FURTHER OBSERVATIONS ON PLANT MICROFOSSILS FROM A CARBONACEOUS SHALE (KROLS) NEAR NAINI TAL, WITH A DISCUSSION ON THE AGE OF THE BEDS

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ABSTRACT

The plant microfossils recovered from a carbonaceous shale from Brewery, near Naini Tal, belonging to the Krol series, have been described. The recognizable dispersed spores have been assigned to eleven genera and eighteen species. They have been arranged according to the system proposed by Potonié and Kremp. The isolated seeds and fragments of woods and cuticles have been grouped as " Plantae incertae sedis ". The age of the Krol series has been discussed in the light of the microfossils recovered.

INTRODUCTION

A PRELIMINARY note announcing the recovery of plant microfossils from a carbonaceous shale from Brewery, near Naini Tal, was published by Sitholey, Sah and Dubey in 1954. From the location of the shale bed it was inferred that it belonged to the Krol series, which were till then known to be devoid of any organic remains. This raised two issues; firstly to confirm that the shale actually belonged to the Krol series; and secondly to extend the micro-palaeobotanical investigation to samples of Krol formation from other regions so as to build up a more complete microflora characteristic of this formation.

The area around Brewery was revisited in 1954 and 1955 to study its geology and ascertain the exact source of the carbonaceous shale. The locality (approx. 29°21′38″N; 79°28′8″E) lies about 3 miles S.E.S. of Naini Tal and about 1¼ miles N.W.N. of Jeolikot. The shale was collected from a gulch where the rocks have been disturbed by local slips and displacements. The shale bed is intercalated with bluish limestone and purple, grey and green shales. These beds overlie quartzites and greyish slates exposed along the road cutting near the main boundary fault separating these older formations from the Tertiary Nahan sandstones.

The Krol belt, extending over 180 miles from Subathu in Simla Hills to Naini Tal, consists of three main rock groups. At the bottom is a glacial boulder bed — the Blaini conglomerate. It is overlain in turn by the Infra-Krol series (composed of shaly slates and quartzite) and the Krol series.

The following is a generalized sequence of rocks forming the Krol series (*see* KRISHNAN, 1956, pp. 346, 347):

Upper {
- Krol E — Massive cream coloured limestone, calcareous sandstone and brown shales.
- Krol D — Cherty limestone, dark limestone, bleached shales and quartzites.
- Krol C — Massive crystalline limestone, often sulphurous.

Middle — Krol B — Red and green shales with dolomitic limestone.

Lower — Krol A — Thin bedded blue limestone, shale limestone, calcareous and carbonaceous shales.

However, there are local variations in the nature of these rocks, e.g. in the Middle Krols there may be only purple or red shales instead of red and green.

Our sample, occurring in close association with the limestone and purple and green shales, seems to belong to the lower part of the Krol series.

The rock groups of the Krol belt are doubtfully referred to the Upper Carboniferous and Permian "on the probable parallelism of the sequence commencing with a glacial boulder bed (? Talchir)" in Hazara and Salt Range regions (WADIA, 1953, p. 229). According to Krishnan (1956, p. 347) " The Blainis may be roughly correlated with the Permo-Carboniferous, and the Infra-Krol and Krol beds with the Permian. This is, however, a mere conjecture."

It is apparent that there has been a certain measure of doubt with regard to the age of these rock groups. The discovery of plant microfossils from the Krol series reported by Sitholey *et al.* (1954) was, therefore, significant as it could provide a palaeobotanical basis for determining the relative age of these beds. It was with this view that the present detailed investigation of the microflora recovered from the carbonaceous shale was undertaken.

In order to bring forth further observations on this problem, extensive micropalaeobotanical investigations were carried out on the Krol shales of Nahan (Sirmur) and Simla-Solan areas. Unfortunately, these investigations did not yield any recognizable microfossils.

The work embodied in this paper forms the part of a project on 'Palaeobotanical investigations in relation to measurement of the geological age of rocks' sponsored by the Council of Scientific & Industrial Research at the Birbal Sahni Institute of Palaeobotany. We wish to express our deep gratitude to Professor Dr. Robert Potonié for his valuable suggestions in the identification of the dispersed spores.

TECHNIQUE

The samples were macerated in small parts and in bulk with concentrated commercial nitric acid (about 70 per cent) as Schultze's solution was found to be rather strong. Best results were obtained when the shale was first treated with hydrofluoric acid (overnight) and later with nitric acid. Complete maceration took about 8 days. After maceration the material was washed several times with distilled water to free it of acid. Then the material was treated with 10 per cent potassium hydroxide for about 20 minutes and again washed with water. The permanent slides were prepared in glycerine jelly.

SYSTEMATIC DESCRIPTION OF SPORAE DISPERSAE

SUPERDIVISION — **Sporites** H. Pot.
DIVISION — **Triletes** (Reinsch) Pot. & Kr.
SUBDIVISION — **Azonotriletes** Luber
SERIES — **Laevigati** (B. & K.) Pot. & Kr.
GENUS — ***Calamospora*** S.W. & B.

Calamospora sp.

Pl. 1, Fig. 1

Description — Spherical spores appearing somewhat oval due to characteristic folding of the *extrema lineamenta*. Size varying from 82 to 100 μ. Y-mark not distinct, rays short, less than ½ the radius, labra thin. Exine laevigate, thin and folded.

Discussion — The thin, characteristically folded, laevigate exine indicates the identity of these spores with *Calamospora*. But as the preservation is not good enough to show sufficient structural details (Y-mark being observed in only one instance) and the number of specimens is rather small, it is not possible to assign these spores to any distinct species.

SERIES — **Apiculati** (B. & K.) Pot. & Kr.
GENUS — ***Planisporites*** (Knox) Pot. & Kr.

Planisporites parvus n. sp.

Pl. 1, Figs. 2, 3

Holotype — Pl. 1, Fig. 2; Reg. No.—M.G.T./20; Slide No. 2/4.

Diagnosis — Size 25-35 μ, holotype 29 μ; circular to ± oval; Y-mark distinct, rays extending to ± two-thirds of radial distance; coni small, regularly distributed, ± 50 along the circumference.

Description — Miospores usually circular, sometimes oval perhaps due to flattening. Y-mark has opened sutures with thin labra; rays of Y-mark equal in length. Exine covered with very small regularly distributed coni.

Discussion — In the small size of the spores and minute, low coni our species is distinct from any other described so far. The coni are very similar to those of *Planisporites spinulistratus* (Loose) Pot. & Kr. (1955, p. 71) which, however, is bigger in size and has a larger number of coni along the circumference.

SERIES — **Murornati** Pot. & Kr.
GENUS — ***Dictyotriletes*** (Naum.) Pot. & Kr.

Dictyotriletes sp.

Pl. 1, Fig. 6

Description — A single spore measuring about 84 μ; appearing ovate, perhaps due to preservation. Exine reticulate, reticulations seen only on one side (? distal), the other being smooth; muri about 3 μ wide, enclosing 18 or 19 irregular, thin and smooth lumina. Y-mark not seen.

Discussion — Because of the characteristic reticulations with low muri (not showing any projections in the outline) the spore is assigned to *Dictyotriletes*. Professor Potonié has informed us that in this genus the Y-mark is not seen in most of the specimens.

As there is only one rather incomplete specimen available, no specific name has been given to it. It shows resemblance with *D. mediareticulatus* (Ibr.) Pot. & Kr. (1955, PL. 16, FIGS. 314-315, p. 110) in size and number of meshes.

DIVISION — **Monoletes** Ibrahim
SUBDIVISION — **Azonomonoletes** Luber
SERIES — **Psilamonoleti** v.d. Hammen
GENUS — ***Laevigatosporites*** Ibrahim

Laevigatosporites minor (Loose) Pot. & Kr.

Pl. 1, Figs. 4, 5

Description—Spores bean-shaped, measuring 53-65 μ in the longer axis. Exine infrapunctate, sometimes folded. Monolete mark more than half the length of the spore; slit narrow; ends not bifurcated; labra thin.

Discussion — On the few visible characters of the genus (especially the size) on which the specific differences are based, these spores show identity with *L. minor*, and hence must be placed under the same species. It is, however, open to question whether in Palaeozoic times a species occurring in Europe would also be found in India.

SUPERDIVISION — **Pollenites** R. Pot.
DIVISION — **Saccites** Erdtman
SUBDIVISION — **Disaccites** Cookson
SERIES — **Striatiti** Pant
GENUS — ***Striatites*** Pant

Striatites sewardi Pant

Pl. 1, Figs. 7, 8

Description — Bisaccate spores measuring $55\text{-}96 \times 41\text{-}46$ μ (including sacci). Body $\pm$ rounded, measuring approximately 32 μ in diameter, with 4-6 horizontal striations. Bladders larger than the body, approaching closer on the dorsal side, leaving a narrow slit in between.

Discussion — These diploxylonoid spores seem identical in their structure with one (VIRKKI, 1937, TEXT-FIG. 2A) selected by Pant (1955, p. 762) as the type specimen for *Striatites sewardi*. However, the Bacchus Marsh Tillite spores included by Pant (loc. cit., PL. XIX, FIGS. 3-5) under the same species seem to be different which, judging from his illustrations, appear to be haploxylonoid. But for their larger size, Pant's spores resemble more the genus *Lunatisporites* Leschik (1955) which has characteristic haploxylonoid forms.

Striatites renisaccatus n. sp.

Pl. 1, Fig. 9

Holotype — Pl. 1, Fig. 9; Reg. No.— M.G.T./20; Slide No. 27/3.

Diagnosis — Disaccate spore; holotype 107×73 μ (sacci included); body round, ± 60 μ in diameter; body-wall with 6-8 transverse striae, some bifurcating and anastomosing with the adjacent ones.

Description — The body is almost circular and quite distinct; dehiscence mark not seen. Exine reticulate; meshes regular and fairly broad. Sacci infrareticulate, distally pendant, almost overlapping the body on both sides.

Discussion — The almost circular body with bifurcating and anastomosing striae and characteristic reniform sacci distinguish this species from the already known ones.

Striatites kumaonensis n. sp.

Pl. 1, Fig. 13

Holotype — Pl. 1, Fig. 13; Reg. No.— M.G.T./20; Slide No. 32/2.

Diagnosis — Disaccate spore; holotype 99×66 μ (sacci included); body oblate-rounded, 66×60 μ, with ± 8 transverse striae; sacci subcircular, slightly larger (about 66 μ) than the body along the vertical axis but shorter (about 47 μ) horizontally, giving almost a haploxylonoid appearance; a narrow vertical slit visible on the body.

Description — The oblately rounded body is comparatively larger than the individual sacs. The sacs are, however, slightly larger along the vertical axis, just giving the spore a diploxylonoid shape which would otherwise have been haploxylonoid. Exine of the body granular, sacci infrareticulate.

Discussion — In the almost haploxylonoid shape of the spores, with a comparatively larger body bearing a vertical slit, this species is quite different from the others described so far.

The specific name is based on "Kumaon" the hill division in which the locality of these shales lies.

Striatites sp.

Pl. 1, Fig. 12

Description — Bisaccate spore measuring 69×34 μ (including sacci). Body oblate, measuring $43 \times 22\ \mu$, with 4 prominent transverse striae appearing to extend over the sacs. Sacs rounded, about $34\ \mu$ in diameter, inclined distally. Exine reticulate, reticulation finer on the body, slightly coarser on the sacs.

Discussion — The spore is obviously lying in an oblique proximal view. From its general shape and size, especially the distally inclined rounded sacs, it most probably belongs to *S. sewardi*. But the proportionately much wider body with transverse striae, seemingly extending beyond the limits of the body on to the sacs, is an interesting feature which is not known to occur in *S. sewardi*. Perhaps this difference is only due to a different view of the spore which in equatorial view would be similar to the commonly known spores of *S. sewardi*. Spores similar to ours have been reported by Virkki (1946, PL. 7, FIGS. 90, 96) from the Lower Gondwana rocks of the Salt Range, Pakistan, and by Ghosh & Sen (1948, PL. 3, TEXT-FIG. 2) from the Raniganj Coalfield of Bihar, India.

GENUS — *Lunatisporites* Leschik

Lunatisporites sp.

Pl. 1, Fig. 11

Description — Bisaccate haploxylonoid spores, measuring $\pm 125 \times 105\ \mu$ (including sacci). Body broadly elliptical, $\pm 105 \times 75\ \mu$, having 8-10 transverse striae, sometimes bifurcating and anastomosing adjacently. Sacci large, $\pm$ semicircular, almost covering the body except for a narrow vertical strip. Exine reticulate, thinly on the body and coarsely on the sacs; muri of the reticulations on the external margins of the sacs elongated radially, appearing radially ridged in high focus.

Discussion — The haploxylonoid form and general shape of the spores with large semicircular sacs indicate their identity with the genus *Lunatisporites*. The spores seem to be laterally compressed to various degrees as is apparent from the elliptic shape of the body, and the sacs almost meeting each other in the middle of the spores. Because of this *anomaly* in their preservation it is not considered right to create a new species for them. The spores illustrated by Pant (1955, PL. 19, FIGS. 3-5) from the Bacchus Marsh Tillites of Australia as *Striatites sewardi* are very similar to our spores except for the reticulations of the sacs. We feel that because of the haploxylonoid form of his spores, they should be assigned to *Lunatisporites* rather than to *Striatites*.

GENUS — *Striatopodocarpites* (SORIT. & SEDOWA) R. Pot.

Striatopodocarpites fusus (Balme & Henn.) R. Pot.

Pl. 1, Fig. 10

Description — Bisaccate spores, measuring $\pm 133 \times 96\ \mu$. Body thick, oblately rounded, $\pm 60 \times 47\ \mu$, with 5-6 faintly discernible striae. Sacci large, subcircular, almost covering the body except for a very narrow vertical strip appearing as a slit. Exine of the sacci having internal reticulum; the lumina of the meshes bearing 4-6 small rods or perforations.

Discussion — In their general shape and size and the large characteristic sacs, these spores are indistinguishable from those described by Balme and Hennelly (1955, p. 92, PL. 1, FIGS. 6-10) from the Permian coals of Australia. They had placed them under the species *Lueckisporites fusus* but in his recent synopsis of the genera of sporae dispersae Potonié (1958, p. 54) has assigned them to the genus *Striatopodocarpites*.

The spores represented in Pl. 3, Figs. 1, 3, 4 and 6 by Ghosh & Sen (1948) from Raniganj coal appear to be identical with this species.

Potonié (l.c.) has listed *Striatopodocarpites* under " $\pm$ Haploxylonoide Formen " but the spores of *S. fusus* are prominently diploxylonoid.

Striatopodocarpites gondwanensis n. sp.

Pl. 1, Figs. 14-16

Holotype — Pl. 1, Fig. 15; Reg. No.— M.G.T./20; Slide No. 7/2.

Diagnosis — Bisaccate spores, measuring $85\text{-}100 \times 50\text{-}65\ \mu$, holotype $97 \times 52\ \mu$; body round to subcircular, 30-45 μ in diameter (holotype 40 μ); body-wall having 8-10 transverse striae, some bifurcating and joining adjacently; a number of short rod-like striations occurring regularly across the transverse striae; sacci large, circular, ornamented with coarse reticulum.

Description — This is the commonest type of spores found in our sample. The body is, in most cases, almost circular. The short cross-striations between the transverse striae are very characteristic. The reticulations on the sacs in parts seem to be radially orientated.

Discussion — The large, almost circular, sacs covering a round striated body is indicative of the identity of these spores with *Striatopodocarpites*. The short rod-like striations across the transverse striae are a characteristic feature of this species, which has not been observed in any other species of this genus. Hence it is given a new name.

SERIES — **Disacciatrileti** (Leschik) R. Pot.

GENUS — ***Pityosporites*** (Seward) Pot. & Kl.

***Pityosporites potoniei* n. sp.**

Pl. 2, Figs. 18-20

Holotype — Pl. 2, Fig. 18; Reg. No.— M.G.T./20; Slide No. 27/5.

Diagnosis — Bisaccate spores, $\pm$ oval, measuring 90-135 $\times$ 65-112 μ, holotype 133×112 μ; body indistinct, $\pm$ subcircular; sacci large, covering the body, leaving a very narrow vertical strip; exine reticulate, reticulations fine towards the centre, coarser and slightly elongated towards the periphery.

Description — The spores of this type are quite common in our material. They are rather transparent obviously due to overmaceration. Originally the body-wall must have been thin because it is difficult to make out its outline in these spores. The sacci cover the body so completely and meet each other so closely, that except for a very narrow vertical strip, which too is in some cases quite indistinct, the spores appear to be monosaccate.

Discussion — In size and general shape of the spores, with the sacs leaving a very narrow, sometimes almost indistinct, vertical strip in between, this species is different from the already known ones.

Of the spores described as *Florinites eremus* by Balme & Hennelly (1955) from the Permian of Australia, those illustrated in Pl. 5, Figs. 46, 47 seem to have a narrow vertical strip as in our spores. In other characters also they appear to be very similar to the spores of *P. potoniei*.

It is named after Professor Dr. R. Potonié in gratitude for his kind help in the identification of our spores.

***Pityosporites* (*Florinites*) *ovatus* (Balme & Hennelly, 1955) n. comb.**

Pl. 1, Fig. 17

Holotype — Balme & Hennelly, 1955, Pl. 5, Fig. 49.

Paratypes — Balme & Hennelly, 1955, Pl. 5, Fig. 51; Present paper, Pl. 1, Fig. 17; Reg. No.— M.G.T./20; Slide No. 2/6.

Emended Diagnosis — Bisaccate spores, $\pm$ oval in outline, measuring 46-74 $\times$ 36-65 μ; body faintly discernible, broadly elliptical to oval (short axis 28-48 μ); sacci almost covering the body leaving a very narrow vertical strip in between; exine finely reticulate.

Description — As in *P. potoniei* the body-wall in this species also seems to have been fairly thin. The body is characteristically covered by the sacs giving the spores a seemingly monosaccate appearance.

Discussion — The spores figured by Balme & Hennelly (1955, PL. 5, FIGS. 49-52) as those of *Florinites ovatus* are so much similar to our spores as represented in Pl. 1, Fig. 17, that there seems to be no doubt about their being identical. In all these spores the 2-winged nature is quite clear and hence their reference to *Florinites* is not justified. On the basis of their general characteristics we are here assigning them to the bisaccate genus *Pityosporites*.

GENUS — ***Succinctisporites*** Leschik

***Succinctisporites ovalis* n. sp.**

Pl. 2, Figs. 21, 22

Holotype — Pl. 2, Fig. 22; Reg. No.— M.G.T./20; Slide No. 5/1.

Diagnosis — Spores oval in shape, 65-85 $\times$ 55-65 μ, holotype 85×65 μ; body thick, oval, about 54×37 μ (holotype 52×43 μ); ? having ± 6 striations transverse to the longer axis; surrounded by a sac bearing a notch on one side approaching bisaccate condition.

Description — The outline of the spore and its body are oval; the body is fairly thick and stands out from the thinner background of the sac. A strange feature is the occurrence on the body of striations which are transverse to the longer axis of the spore (*see* PL. 2, FIG. 21). These striations are, however, not prominent in all the spores, perhaps due to varying degrees of maceration. The exine of the sacs is reticulate, reticulum formed of irregular meshes.

Discussion — A thick body surrounded by a sac bearing a notch on one side (approaching disaccate condition) points to the identity of these spores with *Succinctisporites*. The size and general shape of these spores, especially a regularly oval outline of the body with striations, distinguish them from all the previously known species. There are clear indications of the occurrence of striations on the body in *S. interruptus* Leschik (1955, PL. 7, FIG. 5), but the outline of the body in this species is circular. In general shape and size *S. grandior* Leschik (1955, PL. 7, FIG. 12) somewhat approaches our species although it is slightly larger and does not seem to have the striations on the body.

SERIES — ***Pinosacciti*** (Erdtman) R. Pot.
GENUS — ***Alisporites*** Daugherty

Alisporites phaselosaccatus n. sp.

Pl. 2, Figs. 24-26

Holotype — Pl. 2, Fig. 24; Reg. No.— M.G.T./20; Slide No. 25/3.

Diagnosis — Bisaccate spores, measuring 85-95 × 68-75 μ (including sacci), holotype 92×73 μ; body subcircular, fairly thick, about 39 μ in diameter, with a vertical fusiform furrow; sacci large, bean-shaped, reticulately ornamented.

Description — The large sacs of these spores are very characteristic in being bean-shaped. The muri of the reticulations on the wings are quite broad giving the exine a thick appearance.

Discussion — The vertical fusiform furrow on the body in between two large reticulately ornamented sacs are indicative of the identity of these spores with *Alisporites*. However, the bean-shaped sacs, so characteristic of our spores, have not been observed in any other species of this genus and hence they are assigned to a new species.

SERIES — **Podocarpoiditi** Pot., Thoms. & Thierg.
GENUS — ***Platysaccus*** (Naum.) Pot. & Kl.

Platysaccus tenuis n. sp.

Pl. 2, Fig. 23

Holotype — Pl. 2, Fig. 23; Reg. No.— M.G.T./20; Slide No. 11/5.

Diagnosis — Bisaccate spores, measuring about 187×62 μ (holotype) including sacs; body rather thin, ± circular, about 38 μ in diameter; rim narrow about 1·5 μ thick; sacci large, broadly oval with faint radial striations towards the body; exine thin, infrareticulate.

Description — The sacs are comparatively much larger than the body, each measuring about 62×45 μ. In general the spores appear rather thin.

Discussion — Usually the body in *Platysaccus* is quite thick but in our spores it is rather thin. On the basis of this character and their general shape and size these spores are assigned to a new species.

Platysaccus crassimarginatus n. sp.

Pl. 2, Fig. 27

Holotype — Pl. 2, Fig. 27; Reg. No.— M.G.T./20; Slide No. 3/1.

Diagnosis — Bisaccate spores, measuring ± 74×60 μ (holotype) including sacci; body thick, circular, ± 38 μ in diameter, granular, with a thick rim about 5-6 μ wide; sacci large, rather bean-shaped, reticulate, with radial striations arising from the proximal margins.

Description — In outline the sacs are almost semicircular with rounded edges. Proportionate to the body they do not seem to be as big as in the other species of this genus. The reticulations on the sacs are fairly big.

Discussion — A characteristic feature of these spores is the thick rim of the body which has not been observed in any other species of *Platysaccus*.

Platysaccus sp.

Pl. 2, Fig. 28

Description — Bisaccate spore, about 65×42 μ (including sacci). Body thick, ± circular, about 26 μ in diameter. Sacci oblately circular, overlapping the body. Exine infrareticulate with almost rounded lumina.

Discussion — Although looking quite characteristic, this spore seems to be preserved in the distally polar view, the wings covering the body. In this state of preservation it is not possible to trace its exact affinities. However, because of the large circular sacs and a small, thick, circular body it most probably belongs to *Platysaccus*.

PLANTAE INCERTAE SEDIS

SEED

Pl. 2, Fig. 29

A few seed-like bodies were recovered but unfortunately none of them is complete and well enough preserved to throw light on their affinities. The specimen figured here is the upper part of a broken seed consisting of a dark nucellus surrounded by a thin integument. The pointed end at the top looks very much like the micropylar end. The specimen, as preserved, measures about 900 μ in length and about 800 μ in width. The integument is translucent and formed of rectangular cells, about 50×18 μ in size, with sinuous walls. Near the ?micropylar end the cell walls are not sinuous but straight. At this end the cells seem to surround an irregular pore, but this may be only due to rupturing of the integument in preservation. The cells of the nucellus are dark, rounded-polygonal, with thick cell walls.

FRAGMENTS OF WOOD

A large number of wood fragments were recovered. They show a considerable range of pitting and are described here to complete the flora as far as possible. The majority of the fragments belong to coniferous woods.

Type 1

Pl. 3, Fig. 39

The fragment is the part of a wood in radial view. The tracheids are short showing 2- to 4-seriate, circular bordered pits. When biseriate, the pits are either separate or contiguous and opposite or sub-opposite; when 3- to 4-seriate, they are contiguous, sub-opposite or alternate and slightly flattened to hexagonal shape. They measure 14-15 μ in diameter. The pores are large and circular. Rims of Sanio are distinctly seen. Pits in the field are circular and 2-6 in number, with elliptical pores generally placed horizontally, sometimes slightly oblique.

Type 2

Pl. 3, Figs. 36, 38

Fragments showing tracheids with 2- to 3-seriate, alternate, contiguous, circular or flattened bordered pits, about 15 μ in diameter. The pores are circular, about 6 μ in diameter. The wood is comparable to some of the *Dadoxylon* types.

Type 3

Pl. 3, Fig. 35

A fragment showing a part of a tracheid with 3- to 4-seriate bordered pits. The pits are contiguous and flattened transversely into hexagons. They measure 18×32 μ. The pores are comparatively large, oval, measuring about 13×8 μ.

Type 4

Pl. 3, Fig. 37

A part of a tracheid showing scalariform thickening and a few bordered pits. The scalariform thickenings occupy the whole width of the tracheid and measure 3·5-4·5 μ in breadth and 18-20 μ in length. This tracheid is probably a part of the primary element of a coniferous wood.

CUTICULAR FRAGMENTS

Type 1

Pl. 3, Figs. 33, 34

The fragment is a part of a moderately thick cuticle having stomatiferous and non-stomatiferous bands. The epidermal cells of the non-stomatiferous bands are rectangular, much longer than broad with lateral and end walls thick and almost straight, at places slightly undulated. The surface walls are smooth or papillate. Cells of the stomatiferous region are polygonal, thin-walled and of various shapes and sizes. The lateral and end walls sinuous or slightly wavy. Surface walls thickened; in some definite, solid, circular papillae are visible. The stomata are few and longitudinally placed. Subsidiary cells, 5-6 in number, having a dumb-bell shaped or oval opening (Pl. 3, Fig. 34). Guard cells sunken, mostly not preserved, but when preserved, thinly cutinized.

Type 2

Pl. 3, Fig. 31

The fragment is the part of a cuticle devoid of stomata. The epidermal cells are rectangular or polygonal. Cell-walls thin and markedly sinuous. Some cells having cuticular thickenings on the surface wall. This type is fairly common in the shale.

Type 3

Pl. 3, Fig. 32

Fragment of a cuticle devoid of stomata. The cells are mostly rectangular, a few polygonal and arranged in series. Lateral and end walls thick, straight or slightly wavy at places. Surface walls with numerous, small, oval, circular or irregular thickenings. Very common.

Type 4

Pl. 3, Fig. 30

A small piece of cuticle without stomata. The cells are elongated, rectangular or polygonal. Lateral and end walls fairly thick and almost straight, very rarely slightly wavy. Surface wall with a small oval thickening in the centre.

DISCUSSION

Elements of the Flora — The microflora comprises a large number of dispersed spores, fragments of wood, small pieces of cuticles and a few stray seeds. Apart from a number of unidentifiable forms, the following 18 species of sporae dispersae, belonging to 11 genera, have been recognized.

I Super division: Sporites
  Division: Triletes
  Subdivision: Azonotriletes
  1. *Calamospora* sp.
  2. *Planisporites parvus* n. sp.
  3. *Dictyotriletes* sp.
  Division: Monoletes
  Subdivision: Azonomonoletes
  4. *Laevigatosporites minor* (Loose) Pot. & Kr.

II Superdivision: Pollenites
  Division: Saccites
  Subdivision: Disaccites
  5. *Striatites sewardi* Pant
  6. *S. renisaccatus* n. sp.
  7. *S. kumaonensis* n. sp.
  8. *Striatites* sp.
  9. *Lunatisporites* sp.
  10. *Striatopodocarpites fusus* (Balme & Hennelly) R. Pot.
  11. *S. gondwanensis* n. sp.
  12. *Pityosporites potoniei* n. sp.
  13. *P.* (*Florinites*) *ovatus* (Balme & Hennelly) n. comb.
  14. *Succinctisporites ovalis* n. sp.
  15. *Alisporites phaselosaccatus* n. sp.
  16. *Platysaccus tenuis* n. sp.
  17. *P. crassimarginatus* n. sp.
  18. *Platysaccus* sp.

Of these *Striatopodocarpites gondwanensis* is the most abundant. *Pityosporites potoniei* is also quite common. The next in order of frequency are the spores of *Alisporites phaselosaccatus*, *Platysaccus tenuis* and *Lunatisporites* sp. The rest of the spore types occur sporadically.

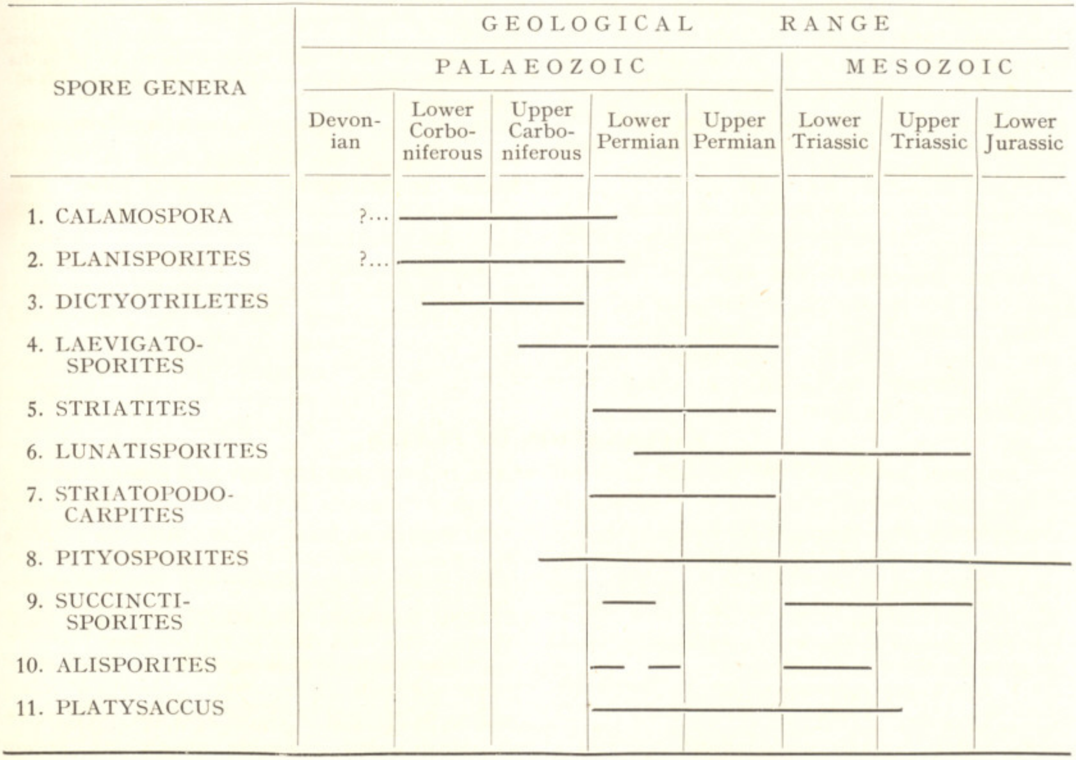
The pieces of wood and cuticles, although fairly common, are fragmentary in nature and hence unidentifiable. Similarly the few imperfectly preserved seed-like bodies are also not identifiable.

Age of the Beds — As already mentioned, the age of the Blainis is regarded as Permo-Carboniferous and that of the Infra-Krols and Krols as Permian. This correlation is based on the probable parallelism of the sequence of rock groups composing the Krol belt with those of the Infra-Triassic formations of Kashmir-Hazara and Salt Range. However, as pointed out by Krishnan (1956, p. 346) " there is little lithological similarity between the rocks of the two areas ". Thus, the above inference regarding the age of the Krols is " a mere conjecture ". The observations based on the present microflora thus furnish the first direct and fairly conclusive evidence towards this problem.

In general aspect, the microflora as a whole fits in the Permo-Carboniferous of the Gondwanaland. More or less similar looking microfossils have been reported from the Jharia (Permo-Carboniferous) and Raniganj (Permian) coalfields in Bihar and Pali beds (Upper Permian) in Central India. The spores described by Balme & Henelly (1955) from the Permian coals of Australia also bear general resemblance with ours. Dr. M. N. Bose, who has just completed, in collaboration with Professor O. A. Höeg, an investigation of the Permo-Carboniferous plant fossils of Belgian Congo, tells us that our microfossils look similar to those of Congo.

On considering the geological distribution of the spore genera represented in our sample (TABLE 1) a more definite idea of age can be obtained. The genera *Calamospora, Planisporites* and *Laevigatosporites* are known from Carboniferous to Permian. *Pityosporites* has been recorded from uppermost Carboniferous upwards through all the geological horizons. *Dictyotriletes* is so far reported only from the Carboniferous. *Striatites* and *Striatopodocarpites* are found in Permian. *Lunatisporites, Succinctisporites, Alisporites* and *Platysaccus* have been described from

TABLE 1 — CHART SHOWING THE GEOLOGICAL RANGE OF DISTRIBUTION OF SPORE GENERA FOUND IN KROL SHALE



Permian and Triassic. It is evident that the majority of these genera have distribution in the Permian, more towards the upper horizons. Our commonest species, *Striatopodocarpites gondwanensis*, belongs to a Permian genus. The next frequent species, *Pityosporites potoniei*, also belongs to a genus occurring in uppermost Carboniferous to lowermost Triassic beds. The other common species, *Alisporites phaselosaccatus*, *Platysaccus tenuis* and *Lunatisporites* sp., all belong to genera found from Permian to Triassic. The geological record of the spores allied to those common in our shale, therefore, points towards a Permian age. As very little work has been done on the stratigraphical application of spores in India, it is not possible to derive a more precise conclusion.

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EXPLANATION OF PLATES

(Specimen No. M.G.T. 20; All slides preserved at the Birbal Sahni Institute of Palaeobotany)

PLATE 1

1. *Calamospora* sp. Slide No. 24/3. × 500.

2. *Planisporites parvus* n. sp. (Holotype). Slide No. 2/4. × 500.

3. *Planisporites parvus* n. sp. (Paratype). Slide No. 2/11. × 500.

4, 5. *Laevigatosporites minor* (Loose) Pot. & Kr. Slide Nos. 13/3 & 20/5. × 500.

6. *Dictyotriletes* sp. Slide No. 12/10. × 500.

7, 8. *Striatites sewardi* Pant. Slide Nos. 23/1 & 27/2. × 500.

9. *Striatites renisaccatus* n. sp. (Holotype). Slide No. 27/3. × 500.

10. *Striatopodocarpites fusus* (Bal. & Henn.) Pot. Slide No. 10/2. × 500.

11. *Lunatisporites* sp. Slide No. 19/2. × 500.

12. *Striatites* sp. Slide No. 1/8. × 500.

13. *Striatites kumaonensis* n. sp. (Holotype). Slide No. 32/2. × 500.

14. *Striatopodocarpites gondwanensis* n. sp. (Paratype). Slide No. 24/4. × 500.

15. *Striatopodocarpites gondwanensis* n. sp. (Holotype). Slide No. 7/2. × 500.

16. *Striatopodocarpites gondwanensis* n. sp. (Paratype). Slide No. 10/3. × 500.

17. *Pityosporites* (*Florinites*) *ovatus* (Bal. & Henn.) n. comb. (Paratype). Slide No. 2/6. × 500.

PLATE 2

18. *Pityosporites potoniei* n. sp. (Holotype). Slide No. 27/5. × 500.

19, 20. *Pityosporites potoniei* n. sp. (Paratypes). Slide Nos. 28/2 & 23/4. × 500.

21. *Succinctisporites ovalis* n. sp. (Paratype). Slide No. 1/10. × 500. Retouched to show the striations on the body.

22. *Succinctisporites ovalis* n. sp. (Holotyp). Slide No. 5/1 × 500.

23. *Platysaccus tenuis* n. sp. (Holotype). Slide No. 11/5. × 500.

24. *Alisporites phaselosaccatus* n. sp. (Holotype). Slide No. 25/3. × 500.

25, 26. *Alisporites phaselosaccatus* n. sp. (Paratypes). Slide Nos. 10/1 & 22/3. × 500.

27. *Platysaccus crassimarginatus* n. sp. (Holotype). Slide No. 3/1. × 500.

28. *Platysaccus* sp. Slide No. 20/1. × 500.

29. Seed-like body, showing a dark nucellus surrounded by a thin integument. Slide No. 36. × 100.

PLATE 3

30. Cuticle Type 4. Note surface wall of each cell having a small oval thickening in the centre. Slide No. 37/3. × 100.

31. Cuticle Type 2. Note the sinuous cell-walls of the epidermal cells. Slide No. 39/1. × 100.

32. Cuticle Type 3. Surface walls of the epidermal cells with numerous, small thickenings. Slide No. 40/4. × 100.

33. Cuticle Type 1. Showing a few stomata and the cuticular papillae. Slide No. 39/2. × 150.

34. Cuticle Type 1. Enlarged to show a stoma with a dumb-bell shaped opening. Slide No. 39/2. × 500.

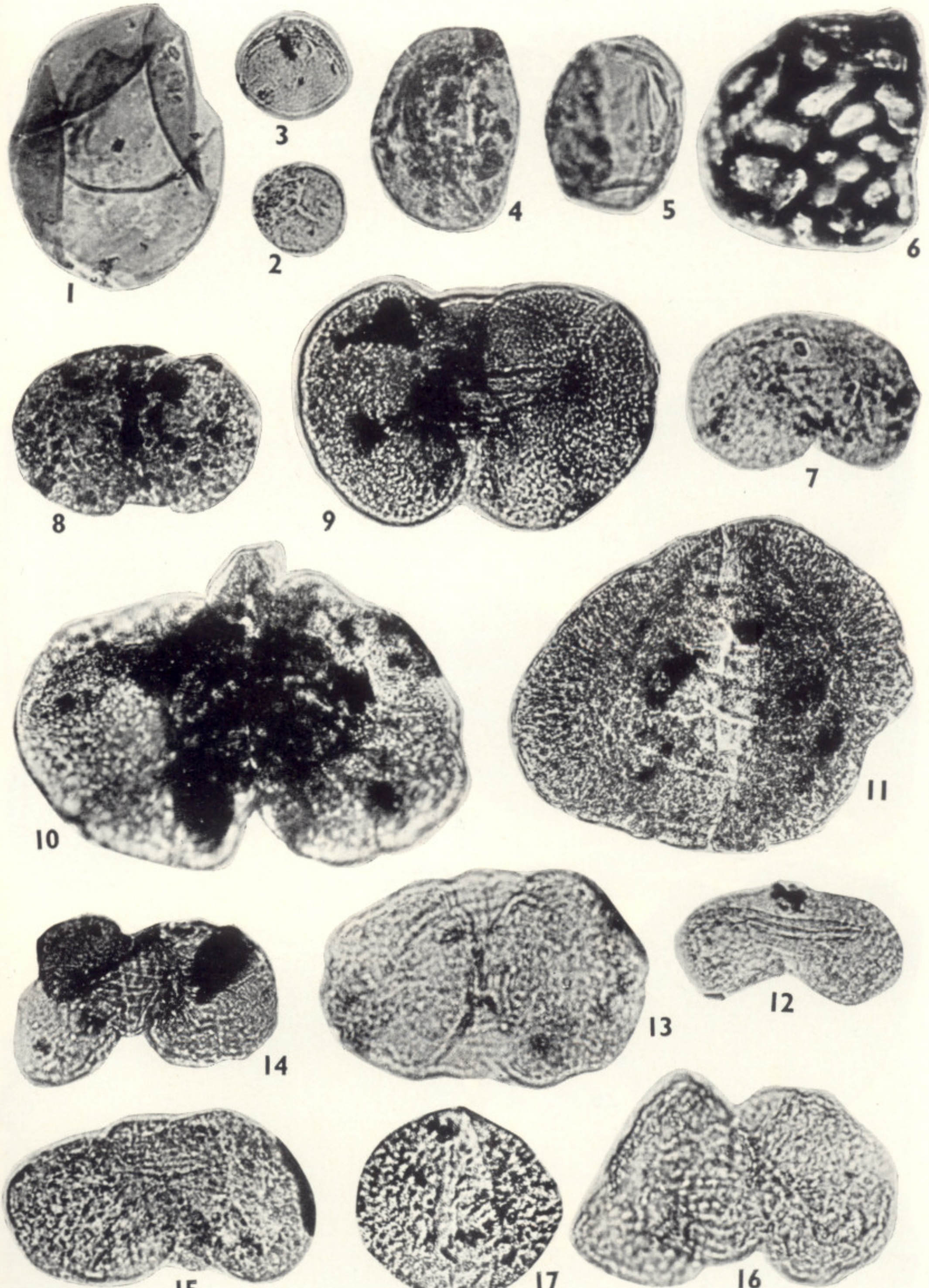
35. A part of a tracheid with 3- to 4-seriate, bordered pits. Slide No. 16/1. × 250.

36. Fragment showing 2- to 3-seriate, alternate, contiguous, circular bordered pits. Slide No. 17/5. × 250.

37. Another fragment showing scalariform pitting. Slide No. 12/5. × 250.

38. A wood fragment showing tracheids with 2-seriate, alternate, contiguous ond flottened bordered pit. × 250.

39. Part of a wood in radial view showing pitting in the tracheids and the medullary rays. Note the Bars of Sanio. Slide No. 37/1. × 200.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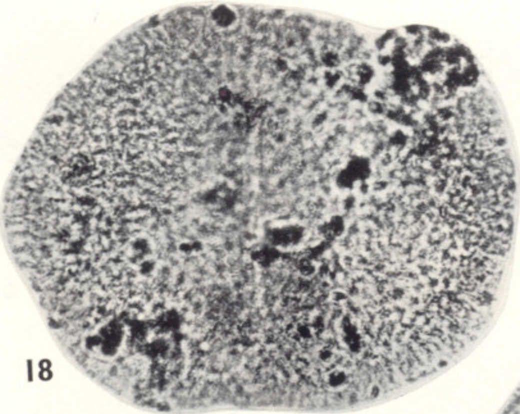
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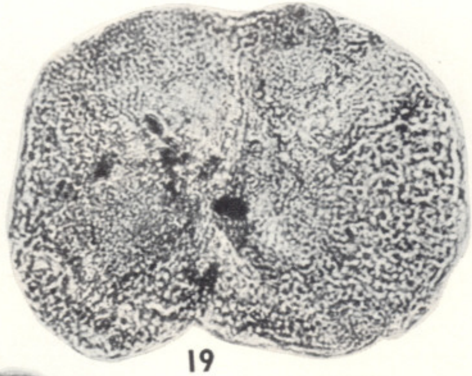
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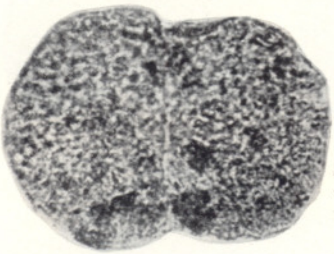
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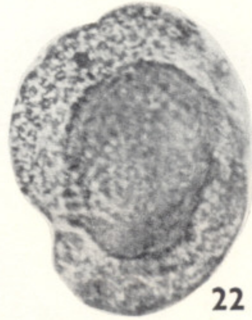
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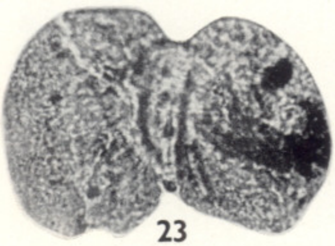
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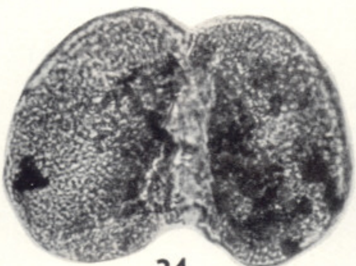
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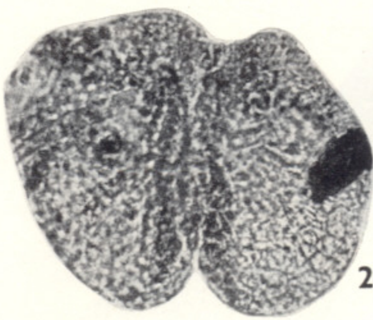
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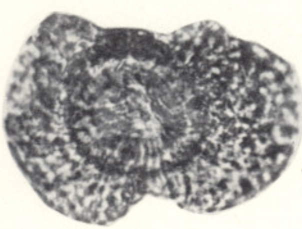
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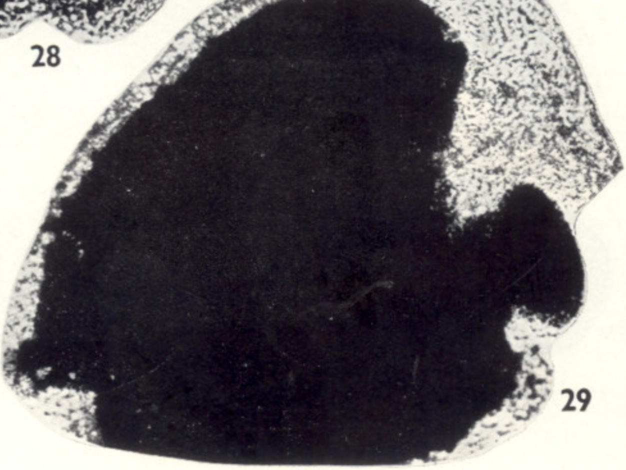
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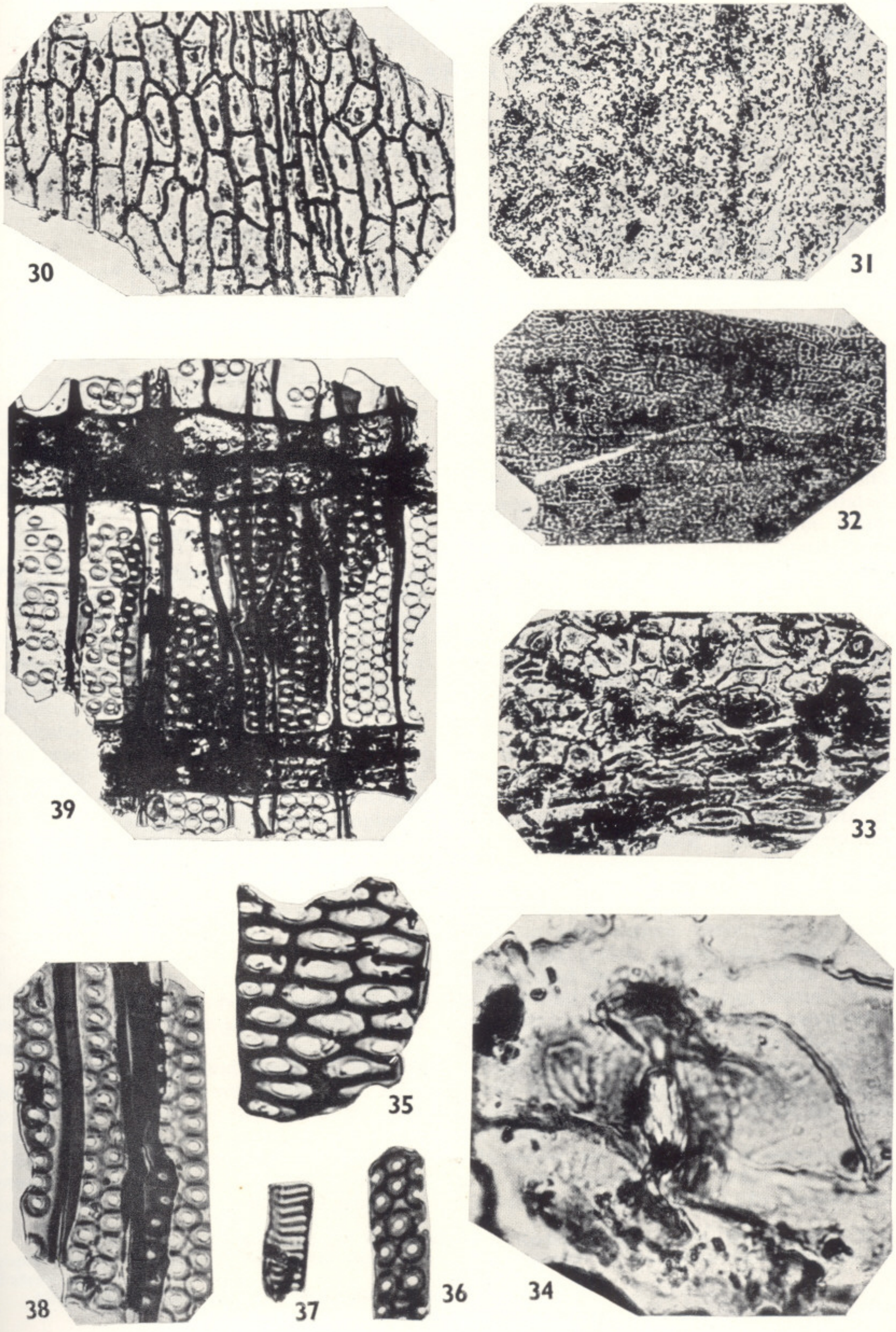
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