

Plant fossil assemblages from the Barakar Formation of Raniganj Coalfield, India

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Morphological and systematic investigation of plant fossils namely Equisetales (*Phyllotheca*, *Lelstotheca*, Phyllothecan cone, *Trizygia*), Filicales (*Neomariopteris*, *Palastbalia* gen. nov. showing sterile frond with auriculate base and pectopteroid venation pattern), glossopterids (leaves of *Euryphyllum*, *Gangamopteris*, *Glossopteris*, *Palaeovittaria*, *Gondwanophyllites*, *Maheshwariphyllum* gen. nov. having complete midrib and dichotomizing lateral veins, *Partha*, *Scutum* fructifications), Cordaitales (*Noeggerathiopsis*, *Cordaites*), detached seeds of *Samaropsis* and *Cordaitcarpus* and scale leaves from different seams of Barakar Formation of Raniganj Coalfield are described. The flora of the lower seams (nos. B II-B IV) is comparatively more diversified and shows affinity with the Karharbari flora, whereas the flora of upper seams (nos. B V-B VII) is monotonous in composition in being mostly represented by *Glossopteris* species. The composition of the flora in relation to evolution and climatic changes suggests lineage towards the development of midrib character in the glossopterid leaves and existence of temperate climate with a change from warm moist to warm dry condition.

Key-words—Morphology, Palaeoclimate, Equisetales, Filicales, Glossopteridales, Cordaitales, Barakar Formation (India)

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सारांश

रानीगंज कोयला-क्षेत्र (भारत) के बराकर शैल-समूह से अश्रित पावप समुच्चय

अश्रितनी कुमार श्रीवास्तव

रानीगंज कोयला-क्षेत्र के बराकर शैल-समूह की विभिन्न सीमों से प्राप्त इक्वीसिटेल्स (फिल्लोथीका, लेल्सटोथीका, फिल्लोथीकी कोन, ट्राइजीआ), फिलिकेल्स (नियोमैरिऑप्टेरिस, पलस्थालिआ नव प्रजाति), ग्लोसोप्टेरिड (यूरीफिल्लम, गंगामोप्टेरिस, ग्लोसोप्टेरिस, पेलिपोविटारिया, गोंडवानोफिल्लाइटिस एवं माहेश्वरीफिल्लम नव प्रजाति की पत्तियाँ, तथा पार्था एवं स्कूटम के फलन), कोर्डैटेल्स (नोएग्गेरथिऑप्सिस, कोर्डैटेल्स, समारोप्सिस एवं कोर्डैटेल्स के पृथक्कृत बीज तथा शल्की पत्तियों का वर्णन किया गया है। निचली सीमों (सीम ब 2-ब 4) के वनस्पतिजात में अपेक्षाकृत अधिक विभिन्नताएँ हैं तथा यह करहरबारी वनस्पतिजात से समानता प्रदर्शित करता है, जबकि उपरी सीमों (ब 5-ब 7) के वनस्पतिजात में अधिकतर ग्लोसोप्टेरिस की पत्तियाँ ही मिलती हैं तथा किसी प्रकार की विभिन्नता देखने को नहीं मिलती। विकास एवं जलवायवी परिवर्तनों के आधार पर वनस्पतिजात की संरचना से ग्लोसोप्टेरिडी पत्तियों में मध्यशिरा लक्षण के विकास तथा गर्म-नम से गर्म-शुष्क परिस्थितियों सहित शीतोष्ण जलवायु के मध्य पारस्परिक सम्बन्ध व्यक्त होता है।

THE geology of the Raniganj Coalfield has been dealt in detail by Gee (1932) and Mehta (1956). The rocks of Barakar Formation cover an area of about 155 sq km and attain a maximum thickness of 640 meters. Earlier, the coal seams were known by local name; now all these seams have been correlated by Coal India Limited and seams B-I to B-VIII have been recognised. The plant fossils have been found in all the seams, except the lowest and topmost seams.

The palaeobotanical investigation of the

Raniganj Coalfield was so far mainly confined to the Raniganj Formation; only few reports are available on plant fossils of the Barakar Formation by Feistmantel (1886), Bandyopadhyay (1959), Maithy (1974b), Chandra and Srivastava (1981), Srivastava and Rigby (1983), Maheshwari and Srivastava (1987) and Srivastava (1987, 1988).

The present investigation has been undertaken to study the morphotaxonomy and evolutionary significance of the plant fossil assemblages of

Barakar Formation in Raniganj Coalfield. Therefore systematic and seam-wise collections were made from following different collieries, open cast projects and nala cuttings to find out the distribution and variation pattern of the flora.

| | |
|-------------------------------|------------|
| Chapapur open cast project | Seam B—II |
| Bajna open cast project | Seam B—II |
| Tara open cast project | Seam B—II |
| Palasthali open cast project | Seam B—II |
| Raja Colliery | Seam B—II |
| Dalmia open cast project | Seam B—III |
| Nirsa Colliery | Seam B—III |
| Sangramgarh open cast project | Seam B—IV |
| Gourandih Colliery | Seam B—IV |
| Gopinathpur Colliery | Seam B—IV |
| Nirsa Khas Colliery | Seam B—IV |
| Khudia Colliery | Seam B—IV |
| Amdih Colliery | Seam B—V |
| West Victoria Colliery | Seam B—V |
| Junkundar Colliery | Seam B—V |
| Lakhimata open cast project | Seam B—VI |
| Rajpura open cast project | Seam B—VI |
| Pusai Nala cutting section | Seam B—VI |
| New Bagma Colliery | Seam B—VII |
| Shampur Nala cutting section | Seam B—VII |
| Shampur Colliery | Seam B—VII |

The study is based only on the morphographical features as it was not possible to study the cuticular and cellular details. The thin carbonised crust present over the surface of specimens gets fragmented on chemical treatment. A check-list has been given of well known taxa. Detailed description is given only for important or newly established taxa. Distribution of species is shown in Table 1.

The type and figured specimens are deposited in the Museum of Birbal Sahni Institute of Palaeobotany, Lucknow.

Genus—*Phyllotheca* Brongniart 1828

Phyllotheca indica Bunbury 1861
Pl. 1, fig. 1

The present specimens are comparable with the leaves of *P. indica* described by Pant and Kidwai (1968, pl. 30, figs 4, 6). The occurrence of fertile specimens of *Giridia* in association with sterile

foliage also favours their comparison with *P. indica*.

Genus—*Giridia* Pant, Nautiyal & Misra 1981

Giridia barakarensis sp. nov.

Pl. 1, figs 2-4

Diagnosis—Articulate axis, up to 5 mm wide, internode 1.2 cm, bract-sheath about 1.2 cm wide at node; node shows whorl of bracts and abaxially preserved bunch of copiously branched sporangiophores, penultimate axes measure 2-4 mm in length and 0.5 mm in width, forked, each fork terminally bears rounded to oval sporangia, 0.2-0.5 mm in diameter.

Holotype—BSIP Specimen no. 36599; Seam no. B-IV, Sangramgarh Open Cast Project, Raniganj Coalfield; Barakar Formation, Early Permian.

Description—There are four specimens in the collection. The holotype shows two fertile regions near the node of axis, of them the upper one is fragmentary but clearly demarcates the fertile nature. Faintly striated axis measures 4 cm in length and 5.2 mm in width. The bract sheath is composed of 8-10 bracts. Each bract has a midvein and transverse/longitudinal striations are present over the surface. They are comparable with the vegetative leaf of *P. indica*. The basal portion of bract-sheath near the node bears 14 × 9 mm diameter cone having copiously branched sporangiophores. The primary axes emerge from the nodes at various angles in different directions and widely forked. The true branching pattern is not decipherable due to repeated forking and overlapping, however, the ultimate fork is straight and bears a terminal sporangium measuring 0.2-0.5 mm in diameter.

Comparison and discussion—The nature and organization of present phyllothecan cone compare with that of the genus *Giridia* described by Pant, Nautiyal and Misra (1981) from Giridih Coalfield. The primary axis of sporangiophores in the type species, *G. indica* Pant, Nautiyal & Misra 1981, emerges almost at right angles, whereas in *G. barakarensis* sp. nov. it emerges at various angles in different directions. The ultimate fork which bears sporangia is recurved in former but such behaviour is not identifiable in the latter.

PLATE 1

1. *Phyllotheca indica* Bunbury, specimen no. BSIP 36598, Nat. size.
2. *Giridia barakarensis* sp. nov., holotype showing bract sheath and fertile structures near nodal region, specimen no. BSIP 36599, Ca × 2.
3. Holotype in figure 2 photographed under xylol to show position of cones, Ca × 1.5.
4. Part of specimen to show details of cone structure, photographed under xylol, × 3.

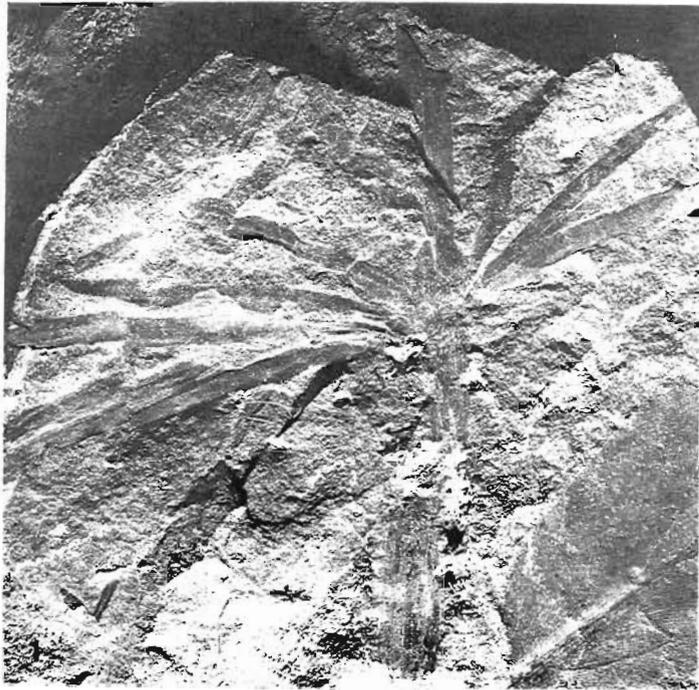


PLATE 1

Genus—*Lelstobeca* Maheshwari 1972

The specimens are comparable with the earlier records of *L. robusta* and *L. striata* reported by Maheshwari and Srivastava (1987, pl. 1, figs 1-5) from the Barakar Formation of Raniganj Coalfield.

Genus—*Palasthalia* gen. nov.

Type species—*Palasthalia indica* gen. et sp. nov.

Generic diagnosis—Imparipinnate sterile frond; rachis winged; pinnules narrow-elongate, alternately arranged; apex obtuse, base broad, auriculate, constricted basally to a narrow point of attachment, midvein arise at 50°-60°, persistent lateral veins emerge at an acute angle, run parallel for some distance then dichotomize thrice, on further branching lower vein dichotomizes once, middle and upper veins dichotomize twice.

Comparison and discussion—In venation pattern, *Palasthalia* gen. nov. compares with *Dichotopteris* Maithy, *Dizeugotheca* Archangelsky & Sota, *Pecopteris* Brongniart and *Santhalea* Maithy. However, all these genera possess smaller pinnules which are attached to the rachis by their broad bases, whereas in *Palasthalia* the base of pinnules is auriculate and are attached to the rachis by a narrow constriction. Narrow constricted bases are known to occur in pinnules of *Neuropteris* type of foliage which, however, is distinct in having cordate bases. The pinnules of *Dunedoonia* Holmes 1977 from the Upper Permian beds of New South Wales, Australia show a distinct auriculate base like *Palasthalia* but it is different in having reticulate venation pattern.

Palasthalia indica sp. nov.
Pl. 2, figs 1-4

Diagnosis—Fronds large, unipinnate; rachis winged, striated; large size narrow-elongate, pinnules alternately arranged, shorter near apical region; apex obtuse to rounded, base auriculate, constricted to a narrow point of attachment; margin entire; midvein thick, striated; lateral veins emerge from midvein at acute angle and run parallel, dichotomize to give three major veins, immediately dichotomizing further, the lower one showing once dichotomy, whereas middle and upper one divide

twice, sometimes proximal veinlet of each lateral veins show further dichotomy.

Holotype—B.S.I.P. Specimen no. 36600; Seam no. B-II, Palasthali open cast project, Raniganj Coalfield; Barakar Formation, Early Permian.

Description—There are four specimens in the collection. The preserved rachis of holotype measures 12.5 cm in length with fine striations. The pinnules are alternate, at angles of 50°-55°, 3.5 cm long, 8-9 mm broad becoming smaller near the apical margin, i.e., 1.2 cm long and 4-6 mm broad. Apex, wherever preserved, is obtuse to rounded. The base of the pinnules is broad and characteristically auriculate and constricted basally to a narrow point of attachment. The midvein of the pinnules is distinct, 1-1.5 mm broad, striated, and present throughout the pinnules. Lateral veins emerge from the midvein at acute angles, run along the midvein for a small distance and after slight arching give off three veins, i.e., lower, middle and upper. The lower vein divides only once whereas the middle and upper veins divide first into two veins and then upper vein, in each case again divides into two.

Genus—*Neomariopteris* Maithy 1974

Neomariopteris polymorpha (Feistmantel) Maithy 1974

N. hughesii (Zeiller) Maithy 1974

Remarks—Specimens are very few in number and show only fragmentary pinnules having similarities with *N. polymorpha* and *N. hughesii* (Maithy, 1974a, pl. 1, figs 1-4; pl. 2, figs 7, 8).

Genus—*Trizygia* Royle 1839

Trizygia speciosa Royle 1839

Many authors considered this species to be a form similar to *Sphenophyllum* Koenig 1825 (Walton, 1929; Pant & Mehra, 1963) but its trizygoid nature of leaf arrangement is distinct with the typical northern sphenophyll, therefore, it is advisable to keep it separate until we get its exact affinity supported by its fructification (see Maheshwari, 1968b; Srivastava & Rigby, 1983; Pant, Srivastava & Das, 1985).

There are only three specimens in the collection. They show 3-5 leaf whorls of six leaves,

PLATE 2

1. *Palasthalia indica* gen. et sp. nov., holotype showing sterile frond, specimen no. BSIP 36600, Nat. size.
2. Enlargement of pinnule to show pecopteroid venation pattern, × 4.

3. Showing auriculate base of pinnule, photographed under xylol, × 4.
4. *Palasthalia indica* gen. et sp. nov., specimen other than holotype, specimen no. BSIP 36601, Nat. size.

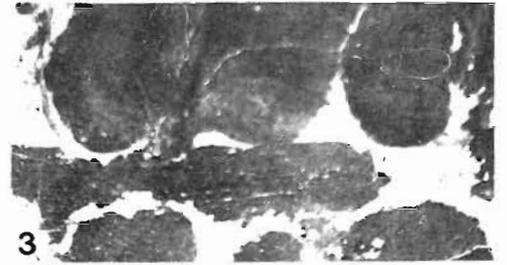
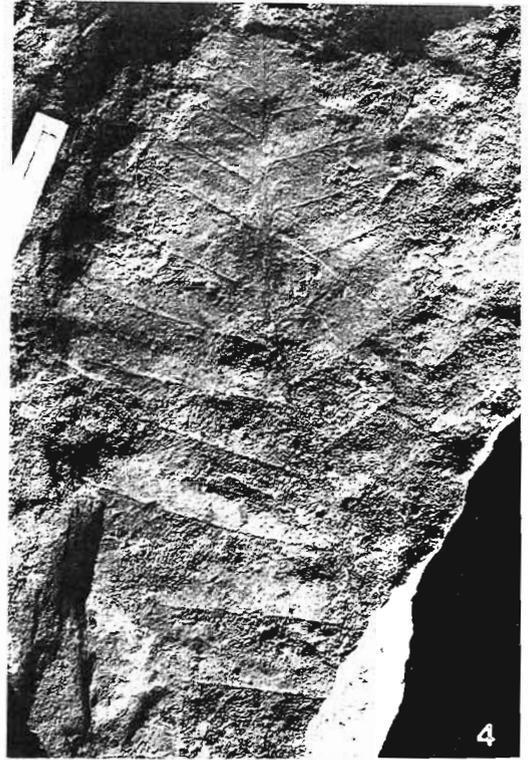


PLATE 2

each whorl has three pairs of leaves of different sizes characteristic of the species (Maithy, 1978, pl. 1, fig. 1).

Genus—*Euryphyllum* Feistmantel 1879

The genus was instituted by Feistmantel (1879) for the leaves having median subparallel veins and arched, dichotomizing lateral veins with asymmetrical ovate, spatulate shape. Arber (1905) merged the genus under *Noeggerathiopsis*. However, Seward and Sahni (1920), Maithy (1965b) and Pant (1982) considered it as a distinct genus. The present assemblage contains a large number of typical *Noeggerathiopsis* leaves and it has been observed that they do not possess the parallel running median veins and arching of lateral veins is also absent. The margin of *Noeggerathiopsis* leaves is symmetrical but in the leaves of *Euryphyllum*, one of the margin shows curvature in comparison to other, thus, exemplify asymmetrical nature. Perhaps due to its doubtful position, the genus is poorly recorded and is known by only one species in the Karharbari Formation. The present record is the first occurrence of *Euryphyllum* leaves in the Barakar Formation.

Euryphyllum elongatum sp. nov.

Pl. 4, fig. 1

Diagnosis—Leaf linear, narrow-oblong, asymmetrical in shape, apex obtuse to acute, base contracted, obtuse; median region occupied by 3-6 straight, parallel running strands; lateral veins emerge from base, arch towards margin at angle of 20°-30°, dichotomize 2-3 times during their upward course, 14-18 veins per cm.

Holotype—BSIP Museum no. 36610; Seam no. B-II, Raja Colliery, Raniganj Coalfield; Barakar Formation, Early Permian.

Description—Four specimens are present in the collection. The complete leaf is 6.6 cm long and 1.9 cm broad at its widest part. The leaves are linear, narrow-oblong in shape, one side of the margin is curved in comparison to other side, apex is obtuse to acute and base is contracted. There are 3-6 straight parallel veins in the median region of leaf. These dichotomize once or twice. Lateral veins

emerge from the base of leaf, arched out at angle of 20°-30°, run parallel to each other for some distance (0.5-1 cm) and then after 2-3 dichotomies arch out towards the margin.

Comparison and discussion—The type species, *Euryphyllum whittianum* Feistmantel (1879, pl. 21, figs 1, 1a; Maithy, 1965b, pl. 1, fig. 9) differs in having ovate-spathulate shape, diverging parallel running veins in the apical portion, and frequently dichotomizing lateral and median veins.

Maithy (1965b) illustrated an incomplete specimen (BSIP no. 20451; pl. 1, fig. 10) as *E. whittianum*. The specimen shows anastomosing of the veins and thus resembles leaves of *Gangamopteris*, and not *Euryphyllum*.

Genus—*Palaeovittaria* Feistmantel 1876

Palaeovittaria kurzii Feistmantel 1876

Pl. 3, figs 1-2

Such leaves are common in the assemblage of Raja Colliery. They are elongate spatulate in shape with obtuse apex and tapering base. The midrib is present only up to 1/2 or 3/4 of leaf lamina, thick (3-4 mm) near the base, striated, grooved sometimes represented by closely spaced 5-6 parallel running strands, evanescent in the apical portion of leaf. Lateral veins run parallel in the basal part and start forking above the base but never anastomose; after forking they diverge from each other and become subparallel.

Comparison and discussion—The present leaves resemble the specimens figured by Feistmantel (1876, pl. 19, figs 3, 3a, 4, 4a) and Pant and Verma (1964b, pl. 16, fig. 3). On the basis of cuticular features, Pant and Verma (1964b) instituted another species, *P. raniganjensis* whose external character is much similar to *P. kurzii* although they have noticed variation in the concentration of veins and presence of occasional fibres. However, recent investigations on cuticular features of *Glossopteris* (Maheshwari & Tewari, in press) suggest that sometimes cuticular features show variation within the same species.

The occurrence of *Palaeovittaria* in the Barakar Formation is interesting because so far they are

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PLATE 3

1. *Palaeovittaria kurzii* Feistmantel, apical portion of leaf showing evanescent nature of midrib, specimen no. BSIP 36602, Ca × 1.5.
2. *Palaeovittaria kurzii* Feistmantel, lower portion of leaf showing midrib, specimen no. BSIP 36603, × 1.5.
3. *Maheshwariphyllum indicum* gen. et sp. nov., holotype showing complete leaf, specimen no. BSIP 36604, Nat. size.
4. *Maheshwariphyllum indicum* gen. et sp. nov., counterpart of holotype enlarged to show complete midrib and dichotomizing lateral veins, specimen no. BSIP 36605, × 3.
5. Scale leaf showing gangamopteroid venation pattern, specimen no. BSIP 36606, × 2.
6. *Samaropsis ganjrensis* Maithy, specimen no. BSIP 36607, × 2.

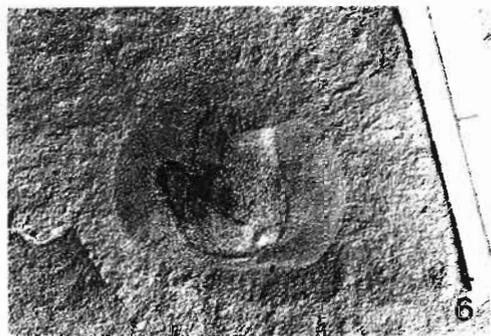
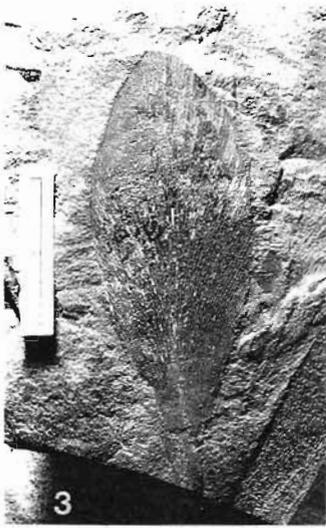


PLATE 3

known only in the flora of Raniganj Formation (Pant & Verma, 1964b).

Genus—*Maheshwariphyllum* gen. nov.

Type species—*Maheshwariphyllum indicum* gen. et sp. nov.

Generic diagnosis—Leaf simple, ovate in shape; apex acute, base cuneate, margin entire; midrib thin, persistent; secondary veins arise at 40°-45°, dichotomize frequently, slightly arched out, never anastomose.

Comparison and discussion—*Rhabdotaenia* Pant 1958 is the only known genus in Glossopteris flora in which dichotomizing secondary veins and complete midrib have been found but in such leaves secondary veins emerge at an angle of 90° and run almost parallel to each other whereas in *Maheshwariphyllum* gen. nov. the secondary veins arise at angle of 40°-45°. *Maheshwariphyllum* is comparable with *Glossopteris* leaves in having persistent midrib but absence of anastomoses in the secondary veins distinguishes it with *Glossopteris* leaves. The leaves of *Gangamopteris* McCoy are distinct in possessing reticulate venation pattern. Leaves of *Palaeovittaria* Feistmantel are similar to *Maheshwariphyllum* but they possess midrib only up to 1/2 or 3/4 of leaf lamina. The leaves of *Euryphyllum* Feistmantel and *Rubidgea* Tate also show dichotomizing lateral veins but they lack midrib. Similarly *Gondwanophyllites* Srivastava differs in having dissected leaf margin.

Appert (1977, pl. 6, figs 1-6) reported a few leaves showing complete midrib and dichotomizing lateral veins. He compared them with the Upper Carboniferous leaf genus *Leksleya* Lesquereux 1879 of northern hemisphere. The leaves are distinct from *Maheshwariphyllum* in having narrow-obovate shape where lateral veins show few (2-3) dichotomization.

Although, at present, there is no information about the structural details of *Maheshwariphyllum* gen. nov. but such leaves with dichotomizing lateral veins with or without midrib, e.g., *Euryphyllum*, *Rubidgea*, *Palaeovittaria* and *Rhabdotaenia* in the Gondwana flora have been assigned to glossopterids

(Surange, 1966, 1973; Maheshwari, 1976; Pant, 1982; Srivastava 1986, 1991). The presence of *Maheshwariphyllum* alongwith other glossopterid leaves (see Table 1) apparently fills a gap between the leaves of *Rubidgea*, *Euryphyllum* and *Palaeovittaria*. These four genera represent the non-reticulate forms of glossopterid. Two former genera are without midrib whereas *Palaeovittaria* demonstrates midrib only up to 1/2 or 3/4 of lamina; and presence of complete midrib in *Maheshwariphyllum* indicates the development of midrib through *Palaeovittaria*-like leaves. Further advancement of midrib feature most likely resulted into solid midrib forms of *Rhabdotaenia*-like leaves.

Maheshwariphyllum indicum sp. nov.

Pl. 3, figs 3, 4

Specific diagnosis—Leaf narrow ovate with acute apex and cuneate base, margin entire; midrib present throughout lamina, thinner towards apical margin, sometimes represented by 3-5 closely spaced parallel running strands; secondary veins emerge from midvein at angle of 40°-45°, frequently dichotomizing, after slight arching reach up to margins, never anastomose, veins 15-20 per cm.

Holotype—BSIP Museum no. 36604 with counterpart no. 36605; Seam no. B-II, Raja Colliery, Raniganj Coalfield; Barakar Formation, Early Permian.

Description—There are five specimens in the collection. One complete narrow-ovate leaf is preserved as part and counterpart and measures 6.2 cm long and 2.3 broad. Apex is narrow-acute while base is cuneate and tapering. Midrib is 1-2 mm broad, striated, persistent but narrows down towards apex. Secondary veins arise from the midrib at angle of 40°-45°, dichotomize during their course and show slight arching before reaching the margin of leaves. The density of veins is 15-20 per cm.

The genus is named after Dr H. K. Maheshwari, BSIP, Lucknow for his contributions to the knowledge of Glossopteris flora.

PLATE 4

1. *Euryphyllum elongatum* sp. nov., holotype showing asymmetrical nature of leaf, median parallel running strands and dichotomizing arched side veins, specimen no. BSIP 36610, × 2.
2. *Noeggerathiopsis bislopii* Feistmantel, complete leaf showing spatulate shape, specimen no. BSIP 36608, Nat. size.
3. *Noeggerathiopsis bislopii* Feistmantel, median portion of a leaf showing uniform dichotomizing erect veins, specimen no. BSIP 36609, × 1.5.
4. *Cordaites* sp., almost complete leaf with shrudded apical margin and alternating thick and thin veins, specimen no. BSIP 36613, × 1.5.
- 5-6. *Cordaites* sp., part and counterpart of a specimen showing thicker and thinner veins with fine striations, specimen nos. BSIP, 36611, 36612, Nat. size.

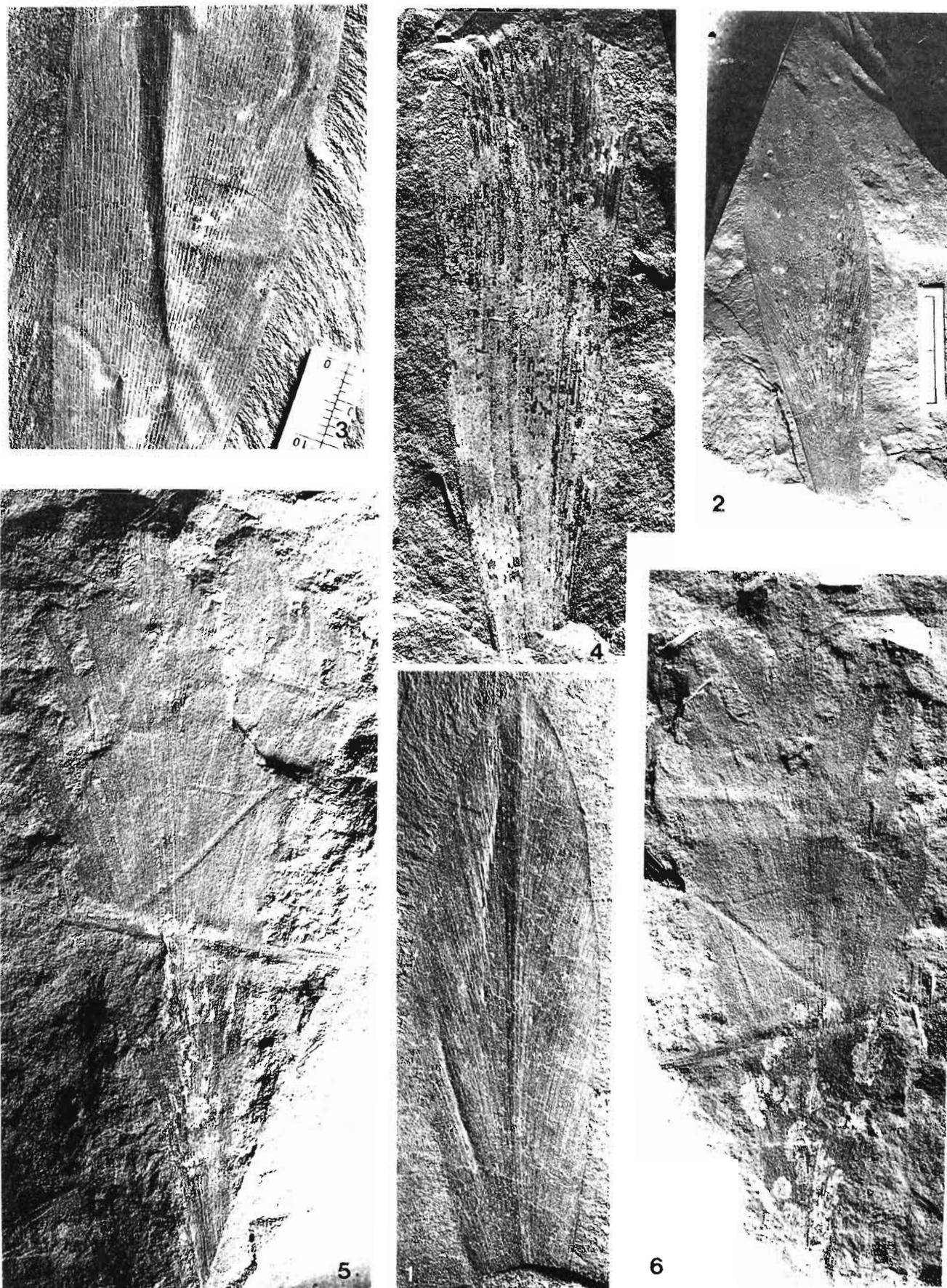


PLATE 4

Genus—*Gangamopteris* McCoy 1861*Gangamopteris cyclopteroides* Feistmantel 1879

Only five incomplete leaf specimens are present in the collection. The median region of leaves is occupied by comparatively thick subparallel, dichotomizing and anastomosing veins. Lateral veins arise at acute angle and form broad, linear, hexagonal meshes in the median region and narrower meshes towards margin. These leaves are comparable with *Gangamopteris cyclopteroides* in all features (Maithy, 1965a, pl. 1, fig. 2; Srivastava, 1977a, pl. 1, fig. 17).

Gangamopteris rajaensis sp. nov.

Pl. 5, figs 1, 2

Diagnosis—Leaf simple, oblanceolate to narrow obovate in shape; apex mucronate; base broadly contracted; margin entire; 4-6 parallel running, dichotomizing veins present in the median region, show fibres in between veins, lateral veins arched, after anastomoses and dichotomization form broad hexagonal meshes in centre and narrow, elongate hexagonal meshes towards margin, 10-14 veins per cm.

Holotype—BSIP Specimen no. 36620; Seam no. B-II, Raja Colliery, Raniganj Coalfield; Barakar Formation, Early Permian.

Description—There are five complete to incomplete leaf specimens in the collection. The complete leaf measures 4.7 cm in length and 2.6 cm in width at its maximum, i.e., near the apical margin of leaf. Apex is broad, a small protruberance makes it mucronate; base is broadly contracted. The median region is occupied by 4-6 parallel running veins, dichotomizing frequently during their upward course and form 2-3 mm long and 0.5-1 mm broad, linear hexagonal meshes, fibres like structures are present in between the veins. Lateral veins arise at acute angle and form 2-3.5 mm long and 0.8-1.5 mm broad, hexagonal meshes in the centre and 1-1.5 mm long and 0.5 mm broad meshes towards margin. The density of veins is 10-14 per cm.

Comparison and discussion—*Gangamopteris rajaensis* sp. nov. is distinct from all the known

species in having mucronate apex and fibres in between the veins in only middle region. *G. fibrosa* Maithy (1965d, pl. 4, figs 26-28) differs in possessing obtuse apex and fibres in between the secondary veins all over the surface of leaf.

Maithy (1965c) instituted the species *G. mucronata* (Pl. 3, figs 17-19) to accommodate the leaves having mucronate apex. Examination of the specimen indicates that the apex is, in fact, acuminate, and as such the leaves are comparable with *G. cyclopteroides* var. *acuminata* Feistmantel (1886, pl. 7, figs 4 (?) 5; pl. 8, fig. 5; pl. 11, figs 4, 7). *G. rajaensis* sp. nov. is the only species which shows mucronate apex.

Gangamopteris sp.

Pl. 5, fig. 3

Description—Single incomplete leaf specimen is present in the collection, which measures 7.5 cm in length and 2.6 cm in breadth at its widest part. The apex, base and margin of the leaf are not preserved. Median sub-parallel veins are absent and instead 4-5 veins emerge from lower part and immediately start dichotomizing and anastomosing to form 5-8 mm long and 0.5-1 mm broad narrow, elongate, hexagonal meshes. The veins are thickened near its emergence. The density of veins is 10-18 per cm.

Comparison and discussion—In the absence of midrib and presence of reticulate venation pattern, the leaf is referable to *Gangamopteris*. All the species show median sub-parallel veins except *G. obliqua* McCoy but it is distinct in having flexuous nature of veins.

Genus—*Gondwanophyllites* Srivastava 1987*Gondwanophyllites dissectus* Srivastava 1987

There are five incomplete leaves showing dissected margin and reticulate venation pattern, which are comparable with *G. dissectus* (Srivastava, 1987; figs 2-3) from Sangramgarh open cast project.

Genus—*Glossopteris* Brongniart 1822

The leaves of *Glossopteris* are the most dominant

PLATE 5

1. *Gangamopteris rajaensis* sp. nov., holotype showing mucronate leaf apex, specimen no. BSIP 36620, × 2.
2. *Gangamopteris rajaensis* sp. nov., another complete leaf showing shape and venation pattern, specimen no. BSIP 36621, × 1.5.
3. *Gangamopteris* sp., incomplete leaf showing frequently dichotomizing and anastomosing veins, specimen no. BSIP 36622, × 2.
4. *Glossopteris communis* Feistmantel, specimen no. BSIP 36624, Nat. size.
5. *Glossopteris indica* Schimper, specimen no. BSIP 36625, Nat. size.
- 6,7. Scale leaves showing parallel interconnecting veins and convexity near base, specimen no. BSIP 36626, × 1.5.

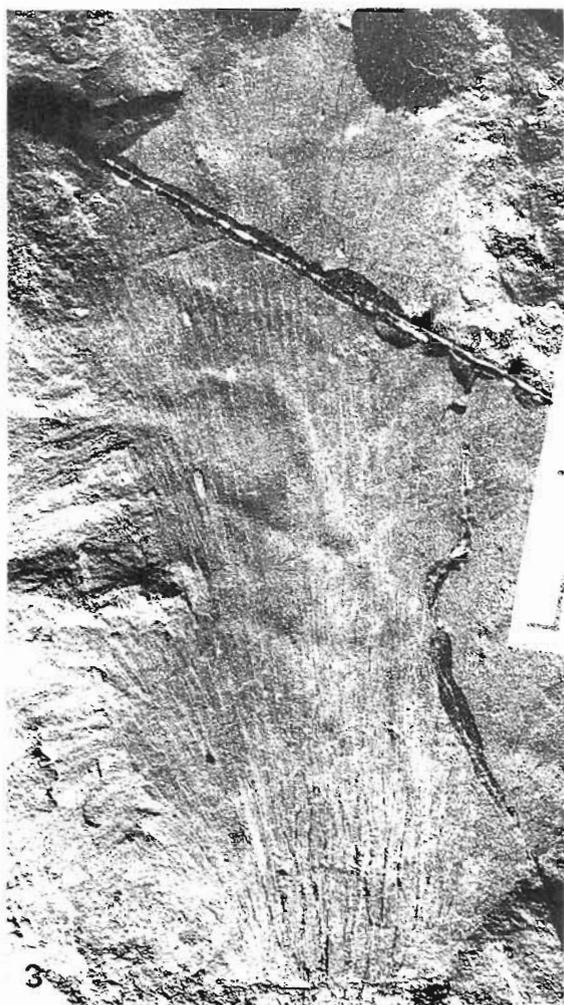


PLATE 5

Brongniart 1828, *G. barakarensis* Kulkarni 1971, *G. communis* Feistmantel 1879, *G. churiensis* Srivastava 1977, *G. damudica* Feistmantel 1879, *G. emarginata* Maheshwari & Prakash 1965, *G. giridibensis* Pant & Gupta, *G. gondwanensis* Pant & Gupta 1971, *G. indica* Schimper 1869, *G. intermittens* Feistmantel 1881, *G. karbarbariensis* Chandra & Surange 1979, *G. karanpurensis* Kulkarni 1971, *G. nimisbea* Chandra & Surange 1979, *G. pandurata* Pant & Gupta 1971, *G. raniganjensis* Chandra & Surange 1979, *G. spatulata* Pant & Singh 1971, *G. stenoneura* Feistmantel 1881, *G. stricta* Bunbury 1861, *G. tenuifolia* Pant & Gupta 1968, *G. tenuinervis* Pant & Gupta 1971, *G. taenioides* Feistmantel 1882, *G. vulgaris* Pant & Gupta 1971, *G. varia* Pant & Gupta 1968, *G. zeilleri* Pant & Gupta 1968.

Morphological analysis of *Glossopteris* species indicates that in most of the leaves midrib is represented by straight parallel running, closely spaced veins. In some cases, e.g., *G. stenoneura*, *G. pandurata*, *G. intermittens* and *G. churiensis* 3-6 veins emerge from the base and run parallel to each other and during upward course the side veins arch out to form secondary veins and ultimately one or two veins reach the apical margin of leaf (Pl. 8, fig. 6). In *G. communis*, *G. angusta*, *G. zeilleri*, *G. karbarbariensis*, *G. vulgaris* and *G. varia*, the midrib is represented by parallel running dichotomizing veins but they never show anastomosis (Pl. 5, fig. 4). In other cases, there are distinct to faint impressions of striation over the surface of midrib. Incidentally, such forms make confusion with the leaves of *Gangamopteris* and sometimes it becomes difficult to identify the midrib and non-midrib forms on external morphological character. Pant and Singh (1971) have suggested some distinction on the basis of cuticular features of midrib and mesh areas. The present investigations of *Glossopteris* and *Gangamopteris* leaves suggest that in *Glossopteris*, the median parallel running strands, whether they diverge out or dichotomise or converge at the apical margin, never show anastomoses, whereas in *Gangamopteris* median veins frequently dichotomize, anastomose and form meshes. Thus, the character of median parallel running strands is vital for taxonomic deliberation of *Glossopteris* and *Gangamopteris* leaves.

Genus—*Scutum* Plumstead 1952

Scutum barakarensis sp. nov.

Pl. 6, figs 1-3

Diagnosis—Fructification attached to midrib in middle or lower half of lamina with small adnate stalk, leaf resembling *Glossopteris longicaulis*

Feistmantel; fertile structure triangular, ovate in shape; apex acute; base broadly obtuse; margin entire; protective bract bears fine veins emerging from base, median veins slightly thickened and run parallel, side veins thin, arched, midrib absent, all veins anastomose and dichotomise to form short to medium size hexagonal meshes; receptacle covered with protective bract, convex, lense-shaped, contains many small seeds or ovules; wing-like rim showing fine striations present all around receptacle.

Holotype—BSIP Museum no. 36614; Seam no. B-IV, Gourandih Colliery, Raniganj Coalfield; Barakar Formation, Early Permian.

Description—There are two similar type of leaf specimens in the collection which show fertile structure attached to the midribs. The leaves are incomplete in which apex is not preserved and the base is petiolate in one of the leaves. The venation comprises broad meshes, lying almost at right angles to the midrib. The long drawn petiole, thick midrib showing grooves and venation pattern of the leaves are comparable with *Glossopteris longicaulis* Feistmantel (Chandra & Surange, 1979).

The fertile structure shows different place of attachment with leaves in two specimens. In one specimen, it is attached in middle portion whereas in other the lower half of leaf bears such structure. The fructification is attached to the midrib by a stalk, measuring 1-1.3 cm long and 1-2 mm broad. The stalk is lying slightly away from the midrib and appressed to the midrib indicating adnate position.

The protective bract and seed-bearing receptacle are superimposed and well distinguishable, though they have not been found preserved separately. Sometimes, the weathered condition of protective bract exposes the seed-bearing receptacle (Pl. 6, fig. 3). The complete structure (excluding stalk) measures 1.8-2.0 cm long and 1-1.3 cm broad, ovate in shape and shows acute rarely acuminate apex and broad obtuse base. The bract is distinctly veined. The veins emerge from the base, 3-6 median veins run parallel to each other and side veins arch out towards the margin. All the veins dichotomize and anastomose to form 0.5-1 mm long and 0.2-0.5 mm broad hexagonal to polygonal meshes. The midrib is absent. The structure and venation pattern are similar with the detached scale leaves of glossopterid (Chandra & Surange, 1977a, b). Seed-bearing receptacle is found beneath the protective bract, convex, lense-shaped and shows 1-1.5 mm broad, finely striated rim all round. Seeds or ovules are less than 0.3 mm in diameter and studded in the central part of receptacle. Their exact arrangement and structural details are not preserved.

Comparison and discussion—Surange and

Chandra (1974) described a species, *Scutum sabnii* attached to the petiole of a leaf of *Glossopteris longicaulis* Feistmantel 1880. Later, while revising the Indian species of *Glossopteris*, they transferred it to *G. maculata* Pant & Singh 1971 (see Chandra & Surange, 1979, p. 42). The present leaves having fructification are quite distinct from *G. maculata* and compare closely with *G. longicaulis*. Apart from attached leaf, *S. sabnii* also differs from *S. barakarensis* sp. nov. in having round to oval-shaped fruiting body, attached with the petiole of leaf and its protective bract is also distinguishable in possessing midrib.

Plumstead (1952, 1958) described a number of species of *Scutum* attached to different species of *Glossopteris*. Since all the species, except one, have been found to be attached with the species of *Glossopteris* other than *G. longicaulis*, it is better to consider them separate than *S. barakarensis* sp. nov. which is found attached with *G. longicaulis* Feistmantel 1880.

Genus—*Partha* Surange & Chandra 1973

Partha raniganjensis sp. nov.

Pl. 7, figs 1-4

Diagnosis—Fertile leaf oblong, ovate in shape, apex obtuse, base narrowly contracted; veins emerge from base, median region occupied by parallel running interconnecting veins, side veins run almost parallel near base, after some distance arch out at angle of 30°-40°, all veins dichotomize and anastomose to form narrow hexagonal meshes; only on one side of leaf 3 stalks emerge in a row near base of leaf, 2 stalks found to be very close near their emergence, each stalk terminally bears a flat disc-shaped seed-bearing organ showing four chambers with one seed in each.

Holotype—BSIP Museum no. 36617 with counterpart no. 36618; Seam no. B-IV, Gopinathpur Colliery, Raniganj Coalfield; Barakar Formation, Early Permian.

Description—There are four specimens in the collection. The holotype represents the part and counterpart. The fertile structure is found attached with scale leaf. The leaf is 2.8 cm long and 1.3 cm wide at its maximum, i.e., near the apical margin, apex is obtuse and base is contracted. The margin is

entire. The median region is occupied by 5-6 parallel running veins, side veins also run straight near its emergence, but soon they arch out at an angle of 30°-40° and finally reach the margin of leaf. The veins frequently dichotomize and anastomose to form 1-2 mm long and 0.5-0.75 mm broad, hexagonal meshes throughout lamina.

Only one side of leaf bears three, 4-6 mm long stalk which emerge from the base of leaf. Two stalks are very close to near their emergence and seem to emerge from a common point, however, the third stalk lies in lower level and found to be attached at a distance of 1 mm. Stalks are 1 mm broad and show fine striations over the surface. The tip of each stalk bears a flat disc or saucer-shaped seed-bearing organ. The diameter of seed-bearing organ is 5-7 mm. It has four distinct lobes with only one seed in each. The convex and concave nature of each lobe in part and counterpart further confirms the presence of one seed. The seeds are almost circular in outline and measure 2-3 mm in diameter. Their surface is finely striated but other structural details are not available.

Comparison and discussion—The present specimens resemble *Partha* Surange & Chandra 1973 in having only one row of fertile structure. Surange and Chandra (1973) interpreted the fructification having two to four separate cupules attached at the apical end of each stalk (see text-figure 3 of Surange & Chandra, 1973, p. 358). However, while describing the genus, they also envisaged the seed-bearing organ as a peltate disc containing four large seeds on the underside of each fertile organ. The organizational structure of fertile organs in present specimens favours such interpretation.

The genus *Partha* is known by only two species, *P. indica* (Surange & Maheshwari) Surange & Chandra 1973 and *P. spathulata* Surange & Chandra 1973. *P. raniganjensis* sp. nov. essentially differs from both the species in having different organizational pattern of seed-bearing organ. The earlier species possess four separate seed-bearing cupules having attached to a common point on each stalk, whereas the present species shows a disc-shaped fertile organ with four seed-bearing chambers. The fertile leaves of *P. indica* and *P. spathulata* are spathulate in shape and bear petiolate

PLATE 6 →

1. *Scutum barakarensis* sp. nov., holotype showing two leaves with attached fructification, specimen no. BSIP 36614, Nat. size.
2. Enlargement of specimen in figure 1 to show attachment of fertile structure with midrib, × 2.

3. Single leaf showing fertile structure, × 2.
4. *Glossopteris churiensis* Srivastava, specimen no. BSIP 36616, Nat. size.
5. *Glossopteris angustifolia* Brongniart, specimen no. BSIP. 36615, Nat. size.

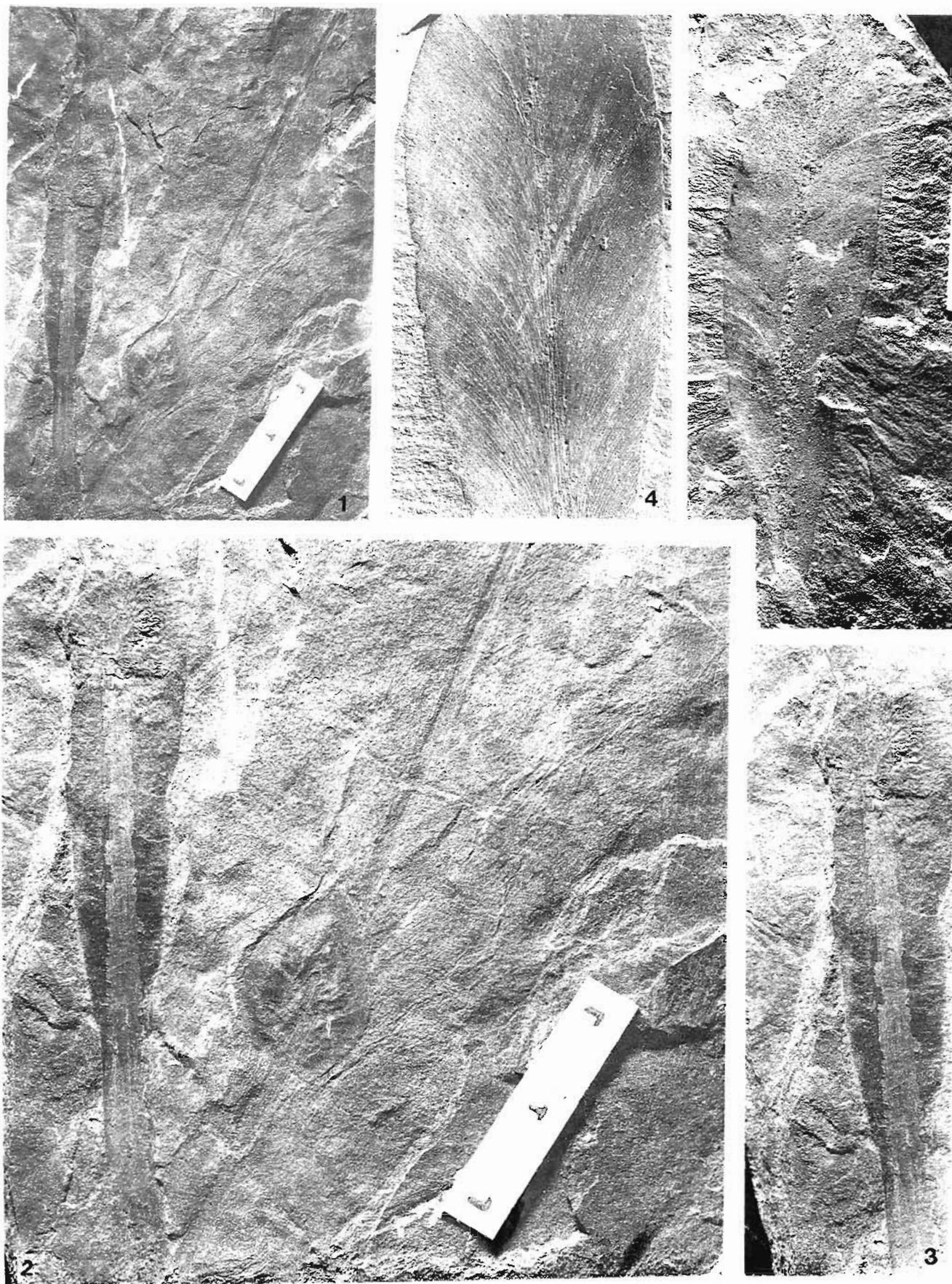


PLATE 6

nature but in *P. raniganjensis*, the fertile leaf is obtuse in shape and do not show the petiolate condition.

Glossopterid scale leaves

Pl. 3, fig. 5; Pl. 5, figs 6, 7

Scale leaves of many different kinds in detached condition are present in the collection. Similar scales occur commonly in the Permian Gondwana flora (Arber, 1905; Walkom, 1922; Surange & Maheshwari, 1970; Chandra & Surange, 1977a, b; Srivastava, 1979). They have usually been attributed to male and female glossopterid fructifications.

The scale leaves vary in size and shape. Rhomboidal scales compare closely with the bract of *Eretmonia* DuToit and *Glossotheca* Surange & Maheshwari 1970, others with spatulate or ovate shape resemble the fructifications—*Lidgettonia* Thomas 1958 and *Partha* Surange & Chandra 1973; more linear scales sometime resemble *Glossopteris* and *Gangamopteris* leaves.

Characteristically some large and medium size scale leaves ranging in size from 2 to 7 cm long and 1 to 2 cm broad have been found in large quantity in the assemblage of Lakhimata Colliery (Pl. 5, figs 6, 7). Such leaves show convexity and concavity near the base and indicate the possible presence of seeds. They possess parallel running interconnecting veins. Such leaves have earlier been observed by Surange and Maheshwari (1970) with seed attached near the base of the scale. Although present specimens do not show the presence of seed but their nature represents similar type of scales.

Genus—*Noeggerathiopsis* Feistmantel 1879

The present investigation indicates that the leaves of *Cordaites* and *Noeggerathiopsis* are distinguishable from each other on the basis of external morphological features leaving aside their variable shapes. The leaves of *Noeggerathiopsis* show erect, simple dichotomizing veins of uniform thickness throughout the lamina (see Pl. 4, figs 2, 3), whereas the leaves of *Cordaites* possess thick, parallel veins and in between these veins, there are thin dichotomizing parallel interstitial fibres/veins (see Pl. 4, figs 4-6). Fortunately, present assemblages contain both the types of leaf and it is possible to

identify them on external morphological feature. The presence of interstitial veins or fibres is an important character of *Cordaites* leaves (Grand Eury, 1877; Harms & Leisman, 1961; Pant & Verma, 1964a) and invariably all the species show this character. But such feature is absent in the leaves of *Noeggerathiopsis*. In one of the cuticular species, *N. fibrosa* Pant & Verma 1964a, occasional fibres in between veins are present.

Noeggerathiopsis bislopii (Bunbury) Feistmantel 1879
Pl. 4, figs 2, 3

Description—The leaves in the collection vary in their shape. They are spatulate, ovate, lanceolate to linear-lanceolate in shape. Their apex is obtuse and base narrow, tapering and sometimes cuneate. Margin of the leaves is entire. The veins arise from the base of leaf and run parallel for some distance then bifurcate frequently during upward course, side veins show divergence towards the leaf margin.

Venation pattern and shape of the leaves are comparable with *N. bislopii* described by Feistmantel (1879, pl. 19, figs 2-6) and Maithy (1965b, pl. 1, figs 1, 2).

Discussion—Although leaves of *Noeggerathiopsis bislopii* were first recorded from the upper most strata of Indian Lower Gondwana, i.e., Kamthi Formation, but later discoveries (Feistmantel, 1876, 1879, 1881; Seward & Sahni, 1920; Saksena, 1963; Lele & Maithy, 1964; Pant & Verma, 1964a; Maithy, 1965b; Srivastava, 1977a) indicate their abundance in the lower horizon, i.e., Karharbari Formation. External morphological study of all the known records of *Noeggerathiopsis* in the Indian Lower Gondwana flora suggests that they belong to only one species, *N. bislopii* (Bunbury) Feistmantel 1879. The species instituted on cuticular features also show similar external morphological character (Pant & Verma, 1964a; Lele & Maithy, 1964; Bajpai, 1990).

N. bislopii is not common in the Barakar and Raniganj formations. Maheshwari and Prakash (1965) and Bajpai (1990) have reported *N. bislopii* from Rajmahal and Deogarh coalfields.

Genus—*Cordaites* Unger 1850

Cordaites sp.

Pl. 4, figs 4-6

PLATE 7

1. *Partha raniganjensis* sp. nov., holotype showing fertile leaf and one row of stalked disc-shaped four chambered seed-bearing organs, specimen no. BSIP 36617, × 4.
2. Counterpart of holotype, specimen no. BSIP 36618, × 4.

3. Holotype in another focus to show details of seed-bearing organs, × 4.
4. *Partha raniganjensis* sp. nov., another specimen showing only one seed-bearing organ, specimen no. BSIP 36619, × 2.



PLATE 7

Description—There are six complete to incomplete leaf specimens in the collection. They are characteristic in having thick parallel running veins and interstitial fibres/veins in between thicker veins.

The leaves are 7 to 12.5 cm long and their maximum width ranges from 2.5 to 5.5 cm. They show narrow-obovate shape where the apex is broadly obtuse. In most of the cases, the apical margin is shredded. Base is narrowly contracted and margin is entire. The leaves show two distinct types of venation pattern. One type possesses 7-8 thick, straight, parallel running, unforked simple ribs emerging from the base of leaf, in between these ribs, there are 2-4 finer dichotomizing parallel running veins. There are 5 thicker and 15 finer veins per cm. Another type contains 10-12 thick parallel running veins, whose surfaces are grooved and striated. The frequently dichotomizing finer veins running along the thicker veins are present in between. The density of veins is 3 thick and 18 thin veins per cm.

Comparison and discussion—The leaves in discussion at first hand show their resemblance with the commonly known Gondwana forms, *Noeggerathiopsis*, but distinct presence of alternating thick and thinner veins clearly distinguish them from such leaves. In this character, they resemble typical *Cordaites* leaf of northern hemisphere (Stopes, 1903; Reed & Sandoe, 1951; Harms & Leisman, 1961; Pant & Verma, 1964a). The specific comparison of present specimens has not been taken much into consideration because at this stage the occurrence of *Cordaites* leaf alongwith *Noeggerathiopsis* leaf in the Gondwana flora of India is much more interesting rather than its specific determination.

Lacey, van Dijk and Gordon Gray (1975) figured a specimen of *N. bislopii* (Specimen no. N.M. 1781) from South Africa to show finer veins in between thicker veins. It indicates that there are leaves of this kind in the *Glossopteris* flora but they have generally been overlooked because of their general resemblance with *Noeggerathiopsis* type of leaf.

The presence of morphologically similar northern hemispheric forms in the Gondwana flora is not unusual, notably amongst them are the

records of sterile remains of *Phyllotheca*, *Schizoneura* and *Sphenophyllum*. Earlier, gondwanan sphenophylls were known by only *Trizygia speciosa* (Maheshwari, 1968) showing trizygoid leaf pattern but recent discovery of *Sphenophyllum gondwanensis* Singh, Srivastava & Maheshwari 1987, a closer representative of northern sphenophylls, showing dentate apical margin and dimorphism of leaves like *S. thonii* signifies that two types of sphenophylls occur in the Indian Lower Gondwana flora. The records of *Noeggerathiopsis* and *Cordaites* in *Glossopteris* flora suggest that two types of cordaitalean leaf forms co-existed in the Gondwana flora. However, their exact affinity can not be ascertained until the discovery of fertile structures in association with such leaves.

Genus—*Gondwanophyton* Maithy 1974

Gondwanophyton indicum Maithy 1974

There are only three small fragments of leaves from Palasthali area. The leaves are fan-shaped with broad rounded apex and frequently dichotomizing veins run parallel to each other. The specimens resemble *G. indicum* Maithy (1974b, pl. 1, fig. 1; pl. 2, figs 6, 7).

Dispersed seeds

The collection includes a number of dispersed seeds which belong to the following two types.

Cordaicarpus zeilleri Maithy 1965

Seeds mostly pear-shaped with cordate base and rounded apex. A narrow border surrounds the striated sclerotesta.

Samaropsis ganjrensis Maithy 1965

Pl. 3, fig. 6

Seeds oval to subcircular in shape, sclerotesta convex to oval with bluntly rounded apex. The sarcotesta thin, surrounds the sclerotesta except at the apical end where it is notched into a V-shaped sinus. The ends of sarcotesta are rounded.

PLATE 8

- Glossopteris raniganjensis* Chandra & Surange, specimen no. BSIP 36627, Nat. size.
- Glossopteris nimishea* Chandra & Surange, specimen no. BSIP 36628, Nat. size.
- Glossopteris stricta* Bunbury, specimen no. BSIP 36629, Nat. size.
- Glossopteris taeniodes* Feistmantel, specimen no. BSIP 36630, Nat. size.
- Glossopteris spatulata* Pant & Singh, specimen no. BSIP 36631, Nat. size.
- Glossopteris stenoneura* Feistmantel, specimen no. BSIP 36632, Nat. size.

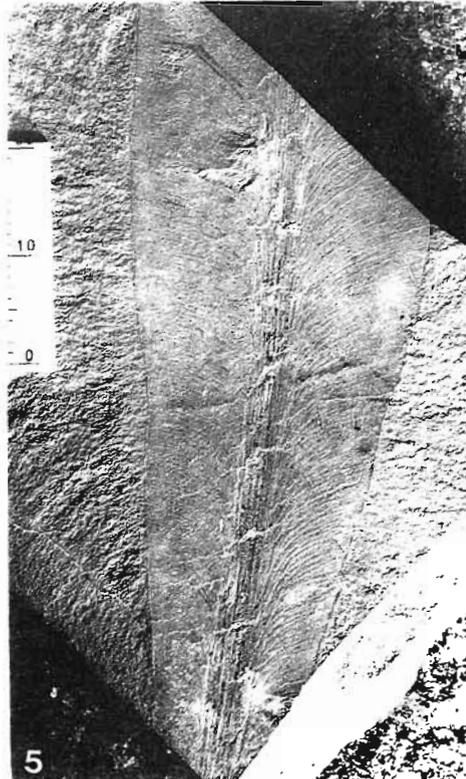
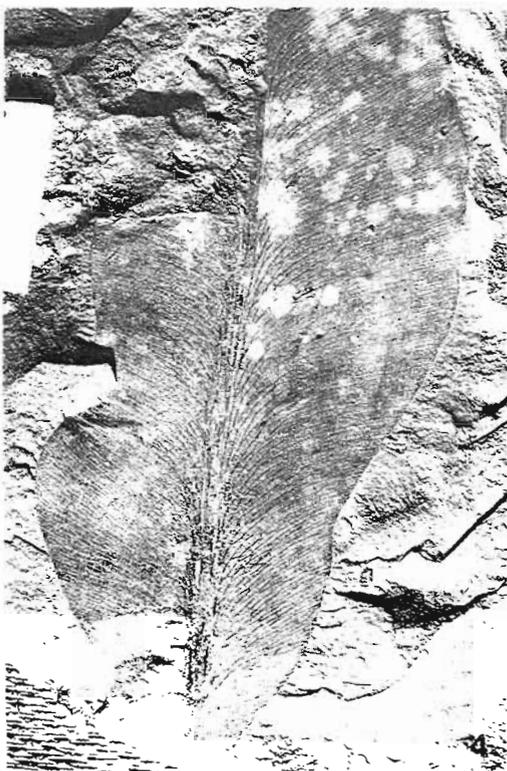
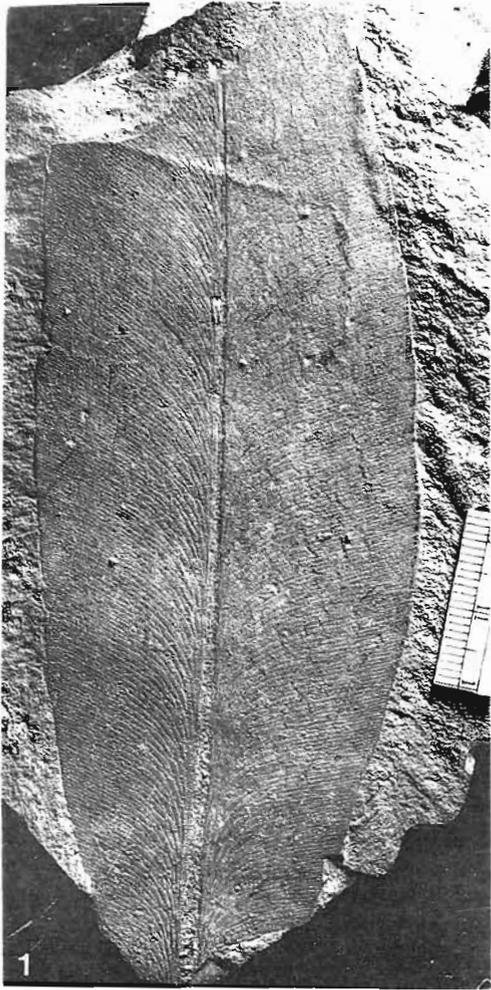


PLATE 8

FLORISTIC COMPARISON

Floristic distribution of each genera and species in different collieries, open cast projects and nala cuttings has been shown in Table 1, which suggests two floral zones in the Barakar Formation of Raniganj Coalfield. The assemblages of Chapapur, Bajna, Tara, Palasthali, Dalmia, Gaurandih, Sangramgarh, Pusai Nala, Nirsra Khas, Khudia and Gopinathpur areas belong to lower seams (nos. II-IV) and represent the early floral zone. The species of *Phyllotheca*, *Giridia*, *Trizygia*, *Lelstotheca*, *Neomariopteris*, *Palasthalia*, *Euryphyllum*, *Gangamopteris*, *Glossopteris*, *Palaeovittaria*, *Gondwanophyllites*, *Maheshwariphyllum*, *Scutum*, *Partha*, *Noeggerathiopsis*, *Cordaites*, *Gondwanophyton*, *Cordaicarpus* and *Samaropsis* are recorded from the lower seams. Amongst them, *Gangamopteris*-*Noeggerathiopsis*-*Glossopteris* complex makes the dominant composition of the flora. Similar type of association has been found to be characteristic of Karharbari flora (Srivastava, 1977a; Bajpai, 1990). However, Shah, Singh and Sastry (1971) have observed *Gondwanidium* (*Botrychiopsis*)—*Buriadia* zone for Karharbari flora but floral distribution indicates that both these genera occur only in the Giridih Coalfield, while in other areas their records are either poor or doubtful. Thus as such they can not be considered as the index fossils (Bajpai, 1990). The species of *Glossopteris*, viz., *G. communis*, *G. zeilleri*, *G. longicaulis*, *G. karharbariensis*, *G. giridibensis*, *G. taeniodes*, *G. pandurata* and *G. angusta* also suggest the floral affiliation with Karharbari flora (Chandra & Surange, 1979). The occurrence of Karharbari components in the lower seams suggests continuation of underlying flora in the Lower Barakar Formation as recently reported in the adjoining Deogarh Coalfield (Bajpai, 1990).

Phyllotheca, *Giridia*, *Neomariopteris*, *Euryphyllum*, *Cordaicarpus* and *Samaropsis* are common in the flora of Karharbari Formation (Maithy, 1969). The presence of *Lelstotheca*, *Trizygia*, *Gondwanophyllites*, *Maheshwariphyllum* and *Gondwanophyton* demonstrates a marked change in the Barakar flora because of their absence in the Karharbari flora.

Quantitatively few representations of *Scutum*, *Partha* and leaves of *Palaeovittaria* are interesting since they have earlier been reported only in the floras of Raniganj and Kamthi formations. The older records of glossopterid fructifications in the Lower Gondwana flora of India, e.g., *Ottokaria* from Karharbari beds (Zeiller, 1902), *Eretmonia* from Barakar of South Karanpura Coalfield (Surange &

Maheshwari, 1970) and the presence of *Scutum* and *Partha* in present assemblage signify the existence of simple ovulate and advanced capitulum nature of fertile structure which resembles glossopterid fructifications of the Raniganj Formation.

The flora of upper seams (nos. V-VII) has been recovered from Junkundar, Amdih, West Victoria, Pusai Nala, Lakhimata, Rajpura, Shampur, Shampur Nala and New Bagma areas and it represents the later stage of the Barakar flora. The assemblages are mostly represented by the species of *Glossopteris*; other elements like *Neomariopteris*, *Phyllotheca*, *Lelstotheca* are poor in number. The representatives of Karharbari flora are entirely absent in the flora. The presence of significant proportion of scale leaves showing affinity with *Eretmonia* type of fructification in Lakhimata and Rajpura assemblages indicates the possible existence of glossopteridalean fructifications in the flora.

Glossopteris dominant flora of upper seams is comparable with the flora of Barakar Formation from Rajmahal (Maheshwari & Prakash, 1965), South Karanpura (Kulkarni, 1971) and Auranga Coalfield (Srivastava, 1977b). The available species, viz., *G. indica*, *G. damudica*, *G. barakarensis*, *G. karanpurensis*, *G. nimishea*, *G. stenoneura*, *G. intermittens*, *G. churiensis* and *G. raniganjensis* in the present assemblage also correlate with the *Glossopteris* species of Barakar Formation (Chandra & Surange, 1979).

FLORISTIC EVOLUTION AND PALAEOCLIMATE

The investigations of the plant fossil assemblages of Barakar Formation indicate a significant change in the flora of lower and upper seams in the Raniganj Coalfield. The flora of lower seams is much more varied and its representatives, viz., *Euryphyllum*, *Palaeovittaria*, *Maheshwariphyllum*, *Cordaites* and *Noeggerathiopsis* (irrespective of their plant groups) show the absence of reticulate venation pattern in their foliage. The non-existence of midrib in *Euryphyllum*, presence of midrib only up to 1/2 or 2/3 of leaf lamina in *Palaeovittaria* and existence of complete midrib in *Maheshwariphyllum* demonstrate a gradual emergence of midrib character in non-reticulate leaves. Similarly, the occurrence of *Gangamopteris*, a non-midrib form, leaves with reticulation in the lower seams and presence of *Glossopteris* leaves showing complete midrib in the flora of upper seams suggest the emergence of midrib through the species of *Gangamopteris* to the species of *Glossopteris* in reticulate leaves.

As discussed earlier, the continuation of Karharbari plant fossils in the early phase of Barakar Formation and their habitual stay away in the flora of Upper Barakar suggests a shift in the climatic set up. After the glaciation phase, the Gondwana climate started getting warmer due to frost free conditions and sufficient rainfall resulted into warm moist climatic condition during Karharbari. The floral affinity of Lower Barakar seams with that of the Karharbari flora suggests the existence of similar climatic conditions in the early phase of Barakar. Successive time span in the Upper Barakar created much more warmer and drier conditions. This climatic change did not favour the continuation of Karharbari plants and in time they disappeared from the floral scene of Upper Barakar Formation (Maheshwari *et al.*, 1991).

The appearance of *Lelstotheca*, *Trizygia*, *Gondwanophyllites*, *Maheshwariphyllum*, *Palaeovittaria* and *Gondwanophyton* in the Barakar flora suggests a shift in climatic conditions. During Upper Barakar the uniform composition of flora indicates more or less stable climatic condition and the dominance of medium-sized *Glossopteris* leaves with narrow mesh supports the existence of warm temperate condition.

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