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# Palynological investigation of the Kopili Formation (Late Eocene) in North Cachar Hills, Assam, India

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ABSTRACT. A rich and diverse palynoassemblage has been recorded from the Kopili Formation (Late Eocene) exposed in North Cachar Hills, Assam, India. The assemblage contains dinoflagellate cysts (1 genus and 1 species), fungal remains (9 genera and 9 species), bryophytic spores (1 genus and 1 species), pteridophytic spores (16 genera and 44 species), gymnospermous pollen (4 genera and 5 species), angiospermous pollen (19 genera and 23 species) and reworked palynomorphs (7 genera and 7 species). Of these, one species and 22 combinations are proposed as new. These are: *Baculatisporites cephalus* (Saxena) comb. nov., *Baculatisporites microgranifer* (Sah & Jain) comb. nov., *Hammenisporis aidaensis* (Kar) comb. nov., *Hammenisporis assamensis* sp. nov., *Hammenisporis microverrucosus* (Kar & Saxena) comb. nov., *Hammenisporis multicostatus* (Kar & Saxena) comb. nov., *Hammenisporis paucicostatus* (Kar) comb. nov., *Hammenisporis susannae* (van der Hammen) comb. nov., *Laevigatosporites chatterjii* (Kar) comb. nov., *Laevigatosporites indicus* (Singh et al.) comb. nov., *Laevigatosporites intrapunctatus* (Kar & Jain) comb. nov., *Laevigatosporites levis* (Sah) comb. nov., *Laevigatosporites punctatus* (Singh et al.) comb. nov., *Laevigatosporites strictus* (Kar & Saxena) comb. nov., *Polypodiisporonites formosus* (Salujha et al.) comb. nov., *Polypodiisporonites minor* (Sah) comb. nov., *Polypodiisporonites ornatus* (Sah) comb. nov., *Polypodiisporonites speciosus* (Sah) comb. nov., *Polypodiisporonites splendidus* (Salujha et al.) comb. nov., *Polypodiisporonites tuberculensis* (Baksi) comb. nov., and *Polypodiisporonites turbinatus* (Sah) comb. nov., *Monocolpopollenites kutchensis* (Venkatachala & Kar) comb. nov., and *Monocolpopollenites nadhamunii* (Venkatachala & Kar) comb. nov. The palynoflora indicates a tropical-subtropical, warm-humid climate with heavy precipitation during the sedimentation of the Kopili Formation. The environment of deposition has been interpreted as coastal with fresh water swamps and ponds nearby. The source area of the reworked Permian palynomorphs may be Lower Gondwana exposures at Singrimari, Garo Hills, Meghalaya. The present assemblage is identical to the Kopili assemblage recorded from the neighbouring Jaintia Hills, Meghalaya and is Late Eocene in age.

KEY WORDS: palynology, Kopili Formation, Late Eocene, Assam, north-eastern India

## INTRODUCTION

The Kopili Formation, instituted by Evans (1932), represents the youngest lithostratigraphic unit of the Jaintia Group. The formation is developed in the southern and south-eastern slopes of Shillong Plateau – Khasi and Jaintia Hills, Meghalaya and North Cachar Hills, Assam (Fig. 1). Equivalents of the Kopili Formation in Garo and West Khasi Hills are known as the Rewak Formation. The Kopili Formation attains a thickness of about 500 metres in its type section located near Umrongso (previously Garampani) in North Cachar Hills District, Assam.

Baksi (1962) initiated the palynological studies on the Kopili Formation exposed along Simsang River Section in Garo Hills, Meghalaya. Baksi (1974) instituted eight palynological zones in the Tertiary sequence of Assam. He proposed *Monocolpopites broadcolpusi* – *Simsangia* Assemblage Zone (=Simsang

Palynological Zone II of Baksi, 1962) for the Kopili Formation. The Simsang Palynological Zone II, recognized in the Kopili Formation, is characterized by the occurrence of *Laevigatosporites kopilia*, *Ginkgopites dubia*, *Simsangia trispinosa*, *Monocolpopites broadcolpusi*, and *Acolporipites spinulosa.*

Sein and Sah (1974) demarcated Late Eocene (=Kopili Formation) and Oligocene (Barails) sediments of Jowai–Badarpur Road, Jaintia Hills, Meghalaya on the basis of recovered palynoassemblage. Dutta and Jain (1980) designated Microplankton Assemblage D for the base of Kopili Formation of Lumshnong area in Jaintia Hills, Meghalaya.

Palynological studies on the Kopili Formation have been carried out also by Sah and Dutta (1968), Salujha et al. (1972, 1974), Tripathi and Singh (1984a, b, 1985), Singh and Tripathi (1987), Tripathi (1989), Trivedi (1985, 1991, 2005) and Trivedi and Saxena (2000)

## STRATIGRAPHY OF THE AREA

The Kopili Formation is made up of thin, usually ferruginous, grayish-black splintery shales interbedded with bands of medium grained sandstone. Thin bands of siltstone, argillaceous limestone and lamellae of coal are also met with. It conformably overlies the Garampani Limestone Formation and is overlain by the Barail sediments. However, in the Umrongso area, the Kopili Formation is covered by alluvial soil. The stratigraphic sequence of the area around Umrongso is given in Table 1 and Figure 2.

## MATERIAL AND METHODS

The area under study is situated in North Cachar Hills District, Assam, India (Fig. 1). The North Cachar Hills constitute the eastern slope of Shillong Plateau. Thirty five samples were collected

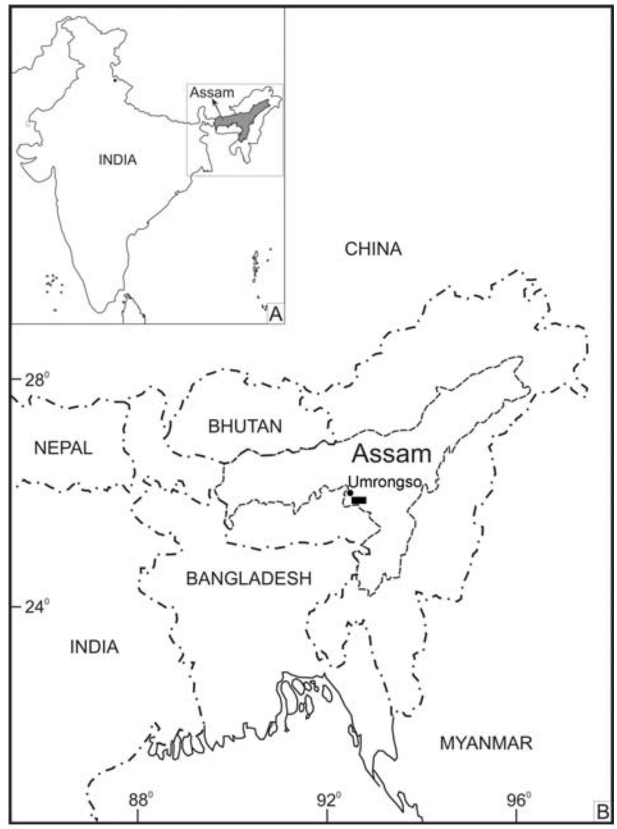


**Fig. 1. A.** Map of India showing location of Assam State; **B.** Map of north-eastern India; ▬ – area of study

from the upper part of the Kopili Formation, exposed at about 10 km south-east of Umrongso Town. Of these, sixteen samples proved to be palynologically productive.

**Table 1.** Stratigraphic succession of the area around Umrongso, North Cachar Hills, Assam

| Lithostratigraphic unit | Lithology | Fossil contents | Age |
|---|---|---|---|
| | Soil and alluvium<br>— unconformity — | | |
| Kopili Formation (500 m) | Shale with thin bands of argillaceous limestone, siltstone, sandstone and strings of coal | Calcareous shale and argillaceous limestone contain molluscs and rich assemblage of foraminifera. Coal contains microflora | Late Eocene |
| Garampani Limestone Formation (127 m) | Foraminiferal limestone with a few layers of marl and calcareous shale | Highly fossiliferous throughout its entire thickness. Floral and faunal elements present. Foraminifera are dominant | Middle to late Middle Eocene |
| Mikir Formation (60 m) | Coarse to medium grained sandstone with occasional siltstone, shale and coal<br>— unconformity —<br>Precambrian Complex | Apparently devoid of faunal remains. Carbonaceous shale and coal contain microflora | Early to early Middle Eocene |

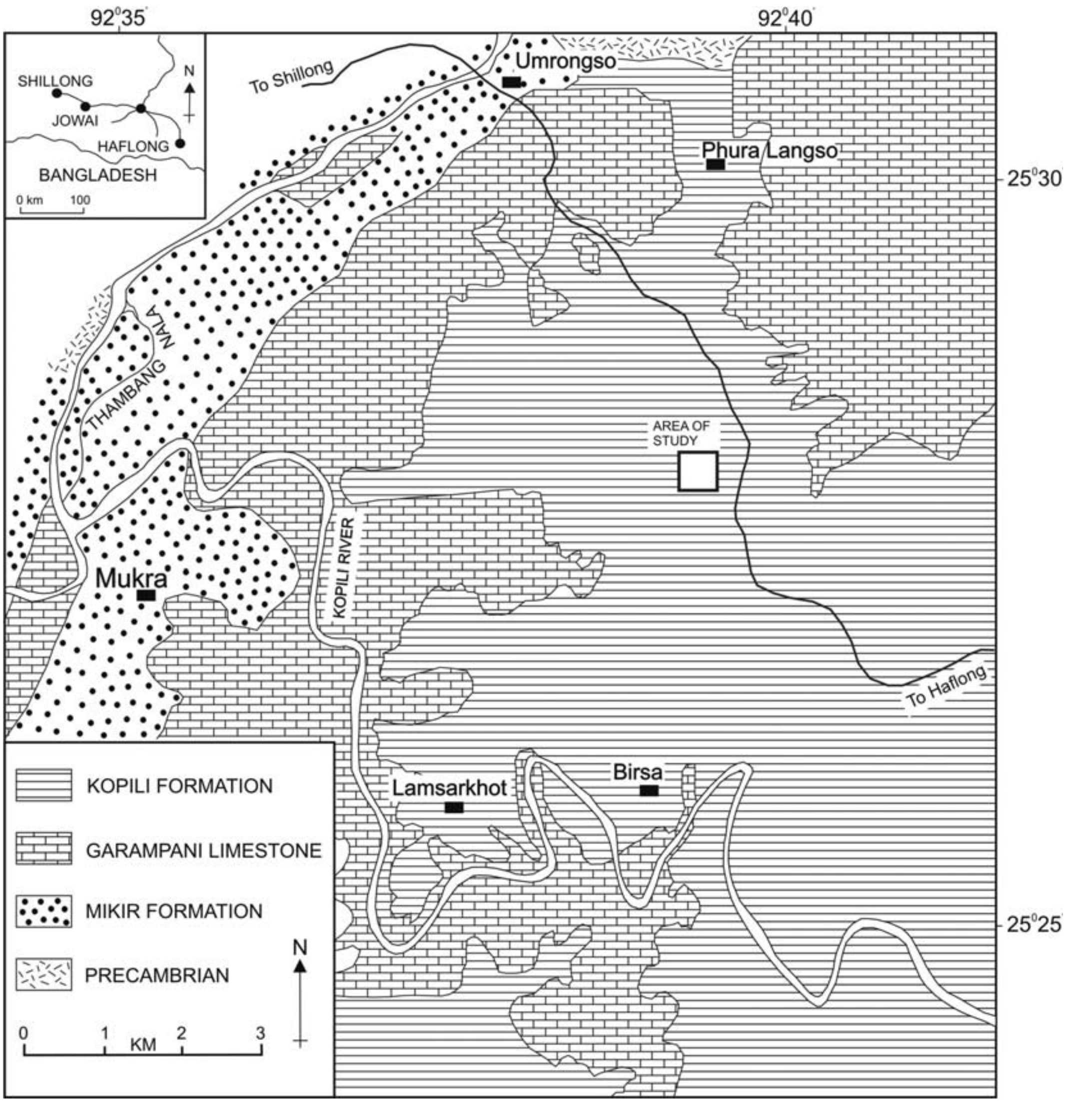


**Fig. 2.** Geological map of a part of North Cachar Hills, Assam, showing area of investigation (after Samanta 1971)

For recovery of palynomorphs, samples were treated with HCl, HF and $HNO_3$ followed by 10% solution of KOH. The material was finally washed with water through a sieve of 37 µm mesh diameter. The slides were prepared in polyvinyl alcohol and mounted in Canada balsam. Leitz Laborlux-S microscope was used for the study and photomicrography. The quantitative analysis of the assemblage has been done on the basis of frequency of palynotaxa in a count of 200 specimens per sample and from such counts, percentage of each palynotaxon or group of palynomorphs were calculated.

The slides of the figured specimens are preserved in the museum of the Birbal Sahni Institute of Palaeobotany, Lucknow, India.

## PALYNOFLORAL COMPOSITION

The recovered palynoassemblage from the Kopili Formation is rich and diversified and is represented by dinoflagellate cysts, fungal spores and fruiting bodies, bryophytic and pteridophytic spores, and gymnospermous and angiospermous pollen, besides reworked palynomorphs. Qualitatively and quantitatively, the assemblage is dominated by pteridophytic spores followed by angiosperm pollen. Spores showing affinity with family Parkeriaceae and Polypodiaceae are abundant in the assemblage. All the recovered palynotaxa are listed in Table 2. Taxa marked with an asterisk (*) are either described or commented upon below.

The important palynotaxa of the assemblage are: *Operculosculptites globatus* Kar, *Baculatisporites wellmanii* (Couper) Krutzsch, *Hammenisporis susannae* (van der Hammen) comb. nov., *H. multicostatus* (Kar & Saxena) comb. nov., *H. paucicostatus* (Kar) comb. nov., *H. assamensis* sp. nov., *Laevigatosporites chatterjii* (Kar) comb. nov., *L. levis* (Sah) comb. nov., *L. tertiarus* (Sah & Dutta) Saxena & Khare,

**Table 2.** List of palynofossil taxa with their botanical affinities and present day distribution of plant families

| Botanical group/family | Palynotaxa | Present day distribution |
|---|---|---|
| **Division Thallophyta** | | |
| Algae | *Cleistosphaeridium diversispinosum* Davey et al. 1966 (Pl. 1, fig. 1) | Marine |
| Fungi | *Didymoporisporonites longus* (Kar) Kalgutkar & Jansonius 2000<br>*Diporicellaesporites stacyi* Elsik 1968 (Pl. 1, fig. 19)<br>*Frasnacritetrus indicus* Saxena & Khare 1992<br>*Inapertisporites kedvesii* Elsik 1968 (Pl. 2, fig. 13)<br>*Kutchiathyrites eccentricus* Kar 1979 (Pl. 2, fig. 9)<br>*Monoporisporites stoveri* Elsik 1968<br>*Phragmothyrites eocaenicus* Edwards 1922<br>*Pluricellaesporites hillsii* Elsik 1968<br>*Trichothyrites setifer* (Cookson) Saxena & Misra 1990 (Pl. 1, fig. 2) | Warm, humid and tropical |
| **Division Bryophyta** | | |
| Calobryaceae | *Operculosculptites globatus* Kar 1991 | Tropical to subtropical |
| **Division Pteridophyta** | | |
| Cyatheaceae | *Cyathidites australis* Couper 1953 (Pl. 1, fig. 11)<br>*Cyathidites minor* Couper 1953 | Tropical to subtropical |
| Lycopodiaceae | *Foveosporites triangulus* Dutta & Sah 1970<br>*Lycopodiumsporites assamicus* Mehrotra & Sah 1980 | Cosmopolitan |
| Osmundaceae | **Baculatisporites cephalus* (Saxena) comb. nov. | Cosmopolitan |
| | **Baculatisporites microgranifer* (Sah & Jain) comb. nov.<br>*Baculatisporites wellmanii* (Couper) Krutzsch 1959 (Pl. 1, fig. 7)<br>*Todisporites major* Couper 1958 (Pl. 3, fig. 9)<br>*Todisporites minor* Couper 1958<br>*Verrutriletes grandis* Salujha et al. 1980 (Pl. 3, fig. 4) | |
| Parkeriaceae | **Hammenisporis aidaensis* (Kar) comb. nov. (Pl. 1, fig. 16)<br>**Hammenisporis assamensis* sp. nov. (Pl. 3, figs 1–2)<br>**Hammenisporis microverrucosus* (Kar & Saxena) comb. nov. (Pl. 1, fig. 10)<br>**Hammenisporis multicostatus* (Kar & Saxena) comb. nov.<br>**Hammenisporis paucicostatus* (Kar) comb. nov. (Pl. 2, fig. 8)<br>**Hammenisporis susannae* (van der Hammen) comb. nov. (Pl. 1, fig. 15) | Tropical |
| Polypodiaceae | **Laevigatosporites chatterjii* (Kar) comb. nov.<br>**Laevigatosporites indicus* (Singh et al.) comb. nov.<br>**Laevigatosporites intrapunctatus* (Kar & Jain) comb. nov.<br>**Laevigatosporites levis* (Sah) comb. nov.<br>**Laevigatosporites punctatus* (Singh et al.) comb. nov.<br>**Laevigatosporites strictus* (Kar & Saxena) comb. nov.<br>*Laevigatosporites tertiarus* (Sah & Dutta) Saxena & Khare 2004 (Pl. 2, fig. 11)<br>*Monolites mawkmaensis* Sah & Dutta 1966 (Pl. 1, fig. 3)<br>*Monolites ovatus* Sah 1967<br>*Pilamonoletes excellensus* Kar 1991 (Pl. 2, fig. 7, Pl. 3, fig. 6)<br>*Polypodiisporonites favus* Potonié 1931<br>**Polypodiisporonites formosus* (Salujha et al.) comb. nov.<br>*Polypodiisporonites mawkmaensis* (Dutta & Sah) Mathur & Chopra 1982<br>**Polypodiisporonites minor* (Sah) comb. nov.<br>**Polypodiisporonites ornatus* (Sah) comb. nov. (Pl. 1, fig. 14)<br>*Polypodiisporonites repandus* (Takahashi) Saxena & Khare 2004<br>**Polypodiisporonites speciosus* (Sah) comb. nov.<br>**Polypodiisporonites splendidus* (Salujha et al.) comb. nov.<br>**Polypodiisporonites tuberculensis* (Baksi) comb. nov. (Pl. 1, fig. 4)<br>**Polypodiisporonites turbinatus* (Sah) comb. nov. (Pl. 2, fig. 10) | Cosmopolitan |
| Schizaeaceae | *Corrugatisporites formosus* Dutta & Sah 1970<br>*Intrapunctisporis apunctis* Krutzsch 1959 (Pl. 3, fig. 3)<br>*Intrapunctisporis intrapunctis* Krutzsch 1959 | Tropical to subtropical |

**Table 2.** Continued

| Botanical group/family | Palynotaxa | Present day distribution |
|---|---|---|
| | *Lygodiumsporites eocenicus* Dutta & Sah 1970<br>*Lygodiumsporites lakiensis* Sah & Kar 1969 (Pl. 2, fig. 14)<br>*Lygodiumsporites pachyexinus* Saxena 1978 (Pl. 2, fig. 3)<br>*Punctatisporites sarangwaraensis* Kar 1979<br>*Schizaeoisporites phaseolus* Delcourt & Sprumont 1955 (Pl. 2, fig. 4) | |
| **Division Spermatophyta Subdivision Gymnospermae** | | |
| Araucariaceae | *Araucariacites australis* Cookson 1947 ex Couper 1953 (Pl. 3, fig. 8)<br>*Inaperturopollenites mirabilis* Salujha et al. 1974<br>*Inaperturopollenites punctatus* (Saxena) Saxena & Bhattacharyya 1987 | In tropics, mainly restricted to higher altitudes |
| Pinaceae | *Pinuspollenites crestus* Kar 1985 (Pl. 1, fig. 17, Pl. 3, fig. 7) | Temperate, members of the family mainly inhabit higher altitudes |
| Podocarpaceae | *Podocarpidites ellipticus* Cookson 1947 ex Couper 1953 (Pl. 3, fig. 10) | Tropical to subtropical |
| **Division Angiospermae Class Monocotyledonae** | | |
| Arecaceae | *Dicolpopollis proprius* Salujha et al. 1972 (Pl. 2, fig. 6)<br>**Monocolpopollenites kutchensis* (Venkatachala & Kar) comb. nov.<br>**Monocolpopollenites nadhamunii* (Venkatachala & Kar) comb. nov.<br>*Palmidites plicatus* Singh in Sah & Singh 1974 (Pl. 1, fig. 12, Pl. 2, fig. 1)<br>*Proxapertites assamicus* (Sah & Dutta) Singh 1975<br>*Proxapertites microreticulatus* Jain et al. 1973 (Pl. 2, fig. 12)<br>*Spinizonocolpites echinatus* Muller 1968 | Tropical to subtropical |
| **Class Dicotyledonae** | | |
| Mimosaceae | *Polyadopollenites levis* Sah 1967 | Cosmopolitan |
| Bombacaceae | *Tricolporopollis matanomadhensis* (Venkatachala & Kar) Tripathi & Singh 1985 | Tropical to subtropical |
| Myricaceae | *Triporopollenites minutus* Rao & Ramanujam 1982 | Tropical |
| Pellicieriaceae | *Pellicieroipollis langenheimii* Sah & Kar 1970 (Pl. 1, fig. 18, Pl. 3, fig. 5) | Tropical |
| Caesalpiniaceae | *Margocolporites complexum* Ramanujam 1966<br>*Margocolporites sahnii* Ramanujam 1966 | Tropical to subtropical |
| Alangiaceae | *Favitricolporites magnus* Sah 1967 (Pl. 1, fig. 9)<br>*Tricolporopilites robustus* (Kar & Saxena) Kar 1985 (Pl. 3, fig. 11) | Tropical |
| Anacardiaceae | *Rhoipites nitidus* Sah & Dutta 1968 (Pl. 1, fig. 13) | Tropical to subtropical |
| **Incertae sedis** | *Densiverrupollenites eocenicus* Tripathi & Singh 1984a (Pl. 1, fig. 8, Pl. 2, fig. 5)<br>*Dermatobrevicolporites dermatus* (Sah & Kar) Kar 1985<br>*Psiloschizosporis psilatus* Kar & Saxena 1981<br>*Retitricolpites crassireticulatus* (Dutta & Sah) Samant & Phadtare 1997 (Pl. 2, fig. 2)<br>*Tricolpites microreticulatus* Belsky et al. 1965<br>*Tricolpites minutus* Sah & Kar 1970<br>*Verrucolporites verrucus* Sah & Kar 1970 | |
| **Reworked palynofossils** | *Callialasporites segmentatus* (Balme) Dev 1961<br>*Cingulatisporites formosus* Venkatachala & Sharma 1974 (Pl. 2, fig. 15)<br>*Cuneatisporites rarus* Kar 1968<br>*Indotriradites sparsus* Tiwari 1964 (Pl. 1, fig. 5)<br>*Klausipollenites sulcatus* Kar et al. 1973<br>*Lundbladispora* sp. (Pl. 1, fig. 6)<br>*Vitreisporites densus* Kar et al. 1973 (Pl. 3, fig. 12) | |

*Monolites mawkmaensis* Sah & Dutta, *Polypodiisporonites ornatus* (Sah) comb. nov., *P. turbinatus* (Sah) comb. nov., *Inaperturopollenites mirabilis* Salujha et al., *Pinuspollenites crestus* Kar, *Densiverrupollenites eocenicus* Tripathi & Singh, *Monocolpopollenites nadhamunii* Venkatachala & Kar, *Favitricolporites magnus* Sah, *Tricolporopilites robustus* (Kar & Saxena) Kar, etc. The reworked palynomorphs are represented by *Cuneatisporites*, *Indotriradites*, *Klausipollenites*, *Lundbladispora*, *Vitreisporites*, *Callialasporites*, and *Cingulatisporites*.

## TAXONOMY

### ***Baculatisporites*** Pflug & Thomson in Thomson & Pflug 1953

Type. *Baculatisporites primarius* (Wolff) Thomson & Pflug 1953

Remarks. Pflug & Thomson in Thomson & Pflug (March, 1953) published the genus *Baculatisporites* with the following diagnosis: Trilete miospores, amb subcircular, trilete mark long, reaching equator, exine ornamentation with numerous ±cylindrical bacula, usually with a straight tip and fairly widely spaced, bacula in type section ca. 3 µm. Later in the same year, Couper proposed *Osmundacidites* (Type: *O. wellmanii*), which is similar to *Baculatisporites* and therefore Krutzsch (1959) transferred *Osmundacidites wellmanii* to *Baculatisporites.* Krutzsch (1967) studied spores of all recent species of *Osmunda* and proposed an enlarged diagnosis for *Baculatisporites* and placed *Osmundacidites* under its synonymy. In the present paper we follow the diagnosis proposed by Krutzsch (1967) and consider *Osmundacidites* a junior synonym of *Baculatisporites.*

### ***Baculatisporites cephalus*** (Saxena) **comb. nov.**

Basionym. *Osmundacidites cephalus* Saxena 1978, p. 450, pl. 2, figs 20, 21.

### ***Baculatisporites microgranifer*** (Sah & Jain) **comb. nov.**

Basionym. *Osmundacidites microgranifer* Sah & Jain 1965, p. 271, pl. 2, fig. 41.

### ***Hammenisporis*** **nom. nov.**

Basionym. *Striatriletes* van der Hammen 1956, p. 115, fig. 5, non Potonié 1956.

Type. *Hammenisporis susannae* (van der Hammen) comb. nov.

Etymology. The genus is named in honour of Dr. T. van der Hammen, the author of its basionym.

Original diagnosis (van der Hammen 1956, p. 115). Trilete spores, sculpture type striate.

Emended diagnosis. Spores triangular to subcircular in polar view, medium to large sized. Trilete mark generally distinct, sometimes indistinct, rays equal, uniformly broad, extending from half to three-fourths radius, commisssure distinct. Exine striate, striations 3–7, running ±parallel to each other but never coalesce, generally arise at inter-radial area or at ray ends and continue on respective distal side as successive concentric rings, striations sparsely or closely placed, generally psilate, sometimes variously ornamented and branched.

Remarks. Van der Hammen (1954) proposed *Striatriletes* as a subgenus of genus *Triletes* without any illustration and without assigning any species to it. *Striatriletes* was therefore nomen nudum in 1954. Potonié (September 1956) published a diagnosis and illustration and designated *Striatriletes sulcatus* (Dijkstra) Potonié 1956 as type of the genus *Striatriletes.* He, therefore, was the first to validly publish the genus *Striatriletes.* Later in the same year, Van der Hammen (1956) validly published another, distinctly different, genus with the same name (*Striatriletes*; type: *S. susannae*). *Striatriletes* van der Hammen 1956 is therefore illegitimate, being a junior homonym of *Striatriletes* Potonié 1956. A new generic name, *Hammenisporis*, is therefore proposed here to replace *Striatriletes* van der Hammen (1956), non Potonié (1956).

Van der Hammen (1956) mentioned that the genus resembles the extant spores of *Anemia* in some features, but also did not rule out its relationship to the spores of Parkeriaceae. Later he stressed on its stratigraphic importance because the genus, in Colombia and neighbouring countries, first occurs in Early

Oligocene and shows its maximum development in Middle and Late Oligocene (van der Hammen 1957).

Potonié (1960) mentioned that *Striatriletes* van der Hammen is a junior synonym of the genus *Cicatricosisporites*. We, however, do not agree with this view. The genus *Striatriletes* (now *Hammenisporis*) accommodates spores of parkeriaceous affinity whereas *Cicatricosisporites* accommodates spores of schizaeaceous affinity. *Cicatricosisporites* (type: *C. dorogensis* Potonié & Gelletich 1933) was proposed by Potonié and Gelletich (1933) from the Eocene brown coal of Dorog, near Budapest, Hungary and accommodates fossil spores of schizaeaceous ferns, viz. *Ruffordia goepperti* (Dunk) Seward and *Pelletiaria valdensis* Seward. This genus is not restricted to Tertiary but also occurs in abundance in the Mesozoic sediments throughout the world.

The extant spores of *Anemia* and *Mohria* have been investigated by Nayar (1969). He also studied the spores of *Ceratopteris* in detail. It has been observed that in all the species of *Anemia* and *Mohria*, there are two distinct sets of striations on proximal and distal surfaces. One set of striations does not continue on the other side but remains confined within the respective inter-radial area. The striations may, sometimes, coalesce with each other to form triangular area. The succeeding striations also coalesce on both the sides forming successive concentric triangles. The spores of *Mohria caffrorum* do not differ much from that of *Anemia.* They also have distinct sets of striations for proximal and distal sides. They can, however, be distinguished from *Anemia* by the presence of paired striations. Each pair is separated from the other by a narrow depression simulating a slit-like appearance while the adjacent pairs have more space in between.

The spores of *Ceratopteris thalictroides*, *C. cornuta*, and *C. siliqulosa* of Parkeriaceae are also striate. However, in these species striations arise on the proximal side at the inter-radial area or at least at ray ends and proceed on the distal side forming more or less successive concentric rings. There is no separate set of striations for the proximal and distal surfaces. On the contrary, same sets are present on both surfaces at each inter-radial area producing thereby three sets of striations (Kar 1979).

### ***Hammenisporis aidaensis*** (Kar) **comb. nov.**

Pl. 1, fig. 16

B a s i o n y m. *Striatriletes aidaensis* Kar 1985, p. 145, pl. 33, figs 8, 9.

### ***Hammenisporis assamensis*** **sp. nov.**

Pl. 3, figs 1, 2

H o l o t y p e. Pl. 3, fig. 1, slide No 13546/ 9, Birbal Sahni Institute of Palaeobotany, Lucknow, India.

T y p e l o c a l i t y. 10 km south-east of Umrongso, off Umrongso-Haflong Road, North Cachar Hills, Assam, India.

T y p e h o r i z o n. Kopili Formation (Late Eocene).

E t y m o l o g y. The specific epithet refers to the Assam State in north-eastern India, where the type locality of the species is situated.

D i a g n o s i s. Spores triangular-subtriangular, 34–58 μm × 40–60 μm, apices rounded. Trilete, rays extending two-third to entire radius. Exine striate, striations smooth, 3–4 at each interapical margin, originate at ray ends, extend on distal side to form concentric rings. Interstriate exine psilate.

C o m p a r i s o n. The present new species differs from *Hammenisporis microverrucosus* in lacking microverrrucae on the striations. It also differs from all other species of *Hammenisporis* by its smaller size.

### ***Hammenisporis microverrucosus*** (Kar & Saxena) **comb. nov.**

Pl. 1, fig. 10

B a s i o n y m. *Striatriletes microverrucosus* Kar & Saxena 1981, p. 109, pl. 1, figs 19, 20.

### ***Hammenisporis multicostatus*** (Kar & Saxena) **comb. nov.**

B a s i o n y m. *Striatriletes multicostatus* Kar & Saxena 1981, p. 108, pl. 1, figs 15, 18.

### ***Hammenisporis paucicostatus*** (Kar) **comb. nov.**

Pl. 2, fig. 8

B a s i o n y m. *Striatriletes paucicostatus* Kar 1985, pp. 143, 145, pl. 33, fig. 10.

### ***Hammenisporis susannae***
### (van der Hammen) **comb. nov.**

Pl. 1, fig. 15

Basionym. *Striatriletes susannae* van der Hammen 1956, p. 115, fig. 5.

### ***Laevigatosporites*** Ibrahim 1933

Type. *Laevigatosporites vulgaris* (Ibrahim in Potonié et al. 1932) Ibrahim 1933

Remarks. Ibrahim (1933) proposed the genus *Laevigatosporites* with the following diagnosis: "Spores with a dehiscence mark and more or less smooth surface." The genus occurs subjugated under the Monoletes: "Bean-shaped spores with a more or less straightened elongate dehiscence mark." Ibrahim (l. c.) selected *Sporites vulgaris* Ibrahim in Potonié et al. (1932), recombined with *Laevigatosporites*, as the type of the genus. Schopf et al. (1944) emended the diagnosis of *Laevigatosporites* and considered *Phaseolites*, *Punctatosporites*, and *Reticulatosporites* as its junior synonyms. Thiergart (1938) proposed *Polypodiaceaesporites* [Type: *Polypodiaceaesporites haardtii* (Potonié & Venitz) Potonié (= *Sporites haardtii* Potonié & Venitz)] and described two species under this generic name. However, he did not give a separate diagnosis required for valid publication. The genus was therefore not validly published (Thiergart 1938) for lack of generic diagnosis. Potonié (1956) published the following diagnosis for *Polypodiaceaesporites*: "Monolete spores, of reniform shape; exine stiff, smooth, may be structured (not sculptured); monolete mark simple, usually shorter than the spore itself; without a perispore". Thomson and Pflug (1953) recombined *Sporites haardtii* (basionym of the type of *Polypodiaceaesporites*) with *Laevigatosporites*. Although this new combination is not validly published for lack of a full and direct reference to its basionym (ICBN: Art. 33.4, McNeill et al. 2006), it clearly indicates authors' intention of transferring the type of *Polypodiaceaesporites* to *Laevigatosporites*.

The above discussion makes it clear that the two genera, *Polypodiaceaesporites* Thiergart (1938) and *Laevigatosporites* Ibrahim (1933), show overall resemblance and cannot be differentiated from each other. Moreover, transfer of the type of *Polypodiaceaesporites* to *Laevigatosporites* by Thomson & Pflug (1953) confirms that the two genera are synonymous. Since *Laevigatosporites* has nomenclatural priority over *Polypodiaceaesporites*, it is being retained here. Srivastava (1971) also considered *Polypodiaceaesporites* Thiergart (1938) as a junior synonym of *Laevigatosporites* Ibrahim (1933). The following species of the present assemblage, originally described in *Polypodiaceaesporites* are therefore transferred to *Laevigatosporites*.

### ***Laevigatosporites chatterjii*** (Kar) **comb. nov.**

Basionym. *Polypodiaceaesporites chatterjii* Kar 1979, p. 25, pl. 2, figs 18, 19.

### ***Laevigatosporites indicus*** (Singh et al.) **comb. nov.**

Basionym. *Polypodiaceaesporites indicus* Singh et al.1985, p. 48, pl. 2, figs 19, 22, 24.

### ***Laevigatosporites intrapunctatus*** (Kar & Jain) **comb. nov.**

Basionym. *Polypodiaceaesporites intrapunctatus* Kar & Jain 1981, p. 116, pl. 2, figs 42, 44, pl. 4, fig. 127.

### ***Laevigatosporites levis*** (Sah) **comb. nov.**

Basionym. *Polypodiaceaesporites levis* Sah 1967, p. 35, pl. 3, figs 13, 15.

### ***Laevigatosporites punctatus*** (Singh et al.) **comb. nov.**

Basionym. *Polypodiaceaesporites punctatus* Singh et al. 1985, p. 48, pl. 2, figs 23, 25, 34.

### ***Laevigatosporites strictus*** (Kar & Saxena) **comb. nov.**

Basionym. *Polypodiaceaesporites strictus* Kar & Saxena 1981, p. 110, pl. 2, figs 30, 31.

### ***Polypodiisporonites*** Potonié 1931

Type. *Polypodiisporonites favus* Potonié 1931.

Remarks. *Polypodiisporites* Potonié (1931) in Potonié & Gelletich (1933) ex Potonié (1956) is an obligate junior synonym of *Polypodiisporonites* Potonié (1931) as both the genera have same type species. The following species described under *Polypodiisporites* are therefore transferred to *Polypodiisporonites.*

***Polypodiisporonites formosus***
(Salujha et al.) **comb. nov.**

Basionym. *Polypodiisporites formosus* Salujha et al. 1972, p. 275, pl 2, figs 39, 40.

***Polypodiisporonites minor*** (Sah)
**comb. nov.**

Basionym. *Polypodiisporites minor* Sah 1967, p. 40, pl. 3, fig. 25.

***Polypodiisporonites ornatus*** (Sah)
**comb. nov.**
Pl. 1, fig. 14

Basionym. *Polypodiisporites ornatus* Sah 1967, p. 37, pl. 3, figs 19, 20, 22.

***Polypodiisporonites speciosus*** (Sah)
**comb. nov.**

Basionym. *Polypodiisporites speciosus* Sah 1967, p. 39, pl. 3, figs 23, 24.

***Polypodiisporonites splendidus***
(Salujha et al.) **comb. nov.**

Basionym. *Polypodiisporites splendidus* Salujha et al. 1972, p. 275, pl 2, figs 41, 42.

***Polypodiisporonites tuberculensis***
(Baksi) **comb. nov.**
Pl. 1, fig. 4

Basionym. *Polypodiaceaesporites tuberculensis* Baksi 1962, p. 19, pl. 3, fig. 40.

Synonym. *Polypodiisporites tuberculensis* (Baksi) Rao & Singh 1987, p. 277, pl. 2, fig. 22.

***Polypodiisporonites turbinatus*** (Sah)
**comb. nov.**
Pl. 2, fig. 10

Basionym. *Polypodiisporites turbinatus* Sah 1967, p. 38, pl. 3, fig. 21.

***Monocolpopollenites*** Pflug & Thomson
in Thomson & Pflug 1953

Type. *Monocolpopollenites tranquillus* (Potonié) Thomson & Pflug 1953

Remarks. *Palmaepollenites* Potonié 1951 ex Potonié 1958 is an obligate junior synonym of *Monocolpopollenites* Pflug & Thomson in Thomson & Pflug 1953, because both the genera have same type species.

***Monocolpopollenites kutchensis***
(Venkatachala & Kar) **comb. nov.**

Basionym. *Palmaepollenites kutchensis* Venkatachala & Kar 1969, p. 159, pl. 1, figs 9, 10.

***Monocolpopollenites nadhamunii***
(Venkatachala & Kar) **comb. nov.**

Basionym. *Palmaepollenites nadhamunii* Venkatachala & Kar 1969, p. 159, pl. 1, figs 11, 12.

## QUALITATIVE ANALYSIS

The palynoassemblage recorded here contains 50 genera and 83 species of palynomorphs. Of these, 1 genus and 1 species belong to dinoflagellate cysts, 9 genera and 9 species to fungal remains, 1 genus and one species to bryophytic spore, 16 genera and 44 species to pteridophytic spores, 4 genera and 5 species to gymnospermous pollen and 19 genera and 23 species to angiospermous pollen. In addition, 7 genera and 7 species of reworked Permian, Triassic and Early Cretaceous sporomorphs have also been recovered. The botanical affinities of the recovered palynotaxa and the present day distribution of the families represented are given in Table 2.

## QUANTITATIVE ANALYSIS

The assemblage is dominated by pteridophytic spores (50.1%) followed by angiospermous pollen (29.4%). The average representation of other groups is as follows. Fungal remains: 4.1%; gymnospermous pollen: 3.0%; dinoflagellate cysts: 3.0%; palynomorphs of unknown affinity: 2.1%; and bryophytic spores:

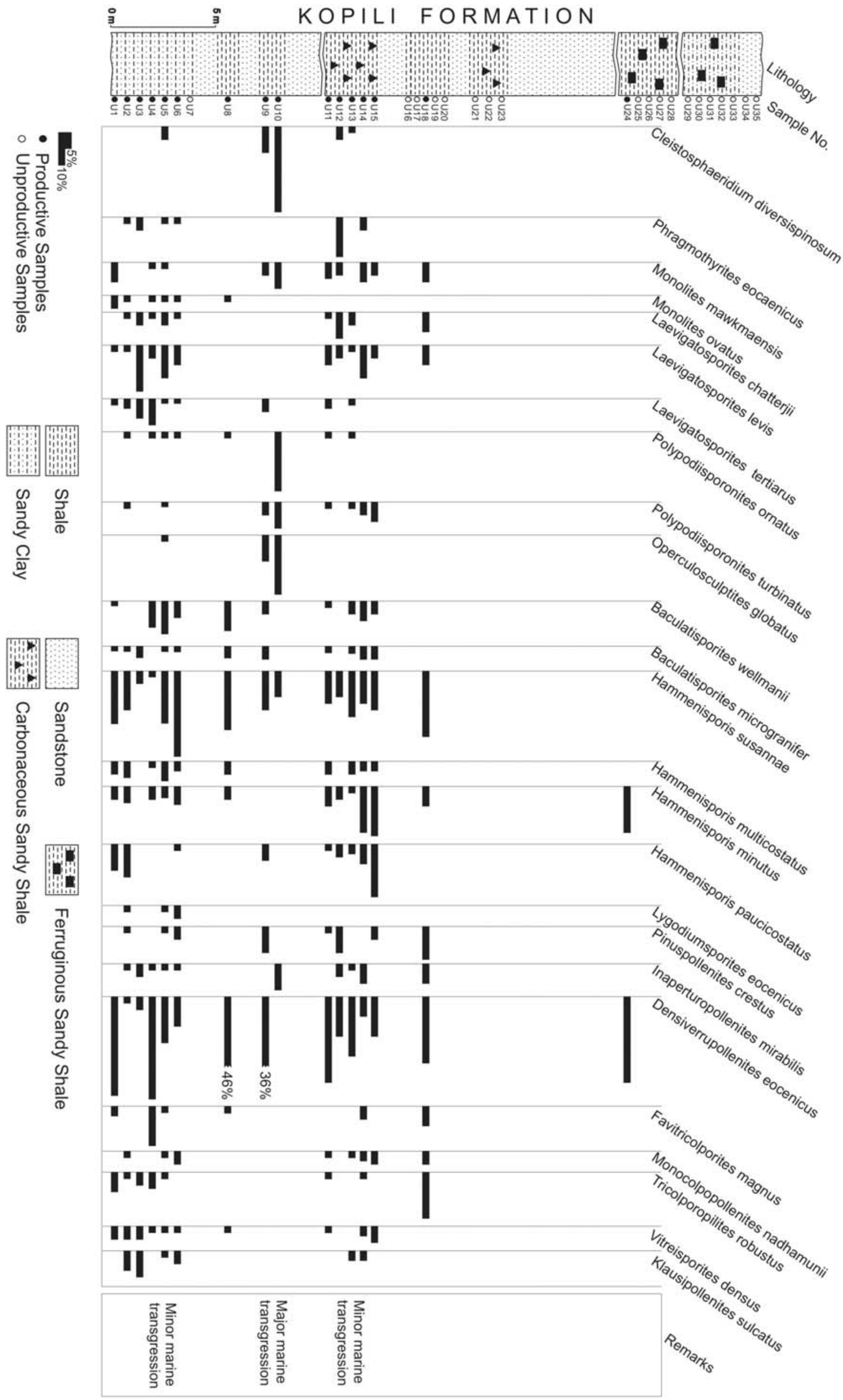


**Fig. 3.** Quantitative representation of palynomorphs in the Kopili Formation exposed near Umrongso, North Cachar Hills, Assam

2.0%. Reworked palynomorphs constitute 6.3% of the assemblage.

The dominant genera of the assemblage are *Hammenisporis* (22%), *Densiverrupollenites* (17.4%), *Laevigatosporites* (8.1%) and *Polypodiisporonites* (4.1%). The dominant species of the assemblage are *Densiverrupollenites eocenicus* (17.4%), *Hammenisporis susannae* (11.8%), *H. assamensis* (5%), *Laevigatosporites levis* (4%), *Monolites mawkmaensis* (2.8%), *Pinuspollenites crestus* (2.4%), and *Hammenisporis multicostatus* (2.3%).

The percentage frequencies of selected palynotaxa, in each sample, are given in Figure 3 which indicates that the dinoflagellate cysts, *Phragmothyrites eocaenicus*, and bryophytic spore *Operculosculptites globatus* show maximum development in the lower part of the profile (sample Nos 9–12). Pteridophytic spores are present throughout the sequence with predominance of psilate and verrucate monolete genera (*Laevigatosporites* and *Polypodiisporonites*) and striate trilete genus *Hammenisporis*. Gymnospermous pollen are also well represented with *Pinuspollenites crestus* showing increase in frequency from the lower part and reaching maximum in the middle part of the sequence (sample No 18). Angiospermous pollen are also well represented throughout the profile with *Densiverrupollenites eocenicus* being the most dominant species (17.4%). Two species, viz. *Lygodiumsporites eocenicus* and *Operculosculptites globatus*, have a restricted occurrence and are present in the lower part of the profile (from sample Nos 2 and 10) only. Reworked Gondwana palynomorphs, viz. *Vitreisporites densus* and *Klausipollenites sulcatus* are present in the lower and lower-middle parts of the profile only. The assemblage does not show sharp changes, except for the recovery of dinoflagellate cysts at three levels suggesting marine transgressions, the middle one being the major. Minor fluctuations in the palynofloral elements may be attributed to ecological-facies variations.

Of the three marine transgressions, marked in the studied profile, the first is a minor one and is indicated in the lower part of the profile (sample No 5). The second marine transgression, the major one, is marked in the middle part of the profile (sample Nos 9, 10) with maximum representation of dinoflagellate cysts. During this period there was a marked decline in the percentage of fresh water elements, e.g. *Hammenisporis*, and absence of coastal forms like *Monocolpopollenites.* The third (minor) marine transgression is marked by the moderate representation of dinoflagellate cysts in sample Nos 12 and 13. This was followed by regressive phase which is evidenced by the increase of coastal, fresh water and inland forms.

## PALAEOCLIMATE AND ENVIRONMENT OF DEPOSITION

Most of the families represented in the assemblage, viz. Calobryaceae, Cyatheaceae, Parkeriaceae, Schizaeaceae, Arecaceae, Bombacaceae, Myricaceae, Pellicieriaceae, Caesalpiniaceae, Alangiaceae, Anacardiaceae, and microthyriaceous fungi have their present day distribution restricted to tropical-subtropical regions. Pinaceae grows in temperate region and appears to be derived from the upland areas. This suggests that the topographically elevated areas were present in the north and north-east, not far away from the basin of deposition. Other families are cosmopolitan in distribution. *Tricolporopollis*, referable to Bombacaceae, is a tropical rain forest element which indicated that the area enjoyed heavy precipitation during Late Eocene. Abundance of fern spores is suggestive of warm-humid climate. This is further supported by the occurrence of fungal remains.

The palynoflora can be divided into various ecological groups, viz. montane, coastal, lowland or inland, fresh water and marine. An analysis of the palynoflora reveals that low land and fresh water elements are dominant over the other groups. The following elements have been distinguished:

1. Montane: *Pinuspollenites crestus.*

2. Coastal: *Spinizonocolpites echinatus*, *Pellicieroipollis langenheimii*, *Monocolpopollenites nadhamunii*, *M. kutchensis*, *Palmidites plicatus*, *Proxapertites assamicus*, *P. microreticulatus.*

3. Lowland or inland: *Tricolporopollis matanomadhensis*, *Margocolporites sahnii*, *M. complexum*, *Monolites mawkmaensis*, *Laevigatosporites indicus*, *L. chatterjii*, *L. punctatus*, *L. intrapunctatus*, *L. levis*, *L. strictus*, *L. tertiarus*, *Polypodiisporonites favus*, *P. formosus*, *P. mawkmaensis*, *P. minor*, *P. ornatus*, *P. repandus*, *P. speciosus*, *P. splendidus*, *P. tuber-

*culensis*, *P. turbinatus*, *Pilamonoletes excellensus*, *Lygodiumsporites lakiensis*, *L. eocenicus*, *L. pachyexinus*, *Schizaeoisporites phaseolus*, *Intrapunctisporis apunctis*, *I. intrapunctis*, *Punctatisporites sarangwaraensis*, *Corrugatisporites formosus*, *Cyathidites australis*, *C. minor*, *Todisporites major*, *T. minor*, *Baculatisporites wellmanii*, *B. cephalus*, and *B. microgranifer*.

4. Fresh water: *Hammenisporis aidaensis*, *H. assamensis*, *H. microverrucosus*, *H. multicostatus*, *H. paucicostatus*, and *H. susannae.*

5. Marine: This group includes dinoflagellate cysts.

Presence of *Lygodiumsporites* and *Hammenisporis* is indicative of fresh water swamps and ponds near the site of deposition. Abundance of *Hammenisporis*, referable to *Ceratopteris* (Parkeriaceae), indicates presence of fresh water ponds in close proximity. Coastal elements, viz. *Pelliciera* (*Pellicieroipollis*), *Nypa* (*Spinizonocolpites*) and other arecaceous plants (palms) constituted coastal vegetation. Ferns and lowland flora thrived behind the coastal plants and their spore-pollen were carried to the depositional site by water channels. The assemblage is dominated by fresh water swamp elements. Pollen grains belonging to Arecaceae (*Monocolpopollenites*, *Palmidites*) occur near the sea coast and are shore line elements. The assemblage from the lower part of the section shows presence of dinoflagellate cysts and pollen having affinity with the family Arecaceae. This indicates that the deposition of these sediments took place under coastal environment. Occurrence of dinoflagellate cysts at certain levels indicates three marine transgressions, of which the middle transgression was a major one. Absence of dinoflagellate cysts in the upper part of the section is suggestive of diminishing marine influence during this phase of deposition.

It may therefore be inferred that the overall vegetation pattern indicates a tropical-subtropical, warm-humid climate during the sedimentation of Kopili Formation in the present area. The sedimentation took place in a coastal marine environment having fresh water connections with swamps and ponds nearby. The coast was bordered by mangroves and other coastal elements.

## REWORKED PALYNOMORPHS

The term 'reworked' or 'recycled' is said of a sediment, fossil rock fragment or other geologic material, that has been removed or displaced by natural agents, e.g. water, wind, etc., from place of its origin and incorporated in recognizable form in a younger formation. In palynology, reworking is more prevalent than in other fields of palaenotology because the fossils involved are many times smaller than the others and are generally transported while enclosed in small particles of sediments. The present study records the occurrence of Permian (*Cuneatisporites rarus*, *Indotriradites sparsus*), Triassic (*Klausipollenites sulcatus*, *Lundbladispora* sp., *Vitreisporites densus*), and Early Cretaceous palynomorphs (*Callialasporites segmentatus*, *Cingulatisporites formosus*).

The reworking of palynotaxa in the present study can be related with the second upheaval of the Himalayas that took place at the end of the Eocene and movements associated with this upheaval continued up to the Early Oligocene. The Gondwana sediments would also have been uplifted and were exposed and were then subjected to various degrees of erosion, subsequently to deposit again with the Tertiary sediments. Presently a small patch of Lower Gondwana deposits is found at Singrimari, West Garo Hills District, Meghalaya, in the west to the present area of investigation. This could possibly be the source area for the Permian palynomorphs. The present study also records Early Cretaceous palynomorphs, viz. *Callialasporites segmentatus* and *Cingulatisporites formosus.* Occurrence of Triassic and Early Cretaceous palynomorphs in the present assemblage indicates existence of sediments of these ages which might have been totally eroded and redeposited or may be present in the subsurface.

## PALYNOFLORAL COMPARISON

A comparison of the present palynoflora with the other Late Eocene palynofloras from Garo Hills, Meghalaya (Baksi 1962, 1974), Jaintia Hills, Meghalaya (Sein & Sah 1974, Tripathi & Singh 1984a, b, 1985, Singh & Tripathi 1987, Tripathi 1989, Trivedi 1985, 1987) and Assam (Sah & Dutta 1968, Kar et al. 1994, Trivedi & Saxena 2000) is given in Table 3.

**Table 3.** Comparison of the palynofloral assemblages from different profiles of the Kopili Formation in north-eastern India; present (+), absent (–)

| Name of palynotaxa | Garo Hills, Meghalaya[1] | Jaintia Hills, Meghalaya[2] | Assam[3] | North Cachar Hills, Assam[4] | Present study |
|---|---|---|---|---|---|
| *Acolporipites spinulosa* | + | – | – | – | – |
| *Araucariacites australis* | – | + | – | + | + |
| *Baculatisporites cephalus* | – | + | + | – | + |
| *Baculatisporites microgranifer* | – | – | – | – | + |
| *Baculatisporites wellmanii* | – | – | – | – | + |
| *Cleistosphaeridium diversispinosum* | – | + | – | + | + |
| *Corrugatisporites formosus* | – | + | – | – | + |
| *Cyathidites australis* | – | + | – | + | + |
| *Cyathidites minor* | – | + | + | + | + |
| *Densiverrupollenites eocenicus* | – | + | – | + | + |
| *Dermatobrevicolporites dermatus* | – | + | – | – | + |
| *Dicolpopollis proprius* | – | – | – | – | + |
| *Favitricolporites magnus* | – | + | + | – | + |
| *Foveosporites triangulus* | – | – | – | – | + |
| *Hammenisporis aidaensis* | – | + | – | – | + |
| *Hammenisporis assamensis* | – | – | – | – | + |
| *Hammenisporis microverrucosus* | – | – | – | – | + |
| *Hammenisporis multicostatus* | – | + | – | + | + |
| *Hammenisporis paucicostatus* | – | + | – | – | + |
| *Hammenisporis susannae* | – | + | + | + | + |
| *Inaperturopollenites mirabilis* | – | – | – | – | + |
| *Inaperturopollenites punctatus* | – | – | – | – | + |
| *Intrapunctisporis apunctis* | – | – | – | – | + |
| *Intrapunctisporis intrapunctis* | – | + | – | + | + |
| *Laevigatosporites chatterjii* | – | + | – | – | + |
| *Laevigatosporites indicus* | – | – | – | – | + |
| *Laevigatosporites intrapunctatus* | – | – | – | – | + |
| *Laevigatosporites kopilia* | + | – | – | – | – |
| *Laevigatosporites levis* | – | – | – | – | + |
| *Laevigatosporites punctatus* | – | – | – | – | + |
| *Laevigatosporites strictus* | – | – | – | – | + |
| *Laevigatosporites tertiarus* | – | + | + | + | + |
| *Lycopodiumsporites assamicus* | – | + | – | – | + |
| *Lygodiumsporites eocenicus* | – | + | + | – | + |
| *Lygodiumsporites lakiensis* | – | – | – | + | + |
| *Lygodiumsporites pachyexinus* | – | – | – | – | + |
| *Margocolporites complexum* | – | + | – | + | + |
| *Margocolporites sahnii* | – | + | – | + | + |
| *Monocolpopites broadcolpusi* | + | – | – | – | – |
| *Monocolpopollenites kutchensis* | – | + | + | – | + |
| *Monocolpopollenites nadhamunii* | – | + | + | + | + |
| *Monolites mawkmaensis* | – | + | + | + | + |
| *Monolites ovatus* | – | – | – | – | + |
| *Operculosculptites globatus* | – | + | – | + | + |
| *Palmidites plicatus* | – | + | – | – | + |
| *Pellicieroipollis langenheimii* | – | + | – | + | + |
| *Pilamonoletes excellensus* | – | + | – | + | + |
| *Pinuspollenites crestus* | – | + | – | + | + |
| *Podocarpidites ellipticus* | – | + | – | – | + |
| *Polyadopollenites levis* | – | – | – | – | + |
| *Polypodiisporonites favus* | – | – | – | – | + |
| *Polypodiisporonites formosus* | – | – | – | – | + |
| *Polypodiisporonites mawkmaensis* | – | + | + | + | + |
| *Polypodiisporonites minor* | – | – | – | – | + |
| *Polypodiisporonites ornatus* | – | – | – | + | + |
| *Polypodiisporonites repandus* | – | – | – | – | + |
| *Polypodiisporonites speciosus* | – | – | – | – | + |
| *Polypodiisporonites splendidus* | – | – | – | + | + |
| *Polypodiisporonites tuberculensis* | – | – | – | – | + |
| *Polypodiisporonites turbinatus* | – | – | – | – | + |
| *Proxapertites assamicus* | – | + | + | – | + |

**Table 3.** Continued

| Name of palynotaxa | Garo Hills, Meghalaya[1] | Jaintia Hills, Meghalaya[2] | Assam[3] | North Cachar Hills, Assam[4] | Present study |
|---|---|---|---|---|---|
| *Proxapertites microreticulatus* | – | – | – | – | + |
| *Psiloschizosporis psilatus* | – | + | – | – | + |
| *Punctatisporites sarangwaraensis* | – | – | – | – | + |
| *Retitricolpites crassireticulatus* | – | – | – | – | + |
| *Rhoipites nitidus* | – | + | + | – | + |
| *Schizaeoisporites phaseolus* | – | – | – | – | + |
| *Simsangia trispinosa* | + | – | – | – | – |
| *Spinizonocolpites echinatus* | – | + | – | + | + |
| *Todisporites major* | – | + | – | + | + |
| *Todisporites minor* | – | – | – | + | + |
| *Tricolpites microreticulatus* | – | + | – | + | + |
| *Tricolpites minutus* | – | – | – | – | + |
| *Tricolporopilites robustus* | – | – | – | – | + |
| *Tricolporopollis matanomadhensis* | – | + | – | + | + |
| *Triporopollenites minutus* | – | – | – | – | + |
| *Verrucolporites verrucus* | – | – | – | – | + |
| *Verrutriletes grandis* | – | – | – | – | + |

[1] Baksi (1962, 1974); [2] Sein & Sah (1974), Tripathi & Singh (1984a, b, 1985), Singh & Tripathi (1987), Tripathi (1989), Trivedi (1985, 1987); [3] Sah & Dutta (1968), Kar et al. (1994); [4] Trivedi & Saxena (2000)

The present palynoassemblage does not compare well with the assemblage recovered by Baksi (1962, 1974) from the Kopili Formation exposed along Simsang River Section, Garo Hills, Meghalaya, because it is poor in palynomorphs. The palynoassemblage recovered from the Kopili Formation by Sah and Dutta (1968) and Kar et al. (1994) have some sporomorphs common with the present assemblage but is not closely comparable. Salujha et al. (1972, 1974) studied the Palaeogene palynoassemblages from Garo, Khasi and Jaintia Hills, Meghalaya but did not list the palynomorphs formation-wise; hence its comparison with the present assemblage could not be possible.

Dutta and Jain (1980) recorded mostly dinoflagellete cysts from the Kopili Formation in the area around Lumshnong, Jaintia Hills, Meghalaya with *Homotryblium plectilum* as the most dominant taxon. However, the present assemblage is not rich in dinoflagellate cysts.

The present assemblage is well comparable with the palynoassemblages recovered from the Kopili Formation of Jaintia Hills, Meghalaya (Sein & Sah 1974, Tripathi & Singh 1984a, b, 1985, Singh & Tripathi 1987, Tripathi 1989). However, the present assemblage is very closely comparable with the palynoassemblages recorded by Trivedi (1985, 1987) from the Kopili Formation of Jowai-Badarpur Road, Jaintia Hills, Meghalaya and by Trivedi and Saxena (2000) from the Kopili Formation of North Cachar Hills, Assam.

## AGE OF THE KOPILI FORMATION

On the basis of animal fossil assemblage, the Kopili Formation has been dated as Late Eocene by Nagappa (1959), Samanta (1971), Mohan (1979), Mohan and Pandey (1973), and others.

Samanta (1971) recovered a rich faunal assemblage from the Kopili Formation, especially pelecypods, gastropods and foraminifers. Of these, foraminifers are the most abundant. Larger and smaller foraminifera are almost equally represented. According to Samanta (op. cit.), *Alveolina*, *Assilina*, *Dictyoconoides*, and large *Nummulites*, which hold considerable significance in the biostratigraphy of the Late Palaeocene to Middle Eocene beds, are totally absent from the Late Eocene. The morphologically distinct genus *Pellatispira* makes its appearance in the Late Eocene, accompanied by abundant small striate species of *Nummulites* and large, highly evolved discocyclines. There is a reduction in the number of larger foraminiferal genera in the Late Eocene. The change is gradual. Samanta (1971) opined that the upper part of the Kopili Formation is apparently devoid of foraminifera and the lower part of the Kopili Formation is Late Eocene in age. The upper part is rich in microfloral assemblage which also points towards the Late Eocene age.

On the basis of recovered palynoflora, Trivedi (1987) assigned Late Eocene age to the Kopili Formation. Since the present assemblage shows close resemblance to the one earlier recorded by Trivedi (1987), a Late Eocene age is suggested for the present studied sediments too. A similar age was assigned to the Kopili Formation by Sein and Sah (1974) and Tripathi and Singh (1984b) on the basis of recovered palynoflora.

The occurrence of *Margocolporites sahnii*, *M. complexum*, *Densiverrupollenites eocenicus*, *Tricolporopollis matanomadhensis*, *Rhoipites nitidus*, *Hammenisporis susannae*, *Monolites mawkmaensis*, *Polypodiisporonites splendidus*, *P. speciosus Pinuspollenites crestus*, and *Podocarpidites ellipticus* are indicative of Late Eocene age for the Kopili Formation.

*Hammenisporis* is very common in Oligocene and Miocene. Although, in the Kutch Basin it occurs in the upper part of the Middle Eocene sediments, but in Assam-Meghalaya region it starts occurring in the Kopili Formation (Late Eocene). The first appearance of bisaccate pollen also points towards the beginning of Late Eocene.

## CONCLUSIONS

1. The assemblage is dominated by pteridophytic spores (average 50.1%).

2. The overall vegetation indicates a tropical-subtropical, warm-humid climate with heavy precipitation during the sedimentation of the Kopili Formation in the present area.

3. The deposition of the Kopili Formation took place in a coastal marine environment having fresh water connections with swamps and ponds nearby. The coast was bordered by mangroves and other coastal elements (Arecaceae).

4. On the basis of occurrence of dinoflagellate cysts, three marine transgressions have been marked in the studied profile, of which the middle one was the major transgression.

5. The present assemblage shows homotaxiality with the Kopili assemblage recorded from the neighbouring Jowai-Badarpur Road in Jaintia Hills, Meghalaya.

6. Late Eocene age is documented for the Kopili Formation on the basis of microfloral and faunal assemblages.

7. Presence of reworked Permian, Triassic and Early Cretaceous palynotaxa indicate that the Gondwana sediments were exposed nearby and were the source rocks for the younger Kopili Formation.

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# PLATES

Plate 1

Scale bar – 25 µm

1. *Cleistosphaeridium diversispinosum* Davey et al., slide No BSIP 13538/ 8
2. *Trichothyrites setifer* (Cookson) Saxena & Misra, slide No BSIP 13539/ 11
3. *Monolites mawkmaensis* Sah & Dutta, slide No BSIP 13540/ 4
4. *Polypodiisporonites tuberculensis* (Baksi) comb. nov., slide No BSIP 13540/ 5
5. *Indotriradites sparsus* Tiwari, slide No BSIP 13541/ 10
6. *Lundbladispora* sp., slide No BSIP 13542/ 13
7. *Baculatisporites wellmanii* (Couper) Krutzsch, slide No BSIP 13543/ 9
8. *Densiverrupollenites eocenicus* Tripathi & Singh, slide No BSIP 13543/ 2
9. *Favitricolporites magnus* Sah, slide No BSIP 13543/ 4
10. *Hammenisporis microverrucosus* (Kar & Saxena) comb. nov., slide No BSIP 13544/ 4
11. *Cyathidites australis* Couper, slide No BSIP 13539/ 8
12. *Palmidites plicatus* Singh in Sah & Singh, slide No BSIP 13545/ 3
13. *Rhoipites nitidus* Sah & Dutta, slide No BSIP 13546/ 11
14. *Polypodiisporonites ornatus* (Sah) comb. nov., slide No BSIP 13541/ 2
15. *Hammenisporis susannae* (van der Hammen) comb. nov., slide No BSIP 13539/ 7
16. *Hammenisporis aidaensis* (Kar) comb. nov., slide No BSIP 13547/ 4
17. *Pinuspollenites crestus* Kar, slide No BSIP 13548/ 4
18. *Pellicieroipollis langenheimii* Sah & Kar, slide No BSIP 13549/ 2
19. *Diporicellaesporites stacyi* Elsik, slide No BSIP 13550/ 1

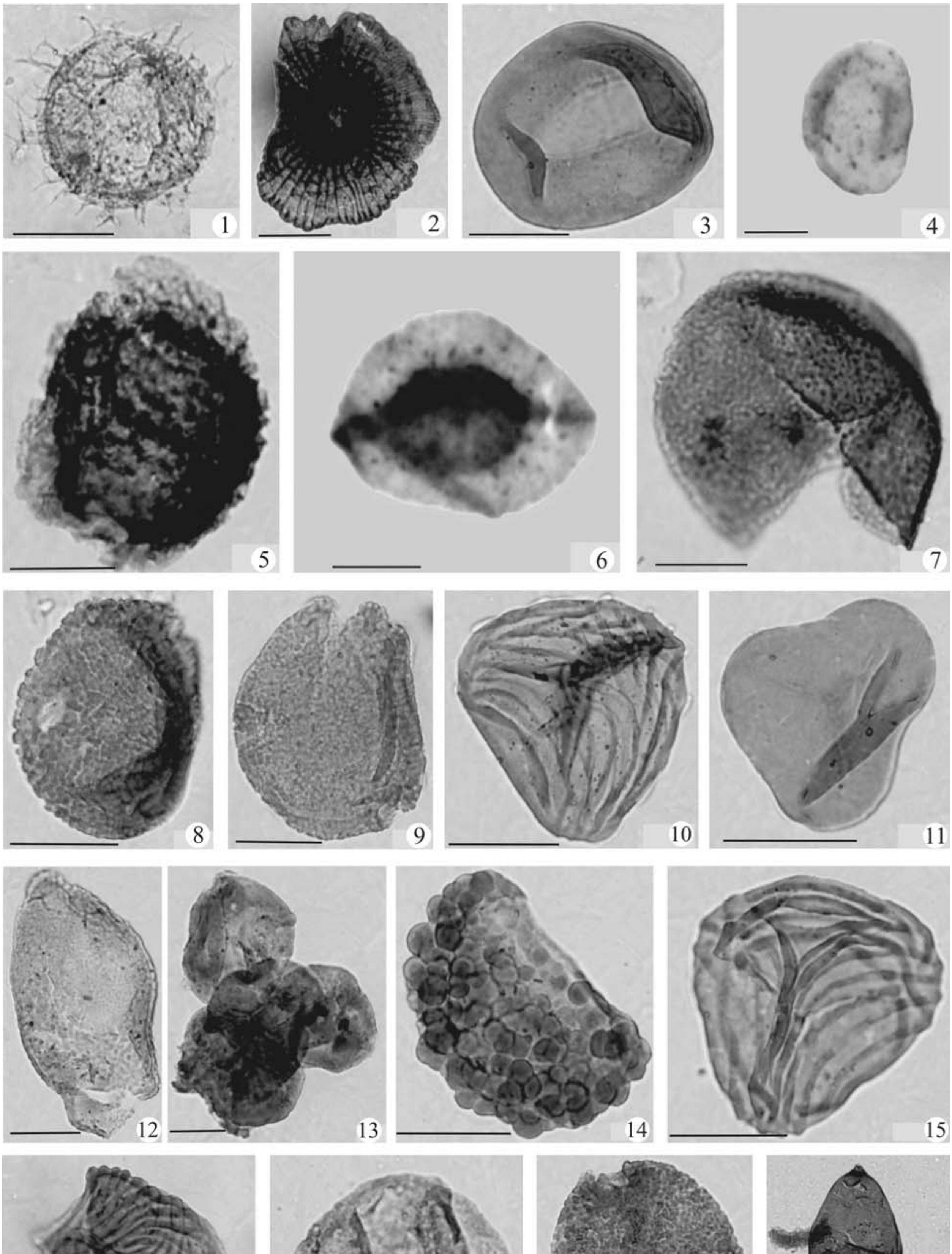
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Plate 2

Scale bar – 25 µm

1. *Palmidites plicatus* Singh in Sah & Singh, slide No BSIP 13551/ 12
2. *Retitricolpites crassireticulatus* (Dutta & Sah) Samant & Phadtare, slide No BSIP 13543/ 8
3. *Lygodiumsporites pachyexinus* Saxena, slide No BSIP 13546/ 2
4. *Schizaeoisporites phaseolus* Delcourt & Sprumont, slide No BSIP 13547/ 4
5. *Densiverrupollenites eocenicus* Tripathi & Singh, slide No BSIP 13549/ 1
6. *Dicolpopollis proprius* Salujha et al., slide No BSIP 13552/ 2
7. *Pilamonoletes excellensus* Kar, slide No BSIP 13547/ 6
8. *Hammenisporis paucicostatus* (Kar) comb. nov., slide No BSIP 13553/ 10
9. *Kutchiathyrites eccentricus* Kar, slide No BSIP 13553/ 7
10. *Polypodiisporonites turbinatus* (Sah) comb. nov., slide No BSIP 13554/ 3
11. *Laevigatosporites tertiarus* (Sah & Dutta) Saxena & Khare, slide No BSIP 13555/ 9
12. *Proxapertites microreticulatus* Jain et al., slide No BSIP 13556/ 1
13. *Inapertisporites kedvesii* Elsik, slide No BSIP 13557/ 3
14. *Lygodiumsporites lakiensis* Sah & Kar, slide No BSIP 13558/ 10
15. *Cingulatisporites formosus* Venkatachala & Sharma, slide No BSIP 13559/ 4

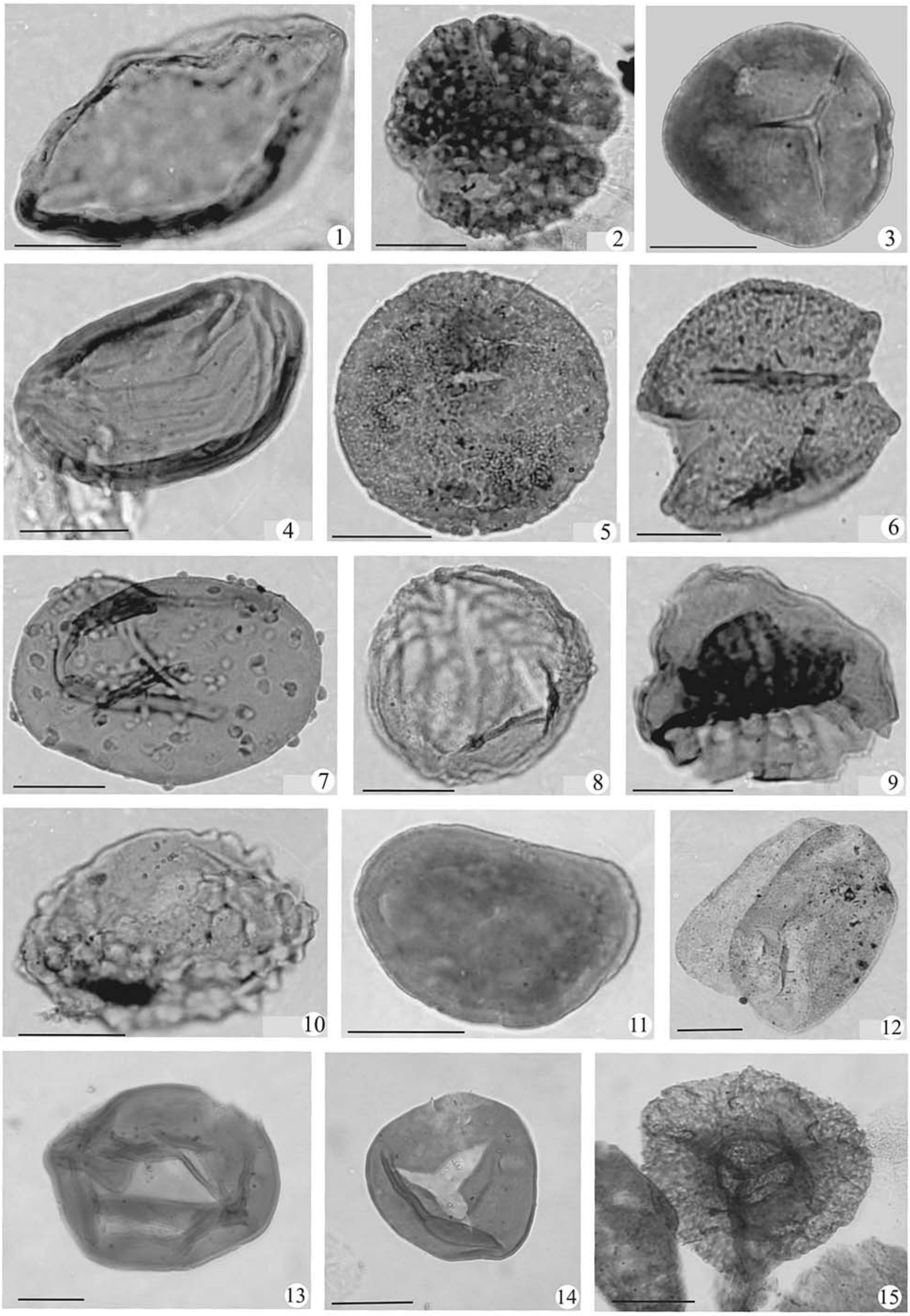
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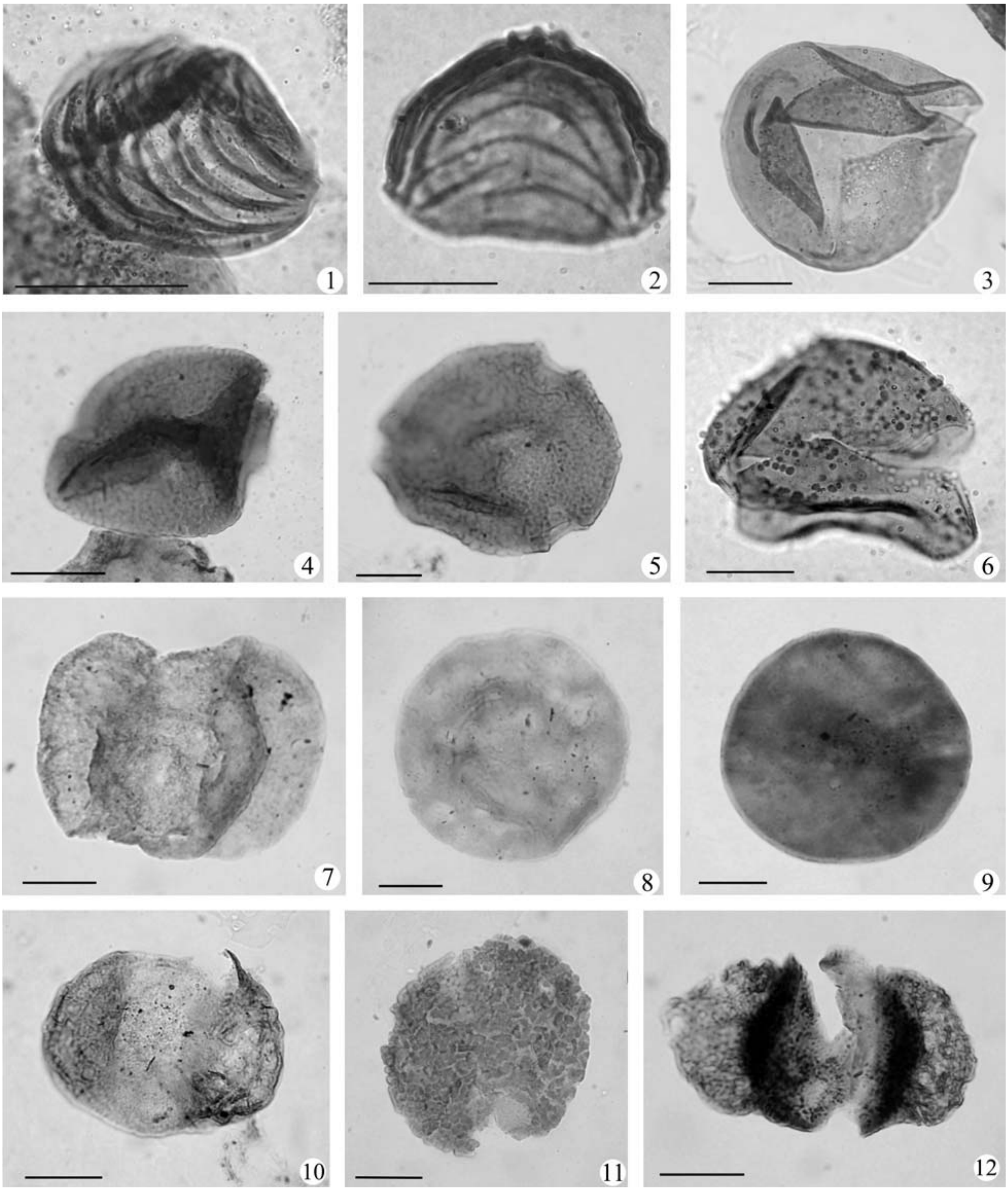
Plate 3

Scale bar – 25 μm

1. *Hammenisporis assamensis* sp. nov., slide No BSIP 13546/ 9
2. *Hammenisporis assamensis* sp. nov., slide No BSIP 13555/ 9
3. *Intrapunctisporis apunctis* Krutzsch, slide No BSIP 13560/ 3
4. *Verrutriletes grandis* Salujha et al., slide No BSIP 13546/ 4
5. *Pellicieroipollis langenheimii* Sah & Kar, slide No BSIP 13547/ 6
6. *Pilamonoletes excellensus* Kar, slide No BSIP 13540/ 3
7. *Pinuspollenites crestus* Kar, slide No BSIP 13558/ 10
8. *Araucariacites australis* Cookson ex Couper, slide No BSIP 13561/ 2
9. *Todisporites major* Couper, slide No BSIP 13556/ 2
10. *Podocarpidites ellipticus* Cookson ex Couper, slide No BSIP 13560/ 4
11. *Tricolporopilites robustus* (Kar & Saxena) Kar, slide No BSIP 13543/ 8
12. *Vitreisporites densus* Kar et al., slide No BSIP 13562/ 5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