*The Palaeobotanist*, **30**(3): 325-339, 1982.

# PALYNOLOGY OF THE PINJOR FORMATION (UPPER SIWALIK) EXPOSED NEAR CHANDIGARH, INDIA

R. K. SAXENA & H. P. SINGH

Birbal Sahni Institute of Palaeobotany, 53 University Road, Lucknow 226 007, India

## ABSTRACT

The paper deals with the systematic description and discussion of the palynoflora recovered from the Pinjor Formation near Chandigarh. A total of 19 genera and 23 species have been recovered. Of these, two species are new.

The study of the Pinjor assemblage reveals that the spores and pollen grains may belong to 11 families, viz., Cyatheaceae, Schizaeaceae, Parkeriaceae, Podocarpaceae, Pinaceae, Palmae, Liliaceae, Gramineae, Magnoliaceae, Proteaceae and Oleaceae. The occurrence of reworked Eocene phytoplanktons has been discussed. The significance of the assemblage has also been commented upon.

*Key-words* — Palynology, Upper Siwalik, Pinjor Formation, Chandigarh (India).

## सारांश

चन्डीगढ़ (भारत) के समीप विगोपित पिंजौर शैल-समूह (उपरि शिवालिक) का परागाणविक अध्ययन – रमेश कुमार सक्सेना एवं हरिपाल सिंह

चन्डीगढ़ के समीपस्थ पिंजौर शैल-समूह से उपलब्ध परागाणविक वनस्पतिजात का वर्गीकृत वर्णन एवं विवेचन किया गया है। कुल मिलाकर 19 प्रजातियाँ एवं 23 जातियाँ प्राप्त हुई हैं जिनमें दो जातियाँ नई हैं।

पिंजौर समुच्चय के अध्ययन से यह व्यक्त होता है कि परागकण एवं बीजाणु 11 कुलों – स्यॅथिएसी, शाइज़िएसी, पार्केरिएसी, पोडोकार्पेसी, पाइनेसी, पाल्मी, लिलीएसी, ग्रेमिनी, मेग्नोलिएसी, प्रोटिएसी एवं ओलिएसी – से सम्बन्धित हैं। पुनः निक्षेपित आदिनूतन युगीन पादप-प्लवकों की उपस्थिति भी विवेचित की गई है। इस समुच्चय के महत्व पर भी टिप्पणी की गई है।

## INTRODUCTION

THE progress of palynological research on the Upper Siwalik sediments has been rather slow because of the paucity of spores and pollen grains in these sediments. The possible reason for the absence or impoverished recovery of palynomorphs seems to be the prevalence of oxidizing environment of deposition in addition to secondary weathering to which these sediments have been exposed as they are mostly coarse grained, loose and friable in nature. In spite of these setbacks, palynologists have recovered assemblages which have been used to throw light on the problems like climatology and environment of deposition (Ghosh, 1977). Informal assemblage zone has also been recognized in the Upper Siwalik (Nandi, 1975). The present paper is the first attempt in which palynology of the Pinjor Formation near Chandigarh has been systematically described and compared with the known comparable assemblages.

The literature on palynology of the Siwalik Group is rather scanty. Banerjee (1968) was the first to publish a paper on the palynology of Lower and Middle Siwalik sediments of Bhakra-Nangal area, Himachal Pradesh. On the basis of the recovered palynoflora, he inferred that during the Lower Siwalik sedimentation the vegetation was coastal having tropical-temperate climate, while during the deposition of Middle Siwalik it changed to a predominantly inland type of vegetation with temperate climate. The dominance of

gymnospermous elements over the angiospermous ones and rather poor representation of pteridophytes lead him to suggest a gradual cooling of the surrounding climate. Lukose (1969) described a palynoflora from the Middle Siwalik of Raxaul, Bihar and discussed about the source of sediments and probable cause of their poor fossiliferous state. Nandi and Bandyopadhyay (1970) published a short note on the microfossils and microstructures from the Middle Siwalik lignite exposed along Bhed Khad in Himachal Pradesh between Ghasoti and Badahr. They described the palynofossils under 5 types, viz., porate, inaperturate, polycolpate, saccate and fungal spores. Venkatachala (1972), while reviewing the palynological contributions to Indian stratigraphy, gave the characteristic palynomorphs of the Lower and Middle Siwalik sediments. Palynoflora from Middle Siwalik sediments of Mohand (East) Field, Uttar Pradesh has been described by Nandi (1972). Based on the palynofloral evidence, she concluded that the sediments were deposited under fresh water condition and a great climatic change occurred during their deposition, i.e. during Upper Miocene to Lower Pliocene. Mathur (1973) described Lower Siwalik palynoflora from Tharukhola-Chepang, located towards north-east of Nepalgange, Nepal, assigning a Miocene age to the sediments. She inferred the prevalence of tropical to subtropical climate during the time of deposition.

Singh, Khanna and Sah (1973) mainly reported the occurrence of *Pinus*-type, monosulcate-type and inaperturate (non-saccate) pollen grains from the Pinjor Formation of which the later mentioned being in abundance. This fact has been confirmed by the present investigation. Singh, Khanna and Sah (1973, p. 76) surmised sub-temperate to temperate climate during the Upper Siwalik times.

Palynostratigraphical studies on the Siwalik Group exposed in Jawalamukhi area of Himachal Pradesh have been attempted for the first time by Nandi (1975). She proposed 4 palynological zones in the Siwalik, i.e. zones 1-4, giving characteristic palynomorphs and their vertical distribution for each zone and concluded the prevalence of tropical to subtropical climate during Lower Siwalik, subtropical to temperate during Middle Siwalik and a distinctly colder one during Upper Siwalik sedimentation. Ghosh (1977) reviewed the palynological work done on Siwalik sediments. He discussed the palaeoecology and palaeoclimate during the Siwalik sedimentation and gave a brief description of the palynological zones originally proposed by Nandi (1975).

From the above mentioned resume, the present authors feel that the terms like subtropical to temperate climate or vegetation have been very loosely used by various authors which need to be avoided in future work.

The material for the present study was collected from a carbonaceous shale bed of the Pinjor Formation exposed in the vicinity of Chandigarh which was kindly made available by Dr S. B. Bhatia of Punjab University, Chandigarh. The slides and unused material have been deposited in the repository of the Birbal Sahni Institute of Palaeobotany, Lucknow.

## SYSTEMATIC PALYNOLOGY

Anteturma — *Proximegerminantes* Potonié, 1970

Turma — *Triletes* Reinsch emend. Dettmann, 1963

Suprasubturma — *Acavatitriletes* Dettmann, 1963

Subturma — *Azonotriletes* Luber emend. Dettmann, 1963

Infraturma — *Laevigati* Bennie & Kidston emend. Dettmann, 1963

### Genus — *Cyathidites* Couper, 1953

*Type Species* — *Cyathidites australis* Couper, 1953.

*Cyathidites minor* Couper, 1953

Pl. 1, fig. 1

*Cyathidites* sp.

Pl. 1, fig. 2

*Description* — Spores triangular-subtriangular, 30-38 μm. Trilete rays extending almost up to the equator. Exine 2-3 μm thick, occasionally slightly thicker at apices, laevigate- ± sculptured.

*Comparison* — The present specimens are identical to *C. minor* Couper (1953) in

shape, size and nature of trilete mark but in the former, the exine is slightly thicker and occasionally faintly sculptured.

**Genus — *Lygodiumsporites* Potonié, Thomson & Thiergart ex Potonié, 1956**

*Type Species* — *Lygodiumsporites adriennis* Potonié, Thomson & Thiergart, 1950.

*Lygodiumsporites* sp.

Pl. 1, fig. 3

*Description* — Spores subtriangular, apices broadly rounded, interapical margin convex, 46 μm. Trilete, rays extending up to the equator. Exine 2.5 μm thick, laevigate-± intrastructured.

*Comparison* — The present spores resemble *Lygodiumsporites pachyexinus* Saxena (1978) in shape and size but in the latter the exine is thicker. *L. lakiensis* Sah & Kar (1969) and *L. eocenicus* Dutta & Sah (1970) are bigger in size.

**Genus — *Todisporites* Couper, 1958**

*Type Species* — *Todisporites major* Couper, 1958.

*Todisporites* sp.

Pl. 1, fig. 4

*Description* — Spores circular-subcircular, 30-35 μm. Trilete, rays extending three-fourth of the radius, generally covered by exinal fold. Exine 1-1.5 μm thick, laevigate.

*Remarks* — The present specimens resemble *Todisporites* cf. *plicatus* Sah & Kar (1969) described by Nandi (1972, p. 376, pl. 1, fig. 7) from the Middle Siwalik sediments of Mohand (East) Field, Uttar Pradesh.

Infraturma — *Murornati* Potonié & Kremp, 1954

**Genus — *Striatriletes* van der Hammen, 1956**

*Type Species* — *Striatriletes susannae* van der Hammen, 1956.

*Striatriletes* sp.

Pl. 1, fig. 5

*Description* — Spore triangular with acute apices, 65 μm. Trilete, rays obscure. Exine 2.5 μm thick, striate, 4 ridges in each interradial region, ridges as wide as furrows, occasionally bifurcating on distal surface to form loop-like structures.

Anteturma — *Variegerminantes* Potonié, 1970
Turma — *Saccites* Erdtman, 1947
Subturma — *Disaccites* Cookson, 1947
Infraturma — *Podocarpoiditi* Potonié, Thomson & Thiergart, 1950

**Genus — *Podocarpidites* Cookson emend. Potonié, 1956**

*Type Species* — *Podocarpidites ellipticus* Cookson, 1947.

*Podocarpidites ellipticus* Cookson, 1947

Pl. 1, fig. 9

*Podocarpidites microreticuloidatus* Cookson, 1947

Pl. 1, fig. 8

*Remarks* — The present specimens are slightly bigger in size than those described by Cookson (1947) from Kerguelen Archipelago.

Infraturma — *Pinosacciti* Erdtman emend. Potonié, 1958

**Genus — *Pinuspollenites* Raatz, 1937**

*Type Species* — *Pinuspollenites labdacus* (Potonié) Raatz, 1937.

*Pinuspollenites* sp.

Pl. 1, fig. 6

*Description* — Pollen grains elliptical in polar view, 88-108 × 58-62 μm. Bisaccate. Central body circular-subcircular, 60-66 × 50-60 μm, very finely reticulate. Sacci equal in size, smaller than central body, reticulate, reticulum fine to coarse, muri

delicate, sometimes meshes irregular and obscure. Sulcus 18-22 μm wide, longitudinally oval.

*Remarks* — The present specimens resemble *Disaccites* sp. 1 and *Disaccites* sp. 5 described by Lukose (1969) from the Middle Siwalik sediments of Bihar.

Infraturma — *Cedrosacciti* Erdtman, 1945

**Genus — *Cedripites* Wodehouse, 1933**

*Type Species* — *Cedripites eocenicus* Wodehouse, 1933.

*Cedripites* sp.

Pl. 1, fig. 7

*Description* — Pollen grains ± oval in polar view, 77-112 μm. Bisaccate. Central body subcircular, 66-70 μm, finely sculptured, granulose. Sacci ± equal in size, smaller than central body, very finely reticulate. Sulcus wide.

*Remarks* — Only two specimens assignable to *Cedripites* Wodehouse (1933) have been found in the present assemblage.

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

**Genus — *Laricoidites* Potonié, Thomson & Thiergart ex Potonié, 1956**

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

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

Pl. 1, fig. 10

*Remarks* — The present species is predominant in the assemblage.

*Laricoidites punctatus* Saxena, 1979a

Pl. 1, fig. 11

Infraturma — *Granulonapiti* Cookson, 1947

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

*Type Species* — *Araucariacites australis* Cookson, 1947.

*Araucariacites australis* Cookson, 1947

Pl. 1, fig. 12

*Remarks* — The occurrence of this species is rare in the present assemblage.

Infraturma — *Reticulonapiti* (Erdtman) Bose & Kar, 1967

**Genus — *Retiinaperturites* Mathur, 1966**

*Type Species* — *Retiinaperturites depressus* Mathur, 1966.

*Retiinaperturites pinjoricus* sp. nov.

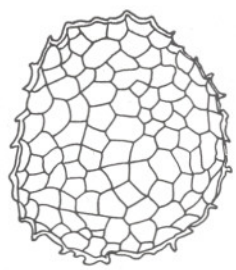
Pl. 1, figs 16-18; Text-fig. 1

*Holotype* — Pl. 1, fig. 16, size 118 × 100 μm; slide no. 6198/2.

*Type Horizon & Locality* — Pinjor Formation, Upper Siwalik, near Chandigarh, India.

*Diagnosis* — Pollen grains subcircular-oval, 93-120 × 68-102 μm. Germinal mark absent. Exine 1-3 μm thick, reticulate, reticulum coarse, muri fairly raised, lumina polygonal-irregular in shape.

*Comparison* — The present species can be differentiated from the type species, *R. depressus* Mathur (1966), in being much bigger in size and in having thicker exine and coarser reticulum.



TEXT-FIG. 1 — *Retiinaperturites pinjoricus* sp. nov., × 250.

Turma — *Plicates* Naumova emend. Potonié, 1960
Subturma — *Monocolpates* Iversen & Troels-Smith, 1950
Infraturma — *Monoptyches* Naumova emend. Potonié, 1958

**Genus — *Palmidites* Couper, 1953**

*Type Species — Palmidites maximus* Couper, 1953.

*Palmidites maximus* Couper, 1953

Pl. 2, fig. 19

**Genus — *Psilamonocolpites* van der Hammen & Garcia de Mutis, 1965**

*Type Species — Psilamonocolpites medius* van der Hammen & Garcia de Mutis, 1965.

*Psilamonocolpites* sp.

Pl. 2, fig. 28

*Description* — Pollen grain elliptical, 100 × 43 μm. Monosulcate, sulcus wide, extending from one end to the other. Exine 1.5 μm thick, laevigate.

**Genus — *Pinjoriapollis* Saxena & Singh, 1981**

*Type Species — Pinjoriapollis magnus* Saxena & Singh, 1981.

*Pinjoriapollis magnus* Saxena & Singh, 1981

Pl. 2, figs 20, 21

*Pinjoriapollis lanceolatus* Saxena & Singh, 1981

Pl. 2, figs 27, 29

Infraturma — *Sculptati* Potonié, 1970

**Genus — *Liliacidites* Couper, 1953**

*Type Species — Liliacidites kaitangataensis* Couper, 1953.

*Liliacidites matanomadhensis* Saxena, 1979a

Pl. 2, fig. 23

Subturma — *Ptychotriporines* Naumova emend. Potonié, 1960
Infraturma — *Prolati* Erdtman, 1943

**Genus — *Favitricolporites* Sah, 1967**

*Type Species — Favitricolporites eminens* Sah, 1967.

*Favitricolporites* sp.

Pl. 2, fig. 24

*Description* — Pollen grain subcircular in polar view, 42 μm. Tricolporate, colpi long, well-developed, funnel-shaped, mesocolpia wide, pore margin slightly thickened. Exine 2·5 μm thick, sexine thinner than nexine, reticulate, reticulum fine, tegillate.

*Remarks* — Only one specimen of this species could be recovered from the present assemblage.

Turma — *Porosus* Naumova emend. Potonié, 1960
Subturma — *Monoporines* Naumova emend. Potonié, 1960

**Genus — *Graminidites* Cookson, 1947**

*Type Species — Graminidites media* Cookson, 1947.

*Graminidites chandigarhensis* sp. nov.

Pl. 2, fig. 25; Text-fig. 2

*Holotype* — Pl. 1, fig. 25, size 47 × 34 μm, slide no. 6192/8.

TEXT-FIG. 2 — *Graminidites chandigarhensis* sp. nov., × 500.

*Type Horizon & Locality* — Pinjor Formation, Upper Siwalik, near Chandigarh, India.

*Diagnosis* — Pollen grains oval, 30-40 × 25-30 μm. Monoporate, pore ± circular with a clearly defined annulus. Exine 0.5-1.5 μm thick, laevigate.

*Comparison* — The present species differs from *G. media* Cookson (1947) and *G. subreticulata* Cookson (1947) in having laevigate exine while the latter two have reticulate ornamentation of the exine. *G. assamicus* Sah & Dutta (1968) is bigger in size.

Subturma — *Triporines* Naumova emend. Potonié, 1960

Infraturma — *Zoniporiti* Ramanujam, 1966

**Genus — *Triorites* Erdtman ex Couper, 1953**

*Type Species — Triorites magnificus* Cookson, 1950.

*Triorites* sp.

Pl. 2, fig. 22

*Description* — Pollen grains subtriangular, 26-40 μm. Triorate, ora distinct, 7-9 μm in diameter, ora margin slightly thickened. Exine 3 μm thick ornamented by a few, very fine, conical, sparsely placed spinules, interspinal area laevigate.

*Comparison* — The present species differs from other species of *Triorites* Erdtman ex Couper (1953) in having very fine sparsely placed conical spinules.

PALYNOMORPH TYPE-1

Pl. 1, fig. 13

*Description* — Spore circular, 24 μm. Trilete, rays extending almost up to the equator. Exine 1 μm thick, spinulose, spinules hair-like, small, up to 2 μm in length, sparsely placed.

PALYNOMORPH TYPE-2

Pl. 2, fig. 30

*Description* — Pollen grains elliptical, 187 × 77 μm. Inaperturate. Exine 2 μm thick, intrapunctate, puncta closely placed and evenly distributed, exine irregularly folded.

*Remarks* — The present specimen resembles *Laricoidites* sp. described by Saxena (1979a) from the Matanomadh Formation of Kachchh.

PALYNOMORPH TYPE-3

Pl. 2, fig. 26

*Description* — Pollen grain elliptical, 49 × 26 μm. Monosulcate, sulcus oval in shape, extending half the length of longer axis. Exine 1.5 μm thick, baculate-pilate, pila/bacula small.

*Remarks* — The present specimen appears to have some affinity with Liliaceae.

## FUNGAL SPORES

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

*Type Species — Inapertisporites pseudoreticulatus* Rouse, 1959.

*Inapertisporites vulgaris* Sheffy & Dilcher, 1971

Pl. 1, fig. 14

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

*Type Species — Monoporisporites minutus* van der Hammen, 1954.

*Monoporisporites minutus* van der Hammen, 1954

Pl. 1, fig. 15

1954 *Monoporisporites minutus* A & B van der Hammen, pl. 21, figs 1, 2, p. 103.

## DISCUSSION

The palynofloral assemblage from the Pinjor Formation consists of fungal and pteridophytic spores alongwith gymnospermous and angiospermous pollen grains. Altogether 19 genera and 23 species have been recovered. Of these, two species are new.

## Quantitative Analysis

An analysis of the mioflora reveals the occurrence of different spores and pollen grains in the following order: gymnospermous pollen (65%), angiospermous pollen (23%), fungal spores (9%) and pteridophytic spores (3%) (Text-figs 3, 4).

Among gymnospermous pollen, *Laricoidites* Potonié, Thomson & Thiergart ex Potonié (57%) is the predominant genus, being represented by two species, viz., *L. magnus* (Potonié) Potonié, Thomson & Thiergart (52%) and *L. punctatus* Saxena (5%), while the other two alete genera, *Araucariacites* Cookson ex Couper (3%) and *Retiinaperturites* Mathur (2%) are meagre in occurrence. The bisaccate pollen are represented by three genera, viz., *Pinuspollenites* Raatz (2%), *Podocarpidites* Cookson emend. Potonié (1%) and *Cedripites* Wodehouse (less than 1%).

Among angiospermous pollen, *Pinjoriapollis* Saxena & Singh (10%), is represented by two species, viz., *P. magnus* Saxena & Singh (4%) and *P. lanceolatus* Saxena & Singh (6%). *Graminidites* Cookson (6%), *Psilamonocolpites* van der Hammen & Garcia de Mutis (3%), *Triorites* Erdtman ex Couper (2%) and *Palmidites* Couper (2%) have also been encountered.

The pteridophytic spores are very poorly represented. Out of 4 genera present in the assemblage, only two appear in the counting, viz., *Cyathidites* Couper (2%) and *Striatriletes* van der Hammen (1%).

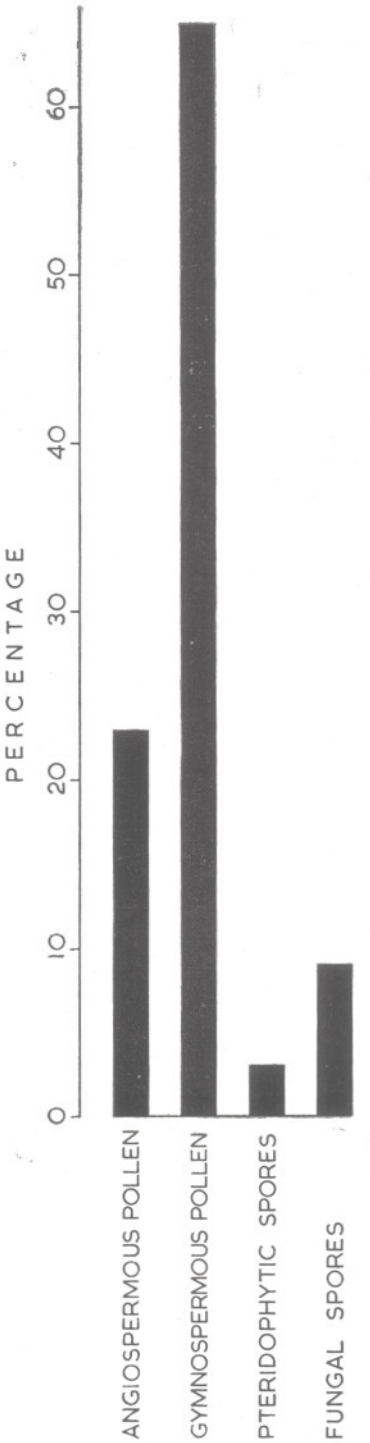
The fungal spores are represented in the assemblage by two genera, *Inapertisporites* van der Hammen emend. Sheffy & Dilcher (9%) and *Monoporisporites* van der Hammen emend. Sheffy & Dilcher. The latter does not figure in the percentage count.

## Qualitative Analysis

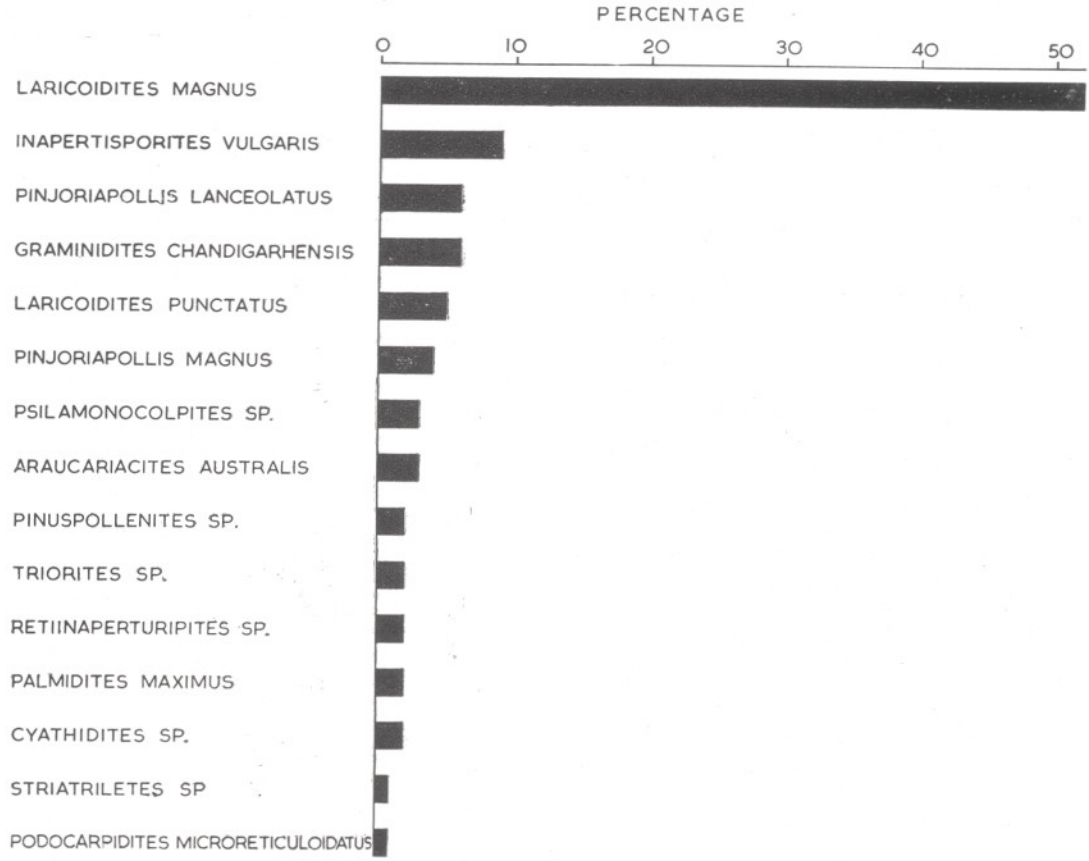
### Pteridophyta

The pteridophytic spores are represented by 4 genera and 5 species and may be related to the following three families:

1. *Cyatheaceae* — The spores referred to *Cyathidites minor* Couper and *Cyathidites* sp. are comparable to those of Cyatheaceae. The present day distribution of this family is in tropical-subtropical region.




TEXT-FIG. 3 — Showing the representation of various plant groups in the Pinjor palynoflora of Chandigarh.




TEXT-FIG. 4 — Showing the representation of various palynomorph species in the Pinjor palynoflora of Chandigarh.

2. *Schizaeaceae* — The spores described under *Lygodiumsporites* sp. and *Todisporites* sp. seem to belong to this family. This family is chiefly distributed in tropical-subtropical climatic belt.

3. *Parkeriaceae* — Only a single specimen referred to *Striatriletes* sp. shows close relationship with this family and probably belongs to the living genus *Ceratopteris*.

## GYMNOSPERMAE

The gymnospermous pollen are represented by six genera and eight species and may be referred to the following two families:

1. *Podocarpaceae* — The pollen grains described under *Podocarpidites ellipticus* Cookson and *P. microreticuloidatus* Cookson have close affinity with Podocarpaceae and in all probability, they represent this family. This family is distributed in both tropical and temperate region.

2. *Pinaceae* — The presence of this family in the present assemblage is evident by *Laricoidites magnus* (Potonié) Potonié, Thomson & Thiergart, *L. punctatus* Saxena, *Araucariacites australis* Cookson, *Pinuspollenites* sp. and *Cedripites* sp. The rich representation of *Laricoidites* Potonié, Thomson & Thiergart ex Potonié clearly testifies that this family constituted the principal element in the present assemblage. The family is distributed in both tropical and temperate climate.

### Angiospermae

The angiospermous pollen are represented by 7 genera and 8 species. Of these, 4 genera and 4 species belong to monocotyledons and 3 genera and 4 species belong to dicotyledons. The monocotyledonous pollen may be related to Palmae, Liliaceae and Gramineae while dicotyledonous ones may be referred to Magnoliaceae, Proteaceae and Oleaceae.

1. *Palmae* — Pollen grains referred to *Palmidites maximus* Couper and *Psilamonocolpites* sp. show close affinity with the pollen grains of Palmae. The geographical distribution of this family is exclusively tropical-subtropical.

2. *Liliaceae* — This family is represented by the pollen grains described under *Liliacidites matanomadhensis* Saxena. The present day distribution of this family is cosmopolitan.

3. *Gramineae* — Pollen grains described under *Graminidites chandigarhensis* sp. nov. prove the presence of this family in the Pinjor assemblage.

4. *Magnoliaceae* — This family is represented by the pollen grains described under *Pinjoriapollis magnus* Saxena & Singh and *P. lanceolatus* Saxena & Singh. This family is distributed primarily in temperate regions.

5. *Proteaceae* — Pollen grains referred to *Triorites* sp. show close relationship with this family. The family is ubiquitous in distribution.

6. *Oleaceae* — A single specimen referred to *Favitricolporites* sp. appears to belong to Oleaceae. The present day distribution of this family is in tropical-warm temperate zone.

### Palynofloral Comparison

Very little has so far been published on the Siwalik palynology. Many taxa reported in the literature are either invalid, viz., *Monosaccites*, *Disaccites* (Lukose, 1969, p. 109) or their morphological details are not available, viz., *Siwalikisporites* (Nandi, 1975, p. 416; Ghosh, 1977, p. 15) or no generic or specific name has been assigned, viz., pollen grains having affinities to Compositae (Asteraceae), Palmae (Arecaceae), Gramineae (Poaceae), etc. (Banerjee, 1968, p. 172). As such a comparison of the present assemblage with those described earlier has been extremely difficult. However, an attempt has been made here in this regard with the help of whatever data is available.

Lower Siwalik palynoflora has so far been recorded by Banerjee (1968), Venkatachala (1972), Mathur (1973), Nandi (1975) and Ghosh (1977). Banerjee (1968) recovered palynomorphs belonging to Compositae (5·5%), Gramineae (8%), Palmae (5·5%), *Pinus* spp. (5·5%), *Disaccites* sp. (2·5%), tricolpate (2·5%), tetracolpate (13·5%), polycolpate (2·5%), inaperturate (5·5%) types alongwith a good percentage (11%) of trilete and monolete spores belonging to Gleicheniaceae, Polypodiaceae, etc. from the Lower Siwalik sediments exposed in Bhakra-Nangal area. This assemblage resembles the present Pinjor assemblage in common occurrence of inaperturate and Gramineae pollen. However, the two assemblages are distinctly different as the Bhakra-Nangal assemblage is rich in tetracolpate, polycolpate and tricolpate pollen which are completely absent in the Pinjor assemblage. On the other hand, Pinjor assemblage is loaded with inaperturate pollen (62%) and magnoliaceous pollen (10%). Of these, former is poor and the latter is totally unrepresented in Bhakra-Nangal palynoflora.

Venkatachala (1972), while reviewing the palynological contributions to Indian stratigraphy, mentioned that the Lower Siwalik sediments are characterized by pollen of Palmae and Gramineae associated with *Quercoidites*, *Holoragacidites*, *Cupuliferoipollenites*, *Sapotaceoidaepollenites* and *Araceopollenites*. Except for the occurrence of Gramineae (6%) and Palmae (2%) pollen, none of these genera could be recorded in the present assemblage.

Mathur (1973) described a rich assemblage from Lower Siwalik sediments exposed in Tharukhola-Chepang, northeast of Nepalgange, Nepal. It consists of *Verrucososporites* (3 spp.), *Polypodiaceoisporites* (1 sp.), *Leiotriletes* (1 sp.), *Cyathidites* (1 sp.), *Hymenophyllumsporites* (1 sp.), *Lycopodiumsporites* (1 sp.), *Perotriletes* (1 sp.), *Cicatricosisporites* (2 spp.), *Contignisporites* (2 spp.), *Pityosporites* (1 sp.), *Sabalpollenites* (1 sp.), *Echimonocolpites* (1 sp.) and *Graminidites* (1 sp.). It is interesting to note that none of the species described by Mathur (1973) is common to the Pinjor palynoflora. More-

over, Mathur's assemblage is dominated by angiospermous pollen followed by pteridophytic spores while gymnospermous pollen are rare, but in the Pinjor assemblage gymnospermous pollen are dominant (65%) followed by angiospermous ones while pteridophytic spores are rare (3%). It may be mentioned here that *Contignisporites* spp. A & B recorded by Mathur (1973) may be recycled Mesozoic spores.

Nandi (1975) and Ghosh (1977) proposed a palynostratigraphic zonation of the Siwalik Group. They mentioned, *Cicatricosisporites*, *Polypodiaceoisporites*, *Pteridacidites*, *Verrucososporites*, *Monoporopollenites*, *Cupuliferoidaepollenites*, *Cyathidites*, *Triplanosporites*, *Verrucatosporites*, *Hymenophyllumsporites*, *Leptolepidites*, *Polypodiaceaesporites*, *Polypodiisporites*, *Palmaepollenites*, *Tetradomonoporites*, *Gleicheniidites*, *Alsophilidites*, *Siwalikisporites*, *Laevigatosporites*, *Polypodiidites*, *Abietineaepollenites*, *Pinuspollenites*, *Piceapollenites*, *Podocarpidites*, *Caryapollenites*, *Alnipollenites*, *Polyadopollenites*, etc. as characteristic palynomorphs of the Lower Siwalik. This assemblage is rich in pteridophytic spores and angiospermous pollen grains while the present assemblage is rich in gymnospermous (65%) pollen, hence easily distinguishable.

The Middle Siwalik assemblages have been recorded by Banerjee (1968), Lukose (1969), Nandi and Bandyopadhyay (1970), Venkatachala (1972), Nandi (1972, 1975) and Ghosh (1977). Banerjee (1968) recovered *Pinus* spp. (26·5%), angiospermous pollen of tricolpate (5·5%) and pentacolpate (2·5%) types and pteridophytic spores of monolete (2·5%) and trilobate (2·5%) types. Inaperturate and magnoliaceous pollen, which are dominant in Pinjor assemblage, are completely absent from the Middle Siwalik assemblage of Bhakra Nangal area. On the other hand, tricolpate and pentaporate pollen and monolete and trilobate spores recorded in the Bhakra Nangal assemblage are completely absent and *Pinus* sp. is poorly represented in the Pinjor assemblage.

Lukose (1969) described Middle Siwalik palynoflora from Raxaul, Bihar. He recorded *Retimonoletes* (1 sp.), *Foveomonoletes* (1 sp.), *Retitriletes* (1 sp.), *Cingutriletes* (1 sp.), *Monosaccites* (2 spp.), *Disaccites* (6 spp.), *Polyadites* (1 sp.), *Inaperturites* (1 sp.), *Retimonocolpites* (1 sp.), *Triporites* (1 sp.), *Retitriporites* (2 spp.). A perusal of this assemblage reveals that none of these genera is common to the Pinjor assemblage except probably for a few bisaccate pollen.

Nandi and Bandyopadhyay (1970) recorded some monoporate, periporate, inaperturate, polycolpate, monosaccate and bisaccate pollen types alongwith a few fungal spores. This assemblage is too scanty to be of any use in specific comparison. However, except for the probable resemblance in inaperturate, bisaccate (cf. *Pinuspollenites*) and monoporate (cf. *Graminidites*) pollen, the two assemblages are entirely different. The high frequency of *Laricoidites magnus* (52%) also makes the present assemblage distinct.

Venkatachala (1972) mentioned that Middle Siwalik assemblage contains palynomorphs belonging to Malvaceae, Betulaceae, Anacardiaceae, Pinaceae and Polypodiaceae. This assemblage shows better representation of gymnospermous pollen than angiospermous ones. In the Pinjor assemblage too, pollen of Pinaceae have been recorded associated with high frequency of inaperturate, magnoliaceous and graminoid pollen.

Nandi (1972) published Middle Siwalik assemblage from Mohand (East) field in Saharanpur District, Uttar Pradesh. This assemblage consists of many spore-pollen species related to Lycopodiaceae, Hymenophyllaceae, Schizaeaceae, Gleicheniaceae, Polypodiaceae, Cyatheaceae, monoporate (Cyperaceae), monosulcate (Palmae), polyporate, tricolporate, inaperturate types alongwith *Pinus* sp., *Podocarpus* sp., *Abies* sp. and monosaccate pollen. The present Pinjor assemblage differs from the Mohand assemblage by having rich representation of *Laricoidites* and *Pinjoriapollis* and scarcity of pteridophytic spores (monolete spores are completely absent) and *Pinus* sp. However, monoporate pollen (cf. *Graminidites*) may be common to both the assemblages. *Klukisporites*, *Concavissimisporites* and *Tsugaepollenites* may be recycled Mesozoic sporomorphs (Saxena, 1979b).

Nandi (1975) and Ghosh (1977) stated that *Pinuspollenites*, *Piceapollenites*, *Abietineaepollenites*, *Podocarpidites*, *Abiespollenites*, *Cyathidites*, *Gleicheniidites*, *Triplanosporites*, *Siwalikisporites*, *Leptolepidites*, *Laevigatosporites*, *Polypodiidites*, *Verrucatosporites*, *Polypodiisporites*, *Alsophilidites*, *Hymenophyllumsporites*, *Poly-*

*podiaceoisporites*, *Tsugaepollenites*, *Cedripites*, *Sciadopityspollenites*, *Betulaepollenites*, *Caryapollenites*, *Monoporopollenites*, *Alnipollenites*, *Polyadopollenites*, *Tetradomonoporites*, *Longapertites*, *Verruinaperturites*, *Cupuliferoidaepollenites*, *Cupuliferoipollenites* are characteristic of Middle Siwalik. This assemblage is fairly rich in pteridophytic (both trilete and monolete) spores and bisaccate pollen and very poor in inaperturate pollen while reverse is the case with Pinjor assemblage.

Nandi (1975) and Ghosh (1977) mentioned that the basal part of Upper Siwalik contains a very poor assemblage represented by *Cyathidites*, *Alsophilidites*, *Leptolepidites*, *Pinuspollenites*, *Podocarpidites*, *Monoporopollenites*, *Alnipollenites* and *Tetradomonoporites*. This assemblage comes comparatively closer to the present assemblage except for the absence of inaperturate and magnoliaceous pollen in the former and *Leptolepidites*, *Alnipollenites* and *Tetradomonoporites* in the latter. Nandi (1975) and Ghosh (1977) also stated that except for the basal part, the rest of the Upper Siwalik is unfossiliferous. The present Pinjor assemblage which represents the middle part of the Upper Siwalik has proved it to be productive now. Palynological assemblages from different horizons in other areas and even from the Boulder Conglomerate bed representing uppermost part of the Siwalik Group have been recovered by the present authors and are being studied for their botanical and stratigraphical importance. It is hoped that the Upper Siwalik palynoflora will be better understood in the coming times because of the enhanced research activity on these sediments by various workers.

## Occurrence of Reworked Palynomorphs

While studying the Pinjor palynoflora, a few specimens of phytoplanktons were also recorded. Their representation in the present assemblage is very poor as only 3 such specimens could be recovered. The preservation of these specimens is poorer than that of the original Pinjor mioflora.

It is very likely that the specimens of phytoplanktons are of Subathu (Lower Eocene) origin. Normally the phytoplanktons are found in the marine sediments while the Pinjor Formation is essentially of fresh-water origin. It, therefore, appears that these phytoplanktons are not part of the original Pinjor assemblage and might have been derived from the Subathu Formation of the neighbouring area. The reworked palynomorphs must have been transported and redeposited in the Pinjor sediments along with the material eroded and transported from the Subathu Formation.

## REFERENCES


Banerjee, D. (1968). Siwalik microflora from Punjab, India. *Rev. Palaeobot. Palynol.*, **6**: 171-176.

Bose, M. N. & Kar, R. K. (1967). Palaeozoic *Sporae dispersae* from Congo-4. On some new miospore genera. *Annls. Mus. r. Afr. cent.* Ser. 8: *Sci. Geol.*, **54**: 85-102.

Cookson, I. C. (1947). Plant microfossils from the lignites of Kerguelen Archipelago. *Rep. B.A.N.Z. antarct. Exped. Ser. A*: 129-142.

Cookson, I. C. (1950). Fossil pollen grains of proteaceous type from Tertiary deposits in Australia. *Aust. J. Sci. Res. Ser. B. Biol. Sci.*, **3** (2): 166-177.

Couper, R. A. (1953). Upper Mesozoic and Cainozoic spores and pollen grains from New Zealand. *Bull. N. Z. geol. Surv. palaeont.*, **22**: 1-77.

Couper, R. A. (1958). British Mesozoic microspores and pollen grains — A systematic and stratigraphic study. *Palaeontographica*, **103B**:75-179.

Dettmann, M. E. (1963). Upper Mesozoic microfloras from South-eastern Australia. *Proc. R. Soc. Vict.*, **77** (1): 1-148.

Dutta, S. K. & Sah, S. C. D. (1970). Palynostratigraphy of the Tertiary sediments of Assam-5. Stratigraphy and palynology of South Shillong Plateau. *Palaeontographica*, **131B** (1-4): 1-72.

Erdtman, G. (1943). *An Introduction to Pollen Analysis*. Waltham Mass, U.S.A.

Erdtman, G. (1947). Suggestions for the classification of fossil and recent pollen grains and spores. *Svensk. bot. Tidskr.*, **41** (1): 104-114.

Ghosh, A. K. (1977). Palynology of the Siwaliks. *Adv. Pollen Spore Res.*, **2**: 14-19.

Ibrahim, A. C. (1933). Sporenformen des Aegirhorizonts des Ruhr Reviers. *Diss Konard Triltsch Wurzburg*,: 1-47.

Iversen, J. & Troels-Smith, J. (1950). Pollen morfologiske definitioner og typer. *Danmarks Geol. Unders*, **4** (8): 1-52.

Lukose, N. G. (1969). Microfossils from the Middle Siwalik of Bihar, India. *J. palynol.*, **4** (2): 107-112.

Mathur, K. (1973). Studies in the paleoflora of the Himalayan foot-hills. 2. On the palynoflora in the Lower Siwalik sediments of Nepal. *J. palynol.*, **8**: 54-62.

Mathur, Y. K. (1966). On the microflora in the Supratrappeans of W. Kutch, India. *Q. Jl geol. Min. metall. Soc. India*, **38**: 33-51.

NANDI, B. (1972). Some observations on the microflora of Middle Siwalik sediments of Mohand (East) Field, Himachal Pradesh. *Proc. Sem. Paleopalynol. Indian Strat., Calcutta*: 375-383.

NANDI, B. (1975). Palynostratigraphy of the Siwalik Group of Punjab. *Him. Geol.*, **5**: 411-423.

NANDI, B. & BANDYOPADHYAY, N. N. (1970). Preliminary observations on the microfossils and microstructures of Siwalik lignite from Himachal Pradesh, India. *Sci. Cult.*, **36**: 240-242.

POTONIÉ, R. (1956). Synopsis der Gattungen der *Sporae dispersae* 1. Teil: Sporites. *Beih. Geol. Jb.*, **23**: 1-103.

POTONIÉ, R. (1958). Synopsis der Gattungen der *Sporae dispersae* II. Teil: Sporites (Nachtrage), Saccites, Aletes Praecolpates, Polyplicates, Monocolpates. *Beih. Geol. Jb.*, **31**: 1-144.

POTONIÉ, R. (1960). Synopsis der Gattungen der *Sporae dispersae* III. Teil: Nachtrage Sporites, Fortsetzung Pollenites mit generalregister zu Teil I-III. *Beih. Geol. Jb.*, **39**: 1-189.

POTONIÉ, R. (1970). Synopsis der Gattungen der *Sporae dispersae* V. Teil. Nachtrage zu allen Gruppen (Turmae). *Beih. Geol. Jb.*, **87**: 1-56.

POTONIÉ, R. & KREMP, G. O. W. (1954). Die Gattungen der palaeozoischen *Sporae dispersae* und ihre Stratigraphie. *Geol. Jb.*, **69**: 111-194.

POTONIÉ, R., THOMSON, P. W. & THIERGART, F. (1950). Zur Nomenklatur und Klassification der neogenen Sporomorphae (Pollen und Sporen). *Geol. Jb.*, **65**: 35-70.

RAATZ, G. V. (1937). Mikrobotanisch-stratigraphisch Untersuchung der Braunkohle des Muskauer Bogens. *Publs Geol. Landes. Berlin*,: 5-48.

RAMANUJAM, C. G. K. (1966). Palynology of the Miocene lignite from South Arcot District, Madras, India. *Pollen Spores*, **8** (1): 149-203.

SAH, S. C. D. (1967). Palynology of an Upper Neogene profile from Rusizi Valley (Burundi). *Annls. Mus. r. Afr. cent.*, Ser. 8°, **57**: 1-173.

SAH, S. C. D. & DUTTA, S. K. (1968). Palynostratigraphy of the Tertiary sedimentary formations of Assam: 2. Stratigraphic significance of spores and pollen in the Tertiary succession of Assam. *Palaeobotanist*, **16** (2): 177-195.

SAH, S. C. D. & KAR, R. K. (1969). Pteridophytic spores from the Laki Series of Kutch, Gujarat, India, pp. 109-121 in Santapau, H. *et al.* (Eds)— *J. Sen Mem. Vol.* Bot. Soc. Bengal, Calcutta.

SAXENA, R. K. (1978). Palynology of the Matanomadh Formation in type area, north-western Kutch, India (Part-1). Systematic description of pteridophytic spores. *Palaeobotanist*, **25**: 448-456.

SAXENA, R. K. (1979a). Palynology of the Matanomadh Formation in type area, north western Kutch, India (Part-2). Systematic description of gymnospermous and angiospermous pollen grains. *Palaeobotanist*, **26** (2): 130-143.

SAXENA, R. K. (1979b). Reworked Cretaceous spores and pollen grains from the Matanomadh Formation (Palaeocene), Kutch, India. *Palaeobotanist*, **26** (2): 167-174.

SAXENA, R. K. & SINGH, H. P. (1981). *Pinjoriapollis*, a new fossil pollen from the Pinjor Formation (Upper Siwalik) exposed near Chandigarh. *Curr. Sci.*, **50** (9): 418-419.

SHEFFY, M. V. & DILCHER, D. L. (1971). Morphology and taxonomy of fungal spores. *Palaeontographica*, **133** (1-3): 34-51.

SINGH, H. P., KHANNA, A. K. & SAH, S. C. D. (1973). Problems and prospects of Tertiary palynology in northern India. *Bull. Indian geol. Assoc.*, **6** (1): 71-77.

VAN DER HAMMEN, T. (1954). El desarrollo de la flora Colombiana en los periodos geologicos. *Boln. geol. Bogota*, **2** (1): 49-106.

VAN DER HAMMEN, T. (1956). Description of some genera and species of fossil pollen and spores. *Boln. geol. Bogota*, **4** (2-3): 114-117.

VAN DER HAMMEN, T. & GARCIA DE MUTIS, C. (1965). The Paleocene pollen flora of Colombia. *Leidse. Geol. Med.*, **35**: 105-116.

VENKATACHALA, B. S. (1972). Observation on some palynological contributions to Indian stratigraphy. *Palaeobotanist*, **19** (3): 284-296.

WODEHOUSE, R. P. (1933). Tertiary pollen II. Pollen of the Green River Oil Shales. *Bull. Torry. bot. Club*, **60**: 479-524.

## EXPLANATION OF PLATES

(All photomicrographs are enlarged *ca.*× 500 unless otherwise mentioned)

PLATE 1

1. *Cyathidites minor* Couper, slide no. 6189/4.
2. *Cyathidites* sp., slide no. 6190/1.
3. *Lygodiumsporites* sp., slide no. 6191/1.
4. *Todisporites* sp., slide no. 6192/1.
5. *Striatriletes* sp., slide no. 6193/2.
6. *Pinuspollenites* sp., slide no. 6194/19.
7. *Cedripites* sp., slide no. 6189/6.
8. *Podocarpidites microreticuloidatus* Cookson, slide no. 6194/10.
9. *Podocarpidites ellipticus* Cookson, slide no. 6195/4.
10. *Laricoidites magnus* (Potonié) Potonié, Thomson & Thiergart, slide no. 6192/2.
11. *Laricoidites punctatus* Saxena, slide no. 6191/6.
12. *Araucariacites australis* Cookson, slide no. 6196/13.
13. Palynomorph type-1, slide no. 6189/20.
14. *Inapertisporites vulgaris* Sheffy & Dilcher, slide no. 6197/2.× 1000.
15. *Monoporisporites minutus* van der Hammen, Slide no. 6197/3.× 1000.

16-18. *Retiinaperturites pinjoricus* sp. nov., slide nos. 6198/2 (Holotype), 6189/21, 6193/5.

PLATE 2

19. *Palmidites maximus* Couper, slide no. 6192/8.
20, 21. *Pinjoriapollis magnus* Saxena & Singh, slide nos. 6196/5, 6189/5.
22. *Triorites* sp., slide no. 6199/12.
23. *Liliacidites matanomadhensis* Saxena, slide no. 6195/6.
24. *Favitricolporites* sp., slide no. 6196/19.
25. *Graminidites chandigarhensis* sp. nov., slide no. 6192/8. (Holotype).
26. Palynomorph type-3, slide no. 6199/4.
27, 29. *Pinjoriapollis lanceolatus* Saxena & Singh, slide nos. 6198/7, 6193/9.
28. *Psilamonocolpites* sp., slide no. 6199/8.
30. Palynomorph type-2, slide no. 6199/13.

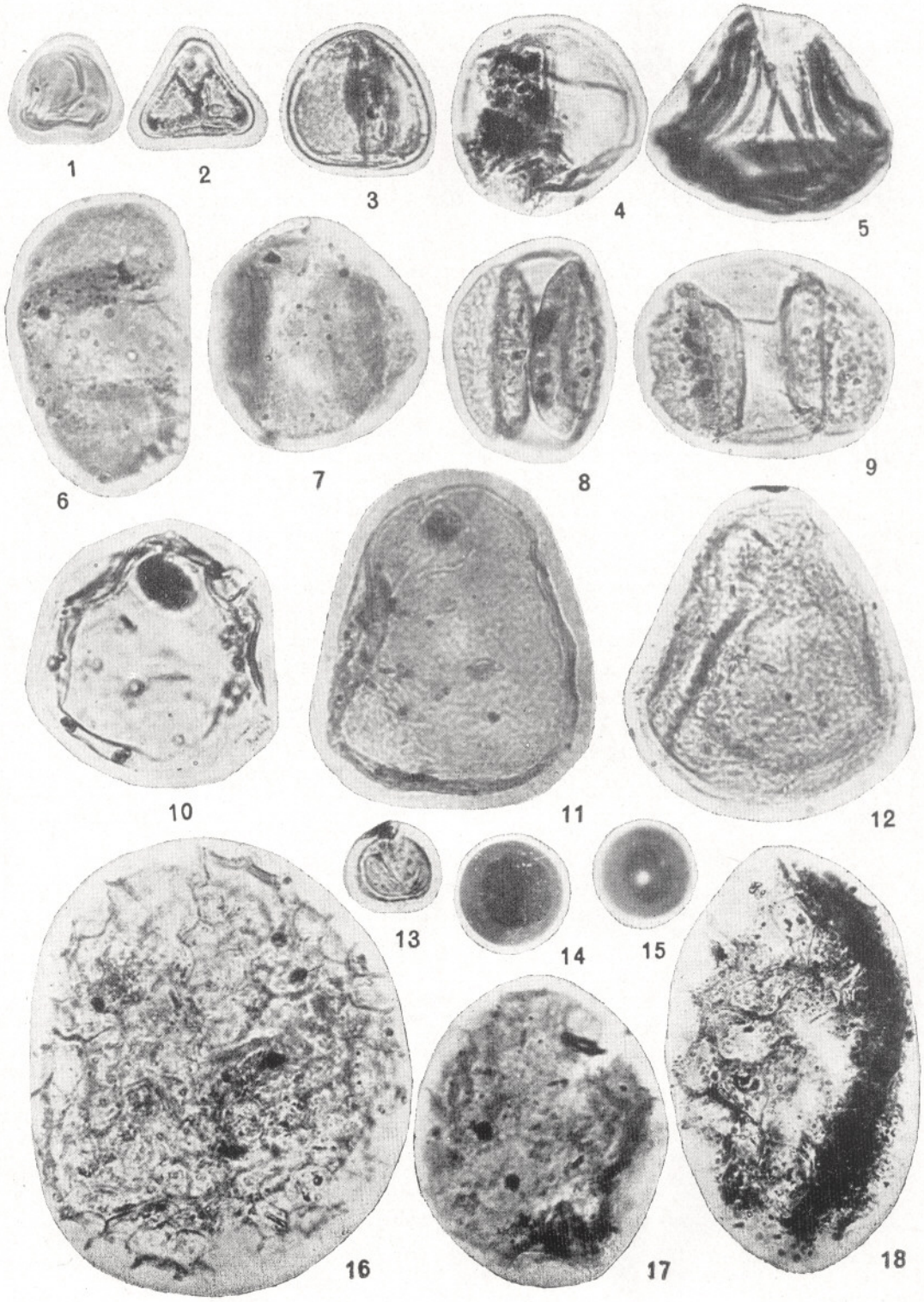



PLATE 1

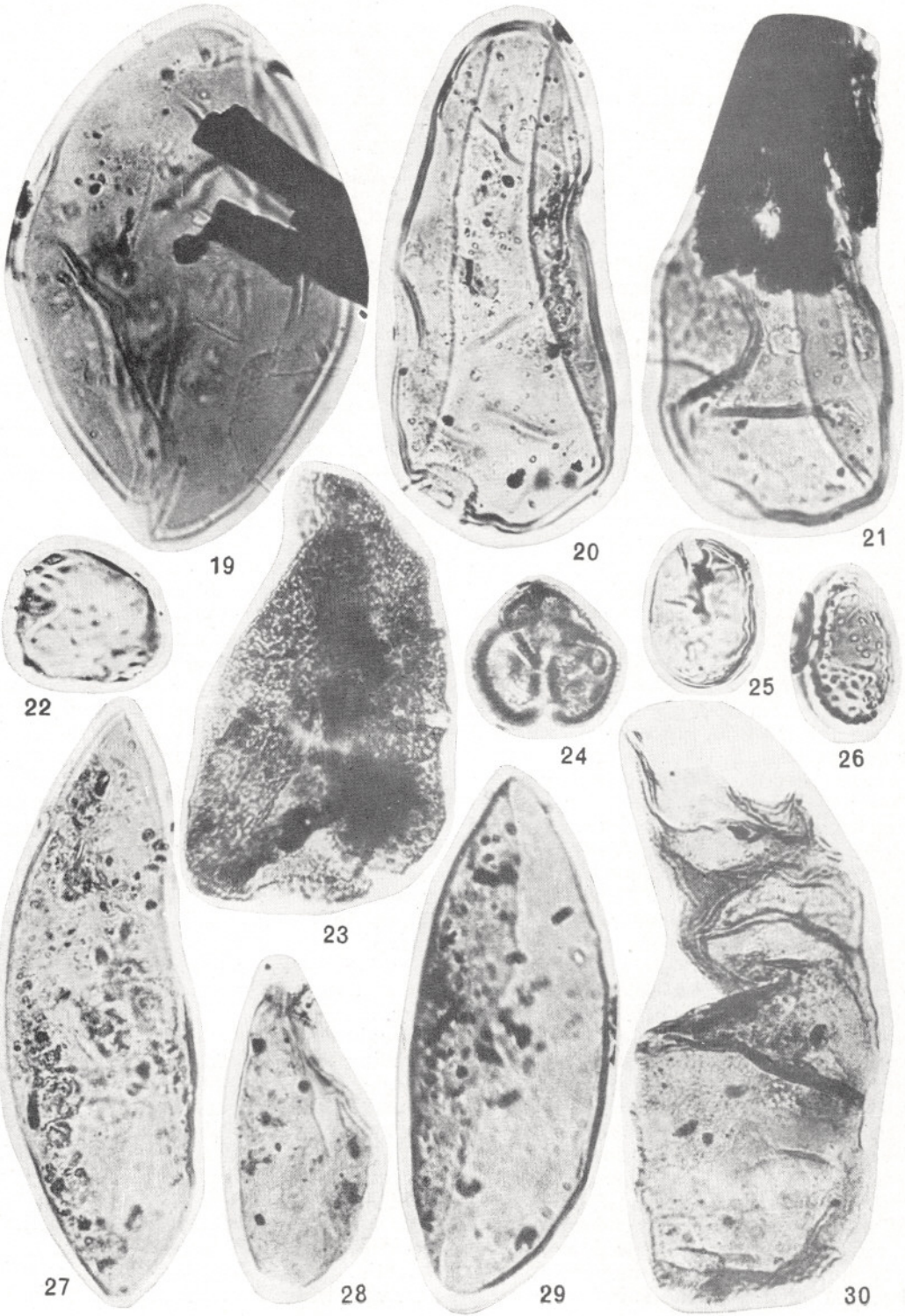



PLATE 2