

# Glossopteris flora from the Early Permian of Karanpura and Bokaro Coalfields

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Glossopteris flora from the Early Permian (Talchir, Barakar and Karharbari formations) of Karanpura and Bokaro Coalfields include the genera *Neomariopteris*, *Glossopteris*, *Gangamopteris*, *Palaeovittaria*, *Pantophyllum*, *Euryphyllum*, *Kawizophyllum*, *Vertebraria*, *Scutum*, *Gonophylloides* and *Cordaicarpus*. The flora includes three new species of *Glossopteris*, one new species each of *Pantophyllum* and *Kawizophyllum*.

**Key-words** - Glossopteris, Early Permian, Karanpura, Bokaro Coalfield, India.

## INTRODUCTION

THE Glossopteris flora appeared after the longest and geographically most widespread period of glaciation in geological history, and its effect dominated the vegetation of Australia, Antarctica, South Africa, South America, and India for about 40 million years. Despite its long duration, richness of fossil remains, and large number of reported occurrences throughout the present southern hemisphere and India, the rise and fall of the Glossopteris flora is poorly understood and has therefore been the subject of much argument. In India, representatives of this flora have been known for about 170 years. The flora has been extensively investigated, particularly in view of the fact that its elements on entombment gave rise to the famous Permian coal deposits of the country.

Extensive collection of plant megafossils was made from the shales associated with several coal seams of the Barakar Formation. Some of these coal seams have been placed under the Karharbari "Formation" by some workers. However, in the present study it has not been possible to recognise the Karharbari as a formation because (i) enough geological data was not collected and (ii) presence of plant fossils supposed to be markers of the Karharbari, for example, *Botrychiopsis* (= *Gondwanidium*) *validum* and *Buriadia sahnii* (= *heterophylla*), has not been noticed. Even the genera *Gangamopteris* and

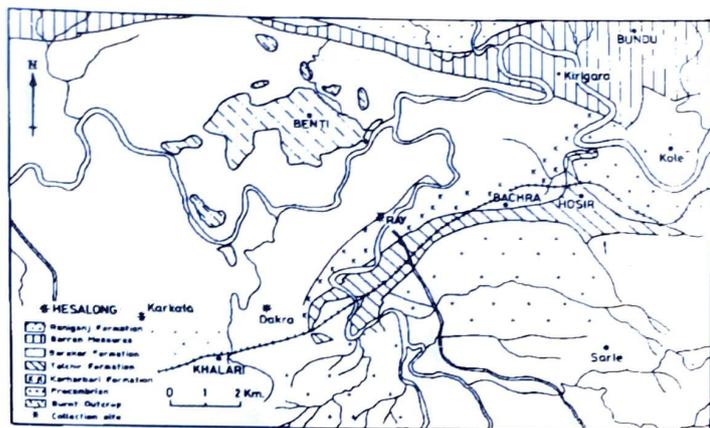
*Pantophyllum* (= *Noeggerathiopsis*) do not show much species diversity. The flora in fact is dominated by species of the genus *Glossopteris*.

## GEOLOGY

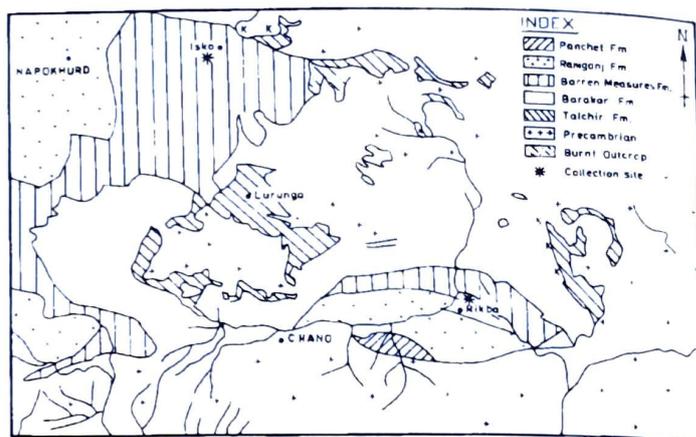
*North Karanpura Coalfield* : This is the westernmost coalfield (Maps 1,2) in the east-west chain of the Damodar Valley basins. It covers a total area of around 1230 sq. km. spread between north latitudes 23° 39' & 23° 59' and east longitudes 84° 46' and 85° 24'. The coalfield has almost a complete succession of Gondwana sequence (see Raja Rao 1987).

*South Karanpura Coalfield* : The South Karanpura Coalfield (Map 3) is situated in the western part of the Damodar Valley and covers an area of about 194 sq. km. between north latitudes 23° 38' to 23° 45' and east longitudes 85° 05' and 85° 28'. The coalfield is a narrow elongated basin and exposes all the main Permian sequence of the Gondwana Supergroup. The Karanpura Coalfields were mapped in detail by Hughes (1871). The area was remapped by Albert Jowett (1925). A generalised stratigraphical sequence in the coalfield is shown in Raja Rao, 1987, p. 144.

*West Bokaro Coalfield* : The West Bokaro Coalfield (Map 4) is spread over an area of 180 sq. km. and is located between latitudes 23° 44' and 23° 50' 30" N and longitudes 85° 24' and 85° 42' E in the



**Map 1.** Geological Map of Ray-Bachra Area, North Karanpura Coalfield (After GSI)



**Map 2.** Geological Map of Chano-Rikba Basin, North Karanpura Coalfield (after GSI)

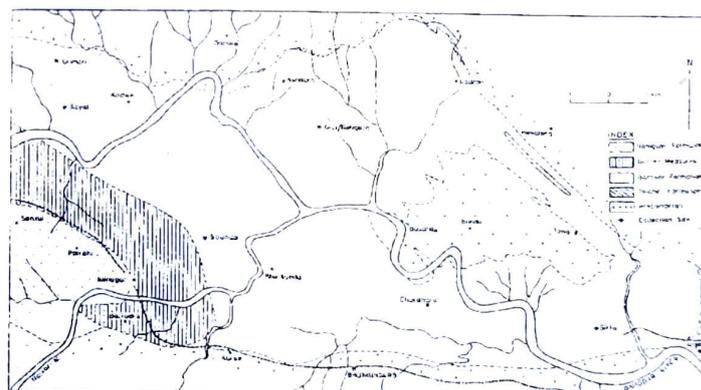
Hazaribagh district of Bihar. A detailed account of the geology of the basin was given by Hughes (1867). The area has been resurveyed by the Geological Survey of India. The generalised stratigraphic sequence in the coalfield is followed after Raja Rao, 1987.

### MATERIAL AND METHOD

The specimens of various species of different genera have been collected from shales associated with different coal seams dumped in campuses of different collieries of Karanpura and Bokaro group of coalfields. The specimens are preserved mostly as impressions, sometimes as compressions. The shales are grey, carbonaceous. The specimens were collected from Talchir (Rikba plant bed of North Karanpura) and Barakar (South Karanpura, North Karanpura and West Bokaro Coalfields) Formations. The method used for present study included cleaning and sorting of specimens, cuticular preparations and photography followed in the laboratory. The specimens used in the present study have been kept in the repository of Birbal Sahni Institute of Palaeobotany, Lucknow, India.

### SYSTEMATIC DESCRIPTION

The assemblage of fossil plants of Early Permian age from North Karanpura, (Maps 1 and 2), South Karanpura (Map 3) and West Bokaro (Map 4) Coalfields consists mainly of *Glossopteris* leaves, with less frequent occurrence of *Neomariopteris lobifolia*, *Gangamopteris obovata*, *G. sp. cf. G. buridica*, *Palaeovittaria*, *Pantophyllum* (= *Noeggerathiopsis*), *Euryphyllum whittianum*, *Kawizophyllum*,



**Map 3.** A Part of Geological Map of South Karanpura Coalfield, Bihar (after GSI)

### PLATE 1

- Glossopteris pseudostricta* sp. nov. specimen BSIP 38813, Religara Colliery, South Karanpura Coalfield, Bihar X reduced (nat. size 28 cm.).
- Kawizophyllum barakarensis* sp. nov., specimen BSIP 38442 Barakar Formation, Shales associated with Naditoli seam, Sirka Colliery, South Karanpura Coalfield, Bihar, X nat. size.
- Glossopteris obovata* sp. nov. specimen BSIP 38814, Barakar Formation, Shales associated with Naditoli seam, Sirka Colliery, South Karanpura Coalfield, Bihar, X nat. size.
- Pantophyllum gidiensis* sp. nov. specimen BSIP 38437, Barakar Formation, Gidi-A Colliery, South Karanpura Coalfield, Bihar, X nat. size.
- An enigmatic plant fossil, *incertae sedis* Bajpai & Singh 1999. (specimen BSIP 38162/4738) from shales associated with Naditoli seam, Sirka Colliery, South Karanpura Coalfield, Bihar, X nat. size.
- Glossopteris pseudotortuosa* sp. nov. specimen BSIP 38815, Barakar Formation, Sirka Colliery, South Karanpura Coalfield, Bihar, X nat. size.
- Gonophylloides* (= *Cistella*) sp. specimen BSIP 38816, Barakar Formation, Sirka Colliery, South Karanpura Coalfield, Bihar, X nat. size.
- Cordaicarpus* sp. specimen BSIP 38817, Barakar Formation, Religara Colliery, South Karanpura Coalfield, Bihar, X 2.

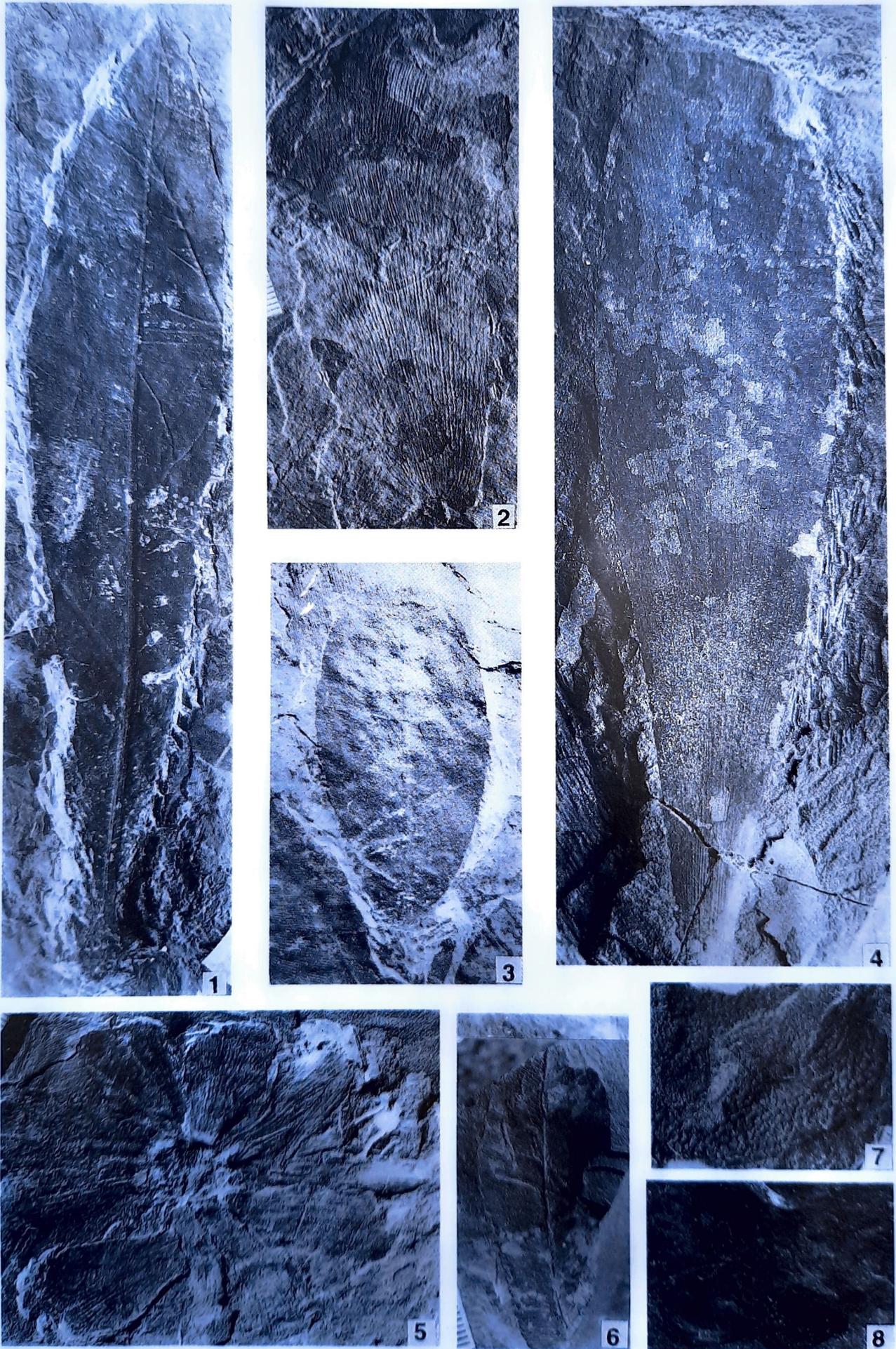


PLATE 1



Map 4. Geological map of West Bokaro Coalfield (after GSI).

*Vertebraria*, equisetalean axes, *Cordaicarpus* (dispersed seed), *Gonophylloides*, *Scutum*, *Ottokaria* (fructifications), roots and axes. Besides these, an enigmatic fossil (*incertae sedis*) has also been described.

### Genus *Glossopteris* Brongniart 1828

From Karanpura and Bokaro Coalfields thirty-two species of genus *Glossopteris* have been identified viz. *G. angustifolia* Brongniart 1831, *G. arberi* Srivastava 1956, *G. barakarensis* Kulkarni 1971, *G. browniana* Brongniart 1828, *G. communis* Feistmantel 1876, *G. clarkei* Feistmantel 1879, *G. danae* Maheshwari & Tewari 1992, *G. decipiens* Feistmantel 1879, *G. emarginata* Maheshwari & Prakash 1965, *G. euryneura* Maheshwari 1965, *G. elongata* Dana 1849, *G. indica* Schimper 1869, *G. intermittens* Feistmantel 1881, *G. intermedia* Feistmantel 1881, *G. karanpuraensis* Kulkarni 1971, *G. linearis* McCoy 1947, *G. longifolia* Pant & Singh 1971, *G. major* Pant & Singh 1971, *G. obscura* Pant & Singh 1971, *G. obovata* sp. nov., *G. oldhamii* Pant & Singh 1974, *G. pseudotortuosa* sp. nov., *G. pseudostricta* sp. nov., *G. raniganjensis* Kulkarni 1971, *G. shillae* Bajpai 1987, *G. stenoneura* Feistmantel 1877, *G. taeniopteroides* Feistmantel 1890, *G. tortuosa* Zeiller 1902, *G. vulgaris* Pant & Singh 1968, *G. waltonii* Pant & Gupta 1968, and *G. zeilleri* Pant & Gupta 1968. Among these three species are new.

### *Glossopteris obovata* sp. nov.

Plate 1, figure 3

1965 *Glossopteris spathulo-cordata* Feistmantel: Maithy, *Palaeobotanist* 13: 257, pl. 5,

fig. 34.

1992 *Glossopteris pandurata* Pant & Gupta 1971 : Maheshwari & Tewari, *Palaeobotanist* 39: 339, pl. 1, figs 3, 4, text-fig. 1c.

*Diagnosis* : Leaf simple, obovate in shape, apex broad obtuse having a notch, base narrow tapering, margin entire, midrib stout, distinct up to 3/4 length or up to apex of lamina. Veins arise at acute angles, dichotomise and anastomose to form narrow meshes. Venation is of close type.

*Specimen nos.* : 21/4578, 7/4752A, BSIP # 38814 (8/4753), 33/4753, 1/4757, 9/5007A

*Locality* : Ray Colliery, North Karanpura Coalfield; Religara, Sirka, Gidi-A and Gidi-C Collieries, South Karanpura Coalfield

*Horizon* : Barakar Formation.

*Holotype* : BSIP specimen no. 36451A, shales associated with coal seam, Barakar Formation, Early Permian; Churulia OCP, Raniganj Coalfield, West Bengal.

*Description* : Simple leaf, shape obovate, length 7.5-9 cm, width 4-2 cm, apex obtuse, base rounded, margin entire, midrib distinct but flat, angle of origin of veins acute, no. of veins/cm : a. near the midrib 11-12; b. near the margin 23-28, lateral veins emerge from the midrib at acute angles, gracefully curve outwards to meet the margin, veins dichotomise and anastomose. Vein dichotomies usually of gamma type, meshes usually arcuate near midrib, cuticle not recovered.

*Comparison* : *Glossopteris obovata* sp. nov. can be compared with *G. pandurata*, *G. spatulata*, *G. angusta*, *G. emarginata* and *G. retusa*; all the species have retuse apex. *G. pandurata* has strong midrib reaching up to apex and venation is close.

### *Glossopteris pseudostricta* sp. nov.

Plate 1, figure 1

*Diagnosis* : Simple leaf, lanceolate in shape, acute apex, cuneate base, probably petiolate, entire margin, midrib strong, striated; lateral veins arise at acute angles, dichotomise and anastomoses to form very narrow-elongate meshes. Veins are very fine, up to 45 per cm. near the margin.

*Specimen nos.* : 28/4738, 12/4752, 6/4752,

BSIP # 38813 (26/4753), 20/4998.

*Locality* : Gidi-C, Religara and Sirka Collieries, South Karanpura Coalfield

*Holotype* : BSIP # 38813 (specimen no. 26/4753), Barakar Formation, Early Permian; Religara Colliery, South Karanpura Coalfield, Bihar.

*Description* : Simple leaf, shape narrow elliptic, length 12-26.6 cm., width 5.4-7 cm, apex acute, base cuneate, petiolate, margin entire, midrib strong, elevated, striated, running up to the apex, angle of origin of veins 85°-87°, no. of veins/cm: a. near the midrib 7-20; b. near the margin 20-45, lateral veins arise at right angles to the midrib, arching little near it, dichotomise and anastomose a few times, and then travel straight horizontally to the margin. Density of veins greater near the margin. Meshes broad near the midrib and then become very narrow and long, cuticle not recovered.

*Comparison* : *Glossopteris pseudostricta* differs from *G. stricta* Bunbury 1861 in being an oval-lanceolate leaf with very fine and dense venation; concentration of veins per centimetre is relatively much more than in the latter species. The species also compares with *G. indica* Schimper and *G. communis* Feistmantel. However, *G. indica* has wider and bigger meshes near the midrib and narrow elongate meshes near the margin. *G. communis* has fine almost equidistant veins throughout the lamina.

***Glossopteris pseudotortuosa* sp. nov.**

Plate 1, figure 6

1992 *Glossopteris rhabdotaenoides* Pant & Singh 1971: Maheshwari & Tewari, *Palaeobotanist* 39 (3): 347, pl. 3 figs 1, 4, 6, text-fig.3A-E.

*Diagnosis* : Simple leaf, shape lanceolate, apex acute, base cuneate, petiolate; midrib striated, stout; lateral veins arise at acute angles, dichotomise and anastomose to form elongate-polygonal meshes; veins approach the margin at right angles. Cuticle shows irregularly polygonal cells in mesh areas while cells are arranged end-to-end in linear rows in vein areas.

*Specimen nos.* : BSIP # 38815 (10/4578, cp 11/4578), 19/4578, (cp 7/4578), 2/4578, 20/5004, 30/5004

*Locality* : Sirka Colliery, South Karanpura Coalfield; Jharkhand Colliery, West Bokaro Coalfield

*Horizon* : Barakar Formation, shales associated with Naditoli seam

*Holotype* : BSIP # 38815 (Specimen No. 10/4578), Barakar Formation, shales associated with Naditoli Seam, Early Permian; Sirka Colliery, South Karanpura Coalfield, Bihar.

*Description* : Simple leaf, shape lanceolate, length 13-17 cm., width 2-4.5 cm., apex acute (in specimen # 30/5004), base cuneate (in specimen # 30/5004), petiolate (in specimen # 20/5004) margin entire, midrib distinct, stout, striated, wider near base, angle of origin of veins 30°-40° degree, no. of veins/cm.: a) near the midrib 9-15, b) near the margin 4-22, lateral veins emerge from the midrib at acute angles, thereafter run straight and almost parallel to each other. After successive dichotomies and anastomoses the veins approach the margin approximately at right angles. Vein dichotomies usually are of gamma and lambda types or rarely of chi and psi types. Cross-connections between the veins which form the meshes are mostly of zeta and eta types or rarely of psi-lambda type. Meshes are mostly deltoid or rarely arcuate near the midrib and commonly pentagonal or elongate pentagonal elsewhere. Cuticle of the only non-stomatiferous surface has been recovered from specimen no. 10/4578. The cuticle is very delicate and shows faint outlines of irregularly polygonal cells of the mesh areas. Cells over the veins are similar but more regularly arranged. Cell walls are broadly wavy.

*Comparison* : *Glossopteris pseudotortuosa* is comparable *G. tortuosa* Zeiller 1902 in general appearance. However, in details of venation, the difference between the two species are quite apparent. *G. tortuosa* has characteristic tortuosa-type venation pattern where the veins take a sinuous course towards the margin. *G. danae*, a somewhat similar species, has a venation pattern comprising broad, polygonal, elongate meshes which are shorter near midrib and the lateral veins meet the margin at approximately 90°. In *G. rhabdotaenoides* the meshes are uniform in size, run at right angles from the midrib.

**Genus *Pantophyllum* (=Noeggerathiopsis)****Rigby 1984*****Pantophyllum gidiensis* sp. nov.**

Plate 1, figure 4

*Diagnosis* : Leaves simple, spathulate in shape, with broadly rounded apex and narrow tapering base, and entire margin; about 4 veins enter the base, dichotomise but do not anastomose, about 20 per cm in the broadest part of the lamina. [Cuticle not known].

*Specimen nos.* : BSIP 38437, 38438, 38439, 38440.

*Locality* : Rikba Plant Bed, North Karanpura Coalfield; Gidi-A Colliery, South Karanpura Coalfield.

*Horizon* : Talchir and Barakar Formations.

*Holotype* : BSIP specimen no. 38477, Argada Seam, Barakar Formation, Gidi-A Colliery, South Karanpur Coalfield.

*Description* : Simple, symmetrical, lanceolate leaf, entire margin, midrib absent, length 5-16.5 cm, width 3.5-4.5 cm, apex probably broad obtuse, base narrow tapering, margin entire. Veins arise from the base frequently dichotomise, parallel angle of divergence commonly less than 5°. About 4 veins enter the base frequently dichotomose, 9-20 per cm in different regions of the lamina. Coalified crust present but did not yield cuticle.

*Comparison* : In overall shape the specimens resemble most *Pantophyllum indica* Maithy; the latter, however, has relatively coarser venation. Many specimens have been collected from Rikba Plant bed, North Karanpura Coalfield (Talchir Formation) and Gidi-A Colliery of South Karanpura Coalfield (Barakar Formation) which show the presence of a single species, *Pantophyllum gidiense* sp. nov.

**Genus *Kawizophyllum* Kapoor 1979**

It is a leaf genus reported by Kapoor from Mamal Formation, *Kawizophyllum dunpathriensis*. *Kawizophyllum barakarensis* sp. nov. is a new contribution from Damodar Basin. The specimens have been collected from Barakar Formation of Sirka Colliery of South Karanpura Coalfield.

***Kawizophyllum barakarensis* sp. nov.**

Plate 1, figure 2

*Diagnosis* : Leaf simple, oval-spathulate in shape, base sessile, apex obtuse, lamina coriaceous, sometimes folded along the median region, venation comprising subparallel, dichotomously branching veins. Epidermis hypostomatic, cuticle of stomatiferous surface very thin, stomata irregular in distribution and orientation.

*Specimen No.* : BSIP-38443B, 38446, 38447, 38449.

*Locality* : Sirka Colliery, South Karanpura Coalfield.

*Horizon* : Barakar Formation, shales associated with Naditoli seam.

*Holotype* : BSIP specimen no. 38447, Naditoli Seam, Sirka Colliery, South Karanpura Coalfield, Bihar.

*Description* : Leaf simple, oval-spathulate in shape, base sessile, apex obtuse, lamina coriaceous, sometimes folded along the median region, venation comprising subparallel, dichotomously branching veins, concentration of veins 14-16 per cm. Length of leaf is 6.5-11 cm and width 3.6-4 cm. Epidermis hypostomatic, cuticle of stomatiferous surface very thin, stomata irregular in distribution and orientation. The nonstomatiferous surface is relatively much thicker and has outlines of polygonal cells.

*Comparison* : In general morphology, the specimens resemble those assigned to *Kawizophyllum dunpathriensis*; however, characters of the epidermis are not known for this species. Furthermore in *K. barakarensis* the characteristic folding of the lamina is not that prominent.

**Fructifications**

In the present collection only few fructifications that too in detached condition are present. These are referable to genera *Gonophylloides*, *Scutum* and *Ottokaria*.

***Gonophylloides* Maheshwari 1968*****Gonophylloides* sp.**

Plate 1, figure 7

Specimens are measuring 3.5-5 cm in length and 1.3-2 cm in width. At the base is a distinct mark of the stalk. The surface is studded with large number of

overlapping, more or less polygonal circular, elevated areas which appear to have been arranged in close spirals. These probably represent bases of ovules/seeds. The specimens of this fructification have been collected from Barakar Formation of Sirka Colliery of South Karanpura Coalfield.

### Seeds

It includes *Cordaicarpus*. It has been collected from Gidi-A Colliery of South Karanpura and Jharkhand Colliery of West Bokaro Coalfields.

#### *Cordaicarpus* sp.

Plate 1, figure 8

Seeds polyspermic, pear shaped, base cordate, apex rounded 0.5-2 cm long, 0.2-3 cm broad, a narrow border (? Sarcotesta), nearly uniform in width, encircles the sclerotesta.

#### *Incertae sedis*

Plate 1, figure 5

*Specimen no.* : BSIP 38162/4738 (cp. 38163/4738)

*Locality* : Sirka Colliery, South Karanpura Coalfield

*Horizon* : Barakar Formation, shale associated with the Naditoli Seam.

*Description* : In the present collection there is one very interesting specimen (with counterpart, and poorly preserved carbonified crust) of uncertain taxonomic status. At first glance it looked apparently like a whorl of heterophyllous leaves. However, after excavation of some part of the rock, particularly from the part presumed to represent the axis, it became clear that the specimen comprises approximately 12 leaves arranged in tight a spiral at a swollen node. Of these, about 8 leaves are comparatively large, obovate to subcuneate in shape and with obtuse rounded apex, cuneate base and entire margin. The leaves are 2.8-3.5 cm long and 1-1.5 cm broad. The other four leaves are much less in breadth and are lanceolate in shape; they are 2.6 cm. at the widest and have acuminate apices. Two (possibly only one) veins enter the base of each leaf, dichotomise a few times, do not anastomose, further up in lamina become slightly curved and end up at the upper margins as well as the apex. In the narrower

leaves, the veins simulate that of *Pantophyllum* and run straight up to the apex. On acid-alkali treatment, the carbonified crust yielded small pieces of cuticle, but only of the nonstomatiferous surface. The cuticular membrane is thick, with straight-walled cellular outlines. The cells are rectangular, longer than broad, 55-110  $\mu\text{m}$  x 20-35  $\mu\text{m}$ , and arranged end-to-end.

*Comparison* : This specimen has a very superficial resemblance with specimens of the genera *Trizygia* and *Sphenophyllum*. *Trizygia* no doubt is heterophyllous but it has only six leaves and that too arranged in three distinct pairs in a whorl. *Sphenophyllum* too has six symmetrical leaves (sometimes may be 9) which too are arranged in a whorl. The cell walls in both *Trizygia* and *Sphenophyllum* are sinuous on both the surface. Therefore, any affinity with the sphenophylls is definitely ruled out.

There is a distinct possibility that this specimen represents a bunch of immature leaves of a taxon related either to *Euryphyllum* or *Pantophyllum*. The exact identification of the taxon may be possible only after recovery of the stomatiferous surface and/or more specimens.

## DISCUSSION AND CONCLUSION

*Glossopteris* is both a general term for the Permian fossil flora of the Gondwana Supercontinent and the name of the dominant plant genus of that flora. Of all the formations of the Early Permian (i.e., Talchir, "Karharbari" and Barakar) of India, the fossil flora of Barakar Formation is richest in genera as well as in species. The fossils generally occur as compressions/impressions on grey carbonaceous shales associated with various coal seams. The genera belonging to the Glossopteridopsida form the major part of the vegetation of Barakar Formation, and also that of the Raniganj Formation. The most abundant element of this group is the genus *Glossopteris*. *Gangamopteris*, probably the oldest member of this group appeared during the Talchir sedimentation to be followed by *Glossopteris*. The former outnumbered *Glossopteris* during the Talchir-Karharbari times and was on the verge of extinction in the upper Barakar wherein maximum species biodiversity had set in *Glossopteris*. *Palaeovittaria*, supposed to be a marker of the

Raniganj Formation, has also been reported from the Barakar Formation (Srivastava, 1992; present study). *Pantophyllum* (= *Noeggerathiopsis*/*Cordaites*) is another important element of the lower Barakar floras.

In the North Karanpura, South Karanpura and West Bokaro Coalfields the distribution of the plant fossils is not the same everywhere. In those localities where *Vertebraria* is dominant, other fossils are not found in any appreciable number. In the Sirka Colliery, South Karanpura Coalfield, the fossiliferous shale-bands show a sequential profile of small, medium, large sized leaves and finally at the base *Vertebraria* axes are found. Equisetalean axes and *Neomariopteris* have a very restricted distribution, occurring only at a few localities, e.g., Religara, Kuju, Gidi-C and Sirka Collieries.

**North Karanpura Coalfield :** Plants reported by earlier workers from the Early Permian of this coalfield include : *Schizoneura* sp., equisetalean axes, *Gangamopteris cyclopteroides*, *G. major*, *Glossopteris angustifolia*, *G. communis*, *Pantophyllum* (*Noeggerathiopsis*) *hislopii* and *Samaropsis* sp.

In the present study presence of following additional species has been noticed: *Neomariopteris lobifolia*, *Glossopteris browniana*, *G. communis*, *G. clarkei*, *G. linearis*, *G. obovata* sp. nov., *G. stenoneura*, *G. waltonii*, *Pantophyllum gidiensis* sp. nov. and *Vertebraria* axes. Plant megafossils were collected from shales associated with K, I, IV and VA coal seams being worked out in Ray, Dakra, Karkata and K.D. Heslong Collieries, respectively.

**South Karanpura Coalfield-** In South Karanpura Coalfield, the megafossil assemblage reported by earlier workers includes - *Phyllothea ampla*, *P. angusta*, *Paratrizygia rhodesii*, *P. crenulatum*, *Gangamopteris buriadica*, *G. cyclopteroides*, *G. intermedia*, *G. spatulata*, *Glossopteris angustifolia*, *G. barakarensis*, *G. browniana*, *G. communis*, *G. damudica*, *G. decipiens*, *G. fusa*, *G. indica*, *G. karanpuraensis*, *G. linearis*, *G. spathulo-cordata*, *G. stricta*, *G. conspicua*, *G. retifera*, *Pantophyllum* (*Noeggerathiopsis*) *hislopii*, *Macrotaeniopteris*

*danaeoides*.

From the present study presence of following additional elements has been observed in the Barakar Formation: equisetalean axes, *Neomariopteris lobifolia*, *Gangamopteris* sp. cf. *G. buriadica*, *G. obovata*, *Glossopteris arberii*, *G. clarkei*, *G. danae*, *G. emarginata*, *G. euryneura*, *G. intermedia*, *G. longifolia*, *G. major*, *G. oldhamii*, *G. obscura*, *G. obovata* sp. nov., *G. pseudostricta* sp. nov., *G. pseudotortuosa* sp. nov., *G. raniganjensis*, *G. shailae*, *G. stenoneura*, *G. taeniopteroides*, *G. tortuosa*, *G. vulgaris*, *G. waltonii*, *G. stenoneura*, *G. taeniopteroides*, *G. tortuosa*, *G. vulgaris*, *G. waltonii*, *G. zeilleri*, *Pantophyllum gidiensis* sp. nov., *Euryphyllum whittianum*, *Kawizophyllum barakarensis* sp. nov., *Gonophylloides* sp., *Scutum* sp., *Cordaicarpus* sp., and *Vertebraria indica*.

The plant megafossils were collected from three coal seams, namely Argada/Sangum, Sirka/Naditoli and Lower Nakari, A perusal brings out an interesting pattern in shales associated with the Argada (locally also called Sangum) coal seam contain besides *Glossopteris*, leaves of the genus *Euryphyllum*. On the other hand, shales associated with the Sirka (locally also known as Naditoli) coal seam contain *Gangamopteris*, *Pantophyllum* (= *Noeggerathiopsis*) and *Kawizophyllum* along with *Gonophylloides* and *Scutum*. *Kawizophyllum*, an enigmatic leaf, is so far known only from the Dunpathri Member of Mamal Formation in Kashmir. Maheshwari, Kapoor and Bajpai (1996) palynologically place the Dunpathri Member equivalent to the Barakar Formation of the peninsula.

**West Bokaro Coalfield-** In West Bokaro Coalfield, the assemblage reported by earlier workers include- *Asterophyllites*, *Schizoneura gondwanensis*, *Trizygia speciosa*, *Sphenopteris polymorpha*, *Glossopteris ampla*, *G. anugustifolia*, *G. conspicua*, *G. decipiens*, *G. retifera*, *G. gondwanensis*, *G. indica*, *G. stricta*, *Vertebraria indica*, *Pantophyllum* (*Noeggerathiopsis*) *bokaroensis*, *Walkomiella indica* and *Spermatites indicus*.

In the new collection from Barakar Formation in the West Bokaro Coalfield the floral assemblage in-



Table 2. Formation-wise distribution of flora of present study in Indian Gondwana (\* + indicates new contribution)

Glossopteris Flora	Talchir	Karharbari	Barakar	Kulti	Raniganj	Kamthi	Bijori	Palit	Pachwara	Hinjir	Maiture	Hirapur	Parsora
<i>Neomariopteris lobifolia</i>			+		+				+		?		
<i>Glossopteris angustifolia</i>		+	+	+	+	+	+	+	+	+	?	+	
<i>Glossopteris arberi</i>			+		+	+							
<i>Glossopteris barakarensis</i>			+		+								
<i>Glossopteris browniana</i>		+	+	+	+	+	+	+	+	+	?		?
<i>Glossopteris clarkei</i>			+		+								
<i>Glossopteris communis</i>		+	+	+	+	+	+	+	+	+	?		
<i>Glossopteris danae</i> (= <i>G. damudica</i> )		+	+	+	+		+	+	+	cf		?	
<i>Glossopteris decipiens</i>		+	+	?	+								
<i>Glossopteris elongata</i>			+	+	+		+	+	+	+	?		
<i>Glossopteris emarginata</i>			+		+			+					
<i>Glossopteris euryneura</i>			+		+								
<i>Glossopteris indica</i>	+	+	+	+	+	+	+	+	+	+	+		+
<i>Glossopteris intermedia</i>			+		+								
<i>Glossopteris intermittens</i>			+		+		+						
<i>Glossopteris karanpuraensis</i>			+										
<i>Glossopteris linearis</i>			+		+								
<i>Glossopteris longifolia</i>			+		+								
<i>Glossopteris major</i>			+		+								
<i>Glossopteris oldhami</i>			+		+								
<i>Glossopteris obscura</i>			+		+								
<i>Glossopteris obovata</i> sp. nov.			+										
<i>G. pseudostricta</i> sp. nov.			+										
<i>Glossopteris pseudotortuosa</i> sp. nov.			+										
<i>Glossopteris raniganjensis</i>			+	+	+	+	+						
<i>Glossopteris shillae</i>			+		+								
<i>Glossopteris stenoneura</i>			+		+								
<i>Glossopteris tortuosa</i>			+	+	+			+					
<i>Glossopteris taeniopteroides</i>			+		+								
<i>Glossopteris tenuinervis</i>			+		+								
<i>Glossopteris vulgaris</i>			+		+								
<i>Glossopteris waltonii</i>			+		+								
<i>Glossopteris zeilleri</i>		+	+		+								
<i>Gangamopteris</i> sp. cf. <i>G. buriadica</i>	+	+	+		?								
<i>Gangamopteris obovata</i>		+	+										
<i>Palaeovittaria</i> sp.			+										
<i>Gonophylloides</i> (= <i>G. cistella</i> )			+										
<i>Scutum</i>			+										
<i>Cordaicarpus</i>	+	+	+										
<i>Pantophyllum gidiensis</i> sp. nov.	+		+										
<i>Euryphyllum whittianum</i>		+	+										
<i>Kawizophyllum dunpathriensis</i>			+										
<i>Kawizophyllum barakarensis</i> sp. nov.			+										
<i>Ginkgopsid</i>			+										
<i>Vertebraria indica</i>	+	+	+	+	+	+	+	+	+	+	+		
Equisetalean axes	+	+	+	+	+	+	+	+	+	+	+		
Incertae sedis			+								+		

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cludes- *Neomariopteris lobifolia*, *Gangamopteris* sp. cf. *G. buriadica*, *Glossopteris barakarensis*, *G. intermittens*, *G. karanpuraensis*, *G. linearis*, *G. major*, *G. pseudotortuosa* sp. nov., *G. waltonii*, *Palaeovittaria* sp., *Scutum* sp., *G. pseudotortuosa* sp., *Vertebraria indica*, *Euryphyllum whittianum* and Equisetalean axes.

In the West Bokaro Coalfield, the plant megafossil assemblages could not be easily related to individual coal seams as in each colliery more than one seam has been opened simultaneously and their shale rejections were not available separately. The distribution of plant fossils in each colliery visited show almost uniform distribution except for the presence of *Euryphyllum* at Sarubera and of *Palaeovittaria* at Kuju.

### The glossopterids in the Karanpura and Bokaro Coalfields

Though the glossopterids are the most abundant of all plants in the Gondwana floras, yet no satisfactory criteria have been evolved for their proper classification. The genera *Gangamopteris*, *Glossopteris*, *Palaeovittaria* and *Rhabdotaenia* which are distinct at the level of surface topography, each shows one or more types when examined for their cuticular morphology (Srivastava, 1957; Surange & Srivastava, 1957; Hoeg & Bose, 1960). *Rubidgea* is another glossopterid leaf, however, its cuticular feature are not known so far. In the Karanpura and Bokaro groups of coalfields, only three genera of the glossopterids, namely, *Gangamopteris*, *Glossopteris* and *Palaeovittaria* have been recorded in the present study. Of these, the species of the genus *Glossopteris* predominate all the assemblages and are thirty-two in number. The distribution is shown in Table-1 & 2.

From the data collected, it is evident that the fossil flora of the Barakar Formation (its lower part comprising Karharbari of author) in the North Karanpura, South Karanpura and West Bokaro Coalfields predominantly comprises species of genus *Glossopteris*. The equisetales and the ferns are extremely rare, while the sphenophylls are virtually absent. The genera *Gangamopteris*, *Euryphyllum* and *Pantophyllum* (= *Noeggerathiopsis*) are found only in the lower part of the formation. The characteristic fossils of the

Karharbari flora, namely, *Botrychiopsis* (= *Gondwanidium*) and *Buriadia* are absent. On the other hand, *Kawizophyllum*, a characteristic fossil of the Dunpathri Member of the Mamal Formation in Kashmir found in South Karanpura Coalfield is the only record from the peninsula. The distribution of the taxa otherwise does not show any appreciable change from the lower to upper part of the formation as investigated presently. However, the composition of the flora at the species level shows definite contrast with that of the older Talchir Formation and the younger Kulti and Raniganj Formations.

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