forming long and narrow meshes. On the other hand, in the fronds of *Gangamopteris major* and *Gangamopteris buriadica* the secondary veins are formed by the bifurcation of a few median veins, radiating directly from the base, forming very errect, long and narrow meshes.

Among the several varieties of *Gangamopteris cyclopteroides*, the fronds referred to var. *attenuata* are characterized by a narrow base and prominent median veins. But in *Gangamopteris indica* the basal portion is very much longer and narrower than in the above fronds. Therefore, I have described this leaf under a new specific name.

Cuticle — The cuticles of the two surfaces are distinct because of their thickness. Stomata are present on both the surfaces.

The cuticle which belongs probably to the upper surface is very thin. The areas of veins and meshes are not clearly marked. The epidermal cells are rectangular, placed end to end measuring 70 × 20 μ. The cell walls are thin and sinuous. Stomata present.

The cuticle of the lower surface (PL. 12, FIG. 81) is thicker than the upper one. Network of veins clearly marked. Over the veins the cells are long and rectangular, about 72 × 36 μ, arranged in longitudinal rows, 2-4 cells wide. In the areas of the meshes, the cells are polygonal or irregular in shape, measuring nearly 54 μ. The walls of the cells, both over the veins and in the meshes, are straight and comparatively thicker than those on the upper surface. Stomata present, confined only to the mesh areas.

Stomata show irregular distribution and orientation (TEXT-FIG. 36). The adjacent stomata are often contiguous, having common subsidiary cells. Stomatal apparatus (TEXT-FIG. 37) is monocyclic or sometimes dicyclic, the subsidiary cells being partly surrounded by a row of encircling cells. A stoma measures nearly 108 μ. The guard cells, measuring 44 μ in length, are fairly thickened. Stomatal opening is visible as a linear slit in between the two guard cells. Subsidiary cells are 5-6, more common number is five. They are polygonal in shape and smaller in size than the other cells in the mesh areas.

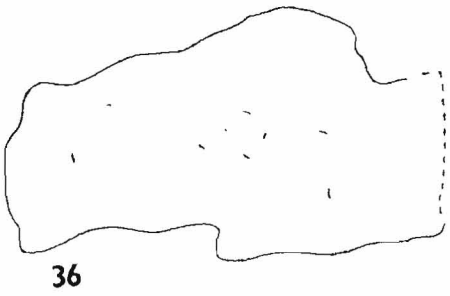
The epidermal cells over the thicker median veins are long, narrow, rectangular in shape placed end to end. These cells measure 64 × 21 μ. The walls of these cells are somewhat thickened and are about 7 μ. Stomata are absent.

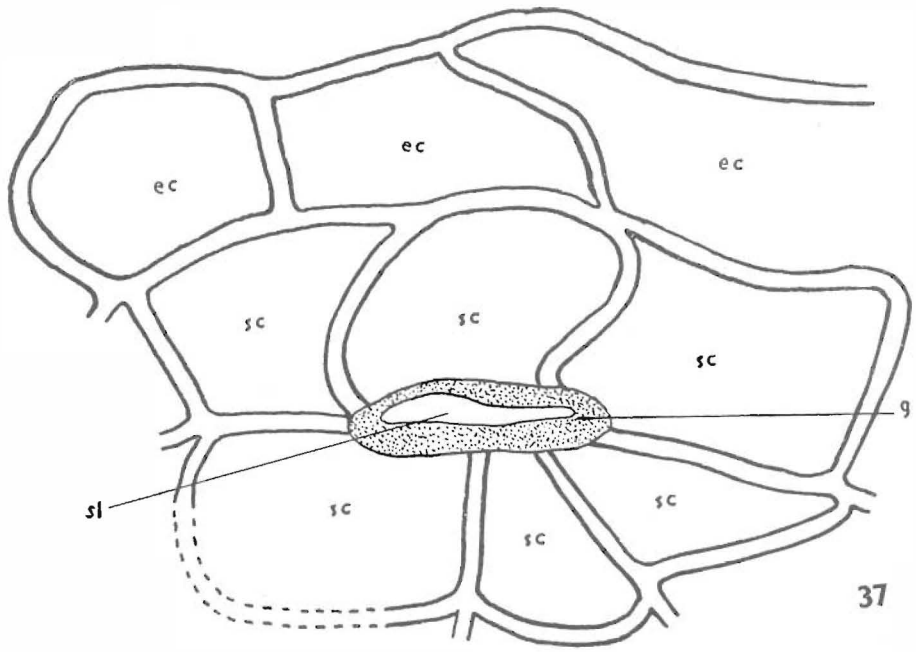
Comparison — The cuticles of *Gangamopteris indica* show a broad similarity with those of *Gangamopteris* cf. *hughesi*, in being thinner on the upper surface and comparatively thicker on the lower side. The epidermal cells in both are sinuous on the upper side and more or less straight on the lower surface. Stomatal apparatuses in both the species are wholly or partly dicyclic having thickened guard cells and usually six, non-papillate subsidiary cells. The two species, however, considerably differ from each other in several other characters. The look of the epidermal cells on the lower cuticle of *Gangamopteris* cf. *hughesi* is very characteristic. They are four-sided, slightly broader than long and there is no demarcation of the areas of the veins and meshes. On the other hand, in *Gangamopteris indica* the cuticles of the lower surface are clearly marked into the areas of the veins and meshes. The cells over the veins are elongately rectangle and in the meshes they are polygonal to irregular in shape. In *Gangamopteris indica* the stomata are present on both the surfaces, but in *Gangamopteris* cf. *hughesi* they are confined to the lower surface only. In *Gangamopteris indica* the stomata are irregular in distribution and orientation but in *Gangamopteris* cf. *hughesi* they are arranged in linear rows showing oblique orientation.

4. *Gangamopteris flexuosa* sp. nov.

One specimen of *Gangamopteris* in my collection from Raniganj showed several distinct characters from all the known species of *Gangamopteris*. This specimen also yielded well-preserved cuticles. I am describing it here under a new specific name, *Gangamopteris flexuosa*. I have given this name because the secondary veins in this leaf are flexuous as seen in *Glossopteris tortuosa* among the Glossopteris fronds.

Diagnosis — Fronds of medium size. The base and apex not known. In the centre of the leaf are seen a few prominent subparallel median veins. Secondary veins radiate out from the basal region and also from some of the median veins at acute





TEXT-FIGS. 36, 37 — *Gangamopteris indica* sp. nov. 36, orientation and distribution of stomata. × 70. 37, an enlarged drawing of a stoma. × 720.

angles, and show repeated bifurcations. After every bifurcation, the two branches run parallel for a considerable distance. Anastomosing of the secondary veins is very rare. Secondary nerves do not follow straight course, but are flexuous.

The cuticles are thin showing no arrangement of veins and meshes. Stomata are confined to the lower surface only. Upper cuticle shows large, elongate, irregular cells having slightly wavy walls. In the lower cuticle the cells are large, elongate and papillate. The cell walls are very sinuous (zigzag). Stomata monocyclic, irregular in distribution and orientation.

Leaf, Specimen No. 8466 — Carbonized impression of an incomplete frond (PL. 12, FIG. 82), the apical and the basal portions of which are broken in the specimen. The broken leaf measures nearly 8 cm. in length and 2·7 cm. in breadth. In the central portion of the frond are seen a few prominent sub-parallel median veins. Secondary veins radiate out from the basal portion of the leaf and also from some of the median nerves at acute angles. They follow flexuous course

and show repeated bifurcations. After each bifurcation the two branches run parallel for a considerable distance. Anastomosing of secondary veins, though present, is very rare. A few of the meshes formed are very long and narrow.

I found a leaf impression similar to my specimen of *Gangamopteris flexuosa* on a slab numbered 5024, from Karharbari Stage, kept in the Geological Survey of India Museum, Calcutta. This slab also bears one leaf impression of *Gangamopteris buriadica*, which has been figured by Feistmantel.

Comparison — Out of nearly one and a half dozen species of *Gangamopteris* described so far, *Gangamopteris major*, *Gangamopteris spatulata*, *Gangamopteris buriadica* and *Gangamopteris indica* are characterized by a long and narrow tapering base. Although my specimen is not complete, from its shape it appears that it must not have possessed a tapering base. Moreover, it further differs from all the above species, except the last one, in having prominent median veins.

Among the other species of *Gangamopteris* my specimen differs from *Gangamopteris cyclopteroides*, *Gangamopteris obliqua* and *Gangamopteris hughesi* in the repeated bifurcation and rare anastomosing of the secondary veins. In all the above species, the secondary veins anastomose freely to form meshes. In the first two species the meshes are comparatively broader and shorter near the median veins, becoming narrower and longer towards the margins.

Gangamopteris anthrophyoides, which, according to Feistmantel, represents the group of smaller leaves among the spatulate fronds, differs from *Gangamopteris flexuosa* in having an attenuated base, straightly radiating secondary nerves and no prominent median veins.

Gangamopteris whittiana, *Gangamopteris conspicua* and *Gangamopteris merseyensis*, differ from my specimen in having much open, broad and short meshes of uniform size throughout the lamina.

From *Gangamopteris angustifolia*, the fronds of *Gangamopteris flexuosa* differ in their probably smaller size and venation. The secondary veins in *Gangamopteris angustifolia* are very crowded, forming regular meshes by anastomosing.

Gangamopteris clarkei differs from my specimen in having a spatulate, rounded shape and no distinct median veins. Secondary veins in *Gangamopteris clarkei* are fairly wide apart and they radiate out from the spatulate base forming oblong meshes.

Among nearly half a dozen species of *Gangamopteris* described from Russia and Siberia, my specimen shows some resemblance with *Gangamopteris rossica* Zalessky in the paucity of the anastomoses, but it differs from it in the flexuous character of the secondary veins.

Lastly, my specimen also differs considerably from *Gangamopteris kashmirensis* in its venation. In *Gangamopteris kashmirensis*, the secondary veins form arches near the median veins and they are more inclined towards the margin of the lamina. Moreover, the median veins in *Gangamopteris kashmirensis* occupy a fairly wide area of the lamina.

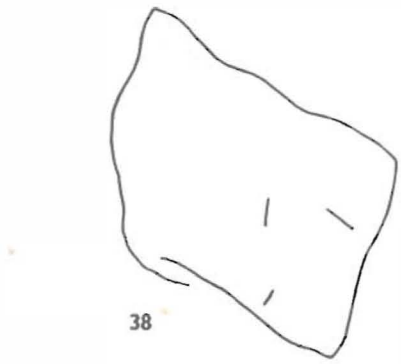
Besides the above-noted individual differences from various species, my specimen appears to differ from all of them in the rarity of the anastomoses and more or less flexuous character of the secondary veins.

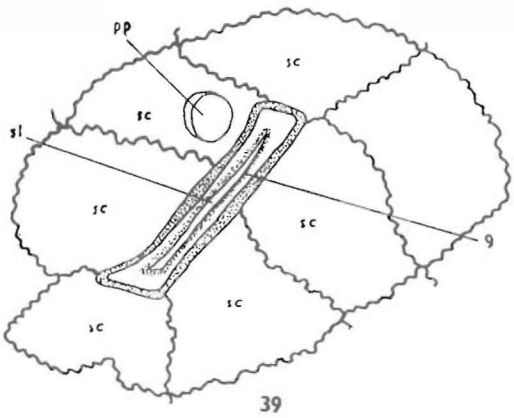
Cuticle — The cuticles are thin and the arrangement of veins and meshes not marked. Stomata are confined to the lower surface of the leaf only.

The cuticle of the upper surface (Pl. 13, Fig. 83) is slightly thicker. The epidermal cells are large, rectangular, polygonal or irregular in shape. Usually the cells are longer than broad, measuring about 118 × 54 μ. The walls of these cells are thin and slightly wavy. The cells are non-papillate and the stomata are absent on this surface.

The cuticle of the lower surface (Pl. 13, Figs. 84, 85) is comparatively thinner. Here also the arrangement of veins and the meshes is not discernible. The outlines of the epidermal cells are faintly marked. The cells are long and narrow, usually rectangular in shape, measuring 162 × 30 μ. The cell walls are thin, but more sinuous (zigzag) than those of the cells of the upper surface. The epidermal cells show large crescent-shaped marks (Pl. 13, Fig. 85), which are most probably the marks of the papillae. Stomata are present on this surface.

The stomata are of the haplocheilic type. They are irregular in distribution and orientation (Text-fig. 38). Adjacent stomata are sometimes contiguous. Stomatal apparatus (Text-fig. 39) shows monocyclic condition. A stoma measures nearly 100 μ. The guard cells, measuring about 54 μ in length, are thickened in the middle portion





TEXT-FIGS. 38, 39 — *Gangamopteris flexuosa* sp. nov. 38, orientation of the stomata. × 107. 39, an enlarged drawing of a stoma. × 576.

of the outer walls and slightly at the poles. Stomatal opening is seen as a linear slit in between the two guard cells. Subsidiary cells are 5-6 in number. They are smaller in size than the other epidermal cells and are polygonal in shape. Their cell walls are also sinuous. Some of the subsidiary cells also show large rounded or crescent-shaped scars which are probably the marks of the papilla.

Comparison — Although *Gangamopteris flexuosa* differs from *Glossopteris arberi* in the external characters by the absence of the midrib, the cuticles of the two species show some broad similarity, which is interesting. In both the species the cuticles are more or less thin, having large rectangular sinuous walled cells. The epidermal cells on the surface of both the leaves possess very sinuous (toothed) walls and big rounded scars, which are probably the marks of the papilla. The stomata in both are confined to the lower surface, irregular in distribution and orientation. In structure also the stomata of the two leaves are not very different. However, *Gangamopteris flexuosa* differs from *Glossopteris arberi* in possessing very large epidermal cells on the upper surface, whereas the cells in *Glossopteris arberi* are comparatively smaller and narrower. The walls of the cells on the upper surface in *Glossopteris arberi* are very sinuous, almost toothed, whereas in *Gangamopteris flexuosa*, the cell walls are somewhat thick and very slightly wavy in character.

5. *Gangamopteris* sp. A

The incomplete specimen of a leaf shown in Pl. 13, Fig. 86, is that of *Gangamopteris* as is evident from the absence of a midrib and the netted venation. On account of the very fragmentary nature of the leaf it is not possible to refer it definitely to any of the known species of *Gangamopteris*. Nevertheless, it shows some resemblance to *Gangamopteris clarkei* Feistmantel (cf. FIG. 86 and FEISTMANTEL 1890, PL. 20, FIG. 3) in its straightly radiating and distant secondary nerves. However, for the present, I am describing this specimen and its cuticles as *Gangamopteris* sp. A.

Leaf, Specimen No. 8619 — Incomplete impression of a small leaf (PL. 13, FIG. 86) having well-preserved carbonized crust. The leaf as seen in the specimen appears to be fan-shaped, with a rounded apex and contracted base. But nothing definite can be said about its shape. The leaf measures about 3 cm. in length and 2 cm. in breadth. In the median portion of the frond are seen a few straightly radiating sub-parallel veins. Secondary veins, which radiate out from the basal portion and from some of the median veins, anastomose to form long and narrow meshes.

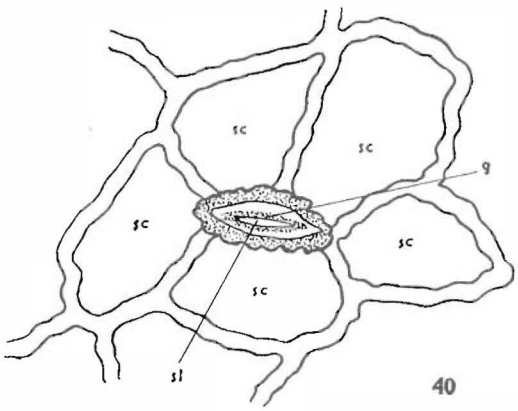
Cuticle — The cuticles are thin and the areas of the veins and meshes are not marked. Stomata are confined to the lower surface only.

The cuticle of the upper surface (PL. 13, FIG. 87) is slightly thicker than the lower one. The epidermal cells are 3 to 4-sided, irregular in shape and arrangement. An average cell measures nearly 72 μ. The cell walls are thin and sinuous, almost dentate. On the surface of each cell is seen a group of

8-10 dark rounded bodies, which may probably be the marks of papillae. Stomata are not seen on this surface.

The cuticle of the lower surface is comparatively thinner. Arrangement of veins and meshes is probably not marked. The epidermal cells are roughly rectangular in shape, but do not show any regular arrangement. These cells measure nearly 60 μ, and the walls are thin and sinuous like those of the cells on the upper surface and are devoid of papillae. Stomata are present on this surface.

The stomata are of the haplocheilic type. They show irregular orientation. Stomatal apparatuses show monocyclic condition. A stoma (PL. 13, FIG. 88; TEXT-FIG. 40) measures nearly 72 μ. The guard cells measuring 28 μ in length are slightly thickened. Subsidiary cells are five in number. They are polygonal in shape and possess sinuous walls.



TEXT-FIG. 40 — *Gangamopteris* sp. A. An enlarged drawing of a stoma. × 540.

Comparison — The cuticles of *Gangamopteris* sp. A show some resemblance with the cuticles of *Gangamopteris flexuosa*. In both the species the cuticles are thin with sinuous cells, arrangement of veins and meshes is not discernible and the stomata are confined to the lower surface, showing irregular orientation. Also the stomatal apparatuses show monocyclic condition. However, the cuticles of the two differ from each other in other important characters. In *Gangamopteris* sp. A the epidermal cells of the upper cuticle are papillate, while they are non-papillate in *Gangamopteris flexuosa*. Subsidiary cells and some other cells in the neighbourhood of the stomata in the lower cuticle of *Gangamopteris flexuosa* are papillate but they are non-papillate in *Gangamopteris* sp. A.

6. *?Gangamopteris* sp. B

The leaf shown in Pl. 13, Fig. 89, at the first glance looks like a *Glossopteris* leaf. On closer examination it is found that there is no distinct midrib, instead a few sub-parallel veins are seen in the median portion of the frond. These median veins bifurcate and anastomose to form long and narrow polygonal meshes throughout the lamina. It has not been possible for me to compare this specimen with any of the known species of *Gangamopteris* on account of its bad preservation. However, it has yielded good cuticles and, therefore, I am provisionally describing this specimen here as *?Gangamopteris* sp. B.

Leaf, Specimen No. 9401 — Incomplete impression of a leaf (PL. 13, FIG. 89) with carbonized crust preserved at a few places. The apical and the basal portions of the leaf are broken in the specimen. It probably had a pointed apex. The leaf measures 6·5 cm. in length and 2·5 cm. in breadth at the widest part. In the median portion of the frond are seen a few sub-parallel veins, which divide and anastomose to form long and narrow polygonal meshes.

Cuticle — The cuticles are thick on both the surfaces, but the stomata are confined to the lower surface only.

The cuticles of the upper surface (PL. 14, FIG. 90) possess epidermal cells which are rectangular or elongate polygonal, arranged end to end. These cells measure nearly 75 × 30 μ. The walls of these cells are straight and thick, measuring nearly 10 μ.

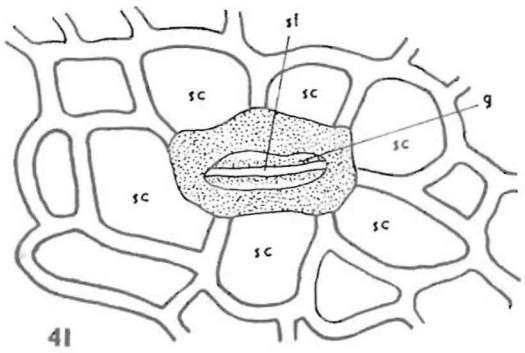
The cuticles of the lower surface (PL. 14, FIG. 91) possess polygonal cells of nearly uniform size, measuring about 37 μ. The cell walls are straight, but less thick than those on the upper surface.

Stomata are of the haplocheilic type. Stomatal apparatus (TEXT-FIG. 41) shows monocyclic condition. A stoma measures about 55 μ in length. Subsidiary cells, which are 6 in number, are similar in shape and size to other epidermal cells. The guard cells are much thickened. Sufficient number of stomata have not been found to

TABLE 2 — DISTINGUISHING EPIDERMAL CHARACTERS OF *GANGAMOPTERIS* SPECIES

Name of the species	Differentiation between veins and meshes	Epidermal cells			Stomata			Guard cells
		Thick or thin straight or sinuous	Size and shape	Papillate or non-papillate	Stomata on both or one surface	Distribution and Orientation	No. of subsidiary cells, papillate or non-papillate	
Gangamopteris cf. *cyclopteroides*	Up–marked	Up–slightly thick, straight	Up: veins–rectangular, 162 × 36 μ; meshes–irregular, 90 × 46 μ	Up–non-papillate	Up–not present	Dis–irregular	5-6, non-papillate	Thickened
	Lw–marked	Lw–less thick, straight	Lw: veins–rectangular, 90 × 28 μ; meshes–four-sided, irregular, 50 μ	Lw–non-papillate	Lw–present	Ori–irregular		
Gangamopteris cf. *hughesi*	Up–marked	Up–thin, sinuous	Up: veins–rectangular, 90 × 36 μ; meshes–polygonal or irregular, 80 × 50 μ	Up–non-papillate	Up–not present	Dis–in linear rows	6, non-papillate	Thickened
	Lw–not marked	Lw–thick, straight or slightly wavy	Lw–four-sided, irregular, 44 μ	Lw–non-papillate	Lw–present	Ori–oblique		
Gangamopteris indica	Up–not marked	Up–thin, sinuous	Up–rectangular, 70 × 20 μ	Up–non-papillate	Up–present	Dis–irregular	5-6, non-papillate	Thickened
	Lw–marked	Lw–moderately thick, straight	Lw: veins–rectangular, 72 × 36 μ; meshes–polygonal or irregular, 54 μ	Lw–non-papillate	Lw–present	Ori–irregular		
Gangamopteris flexuosa	Up–not marked	Up–thin, sinuous	Up–rectangular polygonal or irregular, 118 × 54 μ	Up–non-papillate	Up–not present	Dis–irregular	5-6, papillate	Slightly thickened
	Lw–not marked	Lw–thin, more sinuous	Lw–rectangular, 162 × 30 μ	Lw–papillate	Lw–present	Ori–irregular		
Gangamopteris sp. A	Up–not marked	Up–thin, sinuous	Up–3 to 4-sided, irregular, 72 μ	Up–papillate	Up–not present	Dis–not known	5, non-papillate	Slightly thickened
	Lw–not marked	Lw–thin, sinuous	Lw–rectangular, 60 μ	Lw–non-papillate	Lw–present	Ori–irregular		
Gangamopteris sp. B	Up–not marked	Up–thick, straight	Up–rectangular or elongate polygonal, 75 × 30 μ	Up–non-papillate	Up–not present	Dis–not known	6, non-papillate	Thickened
	Lw–not marked	Lw–less thick, straight	Lw–polygonal, 37 μ	Lw–non-papillate	Lw–not present	Ori–not known		

Note — Up = for cuticle of the upper surface. Lw = for cuticle of the lower surface.



TEXT-FIG. 41 — *?Gangamopteris* sp. B. An enlarged drawing of a stoma. × 366.

throw light on their distribution and orientation.

Comparison — The cuticles of *?Gangamopteris* sp. B show certain similarities with the cuticles of *Gangamopteris* cf. *cyclopteroides*. In both the leaves the cuticles of the upper surface are comparatively thicker than the lower one. The epidermal cells in both possess straight walls and the stomatal apparatuses showing monocyclic condition, are confined to the lower surface only. The non-papillate subsidiary cells in both number 5-6. In spite of these similarities the cuticles of the two differ from each other in more than one respect. In the cuticles described under *?Gangamopteris* sp. B the network of veins is not marked on both the surfaces, but in *Gangamopteris* cf. *cyclopteroides* the network of veins is clearly marked, both on the upper and the lower surfaces. Further, in the lower cuticle of *Gangamopteris* cf. *cyclopteroides* the four-sided epidermal cells are irregular in shape and arrangement, but in the cuticles of *?Gangamopteris* sp. B the epidermal cells on the lower cuticle show striking uniformity in their shape, size and arrangement. All the cells on this surface are perfectly polygonal in shape.

C. GENUS — *PALAEOVITTARIA* FEISTMANTEL

Palaeovittaria kurzi Feistmantel

This is the only species known in this genus and was described by Feistmantel (1876). He named it after Dr. Kurz, who pointed out its resemblance to the recent fern *Vittaria*. Zeiller (1902) described some similar fronds from the Rhaetic beds of Tonquin and also extended the diagnosis of this species. Arber (1905) included it in his catalogue of the *Glossopteris* flora.

The cuticles of this species have been studied from the specimen bearing the number 9294, which is the only specimen of this species in my collection.

Leaf, Specimen No. 9294 — An incomplete impression of a leaf with well-preserved carbonized crust (PL. 14, FIG. 92). The apical portion is more or less complete, but the basal portion is broken. The leaf seems to have a rounded apex and no midrib in the upper portion, but in the lower part, two or three strong veins are seen in the place of a midrib. The preserved portion of the leaf measures nearly 8 cm. in length and 4 cm. in breadth at the widest part. From Feistmantel's Fig. 1, Pl. 44A (1881, Vol. III, Pt. 2) it appears that my leaf impression represents the portion above the midrib. The lateral nerves are very errect, spreading a little, incurved towards the margin. They are seen to dichotomize once or twice in their course, but do not anastomose to form meshes as in *Glossopteris* or *Gangamopteris*.

This specimen agrees with the description and figures of *Palaeovittaria kurzi* given by Feistmantel (cf. PL. 14, FIG. 92 and FEISTMANTEL, 1881, Vol. III, Pt. 2, p. 91, PL. 44A, FIG. 2). It compares with a broken specimen of *Palaeovittaria kurzi* numbered 5326, kept at the Geological Survey of India Museum, Calcutta.

Cuticle — The cuticles of the two surfaces are distinct because of their thickness. The cuticle of the lower surface is very brittle and breaks up into tiny pieces, making it very difficult to get a cuticle piece of good size. Arrangement of veins and meshes is marked on both the surfaces (PL. 14, FIG. 93). Stomata are confined to the lower surface of the leaf only.

The cuticle of the upper surface is rather thick. The arrangement of veins is clearly marked. Over the veins the epidermal cells are rectangular, long and narrow, placed end to end. An average cell measures nearly 108 × 25 μ. The cell walls are moderately thick and straight. In between the veins the epidermal cells are 4 to 5-sided, rectangular or polygonal in shape. These cells are usually longer than broad, measuring nearly 70 μ. The lateral walls of these cells are

sometimes curved. Stomata are not present on this surface.

The cuticle of the lower surface (PL. 14, FIG. 94) is much thinner than the upper one. The cells covering the veins are well marked and are similar to those on the upper surface. The other epidermal cells are also similar to the upper surface, except for the fact that the cell walls are thin. Stomata are present and confined to the areas in between the veins but are absent over the veins.

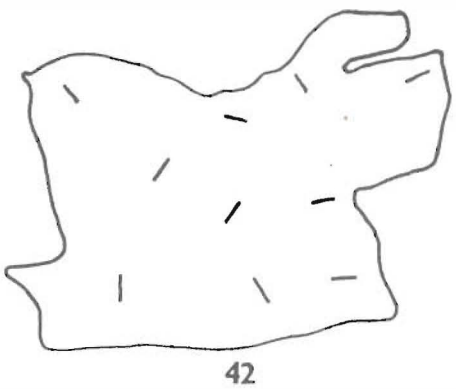
The stomata are of the haplocheilic type. They appear to be rather crowded. A piece measuring 352 × 240 μ showed as many as 14 stomata. Adjacent stomata are contiguous and the subsidiary cells are sometimes common. Stomata are irregular in orientation (TEXT-FIG. 42). Stomatal apparatuses show monocyclic condition. A stoma (PL. 14, FIG. 95; TEXT-FIG. 43) measures nearly 55 μ. The two guard cells, measuring about 37 μ in length, together form a dumble-shaped body in surface view in the centre of which the stomatal opening is seen as a linear slit measuring about 20 μ. The outer walls of the guard cells are slightly thickened and some unequal thickening is seen round the pore also. The subsidiary cells are usually five in number. They are polygonal in shape, sometimes papillate (TEXT-FIG. 43) and smaller in size than the other epidermal cells.

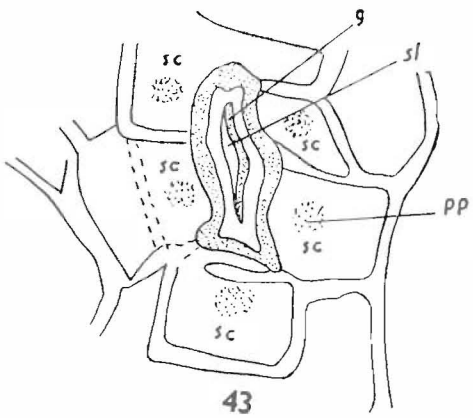
Comparison — Out of all the species of *Glossopteris* and *Gangamopteris* described here, the cuticles of *Palaeovittaria kurzi* show some resemblance with those of *Glossopteris intermittens*.

Feistmantel (1881) described the species *Glossopteris intermittens*. It agrees externally with *Palaeovittaria kurzi* except for the fact that it is smaller in size, possesses a faintly marked midrib up to the apex and shows a few anastomoses in the secondary veins. The cuticles of the two look to be very similar to each other in general shape of the epidermal cells and the distribution, orientation and structure of the stomata (cf. PL. 6, FIG. 42 and PL. 14, FIG. 92; PL. 7, FIG. 46 and PL. 14, FIG. 94).

However, the cuticles of *Palaeovittaria kurzi* differ from those of *Glossopteris intermittens* in having papillae on the subsidiary cells. Moreover, the epidermal cells in the lower cuticles of *Palaeovittaria kurzi* appear to have thinner cell walls than those on the lower cuticle of *Glossopteris intermittens*.

From a comparison of the leaves of *Glossopteris intermittens* and *Palaeovittaria kurzi*, both in external characters and in the structure of the cuticles, it is seen that *Glossopteris intermittens* shows closer affinities to *Palaeovittaria* than to *Glossopteris*. It may be possible that the leaves described as *Glossopteris intermittens* may belong to some species of *Palaeovittaria* or to a plant closely related to *Palaeovittaria*.





TEXT-FIGS. 42, 43 — *Palaeovittaria kurzi*. 42, distribution and orientation of the stomata. × 150. 43, an enlarged drawing of a stoma. × 720.

ACKNOWLEDGEMENTS

It is with deep gratitude that I take this opportunity to thank Dr. K. R. Surange for the inspiration and guidance he has given me throughout the course of this work. I feel,

without his valuable help this work would not have reached the present stage. My thanks are also due to the authorities of the Geological Survey of India for the facilities given to me for comparing the specimens in my collection with the type specimens kept in the museum of the Geological Survey of India at Calcutta.

REFERENCES

ARBER, E. A. N. (1902). On the Clarke collection of Fossil Plants from New South Wales. *Quart. Jour. Geol. Soc.* **58**.

Idem (1905). The Glossopteris flora. *London*.

BRONGNIART, A. (1828). Prodrome d'une Histoire des vegetaux fossiles. *Paris*.

*FEISTMANTEL, O. (1876). On some fossil plants from the Damuda Series in the Raniganj Coalfield, collected by Mr. J. Wood-Mason. *Journ. Asiatic Soc. Bengal.* **45**(2): 329.

Idem (1876). *Rec. Geol. Surv. India.* **9**(3): 76.

Idem (1877). Notes on Fossil Floras in India. *Rec. Geol. Surv. India.* **10**(2): 68.

Idem (1877). Notes on Fossil Floras in India. *Rec. Geol. Surv. India.* **10**(4): 196.

Idem (1879). The Flora of the Talchir-Karharbari Beds. Pt. 1 and Suppl. of Volume 3 of the Fossil Flora of the Gondwana System. *Mem. Geol. Surv. India. Pal. Indica.* Ser. 12.

Idem (1880-81). The Flora of the Damuda-Panchet Divisions. Parts 2-3 of Volume 3 of the Fossil Flora of the Gondwana System. *Mem. Geol. Surv. India. Pal. Indica.* Ser. 12.

Idem (1882). The Fossil Flora of the South Rewah Gondwana Basin. Part 1 of Volume 4 of the Fossil Flora of the Gondwana System. *Mem. Geol. Surv. India. Pal. Indica.* Ser. 12.

Idem (1886). The Fossil Flora of some of the Coalfields in Western Bengal. Part 2 of Volume 4 of the Fossil Flora of Gondwana System. *Mem. Geol. Surv. India. Pal. Indica.* Ser. 12.

Idem (1889). Ubersichtliche darstellung der Geologisch-Palaeontologischen Verhaltnisse Sud-Afrikas. Theil 1. Die Karoo-Formation, und die dieselbe unterlagernden Schichten. *Abhand. Bohm, Gesell. Wiss. Prag.* Ser. 7. **3**(6).

Idem (1890). Geological and Palaeontological relations of the Coal and Plant-bearing beds of Palaeozoic and Mesozoic age in Eastern Australia and Tasmania, etc. *Mem. Geol. Surv. New South Wales. Palaeont.* No. 3.

FLORIN, R. (1940). On *Walkomia* n. gen., a genus of Upper Palaeozoic conifers from Gondwanaland. *K. Svensk. vet. Akad. Hand.* **18**(5).

*McCOY, F. (1847). On the Fossil Botany and Zoology of the rocks associated with the coal of Australia. *Ann. & Mag. Nat. Hist.* **20**.

PLUMSTEAD, E. P. (1952). Description of two new genera and six new species of fructifications borne on *Glossopteris* leave. *Trans. Geol. Soc. S. Africa.* **55**: 290.

SAHNI, B. (1923). The cuticular structure of *Glossopteris angustifolia* Brong. *Rec. Geol. Surv. India.* **54**(3): 277-280.

SCHIMPER, W. P. (1869). Traite de Palaeontologie vegetal. **1**.

SEWARD, A. C. (1897). On the Association of *Siggilaria* and *Glossopteris* in South Africa. *Quart. Jour. Geol. Soc.* **53**: 315.

SEWARD, A. C. & WOODWARD, A. S. (1905). Permo-carboniferous plants and Vertebrates from Kashmir. *Mem. Geol. Surv. India. Pal. Indica. N.S.* **2**. *Mem.* No. 2.

*TATE, R. (1867). On some secondary fossils from South Africa. *Quart. Jour. Geol. Soc.* **23**.

*TENISON-WOODS, J. E. (1883). On the fossil flora of the Coal deposits of Australia. *Proc. Linn. Soc. New South Wales.* **8**(1).

THOMAS, H. H. (1931). A *Glossopteris* with whorled leaves. *Palaeobotanist.* **1**: 435-438.

ZALESSKY, M. D. (1912). On the impressions of plants from the Coal-bearing deposits of Sudzenka, Siberia. *Bull. Soc. Nat. Orel.* (IV).

ZEILLER, R. (1896) Etudes sur quelques plantes fossiles, en particulier *Vertebraria* et *Glossopteris*, des environs de Johannesburg (Transvaal). *Bull. Soc. Geol. France.* Ser. 3. **24**: 368-369.

Idem (1896). Remarques sur la flore fossile de l'Altai, a propos des dernieres decouvertes palaeobotaniques de MM. les Drs. Bodenbender et Kurtz dans la Republique Argentine. *Bull. Soc. Geol. France.* Ser. 3. **24**: 466.

Idem (1902). Observations sur quelques plantes fossiles des Lower Gondwanas. *Mem. Geol. Surv. India. Pal. Indica.* New ser. **2**. *Mem.* No. 1.

Idem (1902-3). Flore Fossile des Gites de Charbon du Tonkin. (Text 1903; Atlas 1902.) *Paris*.

NOTE — Publications marked with asterisks were not accessible to the author.

EXPLANATION OF PLATES

PLATE 1

1. Leaf of *Glossopteris browniana*. × *Ca*. Nat. size.
2. Leaf as shown in Fig. 1 enlarged. × *Ca*. 3.
3. Leaf showing different venation enlarged. × 3.
4. Upper cuticle from the leaf in Fig. 1. × 190.
5. Lower cuticle from the leaf in Fig. 1. × 130.
6. A single stoma enlarged from the lower cuticle of the leaf shown in Fig. 1. × 510.

PLATE 2

7. Leaf of *Glossopteris* cf. *divergens*. × Nat. size.
8. Leaf as shown in Fig. 7 enlarged. × 3.
9. Upper cuticle from the leaf in Fig. 7. × 195.
10. Lower cuticle from the leaf in Fig. 7. × 190.
11. A single stoma enlarged from the lower cuticle of the leaf in Fig. 7. × 460.
12. Leaf of *Glossopteris communis* enlarged. × 3.
13. Upper cuticle from the leaf of *Glossopteris communis*, numbered 5637. × 150.

PLATE 3

14. Lower cuticle from the leaf of *Glossopteris communis*, numbered 5637. × 150.
15. A single stoma enlarged from the lower cuticle shown in Fig. 14. × 510.
16. Upper cuticle of the midrib from the leaf of *Glossopteris communis*, numbered 5637. × 180.
17. Leaf of *Glossopteris communis* var. *stenoneura*. × *Ca*. Nat. size.
18. Leaf as shown in Fig. 17 enlarged. × *Ca*. 3.
19. Upper cuticle from the leaf in Fig. 17. × 190.
20. Lower cuticle from the leaf in Fig. 17. × 190.

PLATE 4

21. Leaf of *Glossopteris conspicua*. × Nat. size.
22. Leaf as shown in Fig. 21 enlarged. × 3.
23. Lower cuticle from the leaf in Fig. 21. × 260.
24. Lower cuticle as shown in Fig. 23 after prolonged maceration. × 190.
25. A single stoma enlarged from the lower cuticle of the leaf shown in Fig. 21.
26. Leaf of *Glossopteris formosa*. × *Ca*. Nat. size.
27. Leaf as shown in Fig. 26 enlarged. × *Ca*. 3.
28. Lower cuticle of the midrib from the leaf shown in Fig. 26. × 150.

PLATE 5

29. Upper cuticle from the leaf in Fig. 26. × 150.
30. Lower cuticle from the leaf in Fig. 26 showing distribution of stomata. × 80.
31. A single stoma enlarged from the lower cuticle shown in Fig. 30. × 460.
32. Leaf of *Glossopteris retifera*. × Nat. size.
33. Leaf as shown in Fig. 32 enlarged. × 3.
34. Upper cuticle from the leaf in Fig. 32. × 210.
35. A single stoma enlarged from the lower cuticle of the leaf shown in Fig. 32. × 780.
36. Cuticle of the midrib from the leaf in Fig. 32. × 210.

PLATE 6

37. Leaf of *Glossopteris damudica*. × *Ca*. Nat. size.
38. Upper cuticle from the leaf in Fig. 37. × 190.
39. Upper cuticle as shown in Fig. 38 enlarged. × 360.
40. Lower cuticle from the leaf in Fig. 37 showing veins and meshes. × 90.
41. Lower cuticle as shown in Fig. 40 enlarged. × 190.
42. Leaf of *Glossopteris intermittens*, enlarged. × 3.

PLATE 7

43. Leaf of *Glossopteris intermittens*. × Nat. size.
44. A cuticle piece showing both the sides obtained from the leaf in Fig. 43. × 170.
45. Upper cuticle from the leaf in Fig. 43. × 210.
46. Lower cuticle from the leaf in Fig. 43, showing distribution of stomata. × 210.
47. A few stomata enlarged from the cuticle piece in Fig. 46. × 680.
48. Leaf of *Glossopteris taeniopteroides*. × Nat. size.
49. Leaf as shown in Fig. 48 enlarged. × 3.

PLATE 8

50. Lower cuticle enlarged. × 170.
51. Upper cuticle from the leaf in Fig. 48. × 170.
52. A single stoma enlarged from the lower cuticle. × 570.
53. Leaf of *Glossopteris sahnii* sp. nov. × Nat. size.
54. Leaf as shown in Fig. 53 enlarged. × *Ca*. 3.
55. A stoma showing guard cells from the cuticle of the leaf in Fig. 53. × 792.
56. Cuticle of the midrib from the leaf in Fig. 53. × *Ca*. 100.

PLATE 9

57. Leaf of *Glossopteris arberi* sp. nov. × *Ca*. Nat. size.
58. Leaf as in Fig. 57 enlarged. × *Ca*. 3.
59. Upper cuticle from the leaf in Fig. 57. × 165.
60. Lower cuticle from the leaf in Fig. 57, showing distribution of stomata. × 190.
61. A single stoma enlarged from the lower cuticle shown in Fig. 60. × 570.

PLATE 10

62. Leaf of *Glossopteris longicaulis*. × *Ca*. Nat. size.
63. Leaf as in Fig. 62 enlarged. × *Ca*. 3.
64. Upper cuticle enlarged, showing arrangement of stomata. × 190.
65. Lower cuticle from the leaf in Fig. 62. × 155.
66. A single stoma enlarged from the cuticle in Fig. 64. × 400.

PLATE 11

67. Leaf of *Glossopteris taenioides*. × Nat. size.
68. Leaf as in Fig. 67 enlarged. × 3.

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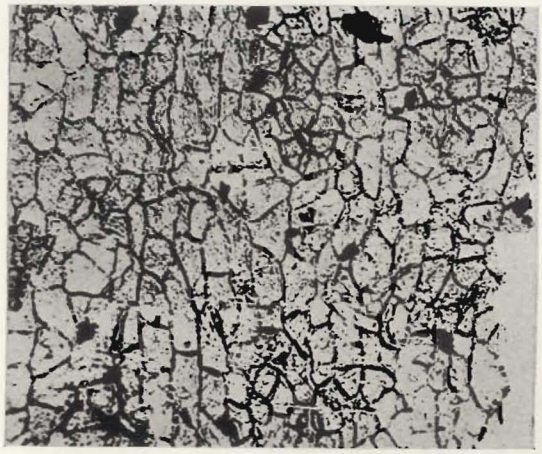

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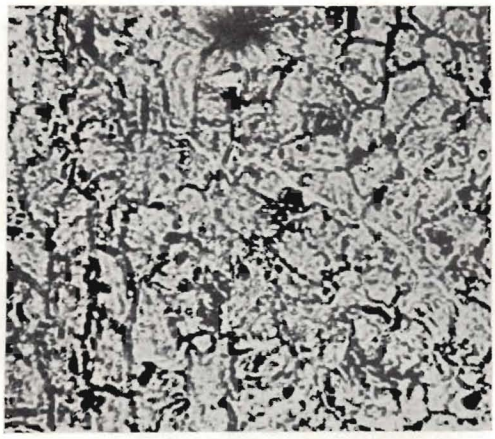

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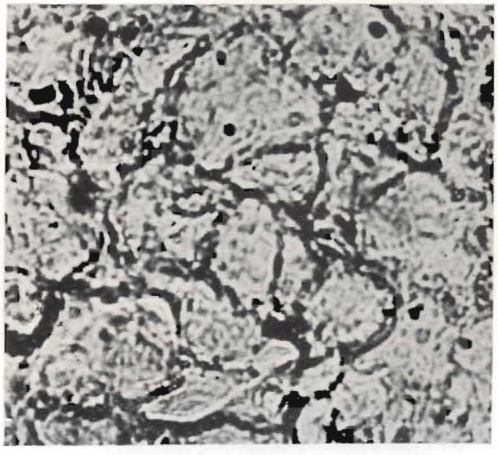

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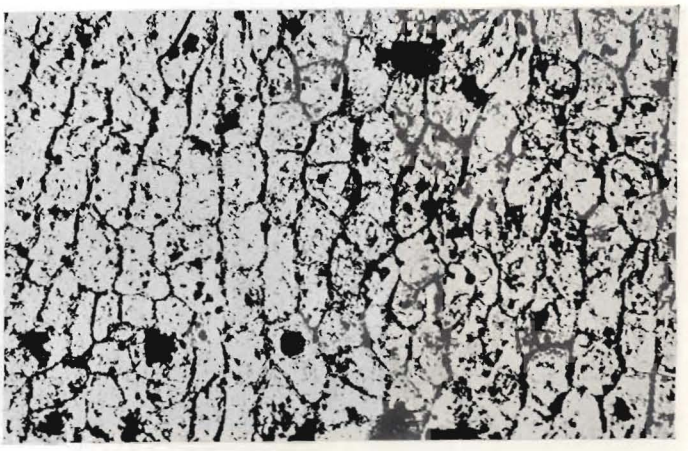

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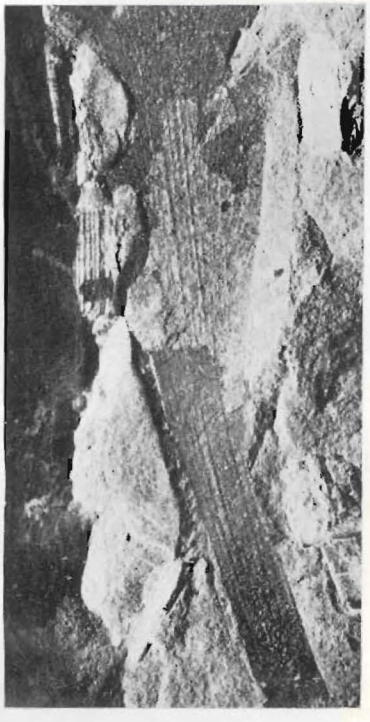

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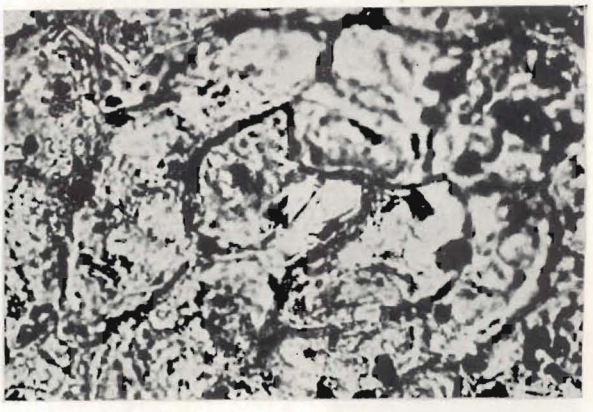

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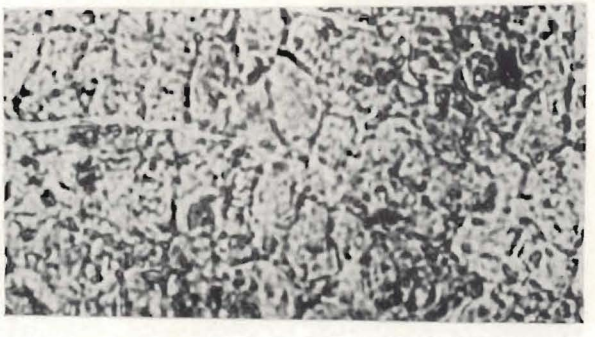

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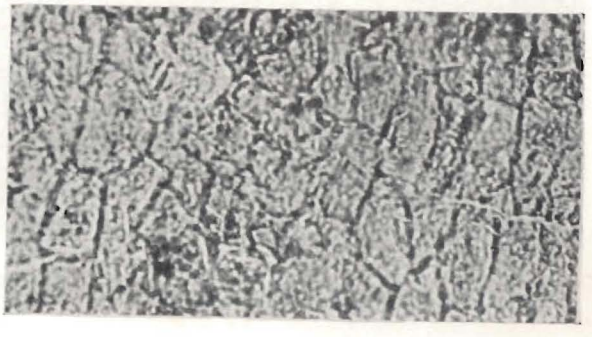

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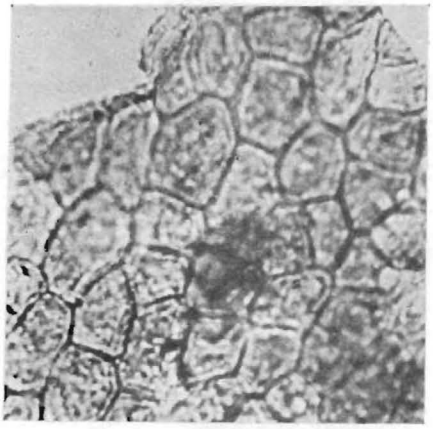

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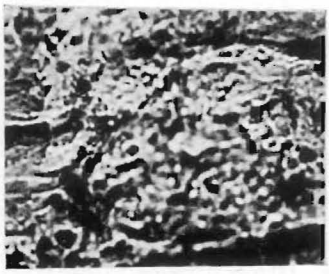

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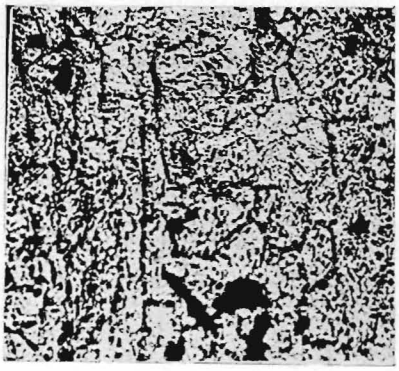

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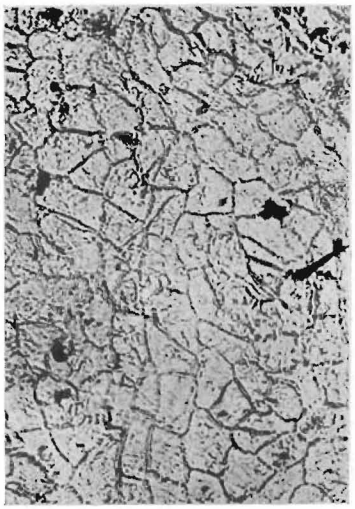

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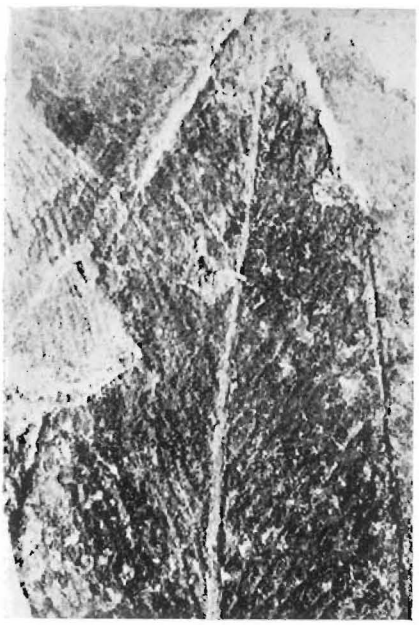

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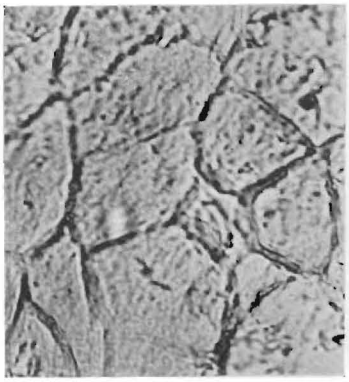

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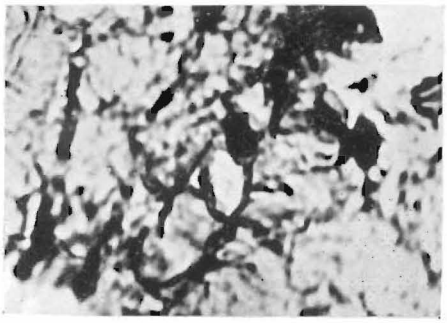

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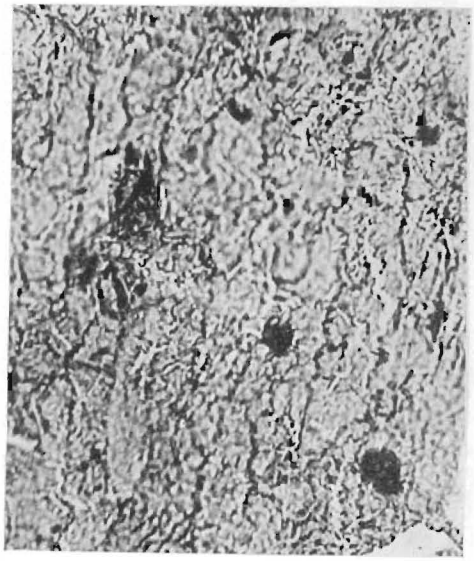

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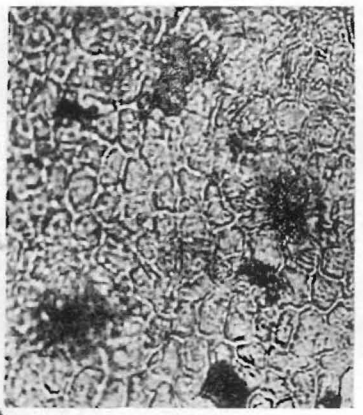

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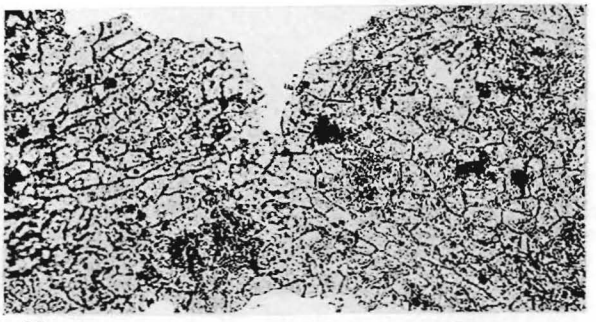

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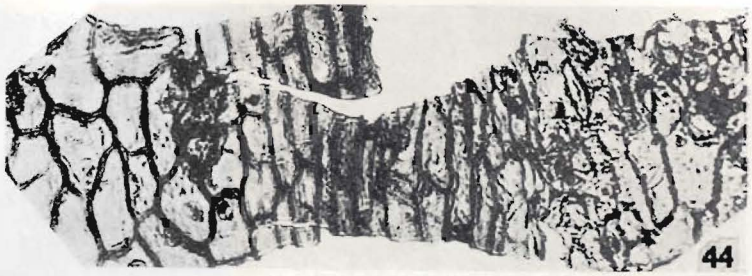

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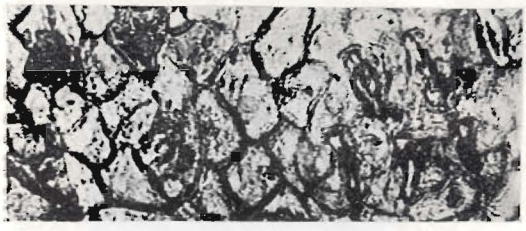

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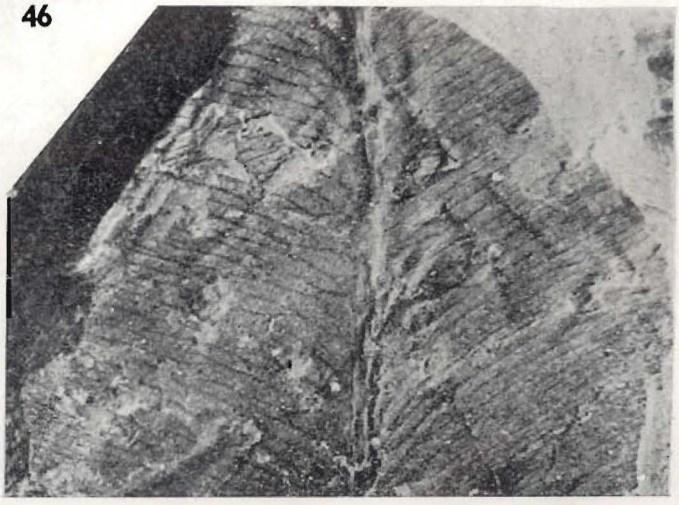

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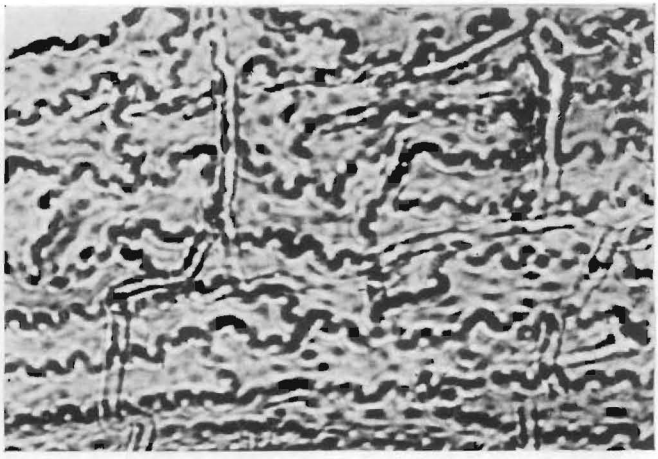

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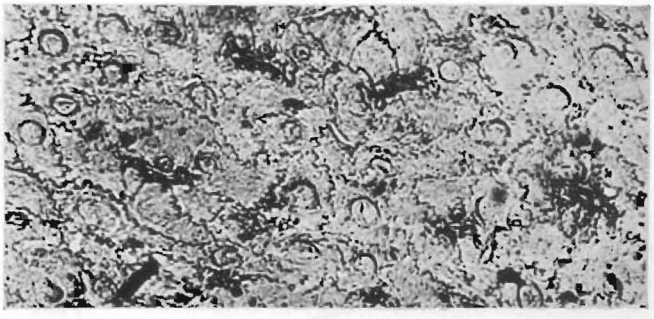

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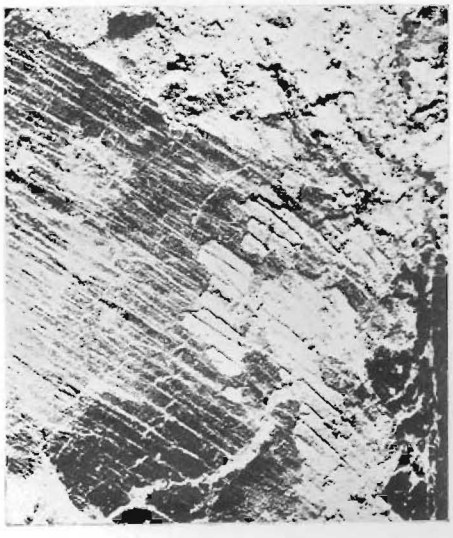

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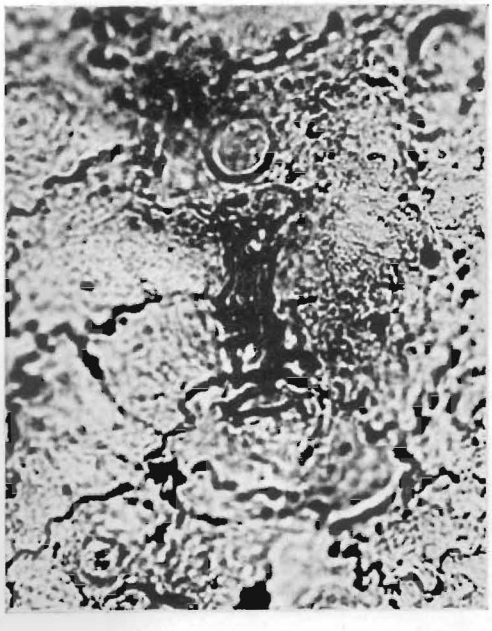

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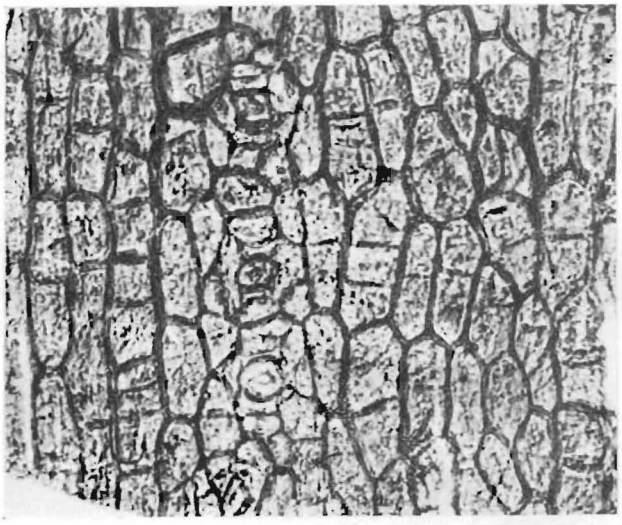

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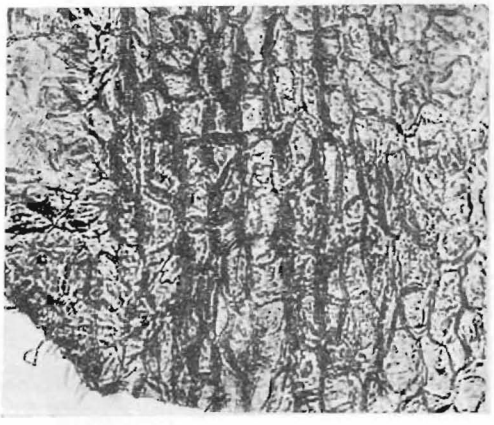

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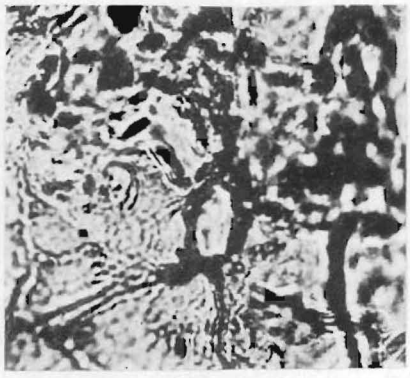

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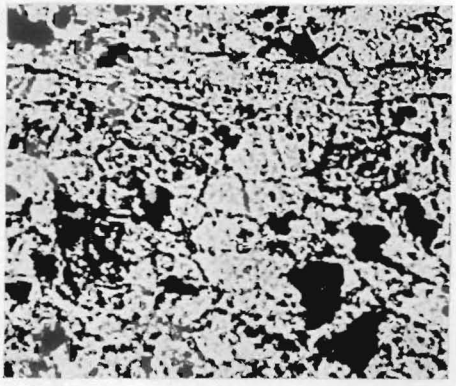

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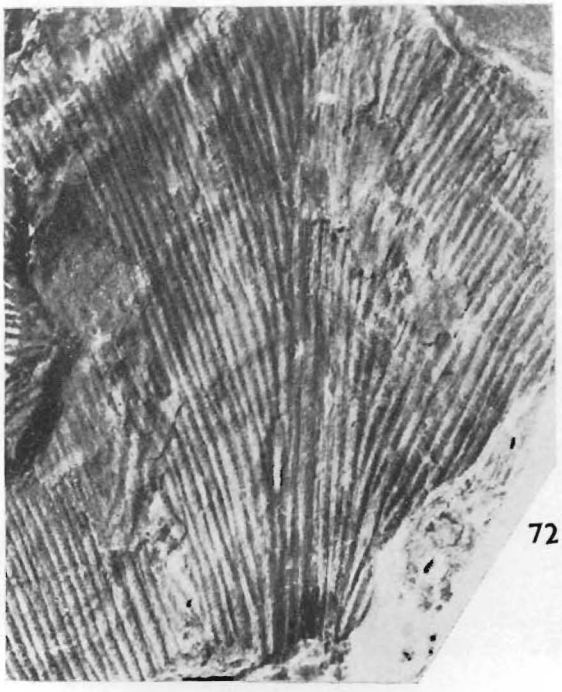

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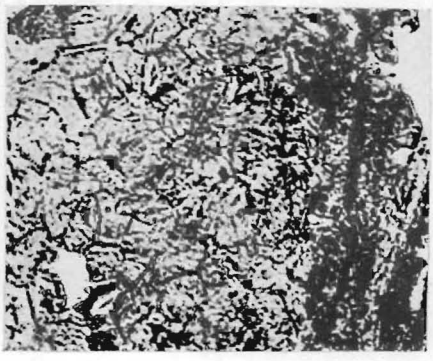

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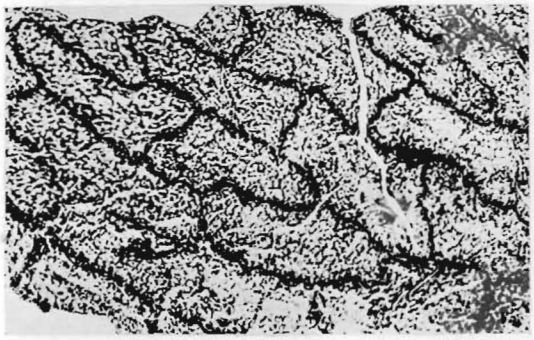

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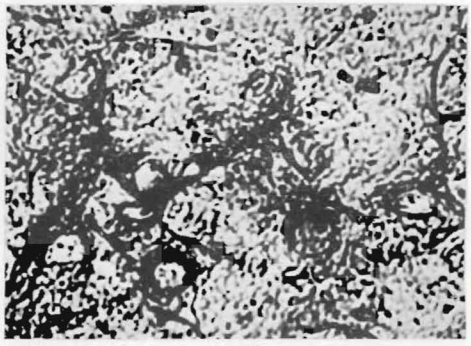

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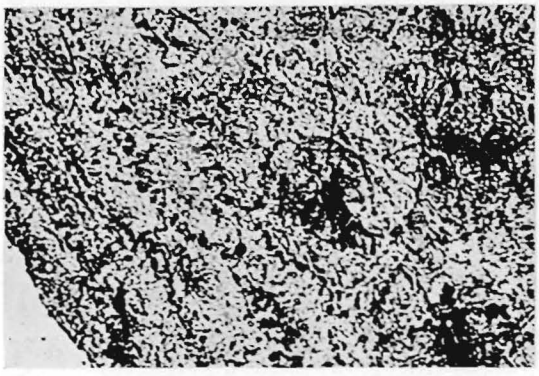

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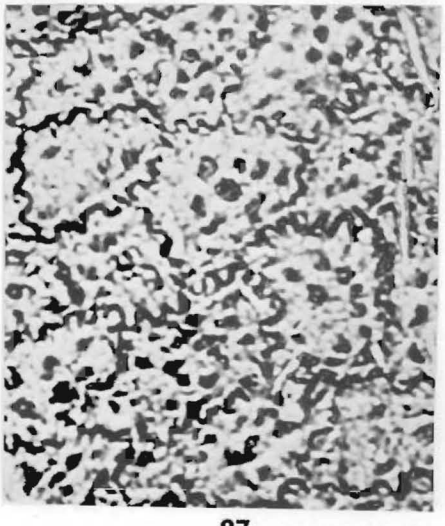

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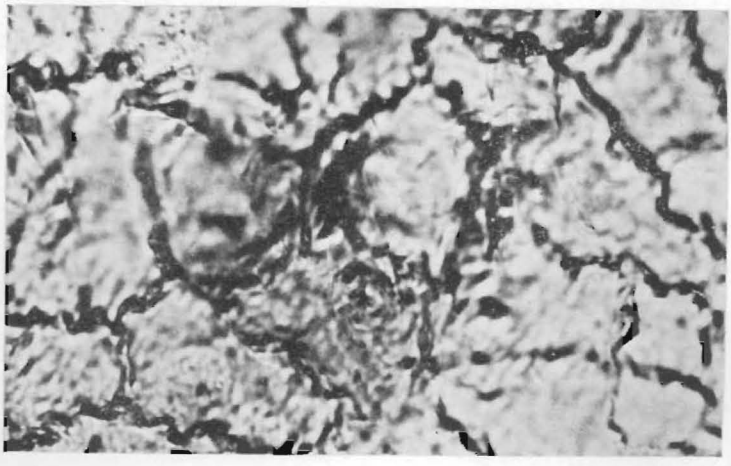

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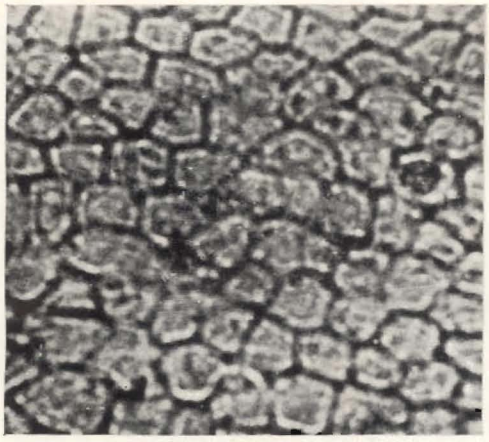

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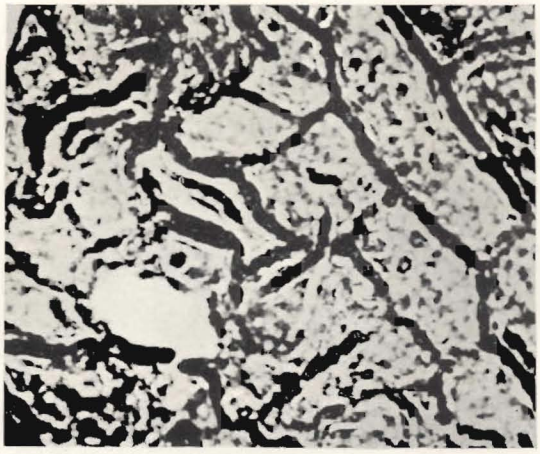

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69. Lower cuticle from the leaf in Fig. 67. × 180.
70. A single stoma enlarged from the cuticle in Fig. 69. × 740.
71. Cuticle of the midrib from the leaf in Fig. 67. × 180.
72. Leaf of *Glossopteris* cf. *cyclopteroides* enlarged. × 3.
73. Upper cuticle from the leaf showing veins and meshes. × 50.
74. Lower cuticle from the leaf showing stomata. × 180.

PLATE 12

75. A single stoma enlarged from the cuticle in Fig. 74. × 600.
76. Leaf of *Gangamopteris* cf. *hughesi*. × Nat. size.
77. Upper cuticle from the leaf in Fig. 76. × 150.
78. Lower cuticle enlarged. × 120.
79. A single stoma enlarged. × 440.
80. Leaf of *Gangamopteris indica* sp. nov. × *Ca.* Nat. size.
81. Lower cuticle from the leaf in Fig. 80 showing veins and meshes. × 70.
82. Leaf of *Gangamopteris flexuosa* sp. nov. × Nat. size.

PLATE 13

83. Upper cuticle from the leaf in Fig. 82. × 150.
84. Lower cuticle from the leaf in Fig. 82 showing stomata. × 210.
85. Lower cuticle from the leaf in Fig. 82 showing papillae on the epidermal cells. × 310.
86. Leaf of *Gangamopteris* sp. A. × Nat. size.
87. Upper cuticle from the leaf in Fig. 86. × 360.
88. A single stoma enlarged. × 580.
89. Leaf of *Gangamopteris* sp. B. × *Ca.* Nat. size.

PLATE 14

90. Upper cuticle from the leaf in Fig. 89. × 190.
91. Lower cuticle from the leaf in Fig. 89. × 190.
92. Leaf of *Palaeovittaria kurzi*. × Nat. size.
93. A piece showing cuticles of both the upper and the lower sides of the leaf in Fig. 92. × 110.
94. Lower cuticle from the leaf in Fig. 92 showing distribution of stomata. × 270.
95. A single stoma from the lower cuticle in Fig. 94 enlarged. × 650.