PLANT MICROFOSSILS FROM A JURASSIC SHALE OF SALT RANGE, WEST PUNJAB (PAKISTAN)

S. C. D. SAH
Birbal Sahni Institute of Palaeobotany, Lucknow

ABSTRACT

The paper describes a rich variety of microfossils obtained by maceration from the variegated shale of the Salt Range. The microflora includes several kinds of spores, both winged and unwinged; few megaspore-like bodies; fragments of wood; and several cuticular pieces. The spores are mostly pteridophytic and coniferous, the cycadophytic grains being rare. Among the large number of cuticles considerable proportion are of the *Brachyphyllum* and *Pagiophyllum* type, indicating that coniferales were strongly represented in the flora. Others with sinuous epidermal cells and syndetocheil type of stomata, suggesting a Bennettitalean affinity, are least represented.

The spores and pollen grains are described under Naumova's (1937) artificial system. New subgroups have been proposed for spores and pollen grains which do not fit in any of the known subgroups. The microflora as a whole suggests a middle Jurassic age for the variegated shale.

INTRODUCTION

THE Salt Range has long been known as one of the most interesting and classical areas, both geologically and palaeontologically, and attracted the attention of geologists as early as the beginning of the nineteenth century. It, however, came into much prominence during the early part of the present century, mainly due to the controversy on the age of the Saline Series (*see* Symposia on the Age of the Saline Series, 1944, 1946).

The spores and other plant fragments described in this paper were recovered from a carbonaceous shale in the variegated stage of the Nammal Gorge (lat. 32°39′18″: long. 71°51′47″), about 2 miles N.E. of Moosakhel, Mianwali district, W. Punjab (*see* Survey of India Sheet No. 38 P/14). This shale was collected by Dr. R. V. Sitholey, along with some other plant fossils, in 1946. He very kindly passed on this shale to me for microfossil investigation.

Plant microfossils, as far as I am aware, have not been recorded from Jurassic rocks of the Salt Range. From other parts of India also, the only Jurassic microfossils known are from the petrified cherts of Nipania in the Rajmahal Hills, Bihar (RAO, 1936, 1943; VISHNU-MITTRE, 1954). A rich microflora has been recently recovered by me from Sakrigalighat in the Rajmahal Hills (*unpublished*).

Plant impressions recorded from the Jurassic beds of the Salt Range are few as compared to the richness of the Jurassic flora of other parts of India. In 1880 Feistmantel recognized *Ptilophyllum* (?) *acutifolium* Morr. and *Podozamites lanceolatus* var. *eichwaldi* Heer in a small collection of plant fragments from Sekh Budin.

Sahni and Sitholey (1945, p. 62) mention '*Pecopteris*' from Moosakhel while describing some plant compressions from Sakesar. Among the Sakesar plants are two new species of the genus *Phlebopteris* Brong., *P. indica* and *P. hirsuta*. Both these species are of interest for the present work as they are fertile and have yielded well-preserved spores (SAHNI & SITHOLEY, l.c., PL. 2, PL. 4). The other forms figured by them are three species of *Cladophlebis* (? *Phlebopteris*). In 1949 Sitholey described a new species of a Cyatheaceous tree fern, *Protopteris nammalensis*, from the variegated stage of the Nammal Gorge. Apart from these the other genera known are *Brachyphyllum*, *Otozamites* and *Pagiophyllum* (SITHOLEY, l.c., p. 2).

MATERIAL AND METHODS

The shale is fairly compact, greyish black in colour, fine-grained and distinctly laminated. It has a distinct sulphureous smell. This may be due to the proximity of the sulphuretted hydrogen springs at the base of sub-stage 4.

Under the microscope the shale is chiefly composed of minute inequigranular particles of quartz. The other constituent minerals are thin flakes of mica (probably muscovite) and small particles of limonite. The interstitial spaces are filled with minute dark-coloured particles, which have a ten-

dency to gather in clots or patches. These grains are of limonite, usually reduced to magnetite.

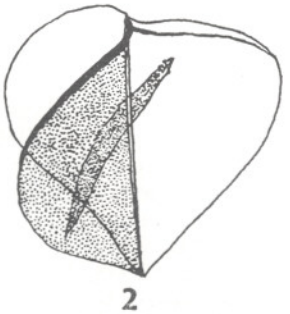
DESCRIPTION

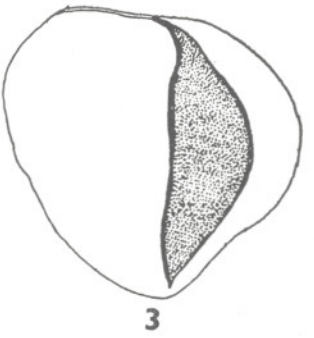
The spore types in the present paper are described under the terminology suggested in Naumova's artificial classification (1937). Many sub-groups include spores which are quite different from one another and may represent new genera or even families. The various sub-groups are used here only to indicate an aggregation of types. New sub-groups are proposed for spore types which cannot be classed under any sub-group. The group *Saccata* has been used by Naumova for coniferous pollen grains with two air sacks only, and so it is difficult to place the three-winged pollen grains of the *Podosporites* Rao type under it. Similarly, only a single sub-group has been created by Naumova (l.c.) under the group *Aletes*. Some of the present specimens lacking a germinal aperture show distinct characters in the ornamentation of the exine and hence cannot be described under a single sub-group.

Sporae

Class — *Rimales* Naum.
Sub-class — *Triletes* Reinsch.
Group — *Azonotriletes* Luber
Sub-group — *Leiotriletes* Naum.

This sub-group is represented by nine distinct types.





TEXT-FIGS. 1-3 — 1, spore showing rounded tubercles and the trilete. × 700. 2, 3, spores in different view showing the flap-like structures (wings ?). × 700.

Type 1

Pl. 1, Fig. 1

Size 58-72 μ, spore triangular in polar view, with pointed corners. Exine laevigate. Trilete mark prominent extending up to the periphery and bordered by a clear area. Spore wall 8-10 μ at the corners and about 2 μ at other places.

The spores figured here are identical, in their shape, size and the thickness of the spore wall, to those of *Phlebopteris hirsuta* described by Sahni and Sitholey (1945, Pl. 2, Figs. 8-9) from Sakesar. Very likely, these spores belong to *Phlebopteris hirsuta*, as the Sakesar plants also come from the Jurassic horizon of the Salt Range.

A large number of spores representing this type are found in the shale.

Type 2

Pl. 1, Figs. 3, 4

Size 54-57·5 μ, spore triangular in polar view with rounded corners. Exine laevigate. Trilete mark prominent, lips open, having a 4-6 μ wide dense border, nearly reaching the spore wall. From the structure seen in Fig. 3 it seems that the lips are raised and presumably the dense border observed in Fig. 4 is due to flattening of the raised lips. Spore wall fairly thick, measuring 4 μ.

Similar spores have also been figured from the Jurassic rocks of Ceylon (Sah, 1953, Pl. 1, Fig. 2). Several spores representing this type were recovered.

Type 3

Pl. 1, Figs. 8, 8a

Size 54 μ, spore triangular in polar view, corners rounded, sides concave. Exine smooth. Trilete prominent, lips open, nearly reaching the periphery (Fig. 8). Spore wall fairly thick and regular (Fig. 8a), measuring 7 μ at the corners and 6 μ at other places.

Type 4

Pl. 1, Figs. 12, 13

Size 40-50 μ, spore sub-triangular in polar view. Corners broadly rounded giving the spore a circular appearance. Exine laevigate. Trilete mark prominent, lips widely gaping when open and nearly reaching the spore wall. Spore wall 3-4 μ thick. Interray area thickened by folds as is also evident in Fig. 12.

Type 5

Pl. 1, Fig. 5

Size 30 μ, polar view triangular, corners round. Exine smooth. Trilete mark prominent, lips thin, extending to more than two-third of the radial distance. This spore is marked by the presence of triradial loops around rays, presumably formed by secondary folding of the spore wall.

In the small size and in its smooth exine the spore may be compared to those of *Selaginella Menziesii* (Knox, 1938, Fig. 10, p. 442), and also to *Plani-sporites priddyi* (Knox, 1950, Pl. 17, Fig. 220, p. 316).

Type 6

Pl. 1, Fig. 7

Size 40-47 μ, spore triangular in polar view, corners round, sides slightly concave. Exine smooth. Trilete mark distinct, lips slightly open, nearly extending to the spore wall.

The spore is comparable in its shape, size and smooth exine to those of *Coniopteris hymenophylloides* Brong., described by Thomas (1911, Pl. 3, Fig. 5); to those of *Thyrsopteris elegans* Kze. (Thomas, l.c., Fig. 7); to those of *Eboracia lobifolia* (Thomas, l.c., p. 387); and also to those of *Cladophlebis* (*Eboracia*) *lobifolia* (Sze, 1933, Pl. 11, Figs. 20-22). Comparable forms have also been figured by Knox (1938, Figs. 101, 119) belonging to Group D14 of Raistrick. This type is fairly common in the shale.

Type 7

Pl. 1, Fig. 10

Size 83 μ, spore spherical, walls thin and folded. Exine laevigate. Trilete mark very prominent, lips narrow, extending more than three-fourth of the radial distance.

A spore similar in shape and size (belonging to Group B_3 of Raistrick) has been figured by Knox (1938, Fig. 87) from the carboniferous coals. The spore, characterized by its large size, form, distinct trilete mark and its thin wall, approaches somewhat the spores of *Calamariaceae* (Knox, l.c., p. 461).

TYPE 8

Pl. 1, Fig. 14

Size 52 μ, spore irregularly rounded to sub-triangular, corners broadly rounded, walls thin and wrinkled. Exine smooth. Trilete mark distinct, extending to three-fourth of the radial distance.

TYPE 9

Pl. 1, Fig. 23

Size 48 μ, spore sub-triangular in polar view, sides somewhat convex. Exine laevigate. Trilete distinct, lips narrow, extending to the margin. Spore wall about 2 μ thick.

In its shape and laevigate exine the spore may be compared to those of *Selaginella nana* figured by Knox (1950, PL. 13, FIG. 107, p. 257). The spores of *S. nana* are, however, slightly smaller in size, ranging from 25 to 30 μ.

Sub-group — *Trachytriletes* Naum.

This sub-group is represented by three types.

TYPE 1

Pl. 1, Fig. 29

Size 48 μ, spore round to sub-triangular, corners broadly round. Exine minutely granular. Trilete mark distinct, lips narrow, extending to the margin. Spore wall about 2 μ thick.

The spore in its form, size and ornamentation is somewhat comparable to those of *Plani-sporites punctatus* described by Knox (1950, PL. 17, FIG. 213, p. 316).

TYPE 2

Pl. 1, Fig. 24

Size 79 μ, spore nearly spherical, walls thin, folded and wrinkled. Exine finely granular. Trilete mark fairly distinct, lips narrow, three-fourth of the radius in length.

Spores of *Calamariaceae* are spherical in form, thin-walled, rendering them liable to folding and wrinkling during fossilization, occasionally punctate, ranging from 70 to 130 μ (KNOX, 1938, p. 461). All these features are noticed in the spore figured here and may probably be indicative of a calamarian affinity.

TYPE 3

Pl. 1, Fig. 6

Size 38 μ, spore nearly spherical in polar view. Exine finely granular. Trilete mark faint, lips narrow, extending to the spore margin. Spore wall about 2 μ thick.

Spores comparable in form and size have been described as *Lycospora pusillus* by Knox (1950, FIG. 277, p. 328).

It is difficult to speak of the affinities of the spore figured here but it is possible that it may belong to the Lycopodiales.

Sub-group — *Lophotriletes* Naum.

TYPE 1

Pl. 1, Fig. 20

Size 68·5 μ, spore triangular in polar view, corners round. Exine closely covered with minute tubercles. Trilete mark prominent, lips narrow, extending to the spore margin. Spore wall fairly thick (*ca.* 4-6 μ). Several spores of this type were recovered.

TYPE 2

Pl. 1, Fig. 31

Size 65 μ, spore rounded to spherical in polar view. Exine thickly covered by short (3-7 μ), finger-like projections. Trilete mark distinct, lips narrow, extending to more than three-fourth of the radius.

Spores somewhat similar in form and sculpturing have been recorded from the Jurassic rocks of Ceylon (SAH, 1953, PL. 1, FIG. 15).

TYPE 3

Pl. 1, Fig. 28; Text-fig. 1

Size 68-86·5 μ, spore sub-triangular in polar view. Exine covered with rounded, large tubercles. Trilete mark clear, lips extending to about three-fourth of the radial distance, widened and frayed during compression (TEXT-FIG. 1). A large number of spores of this type are represented in the shale.

Fossil spore resembling somewhat in form and sculpturing have been recorded by Sahni, Sitholey and Puri (*Palaeobotany in India* — VI, PL. 14, FIG. 7) from the Brail Series (Lower Oligocene) of Assam.

In the general form and sculpturing of the exine the spore shows some similarity with

the spores of *Alsophila chimborazensis* figured by Knox (1938, Fig. 77, p. 455). Relatively large spores (80-115 μ) with somewhat similar sculpturing are found in some species of *Lygodium* (Knox, l.c., p. 447).

Sub-group — *Dictyotriletes* Naum.

Type 1

Pl. 1, Fig. 9

Size 65 μ, spore sub-triangular in polar view. Exine reticulate, with thin lamellae, meshes 3-4 μ. Trilete mark distinct, lips narrow, partly open, extending up to the margin. Spore wall 2-3 μ thick.

Sub-class — *Triletes* Reinsch
Group — *Zonotriletes* Waltz
Sub-group — *Hymenozonotriletes* Naum.

Type 1

Pl. 1, Fig. 17

Size 80-88 μ, monosaccate spore, circular to oval in polar view. Body 52-60 μ, partly covered by the sac, leaving a free central area. Exine in the free area finely reticulate. Bladder radially secondarily folded. Bladder wall indistinctly intra-reticulate.

Pollen grains with a single bladder encircling the body have been observed in *Podocarpus silvestris* (Florin, 1936, Textfigs. 4c, d, e, p. 639); *P. neriifolia* (Chatterjee, 1943, Pl. 13, Fig. 19); *Cedrus deodara* (Chatterjee, l.c., Pl. 5, Fig. 11); *Abies nobilis* (Wodehouse, 1935, Pl. 3, Fig. 8, p. 266) and in *Pinus excelsa* (Puri, 1945, Fig. 1, pp. 255, 256). The present specimen, however, differs from these in the general form and ornamentation of the exine.

Sub-group — *Stenozonotriletes* Naum.

Pl. 1, Fig. 27

Size 39 μ, spore circular to broadly triangular. Exine minutely granular. Trilete mark distinct, lips narrow, extending to the spore margin. Spore wall 3-4 μ. Equatorial flange thin, 1-2 μ broad.

In the general form, size and the sculpturing of the exine, the spore shows a striking resemblance with those of *Lycospora* S. W. and B. figured by Guennel (1952, Pl. 4, Fig. 4) from the Alleghenian coals (Pennsylvanian) of Indiana.

Class — *Rimales* Naum.
Group — *Monoletes* Ibr.
Sub-group — *Azonomonoletes* Luber

Type 1

Pl. 1, Fig. 15

Size 19×58 μ, spore elliptical, boat-shaped; possessing a single, median longitudinal furrow, lips narrow, extending from one end to the other. Exine smooth.

Boat-shaped spores with a single longitudinal furrow have been attributed to the Bennettitales (Wodehouse, 1935, p. 227). The spore may be compared in its general form and in having a single median longitudinal furrow to those of *Cycadeoidea etrusca* Cap. and Solms (Wieland, 1906, Fig. 83, Nos. 8-10; Wodehouse, l.c., Fig. 71, Nos. 1-5) and also to those of *Cycadeoidea dacotensis* (Wieland, l.c., Fig. 83, No. 14).

Type 2

Pl. 1, Fig. 30

Size 25-29 μ, spores bilateral, oval in shape, with a simple monolete suture, lips narrow and simple. Exine smooth. Spore coat thin and translucent.

These spores are probably equivalent to *Laevigatosporites* (Ibrahim) emend., S. W. and B. The size and form of the spore resemble those of *Phaseolites minimus* Wilson and Coe (1940, Fig. 5, p. 183).

Class — *Irrimales* Naum.
Group — *Aletes* Ibr.
Sub-group — *Trachyaletes* New sub-group

Type 1

Pl. 1, Fig. 25

Size 38 μ, spore spheroidal in outline. Exine finely granular. Germinal aperture not visible. Spore coat distinct, about 2 μ thick.

Sub-group — *Striatoaletes* New sub-group

Type 1

Pl. 2, Fig. 18

Size 36×47 μ, spore thin, rounded to ovate in outline. Exine characterized by rather large number of longitudinal, parallel to oblique, relatively thin and narrow stria-

tions. This type is very common in the shale and found in different planes but in none of them any germinal aperture is visible.

In the absence of a germinal aperture it is difficult to compare it with any member of the Filicales. However, spores possessing striations, symmetrical or asymmetrical, parallel or dichotomizing, are produced by the Schizeaceae and the Cyatheaceae. Within Schizeaceae both bilateral (SELLING, 1944, p. 6) and tetrahedral types are produced and the striations are symmetrically arranged (KNOX, 1938, pp. 447, 456). Bilateral spores are not met with in the Cyatheaceae and the striated forms, e.g. *Cyathea decipiens*, have asymmetrically arranged striations (KNOX, l.c., FIG. 82, p. 456).

Sub-group — *Liratoaletes* New sub-group

TYPE 1

Pl. 1, Figs. 11, 11a

Size 40 μ, spore circular to oval in outline. Exine coarsely granular (FIG. 11a). Outer wall in the middle region thrown into a spiral of narrow and distinct ridges round the spore body, like a girdle (FIG. 11). Germinal apertures not visible from any plane. Spore wall distinctly pitted, about 2-3 μ thick.

This is a rather characteristic spore but unfortunately only a single specimen was recovered.

TYPE 2

Pl. 1, Fig. 16

Size 36 μ, spore thin, rounded to oval in outline. Exine granular; about six narrow ridges seen crossing the spore-body, at one end. No germinal aperture visible. Spore wall smooth, about 4-5 μ thick.

In its general form and size, the spore considerably resembles that figured in Type 1.

Pollina

Class — *Aporosa* Naum.
Group — *Saccata* Naum.
Sub-group — *Oedemosaccus* Naum.

Pl. 1, Fig. 21

Size 36×56 μ, body circular, exine extended into two swollen bladders on either side. Surface of both the body and bladders finely reticulate. Body measures 35 μ. This type is fairly common in the shale.

Coniferous pollen with two wings are commonly referred to the genus *Pityosporites* Seward. Comparable forms have been recorded from the Nipania chert (Jurassic) of the Rajmahal Hills, Bihar (RAO, 1943, PL. 2, FIG. 24; VISHNU-MITTRE, 1954, PL. 2, FIG. 45) and also from the Jurassic rocks of Ceylon (SAH, 1953, PL. 1, FIG. 30). These may also be comparable with the two-winged pollen grains met with in the Podocarpineae and the Abietineae. Amongst the two-winged pollen grains of the present-day conifers, the Podocarpineae produces the smallest in size, ranging from 27·4 to 45·7 μ in diameter. In Abietineae the grain size is usually above 50 μ.

Comparisons may also be made with those of *Pityosporites* sp. figured by Solms-Laubach from the Wealden rocks of Franz Josef Land (SEWARD, 1919, FIG. 790, A, p. 399).

Sub-group — *Trisaccus* New sub-group

Pl. 1, Fig. 26

Size 40×61 μ; pollen in distal view, body oblong, longer than broad. Exine extended into three prominent bladders. Bladders elliptic, much smaller than the body, about 25×14 μ and attached on the distal side. Bladder walls fairly thick. Surface of body granular while the bladders are reticulately sculptured.

Some fossil three-winged pollen grains, attributed to the Podocarpineae, have been described under *Podosporites tripakshi* by Rao (1943, PL. 1, FIGS. 1-13) from the Nipania cherts. The grains of *P. tripakshi* Rao are, however, comparatively much smaller in size, being only 30·5×14·75 μ.

Amongst the living Conifers, three or more winged grains are produced by some of the Podocarpineae and the Abietineae. The grains in *Podocarpus dacrydioides* (WODEHOUSE, 1935, p. 279); *Pherosphera Fitzgeraldi* (WODEHOUSE, l.c., p. 28) and *Microcachrys tetragona* (THOMSON, 1909, p. 27) reach only a maximum size of 46 μ.

In the Abietineae the grains are bigger than the maximum size attained by the Podocarps. *Pinus tuberculata* (WODEHOUSE, l.c., p. 258) sometimes produces three or four-winged grains and some similarity is offered with them in the size. Other Abietinous genera which produce pollen grains with

various bladders are *Pinus excelsa* (WODEHOUSE, l.c., p. 261); *Cedrus* (WODEHOUSE, l.c., p. 261; ERDTMAN, 1954, p. 130); and *Abies balsamifera* (WODEHOUSE, l.c., p. 264). These, however, appear to be distinct in the form and ornamentation of the exine.

Class — *Aporosa* Naum.
Group — *Trilobata* Naum.
Sub-group — *Brachytrilistrium* Naum.

TYPE 1

Pl. 1, Fig. 19; Text-figs. 2, 3

Size 50×54 μ, spore probably three-winged, thin and translucent. Exine smooth. Wings (?) triangular, attached as vertical flaps to a longitudinal axis (FIG. 19; TEXT-FIG. 2). Axis about 50 μ long. Wings (?) 32·5 μ at their broadest. Text-fig. 3 shows a similar spore placed in a different view. This type is fairly common in the shale.

Spores very similar in shape have been described under a new genus *Triplanosporites* by Thomson and Pflug (1953, PL. 3, FIGS. 10-25) from the Tertiary rocks of Middle Europe. The spores figured by them show a distinct trilete mark on the longer polar axis (l.c., FIG. 14) and they consider the flap-like structures as characteristic folds. This may be true of the spores figured here but in none of my specimens a trilete mark is seen.

These are described under *Brachytrilistrium*, as Naumova (1937, FIG. 1) has figured a similar spore under this sub-group.

Fossil spores similar in shape have also been recorded from the Bacchus Marsh Tillites of Victoria (Australia) by D. D. Pant (1943, PL. 6, FIG. 6; TEXT-FIG. 2, p. 172) and from Ganjra Nala, near Pali, South Rewa, Central India, by K. R. Mehta (1944, PL. 1, FIG. 7, p. 70).

Sub-group — *Dolichotrilistrium* Naum.

TYPE 1

Pl. 1, Fig. 22

Size 36×61 μ, pollen ellipsoidal, probably trilobate, the elongated lobes placed at an angle to one another. Exine thin and smooth. Germinal aperture not visible.

The spore in its shape and size resemble very much those of *Triplanosporites pseuodsinuosus* Pflug, figured by Thomson and Pflug (l.c., PL. 3, FIGS. 17, 20-21). The trilete mark is, however, not seen in any of my specimens. Fossil pollens, somewhat similar in shape and of lobed appearance, have also been recorded from the Jurassic rocks of Ceylon (SAH, 1953, PL. 1, PHOTO 22; PL. 2, FIG. 57).

Megaspores (?)

Pl. 2, Figs. 32, 33

From the figures and description given in Naumova's classification (1937) it appears that it extends only to the spores and pollen grains. The present megaspore-like bodies could be described under sub-group *Trachytriletes* but owing to their distinctive nature they are treated separately.

Size 320-528 μ, body circular to oval in outline. Exine yellowish, thin and minutely spinose showing several folds. Trilete mark not visible. Arcuate ridges not conspicuous.

The size and general nature of these bodies is highly suggestive of their being megaspores. Megaspores from the Jurassic rocks of India have been recorded by Vishnu-Mittre (1954). These are, however, distinct from the specimens described here in having reticulate exine. From Triassic of Salt Range Sitholey (1943) has recorded some megaspores. Only a few mesozoic megaspores are known from other parts of the world, viz. Black (1929), Dijkstra (1948-49, 1951), Fitting (1907), Harris (1935, 1937) Lundblad (1948, 1950), Miner (1932), Murray (1939), and Seward (1913). None of the known megaspores are, however, comparable to the one figured here.

Cuticular Fragments

(a) BENNETTITALEAN

Three distinct types belong to this group. All the types are rather poorly represented in the shale.

TYPE 1

Pl. 2, Fig. 34; Text-figs. 4, 5

A single piece of cuticle representing this type was recovered. Cuticle thin, probably belonging to the lower part of the pinna. Epidermal cells hard to see, their outline being faintly marked, but at certain places

these appear to be sinuous (TEXT-FIG. 5). Stomata distinct, fairly numerous, all orientated in the same (transverse) direction (TEXT-FIG. 4). Dorsal lamellae of the guard cells have a prominently cutinized area towards the pore. Aperture narrow, about 18 μ long. Dorsal lamellae 40-44 μ in length. Each guard-cell has on its side a large subsidiary cell, 44×32 μ in size (FIG. 34; TEXT-FIG. 5). Trichome bases or papillae scars not present.

The cuticle is too fragmentary to determine its affinity but probably belongs to the *Ptilophyllum-Otozamites* group. Similar cuticles have been described from the Jurassic rocks of Ceylon (SAH, 1953, PL. 3, FIGS. 61-62; TEXT-FIGS. 1-2, p. 8).

TYPE 2

Pl. 2, Fig. 35; Text-figs. 6, 7

A few cuticles of this type have been obtained. All the cuticle pieces belong to only one surface of the pinna, probably lower, showing well-preserved stomata. Epidermal cells thin, more or less oblong, with sinuous walls but obscured by numerous thick-walled cuticular papillae. Scars of papilla circular, hollow and fairly large, about 25-36 μ in diameter. Stomata fairly numerous, transversely orientated and present in two to three longitudinal rows, between the veins (TEXT-FIG. 6). Guard-cells elongated, 40×11 μ. Dorsal lamellae cutinized. Aperture narrow, about 21 μ long. Subsidiary cells well developed, 40 × 18 μ (FIG. 35; TEXT-FIG. 7).

This cuticle also appears to belong to *Ptilophyllum-Otozamites* group.

TYPE 3

Pl. 2, Fig. 36; Text-fig. 8

Cuticle, probably of the lower pinna, showing slightly divergent veins, few of them forking (FIG. 36). Epidermal cells with sinuous walls; cell outline thin and hard to see, mostly obscured by numerous cuticular papillae. Stomata sparse, irregularly distributed between the veins and completely hidden by the papilla scars (TEXT-FIG. 8). Stomata transversely orientated. Guard-cells cutinized, elongated, about 28×10 μ. Subsidiary cells rarely seen, about 28×11 μ. Papilla scars circular to oblong, small, usually about 20×9 μ, and thickly cutinized.

From the disposition of the veins it appears that this type probably belongs to the *Otozamites* group.

(b) CONIFEROUS

This group is characterized by two distinct types. Both the type of cuticle are abundantly represented in the shale.

TYPE 1

Pl. 2, Figs. 39, 40; Text-fig. 9

Fig. 49 shows the epidermis of both the lower and upper cuticles of a pinna. The upper cuticle is thinner than the lower. Cuticle amphistomatic. The epidermal cells of the upper cuticle are polygonal and thick-walled, nearly isodiametric at the centre but slightly elongated nearer the apex and margins. Stomata few, present only nearer the margins, and very similar to those of the lower cuticle.

The epidermal cells of the lower cuticle are also thick-walled and polygonal in outline, nearly isodiametric but tending to be elongated between the stomatal rows. Stomata fairly numerous, arranged in regular longitudinal rows. They are regularly spaced in each row and separated from one another by the width of one stoma (TEXT-FIG. 9). Guard-cells sunken, aperture narrow, about 21 μ long, and orientated at right angles to the veins (FIG. 40). Subsidiary cells 5-6, inner walls sometimes projecting over the guard-cells in a slightly papillate outgrowth.

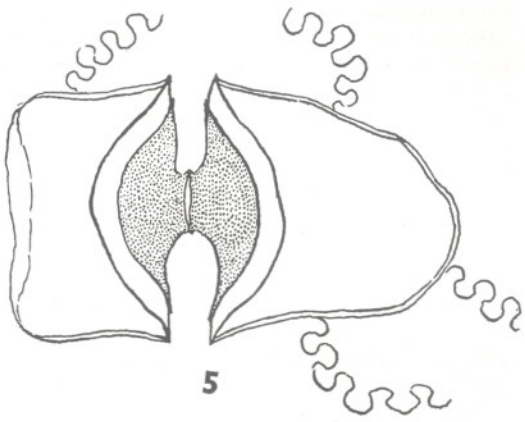
The epidermal characters of the cuticle described above are closely comparable to those of *Brachyphyllum expansum* Sternb. figured by Sahni (1928, PL. 3, FIGS. 36, 37) from the Karatau Mountains, Turkestan.

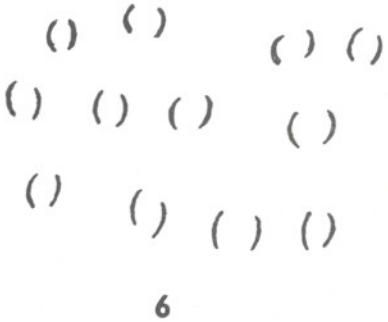
It differs from the Indian form *B. expansum* (Sternb.) var. *indica* Sahni primarily in the arrangement of the stomata, which in the latter are few and scattered (HOLDEN, 1915, PL. 11, FIGS. 5-6, p. 221; SAHNI, 1928, PL. 3, FIGS. 40-42, pp. 21, 22).

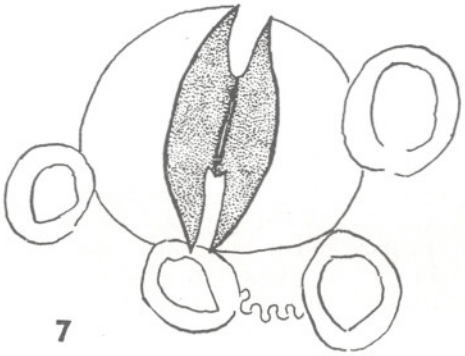
TYPE 2

Pl. 2, Figs. 37, 38; Text-fig. 10

Cuticle of both the surfaces are fairly thick. They are amphistomatic (FIG. 37). Epidermal cells, very similar on both the surfaces, are thick and straight-walled, generally isodiametric, and arranged in longitudinal rows. Stomata almost evenly







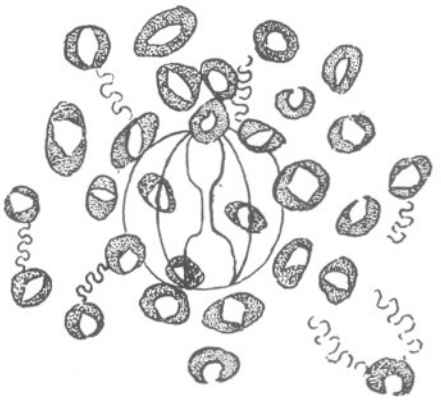
TEXT-FIGS. 4-7 — 4, part of the lower cuticle (Bennettitalean Type 1) showing the distribution of the stomata. × 160. 5, a stoma from the Bennettitalean cuticle Type 1 enlarged; also showing the bulged subsidiary cells and the sinuous epidermal cells. × 700. 6, part of the lower cuticle of Bennettitalean Type 2 showing the distribution of the stomata. × 160. 7, lower cuticle of Bennettitalean Type 2 enlarged. × 700.

scattered but usually tend to form single longitudinal rows. The cells between the stomatal rows are often longitudinally elongated, but sometimes transversely elongated cells are also present. Cuticular papillae absent. Position of the veins not recognizable in the cuticle. Stomata haplochailic, usually amphicyclic. Subsidiary cells slightly smaller, usually six in number. Surface of the subsidiary cells thickened. Guard-cells elongated, about 40-46 μ long, and cutinized. Aperture of the guard-cells irregularly orientated, about 25 μ long, but vary considerably (21-32 μ) and has a distinctly cutinized lining (TEXT-FIG. 10).

The epidermal characters of the cuticle on the whole show a considerable resemblance to those figured as *Desmophyllum indicum* by Sahni (1928, PL. 5, FIGS. 62-63, pp. 9-10) from Hard river, Jabalpur, and with those of *Podozamites lanceolatus* (L. & H.), figured by Holden (1915, PL. 11, FIGS. 7, 10, pp. 223-224) also from the Jabalpur group. The upper and lower cuticles from the variegated shale are, however, equally thick and the stomata are also comparatively fewer in number.

DISCUSSION AND COMPARISON

The Jurassic rocks in this region are regarded as belonging to the middle and upper divisions while the Upper Triassic and early Jurassic rocks are supposed to be



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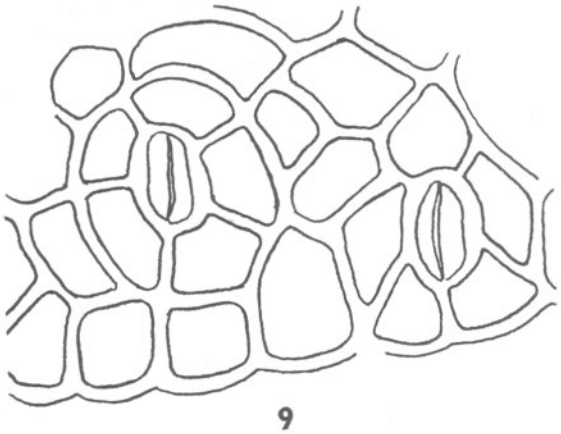

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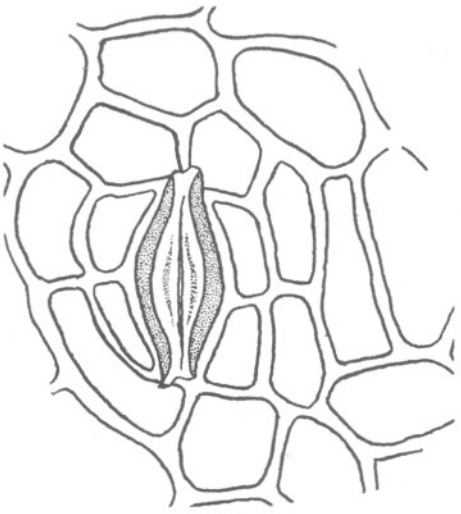

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TEXT-FIGS. 8-10 — 8, lower cuticle of Bennettitalean Type 3 enlarged. × 700. 9, lower cuticle of Coniferous Type 1 enlarged. × 500. 10, lower cuticle of Coniferous Type 2 enlarged. × 500.

missing. The shale from which the microflora is described here comes from the lowermost part of the Salt Range Jurassic succession. Plant megafossils described from this region show affinities with the Jabalpur group (WADIA, 1939, p. 184).

The plant groups presumably represented by the microflora are Pteridophyta, Cycadophyta and the Coniferales. Pteridophytic spores are present in fairly large numbers while the cuticles are entirely missing. Coniferous pollen grains, woody fragments and cuticles, especially the last named, are abundantly represented. Cycadophytic plant remains, so characteristic and prominent a group of the Rajmahal flora, is rather poorly represented. The evidence of the present microflora, especially the preponderance of coniferous cuticles of the *Brachyphyllum* and *Podozamites* type, strongly

suggests a closer affinity with the Jabalpur series, and confirms the prevalent view of a middle Jurassic age for the variegated shale.

Comparison with Andigama microflora — The microflora of the Andigama shale (SAH, 1953) is characterized by the predominance of the Pteridophytic spores, Cycadophytic pollen grains, and Bennettitalean cuticles (SAHNI & JANET, 1942, p. 219; SAH, l.c.). Coniferales are rather poorly represented in spore as well as in cuticle contents. The Andigama flora as a whole suggests a closer affinity with the lower beds of the Rajmahal series than with the Jabalpur group. The present investigation suggests a younger age for the variegated shale than the Andigama beds.

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EXPLANATION OF PLATES

PLATE 1

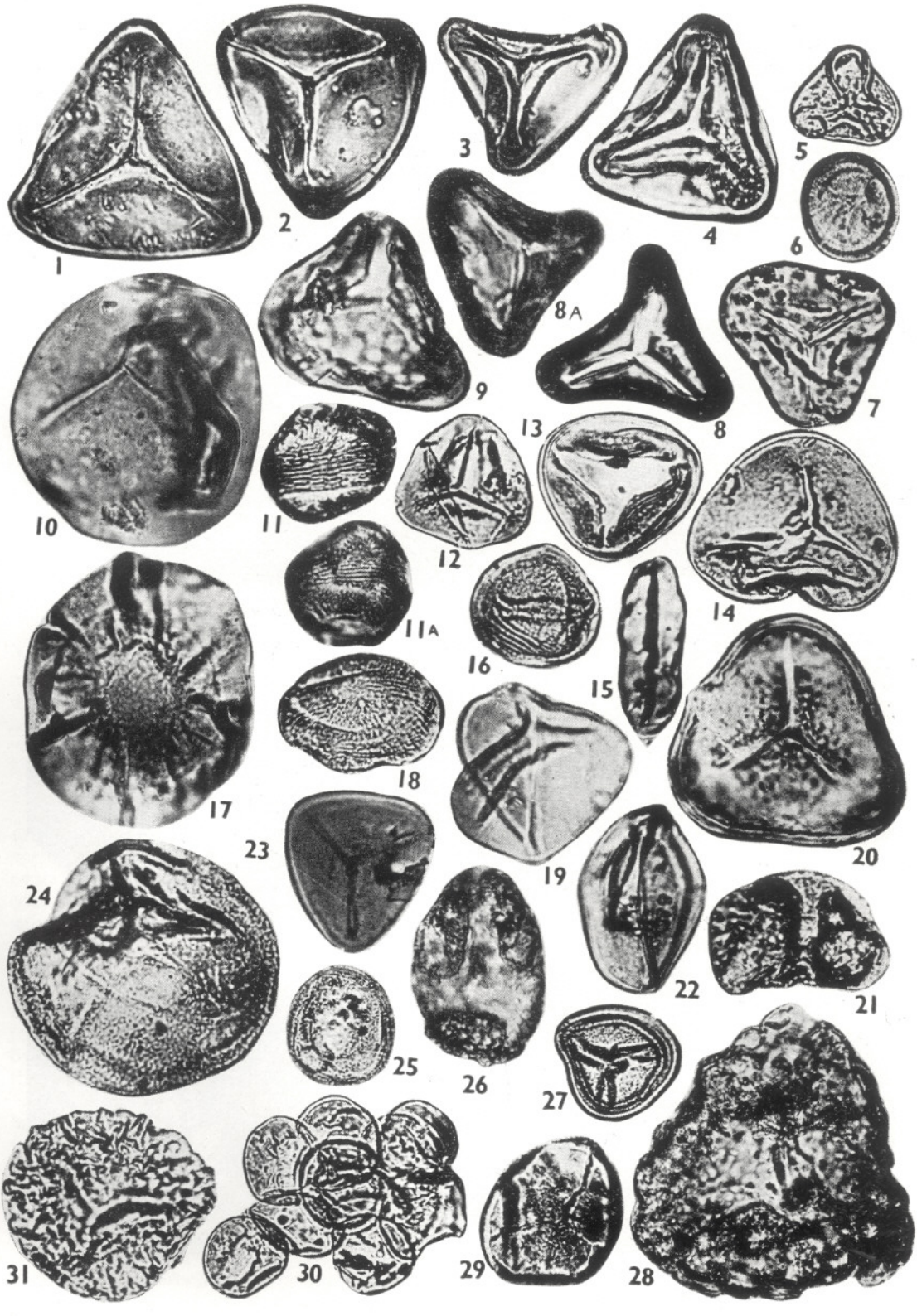
(*All photomicrographs* × 500.— *Specimen number* 6403)

1, 2. Leiotriletes. Exine laevigate.
3, 4. Leiotriletes. Exine laevigate. Note prominent ridge around the trilete.
5. Leiotriletes. A small spore.
6. Trachytriletes. Exine granular, wall prominent.
7. Leiotriletes. Exine laevigate, spore-coat thin.
8. Leiotriletes. Trilete distinct.
8a. Leiotriletes. Same spore as in Fig. 8 focussed to show the thick wall.
9. Dictyotriletes. Exine reticulate.
10. Leiotriletes. Spherical spore with smooth exine.
11. Liratoaletes. See the narrow and parallel ridges.
11a. Liratoaletes. Same spore as in Fig. 11, but in a different focus, showing the ridges as well as the coarsely granular exine.
12,13. Leiotriletes. See the thickened inter-ray zone.
14. Leiotriletes. Exine laevigate.
15. Azonomonoletes. Spore elliptical, with a single longitudinal furrow.
16. Liratoaletes. Exine granular, ridges only at the lower end.
17. Hymenozonotriletes. One-winged spore. Note the free central body.
18. Striatoaletes. Note the narrow, parallel to oblique, striations.
19. Brachytrilistrium. See the three radiating flap-like structures.
20. Lophotriletes. Exine with minute tubercles. Wall and trilete distinct.
21. Oedemosaccus. Two-winged pollen grain.
22. Dolicotrilistrium. Pollen with three elongated lobes.
23. Leiotriletes. Exine laevigate.
24. Trachytriletes. Spore spherical. Exine thin and granular.
25. Trachyaletes. Spore spherical. Exine granular.
26. Trisaccus. Pollen with three wings.
27. Stenozonotriletes. See the distinct spore wall and the equatorial flange. Exine granular.
28. Lophotriletes. Tubercles blunt and rounded.
29. Trachytriletes. Exine granular, trilete distinct.
30. Azonomonoletes. Bilateral spores with a simple suture.
31. Lophotriletes. Spore with finger-like tubercles.

PLATE 2

(*Specimen number* 6403)

32. Megaspore-like body, spherical in outline with minutely spinose exine. × 80.
33. Megaspore-like body very similar to that in Fig. 32 except for the smaller size. × 80.
34. Bennettitalean cuticle Type 1 showing an enlarged stomata, with broad subsidiary cells. × 450.
35. Bennettitalean cuticle Type 2 showing a stomata and the cuticular papillae. × 450.
36. Bennettitalean cuticle Type 3 showing the divergent course of the veins. × 30.
37. Coniferous cuticle Type 2 showing stomata on both the surfaces. × 80.
38. Cuticle in Fig. 37 enlarged, to show the stomata. × 450.
39. Coniferous cuticle Type 1 showing both the surfaces. × 80.
40. Cuticle in Fig. 30 enlarged. × 450.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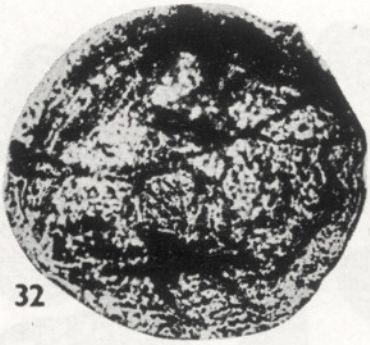
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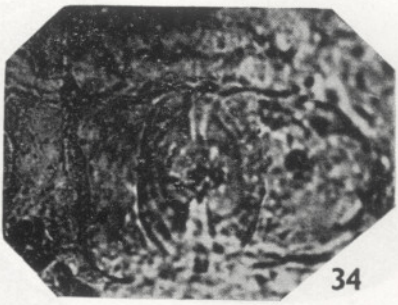
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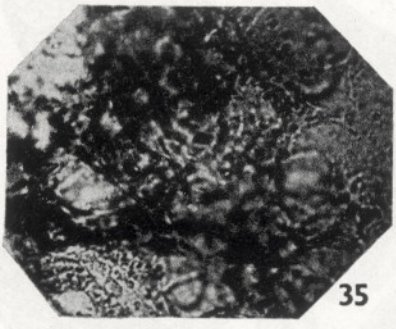
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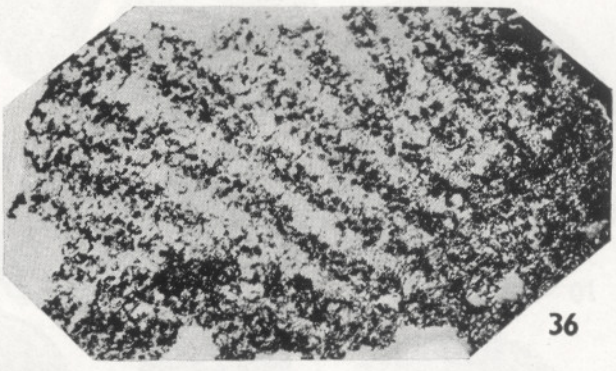
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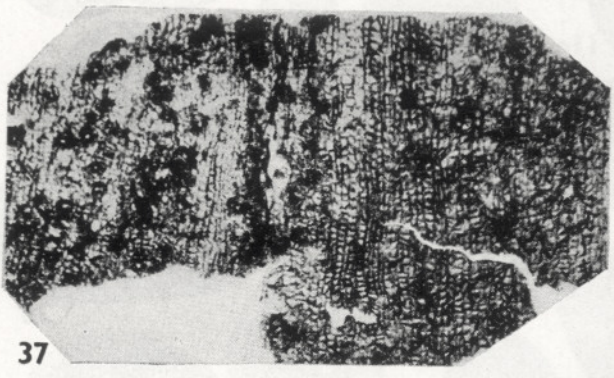
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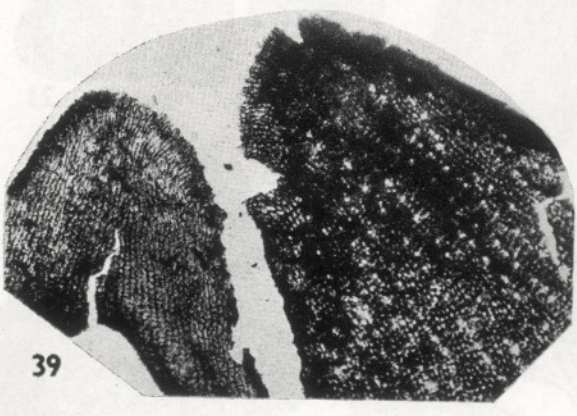
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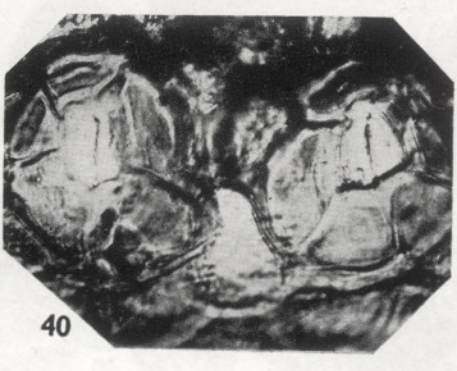
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