PALAEOBOTANICAL EVIDENCES ON THE AGE OF THE COAL-BEARING LOWER GONDWANA FORMATION IN THE JAYANTI COALFIELD, BIHAR

K. M. LELE & REHANA MAKADA (Mrs.)
Birbal Sahni Institute of Palaeobotany, Lucknow

ABSTRACT

The coal-bearing Lower Gondwana beds overlying the Talchir Formation in the Jayanti Coalfield are investigated for their mega- and microfloras. The megaflora, comprising 7 genera and 18 species (2 new), is characterized by *Noeggerathiopsis*, *Gangamopteris*, *Glossopteris* and platyspermic seeds and by the peculiar presence of *Gondwanidium*. The mioflora (33 genera and 57 species) is characterized by the dominance of trilete taxa *Punctatisporites* and *Callumispora* together with the monosaccates *Plicatipollenites*, *Virkkipollenites*, *Potonieisporites* and *Vestigisporites*. Other quantitatively significant genera are *Parasaccites*, *Caheniasaccites*, *Vesicaspora*, *Cuneatisporites*, *Striatites*, *Lunatisporites*, *Faunipollenites* and *Gnetaceaepollenites*.

The mega- and miofloral composition of the assemblages is analysed qualitatively and quantitatively to assess their relative ages. The evidence, especially of the megaflora, leaves no doubt that the coal-bearing succession of the Jayanti basin belongs to the Karharbari Formation and is likely to be of Lower Karharbari age. Palynostratigraphic aspects of the better known Karharbari miofloras are compared and discussed in the light of the present palaeobotanical evidence.

INTRODUCTION

In the Jayanti coal basin the Talchir Formation is overlain by the coal-bearing strata which have been referred to the Barakar Stage or Karharbari Stage by different workers. Puri (1953) reported the occurrence of Karharbari plants in this area. He recorded *Gondwanidium validum*, *Buriadia sewardii*, *Phyllotheca* sp., *Cordaicarpus* sp., *Squama forma integrima*, *Samaropsis raniganjensis* and *Noeggerathiopsis hislopii*. Niyogi and Sanyal (1962) also mentioned the occurrence of plants in the carbonaceous shales and considered that the evidence supported a Barakar age for the rocks. Lele and Maithy (1966) again suggested a Karharbari age for these rocks on the basis of megafossil evidence.

The present study was undertaken to collect substantial palaeobotanical evidences, both mega- and microfossil, with a view to resolve the controversy. It is now concluded that the coal-bearing strata belong to the Karharbari Formation.

MATERIAL AND METHODS

The material for micro- and megafossil studies was collected from the following places : (1) *Misra village* — Megafossils were collected from a section exposed in a tributary of Patharjore Nala about one furlong south of Misra village. The beds show a general northern dip. Details of the section are given below. Most of the fossils were recovered from bed No. 5 (Sample No. DF2). Unfortunately due to deep weathering of the rock, the plant impressions are rather poorly preserved.

Beds	Thickness in ft.	Field sample No.	Remarks
8. Grit with pebbly concentrations			
7. Greyish sandy micaceous shale with few plant fossils	1½	D17	Occasional plant fossils
6. Grit with stem impressions	1		
5. Yellow micaceous muddy, sandy shales	1½	DF2 D18	Rich megaflora and Miospores
4. Carbonaceous shale slightly sandy	1½	D19	Miospores
3. Grit	12		
2. Micaceous shale	½		
1. Grit			

Field observations indicate that the beds at Misra village are stratigraphically closer to the underlying Talchir Formation, the latter being exposed south of Madankata in the Patharjore Nala (Lele & Makada, 1972).

(2) *Banskupi Colliery Area* — Megafossils were collected from the outlying carbonaceous shale dumps belonging to the coal-bearing succession of the deserted Banskupi Colliery (Sample No. DF3). Some fossils were also collected from an old dump near the terminus of the siding branch line near Madankata railway station (Sample No. DF4). Although the stratigraphical location of the Banuskupi shales is unknown, it seems highly probable that they are younger than the beds at Misra village. The plants are carbonized and have yielded cuticles.

For cuticular preparations from the megafossils a thin film of cellulose acetate in acetone was applied over a small part of the carbonized crust and when it was dry the pull was taken off. It was then put into concentrated or dilute commercial nitric acid with or without potassium chlorate. Cuticles of *Noeggerathiopsis* were quite resistant and took 2-3 days for maceration. *Glossopteris* cuticles were oxidized in less than 24 hours. Hydrogen peroxide was also tried for maceration but it took even a longer period for oxidation of pulls. As crust turned brown on completion of oxidation, the pieces were thoroughly washed with water and then treated with a few drops of 5 per cent potassium hydroxide solution, washed with water and during these processes the two cuticular layers became generally separate, or otherwise they were separated by dissecting needles.

The cuticular pieces were stained in 10 per cent aqueous safranin. Permanent preparations were made in Canada balsam.

MEGAFOSSILS

The megafossil assemblage consists of 7 genera belonging to 18 species. Plants marked with an asterisk are described here.

1. *Paracalamites* sp. (Loc. 1)
*2. *Gondwanidium validum* (Feistmantel) Gothan, 1927. (Loc. 1)
3. *Gangamopteris cyclopteroides* Feistmantel, 1876. (Loc. 2)
4. *Gangamopteris* sp. cf. *G. clarkeana* Feistmantel, 1890. (Loc. 1)
*5. *Gangamopteris* sp. cf. *G. gondwanensis* Maithy, 1965c. (Loc. 2)
*6. *Gangamopteris* sp. (Loc. 2)
7. *Glossopteris communis* Feistmantel, 1876. (Loc. 2)
*8. *Glossopteris* sp. cf. *G. fibrosa* Plant, 1958. (Loc. 2)
9. *Glossopteris browniana* Brongniart, 1828. (Loc. 2)
*10. *Glossopteris jayantiensis* sp. nov. (Loc. 2)
*11. *Glossopteris* sp. (Loc. 2)
12. *Noeggerathiopsis hislopii* (Bunbury) Feistmantel, 1879. (Loc. 1 & 2)
*13. *Noeggerathiopsis spathulata* (Dana) Maithy, 1965c. (Loc. 1)
*14. *Noeggerathiopsis conspicua* sp. nov. (Loc. 2)
*15. *Noeggerathiopsis bunburyana* Pant & Verma, 1965. (Loc. 2)
*16. *Samaropsis feistmantelii* Maithy, 1965b. (Loc. 1)
*17. *Samaropsis goraiensis* Surange & Lele, 1957. (Loc. 1)
*18. *Cordaicarpus zeilleri* Maithy, 1965b. (Loc. 1)
*19. Scale leaves: Types 1 & 2. (Loc. 1 & 2)
*20. Branched axes. (Loc. 1)

Genus—*Gondwanidium* Gothan, 1927

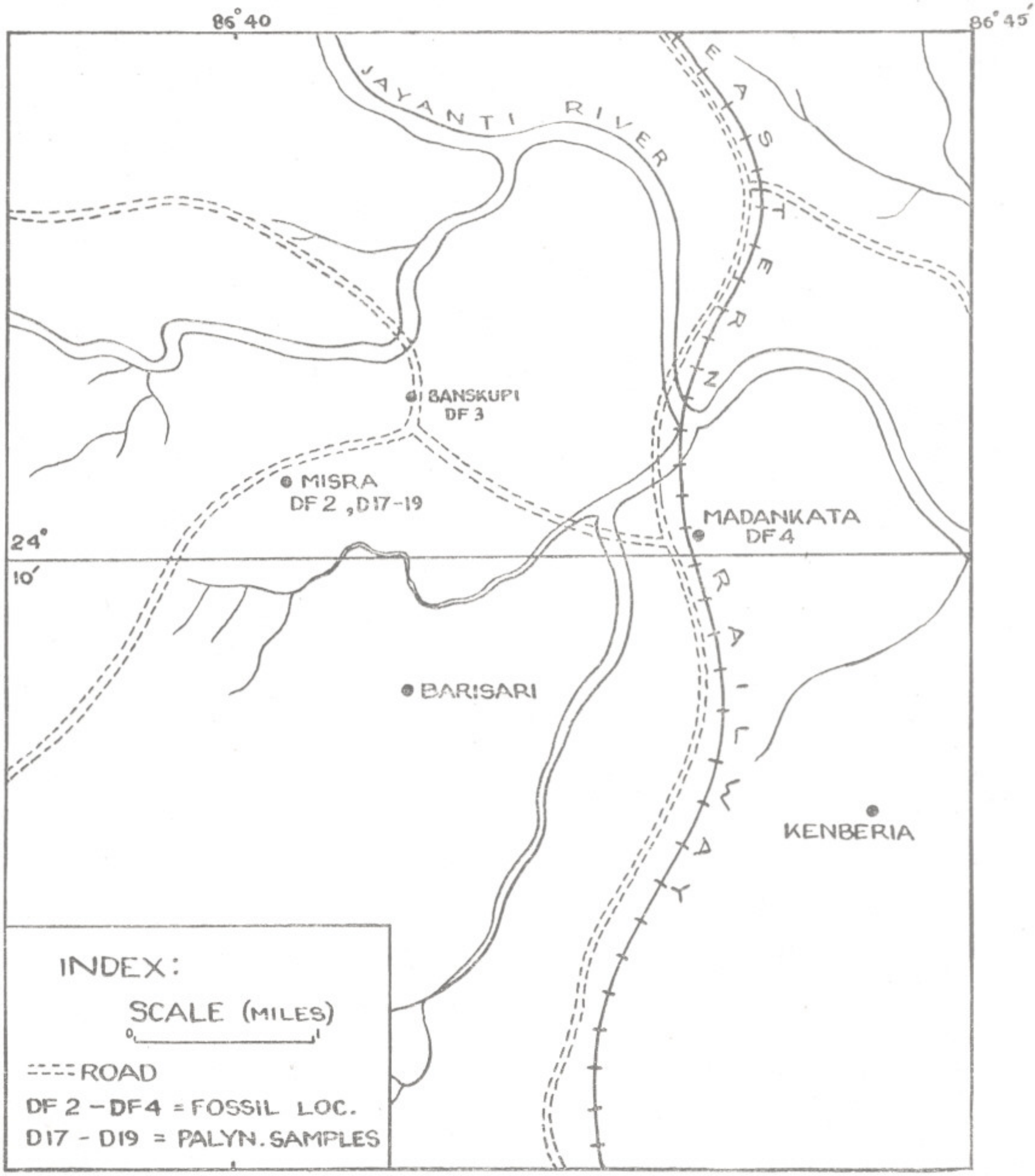
Type species — *Gondwanidium validum* (Feistmantel) Gothan, 1927.

Gondwanidium validum (Feistmantel) Gothan, 1927

Pl. 1, Fig. 6

Description — The solitary specimen (and counterpart) is an impression on a buff grey clayey shale. The incomplete specimen measures 5 cm. in length and 3·6 cm. in breadth. The rachis is strong and flat and 4 mm. in breadth. Pinnules are oval, 4 on either side, 2 cm. long and 1·4 cm. at the broadest, with entire to slightly lobed margin and bluntly rounded apex. They are subopposite to alternate and attached to the rachis obliquely along the whole length of their base. The venation of the pinnules is very obscure.

Comparison — This specimen compares in gross morphological features with *Gondwanidium validum*. Although the venation details are not clearly seen, there are other



Location of palaeobotanical material in the Jayanti Coalfield, Bihar.

detached pinnules in the collection which show the lobing and venation characteristic of *G. validum*.

Occurrence — Misra village (Loc. 1).

Genus—*Gangamopteris* McCoy, 1861

Type species — *Gangamopteris angustifolia* McCoy, 1861.

Gangamopteris sp.

Pl. 1, Fig. 7.

Description — This leaf impression represents only the basal part. The incomplete specimen measures 6·5 cm. in length and 1·5 cm. in breadth from the centre of the lamina to the margin. The lamina strongly tapers towards base but no petiole is formed. The median part shows subparallel veins which anastomose here and there. The meshes are polygonal, 4-5 times longer than broad and nearly uniform in size on the lamina.

Comparison — The specimen is not sufficiently complete and well-preserved for definite identification. The venation is like that of *Gangamopteris karharbariensis* Maithy (1965c)

Occurrence — Banskupi Colliery area (Loc. 2).

Gangamopteris sp. cf. *G. gondwanensis* Maithy, 1965c

Pl. 1, Figs. 8-11

Description — Few incomplete specimens are referable to this species. Nothing is known about the size and shape of the complete leaf. The median region of the leaves is occupied by 1-5 subparallel veins which give rise to lateral veins at acute angles. The veins dichotomize and anastomose to form elongate-polygonal meshes which gradually become narrower towards the margin.

Cuticle — Only one specimen (Pl. 1, Fig. 8) has yielded cuticle. Only one surface is stomatiferous which, by analogy with existing land plants, is possibly the lower cuticle (Sahni, 1923).

Upper Cuticle — This surface is non-stomatiferous and moderately thick. Vein and mesh areas are not marked. Cells are usually four-sided, sometimes irregular, mostly arranged end to end, longer than broad and measure 90-190×25-50 μ. The lateral walls are straight, and end walls generally oblique, 3-4 μ thick; surface walls are unspecialized.

Lower Cuticle — This surface is stomatiferous, comparatively thin and the vein and mesh areas are not marked. Cell outlines are indistinct, walls are straight. Outline of epidermal cells are ill-preserved.

The stomata are haplocheilic, irregular in distribution and orientation. The subsidiary cells (number not known) are unspecialized. Guard cells are 37-70 μ long, elliptical to broadly oval in shape and are thickened towards inner and outer margin. Stomatal opening is a linear-elliptical slit, 22-37 μ long and up to 5 μ broad in the middle.

Comparison — The specimens of Maithy as well as the present specimens compare in venation with *Gangamopteris cyclopteroides* Feistmantel (1876b). Epidermal features of this species were studied by Maithy under incident light. The present material, recovered by maceration, is comparatively better preserved and suggests general agreement with *G. gondwanensis*, with the exception that vein and mesh areas are not distinct in our cuticles.

Occurrence — Banskupi Colliery area (Loc. 2).

Genus—*Glossopteris* Sternberg, 1825

Type species — *Glossopteris browniana* Brongniart, 1828.

Glossopteris sp. cf. *G. fibrosa* Pant, 1958

Pl. 1, Fig. 12

Description — Some incomplete impressions show a strong midrib, running as a groove up to the ± pointed apex (Pl. 1, Fig. 12). The secondary veins are 30-36 per cm. near the margin and form elongate-narrow meshes. Inside the meshes slender, thin interstitial veins are seen occasionally, running ± parallel to the secondary veins.

Comparison — Interstitial veins have so far been reported from *Glossopteris fibrosa* Pant (1958) and *Glossopteris* sp. of Maheshwari (1956). The present specimens resemble rather closely one of the specimens of

G. fibrosa (Pant, 1958, Fig. 1c) in the nature and concentration of the secondary veins but differ in the nature of the apex. Also, the cuticle of the present specimens is not known for definite identification with *G. fibrosa*.

Occurrence — Banskupi Colliery area (Loc. 2).

Glossopteris jayantiensis sp. nov.

Pl. 1, Figs. 13-16; Pl. 2, Figs. 17-19; Text-fig. 1.

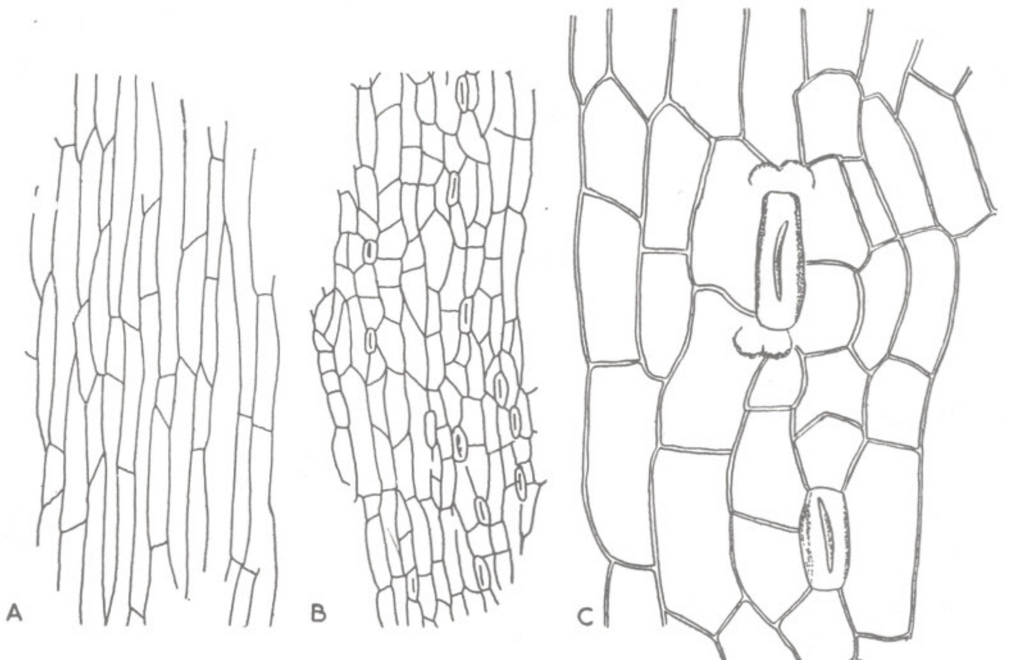
Diagnosis — Leaf simple, midrib flat, longitudinally striated; secondary veins arise at very acute angles, obliquely passing towards the margins; meshes narrow-elongate, uniformly broad throughout.

Cuticle hypostomatic, upper cuticle non-stomatiferous. Cells rectangular to elongate polygonal; cell walls straight and unspecialized.

Lower cuticle stomatiferous; stomata monocyclic, haplocheilic, longitudinally orientated in irregular linear rows; guard cells thin, slightly sunken; faintly thickened at lateral and polar regions and also around stomatal aperture; subsidiary cells 4-6, unspecialized, not forming a ring around stomata.

Description — This species is represented by 3 incomplete specimens (Pl. 1, Figs. 13, 14) all of which have yielded identical cuticles. The best cuticles are from the holotype. The larger specimen (Pl. 1, Fig. 13) measures 7·8 cm. in length and 2·7 cm. in width. The apex is acute to slightly rounded. The midrib is flat and longitudinally striated. The secondary veins arise from the midrib at very acute angles (5-15°) dichotomize and anastomose, forming elongate narrow meshes of almost equal width. The concentration of secondary veins near the margin is 25-35 per cm.

Upper Cuticle — This surface is non-stomatiferous and moderately thick. Vein and mesh areas are not marked. The cells are rectangular to elongate polygonal, much



TEXT-FIGURE 1. A-C. *Glossopteris jayantiensis* sp. nov.

A. Line drawing of the upper cuticle from the holotype. × 105.

B. Line drawing of the lower cuticle from the holotype showing longitudinally distributed stomata. × 105.

C. Two stomata enlarged. Note the polar caps of the guard cells. × 625.

longer than broad, measuring 60-150 × 25-42 μ. The lateral walls are straight and the end walls are truncate or oblique and 2·5 μ thick. Surface walls are unspecialized.

Lower Cuticle — This surface is stomatiferous, comparatively less thick with indistinctly marked vein and mesh areas. The cells over the veins are longer and narrow and arranged end to end. The cells in the mesh areas are sometimes rectangular to polygonal and arranged end to end. They are 50-90 × 18-30 μ in size with straight walls. The surface walls are unspecialized.

The stomatal apparatus is monocyclic. The stomata are haplocheilic and longitudinally orientated in 3-5 linear rows. Stomatal frequency is 80-120 per sq. mm. The guard cells are thin, slightly sunken, ± rectangular, with ± convex outer margin and are 37-45 μ long. The guard cells are slightly thickened along the outer walls as well as around the slit like stomatal aperture which is 17-25 μ long. Occasionally polar caps are also seen on guards cells. Sometimes the stomatal aperture is open. The subsidiary cells usually do not form a ring around the stomata, are 4-6 in number, usually 5 (3 lateral and 2 polar) and practically indistinguishable from other epidermal cells. No papillae have been observed.

Comparison — Morphologically the venation of the leaf is somewhat like *Glososopteris communis* Feistmantel (1876a). However, the cuticle of *G. communis* is totally different from the present species in being amphistomatic with irregularly orientated stomata. The present species is characterized by the longitudinal orientation of the stomata in more or less linear rows, a character which is known so far only from *G. indica* Zeiller (1896) and *G. conspicua* Srivastava (1957). However, in *G. indica* the cells of the lower cuticle are small and rectangular with very thick walls. Details of stomatal apparatus are not known. In *G. conspicua* the subsidiary cells form a ring around the stomata and are much smaller in size than other epidermal cells, and the guard cells are also smaller in size (25 μ). Besides, *G. conspicua* is morphologically very distinct from *G. jayantiensis*.

Holotype — Specimen No. 35008, Pl. 1, Fig. 13.

Type Locality — Banskupi Colliery area (Loc. 2); Jayanti Coalfield, Bihar.

Horizon — Karharbari Formation, Lower Gondwana.

Glossopteris sp.

Pl. 2, Figs. 20-22; Text-fig. 2

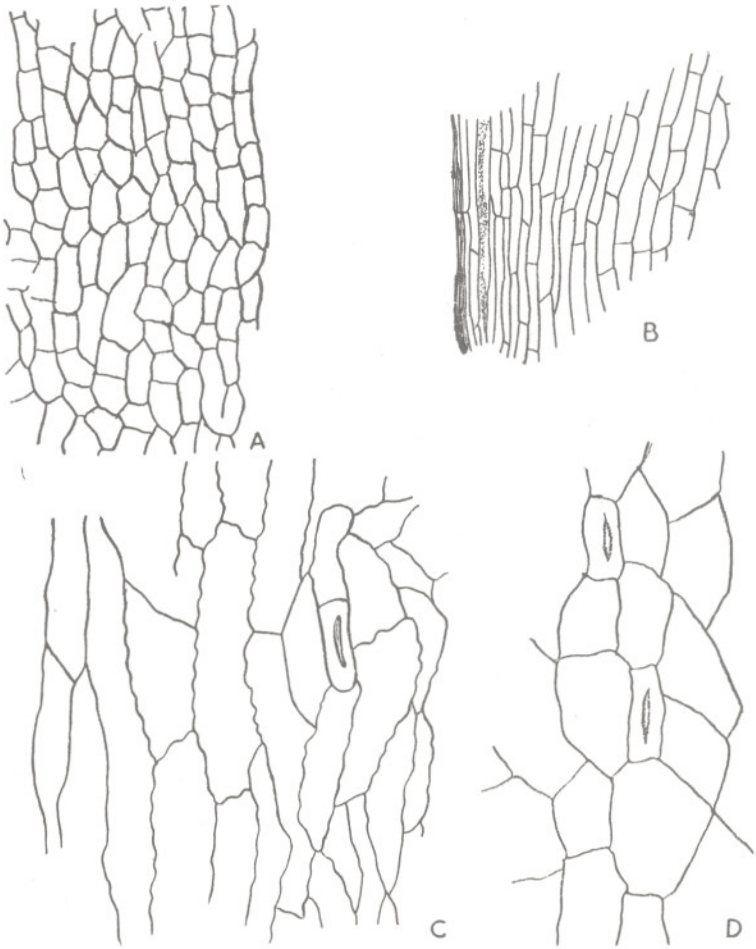
Description — Incomplete leaf with well preserved carbonized crust. The leaf is linear in shape, but the apex and base are not preserved. The midrib is 1·5 mm. broad at the base and continues throughout the preserved length of the leaf lamina. The secondary veins (Pl. 2, Fig. 20) are very close, 25-30 per cm., arise at acute angles. The meshes are narrow-elongate and nearly of equal size throughout.

Cuticle — The cuticle is hypostomatic.

Upper Cuticle — This surface is moderately thick and non-stomatiferous. The cells are elongate, rectangular, polygonal or trapezoid and usually arranged end to end; measure 40-89 × 28-37 μ. The cell walls are straight to undulated, about 3 μ thick. The surface walls are unspecialized.

Lower Cuticle — This surface is thin and stomatiferous. The cuticle pieces are too small to show vein and mesh areas. The cells are elongate to polygonal, measure 58-78 × 24-33 μ in size. Some fragments have more irregular cells with stomata, they may be the mesh regions; while fragments where cells are more elongated may be the regions along the veins. Often the walls of the few subsidiary cells as well as of the cells in the neighbourhood may become sunken. The surface walls are unspecialized except that they show faint granulation. The stomatal apparatus is monocyclic. The stomata are haplocheilic and irregularly distributed and orientated. Subsidiary cells are 5-6 in number and similar to other epidermal cells. Guard cells are thin, sometimes their lateral walls are thick and slightly cutinized, sunken, 30-37 μ long with thin hyaline polar caps. Stomatal slit ± extends up to the cap. The stomatal aperture is 18-25 μ long, slit walls slightly thickened.

Comparison — In venation pattern the present leaf compares with *Glossopteris zeilleri* Pant & Gupta (1968) and *G. angustifolia* Brongniart (1828), but the apex is not preserved in our specimen. The epidermal features of the specimen compares with *G. zeilleri* inasmuch as the cells are



TEXT-FIGRUE 2. A-D. *Glossopteris* sp.

A. Line drawing of the uppre cuticle from the leaf represented in Pl. 2, Fig. 20. × 105.
B. Line drawing of the upper cuticle near the margin of the above leaf. × 105.
C-D. Enlarged line drawing of the lower cuticle from the above leaf showing stomata and straight to sinuous walled cells. × 265

non-papillate and sinuous. However, *G. zeilleri* is distinct in that the papillae overhang the stomatal pit. *G. tenuifolia* Pant & Gupta (1968) differs in having papillate sinuous cells. Our leaf is probably a distinct species, but specimens are insufficient for justifying a new name.

Occurrence — Banskupi Colliery area (Loc. 2).

Genus—*Noeggerathiopsis* (Feistmantel) Maithy, 1956d

Type species — *Noeggerathiopsis hislopii* (Bunbury) Feistmantel, 1879.

Remarks — In the light of the considerable data on the epidermal structure of *Noeggerathiopsis* contributed by Lele & Maithy (1964a) and Pant & Verma (1965), the definition of this genus has been elaborated by Maithy (1965d). It should, however, be remembered that *Noeggerathiopsis* was originally based on an impression occurring in the much younger strata of Kamthi age. The species with cuticular data and other typical forms (in impression state) are, however, more characteristic of the older formations of Talchir and Karharbari age. Maithy (1965d) has marked out the impression-species from the cuticular species although his emended diagnosis of *Noeggerathiopsis* includes the external and cuticular characters.

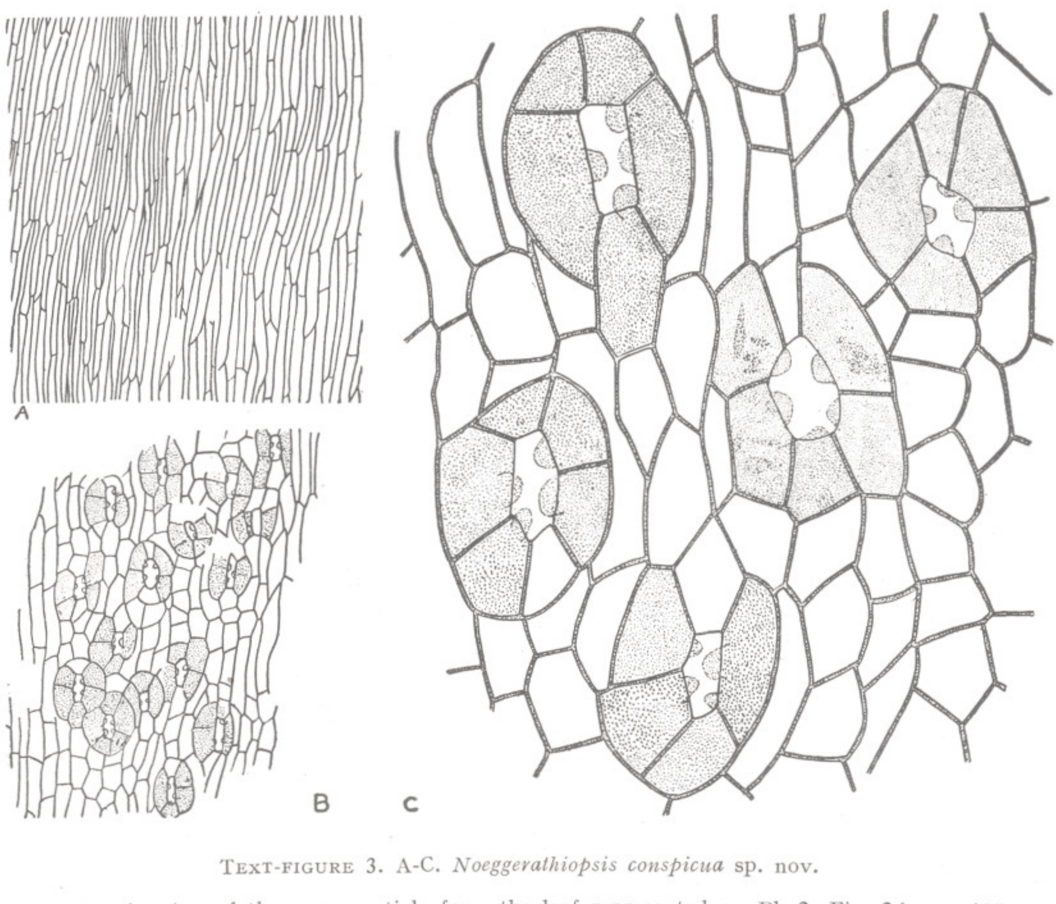
Cuticular studies have already shown that some significant external features such as the leaf apex and venation may be common to different species of *Noggerathiopsis* based on epidermal characters. Similarly we have now more information with regard to the specialization trends in the stomatal apparatus of *Noeggerathiopsis*. Of particular interest in this connection is the conspicuous occurrence of papillae on the subsidiary cells which overhang the guard cells. This specialization is at present known in two species, viz. *N. papillosa* Pant & Verma (1965) and *N. conspicua* sp. nov. described below.

Noeggerathiopsis conspicua sp. nov.

Pl. 2, Figs. 23-26; Pl. 3, Fig. 28; Text-fig. 3, 3A

Diagnosis — Leaves simple, lanceolate-spathulate, apex broadly rounded, lamina gradually tapering forming a narrow base; veins distinct, divergent, straight, 16-20 per cm. in apical part.

Cuticle hypostomatic, cells of upper cuticle arranged in linear rows, mostly end to end, non-papillate, cell walls straight, end walls usually oblique; lower cuticle with alternating stomatiferous and non-



TEXT-FIGURE 3. A-C. *Noeggerathiopsis conspicua* sp. nov.

A. Line drawing of the upper cuticle from the leaf represented on Pl. 2, Fig. 24. × 105.
B. Line drawing of the lower cuticle from the above leaf showing longitudinally orientated stomata. × 100.
C. Stomata from the lower cuticle enlarged to show thickened subsidiary cells with papillae. × 625.

stomatiferous zones, cells of non-stomatiferous zone similar to upper cuticle, cells of stomatiferous zone polygonal, stomata haplocheilic, arranged in 2-6 longitudinal rows stomata of adjacent rows usually alternate, stomatal apparatus monocyclic, subsidiary cells 4-7, 4 lateral subsidiary cells differentially stained, lateral subsidiary cells and very rarely polar subsidiary cells show prominent dome-shaped papillae overhanging guard cells.

Description — Five specimens have been assigned to this species on the basis of similarity in the cuticular structure. The leaves are lanceolate-spathulate in shape. One of the syntypes (Pl. 2, Fig. 23) is complete, measuring 13·5 cm. in length and 2·8 cm. in breadth at the widest part. The largest leaf is 16·2 cm. long and 3 cm. broad. In all the cases the apex is broadly round. The leaf lamina gradually tapers to form a narrow base which is, however, sessile. About 4-6 veins enter the leaf base. The veins are distinct and after 1 or 2 dichotomies pass out divergently but following a straight course. The number of veins per cm. at the broadest region is 16-20.

Cuticle — Both the syntypes have yielded identical cuticles but the best information is obtained from one of them (Pl. 1, Fig. 24). The cuticle is hypostomatic. Monosaccate pollen of *Crucisaccites* type are often found sticking to the cuticles.

Upper Cuticle — On this surface vein and intervein areas can be distinguished. Cells of the intervein areas are comparatively broad than the cells on the veins.

The cells in general are arranged in linear rows, mostly end to end. The lateral cell walls are straight and end walls are usually oblique. The cells are elongate, quadrilateral or many sided, 95-205 μ long and 8-18 μ broad; the cell walls are about 2 μ thick. Cells are non-papillate.

Lower Cuticle — This surface shows alternating stomatiferous and non-stomatiferous zones. The cells of non-stomatiferous zone are similar to the upper cuticle in all the characters. The cells of the stomatiferous zone are polygonal, 27-70 μ long and 18-30 μ broad. Stomatal frequency varies from 140-200 per sq. mm. The stomata are arranged in 2-6 longitudinal rows. The stomata of adjacent rows usually tend to alternate with each other, rarely they may be found lying opposite. The stomatal apparatus is monocylic. The stomata are haplocheilic, sorrounded by 4-7 subsidiary cells, frequently by 6 cells, of which 2 are polar and 4 lateral. The 4 lateral subsidiary cells take a differential staining, darker than the other epiderml cells, probably because of heavy cutinization. The polar subsidiary cells are, however, of the same thickness as that of the other epidermal cells. The epidermal cells are devoid of any papillae. On the other hand, the lateral subsidiary cells and very rarely the polar subsidiary cells show prominent dome-shaped papillae on their inner walls. These papillae overhang the guard cells, though they never completely close the stomatal opening. The guard cells are hyaline, thin and 17-37 μ long, in some cases a slit like stomatal aperture is visible.

Comparison — Morphologically the present leaves are similar to *N. bunburyana* Pant & Verma (1965) but their epidermal characters are very distinctive.

The cuticle of the present species is characterized by the presence of closely placed stomata with characteristically thickened guard cells and the strong papillae of the subsidiary cells overhanging the guard cells. In the close distribution of the stomata and the highly cutinized subsidiary cells the present species compares closely with *N. bunburyana* Pant & Verma (l.c.), but differs in being hypostomatic, in having non-papillate cells and in the presence of prominent papillae of the subsidiary cells overhanging the guard cells. The present species resembles *N. papillosa* Pant & Verma (1965) in being hypostomatic and in the presence of prominent papillae on the subsidiary cells overhanging the guard cells. However, in the case of *N. papillosa* all the cells of the lower cuticle show prominent papillae and the subsidiary cells are otherwise unspecialized and indistinguishable from the epidermal cells. On the other hand, in *N. conspicua* sp. nov. the general epidermal cells of lower cuticle are non-papillate but the subsidiary cells (particularly the lateral ones) are highly cutinized and have overhanging papillae. *N. indica* Lele & Maithy (1964a) differs in having dense papillae on epidermal cells.

Syntypes — Specimen No. 35011, Pl. 2, Fig. 23.
Specimen No. 35012, Pl. 2, Fig. 24.

Type Locality — Banskupi Colliery area (Loc. 2); Jayanti Coalfield, Bihar.

Horizon — Karharbari Formation, Lower Gondwana.

Noeggerathiopsis bunburyana Pant & Verma, 1965

Pl. 2, Fig. 27; Pl. 3, Figs. 29-31

Description — Few leaves have been referred to this species. The figured one is complete though smallest in the collection (3·6 cm. in length and 1·7 cm. in width). It has a well-preserved carbonized crust. The apex is obtusely rounded. The base is narrow and tapering. The veins are distinct, divergent and dichotomizing, 16-28 per cm. in the broadest part.

Upper Cuticle — Cells are ± rectangular arranged in linear rows, 40-80 μ long and 5-10 μ broad, non-papillate. No stomata are seen.

Lower Cuticle — shows alternating stomatiferous and non-stomatiferous zones. The cells of the non-stomatiferous zone are similar to those of the upper cuticle. Stomata are arranged in 2-6 subsidiary cells, heavily cutinized and non-papillate. The epidermal cells are also devoid of any papillae.

Comparison — The present specimens may indicate the lower size range of *Noeggerathiopsis bunburyana* which is not mentioned by Pant and Verma (1965). The cuticular structure of our specimens is almost similar to that described for *Noeggerathiopsis bunburyana*, except for the differences that stomata are not observed on the upper surface and that the epidermal cells are apparently non-papillate. In *N. bunburyana* papillae are occasionally present.

Remarks — There is some overlapping of the characters between the two species of *Noeggerathiopsis*, viz. *N. indica* Lele & Maithy (1964a) and *N. bunburyana* Pant & Verma (1965). However, in favourably preserved material the two forms can be distinguished from each other on the following grounds: *N. indica* has dense papillae but their density varies, papillae are best developed in non-stomatiferous region, moderately present in the stomatiferous region and rudimentary papillae seen on the subsidiary cells. In *N. bunburyana* the papillae are occasionally present on epidermal cells and absent on subsidiary cells. Cuticular preparations from the basal portion of leaf lacks papillae in *N. bunburyana*. From our present knowledge, therefore, it appears desirable to retain the two species separately as also suggested by Pant and Verma, 1965.

Occurrence — Banskupi Colliery area (Loc. 2).

Scale Leaves

Type 1: Pl. 3, Fig. 32 — Some very small leaves are found in the present collection, showing venation of *Noeggerathiopsis*-type. The leaves are spathulate to oval, 1·7-2·3 cm. long and 6-9 mm. broad. The apex is obtuse to broadly rounded. A few veins enter the base and then dichotomize once or twice.

Squama forma integrima of Seward and Sahni (1920, Pl. 2, Fig. 17) differs from the present scale leaves in shape and in having acute to acuminate apex.

Occurrence — Misra village (Loc. 1).

Type 2: Pl. 3, Fig. 33 — Incomplete impression of a scale leaf with a broad base. About 5 veins originate at the base and after a few dichotomies pass straight to the apical margin.

The specimen compares favourably with *squama forma integrima* of Seward and Sahni (1920, Pl. 2. Fig. 17).

Occurrence — Banskupi Colliery area (Loc. 2).

Platyspermic Seeds

Pl. 1, Figs. 1-3

Impressions of platyspermic seeds are common on the shales of the Misra village locality. In some examples a thin carbonized crust is seen but it is not suitable for cuticular preparations. Among the seeds at least three well-known species could be distinguished. These belong to the genera *Samaropsis* and *Cordaicarpus*. The species here recorded are:

1. *Samaropsis goraiensis* Surange & Lele; Pl. 1, Fig. 2
2. *Samaropsis feistmantelii* Maithy; Pl. 1, Fig. 1
3. *Cordaicarpus zeilleri* Maithy; Pl. 1, Fig. 3

Occurrence — Misra village (Loc. 1).

Branched Axes

Pl. 1, Figs. 4, 5

Linear axes are often encountered in various states of preservation on the sandy micaceous shale. They range in width from nearly 1 to 5 mm. Their length is unknown. Some of them taper at one end. In some examples the axes may appear to arise from a common point (Fig. 5); in others sparse branching is noticed at intervals. In wider examples a median dark line runs through the length (Fig. 4). These remains possibly include rootlets, leaflets or lacerated ribbed stems. It is difficult to assign them to any plant, although their close association with *Paracalamites* is noteworthy.

Occurrence — Misra village (Loc. 1).

MIOFLORA

The following 57 miospore species belonging to 33 genera have been recorded from the Karharbari assemblage of Jayanti Coalfield. Species marked with an asterisk are described here:

1. *Leiotriletes sphaerotriangulus* (Loose) Potonié & Kremp, 1954
2. *L. psilatus* Kar & Bose, 1967
*3. *Psilalacinites indicus* sp. nov.
4. *Calamospora exila* Bharadwaj & Salujha, 1964
*5. *Punctatisporites plicatus* (Tiwari & Navale 1967) comb. nov.
6. *P. reticulatus* Pant & Srivastava, 1965
7. *P. gretensis* Balme & Hennelly, 1956b
8. *Callumispora barakarensis* Bharadwaj & Srivastava, 1969
9. *Microfoveolatispora foveolata* Tiwari, 1965
10. *M. directa* (Balme & Hennelly) Bharadwaj, 1962
*11. *Indotriradites* sp.
12. *Tiwariasporis gondwanensis* (Tiwari) Maheshwari & Kar, 1967
13. *Virkkipollenites densus* Lele, 1964
14. *V. triangularis* (Mehta) Lele, 1964
15. *V. obscurus* Lele, 1964
16. *Plicatipollenties indicus* Lele, 1964
17. *P. gondwanensis* (Balme & Hennelly) Lele, 1964
18. *P. diffusus* Lele, 1964
19. *P. trigonalis* Lele, 1964
20. *Rugasaccites ovatus* Lele & Makada (1972)
21. *Parasaccites obscurus* Tiwari, 1965
22. *P. distinctus* Tiwari, 1965
23. *P. talchirensis* Lele & Makada (1972)
24. *Tuberisaccites lobatus* Lele & Makada (1972)
25. *Caheniasaccites flavatus* Bose & Kar, 1966
26. *C. ovatus* Bose & Kar, 1966
27. *C. decorus* Lele & Makada (1972)
28. *Crucisaccites latisulcatus* Lele & Maithy, 1964b
29. *Vesicaspora sulcata* Hart, 1960
30. *V. obliqua* Singh, 1964
31. *Vestigisporites novus* Tiwari, 1965
32. *V. diffusus* Maithy, 1965a
33. *Potonieisporites jayantiensis* Lele & Karim, 1971
34. *P. neglectus* Potonié & Lele, 1961
35. *P. lelei* Maheshwari, 1967
36. *P. elegans* (Wilson & Kosanke) Wilson & Venkatachala, 1964
37. *P. barrelis* Tiwari, 1965
38. *P. triangulatus* Tiwari, 1965
*39. *Striomonosaccites* sp.
40. *Cuneatisporites radialis* Leschik, 1955
41. *C. flavatus* Bose & Kar, 1966
42. *Limitisporites diversus* Lele & Karim, 1971
43. *Sulcatisporites barakarensis* Tiwari, 1965
44. *Striatites tentulus* Tiwari, 1965
*45. *S. medius* sp. nov.
46. *Lahirites rarus* Bharadwaj & Salujha, 1964
47. *Lunatisporites rhombicus* Lele & Makada (1972)
48. *L. amplus* (Balme & Hennelly) Potonié, 1958
49. *L. globosus* Maithy, 1965a
50. *Faunipollenites varius* Bharadwaj, 1962
*51. *Vittatina* cf. *V. subsaccata* Samoilovich, 1953
52. *Gnetaceaepollenites diffusus* sp. nov.
53. *Quadrisporites horridus* Hennelly, 1953
*54. *Pilasporites ovatus* sp. nov.
55. *Balmeela gigantea* Bose & Maheshwari, 1968
*56. *Punctatasporites* sp.
57. *Greinervillites undulatus* Bose & Kar, 1967.

Anteturma — *Sporites* H. Pot., 1893
Turma — *Triletes* (Rein.) Pot. & Kr., 1954
Subturma — *Azonotriletes* Luber, 1935
Infraturma — *Laevigati* (Ben. & Kid.) Potonié, 1956

Genus — Psilalacinites Kar, 1969

Type species — *Psilalacinites triangulus* Kar, 1969.

Psilalacinites indicus sp. nov.

Pl. 3, Figs. 34-35

Diagnosis — Miospores triangular, 42-52 $\times$ 48-54 μ (average, 47×51 μ) in size; trilete mark distinct, rays reaching equator; exine laevigate.

Description — Miospores triangular, apices bluntly rounded, interapical margins straight to convex; exine 2-5 μ thick, laevigate; trilete mark distinct, rays equal in length, reaching equator; straight to sinuous, labra raised, uniformly wide.

Comparison — The type species *Psilalacinites triangulus* Kar (1969) differs in its larger size and thinner exine.

Holotype — Pl. 3, Fig. 35.

Type Locality — Misra village (Loc. 1), Jayanti Coalfield, Bihar.

Horizon — Karharbari Formation.

Number of specimens studied: 16.

Genus — *Punctatisporites* Ibrahim, 1933

Type species — *Punctatisporites punctatus* Ibrahim, 1933.

Punctatisporites plicatus (Tiwari & Navale) comb. nov.

Pl. 3, Fig. 36

Synonym — *Calamospora plicata*, Tiwari & Navale, 1967, Pl. 1, Fig. 2 (Holotype).

Remarks — The present specimens resemble *Calamospora plicata* Tiwari & Navale (1967) in having trilete rays more than 2/3 radius long with thick lips, and intramicropunctate exine with many prominent folds. The present specimens are however, smaller in size (64-85 μ) as compared with the Brazilean specimens (96-102 μ).

The Brazilean specimens as well as the present ones do not show *area contagionis* which is a generic character of *Calamospora* Schopf, Wilson & Bentall (1944). Besides the trilete mark is also much longer than known in *Calamospora*. As such the species *Calamospora plicata* is being transferred to *Punctatisporites* as *P. plicatus* comb. nov. The longer trilete mark and folds are both consistent with the definition of *Punctatisporites*. The spores are not referred to *Callumispora* due to their thin exine and lack of exinal differentiation in the trilete area.

Occurrence — Misra village (Loc. 1).

Turma — *Zonales* (Bennie & Kidston) Potonié, 1956
Subturma — *Zonotriletes* Waltz, 1935
Infraturma — *Cingulati* Potonié & Klaus, 1954

Genus — *Indotriradites* Tiwari, 1964

Type species — *Indotriradites korbaensis* Tiwari, 1964.

Indotriradites sp.

Pl. 3, Fig. 37

Description — Very few miospores, subtriangular with convex sides, apices slightly pointed to rounded, 45-52 μ in size; cingulum serrate to dentate, 2-4 μ wide, small confluent coni seen on the cingulum; trilete mark distinct, rays uniformly broad, entering the cingulum, slightly wavy, labra thick, vertex raised; central area proximally infrapunctate or laevigate, distally vermiculate or with small coni confluent at the base; exine apparently double-layered.

Remarks — These spores are referable to *Indotriradites* on the basis of general resemblance. The specific identification is not possible due to lack of specimens. Some resemblance with *Cristatisporites papillatus* (Pant & Srivastava) Tiwari & Navale (1967) is suggested. In our opinion *Cristatisporites papillatus* needs reallocation.

Occurrence — Misra village (Loc. 1).

Anteturma — *Pollenites* Potonié, 1931
Turma — *Saccites* Erdtman, 1947
Subturma — *Monosaccites* (Chitaley) Potonié & Kremp, 1954
Infraturma — *Striasacciti* Bharadwaj, 1962

Genus — *Striomonosaccites* Bharadwaj, 1962

Type species — *Striomonosaccites ovatus* Bharadwaj, 1962.

Striomonosaccites sp.

Pl. 3, Fig. 38

Description — Single miospore, monosaccate, but appears to be tetrasaccate due to notches, 110×115 μ in size; central body oval, 37×67 μ in size, thick, exine in the saccus free area intramicroreticulate; proximally 7 unbranched horizontal striations; saccus broad, width not uniform all round due to notches, saccus reticulation coarse.

Comparison — This rather abnormal specimen differs from all species of *Striomonosaccites* Bharadwaj (1962) in having a notched saccus.

Occurrence — Banskupi Colliery area (Loc. 2).

Subturma — *Disaccites* Cookson, 1947
Infraturma — *Striatiti* Pant, 1950

Genus — *Striatites* (Pant) Bharadwaj, 1962

Type species — *Striatites sewardi* (Virkki) Pant, 1954.

Striatites medius sp. nov.

Pl. 3, Figs. 39-40; Text-fig. 4

Diagnosis — Miospores, disaccate, 74-82 × 44-54 μ (average, 76 × 49 μ) in size; central body rhomboid, dense, 38-42 × 40-50 μ in size, proximally with 10-12 horizontal striations, distal sulcus narrow, sacci fine intramicroreticulate.

Description — Miospores haploxylonoid; central body rhomboid to vertically oval, distinct, exine microverrucose, proximally with 10-12 horizontal striations, rarely branched, without any vertical partitions; distal saccus attachment straight, distal saccus free area narrow, slit like; sacci ± hemispherical, intrareticulation fine.

Comparison — Present species resembles in rhomboid shape of central body to *Striatites rhombicus* Bharadwaj & Salujha (1964) but the latter differs in having a distinct marginal rim, vertical partitions and convex saccus attachment. *S. karharbariensis* Maithy (1965a) is much bigger (140-170 × 80-110 μ) in size and shows thin central body. Other species differ in shape of the central body.

Holotype — Pl. 3, Fig. 39.

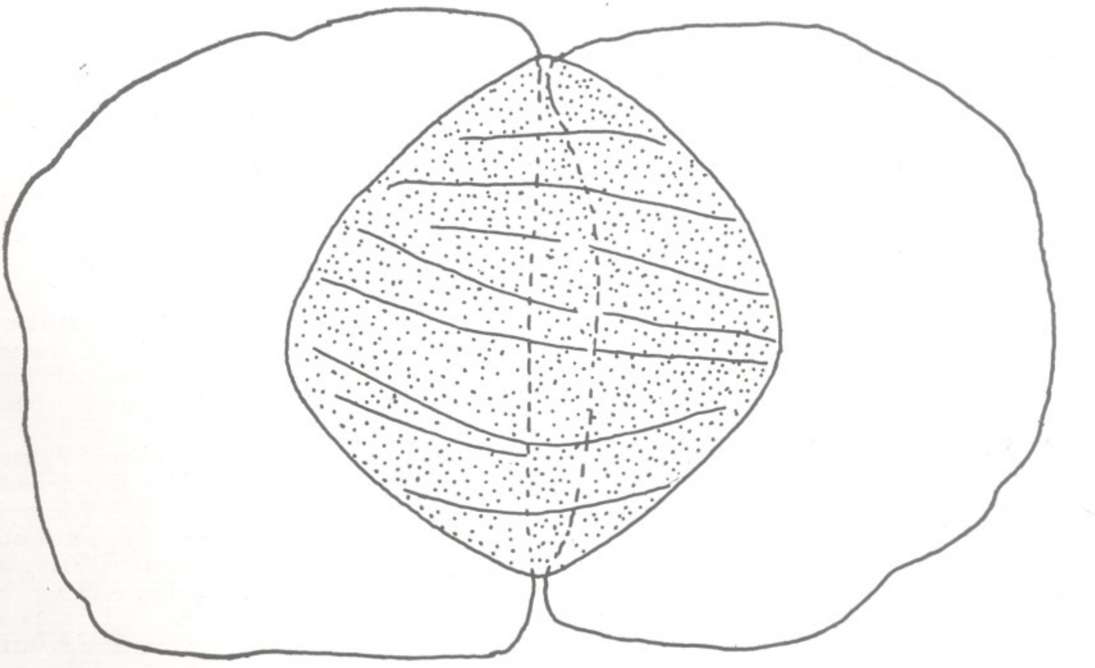
Type Locality — Banskupi Colliery area (Loc. 2); Jayanti Coalfield, Bihar.

Horizon — Karharbari Formation.

Number of specimens studied: 21.

Genus — *Vittatina* (Luber) Wilson, 1962

Type species — *Vittatina subsaccata* Samoilovich, 1953.



TEXT-FIG. 4 — *Striatites medius* sp. nov. drawing of the holotype showing dense and rhomboid central body. ca. × 1750.

Vittatina sp. cf. *V. subsaccata* Samoilovich, 1953

Pl. 3, Fig. 41

Description — Single miospore bilaterally symmetrical, bisaccate folded, 57-61 μ in size; central body 57 μ high, distinct, bigger than sacci, exine ±2 μ thick, 15 horizontal striations; exine in between striations intramicropunctate; sacci rudimentary, intrareticulate.

Remarks — The sacci in this specimen are comparatively more well developed than in the holotype; one of the sacci has overturned on the body.

Occurrence — Misra village (Loc. 1).

Turma — *Plicates* (Naumova) Potonié, 1960
Subturma — *Polyplicates* Erdtman, 1953

Genus — *Gnetaceaepollenites* Thiergart, 1938

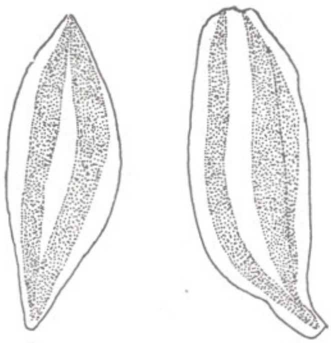
Type species — *Gnetaceaepollenites ellipticus* Thiergart, 1938.

Gnetaceaepollenites diffusus sp. nov.

Pl. 3, Figs. 42-43. Text-fig. 5, A-B

Diagnosis — Miospores ellipitical to spindle-shaped, 90-116×23-48 μ (average, 98×31 μ) in size, usually with 2 rarely 4-5 arcuate folds along the longer axis; exine granulose to punctate.

Description — Miospores elliptical to spindle-shaped with pointed long drawn ends, exine granulose to punctate with usually 2, sometimes 4-5 arcuate folds along longer axis; sometimes exine ruptured in between folds simulating a colpus, split only partial, not from end to end.



TEXT-FIG. 5 A-B — *Gnetaceaepollenites diffusus* sp. nov. drawing of the syntypes, each showing two arcuate folds along longer axis. × 360.

Comparison — The genotype *Gnetaceaepollenites ellipticus* Thiergart (1938) from Tertiary horizons differs from the present species in having a laevigate exine. The spores studied by Bharadwaj (1962) from Raniganj Stage also exhibit characteristically punctate exine. *G. sinuosus* (Balme & Hennelly) Bharadwaj (1962) is smaller in size with only two folds and has smooth exine. *G. grandis* Maheshwari (1967) differs in being much larger in size (78-101×100-210 μ) and in having intrabaculate exine.

Syntypes — Pl. 3, Figs. 42, 43

Type Locality — Misra village, Jayanti Coalfield, Bihar.

Horizon — Karharbari Formation.

Number of specimens studied: 30.

Turma — *Aletes* Ibrahim, 1933
Subturma — *Azonaletes* (Luber) Potonié & Kremp, 1954
Infraturma — *Psilonapiti* Erdtman, 1947

Genus — *Pilasporites* (Balme & Hennelly) Tiwari & Navale, 1967

Type species — *Pilasporites calculus* Balme & Hennelly, 1956a.

Pilasporites ovatus sp. nov.

Pl. 3, Fig. 45; Text-fig. 6

Diagnosis — Miospores suboval, elliptical, 50-57×72-80 μ (average, 54×76 μ) in size; exine thick (1·5-4 μ), smooth, generally splitting along longer axis.

Description — Miospores oval, elliptical to suboval in shape; exine smooth, somewhat faintly infrastructured, 1·5-4 μ thick at the equator, outline smooth, in most of the specimens 1/2 or 3/4 of exine is split, mostly along the longer axis.

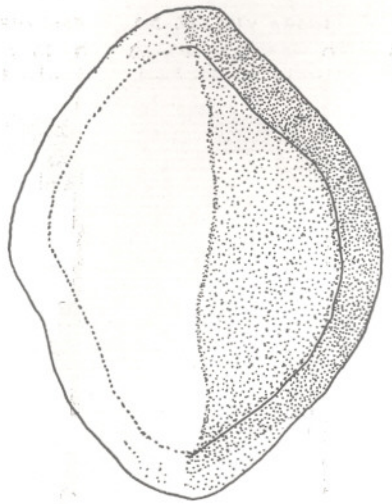
Comparison — *Pilasporites calculus* Balme & Hennelly (1956a) differs from the present species in being ± circular in shape and in having a thicker exine (up to 8 μ). *P. plurigenus* Balme & Hennelly (1956a) is much smaller (12-36 μ) in size.

Holotype — Pl. 3, Fig. 45.

Type Locality — Misra village, Jayanti, Coalfield, Bihar.

Horizon — Karharbari Formation.

Number of specimens studied: 13



TEXT-FIG. 6 — *Pilasporites ovatus* sp. nov. drawing of the holotype showing thick exine. × 900.

Genus — *Punctatasporties* Ibrahim, 1933

Type species — *Punctatasporites sebulosus* Ibrahim, 1933

Punctatasporites sp.

Pl. 3, Fig. 44

Description — Miospores subcircular, variously irregularly folded; without any mark; exine 1-2 μ thick, fine infra-micropunctate; *extrema lineamenta* uneven.

Remarks — The specimens do not show any tetrad mark. They are otherwise closely comparable with *Punctatisporites plicatus* (Tiwari & Navale) comb. nov. which also occurs in the material.

DISCUSSION AND CONCLUSION

The fossil flora of the Karharbari Stage of Jayanti Coalfield comprises megafossils and miospores. Megafossils are few in number but the miospore assemblages are rich both quantitatively and qualitatively.

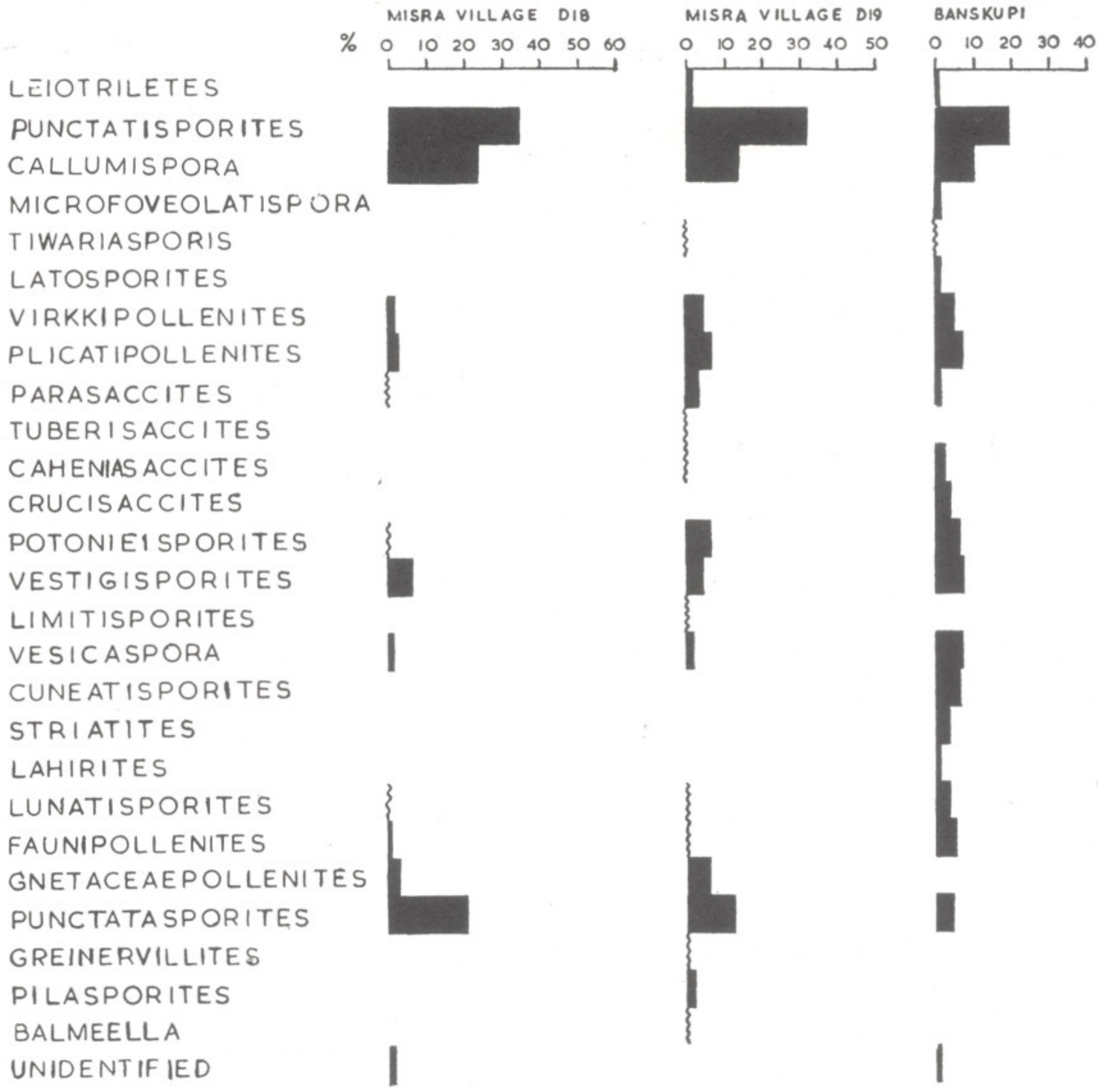
MEGAFLORA — The plant megafossils recovered from the two localities are represented by *Gondwanidium* (1 species), *Gangamopteris* (4 species), *Glossopteris* (5 species), *Noeggerathiopsis* (4 species), *Samaropsis* (2 species), *Cordaicarpus* (1 species) and some indeterminate remains.

Gangamopteris and *Noeggerathiopsis* are common to the floras from Misra village and Banskupi Colliery area. However, in the details of composition and incidence of the various taxa, the two megafloras indicate notable differences. The Misra flora is rather imperfectly preserved to permit a clear quantitative assessment. However, the presence of *Gondwanidium* and platyspermic seeds in this assemblage is striking. *Paracalamites*, *Gangamopteris*, and *Noeggerathiopsis* are moderately represented. *Glossopteris* has not been encountered. On the contrary, the Banskupi flora is more well preserved and shows an abundance of *Gangamopteris*, *Glossopteris* and *Noeggerathiopsis*. *Paracalamites*, *Gondwanidium* and platyspermic seeds have not been found. On the whole, the Banskupi flora appears more diversified and younger in aspect than the Misra flora. This may lend support to the possibility that the Banskupi carbonaceous shales are stratigraphically higher than the micaceous shales in the Misra section.

MIOFLORA — The miospore assemblage consists of 57 species belonging to 33 genera. The quantitative distribution of important miospore genera in various samples is shown in Histogram 1 and Table 1. The percentage frequencies are based on a count of 200 specimens.

Qualitative considerations

In the present paper the genera *Callumispora* and *Punctatisporites* are followed. *Callumispora* is used in a somewhat restricted sense for only those forms which show all the features typified by the genoholotype. Other specimens of *Callumispora* tend to confuse and overlap with *Punctatisporites*. For instance, *Callumispora tenuis* var. *minor* can hardly be distinguished from *Punctatisporites* as the forms are not appreciably thick (2 μ), the exine is non-stratified and the inter-ray area is only faintly differentiated. Similarly *Punctatisporites reticulatus* Pant & Srivastava (1965) also shows a wide range of variation in the exine, so that its transfer to *Callumispora* as proposed by Bharadwaj & Srivastava (1969) needs further critical study.



HISTOGRAM 1 — Quantitative distribution of important miospore genera in the Karharbari samples of the Jayanti Coalfield.

Quantitative Analysis

Assemblage from Misra Village

The assemblage from Misra village shows a more or less uniform distribution of miospore taxa in the two samples (Table 1). Both the samples are characterized by the dominance of the trilete genera *Punctatisporites* and *Callumispora*. The high percentage of aletes and the significant proportion of polyplicates (*Gnetaceaepollenites*) is also a noteworthy feature of the assemblage. Monosaccates are more conspicuous in sample D19 as compared to D18. Among these the more significant genera are *Virkkipollenties*, *Plicatipollenites*, *Potonieisporites*, *Vestigisporites* and *Parasaccites*. The Disaccates are poorly represented in both samples. Based on miospore

TABLE 1 — PER CENT DISTRIBUTION OF MIOSPORE GENERA IN SAMPLES OF KARHARBARI FORMATION OF JAYANTI COALFIELD

GENERA	MISRA VILLAGE		BANSKUPI COLLIERY AREA
	D18	D19	
1. *Leiotriletes*	—	1·5	1·0
2. *Punctatisporites*	35·0	31·5	19·5
3. *Callumispora*	24·0	14·0	10·0
4. *Microfoveolatispora*	—	—	1·5
5. *Tiwariasporis*	—	0·5	—
6. *Latosporites*	—	—	1·5
7. *Virkkipollenites*	2·0	5·0	5·0
8. *Plicatipollenites*	3·0	7·0	7·5
9. *Parasaccites*	0·5	3·5	1·5
10. *Tuberisaccites*	—	0·5	—
11. *Caheniasaccites*	—	0·5	2·5
12. *Crucisaccites*	—	—	4·0
13. *Potonieisporites*	0·5	6·5	6·5
14. *Vestigisporites*	0·5	3·4	7·5
15. *Vesicaspora*	1·5	2·0	7·0
16. *Limitisporites*	—	0·5	—
17. *Cuneatisporites*	—	—	6·5
18. *Striatites*	—	—	3·5
19. *Lahirites*	—	—	1·0
20. *Lunatisporites*	0·5	0·5	3·5
21. *Faunipollenites*	1·0	0·5	5·0
22. *Gnetaceaepollenites*	3·0	6·0	—
23. *Punctatasporites*	21·0	12·0	4·5
24. *Greinervillites*	—	0·5	—
25. *Pilasporites*	—	2·0	—
26. *Balmeella*	—	0·5	—
27. *Unidentified*	1·5	—	1·0

group distribution, the following position is obtained in the Misra samples:

Dominant Taxa	D18 %	D19 %	Average %
Triletes	59	47·0	53·0
Subdominant Taxa			
Monosaccates	8·0	28·4	18·2
Aletes	21·0	15·0	18·0
Polyplicates	3·0	6·0	4·5
Rest Taxa			
Disaccates	1·5	1·5	1·5
Monoletes	—	0·5	0·3

Assemblage from Banskupi Area

The Banskupi assemblage also contains a high proportion of the monosaccates and the trilete genera *Punctatisporites* and *Callumispora*. However, there are some significant differences from the previous assemblages. Firstly, in the Banskupi assemblage the trilete group has apparently lost its dominating position to the monosaccates. Secondly, the disaccates have also risen to prominence. Thirdly, the polyplicates are not represented. Based on generic group distribution, the following position is obtained for the Banskupi assemblage:

Dominant Taxa	%
Monosaccates	41·5
Subdominant Taxa	
Triletes	32·0
Disaccates	19·5
Rest Taxa	
Aletes	4·5
Monoletes	1·5

The above quantitative assessments indicate that the assemblage from Misra village is distinguishable from that of the Banskupi area in details. Both are, however, closely linked with each other by the characteristic abundance of Monosaccates and Triletes (*Punctatisporites* and *Callumispora*). Among the two assemblages the Banskupi assemblage is more diversified and apparently younger as is also indicated by the megafloristic evidence. It contains a significant number of the following genera which are absent from the Misra village assemblage; *Microfoveolatispora, Latosporites, Cahenisaccites, Crucisaccites, Cuneatisporites, Striatites, Lahirites, Lunatisporites* and *Faunipollenites*. On the contrary. *Gnetaceaepollenites* (polypicates) is restricted to the Misra assemblage. From stratigraphical point of view, however, both the assemblages are referable to the Karharbari Formation on the basis of comparisons with the known Karharbari miofloras.

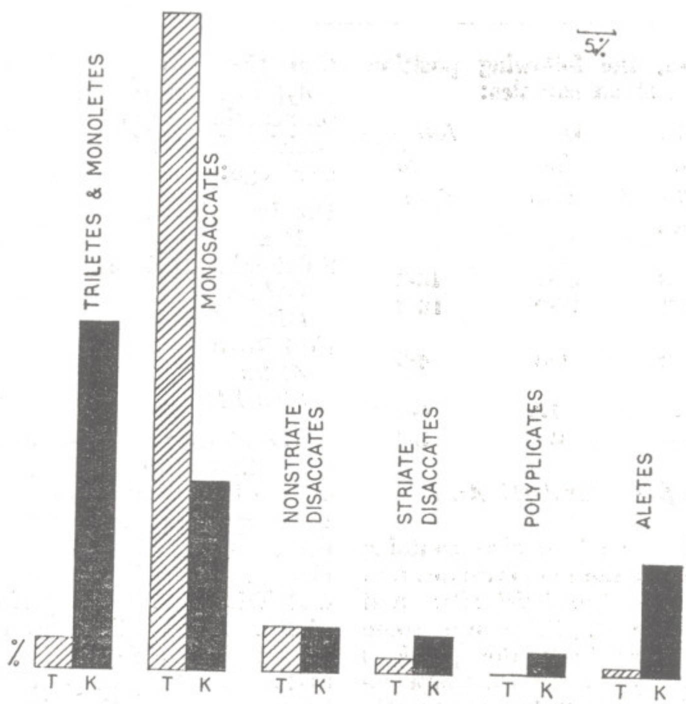
AGE OF THE COAL-BEARING BEDS

The age of the coal-bearing beds in the Jayanti Coalfield has remained controversial. Niyogi & Sanyal (1962) and Niyogi (1964) continue to refer the beds to the Barakar Formation, although Puri (1953) suggested a Karharbari age on plant fossil evidence. The findings of Lele and Maithy (1966) also supported a Karharbari age for the beds.

The present investigation has made it possible to reconsider the problem both from megafossil and miofloral standpoints.

The plant fossils recovered from Misra and Banskupi shales are essentially those that characterize the Karharbari Formation in the type area (Giridih basin) and elsewhere. The abundance of the genera *Noeggerathiopsis* and *Gangamopteris* (often yielding cuticular structure), along with the significant occurrence of platyspermic seeds and above all, the characteristic presence of *Gondwanidium* provide unmistakable proof in support of a Karharbari age. The Karharbari age of the Misra section is particularly attested by the presence of *Gondwanidium*. The Banskupi shales are apparently younger than the Misra section.

Miofloristically also, the Jayanti assemblages approach closest to the Karharbari miofloras in their abundance and variety of monosaccate taxa along with a significant proportion of triletes and/or bisaccates. The presence of *Crucisaccites* in the Jayanti mioflora adds emphasis to its Karharbari age. In contrast, the older miofloras of the Talchir Formation are distinguishable by the supreme dominance of the Monosaccates (especially *Parasaccites, Plicatipollenites*) and the sporadic presence of Triletes and disaccates (for Jayanti Coalfield *vide* Histogram 2 & Tables 2 & 3). On the other hand,



HISTOGRAM 2 — Comparative quantitative ditribution of important miospore groups in the Talchir (T) and Karharbari (K) Formations of the Jayanti Coalfield.

TABLE 2 — DISTRIBUTION OF SPECIES IN THE TALCHIR AND KARHARBARI FORMATIONS OF THE JAYANTI COALFIELD

SL No.	SPECIES	TALCHIR	KARHARBARI
1.	Leiotriletes sphaerotriangulus	—	+
2.	,, psilatus	—	+
3.	Leiotriletes sp.	+	—
4.	Psilalacinites indicus sp. nov.	—	+
5.	Calamospora exila	—	+
6.	Punctatisporites minutus	+	—
7.	,, ganjrensis	+	—
8.	,, reticulatus	—	+
9.	,, gretensis	+	+
10.	,, plicatus comb. nov.	—	+
11.	Callumispora barakarensis	—	+
12.	Henellysporites sp.	+	—
13.	Granulatisporites granulatus	+	—
14.	,, sp.	+	—
15.	Plicatisporites distinctus gen.	+	—
16.	Cyclogranisporites plicatus	+	—
17.	,, gondwanensis	+	—
18.	Verrucosisporites varius	+	—
19.	,, sp.	+	—
20.	Horriditriletes novus	+	—
21.	,, bulbosus	+	—
22.	,, sp.	+	—
23.	Lacinitriletes budamensis	+	—
24.	,, minutus	+	—
25.	Acanthotriletes filiformis	+	—
26.	Microfoveolatispora directa	+	+
27.	,, foveolata	—	+
28.	Brevitriletes unicus	+	—
29.	Indotriradites sp.	—	+
30.	Jayantispories pseudozonatus	+	—
31.	Jayantisporites indicus	+	—
32.	,, conatus	+	—
33.	Tiwariasporis gondwanensis	—	+
34.	Virkkipollenites densus	+	+
35.	,, obscurus	+	+
36.	,, triangularis	—	+
37.	Plicatipollenites indicus	+	+
38.	,, trigonalis	+	+
39.	,, diffusus	+	+
40.	,, gondwanensis	+	+
41.	,, densus	+	—
42.	,, stigmatus	+	—
43.	,, maculatus	+	—
44.	Rugasaccites obscurus	+	—
45.	,, orbiculatus	+	—
46.	,, ovatus	+	+
47.	Parasaccites obscurus	+	+
48.	,, diffusus	+	—
49.	,, densus	+	—
50.	,, perfectus	+	—
51.	,, fimbriatus	+	—
52.	,, talchirensis	+	+
53.	,, plicatus	+	—
54.	,, distinctus	—	+
55.	Parastriopollenites segmentus	+	—
56.	,, indicus	+	—
57.	,, sp.	+	—
58.	Tuberisaccites varius	+	—
59.	,, lobatus	+	+
60.	,, tuberculatus	+	—
61.	Caheniasaccites ovatus	+	+
62.	,, densus	+	—

TABLE 2 — DISTRIBUTION OF SPECIES IN THE TALCHIR AND KARHARBARI FORMATIONS OF THE JAYANTI COALFIELD — *Continued*

SL No.	SPECIES	TALCHIR	KARHARBARI
63.	Caheniasaccites distinctus	+	—
64.	,, decorus	+	+
65.	,, flavatus	—	+
66.	Divarisaccus lelei	+	—
67.	,, scorteus	+	—
68.	,, sp.	—	—
69.	Crucisaccites latisulcatus	+	+
70.	Vestigisporites diffusus	+	+
71.	,, novus	+	+
72.	,, nigratus	+	—
73.	Potonieisporites neglectus	+	+
74.	,, densus	+	—
75.	,, lelei	Cf. +	+
76.	,, magnus	+	—
77.	,, jayantiensis	+	+
78.	,, elegans	—	+
79.	,, barrelis	—	+
80.	,, triangulatus	—	+
81.	Cf. Rimospora	+	—
82.	Striomonosaccites sp.	—	+
83.	Cuneatisporites radialis	—	+
84.	,, flavatus	—	+
85.	Valiasaccites densus	+	—
86.	,, indicus	+	—
87.	Limitisporites diversus	+	+
88.	,, elongatus	+	—
89.	,, cf. monosaccoides	+	—
90.	,, cf. congoensis	+	—
91.	,, cf. hexagonalis	+	—
92.	,, cf. leschikii	+	—
93.	Labiisporites granulatus	Cf. +	—
94.	,, densus	+	—
95.	Gigantosporites indicus	+	—
96.	Platysaccus papilionis	+	—
97.	Alisporites opii	+	—
98.	Illinites purus	+	—
99.	,, notus	+	—
100.	,, sp.	+	—
101.	Vesicaspora obliqua	+	+
102.	,, ovata	+	—
103.	,, breckmanii	+	—
104.	,, crassa	+	—
105.	,, sulcata	—	+
106.	Sulcatisporites maximus	+	—
107.	,, tentulus	+	—
108.	,, barakarensis	—	+
109.	Rhizomaspora singula	+	—
110.	Strotersporites rhombicus	+	—
111.	,, sp.	+	—
112.	Faunipollenites various	+	+
113.	,, goraiensis	+	—
114.	,, sp.	+	—
115.	Circumstriatites talchirensis	+	—
116.	,, obscurus	+	—
117.	,, ovatus	+	—
118.	Striatites tentulus	—	+
119.	,, medius	—	+
120.	Lahirites singularis	+	—
121.	,, rarus	—	+
122.	Lunatisporites rhombicus	—	+
123.	,, amplus	—	+
124.	,, globosus	—	+

TABLE 2 — DISTRIBUTION OF SPECIES IN THE TALCHIR AND KARHARBARI FORMATIONS OF THE JAYANTI COALFIELD — *Continued*

SL No.	SPECIES	TALCHIR	KARHARBARI
125.	Crustaesporites sp.	+	—
126.	Striasulcites sp.	+	—
127.	Vittatina subsaccata	—	Cf.+
128.	Ginkgocycadophytus novus	+	—
129.	Gnetaceaepollenites diffusus	—	+
130.	Quadrisporites horridus	—	+
131.	Pilasporites calculus	+	—
132.	,, ovatus	—	+
133.	Balmeela gigantea	—	+
134.	Punctatasporites sp.	—	+
135.	Greinervillites undulatus	—	+
136.	Leiosphaeridia talchirensis	+	—

TABLE 3 — AVERAGE PERCENTAGE OF IMPORTANT MIOSPORE GENERA AND MAJOR GROUPS IN THE TALCHIR AND KARHARBARI FORMATIONS OF THE JAYANTI COALFIELD. Genera present, but not appearing in average, are shown by (+) sign; genera absent are indicated by (—) sign

MAJOR GROUPS	SPORE GENERA	TALCHIR-AVERAGE OF SAMPLE D1-D16		KARHARBARI-AVERAGE OF MISRA AND BANSKUPI ASSEMBLAGES	
Triletes & aletes	1. Leiotriletes	—	3·8	0·8	46·4
	2. Punctatisporites	1·1		28·5	
	3. Callumispora	—		16·0	
	4. Plicatisporites	0·9		—	
	5. Granulatisporites	0·2		—	
	6. Lacinitriletes	+		—	
	7. Verrucosisporites	+		—	
	8. Acanthotriletes	+		—	
	9. Apiculatisporis	+		—	
	10. Horriditriletes	0·2		—	
	11. Microbaculispora	+		—	
	12. Microfoveolatispora	+		0·5	
	13. Jayantisporites	1·0		—	
	14. Spore tetrad	0·4		—	
	15. Tiwariasporis	—		0·1	
	16. Latosporites	—		0·5	
Monosaccates	17. Virkkipollenites	10·1	89·0	4·0	28·4
	18. Plicatipollenites	25·8		5·8	
	19. Parasaccites	35·3		1·8	
	20. Parastriopollenites	1·6		—	
	21. Tuberisaccites	4·4		0·2	
	22. Caheniasaccites	1·1		1·0	
	23. Divarisaccus	0·7		—	
	24. Vesicaspora	1·6		3·5	
	25. Crucisaccites	+		1·4	
	26. Vestigisporites	5·9		6·2	
	27. Potonieisporites	2·5		4·5	
Nonstriate Disaccates	28. Platysaccus	+	3·9	—	2·4
	29. Valiasaccites	0·5		—	
	30. Limitisporites	2·8		0·2	
	31. Labiisporites	0·4		—	
	32. Gigantosporites	+		—	
	33. Illinites	+		—	
	34. Sulcatisporites	0·2		—	
	35. Cuneatisporites	—		2·2	

TABLE 3 — contd.

Major Groups	Spore Genera	Talchir-average of sample D1-D16		Karharbari-average of Misra and Banskupi assemblages	
Striate disaccates	36. Striatites	—	2·0	1·2	5·2
	37. Lahirites	—		0·3	
	38. Lunatisporites	0·1		1·5	
	39. Striatopodocarpites	+		—	
	40. Faunipollenites	1·2		2·2	
	41. Circumstriatites	0·7		—	
	42. Rhizomaspora	+		—	
Polyplicates	43. Gnetaceaepollenites	—		3·0	3·0
Aletes, etc.	44. Punctatasporites	+	1·3	12·6	14·4
	45. Greinervillites	0·2		0·2	
	46. Pilasporites	—		0·6	
	47. Balmeela	—		0·2	
	48. Leiospheres	+		—	
	49. Unidentified	1·1		0·8	

the Barakar miofloras are characterized by *Lophotriletes*, *Retusotriletes* (*Hennellysporites*), *Indotriradites*, *Dentatispora*, *Microbaculispora* and *Latosporites* (*sensu* Bharadwaj, 1966) along with increasingly diversified disaccates. According to more recent reappraisals, the Lower Barakar miofloras are believed to be characterized by zonate trilete spores and other genera like *Brevitriletes* and *Microbaculispora* (Bharadwaj, 1969: 264). In the North Karanpura basin, the Barakar miofloras are generally characterized by striate disaccates, especially *Stroterosporites*, *Striatopiceites* and *Striatites* (Kar, 1972). It is thus clear that the characteristic Barakar taxa are practically missing from the Jayanti mioflora which cannot, therefore, be referred to the Barakar Formation. It is evident from these comparisons that the beds near Misra and those of Banskupi area in the coal-bearing succession of the Jayanti Coalfield belong to the Karharbari Formation.

PALYNOSTRATIGRAPHIC COMPARISONS

Beyond the type area of the Giridih Coalfield (Maithy, 1965a), only few basins have so far been investigated for the palynostratigraphy of the Karharbari Formation. Among these are:

(i) Mohpani Coalfiled, where a succession ranging from the Talchir to the Karharbari Formation has been studied palynologically (Bharadwaj & Anand-Prakash, 1972).

(ii) South Karanpura Coalfield, Argada sector, where the Argada 'S' coal seam and associated shale as well as some shales lying 70 ft. above the Argada 'S' seam have been palynologically referred to the Karharbari Formation (Lele & Kulkarni, 1969; Bharadwaj & Anand-Prakash, 1972a).

(iii) Korba Coalfield, where a 689 metres deep sub-surface bore-core (No. NCKB 19) has been delimited into palynological zones ranging from the Talchir to the Karharbari Formation (Bharadwaj & Srivastava, 1973).

(iv) North Karanpura Coalfield, where the Lower Gondwanas, ranging from the Talchir to the Raniganj Formation, have been delimited palynologically (Kar, 1972).

The above investigations have, no doubt, given some glimpse of the miospore associations of the Karharbari Formation, but much more remains to be done in order to establish the palynological sequences across the formation, and more specially along its lower and upper limits. Notwithstanding these difficulties, the available data indicates that in some areas the Karharbari miofloras are characterized by the abundance of *Sulcatisporites* together with certain pteridophytic trilete taxa (e.g. *Brevitriletes, Indotriradites, Lophotriletes, Horriditriletes, Microbaculispora,* etc). Such miofloral associations are typically known from the Argada 'S' coal and associated shale and from the Assemblage Zone II in the Mohpani Coalfield. However in the Korba bore-core, the younger subzone in Biozone I (Lower part of the Karharbari Formation) shows dominance of *Callumispora* (average 28%) together with *Parasaccites* (average 27%). Higher up, in the Biozone II *Parasaccites* is dominant with subdominant *Sulcatisporites* and in Biozone III, *Sulcatisporites* attains a dominating position together with a conspicuous representation of some striate disaccate taxa. Bharadwaj & Srivastava (1973) refer the younger subzone of Biozone I along with the Biozones II and III to the Karharbari Stage. Studies in the North Karanpura Coalfield (Kar, 1972) indicate that the Lower Karharbari Formation is marked by an almost abrupt dominance (50%) of the triletes (especially, *Punctatisporites/Callumispora, Indotriradites* and *Lacinitriletes*) followed by monosaccates (32%); in the Upper Karharbari Formation monosaccates become dominant (60%) followed by disaccates (25%). Curiously enough, *Sulcatisporites* does not find any recognition in the Karharbari miofloras of the North Karanpura Coalfield. The Giridih mioflora (Maithy, 1965a) which is likely to be Lower Karharbari gives yet another picture. The assemblage is dominated by monosaccates along with a significant proportion of striate disaccates and a recognizable presence of *Welwitschiapites*. Trilete taxa are conspicuously insignificant.

The above brief survey indicates that the miofloral associations are not of the same kind in the Lower Karharbari of different basins. To this list, we may now add the Jayanti miofloral associations of Misra village and Banskupi area which are also very likely to be Lower Karharbari in position. A characteristic feature of the Jayanti mioflora is the dominance of *Callumispora/Punctatisporites* together with monosaccates. This aspect is evidently very close to the miofloral composition of the Biozone I (Younger subzone) in the Korba bore-core as well as to that of the Lower Karharbari in the North Karanpura Coalfield. However, a noteworthy difference is that the Korba assemblage also carries a significant proprotion of other pteridophytic triletes (14%) including *Leiotriletes, Lophotriletes, Horriditriletes* and *Microbaculispora* in particular. These trilete elements are wanting in the Jayanti mioflora. At any rate, the available evidences tend to indicate that a *Callumispora* + *Parasaccites* dominant association can be well identified in the lower Karharbari Formation at least in the coalfields of Korba, North Karanpura and Jayanti. This miofloral association is succeeded by a *Parasaccites* + *Sulcatisporites* rich mioflora in the Korba bore-core.

Note — While this paper was in press Srivastava (1973) has also recognized a *Callumispora-Parasaccites* rich assemblage in the basal Karharbari Formation of the Giridih Coalfield (Type area). Thus a Lower Karharbari age for the coal-bearing beds of the Jayanti basin is now well established.

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EXPLANATION OF PLATES

(Figured specimens and type slides are preserved at the B. Sahni Institute of Palaeobotany Museum, Lucknow)

PLATE 1

1. *Samaropsis feistmantelii* Maithy. × 5.
2. *Samaropsis goraiensis* Surange & Lele. × 5.
3. *Cordaicarpus zeilleri* Maithy. × 5.

4-5. Branched axes. 35003. × Nat. size.

6. *Gondwanidium validum* (Feistm.) Gothan. 35004. × Nat. size. A part of the pinnate frond.

7. *Gangamopteris* sp. 35005. × Nat. size.

8. *Gangamopteris* sp. cf. *G. gondwanensis* Maithy. 35006. × Nat. size.

9. Upper cuticle from the leaf in Fig. 8. × 100 (Slide No. 4389).

10. Lower cuticle from the leaf in Fig. 8. × 100 (Slide No. 4390).

11. Stomata enlarged from the cuticle in Fig. 10. × 500 (Slide No. 4390).

12. *Glossopteris* sp. cf. *G. fibrosa* Pant. 35007. × Nat. size.

13-14. *Glossopteris jayantiensis* sp. nov. Specimens showing different regions of leaf lamina. 35008, 35009. × Nat. size.

15. Leaf in Fig. 13 enlarged to show details of venation. × 4.

16. Upper cuticle from the leaf in Fig. 13. × 100 (Slide No. 4391).

PLATE 2

17. Lower cuticle from the leaf in Fig. 13. × 100 (Slide No. 4392).

18-19. Stomata enlarged from the Lower cuticle of specimen in Pl. 1, Fig. 13, Slide No. 4392.

20. *Glossopteris* sp. showing linear leaf with broken apex and base. 35010. × Nat. size.

21. Upper cuticle from the leaf in Fig. 20. × 100 (Slide No. 4398).

22. Lower cuticle from the leaf in Fig. 20. ×100 (Slide No. 4399).

23. *Noeggerathiopsis conspicua* sp. nov. complete leaf showing both apical and basal portions. 35011. × Nat. size.

24. *Noeggerathiopsis conspicua* sp. nov. showing apical part of the leaf 35012. × Nat. size.

25. Upper cuticle from the leaf in Fig. 24. ×100 (Slide No. 4400).

26. Lower Cuticle from the leaf in Fig. 24. ×100 (Slide No. 4401).

27. *Noeggerathiopsis bunburyana* Pant & Verma showing an immature complete leaf. 35013 × Nat. size.

PLATE 3

28. *Noeggerathipsis conspicua* sp. nov. stoma enlarged from the Lower cuticle of specimen in Pl. 2, Fig. 24 (Slide No. 4401).

29. *Noeggerathiopsis bunburyana* Pant & Verma Upper cuticle from the leaf in Fig. 27. × 100 (Slide No. 4404).

30. Lower cuticle from the leaf in Fig. 27. × 100 (Slide No. 4404).

31. Stomata enlarged from the Lower cuticle in Fig. 30. × 100 (Slide No. 4404).

32. Scale leaves — Type 1, 35014.

33. Scale leaf — Type 2. 35015

MICROFOSSILS (All × 500)

34-35. *Psilalacinites indicus* sp. nov. Slide Nos. 4380, 4381 (Holotype).

36. *Callumispora plicata* comb. nov. Slide No. 4382.

37. *Indotriradites* sp. Slide No. 4383.

38. *Striomonosaccites* sp. Slide No. 4384.

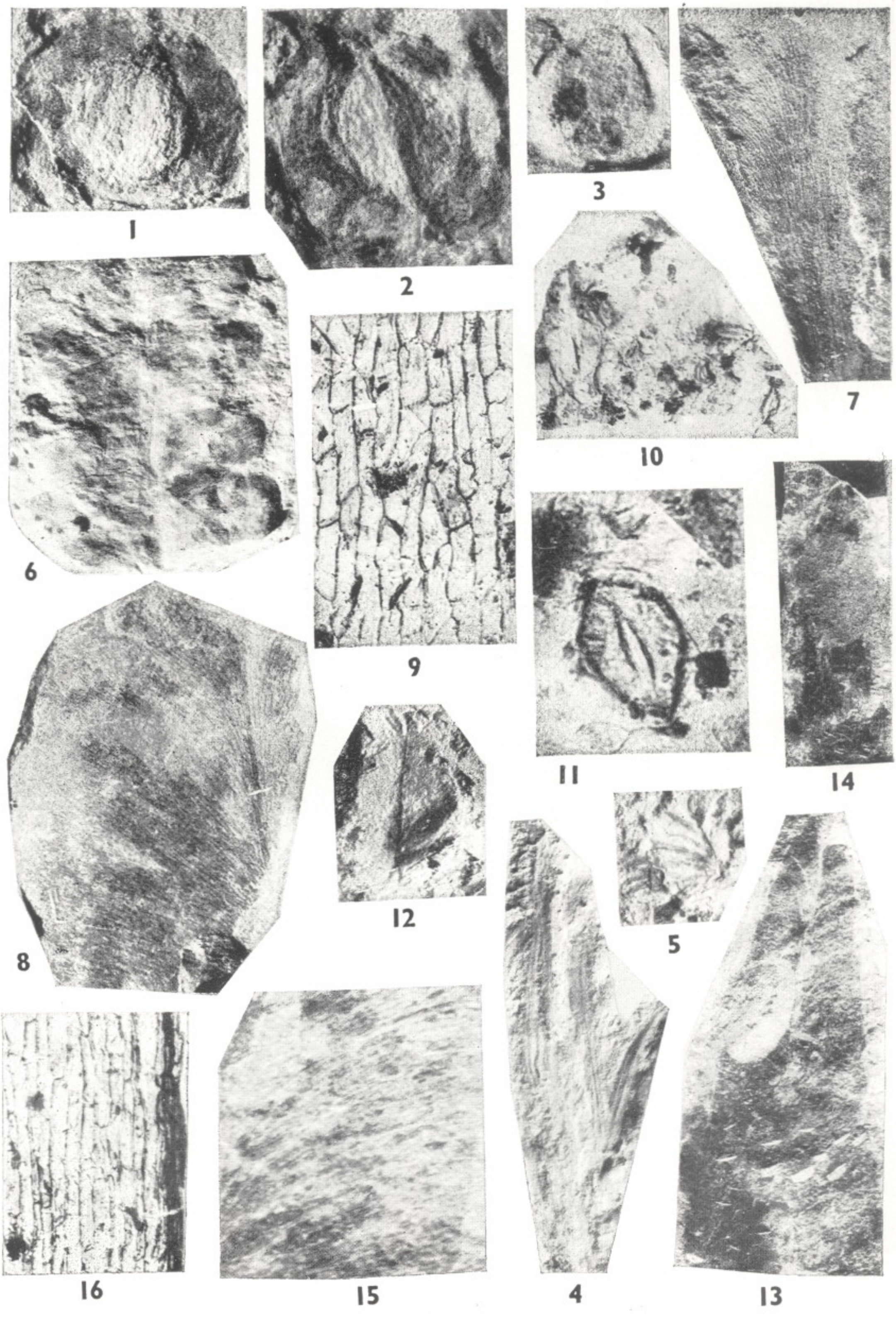
39-40. *Striatites medius* sp. nov. Slide Nos. 4385, 4384 (Holotype).

41. *Vittatina* cf. *V. subsaccata* Samoilovich. Slide No. 4382.

42-43. *Gnetaceaepollenites diffusus* sp. nov. Syntypes. Slide Nos. 4386, 4387.

44. *Punctatasporites* sp. Slide No. 4386.

45. *Pilasporites ovatus* sp. nov. Slide No. 4388 (Holotype).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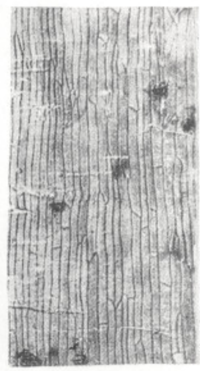

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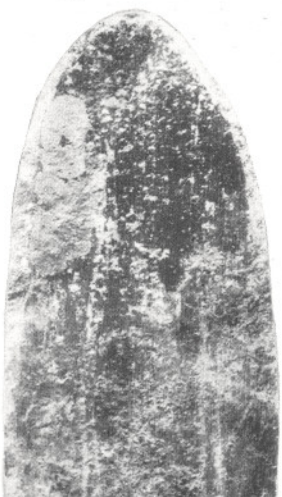

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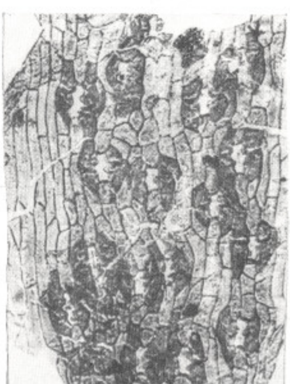

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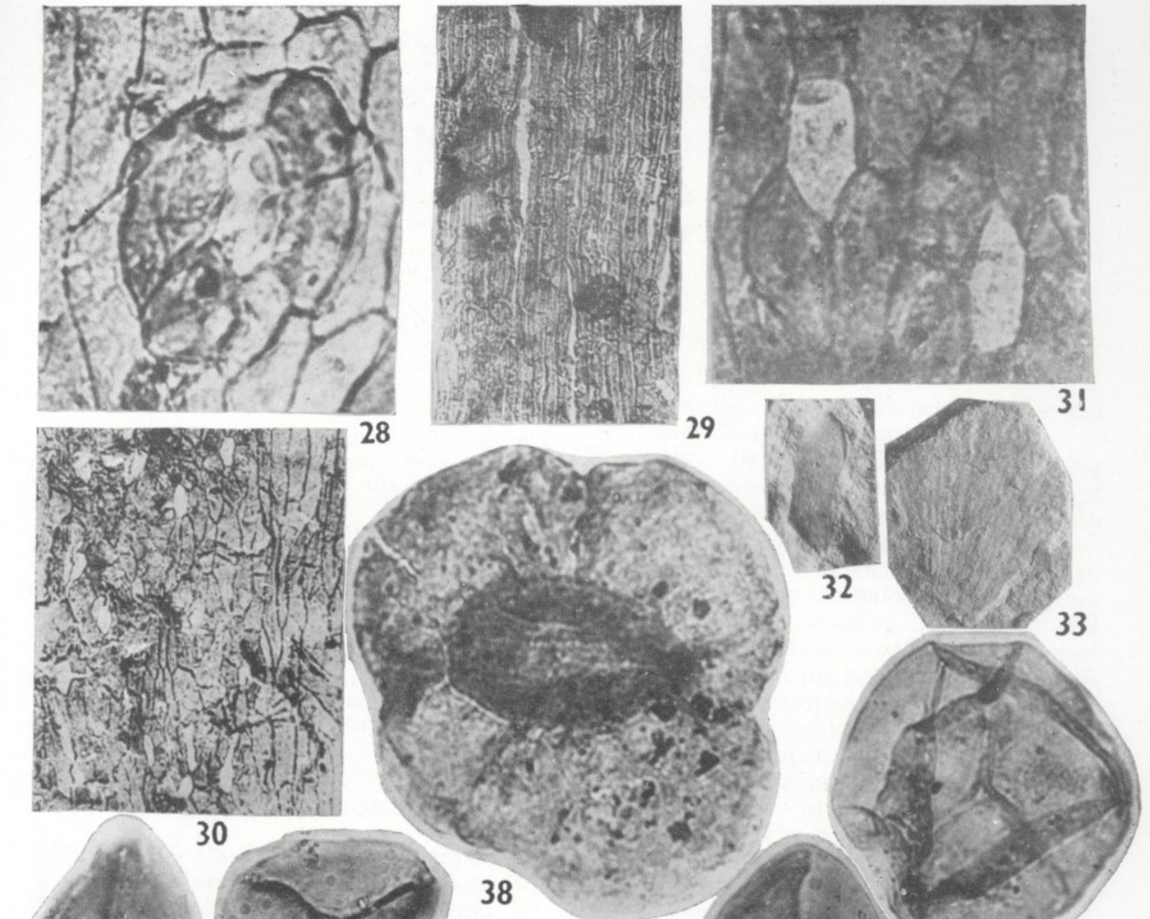
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