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PALYNOLOGICAL STUDIES OF THE TETHYAN SEQUENCE IN MALLA JOHAR AREA, KUMAON HIMALAYA, INDIA

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ABSTRACT

The sediments ranging from Palaeozoic to Mesozoic in the Tethyan sequence of Malla Johar were palynologically analysed. In spite of ill-preservation a significant assemblage has been recovered from the Upper Permian to Jurassic comprising 35 genera and 45 species of pollen and spores, and a number of fungal as well as other alete forms. The Devonian sediments have also yielded a eharacteristic assemblage of Chitinozoa. The miospore assemblages show a general resemblance with the constituents of the corresponding miofloras known from the Peninsular India. The comparisons with other miofloras indicate a Gondwana affinity rather than the Angarian resemblance.

Key-words — Palynology, Palaeozoic, Mesozoic, Tethyan sequence, Chitinizoa, Gondwana (India).

सारांँश

कुमायूं हिमालय (भारत) के मल्ला जोहर क्षेत्र में स्थित टॅथियन अनुक्रम का परागाणविक अध्ययन – राम शंकर तिवारी, विजया सिंह, सुरेन्द्र कुमार एवं इन्द्रबीर सिंह

मल्ला जोहर के टॅथियन अनुक्रम में पुराजीवी से मध्यजीवी कल्प तक विस्तृत अवसादों का परागाणविक विश्लेषण किया गया। क्षुद्र परिरक्षित होने पर भी उपरि परमी से जूराई कल्प तक विस्तृत एक विशिष्ट समुच्चय खोजी गई है जिससे कि परागकणों व बीजाणुओं के 35 वंश तथा 45 प्रजातियाँ तथा काफी मात्रा में कवकीय एवं अन्य अर-हीन प्रारूप प्राप्त हुए हैं। डिवोनी अवसादों से काइटीनोजीवीयों से युक्त एक लाक्षणिक समुच्चय उपलब्ध हुई है। प्रायद्वीपीय भारत से विदित सम्बद्ध सूक्ष्मवनस्पतिजातों के अवयवों से मिओबीजाणु समुच्चय प्राय: समानता प्रदर्शित करते हैं। उपलब्ध प्रारूपों तथा अन्य सूक्ष्मवनस्पतिजातों की तुलना करने से ये अँगारा से समानता व्यक्त करने के बजाय गोंडवाना से सम्बन्ध प्रदर्शित करते हैं।

INTRODUCTION

THE sediments of Tethyan zone attaining a great thickness of more than 15,000 m and covering a time span from Precambrian to Cretaceous, are well-exposed in the northern-most part of the Kumaon and Himachal Himalaya. The Tethyan-zone-sediments differ in tectonic setting, lithologic frame-work and stratigraphic attributes from the sedimentary sequences exposed in the Lesser Himalaya which are separated from the Tethys sequence by a well-defined zone of high grade metamorphic rocks of the Central Crystallines of possibly Archean to Early Proterozoic age(?).

The present paper deals with the palynological study of the Tethys sediments exposed in Malla Johar area of the Kumaon Himalaya (U.P.). Tiwari *et al.* (1980) were the first to give a preliminary account of the palynological study of these sediments and the present paper is the final report of the same work which examines the data in detail.

GEOLOGICAL SETTING

The Tethys sediments of Malla Johar area occupy a terrain where height ranges from 3,500 to 7,000 m. Because of the extreme height and remoteness, the accessibility of the area is not only difficult but hazardous too. Except for the period from July to October, the area is covered throughout the year with snow. It is approachable from Rishikesh up to Malari by bus and from Malari by mule-tracks.

The Tethys sediments show almost continuous sequence from Precambrian to Cretaceous. In the southern part of the area, these rocks show a tectonic contact with the rocks of the Central Crystallines and in the north they are bounded by rocks of the exotic formation with a thrusted contact. Recently, the entire Tethys sequence has been designated as the Malla Johar Supergroup by Kumar *et al.* (1977). The Malla Johar Supergroup has been lithostratigraphically subdivided into four groups, viz., Malari Group, Sumna Group, Rawalibagar Group and Sancha Malla Group. Each group has been further subdivided into a number of formations. The lithostratigraphic scheme is given in Table 1.

The succession of the Malla Johar Supergroup represents deposits of a single sedimentation basin without any significant intermittent breaks (Kumar *et al.*, 1977). However, there are suggestions for a time-gap from Carboniferous to Lower Permian or epirogranic change in sedimentation between the deposition of the Sumna and Rawalibagar groups. The sediments of the Malla Johar Supergroup are dominantly shallow-water-deposits except in the case of rocks of the Sancha Malla Group which show characteristics of the deeper-water-deposits (Heim & Gansser, 1939; Kumar *et al.*, 1977).

The rocks of the area, in general, show effects of very low grade of metamorphism and are tectonically deformed. Geomorphologically the area shows juvenile landscape.

TABLE 1 — LIST OF SAMPLES FROM MALLA JOHAR AREA

FORMATION	LITHOLOGY	SAMPLE No.
SPITI SHALE	Shale	L 28*
	Shale	L 27*
	Shale	1*-10* (except 4, 9)
KIOTO LIMESTONE	Shale	117*, 116*
	Limestone	110*, 109*
PASSAGE FORMATION	Limestone	103*
	Shale	96*
KUTI SHALE	Shale	91
	Shale	KK 9
	Shale	KK 2
	Shale	KK 1
	Shale	382
	Shale	380, 379*
	Shale	377
	Shale	376
	Shale	375
	Shale	374
	Limestone	372*
	Limestone	371
KALAPANI LIMESTONE	Limestone	370 to 365
	Ammonoid	E_3 1
	Ammonoid	E_2 2
	Ammonoid	E_3 3
	Shale	364
	Limestone	363*
KULING SHALE	Shale	384
	Shale	385*, 386*, 387*
	Shale	388
	Sandstone	389*
	Siltstone	390
	Sandstone	391*, 392*, 393*
	Siltstone	394
	Siltstone	395
MUTH FORMATION	Sandstone	KP 31
	Siltstone	KP 32
	Shale	KP 33*
	Siltstone	KP 34*

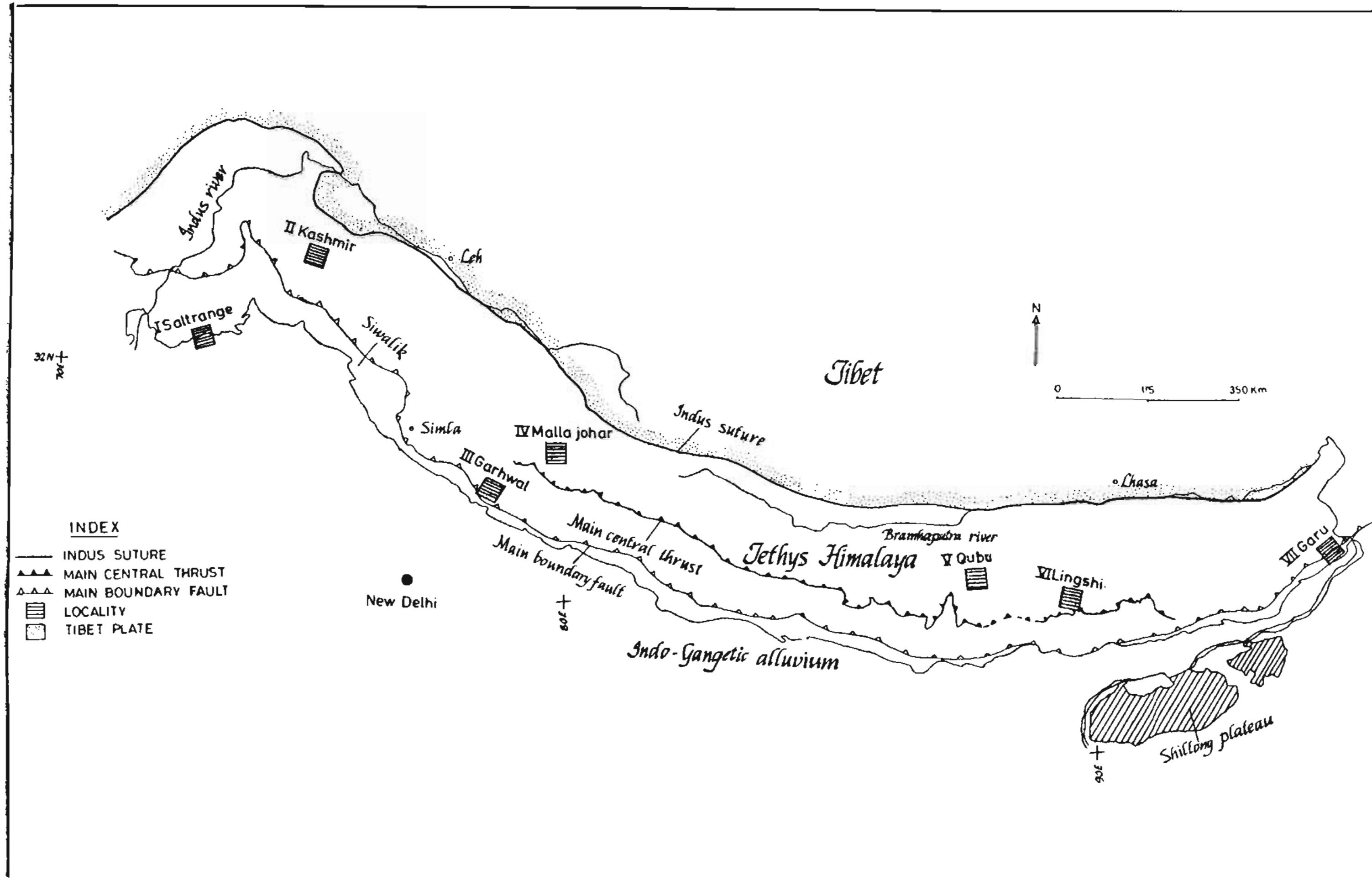
*Productive samples.

MATERIAL AND METHODS

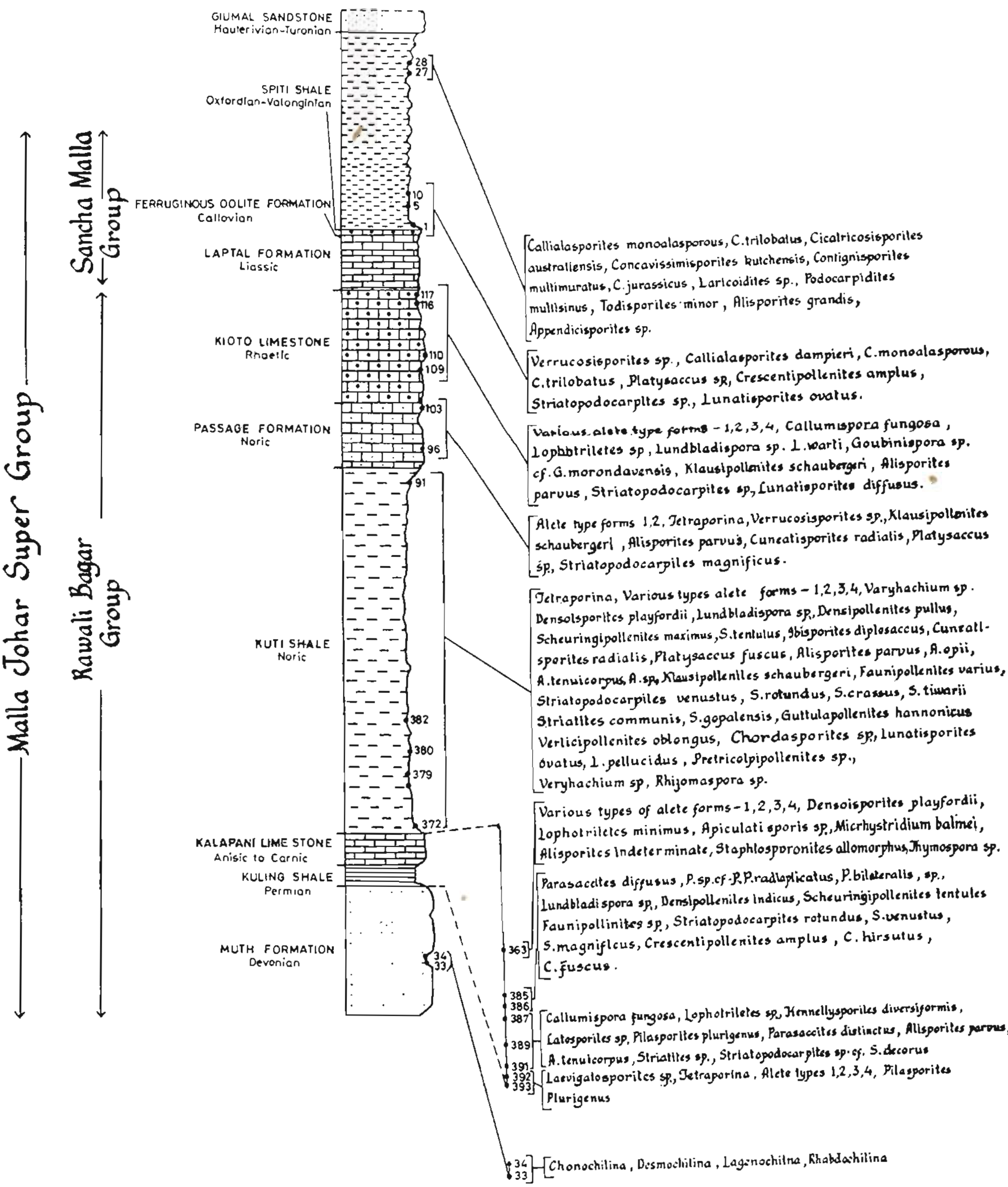
The samples analysed in the present investigation were collected by the members of an expedition organised by the Department of Geology, Lucknow University, Lucknow of which two of us (S.K. & I.B.S.) were the members. The systematic samples were collected along Sumna-Yong Mule-track and Sumna-Sancha-Malla Mule-track (Text-fig. 1; Table 1) in Malla Johar area. Detailed lithological characteristics of the beds met within these traverses are given by Kumar *et al.* (1977). The lithostratigraphy of these sequences alongwith the position of samples studied is given here in Text-fig. 2.

The miofloras were extracted from the samples by using usual method of maceration except that precautions were taken for slow reactions. In all, 58 samples were macerated, out of which 28 yielded the pollen-spore assemblage.

In general, the palynological yield in the samples under study was poor as well as difficult. Some of the specimens are charred,



TEXT-FIG. 1 — Locations of palaeobotanical finds along the Himalayan belt which show a Gondwanic affinity in their constituent, indicating thereby the continuation of Indian Plate up to that extent.



TEXT-FIG. 2 — Succession of miospore assemblages through the sections of Malla Johar area representing Devonian to Jurassic sediments (vertical scale 1 cm = 100 m). In Ferruginous Oolite Formation samples 2, 3, 6, 7 and 8 also yielded.

blackened or otherwise distorted. The reason for general poverty of the miofloral population and their bad preservation may be attributed to the metamorphism and tectonic deformation to which these rocks have been subjected.

DESCRIPTION

The samples from the Garbyang Formation (Cambrian) to Balcha Dhura Formation belonging to Upper Cretaceous were macerated for palynological studies. However, no miospores could be recovered in the rocks of Malari and Sumna groups. The best yield was from the rocks of Rawalibagar Group. In the Sancha Malla Group, only the Spiti Shale yielded a few miospore species. However, Jain *et al.* (in press) have recovered a rich assemblage from the upper reaches of the Spiti Shale.

The following brief descriptions of *sporae dispersae* are being given in order to assess the identification because the photomicrographs do not always exhibit full details due to ill preservation. A few species, however, have neither been illustrated nor described but only included in the list, after identification under microscope.

List of Species

Triletes

Callumispora Bharadwaj & Srivastava, 1969; *C. fungosa* (Balme) Bharadwaj & Srivastava emend. Bharadwaj & Tiwari, 1977 (Pl. 1, fig. 1); *Hennellysporites* Tiwari, 1968; *H. diversiformis* (Balme & Hennelly) Tiwari, 1968; *Lophotriletes* emend. Potonié & Kremp, 1954; *Lophotriletes* sp.; *L. minimus* Salujha, 1965; *Apiculatisporites* Potonié & Kremp, 1954; *Apiculatisporites* sp.; *Densoisporites* Weyland & Krieger emend. Dettmann, 1963; *D. playfordii* (Balme) Dettmann, 1963 (Pl. 1, fig. 6); *Verrucosisporites* Ibrahim emend. Smith *et al.*, 1967; *Verrucosisporites* sp. (Pl. 1, fig. 7) *Lundbladispora* Balme emend. Playford, 1965; *Lundbladispora* sp.

Monoletes

Laevigatosporites Ibrahim, 1933; *Thymospora* Wilson & Venkatachala, 1963.

Monocolpate

Pretricolpipollenites Danze-Corsin & Laevine, 1963; *P. bharadwajii* Balme, 1970.

Monosaccates

Parasaccites Bharadwaj & Tiwari, 1964; *P.* sp. cf. *P. radiaplicatus* Maithy, 1965; *P. diffusus* Tiwari, 1965 (Pl. 1, fig. 2); *P. distinctus* Tiwari, 1965 (Pl. 1, fig. 8); *P. bilateralis* Tiwari, 1965 (Pl. 3, fig. 16); *Densipollenites* Bharadwaj, 1962; *D. indicus* Bharadwaj, 1962; *D. densus* Bharadwaj & Srivastava, 1969 (Pl. 2, fig. 15); *D. pullus* Segroves, 1969 (Pl. 2, fig. 14); *Guttulapollenites* Goubin emend. Venkatachala & Kar, 1967; *G. hannonicus* Goubin, 1965 (Pl. 2, fig. 12); *Callialasporites* Dev, 1961; *C. trilobatus* (Balme) Dev, 1961 (Pl. 2, fig. 9); *C. dampieri* (Balme) Dev, 1961 (Pl. 2, fig. 11); *C. monoalasporus* Dev, 1961 (Pl. 2, fig. 10); *Goubinispora* Tiwari & Rana, 1981; *G.* sp. cf. *G. morondavensis* (Goubin) Tiwari & Rana, 1981 (Pl. 4, fig. 26).

Dsaccates (Non-striate)

Scheuringipollenites Tiwari, 1973; *S. maximus* (Hart) Tiwari, 1973; *S. tentulus* (Tiwari) Tiwari, 1973 (Pl. 3, fig. 19); *Alisporites* Daugherty emend. Jansonius, 1971; *A.* sp. cf. *A. opii* Daugherty, 1941 (Pl. 2, fig. 13); *A. parvus* Thiergart & Frantz, 1962; *A. tenuicorpus* Balme, 1970; *A.* sp. A; *Piceaepollenites* Potonié, 1931; *Piceaepollenites* sp; *Platysaccus* (Naum.) Pot. & Kl., 1954; *P. fuscus* Goubin, 1965; *Klausipollenites* Jansonius, 1962; *K. schaubergeri* (Pot. & Kl.) Janson., 1962 (Pl. 1, fig. 5); *Ibisporites* Tiwari, 1968; *I. diplosaccus* Tiwari, 1968; *Cuneatisporites* Leschik, 1955; *C. radialis* Leschik, 1955 (Pl. 4, fig. 30).

Disaccates (Striate)

Faunipollenites Bharadwaj, 1962; *F. varius* Bharadwaj, 1962; *F.* sp.; *Crescentipollenites* Bharadwaj, Tiwari & Kar, 1974; *C. amplus* (Balme & Hennelly) Tiwari & Rana, 1980 (Pl. 3, fig. 17); *C. fuscus* (Bharad.) Bharad., Tiwari & Kar, 1974; *C.* sp. (Pl. 3, fig. 20); *C. hirsutus* (Kar) Bharadwaj, Tiwari & Kar, 1974; *Striatopodocarpites* Soritsch. & Sedova, 1956; *S. magnificus* Bharad. & Salujha, 1964, (Pl. 1, fig. 3); *S.* sp. cf. *S. decorus* Bharad. & Salujha, 1964 (Pl. 3, fig. 21); *S. venustus* Bharadwaj & Salujha, 1965 (Pl. 3, fig. 18); *S. crassus* Tiwari, 1965; *S. rotundus* (Maheshwari) Bharadwaj & Dwivedi, 1981 (Pl. 3, fig. 23); *S. tiwarii* Bharadwaj & Dwivedi, 1981 (Pl. 3, fig. 22); *Striatites* Pant emend. Bharadwaj 1962; *S. communis* Bharadwaj & Salujha, 1964 (Pl. 4, fig. 25); *S. varius* Kar, 1968 (Pl. 4, fig. 24); *S. gopalensis* Srivastava, 1970 (Pl. 4, fig. 28); *S.* sp. (Pl. 1, fig. 4); *Verticipollenites* Bharadwaj, 1962; *V. oblongus* Bharadwaj, 1962 (Pl. 4, fig. 29); *Rhizomaspora* Wilson, 1962; *Rhizomaspora* sp.

Taeniate

Lunatisporites Leschik emend. Bharadwaj, 1974; *L. ovatus* (Goubin) Maheshwari & Banerji, 1975 (Pl. 4, fig. 31); *L. pellucidus* (Goubin) Maheshwari & Banerji, 1975; *L. diffusus* Bharadwaj & Tiwari 1977; *Chordasporites* Klaus, 1960; *Chordasporites* sp. (Pl. 4, fig. 27).

Incertae sedis (Aletes)

Pilasporites Balme & Hennelly emend. Tiwari & Navale, 1967; *P. plurigenus* Balme & Hennelly, 1956 (Pl. 5, fig. 43); *Tetraporina* Naumova ex Naumova, 1956; *Tetraporina* sp.

Fungal Spores

Type — 1 (Pl. 5, figs 47, 48, 49)
Type — 2 (Pl. 5, figs 45, 46)
Type — 3 (Pl. 5, figs 34, 35, 50, 51, 53, 54)
Type — 4 (Pl. 5, figs 40, 41)
Indeterminate (Pl. 5, figs 33, 36-39)

Achritarchs

Varyhachium Denuff, 1954; *Varyhachium* sp. (Pl. 5, fig. 32); *Staphlosporonites* Sheffy & Dilcher, 1971; *Staphlosporonites allomorphus* Sheffy & Dilcher, 1971; (Pl. 5, figs 42, 52); *Micrhystridium* Deflandre emend. Downie & Sarjeant, 1963; *M. balmei* Sarjeant, 1971 (Pl. 5, fig. 44).

Chitinozoa

Cyathochitina Eisenack, 1955 (Pl. 6, fig. 67); *Ancyrochitina* Eisenack, 1955 (Pl. 6, fig. 62); *Chonochitina* Eisenack, 1931 restr. Eisenack, 1955 (Pl. 6, figs 60, 65); cf. *Chonochitina* sp. (Pl. 6, fig. 69); *Angochitina* Eisenack, 1931 (Pl. 6, figs 56, 59); *Rhabdochitina* Eisenack, 1931 (Pl. 6, fig. 58); *Lagenochitina* Eisenack, 1931 (Pl. 6, figs 61, 68); cf. *Lagenochitina* (Pl. 6, fig. 64); *Desmochitina* Eisenack emend. Eisenack, 1962 (Pl. 6, figs 55, 57, 63, 66).

Genus — *Callumispora* Bharadwaj & Srivastava, 1969

Type species — Callumispora barakarensis Bharadwaj & Srivastava, 1969.

Callumispora fungosa (Balme) Bharadwaj & Srivastava emend. Bharadwaj & Tiwari, 1977

Pl. 1. fig. 1

Holotype — Balme, 1963; pl. 4, fig. 10.

Description — Subcircular, trilete spore, 95 μm in diameter; exine 3 μm thick, uniformly and coarsely infrapunctate. *Extrema lineamenta* smooth.

Remarks — It is typically a Triassic species in the Indian Gondwana sequence.

Genus — *Densoisporites* Weyland & Krieger emend. Dettmann, 1963

Type Species — Densoisporites velatus Weyland & Krieger, 1953.

Densoisporites playfordii (Balme) Dettmann, 1963

Pl. 1, fig. 6

Holotype — Balme, 1963; pl. 5, fig. 4.

Description — Ill-preserved, trilete, cavate spore with thick laevigate cingulum. Exine laevigate, indistinctly infrapunctate; *extrema lineamenta* smooth.

Genus — *Verrucosisporites* Ibrahim emend. Smith. *et al.*, 1971

Type Species — Verrucosisporites verrucosus Ibrahim, 1933.

Verrucosisporites sp.

Pl. 1, fig. 7

Description — Subtriangular, 90×70 μm. Trilete mark not clear; big rounded verrucae-like bodies present which being closely placed along the equator.

Remarks — The massive nature of verrucae on equator is characteristic for this specimen.

Genus — *Lundbladispora* Balme emend. Playford, 1965

Type Species — Lundbladispora willmotti Balme, 1963.

Lundbladispora sp.

Description — A badly preserved, cingulate, cavate spore; Y-mark represented by folds; cingulum thick showing verrucae, coni, mixed ornamentation, central body area apparent, not clearly defined.

Remarks — Since no haptotypic characters are visible, the identification has not been possible up to the specific level.

Genus — *Parasaccites* Bharadwaj & Tiwari, 1964

Type Species — *Parasaccites korbaensis* Bharadwaj & Tiwari, 1964.

Parasaccites diffusus Tiwari, 1965

Pl. 1, fig. 2

Holotype — Bharadwaj & Tiwari, 1964; pl. 2, fig. 11.

Description — Pollen circular, saccus 10-20 μm wide. Central body thin, outline indistinct, Y-mark not seen. Saccus attachment in para-condition, encroaching sub-equatorially on both the surfaces; saccus intrareticulation mediumly coarse.

Remarks — The saccus is restricted to only equatorial region and does not cover the distal side as in *Cordaitina*. The latter organization is not known from the Indian Gondwana assemblages.

Parasaccites distinctus Tiwari, 1965

Pl. 1, fig. 8

Holotype — Tiwari, 1965; pl. 4, fig. 77.

Description — Subcircular 108-120 μm, with girdling monosaccus. Central body thin, outline visible, 90-110 μm in diameter. Saccus uniformly wide, 24 μm in one specimen (Pl. 1, fig. 12) tending to be lobed, para-condition of saccus attachment clear, saccus intrareticulation mediumly coarse.

Parasaccites bilateralis Tiwari, 1965

Pl. 3, fig. 16

Holotype — Bharadwaj & Tiwari, 1964; pl. 2, fig. 12.

Description — Monosaccate, 130×90 μm, saccus 8 μm wide at lateral sides and 36 μm at terminal sides. Central body thin, subcircular. Y-mark not visible. Saccus structure obscure.

Remarks — This species is characterised by its bilateral symmetry resulted by widening of sacci at two opposite terminal sides.

Genus — *Densipollenites* Bharadwaj, 1962

Type Species — *Densipollenites indicus* Bharadwaj, 1962.

Densipollenites pullus Segroves, 1969

Pl. 2, fig. 14

Holotype — Segroves, 1969; pl. 4, fig. A.

Description — Roundly subtriangular in flattened condition, 110×80 μm. Central body seen at the margin due to shifting in certain specimens, circular, dark brown 42 μm in diameter. Saccus enveloping-type, having thick irregular and broken muri; limbus-like structure at equatorial region present.

Remarks — *D. indicus* Bharadwaj, 1962 has a thin body with distinct outline. In the structure of the saccus intrareticulation also, the present specimen differs from the type species.

Densipollenites densus Bharadwaj & Srivastava, 1969

Pl. 2, fig. 15

Holotype — Bharadwaj & Srivastava, 1969; pl. 24, fig. 5.

Description — Pollen grain 100×80 μm; central body 44 μm, subcircular, well-defined, darker than the saccus. Saccus with medium-sized reticulum. Limbus-like structure not clear.

Remarks — Comparatively dense, distinct and big body is the characteristics of this species.

Genus — *Guttulapollenites* Goubin emend. Venkatachala & Kar, 1967

Type Species — *Guttulapollenites hannonicus* Goubin, 1965.

Guttulapollenites hannonicus Goubin, 1965

Pl. 2, fig. 12

Holotype — Goubin, 1965; pl. 6, figs 5, 6.

Description — Pollen subcircular to oval, 72×72 μm. Central body oval. Sacci pyriform, more or less equal in size. Two sets of double sacci-like structures covering the body alternately on two sides. Broken or laterally preserved specimens showing apparently irregular arrangement of the four sacci. Intrareticulation of sacci fine with thick muri.

Genus — *Callialasporites* Dev, 1961

Type Species — *Callialasporites trilobatus* (Balme) Dev, 1961.

Remarks — The specimens described under this genus are blackish and charred in appearance due to high degree of diagenesis.

Callialasporites trilobatus (Balme) Dev, 1961

Pl. 2, fig. 9

Holotype — Balme, 1957; pl. 8, fig. 91.

Description — Roundly subtriangular miospores, 72-74 μm in size. Central body triangular with broad round ends, 50-52 μm; Y-mark not prominent; exine 1-2 μm thick, dark, having a thinner region in the centre. Sacci three, with distinct, complete or incomplete delimitation, 10-12 μm wide at their maximum with ridge-like thickening at the equator but without prominent radiating folds; finely verrucose to chagrinate sculpture seen.

Remarks — The specimens showing three distinct sacci without radiating ridges are included in this species. They are black and appear to be 'charred' hence the infra-structure of exine is not clear.

Callialasporites dampieri (Balme) Dev, 1961

Pl. 2, fig. 11

Holotype — Balme, 1957; pl. 8, fig. 88.

Description — Sub-oval, size 75×68 μm; bladder wide with frilling appearance due to radiating folds, incompletely trilobed, 2 μm thick, granulose to chagrinate; central body subcircular, dark brown. Trilete mark not clear.

Remarks — This species differs from *C. trilobatus* in the absence of clear trilobate condition.

Callialasporites monoalasporus Dev, 1961

Pl. 2, fig. 10

Holotype — Dev, 1961; pl. 4, fig. 59.

Description — Subcircular to oval, size 72-83 μm. Saccus unlobed, 8 μm wide, granulose. Body big, usually not sharply defined. In the central region a thin circular area visible.

Genus — *Goubinispora* Tiwari & Rana, 1981

Type Species — *Goubinispora indica* Tiwari & Rana, 1981.

Goubinispora sp. cf. *G. morondavensis* (Goubin) Tiwari & Rana, 1981

Pl. 4, fig. 26

Holotype — Goubin, 1965; pl. 1, fig. 5.

Description — Badly pres rved monosaccate pollen, saccus apparently girdling, lobed, attachment not clear. Central, body showing chagrinate exine.

Remarks — The tendency of saccus to make lobes and to widen at terminal ends has been noticed, as in the illustrated specimen. This indicates its affinity with the genus *Goubinispora*.

Genus — *Alisporites* Daugherty emend. Jansonius, 1971

Type Species — *Alisporites opii* Daugherty, 1941.

Alisporites sp. cf. *A. opii* Daugherty, 1941

Pl. 2, fig. 13

Holotype — Daugherty, 1941; pl. 34, fig. 2.

Description — Bisaccate, haploxylonoid. Central body distinct, big, vertically oval; exine intramicroreticulate, without striations. Sacci less than hemisphere, 15 μm wide, laterally close to each other and distally inclined to leave a 20 μm wide sulcus; sacci finely intrareticulate.

Remarks — *A. opii* includes grains with finely infragranulose exine.

Genus — *Klausipollenites* Jansonius, 1962

Type Species — *Klausipollenites schaubergeri* (Potonié & Klaus) Jansonius, 1962.

Klausipollenites schaubergeri (Potonié & Klaus) Jansonius, 1962

Pl. 1, fig. 5

Holotype — Potonié & Klaus, 1954; pl. 10, figs 7, 8.

Description — Disaccate, bilaterally oval, haploxylonoid pollen with non-striate, vertically oval central body with clearly inframicroreticulate exine. Size of grain 49.5×

36 μm. Sacci small, narrow, laterally close to each other. Distal sulcus apparently wide and ill-defined. Saccus intrareticulation fine.

Remarks — *Klausipollenites* group of pollen are simple non-striate disaccate having small sacci. The characters being not diversified, no attempts have been made to circumscribe the species in this genus. Most of the Triassic forms reported from India have been described under *K. schaubergeri* (see Bharadwaj & Tiwari, 1977; Maheshwari & Banerji, 1975); as such, they have finely infrareticulate exine structure of the body.

Genus — *Crescentipollenites* Bharadwaj, Tiwari & Kar, 1974

Type Species — *Crescentipollenites fuscus* (Bharadwaj) Bharadwaj, Tiwari & Kar, 1974.

Crescentipollenites amplus (Balme & Henn.) Tiwari & Rana, 1980

Pl. 3, fig. 17

Holotype — Balme & Hennelly, 1956; pl. 3, fig. 24.

Description — Bilateral disaccate, haploxylonoid pollen with rhomboid central body. Distal sulcus distinct, 30 μm wide, in the middle but narrower — 15 μm wide, at lateral sides; zone of saccus attachment of distal side associated with distinct, semilunar folds. Striations 8-10, no vertical partitions between the striations. Exine of body finely intrareticulate; sacci also showing fine meshes as structure.

Crescentipollenites sp.

Pl. 3, fig. 20

Description — Bilateral bisaccate, slightly diploxylonoid pollen. Central body broadly oval with round ends, 44×66 μm, striations 7, distinct; distal sulcus biconvex, 18 μm; sacci laterally close to each other, finely intrareticulate.

Comparison — This species resembles *C. notabilis* (Tiwari) Bharadwaj, Tiwari & Kar, 1974 but does not show the dumb-bell-shaped sulcus. *C. hirsutus* (Kar) Tiwari & Rana, 1980 has an equatorial ridge in the body and the striations are zig zag, hence it is different.

Genus — *Striatopodocarpites* Soritsch & Sedova, emend. Bharadwaj, 1962

Type Species — *Striatopodocarpites tojmensis* Sedova, 1956.

Striatopodocarpites rotundus (Maheshwari) Bharadwaj & Dwivedi, 1981

Pl. 3, fig. 23

Holotype—Maheshwari, 1967; pl. 7, fig. 57.

Description — Badly preserved bilateral, disaccate, diploxylonoid, 84×96 μm. Central body big, subcircular; sacci narrow smaller than the body, laterally widely separated from each other. Zone of sacci attachment at distal side straight without lunar folds; sulcus being wide. Sacci finely intrareticulate.

Striatopodocarpites sp. cf. *S. decorus* Bharadwaj & Salujha, 1964

Pl. 3, fig. 21

Holotype — Bharadwaj & Salujha, 1964; pl. 10, fig. 140.

Description — Slightly laterally flattened, disaccate-striate pollen, 80×44 μm; central body distinct, finely intrareticulate, body ends appearing to be truncate. Sulcus 12 μm wide.

Remarks — *S. decorus* is characterised by rhomboidal body with truncate ends. The real nature of body in this specimen is not discernible due to lateral flattening and thus a provisional assignment to this species has been made.

Striatopodocarpites venustus Bharadwaj & Salujha, 1965

Pl. 3, fig. 18

Holotype — Bharadwaj & Salujha, 1965; pl. 2, fig. 37.

Description — Diploxylonoid pollen 62×109 μm with vertically oval distinct body, exine intrareticulate, striations simple, 7 in number, distal sulcus 15 μm wide; no lunar folds along zones of attachment.

Striatopodocarpites magnificus Bharadwaj & Salujha, 1964

Pl. 1, fig. 3

Holotype — Bharadwaj & Salujha, 1964; pl. 10, fig. 143.

Description — Diploxylonoid grains 68 × 108 μm; Central body distinct, subcircular, 40 × 60 μm; 8-10 striations, simple; exine intramicroreticulate.

Striatopodocarpites tiwarii Bharadwaj & Dwivedi, 1981

Pl. 3, fig. 22

Holotype — Tiwari, 1965; pl. 7, fig. 151.
Description — Diploxylonoid, subcircularly oval grain, 85 × 62 μm. Central body big, well-defined, 60 × 56 μm, Oval with round ends, 6 horizontal striations present. Exine of body intramicroreticulate, Distal sulcus narrow. Sacci narrow, meeting laterally to form distinct notch, mediumly intrareticulate.

Genus — *Striatites* Pant emend. Bharadwaj, 1962

Type Species — *Striatites sewardii* (Virkki) Pant, 1955.

Striatites communis Bharadwaj & Salujha, 1964

Pl. 4, fig. 25

Holotype — Bharadwaj & Salujha, 1964; pl. 7, fig. 105.
Description — Diploxylonoid, 120 × 78 μm. Central body circular, 53 μm without marginal ridge, not very thick; horizontal striations 9, vertical partition absent; sulcus 10 μm wide straight. Sacci spherical, big, medium-sized with intrareticulate structure.

Striatites varius Kar, 1968

Pl. 4, fig. 24

Holotype — Kar, 1968; pl. 2, fig. 55.
Description — Disaccate, diploxylonoid; central body circular dense, 36 μm microverrucose; striations horizontal, no vertical partition, distal sulcus narrow; sacci finely intrareticulate.

Striatites gopalensis Srivastava, 1970

Pl. 4, fig. 28

Holotype — Srivastava, 1970; pl. 1, fig. 13.
Description — Bisaccate, diploxylonoid, 84 × 42 μm. Central body dense, 35 μm in size, distinct, equatorial rim present; horizontal striations 5, no vertical partitions; exine of the body finely microverrucose; distal sulcus narrow, straight; sacci bigger than the body, laterally close to each other, finely intrareticulate.

Striatites sp.

Pl. 1, fig. 4

Description — Haploxylonoid, bisaccate grain. Central body vertically oval with well-defined equatorial rim, 60 × 40 μm horizontal striations 8, no vertical partitions; sulcus 8 μm wide, slightly convex; sacci smaller than the body, medium-sized intrareticulate.
Remarks — No other species is known in this genus with equatorial rim on the body and haploxylonoid construction of the sacci.

Genus — *Verticipollenites* Bharadwaj, 1962

Type Species — *Verticipollenites secretus* Bharadwaj, 1962.

Verticipollenites oblongus Bharadwaj, 1962

Pl. 4, fig. 29

Holotype — Bharadwaj, 1962; pl. 13, fig. 180.
Description — Dissaccate, diploxylonoid, 84 × 48 μm; central body vertically oval, 20 × 17 μm thick, micro-intrareticulate; horizontal striations 6, vertical partitions few. Sacci big, spherical, pitcher-shaped, leaving distally 10 μm wide free-area, finely intrareticulate.
Remarks — The specimens described by Bharadwaj (1962) possess more vertical partitions than the present specimen. However, in other characters the latter resembles the holotype.

Genus — *Lunatisporites* Leschik, 1955 emend. Bharadwaj, 1974

Type Species — *Lunatisporites acutus* Leschik, 1955.

Lunatisporites ovatus (Goubin) Maheshwari & Banerji, 1975

Pl. 4, fig. 31

Holotype — Goubin, 1965; pl. 2, fig. 2.
Description — Disaccate, haploxylonoid, 80 μm. Central body broadly oval, distinct.

40 μm, exine intramicroreticulate; taenie 7, with irregular spaces in between each other. Sulcus 10-15 μm wide, zone of saccus attachment accompanied by lunar folds. Sacci finely intrareticulate.

Genus — *Chordasporites* Klaus, 1960

Type Species — Chordasporites singulichorda Klaus, 1960.

Chordasporites sp.

Pl. 4, fig. 27

Description — Bilateral, nonstriate-disaccate grain. Central body horizontally oval, thin, distinct, proximally bearing a 5 μm wide, straight chord-like strip, entering at both ends in sacci. Body exine finely intrareticulate. Sacci ear-lobe-shaped, more or less equal to the central body, intrareticulate with fine muri and meshes, distally inclined only up to 5 μm entering central body outline; laterally widely apart.

Genus — *Staphlosporonites* Sheffy & Dilcher, 1971

Type Species — Staphlosporonites conoidens Sheffy & Dilcher, 1971.

Staphlosporonites allomorphus Sheffy & Dilcher, 1971

Pl. 5, figs 42, 52

Description — Multicellular, oblong body with irregular cell size and orientation; septa 1 μm thick, surface psilate. Cell wall 1 μm thick; one cell at the narrow end usually elongated.

Remarks — These are fungal cells resembling the modern genus *Alternaria* (Pirozynski, 1976).

Genus — *Veryhachium* Denuff, 1954 emend. Downie & Sarjeant, 1963

Type Species — Veryhachium trisulcum (Denuff) Denuff, 1954.

Veryhachium sp.

Pl. 5, fig. 32

Description — Vesicle triangular lenticular, the corners drawn out into three appendages, one broken, second one half, third one bifurcated at tip. Appendages open into vesicle cavity; wall smooth or with minor sculpture.

Genus — *Micrhystridium* Deflandre, 1937 emend. Sarjeant, 1963

Type Species — Micrhystridium inconspicum Deflandre, 1937.

Micrhystridium bulmei Sarjeant, 1971

Pl. 5, fig. 44

Holotype — Micrhystridium balmei Sarjeant, 1971.

Description — Vesicle 20 μm sphaeroidal to broadly ovoidal bearing 1-1.5 μm long, thin spines with broader bases. Opening as a bent, cryptosuture seen in the form of a fold.

A number of alete sporomorphs having unorganised germinal aperture and with or without ornamentation have been found. These are described here as ' types '.

TYPE 1

Pl. 5, figs 47, 48, 49

Description — Small subcircular to ovoidal body, usually with one or two longitudinal folds; size 15-17 μm. Exine dark thick, beset with 1 μm high verrucae all over the body.

TYPE 2

Pl. 5, figs 45, 46

Description — Subcircular to triangular, 17-19 μm in size. Exine beset with 0.5-1 μm verrucae all over the body; folds generally forming a triangular area. Cryptopore circular distinct in most of the specimens, situated on the reverse side of the folds.

TYPE 3

Pl. 5, figs 34, 35, 50, 51, 53, 54

Description — Circular, 12-20 μm in diameter; exine one or many layered, 1-4 μm thick, psilate, internally finely structured, infragranulose. In some specimens cryptosuture seen as a splitting zone.

TYPE 4

Pl. 5, figs 40, 41

Description — Circular dark brown miospore, 36 μm, including process. Equatorially 4 μm wide, dark, thick zone present; ornamentation 2-4 μm long, flat, thin 4 μm wide squarish papillate covering the surface and projecting on the equator as a 'corona'. Germinal mark not seen.

CHITINOZOA

The Chitinozoa are being assigned only to the comparable generic placement; the detailed work will only be taken after the collection of several more specimens. However, the significance of their record is obvious in these hitherto known nonfossiliferous strata.

Genus — *Chonochitina* Eisenack, 1931 restr. 1955

Type Species — *Chonochitina claviformis* Eisenack, 1931.

Chonochitina sp.

Pl. 6, figs 60, 65

Description — The specimens illustrated here being somewhat variable in shape; test almost conical, constricted, forming oral tube; basal margins rounded, base convex. Oral tube varying in shape. Maximum diameter near base 90-110 μm, total length 145-150 μm. Body-wall laevigate.

cf. *Chonochitina* sp.

Pl. 6, fig. 69

Description — Test elongated, conical, maximum diameter near the base 54 μm, length 166 μm. On the body-wall scars seen, may be remnants of the appendages.

Genus — *Cyathochitina* Eisenack, 1955

Type Species — *Cyathochitina campanulaeformis* (Eisenack) Eisenack, 1955.

Cyathochitina sp.

Pl. 6, fig. 67

Description — Test slightly constricted exhibiting the emergence of oral tube. Basal margin conico-flat measuring 116 μm in width, base flat. Total length 160 μm. Body-wall showing no appendages.

Genus — *Ancyrochitina* Eisenack, 1955

Type Species — *Ancyrochitina ancyrea* (Eisenack) Eisenack, 1955.

Ancyrochitina sp.

Pl. 6, fig. 62

Description — Conical chamber differentiable from cylindrical neck, basal margin slightly convex, basal diameter 130 μm. Total length 146 μm. Spines on side walls of the chamber simple or multifurcate.

Genus — *Angochitina* Eisenack, 1931

Type Species — *Angochitina echinata* Eisenack, 1931.

Angochitina sp.

Pl. 6, figs 56, 59

Description — Test cylindro-conoid in shape, measuring 75·85 μm in diameter, total length being 108-116 μm. Spines are present all over the test, variable in shape and size.

Genus — *Rhabdochitina* Eisenack, 1931

Type Species — *Rhabdochitina magna* Eisenack, 1931.

Rhabdochitina sp.

Pl. 6, fig. 58

Description — Test cylindro-conical, base weakly conical measuring 100×238 μm. Basal scars on body-wall apparent.

Genus — *Lagenochitina* Eisenack, 1931

Type Species — *Lagenochitina baltica* Eisenack, 1931.

Lagenochitina sp.

Pl. 6, figs 61, 68

Description — In the specimens illustrated, the test is large, damaged at apex; basal margin rounded, base slightly convex; maximum diameter near base 76-90 μm. Total length from 114-130 μm. Body wall laevigate.

cf. *Lagenochitina* sp.

Pl. 6, fig. 64

Description — Specimen showing clear differentiation of the test into a chamber and the oral tube. Basal margin of the chamber rounded, base convex, maximum diameter at base 70 μm and the total length 210 μm. Body wall smooth.

Genus — *Desmochitina* Eisenack emend. Eisenack, 1962

Type Species — *Desmochitina nodosa* Eisenack, 1931.

cf. *Desmochitina* sp.

Pl. 6, figs 55, 57, 63, 66

Remarks — Illustrated specimens are variable in their overall shape. Tests are sub-spherical, maximum diameter of these discs varying from 50 to 150 μm and the total length 50-200 μm.

QUALITATIVE COMPOSITION OF MIOFLORAL ASSEMBLAGE

The quantitative determination of the assemblage could not be done because of the paucity of miospore specimens. However, in a fairly good number of specimens the morphographic characters are clearly discernible which have made the specific identifications possible. The palynomorphs, thus, identified are significant enough to be considered as characteristic for each assemblage delimited here. For qualitative assessment, the general pattern of occurrence has been considered to evaluate the situation (also see Text-fig. 2).

1. *Malari Group* — No sample analysed.
2. *Sumna Group* — No yield of miospores except in two samples (34, 33) from the Muth Formation, where some chitinozoans have been found in which the forms *Chonochitina*, *Desmochitina*, *Lagenochitina*, *Rhabdochitina* are significant.

The forms recorded in this paper are quite widely-ranging at generic level, and since no specific-level identifications have been attempted here, the precise dating is not being proposed in this work. However, the important forms diagnostic of the Devonian age are present in these samples — a supporting evidence of the conventional view regarding the age of Muth Formation.

3. *Rawalibagar Group*:

(i) *Kuling Shale* (*Formation*) — The Kuling Shale is the oldest horizon which has yielded miospore in the present study. The fossil yielding sample nos. are 393, 392, 391, 389, 387, 386 and 385. Thus, in addition to the samples which yielded in the earlier work (Tiwari *et al.*, 1980), the sample nos. 391, 392 and 393 have also been found to contain miospores during the present study. The species identified are:

Callumispora fungosa, *Lophotriletes* sp., *Hennellysporites diversiformis*, *Lundbladispora* sp., *Verrucosisporites* sp., *Densipollenites indicus*, *Parasaccites diffusus*, *P. distinctus*, *P. bilateralis*, *P.* sp. cf. *P. radiaplicatus*, *Scheuringipollenites tentulus*, *Alisporites parvus*, *A. tenuicorpus*, *A.* sp., *Faunipollenites* sp., *Crescentipollenites ampulus*, *C. hirsutus*, *C. fuscus*, *C.* sp., *Striatopodocarpites rotundus*, *S. venustus*, *S.* sp. cf. *S. decorus*, *S. magnificus*, *Striatites* sp., *Luevigatosporites* sp., *Pilasporites plurigenus*.

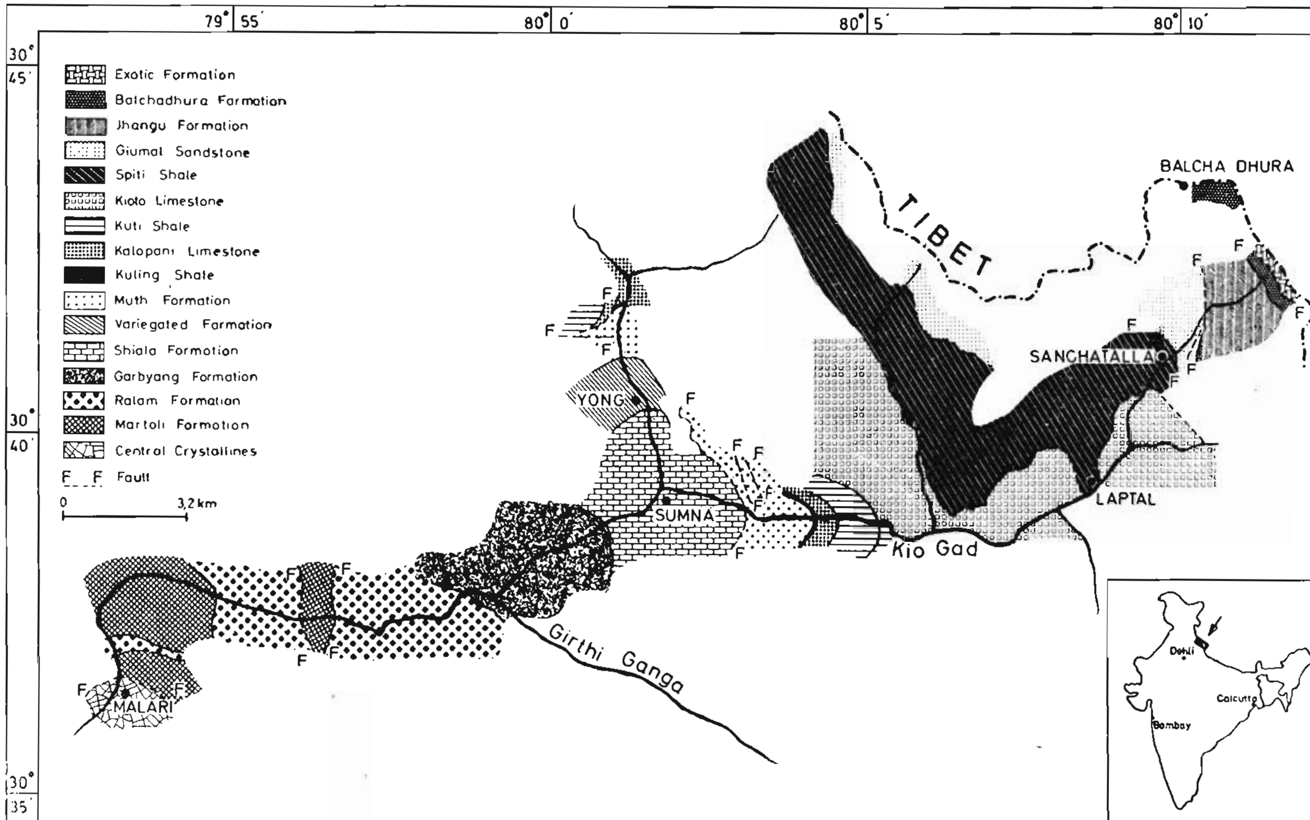
Spores Alete Types — 1, 2, 3, 4

A perusal of the distribution of different species through the Kuling Shale (Table 1) clearly indicates that the older samples — 393 and 392, are prominently represented by alete types and fern spores. This assemblage represents a typical condition prior to the encroachment of the land by thick vegetation in this region. Some of the alete types also suggest a marine shallow water conditions during the advent of Kuling Shale deposition.

The next assemblage represented by sample nos. 391, 389 and 387 is comparable with the early Upper Permian of the Peninsular India in having striate-disaccate pollen and the trilete forms. Above to this, the sample nos. 386 and 385 have a well diversified mioflora having some typical form, such as *Densipollenites*, *Crescentipollenites*, *Lundbladispora*, indicating a late Permian affinity.

The above account clearly indicates that the early Permian assemblage has not been recovered from this Kuling Shale Formation.

(ii) *Kalapani Limestone* — It includes the productive sample no. 363; the preservation



TEXT-FIG. 3 — Geological map of Tethyan Himalaya in Malla Johar area on which the present study is based.

is poor and there is lack of diversity in forms, mainly the aletes and fungal miospores having been encountered. The palynomorphs identified are: *Densoisporites playfordii*, *Lophotriletes minimus*, *Apiculatisporis* sp., *Thymospora* sp. and *Alisporites* (indeterminate). A great diversity has been observed among the alete forms having sculptured exine. These have been informally designated as 'types'. However, the species *Staphlosporonites allomorphus* and *Micrhystridium balmei* could be identified.

The rarity of specimens does not permit to comment upon the composition of this assemblage in detail but, as such, *Densoisporites playfordii* is found in the Lower Triassic mioflora of Peninsular India (Bharadwaj, Tiwari & Anand Prakash, 1979). A change at this level (Kuling/Kalapani Limestone) of deposition is, however, evident. The ornamented alete forms are significant in indicating the brackish water condition of deposition at this level. Thus, the beginning of Triassic exhibits an environmental change of the set up in this region.

(iii) *Kuti Shale* — Five samples have yielded from this bed, out of them two samples (372 & 379) exhibit a rich assemblage comprising *Densoisporites playfordii*, *Lundbladispora* sp., *Densipollenites pullus*, *Alisporites parvus*, *A. opii*, *A. tenuicorpus*, A. sp., *Klausipollenites schaubergeri*, *Cuneatisporites radialis*, *Faunipollenites varius*, *F.* sp., *Scheuringipollenites maximus*, *S. tentulus*, *Piceaepollenites* sp., *Platysaccus fuscus*, *Ibisporites diplosaccus*, *Striatopodocarpites venustus*, *S. rotundus*, *S. tiwarii*, *S.* sp. cf. *S. decorus*, *Striatites communis*, *S. gopalensis*, *Verticipollenites oblongus*, *Chordasporites* sp., *Guttulapollenites hannonicus*, *Lunatisporites pellucidus*, *L. ovatus*, *Rhizomaspora* sp., *Pretricolpipollenites bharadwajii*, *Veryhachium* sp., and Alete types — 1, 2, 3, 4.

This diversified mioflora suddenly declines in samples 380, 382 and 91 — the younger samples in the sequence, where only a few fungal spores along with a nonstriate-disaccate pollen have been found. This reflects a change in the sedimentary environmental condition at these junctures.

(iv) *Passage Formation* — From this bed only two samples (Sample nos. 96 & 103) have yielded ill-preserved specimens. In sample no. 96, several taxa, viz., *Verrucosisporites* sp., *Tetraporina* sp., *Alisporites parvus*, *Cuneatisporites radialis*, *Platysaccus fuscus*, *Striatopodocarpites magnificus*, *Klausipollenites schaubergeri* have been encountered. Sample no. 103 does not contain any miospore except the alete ones. This assemblage, however, is not rich, and therefore, detailed comparison is not being attempted.

(v) *Kiota Limestone* — Sample nos. 109, 110, 116 and 117 have shown the presence of the taxa *Callumispora fungosa*, *Lophotriletes* sp., *Lundbladispora warti*, *L.* sp., *Goubinispora* sp. cf. *G. morondavensis*, *Klausipollenites schaubergeri*, *Alisporites parvus*, A. sp., *Striatopodocarpites* sp., *Lunatisporites diffusus* and Alete Types — 1, 2, 3, 4 from this bed.

The samples in this horizon, viz., nos. 109, 110, 116 and 117 exhibit the presence of a good assemblage. The drastic decline in the representation of striate-disaccate genera and a fair occurrence of monosaccate (referable to *Goubinispora*) and disaccate nonstriate distinguish this association of taxa from the older one. In sample no. 117 again the mioflora has impoverished.

4. *Sancha Malla Group* — The upper most rock unit of Malla Johar Supergroup extends in age from Oxfordian to Upper Cretaceous. The different formations in it are: Spiti Shale, Giumal Sandstone, Jhangu and Balcha Dhura formations.

(i) *Spiti Shale* — The yielding samples are: 1, 2, 3, 5, 6, 7, 8 and 10. The specimens are represented by three species of *Callialasporites* — *C. dampieri*, *C. monoalasporus* and *C. trilobatus*. The other identified species are: *Verrucosisporites* sp., *Platysaccus* sp., *Crescentipollenites amplus*, *Striatopodocarpites* sp. and *Lunatisporites ovatus*.

These pollen yielding samples are from the lower part of Spiti Shale which is considered to be of Oxfordian age on the basis of forams and ammonoids (see Jai Krishna *et al.*, 1982). The Spiti Shale assemblage of miospore is, thus, characterised by the presence of *Callialasporites* which is an indicator of its being of Jurassic age. However, the continuation in the occurrence of the striate and taeniate-disaccate, although meagre, is interesting in this horizon. There is a chance of recycling also as far as these older elements are concerned.

(ii) *Giumal Sandstone* — No samples were analysed in the present study. However, dinoflagellate cysts (Jain *et al.*, 1978) and radiolarian microfauna (Garg *et al.*, 1980) assemblages are known.

It is thus concluded that the present study brings out the following sequential position of miofloral distribution and pattern of changes through the succession.

The record of Chitinozoa from a few samples of Muth Quartzite Formation is very significant in view of the absence of any other microfossils recovered from here. The Devonian age has been indicated by these organisms, although more detailed data is needed for finer dating.

The Kuling Shale is dated to be Late Permian in age supported by the recovered mioflora. Its younger part (sample nos. 385 & 386) is of late Upper Permian.

In Kalapani Limestone, the miospores are recorded for the first time, but the rarity of the forms does not permit detailed comparisons. However, the miofloral change is evident as the Cavate triletes appear and the ornamented aletes qualify the assemblage for a marine environment.

During the present study, the Kuti Shale samples have yielded a fairly well-diversified mioflora (compare — Tiwari *et al.*, 1980). The presence of *Densoisporites*, *Lundbladispora*, *Klausipollenites* and *Lunatisporites* shows late Lower Triassic affinities, while the genera *Densipollenites*, *Alisporites* (?*Nidhipollenites*), *Pretricolpipollenites* even may suggest Middle Triassic affinity. Because of the absence of any well-dated Noric mioflora from Indian Peninsula, no precise comparisons could be attempted. But it could be assertively said on the basis of evidences we have at present, that the mioflora has an older affinity than the Noric level.

The Passage Zone assemblage did not show anything special to distinguish it from the underlying Kuti Shale. The paucity of microfossils is the main reason for this situation. The Kioto Limestone had some elements, viz., *Goubinispora*, to indicate its younger position in comparison to the underlying formations and thus indicates a Middle Triassic affinity vis-a-vis the Peninsular assemblages. However, its Rhaetic age is still not reflected by the mioflora it contains (Heim & Gansser, 1939; Tiwari *et al.*, 1980).

The Spiti Shale mioflora could not exhibit the details of pollen-spore contents, and due to the presence of *Callialasporites* a Jurassic age is indicated, in general. However, concurrently with this study Jain *et al.* (in press) have recovered following taxa from sample L-27, 200 m above the ferrugenous oolite and suggested early Upper Tithonian age.

Alisporites grandis (Cookson) Dettmann, 1963; *Alisporites* sp. A; *Appendicisporites* sp. A; *Callialasporites monoalasporus* Dev, 1961; *C. trilobatus* Dev, 1961; *Cicatricosisporites autraliensis* (Cookson) Potonié, 1956; *Concavissimisporites kutchensis* Venkatachala, 1969; *Contignisporites multimuratus* Dettmann, 1963; *Couperisporites vangaurdensis* Pocock, 1962; *C. jurassicus* Pocock, 1971; *Densoisporites velatus* (Weyland & Krieger) Krasnova, 1961; *D.* sp. cf. *D. playfordii* (Balme) Dettmann, 1983; *Heliosporites* sp. A; *Laricoidites* sp. A; *Lycopodiumsporites* sp. A; *Podocarpidites multisinus* (Bolkhovitina) Pocock, 1962; *Todisporites minor* Couper, 1953.

Absence of mioflora in sediments below Kuling Shale is attributed to the poor preservation and paucity of suitable lithology. The absence of mioflora in the Cretaceous part of the sequence is related to deepening of the basin when deposition took place mostly in the continental slope and land-derived flora was not easily coming.

FLORA OF TETHYAN HIMALAYA WITH REFERENCE TO INDIAN PLATE BOUNDARY

In the context of plate tectonics, the concept regarding the extent of Indian shield (Peninsular India) and its relationship with Himalayan area have changed considerably during the last few years. The northern extent of the Indian plate is still debatable. It is generally believed that Himalaya is the result of collision of the Indian plate with the Asian Plate, and the collision might have taken place along the Indus-suture-zone (Gansser, 1966; Lefort, 1975). A greater Indian plate has been envisaged by many workers which might have extended up to Tien Shan mountains (Crawford, 1974; Kaila & Narain, 1976).

In this model, the earlier concept of a Central Crystalline Ridge (Central Himalaya) to separate the Gondwanaland elements of the Indian shield lying in the south from the Angara land elements in the north, loses its significance. The palaeobotanical data from the Himalayan and Tibet, though meagre, clearly show that the sediments of Tethyan zone as well as southern Tibet exhibit Gondwana affinities (Hsü, 1978; Tiwari *et al.*, 1980; Ganeshan & Bose, 1982).

From the Tethyan Himalayan region Tiwari *et al.* (1980) reported the preliminary results of palyno-assemblage and their studies of Tethyan sediments of Malla Johar area, for the first time showed the Gondwanic affinities of the flora of these sediments. The reasons for Gondwanic affiliations of Malla Johar area put forward by Tiwari *et al.* (1980) were not properly understood by Maheshwari (1982), and some of them were even misinterpreted and or altered for convenience. Maheshwari (1982), probably unaware of the distributional pattern of *Klausipollenites*, doubted its occurrence in Malla Johar without giving any valid reasons for his conclusion. Further, he misquoted Tiwari *et al.* (1980), as saying it (i.e. *Klausipollenites*) to be an indicator of Gondwana affinity.

The present more detailed and comprehensive study has further supported the previous observations regarding the occurrence of the genus *Klausipollenites*. It has been further observed that in the finer details of the exine, the Himalayan taxa are more akin to the Indian Peninsular forms rather than those found in the European sediments (*pers. obs.* Tiwari). It is to be noted that the presence of *Striatopodocarpites* is confirmed which was doubted by Maheshwari (1982) ignorantly. This Gondwanic affinity is further substantiated in the present study by fairly diversified pollen and spore assemblages in the Kuling Shale, the Kalapani Limestone, the Kuti Shale and the Kioto Limestone which makes the present succession. In this context, some of the important findings on palaeobotany and palynology from Himalayan region are being analysed briefly as under:

The palynostratigraphic studies done by Balme (1970) from West Pakistan provide one of the most important data for comparison, because of its systematic morphotaxonomic treatment as well as good preservation of spores and pollen — a rare thing in the Himalayan sediments.

Balme (1970) has studied the Permian and Triassic sediments of Surghar Range and Salt Range, Pakistan (Text-fig. 3, I). He has concluded a Gondwana affiliation for this assemblage in general, but at the same time identified a few northern elements too in the Pakistan mioflora. However, during the last 14 years — after the publication of Balme's work, a substantial new data from India on Permian and Triassic has appeared (Maheshwari & Banerjee, 1975; Bharadwaj, Tiwari & Anand Prakash, 1979; Tiwari & Rana, 1980, 1981) which clearly reveals the presence of almost all the forms in the Indian Peninsular Permian-Triassic sediments which are enlisted by Balme (1970) to be exclusively European or local elements for the Salt Range mioflora. Thus, as it stands now, the Salt Range and Surghar miofloras are akin to the Indian Peninsular miofloras of the same age and show a Gondwanic affiliation rather than the northern one.

In north-western Himalaya (Text-fig. 3, II) the megaflora from the Aishmuqam Formation (Upper Devonian), Syringothyris Limestone and Fenestella Shale Formation (Lower Carboniferous), and Nishatbagh and Mammal formations (Lower Permian) described by Singh *et al.* (1982) shows a mixed tendency having both Gondwanic and the northern elements. Since no Devonian or Carboniferous megaflora (or microflora) is known from the Indian Peninsular region, a detailed comparison of this type is yet to be attempted. Moreover, as the miospores are showing differences after detailed studies, the megafossils may also reveal some characteristic features of their own on further critical study. The basic differences between the European and Gondwanic morphography have yet to be evaluated with respect to the finer details of fossils.

A mioflora from the early Permian sediments (Boulder Slate sequence of the Lower Bijni Tectonic unit, Garhwal Syncline) of Garhwal, Lesser Himalayas (Text-fig. 3, III) has been recovered by Gupta and Visscher (1980); it contains *Callumispora* (*Leiotriletes*), *Parasaccites*, *Plicatipollenites*, *Potonieisporites*, *Crucisaccites*, and striate-disaccate pollen. This composition clearly resembles the early Permian (Talchir) assemblages of the Peninsular India.

In the western and central Himalayas, no other detailed record of plant microfossils is available for comparison. However, recently Ganesan and Bose (1982) have described a megaflora from Lingshi Basin, Nepal (Text-fig. 3, VI) which resembles the plant assemblages known from the Upper

Gondwana of Satpura and Kachchh in having *Pachypteris* sp., cf. *P. indica*, *Ptilophyllum acutifolium*, *Elatocladus jabalpurensis*, *Pagiophyllum*, *Coniferocaulon* sp. cf. *C. rajmahalense*. The Lingshi Basin is a part of Tethyan belt of Higher Himalaya in Nepal and its affiliation with the Indian Peninsula is interesting.

In Bhutan Himalayas, Pantić, Hochuli and Gansser (1981) have dated the Barsong Formation of eastern Bhutan to be of Jurassic age on the basis of palynological fossils. The formation represents a rare Mesozoic deposit between the Tethyan and the Lesser Himalayan facies. Besides the dinoflagellates, Chitinozoa, and microform, the miospore genera *Punctatisporites*, *Deltoidospora* and *Alisporites* have been illustrated. Similar forms are known from all over the world during Mesozoic time. However, unless detailed structure and organization of the palynofossils are known, nothing definite could be ascertained regarding its affiliation on the basis of this poorly represented assemblage. Therefore, in the present context, only it could be remarked that in the assemblage presently studied from the Malla Johar area contains comparable forms which are present in the Kioto Limestone (Early Jurassic) also.

Another recent report on the occurrence of Lower Permian miospores from Bhutan Himalaya is by Banerjee and Dasgupta (1982) who recovered the mioflora from coal exposures in western part of Deothang. It contains *Scheuringipollenites*, *Striatites*, *Faunipollenites*, *Callumispora*, *Horriditriletes*, etc. showing an affinity with the Barakar miofloras of the Peninsular India — particularly that of the Damodar Basin.

From the north- north-eastern portion of Himalayan belt, Hsü (1978) has deduced interesting conclusions on the basis of megafossils studies. He has established the relationship between the *Glossopteris* flora from the Qubu Formation of southern Tibet (Text-fig. 3, V) and that of the main Indian Peninsula (particularly with the Raniganj Formation of Damodar Basin). He indicates the presence of *Glossopteris communis*, *G. indica*, *Sphenophyllum speciosum*, *Raniganjia qubuensis*, etc. in the Qubu Formation. This flora has no affinities with the *Gigantopteris* flora of northern Tibet, although the two localities are only 600 km away from each other.

On detailed study the plant species found by Hsü might show some differences from the Indian Peninsular species but the generic affiliation seems to be akin with the Indian Gondwana since no taxon of northern hemisphere has been identified in these assemblages. This work supports the extension of the northern limits of the Indian plate up to the southern part of Tibet (Hsü, 1978).

Zhaosheng (1980) worked out the middle and upper Triassic miofloras from Ruishui River, Hauting County in Gansu Province of China. Although they have reported some similar forms as have been known from the Triassic of India, the compositions of the assemblages are not comparable. The Ruishui River miofloras have more pteridophytic spores than the Indian counterparts. Besides, a number of new taxa are also present in the former. The detailed comparison needs more data from this region. Yet it can be concluded that no similarity of components exists between the Chinese assemblage under discussion and that of the Malla Johar when same age equivalents are taken into account.

In the far east from Arunachal Pradesh Himalaya, Srivastava and Dutta (1977) while studying the sediments of Garu-Gensi road section, Siang District (Text-fig. 3, VII), have discovered miofloras divisible into two zones, one consisting of *Parasaccites*, *Plicatipollenites*, *Rugasaccites*, *Virkkipollenites*, *Stellapollenites*, *Potonieisporites* and *Illinites* and the other having *Callumispora*, *Indotriradites*, *Microbaculispora*, *Crusisaccites*, etc. as the characteristic miospore genera. These assemblages are similar to the early Lower Gondwana miofloras of the Peninsular India. The genera *Potonieisporites*, *Limitisporites* and *Illinites*, although do occur in the European Permo-Carboniferous succession, have specific differentiation in details of exine structure, etc. from their northern counterparts and hence considered here to be characteristic of the Gondwanic assemblage.

These results are further substantiated by the study of same horizon by T. Singh (1979) who on the basis of palynology has established the close relationship of these sediments with the Lower Permian rocks of Indian Peninsula as well as other Gondwanic continents.

DISCUSSION AND CONCLUSIONS

The foregoing account clearly reveals that the miofloras of Tethys Himalaya have affinity with Indian Shield miofloras of respective age. The similarity with the European forms is only apparent and not the real. This conclusion has been drawn after detailed morphographic study of European as well as Indian specimens. However, some genera cannot be distinguished on such regionalism, and their presence in northern as well as southern hemisphere cannot be denied, but the totality of the assemblage determines the affinity of regional floras.

Thus, the megafossils as well as microfossils of the Permian and Triassic sediments in the Tethyan zone of the Himalaya exhibit Indian Peninsular affinity — of course, with some local elements of their own. This regional character is in any way not more in degree than the differences recorded in any two floral regions (e.g. Damodar and South Rewa Gondwana Basin) within the Peninsula. The distribution of important assemblages has been depicted in Text-fig. 3. This gives general floral boundaries for Indian plate. Indeed more detailed work is needed for precise delimitation of such floral boundaries, and more so in the Tibetean side of the Himalaya. The Tethyan Himalaya has caught the attention of the palaeopalynologists although the bad preservation and paucity of specimen remains the main hurdle; determined improvement in techniques may usher into better data.

It is, therefore, imperative to arrive at the conclusion on the basis of present study as well as the earlier evidences that the Indian Peninsular area, Tethyan Himalaya and the Southern Tibet belong to the same miofloral province, i.e. the Gondwana. It is apparent that at least up to the Indus Suture Zone the Indian Gondwana plate extended. It may be mentioned that the Indian Shield itself extended up to the southern limit of Tethyan zone, as visualized by Singh (1976, 1979). More data is needed from northern Tibet, before detailed comparison of mioflora of north and south of Indus Suture Zone can be done in order to decide the northern limit of larger Indian plate which some of the workers conceive as extending up to Tien Shan mountains (Crawford, 1974).

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EXPLANATION OF PLATES

(All figures unless otherwise stated are × 750)

PLATE 1

1. *Callumispora fungosa* (Balme) Bharadwaj & Srivastava emend. Bharadwaj & Tiwari, 1977; Film no. 26/29; Lab slide no. 110/1; slide no. BSIP 6093. × 750.
2. *Parasaccites diffusus* Tiwari, 1965; Film no. 28/6; Lab slide no. 385/3; slide no. BSIP 6976. × 500.
3. *Striatopodocarpites magnificus* Bharadwaj & Salujha, 1964; Film no. 30/11; Lab slide no. 386/3; slide no. BSIP 6087.
4. *Striatites* sp. Film no. 30/8; Lab slide no. 387/4; slide no. BSIP 6986.
5. *Klausipollenites schaubergeri* Potonié & Klaus) Jansonius, 1962; Film no. 51/1; Lab slide no. 372/1; slide no. BSIP 6979.
6. *Densoisporites playfordii* (Balme) Dettmann, 1963; Film no. 52/5; Lab slide no. 372/2; slide no. BSIP 6980.
7. *Verrucosisporites* sp. Film no. 29/1; Spiti Shale 1; slide no. BSIP 6097.
8. *Parasaccites distinctus* Tiwari, 1965; Film no. 28/10; Lab slide no. 386/4; slide no. BSIP 6088. × 500.

PLATE 2

9. *Callialasporites trilobatus* Dev, 1961; Film no. 29/26; Lab slide no. Spiti shale/10; slide no. BSIP 6981.
10. *Callialasporites monoalasporus* Dev, 1961; Film no. 29/3; Lab slide no. Spiti shale/2; slide no. BSIP 6982.
11. *Callialasporites dampieri* Dev, 1961; Film no. 29/17; Lab slide no. Spiti shale/6; slide no. BSIP 6100.
12. *Guttulapollenites hannonicus* Goubin, 1965; Film no. 51/29; Lab slide no. 372/1; slide no. BSIP 6979. × 500.
13. *Alisporites* sp. cf. *A. opii* Daugherty, 1941; Film no. 57/20; Lab slide no. T-7/S1 slide no. BSIP 6983.
14. *Densipollenites pullus* Segroves, 1969; Film no. 51/34; Lab slide no. 372/2; slide no. BSIP 6980.
15. *Densipollenites densus* Bharadwaj & Srivastava 1969; Film no. 28/15; Lab slide no. 386/2; slide no. BSIP 6086.

PLATE 3

16. *Parasaccites bilateralis* Tiwari, 1965; Film no. 28/7; Lab slide no. 385/3; slide no. BSIP 6976.
17. *Crescentipollenites amplus* (Balme & Hennelly) Tiwari & Rana, 1980 Film no. 28/11; Lab slide no. 386/4; slide no. BSIP 6088.
18. *Striatopodocarpites venustus* Bharadwaj & Salujha, 1965; Film no. 28/8; Lab slide no. 386/4; slide no. BSIP 6088.

19. *Scheuringipollenites tentulus* (Tiwari) Tiwari, 1973; Film no., 51/13; Lab slide no. 372/1; slide no. BSIP 6979.
20. *Crescentipollenites* sp.; Film no. 28/12; Lab slide no. 386/4; slide no. BSIP 6088.
21. *Striatopodocarpites* sp. cf. *S. decorus* Bharadwaj & Salujha, 1964; Film no. 30/10; Lab slide no. 387/5; slide no. BSIP 6997.
22. *Striatopodocarpites tiwarii* Bharadwaj & Dwivedi, 1981; Film no. 52/6; Lab slide no. 372/2; slide no. BSIP 6980.
23. *Striatopodocarpites rotundus* (Maheshwari) Bharadwaj & Dwivedi, 1981; Film no. 28/4; Lab slide no. 385/3; slide no. BSIP 6976.

PLATE 4

24. *Striatites varius* Kar, 1968; Film no. 52/12; Lab slide no. 372/2; slide no. BSIP 6980.
25. *Striatites communis* Bharadwaj & Salujha, 1964; Film no. 52/28; Lab slide no. 379/1; slide no. BSIP 6989.
26. *Goubinispora* sp. cf. *G. morondavensis* (Goubin) Tiwari & Rana, 1981; Film no. 27/28; Lab slide no. 109/2; slide no. BSIP 6984. × 500.
27. *Chordasporites* sp.; Film no. 51/23; Lab slide no. 372/1; slide no. BSIP 6979.
28. *Striatites gopalensis* Srivastava, 1970; Film no. 52/13; Lab slide no. 372/2; slide no. BSIP 6980.
29. *Verticipollenites oblongus* Bharadwaj, 1962; Film no. 53/14; Lab slide no. 379/2; slide no. BSIP 6987.
30. *Cuneatisporites radialis* Leschik, 1955; Film no. 53/10; Lab slide no. 379/2; slide no. BSIP 6987.
31. *Lunatisporites ovatus* (Goubin) Maheshwari & Banerji, 1975; Film no. 57/18; Lab slide no. T-7/2; slide no. BSIP 6991.

PLATE 5

32. *Veryhachium*, Denuff, 1954; Film no. 55/8; Lab slide no. 372/2; slide no. BSIP 6980.
33, 36-39 Indeterminate; Film no. 51/31; Lab slide no. 372/1; slide no. BSIP 6979. Film no. 57/10; Lab slide no. T-7/4; slide no. BSIP 6994. Film no. 27/25; Lab slide no. 109/1; slide no. BSIP 6995. Film no. 57/11; Lab slide no. T-7/4, 11.5 × 108, slide no. BSIP 6994. Film no. 27/23; Lab slide no. 109/3; slide no. BSIP 6094.
34, 35, 50, 51, 53, 54. Type-3; Film nos. 54/24, 54/1, 54/20, 54/6, 51/18, 54/13; Lab slide nos. 393/1, 363/1, 393/1, 363/2, 372/1, 363/2; slide nos. BSIP 6988; 6992, 6988, 6993, 6979, 6993.
40, 41. Type-4; Film no. 53/31, 32; Lab slide no. 363/1; slide no. BSIP 6992.
42, 52. *Staphlosporonites allomorphus* Sheffy, & Dilcher, 1971; Film nos. 53/35, 34; Lab slide no. 363/1; slide no. BSIP 6992.
43. *Pilasporites plurigenus* Balme & Hennelly, 1956; Film no. 26/11; Lab slide no. 391/3; slide no. BSIP 6996.
44. *Micrhystridium balmei* Sarjeant, 1971; Film no. 54/4; Lab slide no. 363/2; slide no. BSIP 6993.
45, 46. Type-2; Film nos. 54/16, 52/10; Lab slide nos. 363/2, 372/2; Slide no. BSIP 6993, 6980.
47-49. Type-1; Film nos. 53/26, 27, 54/2; Lab slide nos. 363/1 363/2; slide nos. BSIP 6992, 6993.

PLATE 6

(All figures are. × 300)

55, 57, 63, 66. cf *Desmochitina* Eisenack, 1981; Film nos. 107/32, 25, 12, 19; Lab slide no. 33/2, 33/34/1, 33/1; slide no. BSIP 8005.
56, 59. *Angochitina* Eisenack, 1931; Film nos. 107/10, 9; Lab slide no. 34/1; slide no. BSIP 8004.
58. *Rhabdochitina* Eisenack, 1931; Film no. 107/34; Lab slide no. 33/2; slide no. BSIP 8005.
60, 65. *Conchitina* Eisenack, 1931; Film nos. 107/21, 20; Lab slide no. 33/1; slide no. BSIP 8006.
61, 68. *Lagenochitina* Eisenack, 1931; Film nos. 107/17, 13; Lab slide nos. 33/3, 34/1; slide no. BSIP 8007 and 8004.
62. *Ancyrochitina* Eisenack, 1955; Film no. 107/6; Lab slide no. 34/1; slide no. BSIP 8004.
64. cf. *Lagenochitina* Eisenack, 1931; Film no. 107/29; Lab slide no., 33/2; slide no. BSIP 8005.
67. *Cyathochitina* Eisenack, 1955; Film no. 107/35, Lab slide no., 33/2; slide no. BSIP 8005.
69. cf. *Conochitina* Eisenack, 1931; Film no. 107/7; Lab slide no. 34/1; slide no. BSIP 8004.

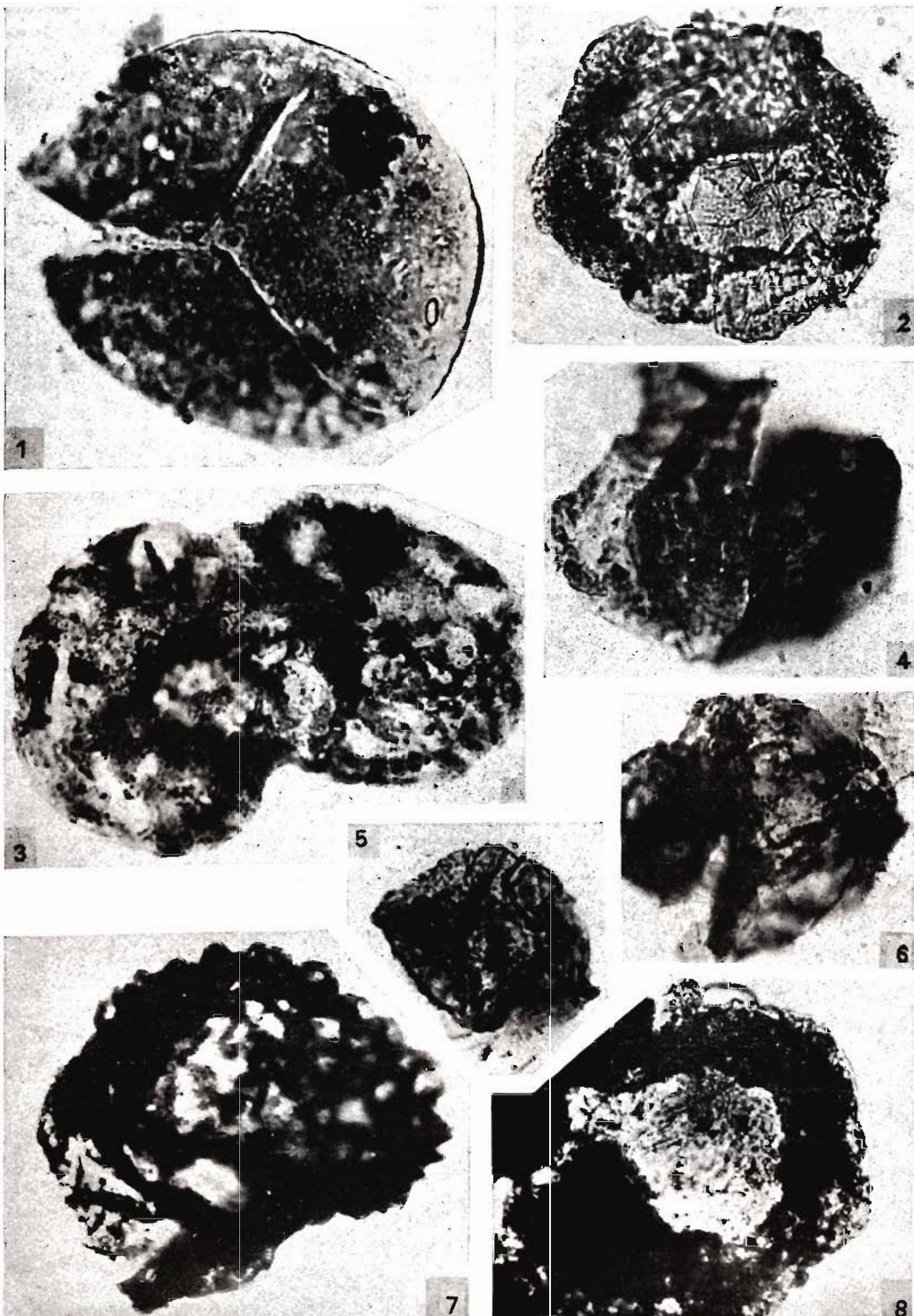
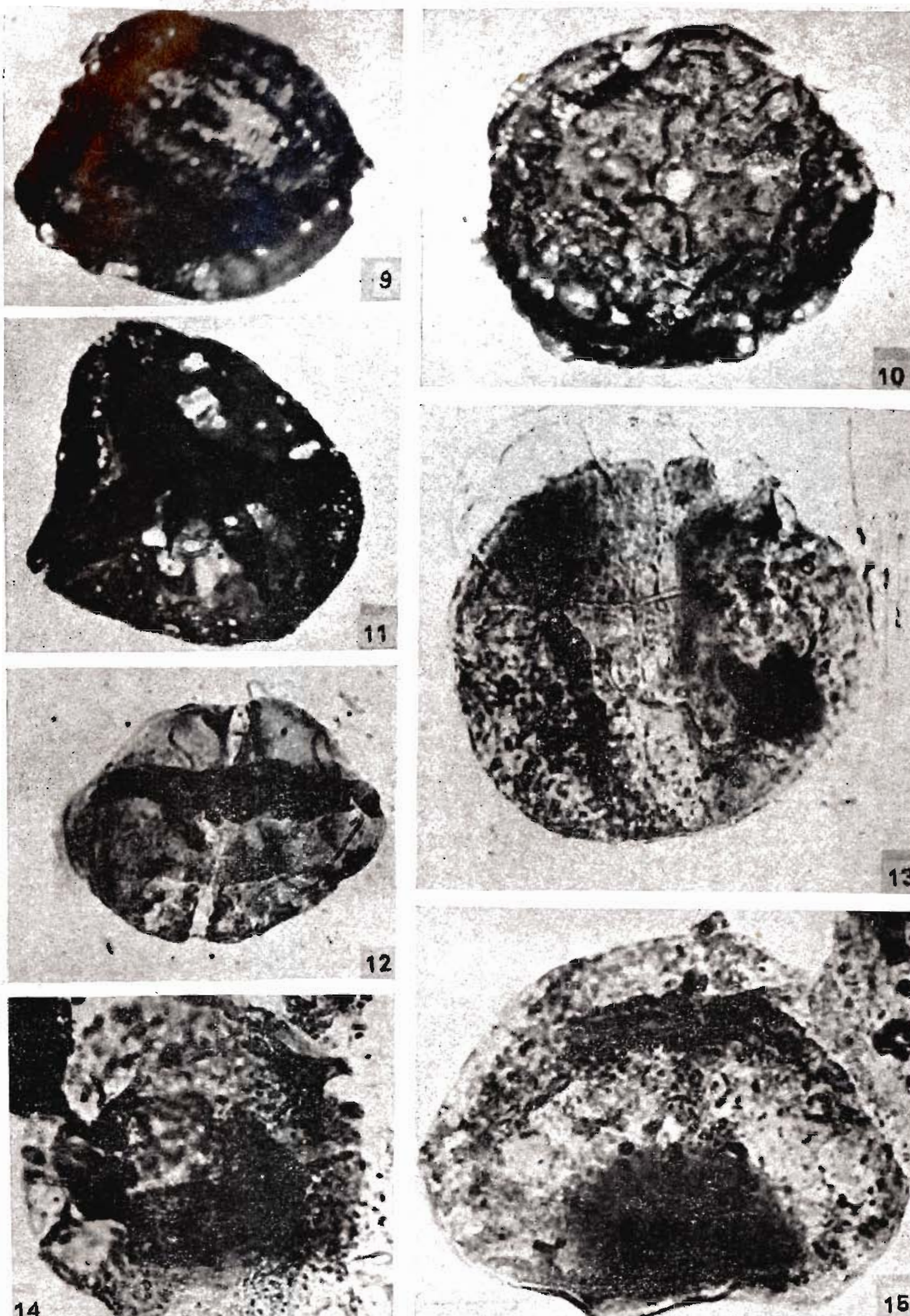


PLATE 1



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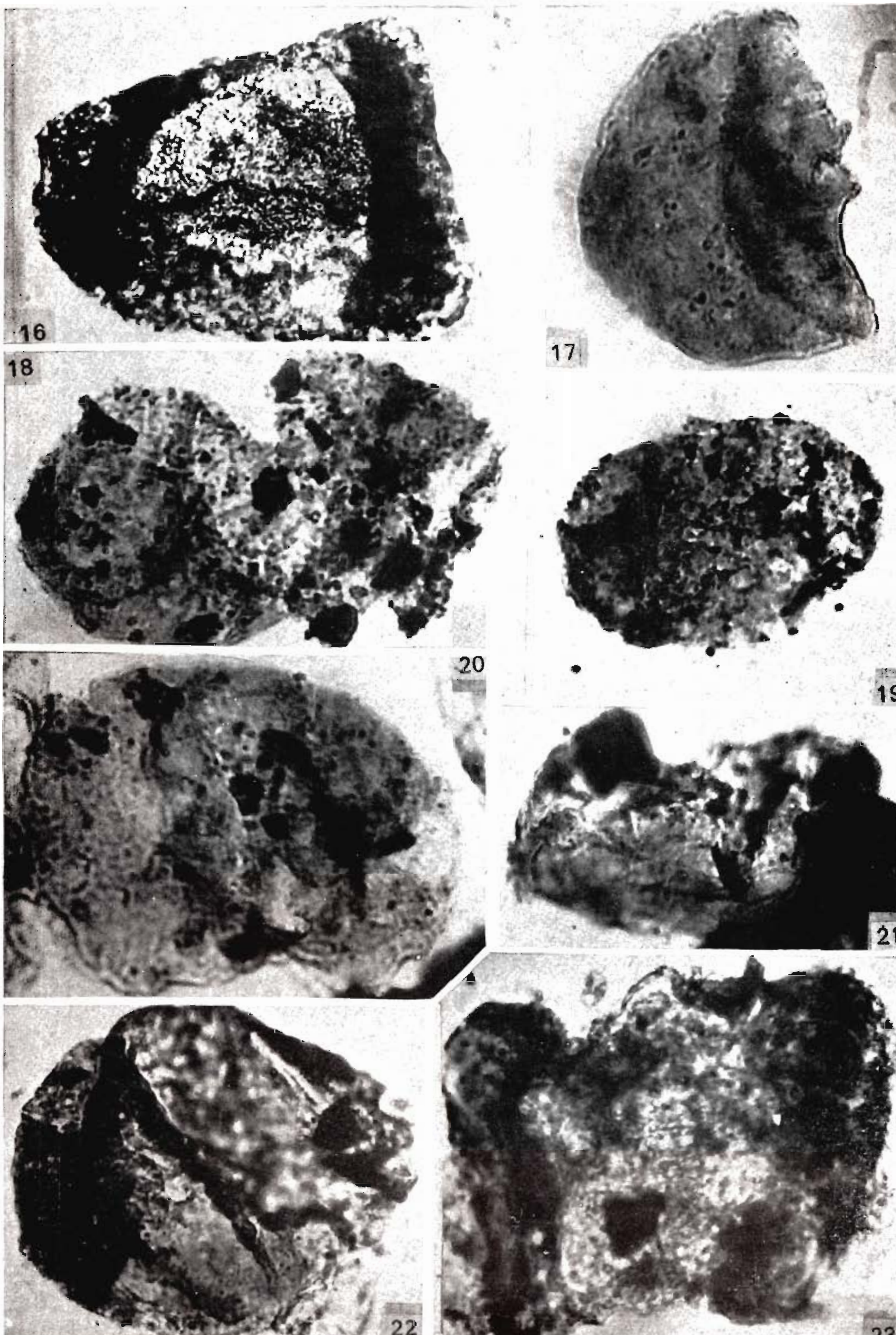
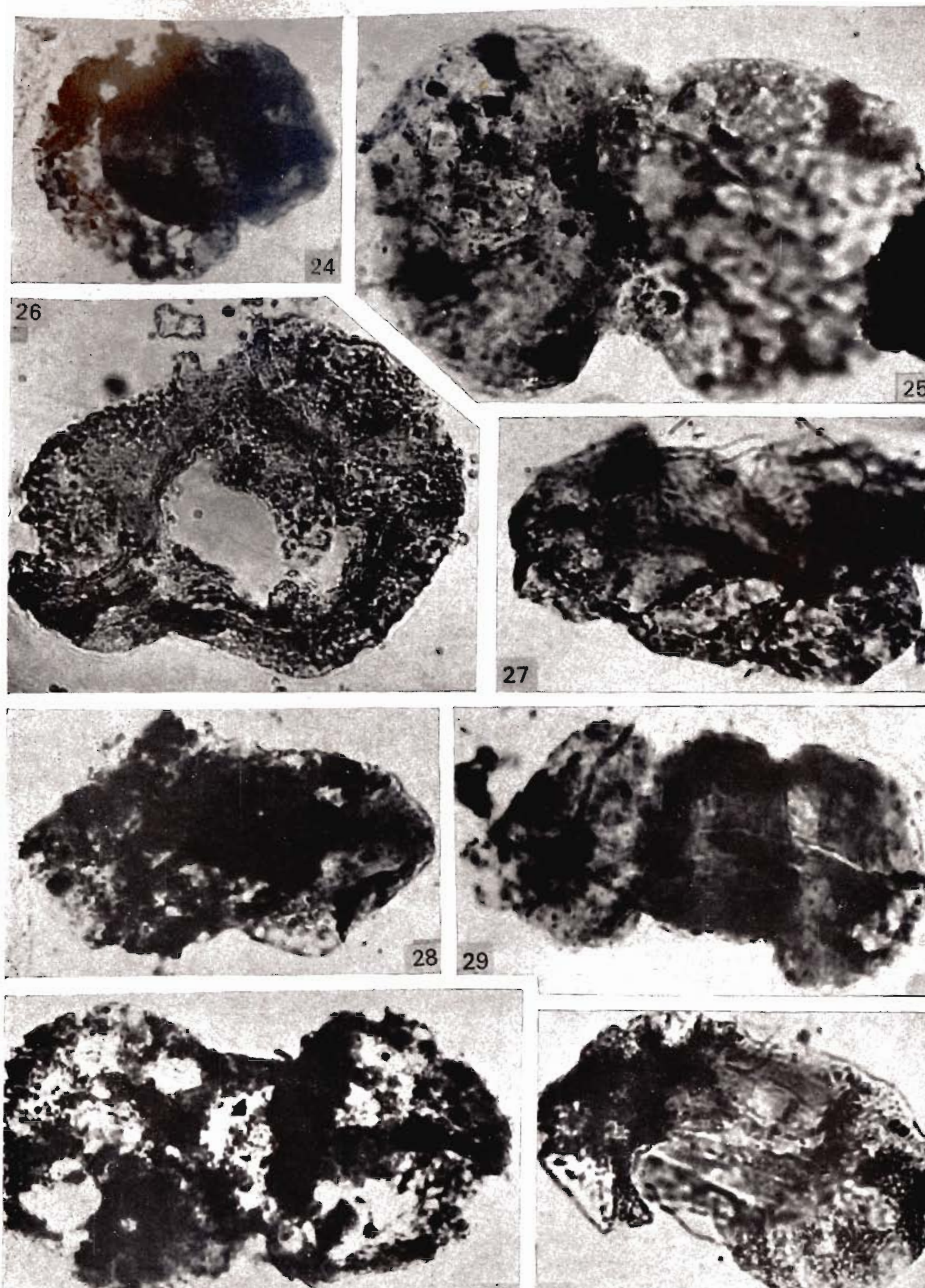


PLATE 3



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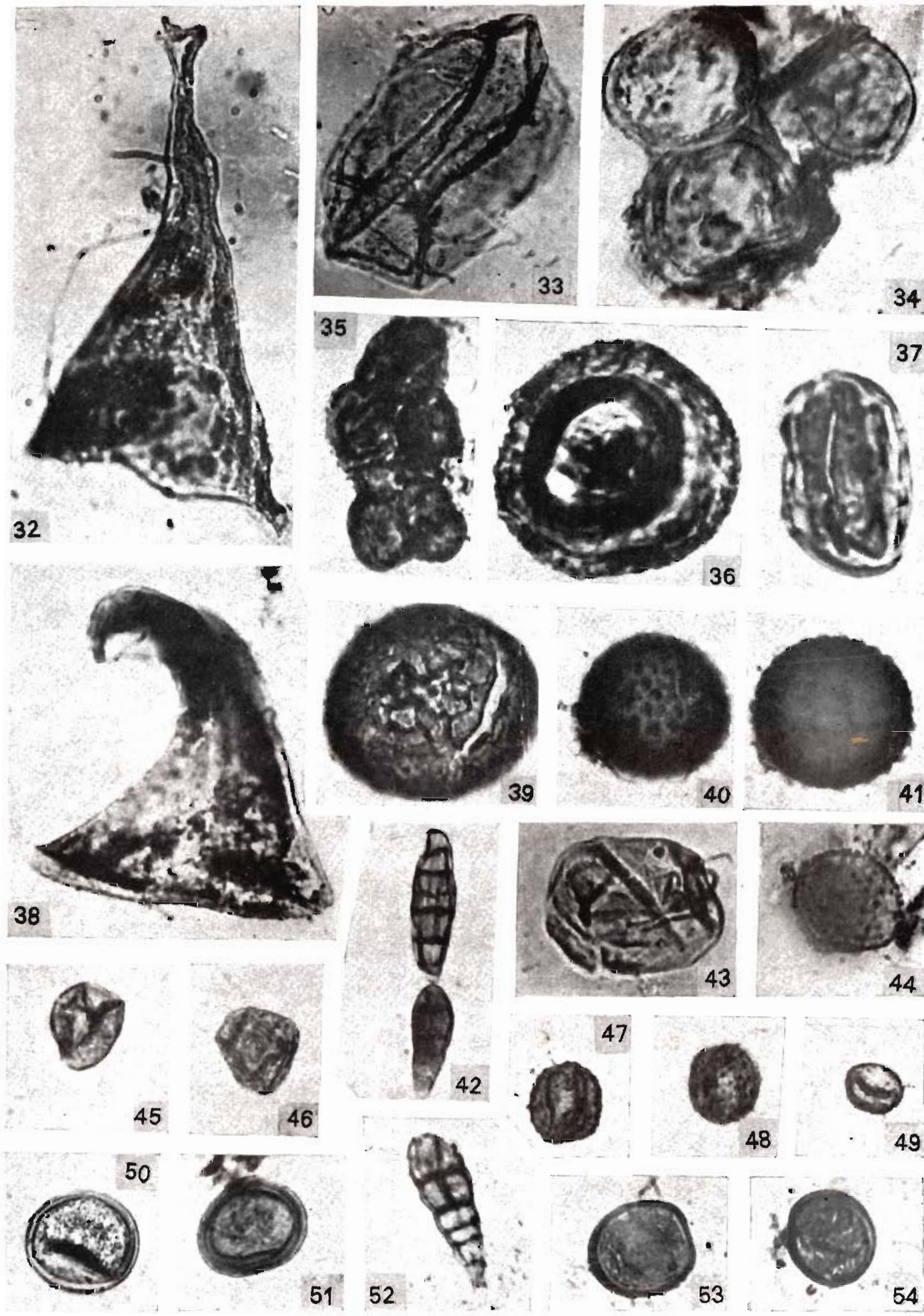

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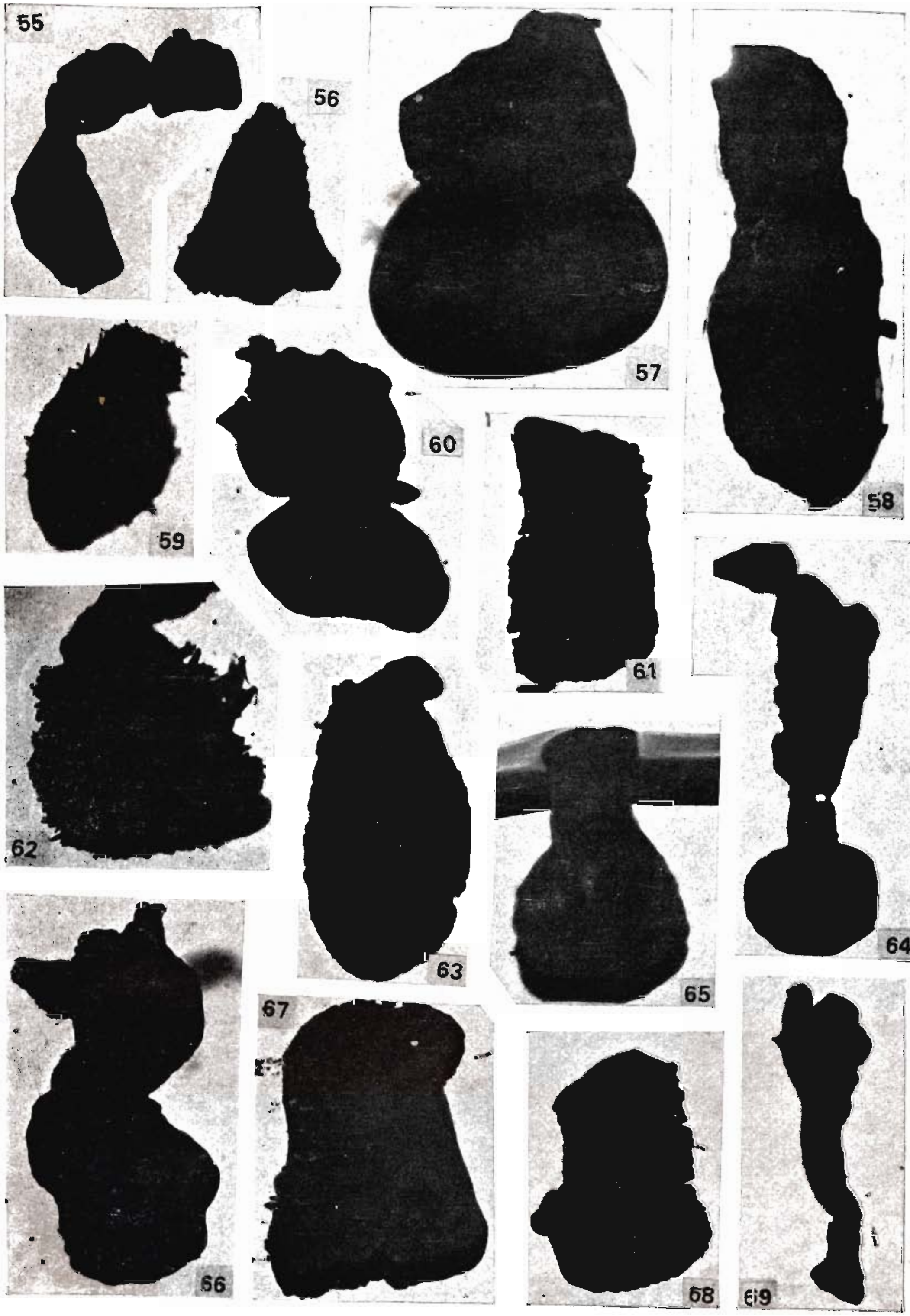

PLATE 6