PALYNOLOGICAL INVESTIGATION OF THE UPPER SIWALIK SEDIMENTS EXPOSED ALONG HOSHIARPUR-UNA ROAD SECTION IN PUNJAB AND HIMACHAL PRADESH

R. K. SAXENA AND H. P. SINGH

Birbal Sahni Institute of Palaeobotany, Lucknow-226 007

ABSTRACT

The results of the palynofloral study of the Upper Siwalik sediments exposed along Hoshiarpur-Una Road in Hoshiarpur district of Punjab and Una district of Himachal Pradesh have been incorporated here. The palynoflora consists of 25 genera and 31 species. Of these, 2 genera, viz. *Quadrangulosaccites* and *Siwalikiathyrites*, and 5 species are new. The gymnospermous pollen grains are dominant (70%) while other groups are subordinately represented. The comparison of the present palynomorphs with their living counterparts indicates the representation of 8 families : Schizaeaceae, Polypodiaceae, Pinaceae, Palmae, Potamogetonaceae, Poaceae, Mimosaceae and Euphorbiaceae.

Quantitatively two assemblages have been recognised; Assemblage-1 is characterised by rich representation of inaperturate (45%) and bisaccate (9.5%) pollen grains while in Assemblage-2 bisaccate pollen increase (77%) with corresponding decrease of inaperturate pollen (12%). A comparison of the present assemblages with the already known Upper Siwalik assemblages reveals the homotaxiality of the Assemblage-1 with the Pinjor Assemblage near Chandigarh and that of Assemblage-2 with the Upper Siwalik assemblage from Gagret-Bharwain Road section, Himachal Pradesh. On the basis of high frequency of the pinaceous pollen grains temperate climate has been deduced in the north of present area. The environment of deposition has been interpreted as fluviatile.

INTRODUCTION

The Siwalik Group, developed in foot-hills all along the southern margin of the Himalayan Range, constitutes a significant sequence of fresh water sediments. This sequence is well known for its treasure of mammalian fossils, on which huge amount of literature has already been published. However, palynological studies of these sediments were started in 1968 with the appearance of BANERJEE's paper which deals with the palynoflora, palaeoclimate and depositional environment of the Lower-Middle Siwalik sediments exposed in Bhakra-Nangal area of Punjab (now in Himachal Pradesh). This was followed by some more palynological information on Lower Siwalik by VENKATACHALA (1972) and MATHUR (1973), and on Middle Siwalik by LUKOSE (1969), NANDI AND BANDYOPADHYAY (1970), VENKATACHALA (1972), and NANDI (1972). SINGH, KHANNA AND SAH (1973), for the first time, reported the occurrence of *Pinus*-type, monosulcate-type and inaperturate (nonsaccate) pollen grains from the Upper Siwalik (Pinjor Formation). Thereafter, NANDI (1975) gave a first systematic account on the palynostratigraphy of the Siwalik sequence exposed in the Jawalamukhi area of Punjab (now in Himachal Pradesh). NANDI (*loc. cit.*) proposed 4 informal zones, viz. zones 1 to 4. Her Zone 1 includes the lower and partly the middle part of Lower Siwalik; Zone 2 includes the remaining middle and upper part of Lower Siwalik and the basal part of Middle Siwalik; Zone 3 includes the Middle Siwalik except for its basal and topmost horizons; and Zone 4 includes topmost part of Middle Siwalik and Upper Siwalik. In the Upper Siwalik, palynofossils were recovered only from its basalmost part while remaining part was found completely unfossiliferous. The studies on the Siwalik palynology have

been reviewed by GHOSH (1977) and SAXENA AND SINGH (1982). Recently, some work on the Upper Siwalik palynology has been carried out at the Birbal Sahni Institute of Palaeobotany, Lucknow by SAXENA AND SINGH (1980, 1981, 1982) and SINGH AND SAXENA (1980, 1981). The above assemblages are from the middle part of the Upper Siwalik which was reported by NANDI (1975) and GHOSH (1977) as "completely unfossiliferous". The occurrence of palynofossils in this part of Upper Siwalik is therefore significant. The present paper deals with the palynofloral investigation of the Upper Siwalik sediments exposed along Hoshiarpur-Una Road section in Punjab and Himachal Pradesh.

MATERIAL AND METHOD

The material for the present study is represented by 30 rock samples, mostly shales and siltstones, and was collected from the Upper Siwalik sediments exposed between Chaksadu and Una along Hoshiarpur-Una Road section in Hoshiarpur district of Punjab and Una district of Himachal Pradesh (Fig. 1). Of these, only 21 samples proved to be productive (see Table 1). The slides were prepared in polyvenyl alcohol and mounted in canada balsam. The slides and negatives of the palynomorphs have been deposited in the repository of the Birbal Sahni Institute of Palaeobotany, Lucknow.

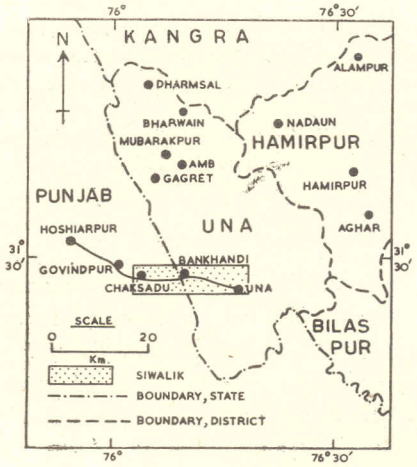

Fig. 1. Showing the location of Hoshiarpur-Una Road section in Punjab and Himachal Pradesh from where the samples were collected, and geological formation exposed along it.

SYSTEMATIC PALYNOLOGY

Genus—**Lygodiumsporites** Potonié, Thomson & Thiergart emend. Potonié, 1956
Type species—Lygodiumsporites adriennis Potonié, Thomson & Thiergart, 1950

Lygodiumsporites lakiensis Sah & Kar, 1969
Pl. 1, Fig. 1

Genus—**Todisporites** Couper, 1958
Type species—Todisporites major Couper, 1958

Todisporites flavatus Sah & Kar, 1969

Genus—**Monolites** Cookson ex Potonié, 1956
Type species—Monolites major Cookson, 1947

Table 1—Section showing lithology, stratigraphic position and location of the samples.

Sample no.	Spore-Pollen occurrence	Lithology	Locality
30+	Poor	Clay	Near 37 km on way to Una
29+	Abundant	Conglomerate	
28+	Poor	Silty clay	22.5 km from Hoshiarpur
27+	Poor	Pinkish clay	100 metres away from the above locality
26+	Poor	Pinkish-greyish clay	250 metres away from the above locality
25+	Poor	Siltstone	21.6 km from Hoshiarpur
24—	—	Greyish siltstone	
23—	—	Greyish clay	21.2 km from Hoshiarpur
22+	Poor	Clay	100 metres away from the above locality
21+	Poor	Greyish clay	100 metres away from the above locality
20+	Poor		
19—	—		
18+	Poor	Siltstone	Near Bankhandi
17+	Poor		
16+	Poor		
15+	Poor	Pinkish siltstone	15.2 km from Hoshiarpur near the bridge
14—	—		
13+	Poor		0.8 km above the Cho bridge, near 14.3 km from Hoshiarpur
12+	Poor	Siltstone	
11—	—		
10+	Poor		
9+	Poor		Near the bridge of Cho, as the ascend starts for Una
8+	Poor	Siltstone	
7—	—		
6+	Poor		
5—	—		
4—	—	Siltstone and clay	Near Chaksadu
3+	Poor		
2—	—		
1+	Poor		

+productive ; —unproductive

Monolites sp.
Pl. 1, Fig. 2

Description—Spore subcircular, size 67 ×60 μm. Monolete, ray about half of the longer axis. Exine 2.5 μm thick, laevigate, two curved exinal folds, one each on either end of the monolete mark present.

Comparison—The present species resembles *M. discordatus* (Pflug, *in* Thomson & Pflug) Potonié (1956) and *M. mawkmaensis* Sah & Dutta (1966), figured by DUTTA AND SAH (1970) but differs in having larger size range.

Genus—**Verrucatosporites** (Pflug) Potonié, 1956
Type species—Verrucatosporites alienus (Potonié) Thomson & Pflug, 1953

Verrucatosporites usmensis (van der Hammen) Potonié, 1960
Pl. 1, Fig. 3

Remarks—Spores are similar to those described by SINGH AND SAXENA (in press) except for having low-set, flat-topped verrucae and reniform shape.

cf. **Verrucatosporites** sp.
Pl. 1, Fig. 4

Description—Spore reniform, size 55×36 μm. Monolete, ray not clearly discernible. Exine 1.5 μm thick, ornamented by baculae and blunt end coni, baculae/coni up to 5 μm high, sparsely placed.

Remarks—This specimen differs from *Verrucatosporites* by having baculate/conate sculpture, while the latter is verrucate. However, the former comes closest to *Verrucatosporites*, hence compared with it.

Genus—**Pinuspollenites** Raatz, 1937

Type species—Pinuspollenites labdacus (Potonié) Raatz, 1937

Pinuspollenites siwalikus Singh & Saxena, 1981
Pl. 1, Fig. 5

Remarks—Specimens are similar to those recorded by SINGH AND SAXENA (1981) but possess bigger central body (52-62×46-55 μm). The upper limit of size-range may be extended accordingly.

Pinuspollenites sp.
Pl. 1, Fig. 6

Description—Bisaccate, 78×53 μm. Central body circular, 58×52 μm, faintly reticulate. Sacci equal in size, smaller than central body, finely reticulate. Saccus-free-area 19 μm wide.

Remarks—The specimen is similar to *Pinuspollenites* sp. described by SAXENA AND SINGH (1982) from the Pinjor Formation near Chandigarh except for being slightly smaller in size.

Genus—**Abiespollenites** Thiergart *in* Raatz, 1937

Type species—Abiespollenites absolutus Thiergart *in* Raatz, 1937

Abiespollenites sp.
Pl. 1, Fig. 7

Description—Pollen grains bisaccate, size-range 105-119×60-68 μm. Central body subcircular, 50-65×49-63 μm, finely sculptured, sculptural elements mostly consisting of grana, occasionally verrucae, closely placed; thick marginal rim present, saccus-free-area narrow, only 5 μm wide, ±quadrangular. Sacci almost as large as central body.

Genus—**Abietineaepollenites** Potonié *ex* Delcourt & Sprumont, 1955

Type species—Abietineaepollenites microlatus (Potonié) Delcourt & Sprumont, 1955

Abietineaepollenites sp.
Pl. 1, Fig. 8

Description—Bisaccate, size 70-88×45-55 μm. Central body subcircular-horizontally oval, 45-58×35-48 μm, finely granulose, with well-developed marginal rim. Attachment of sacci with central body always at an angle and never straight. Sacci smaller than central body, 30-35×22-28 μm in size, saccus-free-area narrow.

Genus—**Phyllocladidites** Cookson *ex* Couper, 1953

Type species—Phyllocladidites mawsonii Cookson *ex* Couper, 1953

Phyllocladidites sp.
Pl. 1, Fig. 9

Description—Pollen grains bisaccate, oval, size-range 40-48 × 24-34 μm. Central body 52 × 30 μm, ±laevigate, marginal rim present. Sacci very small in size, reticulate.

Remarks—This species is clearly differentiated from other bisaccate pollen of the present assemblage by its very small sacci.

Genus—**Quadrangulosaccites** gen. nov.

Type species—*Quadrangulosaccites himachalensis* gen. *et* sp. nov.

Generic diagnosis—Pollen grains bisaccate, outline ±quadrangular in polar view. Central body characteristically quadrangular, length being more than its width; granulose to verrucose, sometimes smooth. Sacci attached to the central body laterally without making any angle with the latter, elliptical in shape, finely reticulate. Saccus-free-area narrow, marginal rim present but only occasionally well-developed.

Comparison—The present genus is comparable to *Phyllocladidites* Cookson *ex* Couper (1953) in having smaller sacci but differs in having quadrangular central body. *Abies-pollenites* can be differentiated by having subcircular central body and large size. In *Abietineaepollenites* sacci are attached to the central body at an angle. From other bisaccate genera, like *Pinuspollenites*, *Piceapollenites*, etc., *Quadrangulosaccites* differs in having a quadrangular central body.

Quadrangulosaccites himachalensis sp. nov.

Pl. 1, Figs. 10-12

Holotype—Pl. 1, Fig. 10, size 55 × 36 μm; Slide no. BSIP 6688/9.

Type Locality—Hoshiarpur-Una Road section near 37 km stone, Una district, Himachal Pradesh.

Diagnosis—Pollen grains bisaccate with ±quadrangular outline, size-range 50-60 × 45-53 μm. Central body quadrangular, vertical axis longer than the horizontal one, 45-60 × 32-46 μm, finely sculptured with grana. Sacci small in size, much smaller than central body, kidney-shaped, finely reticulate, generally not extending much beyond the equator. Saccus-free-area narrow. Marginal rim present.

Bisaccate pollen-type

Pl. 1, Fig. 13

Description—Bisaccate, size-range 78-90 × 35-38 μm. Central body horizontally elliptical, 68-71 × 35-38 μm, laevigate to weakly sculptured, marginal rim present, sacci smaller than the central body. Saccus-free-area 22-24 μm wide.

Remarks—The present pollen type differs from other bisaccate pollen grains by its elliptical central body, smaller sacci and a characteristic wider saccus-free-area.

Genus—**Laricoidites** Potonié, Thomson & Thiergart, 1950

Type species—*Laricoidites magnus* (Potonié) Potonié, Thomson & Thiergart, 1950

Laricoidites magnus (Potonié) Potonié, Thomson & Thiergart, 1950

Remarks—This species is common in the assemblage. The size range of the present specimens is larger (45-100 × 45-86 μm) than that of pollen grains described by Potonié, Thomson and Thiergart (1950).

Laricoidites minutus Singh & Saxena (in press)

Pl. 1, Fig. 14

Remarks—The present specimens are exactly similar to those described by Singh and Saxena (in press). This species is rare in the assemblage.

Genus—**Inaperturopollenites** Pflug emend. Potonié, 1958

Type species—Inaperturopollenites dubius (Potonié & Venitz) Thomson & Pflug, 1953

Inaperturopollenites foveolatus Singh & Saxena (in press)

Remarks—Specimens are mostly oval in shape and larger in size (75-102 × 52-70 μm) than those recorded by SINGH AND SAXENA (in press) from the Girujan Clay of Jorajan Well 3, Upper Assam; the latter are subcircular in shape and 53-81 × 53-70 μm in size.

Genus—**Aplanosporites** Kar, 1979

Type species—Aplanosporites robustus Kar, 1979

Aplanosporites bharwainensis Singh & Saxena, 1981

Remarks—The specimens have a larger size range (57-76 × 45-62 μm) than those described by SINGH AND SAXENA (1981, size 55-66 × 48-52 μm).

Genus—**Assamiapollenites** Singh emend. Singh & Saxena (in press)

Type species—Assamiapollenites brownii (Biswas) Singh, 1975

Assamiapollenites ghoshii Singh & Saxena (in press)

Pl. 1, Fig. 15

Genus—**Verrualetes** Singh & Saxena (in press)

Type species—Verrualetes assamicus Singh & Saxena (in press)

Verrualetes sp.

Pl. 1, Fig. 16

Description—Pollen grain oval, size 102 × 77 μm. Inaperturate. Exine 0.5 μm thick, verrucate, verrucae large, up to 7 μm in diameter, not very closely placed but evenly distributed.

Comparison—This species differs from *V. assamicus* Singh & Saxena (in press) by its larger size and oval shape. Other species of *Verrualetes* also differ from the present species by being smaller in size.

Genus—**Palmidites** Couper, 1953

Type species—Palmidites maximus Couper, 1953

Palmidites plicatus Singh, 1977

Remarks—SINGH (1977) published 4 figures of this species, viz. pl. 3, figs. 47, 48, 49 and 50, and designated fig. 50 as its holotype, but under 'Explanation of Plates' he mentioned fig. 49 as its holotype which is contradictory to the holotype designated in the text. After examining all the figured specimens, pl. 3, fig. 50 of SINGH (1977) is being proposed here as the 'lectotype' for the present species.

Genus—**Couperipollis** Venkatachala & Kar, 1969

Type species—Couperipollis perspinosus (Couper) Venkatachala & Kar, 1969

Couperipollis wodehousei (Biswas) Venkatachala & Kar, 1969

Monosulcate palynomorph

Pl. 1, Fig. 18

Description—Palynomorph ±oval with acute ends; size 88 × 54 μm. Monosulcate, sulcus end to end, about 10 μm wide. Exine up to 0.5 μm thick, laevigate.

Genus—**Lakiapollis** Venkatachala & Kar, 1969

Type species—Lakiapollis ovatus Venkatachala & Kar, 1969

Lakiapollis ovatus Venkatachala & Kar, 1969

Lakiapollis matanamadhensis Venkatachala & Kar, 1969

Remarks—The present specimens bear coarse reticulation similar to that in the pollen described by SAXENA (1979, p. 135, pl. 3, fig. 39).

Tricolporate pollen-type

Pl. 1, Fig. 19

Description—Pollen grain elliptical in equatorial view, size 55×34 μm. Tricolporate, colpi long, pore *ca* 2.5 μm in diameter with slightly thickened pore margin. Exine 0.5 μm thick, laevigate

Genus—**Graminidites** Cookson, 1947

Type species—Graminidites media Cookson, 1947

Graminidites pliocenicus Singh & Saxena, 1981

Pl. 1, Fig. 20

Graminidites sp.

Pl. 1, Fig. 21

Description—Pollen grain circular, size 75 μm. Monoulcate, ulcus circular, about 3 μm in diameter, surrounded by a prominent annulus. Exine about 2.5 μm thick, ±granulose.

Remarks—The present species differs from *G. pliocenicus* Singh & Saxena (1981) in being bigger in size and having granulose exine.

Monoporate palynomorph

Pl. 1, Fig. 22

Description—Palynomorph circular, size 104×95 μm. Monoporate, pore elongated, 22×7 μm in dimension. Exine 2 μm thick, laevigate.

Remarks—The present specimen differs from *Graminidites* by its elongated aperture and bigger size.

Genus—**Polyadopollenites** Pflug & Thomson *in* Thomson & Pflug, 1953

Type species—Polyadopollenites multipartitus Pflug & Thomson *in* Thomson & Pflug, 1953

Polyadopollenites siwalikus sp. nov.

Pl. 1, Fig. 23

Holotype—Pl. 1, Fig. 23, size 77×65 μm; Slide no. BSIP 6697/2.

Type Locality—Hoshiarpur-Una Road section, near Chaksadu, Hoshiarpur district, Punjab.

Diagnosis—Polyad, quadrangular to subcircular; size-range 72-77×61-65 μm. Each polyad containing 16 individual pollen grains, middle ones appearing to be bigger than the marginal ones. Individual pollen also quadrangular in shape and 20-25 μm in size. No pore visible. Exine 1 to 1.5 μm thick, laevigate.

Comparison—The present species resembles *P. miocenicus* Ramanujam (1966) in general organisation as well as in having 16 individual pollen grains but differs by being larger in size and having no pore, while the latter bears 3 pores in each individual pollen.

P. multifidus Potonié & Sah (1960) differs by having more than 20 or sometimes even more than hundred grains. *P. granulatus* Sah (1967) has granulose sculpture of exine and apertures in the lateral walls.

Fungal Remains

Genus—**Siwalikiathyrites** gen. nov.

Type species—Siwalikiathyrites ramanujamii gen. *et* sp. nov.

Generic Diagnosis—Ascostromata subcircular to circular, dimidiate, non-ostiolate, no free hyphae, arrangement of hyphae not radial, divided into cells, central cells polygonal, outer cells mostly elongate. Pores absent.

Comparison—The present genus closely compares with *Phragmothyrites* Edwards emend. Kar & Saxena (1976) in being circular and non-ostiolate and in having no free hyphae, but can be separated from the latter by non-radial arrangement of aporate cells. Moreover, the present genus contains polygonal cells which are ±squarish-quadrangular in *Phragmothyrites* (KAR & SAXENA, 1976, pp. 8-9). *Notothyrites* Cookson (1947) differs in being ostiolate. *Kutchiathyrites* Kar (1979) differs in being fish-scale like in shape.

Derivation of Name—After Siwalik Group.

Siwalikiathyrites ramanujamii sp. nov.

Pl. 2, Figs. 24-25

Holotype—Pl. 2, Fig. 25, size 78 μm; Slide no. BSIP 6689/6.

Type Locality—Hoshiarpur-Una Road section, near Bankhandi, Hoshiarpur district, Punjab.

Diagnosis—Ascostromata subcircular to circular, size-range 64-86 μm, no free hyphae observed, dimidiate, non-ostiolate, arrangement of hyphae not radial, divided into central polygonal and outer elongated pseudoparenchymatus cells, cells nonporate.

Derivation of name—This species has been named in honour of Dr. C. G. K. Ramanujam for his well known work on Indian fossil fungi.

Genus—**Inapertisporites** van der Hammen emend. Sheffy & Dilcher, 1971

Type species—Inapertisporites pseudoreticulatus Rouse, 1959

Inapertisporites ellipticus Chandra, Saxena, & Setty (in press)

Pl. 1, Fig. 17

Genus—**Dicellaesporites** Elsik emend. Sheffy & Dilcher, 1971

Type species—Dicellaesporites popovii Elsik, 1968

Dicellaesporites sp.

Pl. 2, Fig. 26

Description—Fungal spore ±oval, size 89 × 79 μm. Dicellate, cells unequal in size, smaller cell has broadly rounded end but bigger one has ±pointed end. Uniseptate, septa about 5 μm thick, dark in colour. Inaperturate. Spore wall 0.5 μm thick, punctate, having few irregular folds.

Remarks—The present species can easily be distinguished from other species of this genus by its bigger size.

Genus—**Staphlosporonites** Sheffy & Dilcher, 1971

Type species—Staphlosporonites conoideus Sheffy & Dilcher, 1971

Staphlosporonites multicellatus sp. nov.

Pl. 2, Figs. 28-29

Holotype—Pl. 2, Fig. 28, size 64×52 μm; Slide no. BSIP 6685/8.

Type Locality—Hoshiarpur-Una Road section, near Chaksadu, Hoshiarpur district, Punjab.

Diagnosis—Fungal spores circular to subcircular, size-range 58-80×40-80 μm. Multicellate, number of cells more than 25 in each spore, individual cell polygonal in shape and about 5-8 μm in size. Inaperturate. Septa very thin. Spore wall up to 2 μm thick, psilate, sometimes weakly granulose.

Comparison—The present species can easily be differentiated from *S. conoideus*, *S. tristratosus*, *S. ovalis* and *S. allomorphus* all instituted by SHEFFY AND DILCHER (1971) in being bigger and in having larger number of polygonal cells.

Genus—**Lacrimasporonites** (Clarke) Elsik, 1968

Type species—Lacrimasporonites levis Clarke, 1965

Lacrimasporonites magnus sp. nov.

Pl. 2, Fig. 27

Holotype—Pl. 2, Fig. 27, size 120×47 μm; Slide no. BSIP 6698/37.

Type Locality—Hoshiarpur-Una Road section, near 37 km stone, Una district, Himachal Pradesh.

Diagnosis—Fungal spore±elliptical, size 120×47 μm, distal end of spore pointed and proximal end broad. Unicellate, nonseptate. Monoporate, pore apical, on the broader end, 27 μm in diameter, surrounded by thickening. Spore wall 0.5 μm thick, psilate.

Comparison—This species differs from *L. basidii* (9-14×6-8 μm), *L. westii* (18×10 μm) and *L. stoughii* (11×6.5 μm) described by ELSIK (1968), and *L. singularis* Sheffy & Dilcher (1971, 16.4×10.6 μm) in being much bigger in size.

Derivation of name—The specific name indicates big size of spores.

Lacrimasporonites sp.

Pl. 2, Fig. 32

Description—Fungal spore oval, size 66×44 μm. Unicellate, nonseptate. Monoporate, pore apical, pore diameter *ca* 1 μm, surrounded by thickening. Spore wall about 1 μm thick, psilate.

Remarks—This specimen differs from those of *L. magnus* sp. nov. in having smaller size and oval shape and from other species of the genus by its bigger size.

Monoporate spore-type

Pl. 2, Fig. 31

Description—Palynomorph circular, probably a fungal spore, size 79×77 μm. Monoporate, pore oval, 10×7 μm in size, margin not thickened. Spore wall up to 0.5 μm thick, reticulate, reticulum imperfect, meshes subcircular to polygonal in shape, varying from 4 to 10 μm in diameter, irregularly distributed over the spore wall.

Remarks—Brown colour, typical of fungal spores, and unstratified nontectate spore wall suggests the present specimen to be a fungal spore.

Genus—**Tetraploa** Berk. & Br.

Tetraploa sp.

Pl. 2, Fig. 30

Description—Fungal conidia quadrangular in shape consisting of 4 columns, each terminating into a nonseptate unicellular process, size 30 × 15 μm (excluding processes), processes 42-58 μm long and 3-4 μm wide. Ornamentation of body granulose, grana closely placed and evenly distributed. Processes psilate.

Remarks—The present species differs from Type 89: *T. aristata* Berk. & Br. described by VAN GEEL (1978, p. 52, pl. 17, fig. 89) by its nonseptate and psilate processes which in the latter are septate and verrucate. *Tetraploa* sp. described by SINGH AND SAXENA (1981) from the Upper Siwalik of Gagret-Bharwain Road section, Himachal Pradesh closely compares with the present species in having nonseptate and psilate appendages but differs in having a psilate body.

Palynomorph type-1

Pl. 2, Figs. 33-34

Description—Palynomorphs circular, size-range 70-95 μm. In some specimens a pore on a protuberance present, pouring out the inner material (Pl. 2, Fig. 33) while in others (Pl. 2, Fig. 34) no pore is visible. Outer wall 3 to 4.5 μm thick, laevigate, having a few very sparsely placed, wart-like or elongated sculptures.

Remarks—Only four specimens of this type could be recovered in the assemblage.

Palynomorph type-2

Pl. 2, Figs. 35-36

Description—Palynomorphs ±elliptical in shape with well rounded ends, size-range 78-115 × 54-75 μm. Monoaperturate, aperture apical, surrounded by a thickening about 1.5 μm thick. Wall less than 0.5 μm thick, psilate, highly folded by very small irregular wrinkles, imparting a pseudoreticulate pattern over the wall.

Palynomorph type-3

Pl 2, Figs 37-38

Description—Palynomorphs elongated with wavy margin and rounded ends, size-range 160-300 × 51-74 μm. No aperture visible. Surface smooth.

Remarks—This palynomorph type closely resembles *Foveofusa* described by LELE AND CHANDRA (1972) from the marine intercalations in Lower Gondwana of Madhya Pradesh in size-range and general organization but differs in having an irregular and wavy margin.

DISCUSSION

The palynoflora recorded here from the Upper Siwalik sediments exposed along Hoshiarpur-Una Road section in Punjab and Himachal Pradesh, consists of fungal remains (both spores and bodies), pteridophytic spores, gymnospermous and angiospermous pollen grains and a few palynomorphs of uncertain affinity. The assemblage is totally devoid of bryophytic spores. The qualitative analysis of the palynoflora has been summarized in table-2.

QUANTITATIVE ANALYSIS

The present palynoflora is populated by 25 genera and 31 species of fungal remains, pteridophytic spores and gymnospermous and angiospermous pollen grains. Of these, 2 genera, viz. *Quadrangulosaccites* and *Siwalikiathyrites*, are newly proposed. Out of 21 productive samples, only one (sample no. 29) is rich in spores and pollen grains. The poor recovery of palynomorphs in other samples posed a considerable difficulty

Table 2—Showing the affinity of various palynomorphs with the modern superageneric taxa.

Superageneric Taxa	Palynomorph species
Fungi	*Inapertisporites ellipticus*
	Dicellaesporites sp.
	Staphlosporonites multicellatus
	Lacrimasporonites magnus
	Lacrimasporonites sp.
	Tetraploa sp.
	Siwalikiathyrites ramanujamii
Pteridophyta	
Schizaeaceae	*Lygodiumsporites lakiensis*
	Todisporites flavatus
Polypodiaceae	*Monolites* sp.
	Verrucatosporites usmensis
	cf. *Verrucatosporites* sp.
Gymnospermae	*Pinuspollenites siwalikus*
Pinaceae	*Pinuspollenites* sp.
	Abiespollenites sp.
	Abietineaepollenites sp.
	Phyllocladidites sp.
	Quadrangulosaccites himachalensis
	Laricoidites magnus
	Laricoidites minutus
	Inaperturopollenites foveolatus
Angiospermae	
Palmae	*Palmidites plicatus*
	Couperipollis wodehousei
Potamogetonaceae	*Assamiapollenites ghoshii*
	Verrualetes sp.
Poaceae	*Graminidites pliocenicus*
	Graminidites sp.
Mimosaceae	*Polyadopollenites siwalikus*
Euphorbiaceae	*Lakiapollis ovatus*
	Lakiapollis matanamadhensis

in quantitative evaluation of the present palynofloral succession. To overcome this, the samples containing almost like species were grouped into one, and palynomorphs obtained from all of them were considered together as if from one sample only. For making such groups of samples (representing one type of assemblage) bisaccate and inaperturate pollen grains played deciding role, as is evident from the actual counts shown in table-3. Two distinct assemblages have been recognised. The older, Assemblage-1, was obtained from sample nos. 1 to 25 and the younger, Assemblage-2, from sample nos. 26 to 30.

The stratigraphic interval covered by Assemblage-1 is characterized by the high frequency (45%) of inaperturate and 9.5 per cent of bisaccate pollen grains. The gymnospermous pollen grains thus constitute 54.5 per cent of the Assemblage-1. Amongst the inaperturate pollen, two species of *Laricoidites*, viz. *L. magnus* and *L. minutus* constitute 43

Table 3—Showing the actual counts of palynotaxa in productive samples.

Palynomorph species/ Sample Nos.	1	3	6	8	9	10	12	13	15	16	17	18	20	21	22	25	26	27	28	29	30
Lygodium-sporites lakiensis	..	..	..	..	..	..	..	..	..	..	..	..	..	1	..	1	..	2	..	..	..
Todisporites flavatus	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	1	..	..	..
Monolites sp.	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	1	..	..
Verrucatosporites usmensis	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	1	..
cf. *Verrucato-sporites* sp.	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	1	..
Pinuspollenites siwalikus	..	..	..	..	..	1	1	..	..	..	..	2	..	..	..	..	1	2	2	38	8
Pinuspollenites sp.	..	..	..	..	..	..	..	..	..	..	..	1	..	..		..	..	..	..	..	..
Abiespollenites sp.	..	..	..	..	..	..	..	..	..	..	1	1	..	..	..	..	..	..	..	2	1
Abietineaepollen-ites sp.	..	..	..	3	..	..	..	..	..	..	3	2	..	..	..	..	..	1	3	11	1
Phyllocladidites sp.	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	6	..
Quadrangulosac-cites himachal-ensis	..	..	..	2	..	1	..	..	..	..	3	3	..	..	..	..	..	..	2	35	4
Bisaccate pollen type	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	1	..	..
Laricoidites magnus	..	1	1	..	2	1	6	2	2	2	6	5	1	5	13	1	6	2	6	2	..	5
Laricoidites minutus	..	1	..	1	..	..	1	16	6	..	..	3	3	13	7	1	..	3	..	..	..	..
Inaperturopollen-ites foveolatus	..	1	..	..	..	1	..	1	2	1	..	..	..	..	..	..	..	..	..	1	..
Aplanosporites bharwainensis	..	..	..	..	..	7	..	..	..	5	2	2	1	16	..	3	..	..	..	..	..
Assamiapollenites ghoshii	..	..	..	..	..	1	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Verrualetes sp.	..	..	..	..	..	5	3	..	..	..	..	..	..	..	..	..	..	1	..	1	..
Palmidites plicatus	..	..	..	..	..	..	1	..	..	..	..	..	..	1	1	..	..	2	1	..	..
Couperipollis wodehousei	..	..	..	..	1	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..

Table 3—(*Contd.*)

Palynomorph species/ Sample Nos.	1	3	6	8	9	10	12	13	15	16	17	18	20	21	22	25	26	27	28	29	30
Monosulcate palynomorph	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	1	..
Lakiapollis ovatus	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	1	..	..
Lakiapollis matanamadhensis	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	2	..	1
Tricolporate pollen type	..	..	..	..	..	..	..	..	..	..	..	1	..	..	..	..	..	..	..	..	..
Graminidites pliocenicus	1	..	3	..	..	..	..	..	..	..	..	..	..	1	..	..	..	..	..	..	..
Graminidites sp.	..	..	..	..	..	1	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Monoporate palynomorph	..	..	..	..	..	..	..	..	..	..	..	..	1	..	..	..	..	..	..	..	..
Polyadopollenites siwalikus	..	..	..	..	2	..	..	..	..	..	..	..	..	..	..	1	..	..	..	..	..
Siwalikiathyrites ramanujamii	..	..	..	..	..	..	..	..	..	..	2	4	2	1	..	..	..	..	..	..	..
Inapertisporites ellipticus	..	..	..	..	..	3	1	..	..	..	3	..	..	..	..	..	..	..	..	..	..
Dicellaesporites sp.	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	1	..	..	..
Staphlosporonites multicellatus	..	..	..	..	..	4	..	1	..	..	3	..	1	..	..	..	..	..	..	..	..
Lacrimasporonites magnus	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	1	..
Lacrimasporonites sp.	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	1	..
Monoporate spore type	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	1
Tetraploa sp.	..	..	..	..	..	1	1	..	..	2	..	..	..	..	..	..	..	..	..	..	..
Palynomorph type 1	..	..	..	..	..	3	..	..	..	..	..	..	..	15	..	..	..	..	..	..	..
Palynomorph type 2	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	1	..
Palynomorph type 3	..	..	..	..	..	..	..	..	..	..	..	..	..	1	..	..	..	..	..	..	..
Total no. of specimens	3	2	4	7	4	35	25	10	4	14	25	20	23	56	3	11	6	16	15	100	21

per cent and rest are *Inaperturopollenites foveolatus*. Amongst bisaccate pollen grains *Quadrangulosaccites* (3.5%), *Abietineaepollenites* (3%), *Pinuspollenites* (2%) and *Abiespollenites* (1%) are present. Besides the above, pteridophytic spores are very poor (1.5%), angiospermous pollen share 9 per cent, fungal remains (both spores and bodies) 13 per cent and palynomorph of uncertain affinity 22 per cent.

On the other hand, Assemblage-2 is very rich (77%) in bisaccate pollen grains while inaperturate pollen decrease in frequency (12%). The gymnospermous pollen thus constitute 89 per cent of the assemblage, much higher than in Assemblage-1. The other taxa are not present in any appreciable frequency and hence are of limited value as zone indicator. The pteridophytic spores constitute 2.5 per cent, angiospermous pollen grains 5.5 per cent and fungal remains 3 per cent of the Assemblage-2. This assemblage is thus easily distinguishable from the Assemblage-1 by the very high frequency of bisaccate pollen with corresponding decrease in inaperturate ones (12%). The high frequency of bisaccate grains is attributed to the 27 per cent representation of *Quadrangulosaccites himachalensis*, 34 per cent of *Pinuspollenites siwalikus*, 2 per cent of *Abiespollenites* sp., 10 per cent of *Abietineaepollenites* sp. and 4 per cent of *Phyllocladidites* sp. (Figs. 2, 3).

The quantitative analysis also revealed the overall dominance of gymnospermous pollen (70%). Of these, bisaccate pollen represented by 5 genera and 6 species constitute 37 per cent and inaperturate pollen represented by 2 genera and 3 species share 33 per cent. The pteridophytic spores are represented by 4 genera and 5 species (2.5%), angiospermous pollen by 7 genera and 9 species (8%), fungal spores and bodies by 6 genera and 7 species (9.5%) and palynomorphs of uncertain affinity by 1 genus and 1 species (10%). The assemblage is completely devoid of bryophytic spores.

PALAEOCLIMATE AND ENVIRONMENT OF DEPOSITION

The present assemblage, as a whole, is rich in gymnospermous pollen, both bisaccate and inaperturate ones, related to Pinaceae. The pteridophytic spores related to Schizaeaceae and Polypodiaceae are very rare (2.5%) ; angiospermous pollen grains related to Palmae, Potamogetonaceae, Poaceae, Mimosaceae and Euphorbiaceae are 8 per cent ; fungal remains are 9.5 per cent and others are 10 per cent. The frequency of the bisaccate pollen grains sharply increases in the Assemblage-2. The present day distribution of the various families is given in table 4.

Table 4 —Showing the present day distribution of the various families represented in the assemblage.

	Tropical	Subtropical-Temperate	Cosmopolitan (Tropical—Temperate)
1.	..	..	Schizaeaceae (mostly tropical-subtropical)
2.	..	..	Polypodiaceae
3.	..	Pinaceae (mostly temperate)	..
4.	Palmae	..	..
5.	..	..	Potamogetonaceae
6.	..	..	Poaceae
7.	..	..	Mimosaceae
8.	..	..	Euphorbiaceae

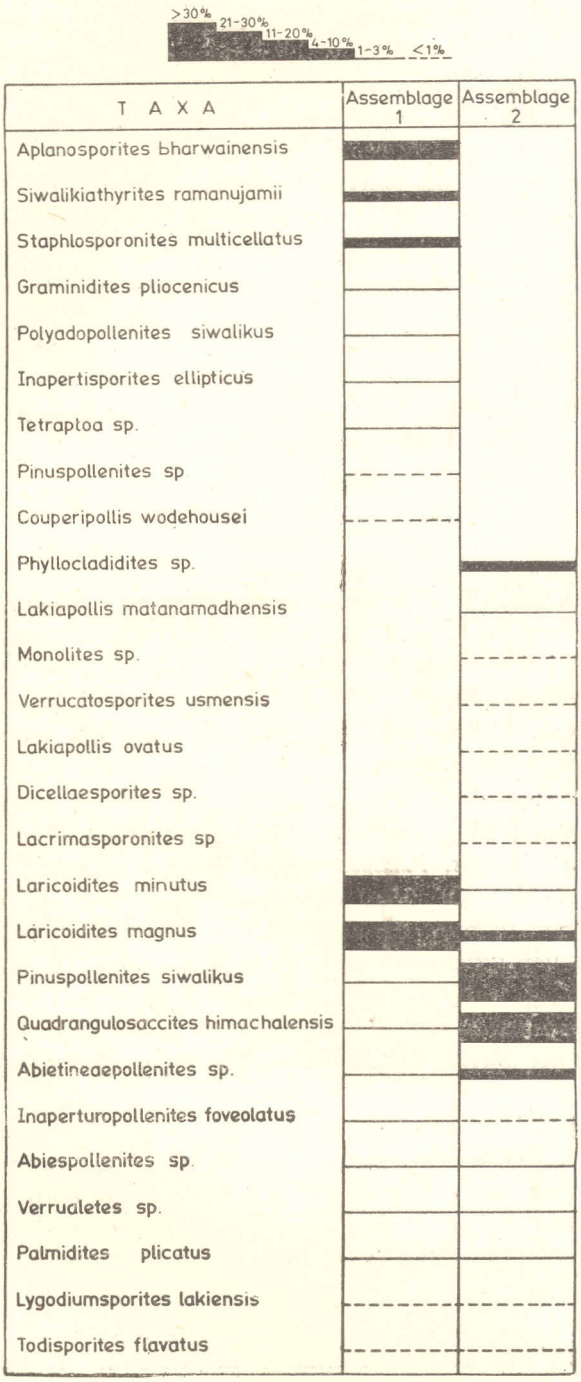

Fig. 2. Showing the stratigraphic occurrence of the various palynomorph species in the Upper Siwalik of Hoshiarpur-Una Road section.

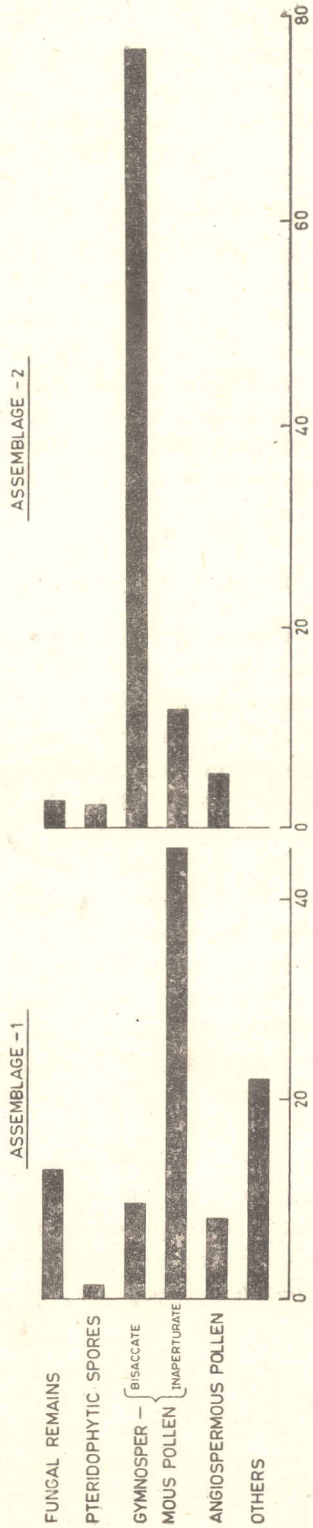

Fig. 3. Showing the percentage of various groups in Assemblage-1 and Assemblage-2.

Out of the total 8 families only 2, viz. Schizaeaceae and Palmae (both very poorly represented), are found in tropical-subtropical regions. One family, viz. Pinaceae, is distributed mainly in temperate region and 5 families, viz. Polypodiaceae, Potamogetonaceae, Poaceae, Mimosaceae and Euphorbiaceae are cosmopolitan in distribution. The above account indicates that the assemblage includes both tropical and temperate elements. The tropical elements which are poorly represented may be derived from the southern side of the depositional site while the temperate elements must have been derived from the high Himalayan ranges which by that time would have been considerably high to support pinaceous flora.

The analysis of the present palynoflora also reveals that it does not contain any element indicating marine or brackish water influence. Potamogetonaceous pollen, although less in number, suggest fresh water conditions. The gymnospermous pollen would have been transported from north either by wind or by drainage water running from northern hills towards the site of deposition. It is, therefore, reasonable to deduce a fluviatile environment of deposition for the Upper Siwalik sedimentation in the present area.

PALYNOFLORAL COMPARISON

Prior to this, Upper Siwalik palynofloras have been reported from 3 places only : (i) from the lowermost part of the Upper Siwalik of Jawalamukhi area of Himachal Pradesh (Nandi, 1975 ; Ghosh, 1977) ; (ii) from the Pinjor Formation exposed near Chandigarh (Saxena & Singh, 1980, 1981, 1982) ; and (iii) from the middle part of the Upper Siwalik exposed along Gagret-Bharwain Section, Himachal Pradesh (Singh & Saxena, 1980, 1981). A comparison of the present palynoflora with the above three is discussed below :

The palynoflora from Upper Siwalik of Jawalamukhi area of Himachal Pradesh consists of *Cyathidites*, *Alsophilidites*, *Leptolepidites*, *Pinuspollenites*, *Podocarpidites*, *Monoporopollenites*, *Alnipollenites* and *Tetradomonoporites*. Of these, only *Pinuspollenites* and *Monoporopollenites* (±=*Graminidites*) are common to both the assemblages. Many other significant bisaccate and inaperturate pollen genera of the present palynoflora are unrepresented in the Jawalamukhi assemblage while reverse is the case with pteridophytic spore genera and *Podocarpidites*, *Alnipollenites* and *Tetradomonoporites*. The difference between the two asemblages may be attributed to the disparity in their stratigraphic positions.

The palynoflora from the Pinjor Formation exposed near Chandigarh is closely comparable with the Assemblage-1 of the present palynoflora. Both of these are rich in inaperturate pollen grains belonging to *Laricoidites*. Other elements of both the assemblages are also more or less similar except for the 22 per cent representation of *Aplanosporites*, a palynomorph of uncertain affinity, in the present Assemblage-1 (Table 5).

Similarly, the Upper Siwalik palynoflora from the Gagret-Bharwain Road section, Himachal Pradesh is closely identical to the present Assemblage-2. In both of these, bisaccate pollen grains are dominant. In the former, inaperturate pollen grains are also found in considerably high frequency. The other elements, viz. pteridophytic and fungal spores and angiospermous pollen, are more or less similar in both the assemblages (Table-6).

Table 5—Group-wise comparison of the Assemblage-1 with the Pinjor Formation palynoflora from near Chandigarh.

Groups	Assemblage 1	Pinjor Formation (Upper Siwalik) near Chandigarh
Pteridophytic spores	1.5%	3%
Gymnospermous bisaccate pollen	9.5%	4%
Gymnospermous inaperturate pollen	45%	61%
Angiospermous pollen	9%	23%
Fungal remains	13%	9%
Palynomorphs of uncertain affinity	22%	0
Reworked phytoplanktons	0	Present

Table 6—Group-wise comparison of the Assemblage-2 with the Upper Siwalik palynoflora from Gagret-Bharwain Road Section, Himachal Pradesh.

Groups	Assemblage-2	Upper Siwalik of Gagret-Bharwain Road section Himachal Pradesh
Pteridophytic spores	2.5%	0
Gymnospermous bisaccate pollen	77%	33%
Gymnospermous inaperturate pollen	12%	32%
Angiospermous pollen	5.5%	7%
Fungal remains	3%	14%
Palynomorphs of uncertain affinity	0	14%
Reworked phytoplanktons	0	Present

It may, therefore, be concluded that Assemblage 1 and 2 hold the same stratigraphic positions as those from Chandigarh and Gagret-Bharwain Road section, respectively.

CONCLUSION

From the foregoing account the following conclusions have been derived :

(i) The present Upper Siwalik palynoflora is a mixed assemblage.

(ii) The gymnospermous pollen grains are the dominant constituents of the present palynoflora.

(iii) Qualitative analysis indicates that the pteridophytic spores may be related to Schizaeaccae and Polypodiaceae ; gymnospermous pollen grains may be referred to Pinaceae ; angiospermous pollen grains may be related to Palmae, Potamogetonaceae, Poaceae, Mimosaceae and Euphorbiaceae.

(iv) The quantitative analysis of the palynoflora revealed two distinct assemblages.

(v) The present palynoflora contains both tropical-subtropical and temperate elements. It appears that the tropical elements have been derived from southern side while the temperate, pinaceous elements have been derived from north. Temperate elements, which are in abundance, might have been supported by the Himalayan ranges in the north which would have been considerably high by that time.

(vi) The environment of deposition has been interpreted as fluviatile. Any kind of marine influence, as suspected by some previous workers is completely ruled out.

(vii) A comparison of the present palynoflora reveals that Assemblage-1 closely resembles the palynoflora recorded from the Pinjor Formation near Chandigarh. The Assemblage-2 resembles the Upper Siwalik palynoflora from the Gagret-Bharwain Road section, Himachal Pradesh.

(viii) The present flora does not contain even a single specimen of reworked phytoplanktons. It appears that either its source would have been different than those of Chandigarh and Gagret-Bharwain Road section assemblages which contain reworked phytoplanktons, or they might have been destroyed during the course of sediments transportation.

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EXPLANATION OF PLATES

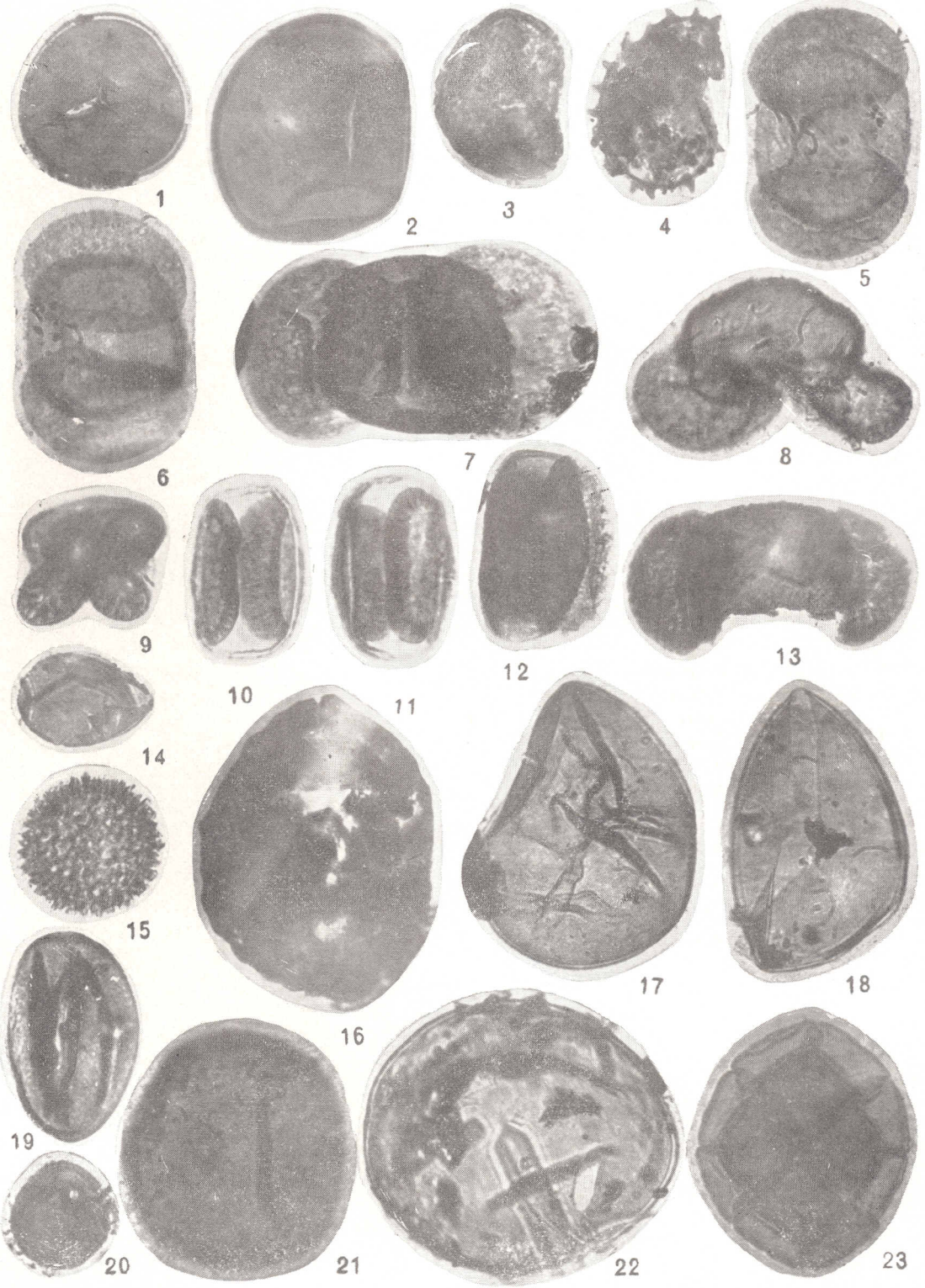
(All photomicrographs are enlarged *ca* ×500)

PLATE 1

1. *Lygodiumsporites lakiensis* Sah & Kar, Slide no. 6684/7.
2. *Monolites* sp., Slide no. 6686/1.
3. *Verrucatosporites usmensis* (van der Hammen) Potonié, Slide no. 6687/8.
4. cf. *Verrucatosporites* sp., Slide no. 6684/26.
5. *Pinuspollenites siwalikus* Singh & Saxena, Slide no. 6688/4.
6. *Pinuspollenites* sp., Slide no. 6685/14.
7. *Abiespollenites* sp., Slide no. 6689/5.
8. *Abietineaepollenites* sp., Slide no. 6690/1.
9. *Phyllocladidites* sp., Slide no. 6688/11.
10-12. *Quadrangulosaccites himachalensis* gen. *et* sp. nov., Slide nos. 6688/9 (Holotype), 6691/3, 6688/10.
13. Bisaccate pollen type, Slide no. 6689/2.
14. *Laricoidites minutus* Singh & Saxena, Slide no. 6895/3.
15. *Assamiapollenites ghoshii* Singh & Saxena, Slide no. 6685/16.
16. *Verrualetes* sp., Slide no. 6696/4.
17. *Inapertisporites ellipticus* Chandra, Saxena & Setty, Slide no. 6702/1.
18. Monosulcate palynomorph, Slide no. 6698/2.
19. Tricolporate pollen type, Slide no. 6689/3.
20. *Graminidites pliocenicus* Singh & Saxena, Slide no. 6695/2.
21. *Graminidites* sp., Slide no. 6685/13.
22. Monoporate palynomorph, Slide no. 6700/2.
23. *Polyadopollenites siwalikus* sp. nov., Slide no., 6697/2 (Holotype).

PLATE 2

24-25. *Siwalikiathyrites ramanujamii* gen. *et* sp. nov., Slide nos. 6689/1, 6689/6 (Holotype).
26. *Dicellaesporites* sp., Slide no. 6702 a/1.
27. *Lacrimasporonites magnus* sp. nov., Slide no. 6698/37 (Holotype).
28-29. *Staphlosporonites multicellatus* sp. nov., Slide nos. 6685/8 (Holotype), 6685/5.
30. *Tetraploa* sp., Slide no. 6693/2.
31. Monoporate spore type, Slide no. 6687/14.
32. *Lacrimasporonites* sp., Slide no. 6687/31.
33-34. Palynomorph type-1, Slide nos. 6685/6, 6685/2.
35-36. Palynomorph type-2, Slide nos. 6687/33, 6698/49.
37-38. Palynomorph type-3, Slide nos. 6694/10, 6694/9.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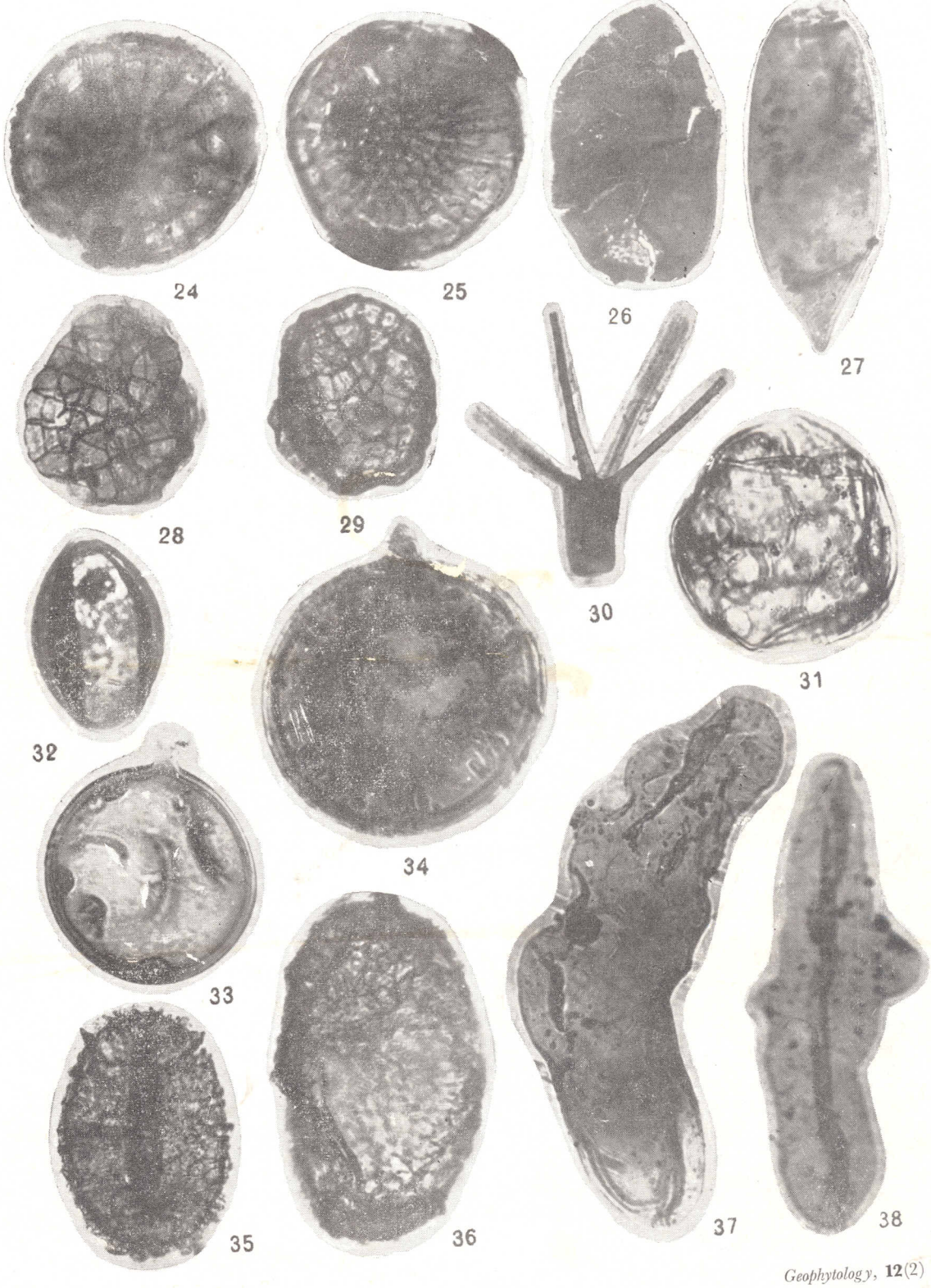

Saxena & Singh—Plate 2