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LOWER PERMIAN PLANT FOSSILS FROM INDIA AND EARLY DEVELOPMENTAL HISTORY OF THE GLOSSOPTERIS FLORA

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ABSTRACT. Plant fossils belonging to the early Permian sequence in Talchir Formation of the Lower Gondwana have been described from the Chandas Nala Section of the Anuppur area, Shahdol District, Madhya Pradesh, India. The assemblage is represented by six species of *Gangamopteris*, one species each of *Glossopteris*, *Noeggerathiopsis* and *Vertebraria*. Many specimens of stem impression showing grooved surface with and without nodes and internodes are also recorded. The known fossil assemblages of the Talchir Formation are analysed and discussed. The combined evidence denote the presence of three floral zones during the beginning stage of Glossopteris flora. It has been concluded that the midrib less forms of Gangamopteroid type were adapted during the early phase of Glossopteris flora and this form resulted into the development of midrib forms of Glossopteroid type in the later phase.

KEY WORDS: Glossopteris flora, leaves, Lower Permian, India

INTRODUCTION

The lower most sequence of Indian Gondwana represents the Talchir Formation i.e. early phase of Permian. The Formation is recognised by Talchir Boulder Bed at the base followed up by Talchir Needle Shales in the middle and Rikba Beds at the top.

There are very few definite records of the plant fossils from Talchir Formation. As is expected no plant fossils are recovered from the lowest strata i.e. Boulder Bed sequence of the Talchir Formation. Contrary to mega plant fossils, many palynological assemblages are recovered from the Boulder Bed strata of the Jayanti Coalfield (Lele & Karim 1971), Palar Basin (Venkatachala & Rawat 1983), Pengaga River Section (Lele 1984) and Athgarh Sandstone bed of Mahanadi Basin (Tiwari et al. 1987). All these palynological reports are considered as the earliest representative of plants in the Gondwana sequence of India.

It was Feistmantel (1879, 1881, 1882) who recorded Talchir plant fossils for the first time from the coalfields of Auranga, Hutar, Karanpura and some of the localities of South Rewa Gondwana Basin. Later, Surange and Lele (1956, 1957) reported plant fossils from Giridih Coalfield and Goraia area of South Rewa Gondwana Basin. Ganguly (1959) and Chandra and Srivastava (1982) reported Talchir plant fossils from Chirimiri and Anuppur area of the South Rewa Gondwana Basin.

Several excursions to the lower Gondwana sequences of the South Rewa Gondwana Basin were undertaken to collect well preserved plant fossils of Talchir Formation. As a result of systematic and successive survey of different beds in different areas of this great basin, rich plant fossils have been recovered from the Chandas Nala Section (see section D and Map 3 of Chandra & Srivastava 1982, p. 150–51) of Anuppur area and from the Talchir beds exposed near Jwalamukhi in Umaria area. The plant fossils of Umaria area are mainly represented by nonvascular elements, probably belonging to *Bryophytes*. However, fragmentary remains of *Gangamopteris* and *Noeggerathiopsis* as previously reported by Chandra and Srivastava (1982) were also found. The investigations of problematic nonvascular remains are being carried out separately. The present paper deals with the systematic description of the plant fossil assemblages of Anuppur area. All the known plant assemblages of Talchir Formation by ealier workers have been considered to trace out the early developmental history of the Glossopteris flora.

As already mentioned and shown by Chandra and Srivastava (1982, Map. 3), the fossiliferous bed is exposed about 1.6 km north-east of the Chandas Nala Railway Bridge. Our collection includes six species of *Gangamopteris* and one species each of *Glossopteris, Noeggerathiopsis* and *Vertebraria*. Several specimens of equisetaceous stems are also found indicating presence of hydrophilous plants in the assemblage. The venation details of the leaf forms are well preserved so that we could identify them up to specific level. The fossils are preserved in the form of impressions on yellowish brown to dark brown coloured needle shales of the Talchir Formation. Due to fragile and delicate nature of the shales, it is very difficult to recover complete specimens of the leaf forms. The fossil assemblage is made up of well known species and therefore only brief and characteristic features of the leaf forms are discussed. All the type and figured specimens are deposited at the Museum of Birbal Sahni Institute of Palaeobotany, Lucknow.

DESCRIPTION OF PLANT FOSSILS

Genus *Gangamopteris* McCoy

Gangamopteris cyclopteroides Feistmantel

(Pl. 2, fig. 1)

Description. There are 10 incomplete leaves. One specimen shows the upper half of the leaf with details of the veins. The leaves are obovate in shape, apex narrow obtuse, margin entire and base not preserved. There are 6–8 thick subparallel veins in the central part of the leaf. The lateral veins arch out at an angles of 10° to 15°, dichotomize and anastomose to form broad, polygonal meshes in the middle and linear, narrow meshes near the margin.

Comparison. In its venation pattern and leaf morphology the specimens are identical to *Gangamopteris cyclopteroides* (Feistmantel 1879; pl. 27, fig. 2 and Chandra & Srivastava 1982; pl. 1, fig. 1). The figured specimen (no. 36407) represents only the upper portion of the leaf. The leaf is 11.5 cm long, 8.7 cm broad, at its maximum. Such a large size of leaf is rare in Talchir flora. *Gangamopteris* leaves of such size are com-

monly found in the Karharbari flora (Feistmantel 1879). Feistmantel (1879, 1886) has instituted many varieties of this species e.g. var. *subauriculata, areolata, attenuata, cordifolia* but on examination, Srivastava (1977) has considered all these forms under *G. cyclopteroides* and selected a typical example of *G. cyclopteroides* (Feistmantel 1879; pl. 27, fig. 2).

Gangamopteris major Feistmantel

(Pl. 1, fig. 2, Pl. 3, fig. 2)

Description. There are 8 incomplete leaf impressions. The leaves are narrow-elongate in shape, margin entire, apex and base are not preserved. Median region is occupied by 4–6 parallel running strands. The secondary veins are slightly arched, dichotomize and anastomose to form narrow-elongate meshes throughout the lamina.

Comparison. Our specimens are very similar to the specimens of *G. major* identified by Feistmantel (1879; pl. 14, fig. 3) and Chandra & Srivastava (1982; pl. 1, fig. 5).

Gangamopteris obliqua McCoy

(Pl. 1, fig. 3)

Description. There are 4 incomplete leaf impressions in the assemblage. The apex, base and margin of the leaves are not well preserved. The leaves are characteristic in having arched, flexuous secondary veins, frequently dichotomizing and anastomosing to form hexagonal to polygonal meshes.

Comparison. Our leaves are identical to the leaves of *G. obliqua* identified by Feistmantel (1881; pl. 2, fig. 5) and Maithy (1965; pl. 3, fig. 20) in possessing arched flexuous secondary veins.

Gangamopteris clarkeana Feistmantel

(Pl. 3, figs. 3, 4)

Description. The collection includes 4 leaf specimens, only one is almost complete. The leaves are obovate in shape with obtuse apex and tapering base, their margin is entire. Median region is occupied by interconnecting parallel running strands, leteral veins radiate out and form oblong meshes throughout the lamina.

Comparison. In their shape and venation pattern the leaves are similar to the leaves of *G. clarkeana* identified by Feistmantel (1879; pl. 20, fig. 3), Maithy (1965; pl. 4, fig. 25) and Srivastava (1977; pl. 2, fig. 9). Arber (1905) has considered this form under *G. cyclopteroides* but Maithy (1965) and Srivastava (1977) considered it as a distinct species in having obovate shape, broad obtuse apex and tapering or contracted base.

Gangamopteris angustifolia McCoy

(Pl. 1, fig. 4, Pl. 2, fig. 2)

Description. The collection includes 5 incomplete leaf impressions.

The apex and base are not preserved while margin is entire. The median region is occupied by 2–4 interconnecting subparallel veins which give rise to slightly arched secondary veins. The meshes are narrow-elongate and hexagonal in shape.

Comparison. The leaves are identical to *G. angustifolia* described by Feistmantel (1879; Pl. 9, fig. 5). Surange and Lele (1957) have reported a single specimen of *G.* cf. *angustifolia* from Talchir beds of South Rewa Gondwana Basin which is different from typical specimens of *G. angustifolia* in having deep arching (about 10–20°) of secondary veins.

Gangamopteris sp.

(Pl. 2, fig. 3)

Description. There are many fragmentary leaf specimens of 1–4 cm length in size. In such specimen there is no midrib and lateral veins form narrow-elongate, hexagonal to polygonal meshes. In the absence of apex, base, margin and other details it is difficult to assign them to any known species of *Gangamopteris*.

Genus *Glossopteris* Brongniart

Glossopteris talchirensis Chandra & Surange

(Pl. 3, fig. 1)

Description. Fragmentary remains of leaf forms with definite midrib are found in the collection. The specimens are 1–4 cm long and 2–4 cm broad. The secondary veins form narrow-elongate meshes.

Comparison. The venation pattern of Anuppur leaves are similar to *G. talchirensis* instituted by Chandra and Surange (1979) for accomondating *Glossopteris* leaves from Talchir Formation.

Noeggerathiopsis Feistmantel

Noeggerathiopsis hislopii (Bunbury) Feistmantel

(Pl. 1, fig. 1)

Description. There are 8 fragmentary leaf specimens in the collection.

The apex and base are not preserved, margin entire. The figured specimen is preserved with its counterpart. The veins emerge from the base and dichotomize several times, without anastomosing.

Comparison. The fragmentary leaves are identical to *N. hislopii* described by Feistmantel (1879, pl. 20, fig. 1; pl. 29, figs. 1, 2), Maithy (1965, pl. 1, figs. 1, 2) Chandra and Srivastava (1982, pl. 1, fig. 7).

Vertebraria Royle

Vertebraria indica Royle

(Pl. 2, fig. 4)

Description. There are 10 specimens in the collection, the largest one measures 8.8 cm in length. The axis consists of square areas in two linear rows, separated by a median longitudinal furrow. The areas are transversely separated by grooves.

Equisetaceous stems

Description. The collection includes 15 specimens having continuous ridges and furrows some times they are preserved with nodes and internodes. Its presence indicates that hydrophytic plants of equisetalean affinity were growing in the vicinity of this area.

COMPARISON OF THE FLORA WITH THE KNOWN ASSEMBLAGES OF THE TALCHIR FORMATION

The plant fossils reported by Feistmantel (1879, 1881, 1882) from the localities of Auranga, Hutar and South Rewa Gondwana Basin are represented by *Gangamopteris cyclopteroides, G. cyclopteroides* var. *subauriculata, G. cyclopteroides* var. *attenuata, G. cyclopteroides* var. *cordifolia, G.* cf. *spathulata, Glossopteris* sp., *Noeggerathiopsis hislopii, Samaropsis* sp., *Vertebraria indica* and unidentified specimens of equisetaceous stems. The present assemblage of Anuppur area also consists of six different species of *Gangamopteris* and one each of *Glossopteris* and *Noeggerathiopsis.* Therefore, in its floral composition, it is very similar to the Talchir flora of Auranga, Hutar and South Rewa Gondwana Basin. In 1886 Feistmantel reported a rich assemblage from the Rikba beds of North Karanpura Coalfield. The floral composition is represented by *Gangamopteris cyclopteroides, G. cyclopteroides* var. *subauriculata, G. cycloptroides* var. *attenuata, G. cyclopteroides* var. *acuminata, G. cyclopteroides* var. *cordifolia, G. obliqua, G. angustifolia, G. buriadica, G. major, G. talchirensis, Glossopteris communis, Noeggerathiopsis hislopii* and *Samaropsis* sp. In having 9 species of *Gangamopteris* and one species of *Glossopteris,* the Rikba bed assemblage is the richest among all the known assemblages of Talchir Formation and this flora is a quite distinct from the flora of Anuppur area.

Surange and Lele (1956) reported plant fossils from the Talchir Needle Shales of Giridih Coalfield. The authors considered the fossiliferous bed quite close to the base of the Talchirs. The plant fossils are meager and represent only *Gangamopteris cyclopteroides, Noeggerathiopsis* cf. *hislopii, Noeggerathiopsis* sp. and branched axes. The Anuppur flora in its variety of forms certainly differs from the Giridih flora. Surange and Lele (1957) have reported Talchir fossils from the South Rewa Gondwana Basin. The flora is known by *Gangamopteris cyclopteroides* var. *attenuata, G.* cf. *angustifolia, G.* sp., *Noeggerathiopsis hislopii, N.* sp., *Paranocladus ? indica, Arberia umbellata, Samaropsis goraiensis* and *Cordaicarpus furcata.* This assemblage represents some of the rare forms like *Paranocladus* and fertile form, *Arberia,* however, the fossils are fewer in number. The cmmonest plant element is *Gangamopteris* like that of fossil assemblage of Chandas Nala Section, Anuppur. The stratigraphical sequence of the fossiliferous bed of Salt Range, having variety of forms, was ealier considered to be equivalent to the Rikba beds (Krishnan 1968) but now its exact age is a matter of controversy (Venkatachala & Kar 1968). Such assemblage has not been incorporated in our study.

Systematic analysis of all the plant fossil records of Talchir Formation known from Giridih, Auranga, Hutar, Karanpura Coalfields and South Rewa Gondwana Basin indicate that in the early phase of Gondwana i.e. in Talchir Formation three floral zones can be idenitified. Considering the stratigraphical location of plant the fossil bed of Giridih Coalfield i.e. very near the base of Talchir, we can now say that it represents the early floristic zone. The poor quantity and quality of fossil indicate that during early time, there were very few plant communities and were growing only in some hospitable places. The Talchir flora of Auranga, Hutar and South Rewa Gondwana Basin are better

represented in quantity and quality . Such uniformity in flora in distand coalfields and Basins suggests that due to rise in temperature, the climate became hospitable for the growth of plant communities and they occupied the land in quicker succession. The Rikba beds, which is supposed to be the top most sequence of the Talchir Formation, is only known in the Karanpura Coalfield and its equivalent has so far not been traced out in other areas. The flora of Rikba bed which is very rich in quantity and quality can, therefore, be correlated with the upper floristic zone of the Talchir Formation. Lele (1966), while synthesising the data of Talchir fossils has suggested that in all probability plant fossils of Rikba Bed suggest a transitory flora inbetween Talchir and overlying flora of Karharbari Formation.

EARLY DEVELPOMENTAL HISTORY OF THE GLOSSOPTERIS FLORA

The discovery of plant remains from the sediments in close association with the glacial activity in Southern Hemisphere countries during Upper Carboniferous and Lower Permian period has evoked great interest regarding early development of the Glossopteris flora. The discovery of spore pollen assemblage from the Bachhus Marsh Tillite of Victoria, Australia (Pant 1955, Pant & Mehra 1963) and the plant remains of Dwyka Tillite of South Africa (Leslie 1921, Du Toit 1924) are some of the definite evidences of the earliest representatives of the Glossopteris flora in coexistence with the ice age.

The evidence of Glossopteris flora in the glacial sediments of Talchir Formation of India was strongly differed by Fox (1931). However, Sahni, in series of papers (1926, 1937, 1939) favoured the existence of this flora in such sediments.

The Talchir Formation represents the basal most sequence of the Indian Gondwana System. Its age has been assigned to Lower Permian (Sastry & Shah 1964, Tiwari 1975) and the lower most strata of Talchir i.e. Boulder Bed signifies the glacial facies. Recent discoveries of palynofossils extracted from the matrix inbetween the Talchir boulders of Palar Basin (Venkatachala & Rawat 1983), Pengaga River Section (Lele 1984) and Mahandi Basin (Tiwari et al. 1987) firmly demonstrate the existence of plant communities during the glacial phase.

Tiwari (1975) while compiling the palynological assemblages of Talchir Formation recognised three palynozones in this formation. Although not in correspondence with Tiwari's studies, the present analysis of megafossil also indicates three megafloral zones. Though, with the present state of our knowledge there is no evidence of plant megafossils from the oldest strata i.e. Talchir Boulder Bed but megafossils recovered from the needle shale bed, closely situated with the Boulder Bed in Giridih Coalfield (Surange & Lele 1956) can well be considered as the oldest plant fossil record of the Indian Gondwana System. The combined evidences of mega and miofloral assemblages suggest that during glacial phase the elements of Glossopteris flora were already existing and they must have been groving in some ice free pockets. Such contentions have also been suggested by Plumstead (1969) in South Africa and Rigby (1973) in Australia.

The megaflora from Talchir Formation is frequented by *Gangamopteris* leaves with significant proportion of *Noeggerathiopsis* leaves, whereas the leaves of *Glossopteris* are very few in number. The observation reveals that the plants having *Gangamopteris* type of leaves were well adapted to cooler climatic condition of the ice age than the leaves of *Glossopteris*. It can also be inferred that the *Glossopteris* plant come on the scene through the developmental stages of Gangamopteroid type of plant. Such conditions are also revealed by the fossil assemblage recovered from the glacial beds of Dwyka Tillite of South Africa. Plumstead (1966) has used the term "*Protoglossopteris*" for the leaves recovered from the glacial beds of Antarctica. Such leaves do not possess meshes in their venation pattern. From the photograph and description of *Protoglossopteris* leaves, it appears that they actually belong to *Noeggerathiopsis* like forms which are frequently found in the present assemblage under study (Pl. 1, fig. 1). Such leaves are commonly known in the assemblages of glacial deposits. In general, we can positively conclude that the midrib less forms of *Gangamopteris* type were the earliest representative of the Glossopteris flora.

By the end of Talchir period, the leaf forms with definite midrib i.e. *Glossopteris* appeared as evidenced by the flora of Rikba Bed. We have definite representation of *Glossopteris* plant in Rikba bed but the flora is still dominated by Gangamopteroid plants. In fact it started proliferating at his stage and became dominant in the younger flora in Karharbari time. The genus, *Gangamopteris* is represented by 14 species but at the same time, *Glossopteris* also occupied a place in significant proportion (8 species) in the younger Karharbari flora. It is also interesting to note that in the Karharbari flora we find permutation and combination of Gangamopteroid character in the leaves of *Rubidgea* and *Euryphyllum* (Pant 1982). Strikingly, such midrib less forms disappeared in the younger flora of Barakar and Raniganj formations. The flora of these younger horizons are exclusively dominated by the forms having distinct midrib i.e. *Glossopteris*, *Rhabdotaenia* and *Belemnopteris* (Pant 1982). Thus, it can be inferred that during the early phase of Glossopteris flora, the Gangamopteroid forms were in total dominance which in turn developed into the Glossopteroid type of plant. These changes have been correlated which the change in the climatic condition during different stratigraphic levels of Gondwana System (Lele 1976).

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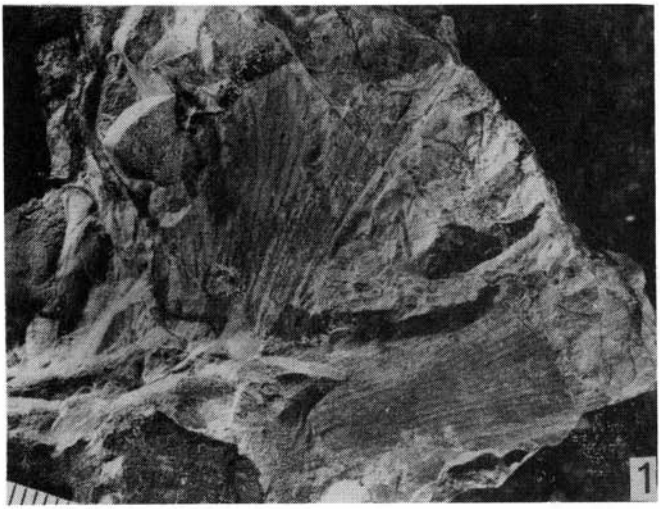
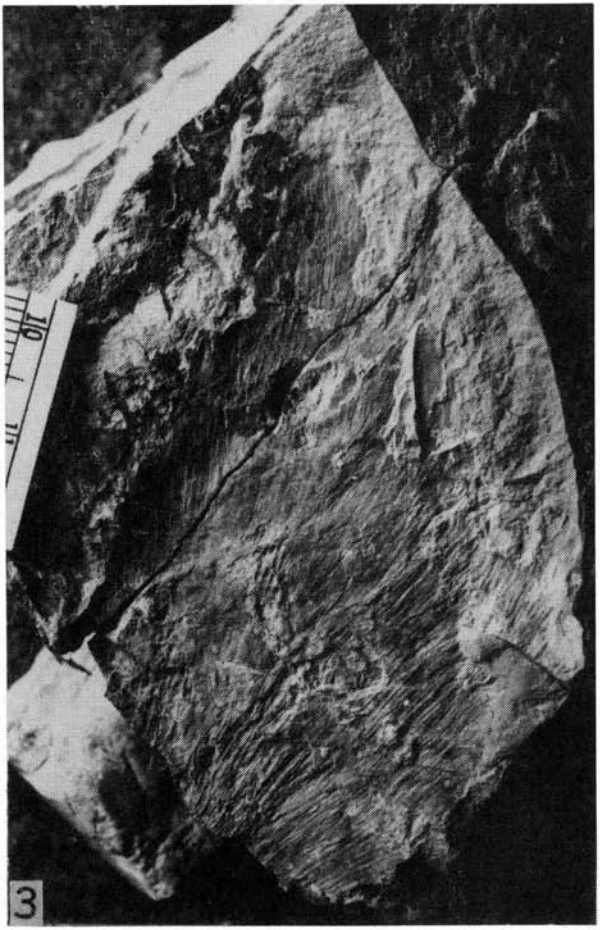
PLATES

Plate 1

1. Showing two fragmentary leaf specimens of *Noeggerathiopsis hislopii* (Bunbury) Feistmantel. B. S. I. P. specimen no. 36408, x 1.5
2. *Gangamopteris major* Feistmantel, showing slightly arched lateral veins. B. S. I. P. specimen no. 36407, x 1.5
3. *Gangamopteris obliqua* McCoy, showing arched, flexuous nature of Secondary veins. B. S. I. P. specimen no. 36409, x 1.5
4. *Gangamopteris angustifolia* McCoy, leaf fragment showing venation pattern. B. S. I. P. specimen no. 36410, x 1.5





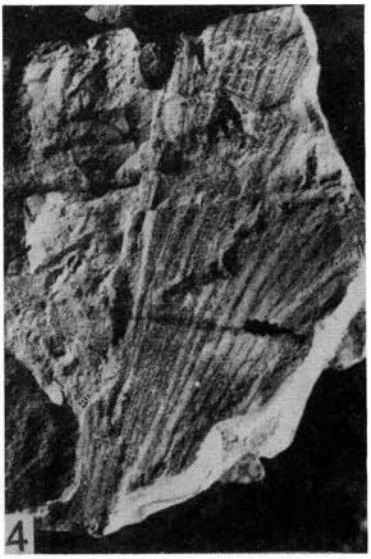


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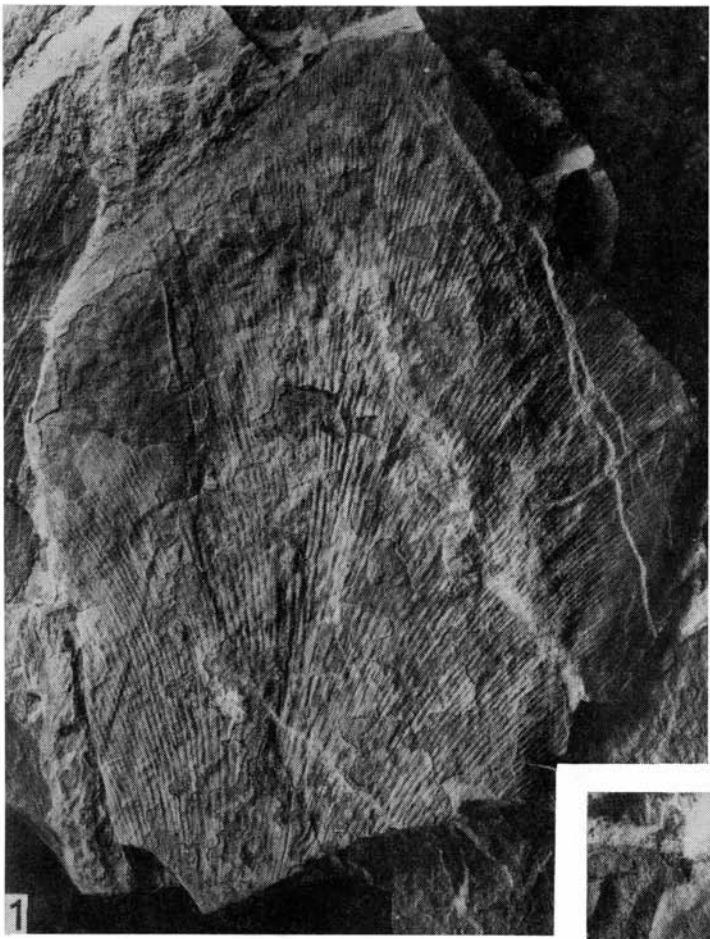
Plate 2

1. *Gangamopteris cyclopteroides* Feistmantel, large size leaf showing broad polygonal meshes in the Middle and narrow-linear meshes near the margin. B. S. I. P. specimen no. 36407, x 1
2. *Gangamopteris angustifolia* McCoy, showing median subparallel, interconnecting veins and arched secondary veins. B. S. I. P. specimen no. 36415, x 1.5
3. *Gangamopteris* sp. showing middle portion of lamina. B. S. I. P. specimen no. 36416, x 1.5
4. *Vertebraria indica* Royle, showing ridges and furrows. B. S. I. P. specimen no. 36417, x 1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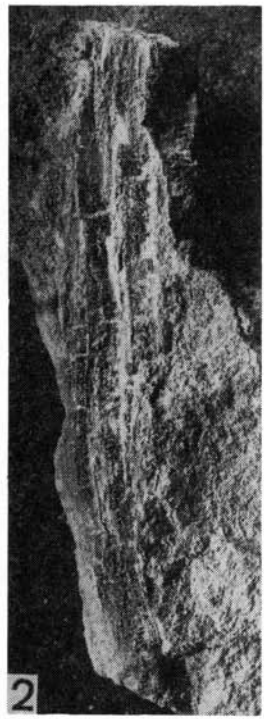
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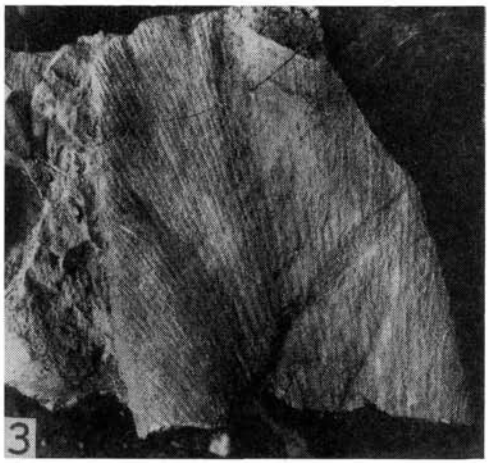
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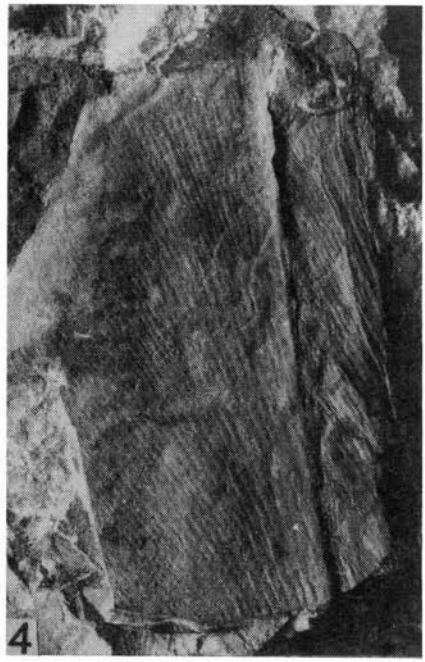
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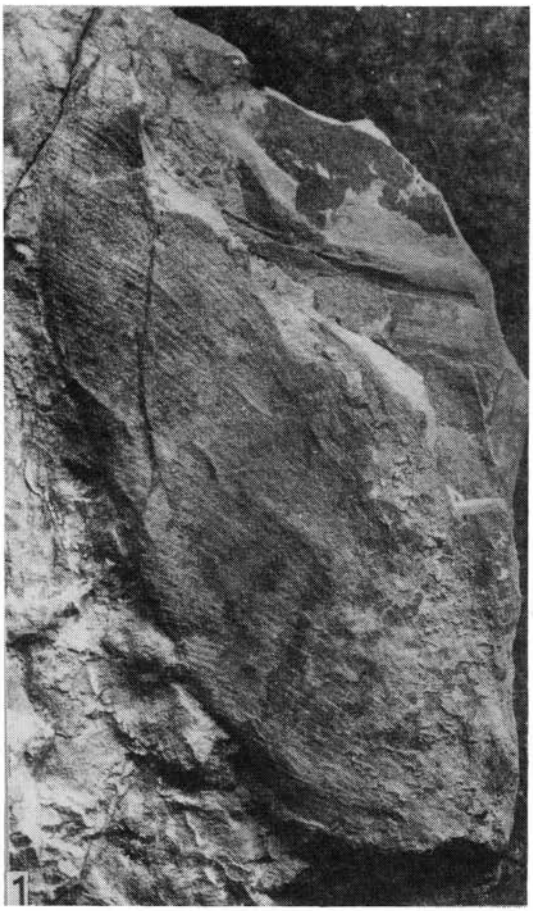
Plate 3

1. *Glossopteris talchirensis* Chandra & Surange, fragmentary leaf specimen showing faint but definite presence of midrib and lateral veins. B. S. I. P. specimen no 36412, x 1.5
2. *Gangamopteris major* Feistmantel, another leaf showing sub-parallel veins where lateral veins dichotomize and anastomose to form narrow-elongate meshes. B. S. I. P. specimen no. 36411, x 2
3. *Gangamopteris clarkeana* Feistmantel, figure-3 shows an almost complete obovate shape leaf, figure-4 demonstrates the venation pattern. B. S. I. P specimen no. 36413, 36414, x 1.5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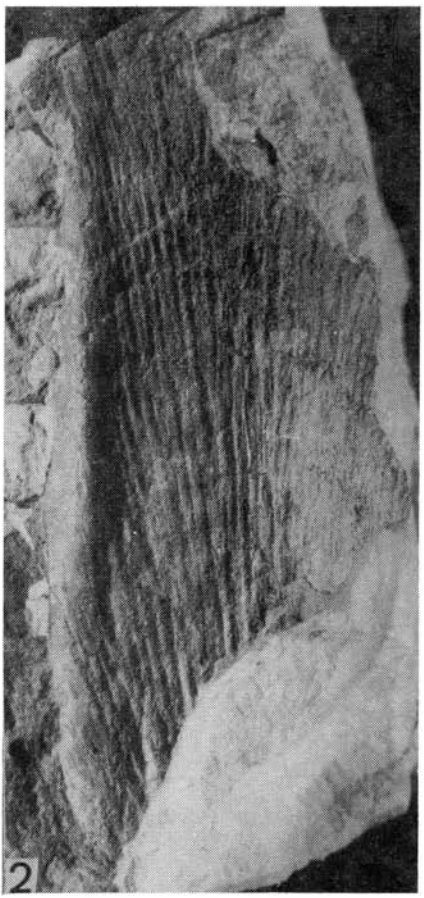
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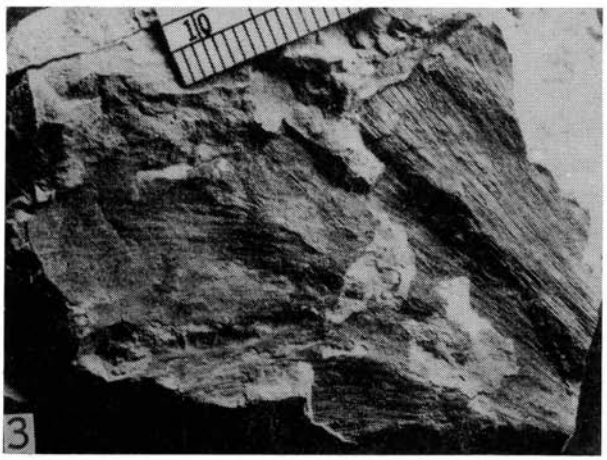
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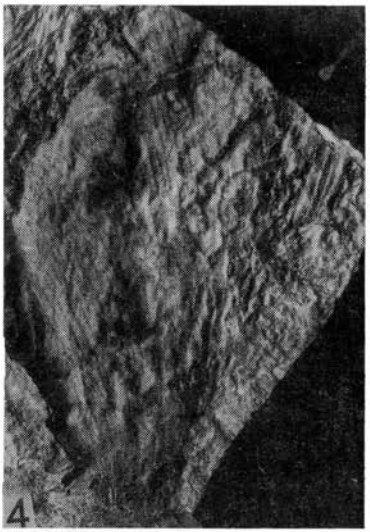
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