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Palynology of the Barail Group exposed along Mariani-Changki Road, Mokokchung District, Nagaland, India and its palaeoenvironmental implications

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ABSTRACT

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Assorted palynofloral assemblages from the diversified shale samples of Barail Group of Naga Hills exposed along the Mariani-Changki road section, Mokokchung District, Nagaland have been catalogued. A total of 42 species of palynomorphs including reworked Permian bisaccate grains and dinoflagellate were identified. The palynofloral assemblage is represented by spores, pollen, acritarchs and dinoflagellates. Pteridophytic spores, gymnosperm and angiosperm pollen like *Polypodiisporonites* sp., *Meyeripollis naharkotensis, Marginipollis kutchensis, Podocarpidites classicus* are the abundantly recovered palynomorphs. Two new combinations, viz. *Polypodiisporonites oligocenicus* (S.C.D. Sah & S.K. Dutta) Saikia & Bhuyan and *Heliospermopsis immodiscus* (Salujha, Kindra & Rehman) Saikia & Bhuyan, have been proposed. The existence of palynomorphs together with dinoflagellates and spinose acritarchs suggest deltaic to shallow marine sedimentary facies in a basin margin environment. The prolific presence of coaliferous bands together with fern spores and fungal remains indicate heavy precipitation and warm humid condition during deposition of the Barail Group suggesting a tropical to subtropical climate. The palynofossil assemblage suggests Oligocene age.

Keywords: Palynology, Palaeoenvironment, Barail Group, Nagaland, India.

INTRODUCTION

Changki (Lat. 26°41' N, Long. 94°38' E) is situated in the Mokokchung District of Nagaland, Arakan-Yoma Ranges of the Indian plate. Nagaland harbours very rich biodiversity and falls within the Indo-Burma biodiversity hotspot bordering the species-rich Indian and Indo-Chinese Zoogeographic sub-region. Geological studies of the Naga Hills commenced with the attempts for locating and evaluating Tertiary coal deposits by Mallet (1876), Hayden (1910), etc. Evans (1932) carried out a systematic survey in the parts of Naga Hills. Nagappa (1959) reported two localities having sporadic occurrence of microfossils near the contact of Disang and Barail sequences. These authors have contributed on the geology of Nagaland through various publications. Also, Oil and Natural Gas Corporation (ONGC), Geological Survey of India (GSI) and the Directorate of Geology and Mining (DGM), Government of Nagaland have made few publications on the stratigraphy, structures and tectonics of Naga Hills. Very limited literature on palaeontological and palynological works from the Mokokchung area of Nagaland is available so far. The present study area is situated between the Naga Thrust and the Disang Thrust. From the Naga thrust, the topography varies from floodplains to mountainous regions. The study area

starts from Lat. 26°30'9.8" N, Long. 94°22'10.1" E, near the bridge above the Tsurang or Disai River, from where the topography changes to mountains. The area was uplifted probably due to Naga thrust. The present study has been undertaken for palynological analysis aiming to understand the nature, composition, and vertical distribution of palynomorphs within the Tertiary sediments of Changki area of Nagaland (Figure 1). Palynological study of ancient vegetation systems from the Barail Group of rocks will provide better understanding of the past ecosystem of this unique biodiversity hotspot. The micropalaeontological studies will reveal information about palaeoclimate, palaeoecology, palaeoenvironmental conditions of the area which in turn will help in the research of the present days' ecological condition of this special ecological zone.

MATERIALS AND METHODS

Unweathered samples were collected from fresh outcrops of road cuttings and coalmines along Mariani-Changki road section between Lat. 26º22' and 27º43' N and Long. 94º30' and 94º40' E. Forty samples were processed in the laboratory of the Department of Applied Geology, Dibrugarh University, and Regional Geosciences Laboratory of ONGC, Sibsagar, Assam. Standard procedure was followed to macerate the samples for the extraction of palynomorphs. In essence, each sample was treated with various acids (hydrochloric acid (HCl 40%), hydrofluoric acid (HF 40%), nitric (HNO_3 30–40%)] and alkali [potassium hydroxide (KOH) solution (10%)] to remove the irrelevant matter, carbonate, silicate, humic particles, etc. Samples were subsequently cleaned with distilled water to remove all traces of acids and alkali. Permanent slides of each sample were prepared in polyvinyl alcohol and mounted in Canada balsam. The slides were scanned under 200x, 400x and 1000x magnification using the light compound microscope for the identification, counting and photography of the recovered palynomorphs. All the materials (slides, residues, rock samples) are housed in the Palaeontological Laboratory of Applied Geology, Dibrugarh University, Dibrugarh.

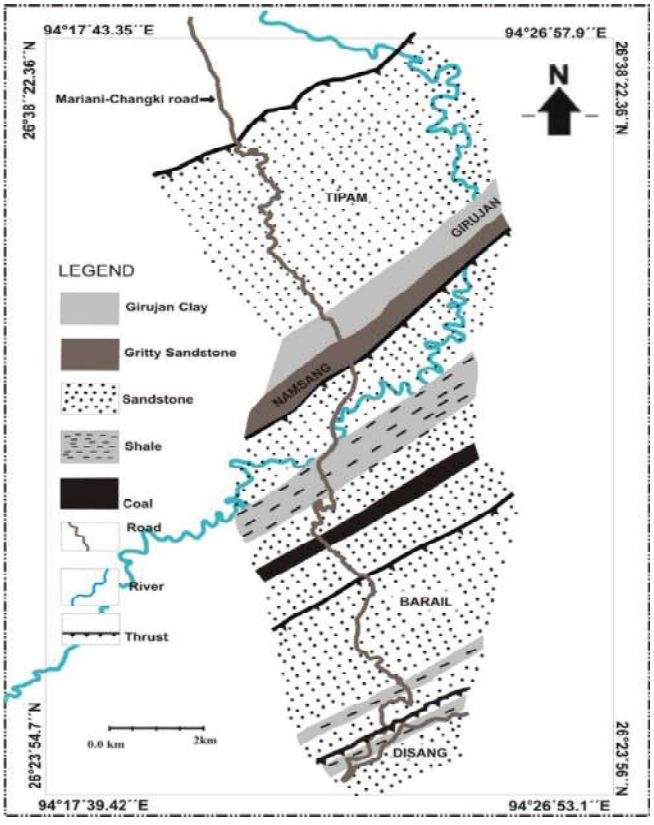

Figure 1. Location and geological map of the study area.

GEOLOGICAL SETTING

Nagaland is located in the northern extension of the Arakan Yoma ranges which are of Cretaceous-Tertiary age and belong to a fairly young unstable belt of the earth (Director General, Geological Survey of India 1974). Geotectonically, four distinct domains have been identified in the Naga Hills, which are framed between the foreland spur of Shillong and Mikir massifs to the west, and central Myanmar basin to the east. These are: (1) Assam Shelf, (2) Schuppen Belt, outer belt of imbricate, anastomosing thrusts (Mathur & Evans 1964), (3) Inner Palaeogene Fold Belt, comprising thick folded sequence of Disang and Barail rocks, and (4) Ophiolitic Complex occurring further east, close to Indo-Myanmar border, associated with Late Mesozoic-Tertiary sediments (Geological Survey of India 2011). Assam shelf comprises a relatively thin sequence of sediments of Barail, Surma and Tipam groups, resting unconformably on a pre-Tertiary granitic basement exposed mainly in Dhansiri valley. A part of Assam Shelf

sediments has been thrusted over by tectonic slices of Schuppen Belt. The seismic survey conducted in the frontal part of Schuppen Belt clearly indicates extension of Assam Shelf under the Schuppen Belt in Nagaland. The NW–SE structural elements in the platform appear to continue underneath the NE–SW striking Schuppen Belt (Ranga Rao 1983).

Schuppen belt defines the western flank of Naga Hills. It is composed of six tectonic blocks formed by several thrust slices occurring along Naga Patkai Hill ranges of Nagaland. The belt comprises of Barail Group, Surma Group, Tipam Group, Namsang Formation and Dihing Formation (Mathur & Evans 1964). Inner Palaeogene fold belt covers major part of the central segment of Naga Hills. It comprises folded and thrusted post-Late Cretaceous sequence commencing from Disang Group onwards to Surma Group of sedimentary rocks, over which Pleistocene and Holocene sediments have been deposited. The Ophiolite complex of Nagaland demarcates the eastern boundary of the Indo-Burma Ranges, which is made up of unfossiliferous pre-Mesozoic, low to medium grade metasediments and ophiolite suites (Acharyya 2007). N–S to NNE–SSW trending arcuate Ophiolite Belt of Nagaland and Manipur extends approximately for 200 km. The contact between Ophiolite suite and Disang Formation is marked by shearing, brecciation and silicification with occasional development of tight to isoclinal folds. The Ophiolite belt has a tectonic contact with Inner Palaeogene fold belt in the west and Saramati Formation in the east of pre-Mesozoic age as the oldest formation in the belt. Nimi Formation overlies Saramati Formation, which is succeeded by Ophiolite Suite, followed by Salumi Formation. Phokphur Formation is the youngest group of rocks in the belt.

STRATIGRAPHY

Stratigraphy of the study area mainly comprises of Barail Group (Table 1) that represents a lithological package belonging to the geosynclinal facies. Rocks of this group are exposed along the two different strips, one in the south-eastern part of North Cachar Hills, i.e. to the South of Haflong-Disang Thrust, and secondly in parts north of the Cachar and Karbi (Mikir) Hills, i.e. to the north of Haflong-Disang Thrust in Upper Assam. The geosynclinal facies of Barail Group in Surma valley and North Cachar Hills are subdivided into Laisong, Jenam and Renji Formations. Laisong Formation consists of thin bedded greyish sandstone with interbedded thin sandy shale, rare massive sandstone, carbonaceous shales and streaks of coal. Laisong Formation gradationally passes into argillaceous Jenam Formation comprising mainly of shale, sandy shale, and carbonaceous shale with streaks of coal and interbedded hard sandstone. Renji Formation comprises of hard massive sandstone with rare beds of shale and sandy shale.

In upper Assam, the Barail Group has been

Table 1. Generalized stratigraphic succession of Nagaland.

Age	Group/Formation	Lithology
Pleistocene and Recent	Alluvium and terrace deposit	
	Unconformity	
Plio-Pleistocene	Dihing Formation	Conglomerates, grits, sandstone and clay beds
	Unconformity	
Pliocene	Namsang Formation	Thick beds of grits and with occasional sandstone and claystone
	Unconformity	
Miocene	Tipam Group	Girujan clay lenses, thickly medium to coarse ferruginous sandstones With interbands of siltstones and clay. Sandstone thickly bedded, medium to coarse ferruginous sandstones with interbands of siltstones and clay
	Unconformity	
Oligocene	Barail Group	Very thick sequence of hard, ferruginous, thickly bedded sandstone with minor shale and siltstone. Shales carbonaceous shales siltstones and sandstones with a number of coal seams. Well bedded, laminated sandstone occasionally with alternating silt-stones. Thick units of shales occur sometimes in the upper part.
Upper Cretaceous to Eocene	Disang Group	-

classified as Naogaon Formation, Baragolai Formation and Tikak Parbat Formation. The lowermost division, i.e. the Naogaon Formation, consists of fine grained, hard, thin bedded, light-darker grey flaggy sandstone along with thin partings of greyish splintery shales and thinly bedded sandy shales. The intermediate Baragolai Formation is comprised of sandstone, clay, clayey sandstone, sandy clay, thin ferruginous sandstone, carbonaceous shale with laminae of coaly material and leaf impressions and coal seams. The topmost formation i.e. the Tikak Parbat Formation comprised of medium to coarse grained light coloured quartzose sandstone with interbedded shale, sandy shales, clays, carbonaceous shale with coal seams. Carbonaceous shales exhibit leaf impressions (Geology and mineral resources of Assam, Geological Survey of India, Misc. Publ. 30, Part 4).

PALYNOLOGICAL RESULTS

The recovered palynological assemblage reflects a rich and diverse palaeovegetation, with a predominance of angiosperm pollen grains followed by pteridophytic spores, acritarchs, dinoflagellate cysts, fungal remains and a few gymnosperm pollen. The investigated area mainly consists of arenaceous and argillaceous sediments with occasional coal seams. Majority of the palynotaxa in this section have been recorded from the associated shaly layers. Coal bands of the Barail Group in this section have a prolific abundance of fungal remains and leaf cuticles. The palynotaxa assemblage recovered from the Barail Group comprises of 42 species belonging to 35 genera. Of these, 27 species of 24 genera belong to angiosperm pollen, 8 species of 7 genera to pteridophytic spores, and 4 species of 2 genera to acritarchs.

Angiosperm pollen constitute the most dominant group amongst all the palynotaxa groups and are documented by *Alnipollenites* sp., *Anacolosidites trilobatus, Dicolpopollis edavensis, Dicolpopollis proprius, Diporopollis assamica, Florschuetzia levipoli, Foveotricolporites callosus, Graminidites* sp., *Kindopollis* sp. cf. *K. decoris, Liliacidites* sp. cf. *L. ellipticus, Longapertites retipilatus, Marginipollis kutchensis, Meyeripollis naharkotensis, Myrtaceidites pretiosus, Polycolpites cooksoniae, Polycolpites ornatus, Polycolpites* sp., *Polygalacidites clarus*, *Proxapertites microreticulatus, Proxapertites operculatus, Retistephanocolpites granulatus, Retitrescolpites minor, Santalumidites cainozoicus, Spinizonocolpites echinatus, Striatopollis bellus* and *Tricolpites reticulatus.* However, *Meyeripollis* and *Marginipollis* are quantitatively very rich in the angiosperm pollen assemblage. Gymnosperm pollen are represented by *Podocarpidites classicus.* Possible affinities of palynomorphs identified in the assemblage and present-day distribution of their families are given in Table 2. The palynofloral assemblage is briefly described below. The genera and species are arranged alphabetically under the broad heading of 1. Dinoflagellate cysts; 2. Acritarchs; 3. Fungal remains; 4. Pteridophytic spores, 5. Gymnospermous pollen; 6. Angiospermous pollen; 7. Salt glands of mangrove plants; and 8. Reworked palynomorphs.

PALYNOFLORAL DESCRIPTION

1. Dinoflagellate cyst

Genus: *Operculodinium* D. Wall 1967

Operculodinium centrocarpum (Deflandre & Cookson) D. Wall 1967

Figure 2.3

Description: Spheroidal proximochorate cyst with densely ornamented surface. Granule's distribution and virage is nontubular. Virage is also acuminate.

Occurrence: Barail Group, Nagaland.

2. Acritarchs

Genus: *Micrhystridium* Deflandre 1937

Micrhystridium teichertii Sarjeant 1973

Figure 3.4

Description: Ovoid vesicle with spiniform processes, spines hollow and simple. Thick wall. Thorns with blunt apex, strong and broad base.

Occurrence: Barail Group, Nagaland.

Micrhystridium* sp. cf. *M. castaninum Valensi 1953

Table 2. Present day distribution of families related to the palynotaxa found in the Barail Group.

Fossil Taxa	Botanical Affinity	Distribution and Habitat
Graminidites sp.	*Poaceae*	Grass of monocotyledonous flowering plants.
Foveotricolporites callosus	*Caesalpiniaceae*	Cosmopolitan.
Florschuetzia levipoli	*Sonneratiaceae*	Tropical-subtropical Mangrove tree.
Iugopollis sp.	*Sapotaceae*	Tropics, member of evergreen vegetation.
Liliacidites cf. *ellipticus*	?*Liliaceae*	Cosmopolitan.
Marginipollis kutchensis	*Lecythidaceae*	Tropical regions.
Alnipollenites sp.	*Betulaceae* (*Alnus*)	Cosmopolitan, Trees in rainforest.
Retitrescolpites minor	*Oleaceae*	Mainly tropical.
Podocarpidites classicus	*Podocarpaceae*	Temperate.
Proxapertites microreticulatus.	*Arecaceae*	Tropical- subtropical, climbers in evergreen forest, mangrove shrubs.
Proxapertites operculatus	*Arecaceae*	Tropical- subtropical, climbers in evergreen forest, mangrove shrubs.
Spinizonocolpites echinatus	*Nypa fruticans*, *Arecaceae*	Tropics of southeast Asia and Australia, true mangrove palm.
Longapertites retipilatus	*Eugeissona*, *Lepidocaryoideae*	Palms of lowland evergreen vegetation.
Anacolosidites reklawensis	*Oleaceae*	Mainly tropical.
Dicolpopollis proprius	*Arecaceae*	Pantropical, evergreen forest.
Dicolpopollis edavensis	*Arecaceae*	Pantropical, evergreen forest.
Tricolpites reticulatus	*Gunneraceae*	Cosmopolitan. Rhizomatic perennial herb on marshy places.
Santalumidites cainozoicus	*Santalaceae*	Mainly tropical regions.
Hammenisporis susannae	*Schizaeaceae*	Tropical- Subtropical.
Polypodiisporonites sp.	*Polypodiaceae*	Cosmopolitan, Perennial climbing fern, rainforest.
Polypodiisporonites oligocenicus	*Polypodiaceae*	Cosmopolitan, Perennial climbing fern.
Laevigatosporites copiosus	*Polypodiaceae*	Tropical, Tree fern.
Laevigatosporites gracilis	*Polypodiaceae*	Tropical.
Dandotiaspora dilata	*Matoniaceae*	Tropical to subtropical. Sub aquatic to swampy.
Lycopodiumsporites rarus	*Lycopodiales*	Climbing fern associated with shrubby vegetation around thick forest.
Fungal remains		Warm, humid and tropical.
Acritarch and dinoflagellate cysts		Shallow marine.

Figure 2.8

Description: Body spherical, with a smooth wall ornamented. Distally the processes are curved, straight and acuminate. They are evenly spaced over the surface although no pattern could be resolved. Nobody opening was found.

Occurrences: Barail Group, Nagaland.

***Micrhystridium* sp.**

Figure 4.1

Description: Subspherical, subcircular in outline. Wall is thin, psilate and covered uniformly with widely dispersed spines which are of different lengths. Due to poor preservation, it is not possible to compare it with other known species of *Micrhystridium*.

Occurrences: Barail Group, Nagaland.

Genus: *Veryhachium* Deunff 1954

Veryhachium sedecimspinosum Staplin 1961

Figure 4.6

Description: Vesicle subquadrate in outline, wall thin, microgranulate; major and minor spines arise from the angles and proximally merge smoothly with the vesicle wall, both type of spines opening into and freely communicating with vesicle interior.

Occurrence: Barail Group, Nagaland.

Veryhachium trispinosum (Eisenack) Stockmans & Williere 1962

Figure 3.6.

Description: Vesicle cushion-shaped, triangular in outline, with concave sides. Spines arise from the angles and proximally merge with the vesicle wall so smoothly that no exact limit can be set to their bases. They are arranged in a single plane. Spines acuminate in shape and uniform in size; distally they are closed, simple and pointed.

Occurrence: Barail Group, Nagaland.

3. Fungal remains

Fungal Spore

Figure 4.8

Description: The fungal spore is brown, subspherical inaperturate. Spore wall is thick; no

distinct reticulation is seen and broken.

Occurrence: Barail Group, Nagaland.

4. Pteridophytic spores

Genus: *Acanthotriletes* S.N. Naumova ex R. Potonié & Kremp 1954

***Acanthotriletes* sp.**

Figure 5.3

Description: Trilete spore. Triangular outline with concave sides and rounded corners. Y-mark is not distinct. Exine is thin and echinate. Short spines distributed all over the surface.

Occurrence: Barail Group, Nagaland.

Genus: *Dandotiaspora* S.C.D. Sah et al. 1971

Dandotiaspora dilata (Y.K. Mathur) S.C.D. Sah et al. 1971

Figure 5.4.

Description: Miospore trilete. Amb roundly triangular with broadly rounded angles. Trilete mark is distinct. Laesura is straight. Exine fairly thick. Surface is unsculptured.

Occurrence: Barail Group, Nagaland.

Genus: *Hammenisporis* R.K. Saxena & G.K. Trivedi 2009

Hammenisporis susannae (Hammen) R.K. Saxena & G.K. Trivedi 2009

Figure 2.6

Description: Trilete spore with striations. Outline is subtriangular with rounded corners. It has a distinct 'Y' mark. Exine is smooth and covered by flat costae. Costae are converging at the laesurae ends, which is separated by narrow groves.

Occurrence: Barail Group, Nagaland.

Genus: *Intertriletes* Anderson 1960

***Intertriletes* sp.**

Figure 3.3

Description: Trilete spore. In polar view, the amb is subtriangular with rounded corners. Trilete mark is not distinct. Fine reticulation is seen on the contact area of the proximal face. The contact area has excellently spread reticulate exine. Due to poor preservation, it is not possible to compare it with other known species of *Intertriletes*.

Occurrence: Barail Group, Nagaland.

Genus: *Laevigatosporites* Ibrahim 1933

Laevigatosporites copiosus Salujha et al. 1972

Figure 4.12

Description: Monolete spore. Planoconvex with rounded ends in lateral view. Laesura is thin. Thick and psilate exine.

Occurrence: Barail Group, Nagaland.

Laevigatosporites gracilis Wilson &Webster 1946

Figure 3.7

Description: Monolete spore. Outline subspherical with broadly rounded ends in lateral view. Exine is thick, psilate to scabrate.

Occurrence: Barail Group, Nagaland.

Genus: *Lycopodiumsporites* Thiergart ex Delcourt & Sprumont 1955

Lycopodiumsporites rarus Salujha et al. 1972

Figure 2.11

Description: Amb convexly triangular, with broad rounded angles. Trilete mark is fairly distinct. Exine is thick. Surface with comparatively reduced reticulum.

Occurrence: Barail Group, Nagaland.

Genus: *Polypodiisporonites* R. Potonié 1931

Polypodiisporonites oligocenicus (S.C.D. Sah & S.K. Dutta) Saikia & Bhuyan, **comb. nov.**

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Figure 2.1. *Longapertites retipilatus* R.K. Kar 1985. **2.** *Polypodiisporonites* sp. **3.** *Operculodinium centrocarpum* (Deflandre & Cookson) Wall 1967. **4.** *Dicolpopollis proprius* Salujha et al. 1972. **5.** *Platysaccus papilionis* R. Potonié & W. Klaus 1954. **6.** *Hammenisporis susannae* (Hammen) R.K. Saxena & G.K. Trivedi 2009. **7.** *Polygalacidites clarus* S.C.D. Sah & S.K. Dutta 1966. **8.** *Micrhystridium* sp. cf. *M. castaninum* Valensi 1953. **9.** *Graminidites* sp. **10.** *Retitrescolpites minor* S.C.D. Sah 1967. **11.** *Lycopodiumsporites rarus* Salujha et al. 1972. **12.** *Dicolpopollis edavensis* K.P. Rao & Ramanujam 1978.

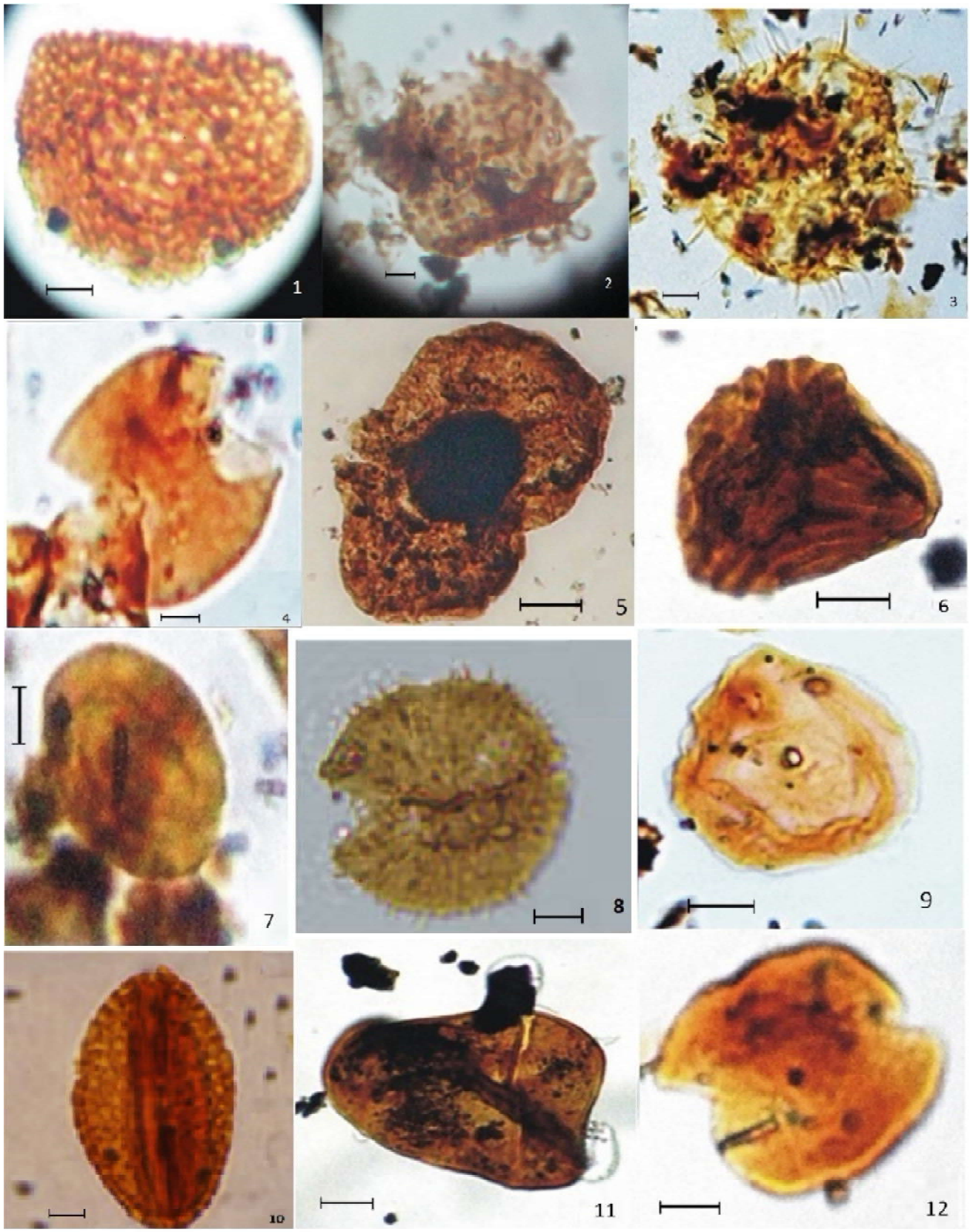

Figure 2

Figures 3.12, 5.6

Basionym: *Polypodiisporites oligocenicus* S.C.D. Sah & S.K. Dutta, Palaeobotanist 15(1–2): 186, plate 1, figure 11. 1968.

Description: Monolete spore. Outline bean shaped in lateral view. Laesura is short and narrow. Verrucate with rounded tip and distributed all over the surface.

Occurrence: Barail Group, Nagaland.

***Polypodiisporonites* sp.**

Figure 2.2

Description: Monolete spore. Nearly bean shaped. Marginally concavo-convex in lateral view. Leasura is thin. Exine is thick, verrucate. Due to poor preservation, it is not possible to compare it with other known species of *Polypodiisporonites*.

Occurrence: Barail Group, Nagaland.

5. Gymnospermous pollen

Genus: *Podocarpidites* Cookson ex Couper 1953

Podocarpidites classicus Salujha et al. 1972.

Figure 5.5.

Description: Bilateral, bisaccate, central body oval, smaller than the bladders in heights, outline faintly discernible, foveolate, bladders hemispherical, microreticulate, distally attached. Slightly biconvex sulcus.

Occurrence: Barail Group, Nagaland.

6. Angiospermous pollen

Genus: *Alnipollenites* R. Potonié 1931

***Alnipollenites* sp.**

Figure 4.3

Description: Outline is pentangular in polar view, pentaporate pollen grain. Sides are concave. Pores are situated at the corners and are placed on the equatorial plane. Exine is thin and psilate with arci.

Occurrence: Barail Group, Nagaland.

Genus: *Anacolosidites* Cookson & Pike 1954

Anacolosidites trilobatus Venkatach. & M.S. Rawat 1972

Figure 3.10

Description: Triangular outline. Six pored with 3 aperatures on each hemisphere which are located away from equator. Distal and proximal aperature positioned one over another 3 pores in each hemisphere. Exine is thick and double layered. Surface is psilate.

Occurrence: Barail Group, Nagaland.

Genus: *Dicolpopollis* Pflanzl 1956

Dicolpopollis edavensis K.P. Rao & Ramanujam 1978

Figure 2.12

Description: Dicolpate pollen with barrel shaped amb which is biconvex in polar view. Colpi short, wide and deep. Exine is tectate punctate and reticulate surface.

Occurrence: Barail Group, Nagaland.

Dicolpopollis proprius Salujha et al. 1972

Figure 2.4

Description: Dicolpate pollen with ovoidal outline. The sides are convex. Exine is thin and the surface is microreticulate.

Occurrence: Barail Group, Nagaland.

Genus: *Diporopollis* S.K. Dutta & S.C.D. Sah 1970

Diporopollis assamica S.K. Dutta & S.C.D. Sah 1970

Figure 3.1

→

Figure 3. 1. *Diporopollis assamica* S.K. Dutta & S.C.D. Sah 1970. **2.** *Tricolpites reticulatus* Cookson ex Couper 1953. **3.** *Intertriletes* sp. **4.** *Micrhystridium teichertii* Sarjeant 1973. **5.** *Santalumidites cainozoicus* Cookson & Pike 1954. **6.** *Veryhachium trispinosum* Eisenack 1938 Stockmans &Williere 1962. **7.** *Laevigatosporites gracilis* Wilson & Webster 1946. **8.** *Retitrescolpites minor* S.C.D. Sah 1967. **9.** *Meyeripollis naharkotensis* Baksi & Venkatach. 1970. **10.** *Anacolosidites trilobatus* Venkatach. & M.S. Rawat 1971. **11.** *Polycolpites cooksoniae* S.C.D. Sah & S.K. Dutta 1966. **12.** *Polypodiisporonites oligocenicus* (S.C.D. Sah & R.K. Kar) Saikia & Bhuyan, comb. nov.

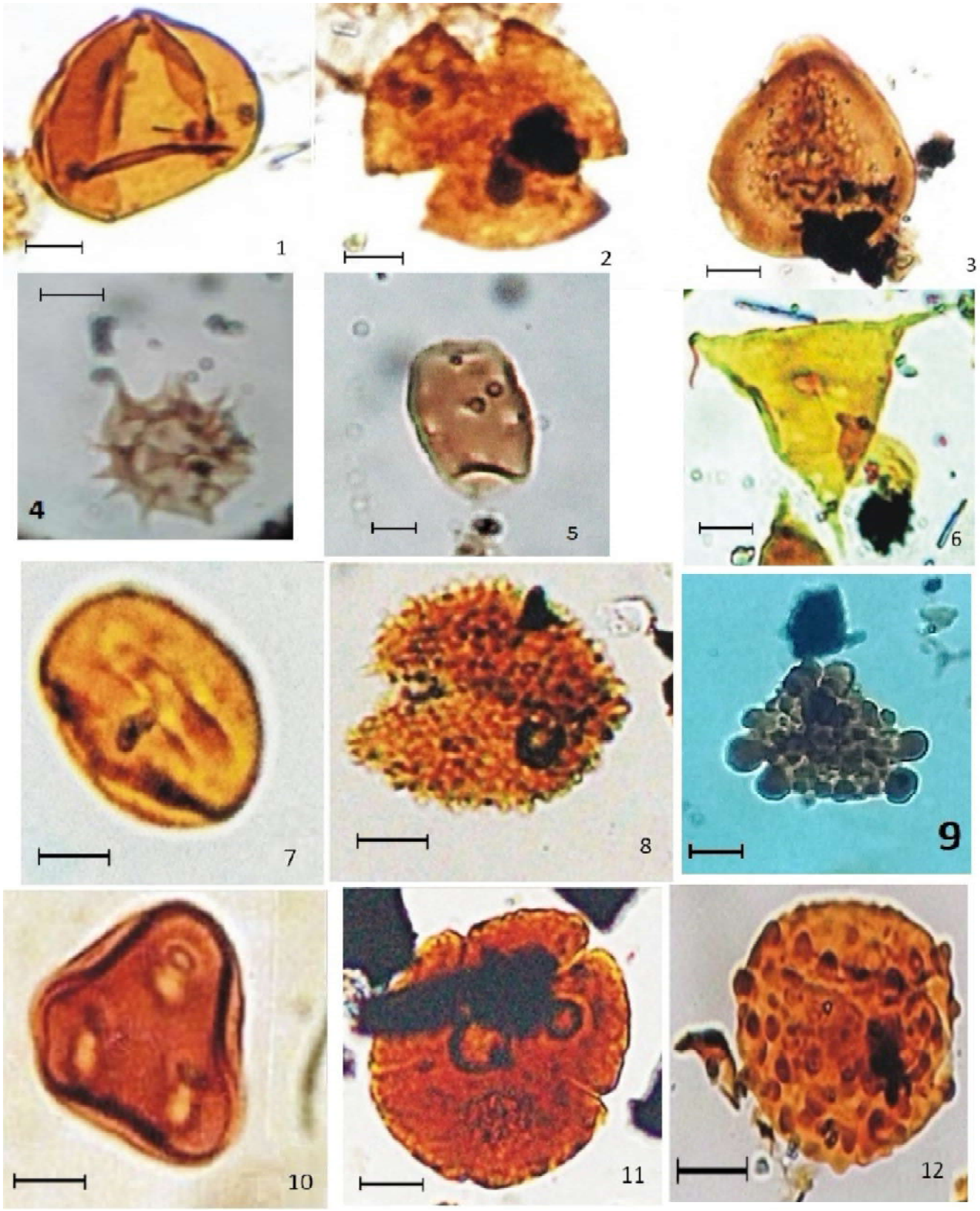

Figure 3

Description: Diporate. Amb is globular. Pores placed one over another. Encircled by one or more thickened rims. Exine thin, surface sculpture is psilate. Diporopollis have elongate form. Aperature situated at the polar ends.

Occurrence: Barail Group, Nagaland.

Genus: *Florschuetzia* Germeraad et al. 1968

Florschuetzia levipoli Germeraad et al. 1968

Figure 5.12

Description: Triporate pollen grain. Subspherical, trilobate; one lobe distinct, two others are faintly preserved. One pore distinct and the other two indistinct; pores circular, exine is two layered but not clearly differentiated, slightly thicker in the meridional region.

Occurrence: Barail Group, Nagaland.

Genus: *Foveotricolporites* R.L. Pierce 1961

Foveotricolporites callosus C. Singh 1983

Figure 5.1

Description: Tricolporate pollen, spheroidal, amb is slightly rounded triangular with blunt corners; colpi bordered by prominent margins of thickened ektexine, sculpture foveolate.

Occurrence: Barail Group, Nagaland.

Genus: *Graminidites* Cookson ex R. Potonié 1960

***Graminidites* sp.**

Figure 2.9

Description: Brown, subcircular, flattened on one side. Monoporate grain with wide pore. Exine is thick and smooth.

Occurrence: Barail Group, Nagaland.

Genus: *Iugopollis* Venkatach. & M.S. Rawat 1972

***Iugopollis* sp.**

Figure 4.11

Description: Tetracolporate pollen, oval shaped pollen grain. Colpi is short. On the equatorial band exine is psilate and scabrate. Due to poor preservation, it is not possible to compare it with other known species of *Iugopollis*.

Occurrence: Barail Group, Nagaland.

Genus: *Kindopollis* Y.K. Mathur & A.K. Jain 1980

Kindopollis* sp. cf. *K. decoris Y.K. Mathur & Chopra 1987.

Figure 6.5

Description: Tetracolporate, oval pollen grain with thick oval band. Colpi is short, restricted to the short band and pores small and elongate. Exine psilate on the equatorial band and scabrate all around.

Occurrence: Barail Group, Nagaland.

Genus: *Lakiapollis* Venkatach. & R.K. Kar 1969.

Lakiapollis ovatus Venkatach. & R.K. Kar 1969

Figure 5.8

Description: Pollen grain is elliptic to subcircular in polar view, Tricolporate grain. Colpi is narrow. Pores are well developed. Irregularly placed aperture, Exine is thick whereas sexine and nexine cannot be differentiated. Surface is scabrate.

Occurrence: Barail Group, Nagaland.

Genus: *Liliacidites* Couper 1953

Liliacidites* sp. cf. *L. ellipticus Venkatach. & R.K. Kar 1969

Figure 4.7

Description: Monosulcate pollen grain, subcircular in shape. Sulcus is broad more or less boat

→

Figure 4. 1. *Micrhystridium* sp. **2.** *Oudhkusumites immodiscus* (Salujha et al.) Saikia & Bhuyan, comb. nov. **3.** *Alnipollenites* sp. **4.** *Retistephanocolpites granulatus* (S.C.D. Sah & R.K. Kar) R.K. Kar 1985. **5.** *Myrtaceidites pretiosus* Salujha et al. 1972. **6.** *Veryhachium sedecimspinosum* Staplin 1961. **7.** *Liliacidites* cf. *ellipticus* Venkatach. & R.K. Kar 1969. **8.** Fungal spore. **9.** *Spinizonocolpites echinatus* J. Muller 1968. **10.** *Polycolpites ornatus* S.K. Dutta & S.C.D. Sah 1970. **11.** *Iugopollis* sp. **12.** *Laevigatosporites copiosus* Salujha et al. 1972.

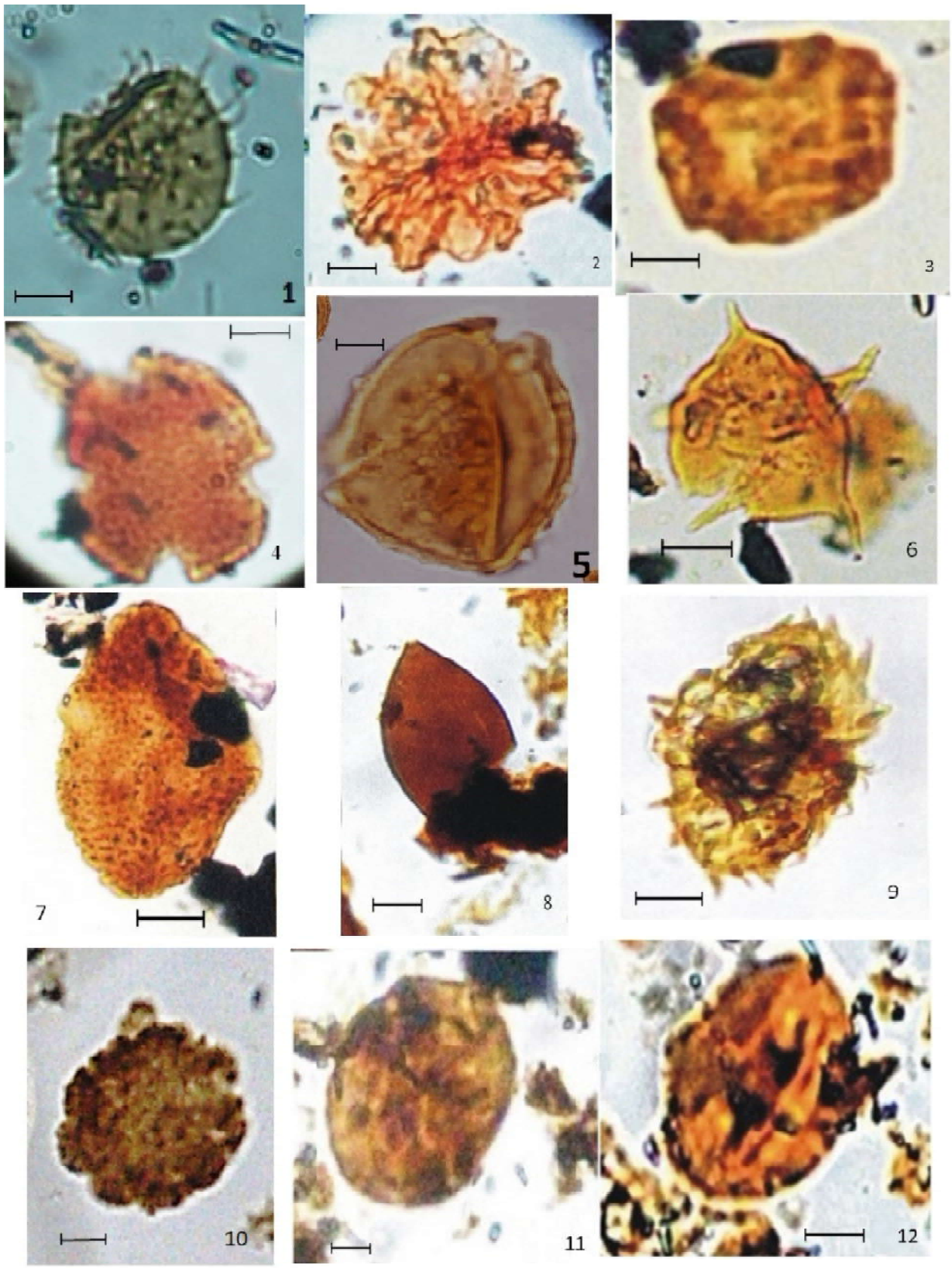

Figure 4

shaped. Exine is microreticulate. Double walled. Sexine is thicker than nexine.

Occurrence: Barail Group, Nagaland.

Genus: *Longapertites* Hoeken-Klink. 1964

Longapertites retipilatus R.K. Kar 1985

Figure 2.1

Description: Outline circular in equatorial view. Monosulcate. Sulcus is long extending to the proximal surface. Margins of sulcus infolded. Exine is thick. Sculpture is perforated.

Occurrence:: Barail Group, Nagaland.

Genus: *Marginipollis* Clarke & N.O. Fred. 1968

Marginipollis kutchensis (Venkatach. & R.K. Kar) M.S. Rawat et al. 1977

Figure 5.10

Description: Tricolpate pollen grain. Sphaeroidal in equatorial view. Zonaperture and syncolpate. Colpi is long and end at poles. Exine surface is finely structured.

Occurrence: Barail Group, Nagaland.

Genus: *Meyeripollis* Baksi & Venkatach. 1970

Meyeripollis naharkotensis Baksi & Venkatach. 1970

Figures 3.9, 5.7.

Description: Trisyncolpate pollen grains. "Y" shape is not distinct. Triradiate, with 3 radiating arms of uniform width, longer than wide; length of arms varies, one arm slightly longer than the other. Colpi is narrow, almost like a tube present in the middle of the arms, and meeting at the ``Y" junction. Surface is covered by tubercles.

Occurrence: Barail Group, Nagaland.

Genus: *Myrtaceidites* Cookson & Pike 1954

Myrtaceidites pretiosus Salujha et al. 1972.

Figure 4.5

Description: Triporate pollen grain. Outline roundly triangular with slightly convex sides in polar view. Pores are small, angulaperature. Arci joining with the pores and forming a triangular area at the polar ends. Exine is thin, exine surface is psilate.

Occurrence: Barail Group, Nagaland.

Genus: *Polycolpites* Couper 1953

Polycolpites cooksoniae S.C.D. Sah & S.K. Dutta 1966

Figure 3.11

Description: Spheroidal in outline. 5 colpate. Colpi long. Exine thick. Surface sculpture finely granulose.

Occurrence: Barail Group, Nagaland.

Polycolpites ornatus S.K. Dutta & S.C.D. Sah 1970

Figure 4.10

Description: Outline is subcircular. It has six colpi. Exine is coarsely reticulate.

Occurrence: Barail Group, Nagaland.

***Polycolpites* sp.**

Figure 5.9

Description: Pollen grain is subrounded. Polycolpate. Colpi is wide and deep. Exine is thin. Sexine and nexine cannot be differentiated. Surface is psilate to scabrate. Due to poor preservation, it is not possible to compare it with other known species of *Polycolpites*.

Occurrence: Barail Group, Nagaland.

Genus: *Polygalacidites* S.C.D. Sah & S.K. Dutta 1966

Polygalacidites clarus S.C.D. Sah & S.K. Dutta 1966

→

Figure 5. 1. *Foveotricolporites callosus* C. Singh 1983. **2.** *Spinizonocolpites echinatus* J. Muller 1968. **3.** *Acanthotriletes* sp. **4.** *Dandotiaspora dilata* (Y.K. Mathur) S.C.D. Sah et al. 1971. **5.** *Podocarpidites classicus* Salujha et al. 1972. **6.** *Polypodiisporonites oligocenicus* (S.C.D. Sah & R.K. Kar) Saikia & Bhuyan, comb. nov. **7.** *Meyeripollis naharkotensis* Baksi & Venkatach. 1970. **8.** *Lakiapollis ovatus* Venkatach. & R.K. Kar 1969. **9.** *Polycolpites* sp. **10.** *Marginipollis kutchensis* Venkatach. & R.K. Kar 1969. **11.** *Striatopollis bellus* S.C.D. Sah 1967. **12.** *Florschuetzia levipoli* Germeraad et al. 1968.

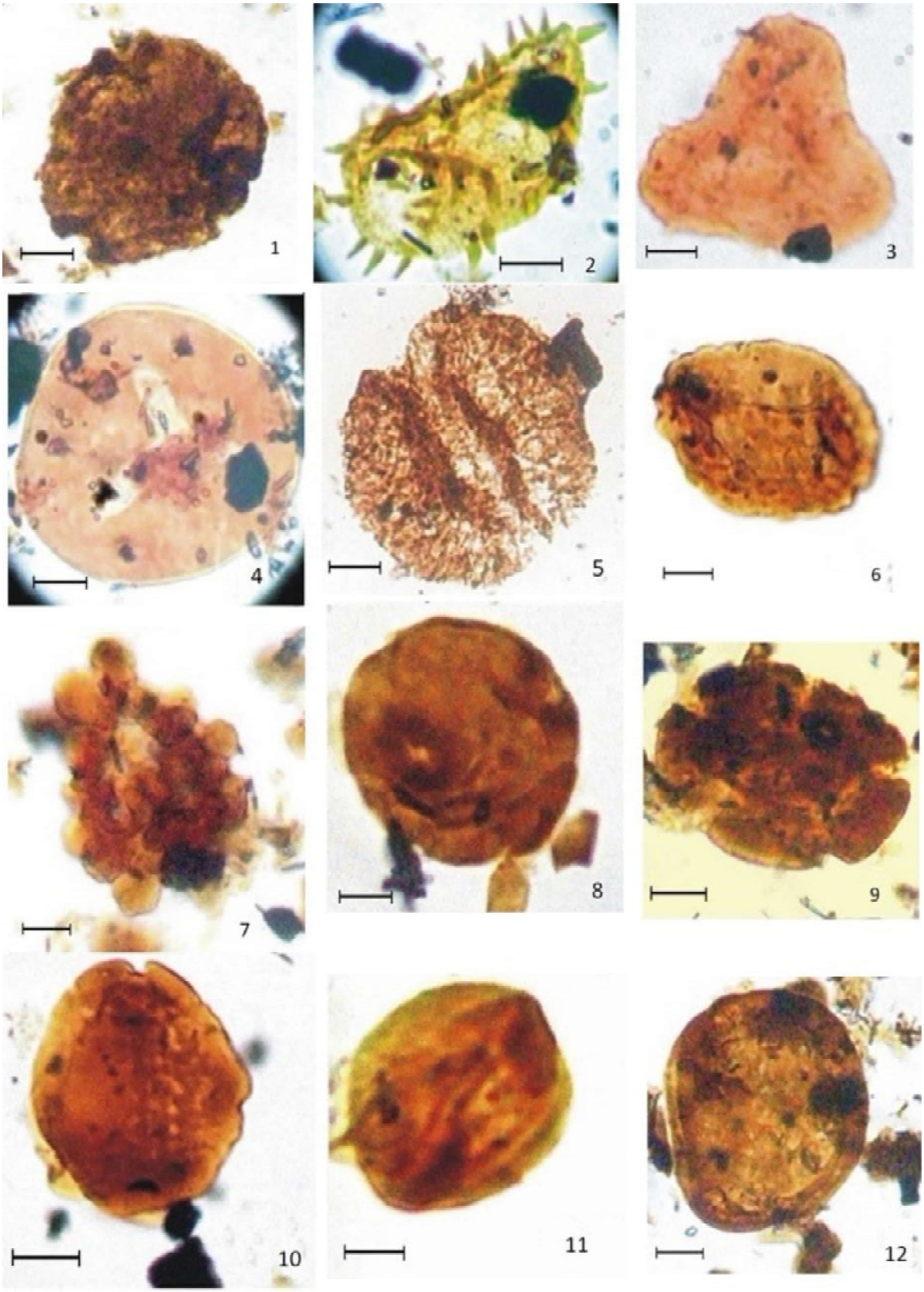

Figure 5

Figures 2.7, 6.3

Description: Stephanocolporate. Outline is oval. Colpi is long. Exine is thick, finely granulate.

Occurrence: Barail Group, Nagaland.

Genus: *Proxapertites* Hammen 1956

Proxapertites microreticulatus K.P. Jain et al. 1973

Figure 6.6

Description: Long sulcus which is placed along the meridian of the pollen. The aperture causes an easy split of pollen into two more or less equal halves. Exine is finely reticulate.

Occurrence: Barail Group, Nagaland.

Proxapertites operculatus Hammen 1956

Figure 6.1

Description: Outline is subcircular. Equatorially splits into two equal halves. Exine is thin. Exine ornamentation is scabrate.

Occurrence: Barail Group, Nagaland.

Genus: *Retistephanocolpites* Leidelmey. 1966

Retistephanocolpites granulatus (S.C.D. Sah & R.K. Kar) R.K. Kar 1985

Figure 4.4

Description: Stephanocolpate pollen grain. Outline subcircular in polar view. Pentacolpate pollen. Colpi wide and deep. Exine is thick single layered, surface is finely reticulate.

Occurrence: Barail Group, Nagaland.

Genus: *Retitrescolpites* S.C.D. Sah 1967

Retitrescolpites minor S.C.D. Sah 1967

Figure 2.10, 3.8

Description: Spheroidal in polar view. 3 colpate. Colpi long. Exine is thick. Surface structure is reticulum formed of thick irregular small lamina.

Occurrence: Barail Group, Nagaland.

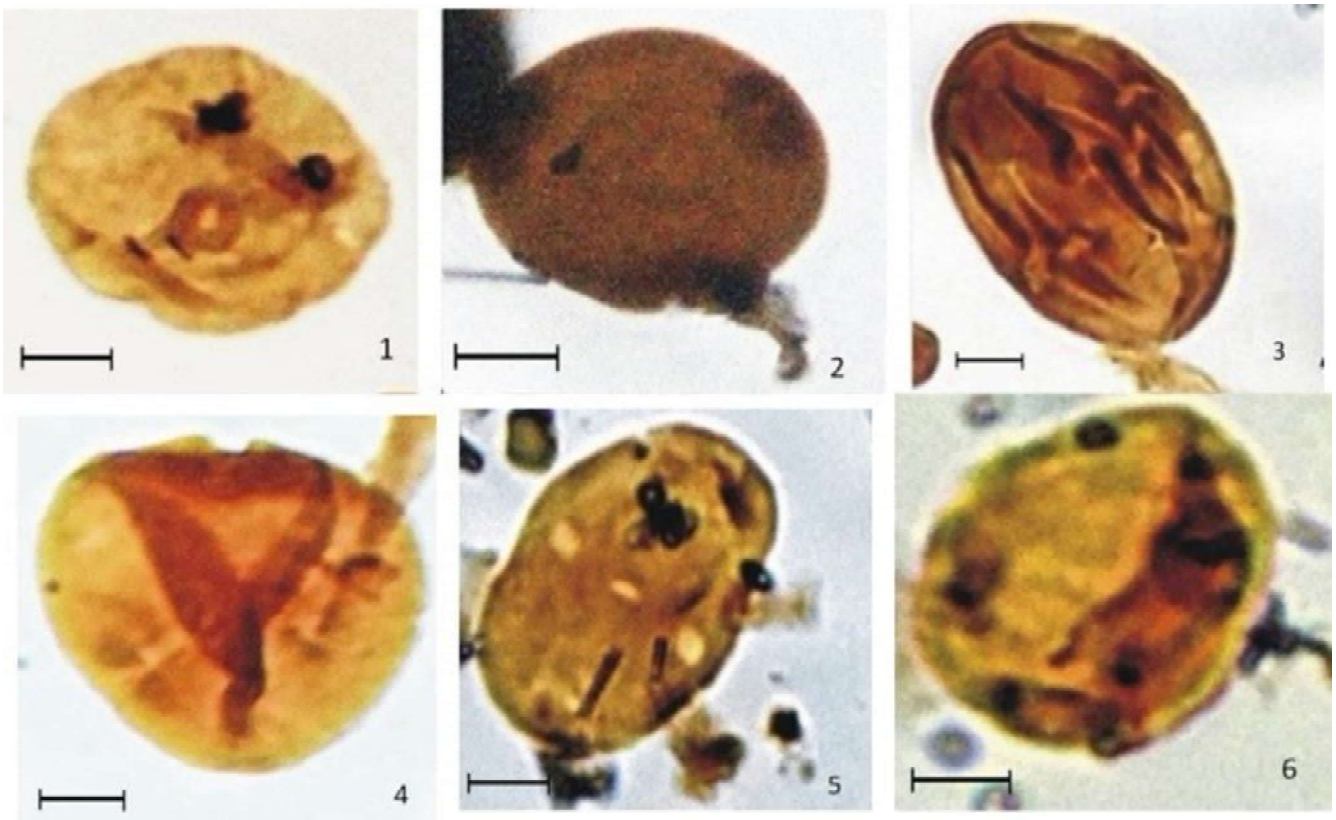

Figure 6. 1. *Proxapertites operculatus* Hammen 1956. **2.** Triporate pollen. **3.** *Polygalacidites clarus* S.C.D. Sah & S.K. Dutta 1966. **4.** Trilete spore. **5.** *Kindopollis* sp. cf. *K. decoris* Y.K. Mathur & A.S. Chopra 1987. **6.** *Proxapertites microreticulatus* K.P. Jain et al. 1973.

Genus: *Santalumidites* Cookson & Pike 1954

Santalumidites cainozoicus Cookson & Pike 1954

Figure 3.5

Description: Outline elongated ovoidal. Tricolporate pollen. Exine is thin. Surface psilate.

Occurrence: Barail Group, Nagaland.

Genus: *Spinizonocolpites* J. Muller 1968

Spinizonocolpites echinatus J. Muller 1968

Figure 4.9, 5.2

Description: Ovoidal in shape, possess an extended sulcus and are provided with a spinose exine. Shape and size of spines are variable, being straight to slightly curved at the tip. The inter-spinal area is smooth to reticulate.

Occurrence: Barail Group, Nagaland.

Genus: *Striatopollis* Krutzsch 1959

Striatopollis bellus S.C.D. Sah 1967

Figure 5.11

Description: Tricolpate pollen grain. Amb subcircular in equatorial view. Colpi long, reaching the poles, wider at equator. Exine non-striated, rib running parallel to the polar axis.

Occurrence: Barail Group, Nagaland.

Genus: *Tricolpites* Cookson ex Couper 1953

Tricolpites reticulatus Cookson ex Couper 1953

Figure 3.2

Description: Roundly triangular in outline, tricolpate with wide colpi. Exine is thick, smooth and also foveolate sparely.

Occurrence: Barail Group, Nagaland.

7. Salt glands of mangrove plants

Genus: *Heliospermopsis* Nagy 1965

Heliospermopsis immodiscus (Salujha, Kindra & Rehman) Saikia & Bhuyan, **comb. nov.**

Figure 4.2

Basionym: *Oudhkusumites immodiscus* Salujha, Kindra & Rehman in Ghosh A.K. et al. (Editors) – Proceedings of the Symposium on Palaeopalynology and Indian Stratigraphy, Botany Department, Calcutta University, Calcutta, pp. 288–289, plate 3, figures 104–105. 1972.

Description: Circular body with wall ornamentation. Projections are regularly spaced all over the surface. The projections vary greatly in form, which are simple.

Occurrence: Barail Group, Nagaland.

8. Reworked palynomorphs

Genus: *Platysaccus* R. Potonié & W. Klaus 1954

Platysaccus papilionis R. Potonié & W. Klaus 1954

Figure 2.5

Description: Bisaccate pollen grain, amb strongly diploxylonoid. Corpus well defined, slightly longitudinally oval. But lack of description prevents a more precise comparison.

Occurrence: Barail Group, Nagaland.

PALAEOCLIMATE AND PALAEOENVIRONMENT OF DEPOSITION

The palynofloral assemblage of the Barail Group of Changki-Mariani section is rich, both qualitatively and quantitatively. Most of the taxa recovered by the present investigation are prominent indicators of the climatic and ecological conditions. Several ecological and climatic indicator taxa recovered in the assemblage are shown in Table 3. Fungal remains recovered from the studied sequence suggest the then presence of a mesophytic forest of tropical to subtropical climatic conditions experiencing heavy rainfall (Selkrik 1975). Angiospermous pollen belonging to several families like *Poaceae* (*Graminidites*), *Sapotaceae* (*Iugopollis*), *Lepidocaryoideae* (*Longapertites*), *Oleaceae* (*Retitrescolpites*, *Anacolosidites*), *Santalaceae* (*Santalumidites*) *Lecythidaceae* (*Marginipollis*) also suggest warm tropical humid climate. *Olacaceae* is a tropical angiosperm family with a pantropical distribution. The fossils of this family are suggestive of a tropical climate, and in addition, are frequently used as a stratigraphic marker. Families *Betulaceae*

Table 3. Showing different ecological groups with their respective palynotaxa.

Ecological Groups	Palynotaxa
Low land elements	*Lakiapollis ovatus*
	Polycolpites ornatus
	Anacolosidites trilobatus
	Foveotricolporites callosus
Freshwater, swamps and water edge elements	*Lygodiumsporites rarus*
	Polygalacidites clarus
	Polypodiisporonites oligocenicus
	Retistephanocolpites granulatus
	Marginipollis kutchensis
Highland tropical elements	*Dicolpopollis proprius*
	Dicolpopollis edavensis
Sandy beach elements	*Spinizonocolpites echinatus*
	Liliacidites sp. cf. *L. ellipticus*

(*Alnipollenites*), *Gunneraceae* (*Tricolpites*), *Caesalpiniaceae* (*Foveotricolporites*) are cosmopolitan. *Tricolpites reticulatus* is a rhizomatic perennial herb of marshy places. *Gunneraceae* indicates freshwater swampy habitat. *Arecaceae* (*Proxapertites*, *Spinizonocolpites*) is a typical element of tropical climate and is restricted to the tropical-subtropical climatic zones. *Proxapertites microreticulatus* and *P. operculatus* are the climbers in evergreen forests and mangrove shrub zones. The mangrove taxa *Spinizonocolpites echinatus, Florschuetzia levipoli* are indicative of deposition of sediments in a brackish-water environment all along the coastal line, which is also known as delta front, inter-tidal, or a shallow marine environment. The family *Arecaceae* (*Dicolpopollis*) is a component of pantropical evergreen forest. The rhizomatous palm genus *Nypa* indicates true mangrove vegetation. Mangrove pollen grains *Nypa* and *Spinizonocolpites echinatus* (*Arecaceae*), suggest a deltaic and shallow marine environment (Monga et al. 2015). *Meyeripollis naharkotensis, Diporopollis assamica, Marginipollis kutchensis,* and the occurrence of coal seams indicate that the sediments were deposited in a deltaic swampy environment. The Barail Group is mainly characterized by the occurrence of marker fossil *Meyeripollis naharkotensis,* which is restricted to the Oligocene Barail Group (Banerjee 1975). Pteridophytic families *Matoniaceae* (*Dandotiaspora*), *Schizaeaceae* (*Hammenisporis*) and *Polypodiaceae* (*Laevigatosporites*) are the characteristic of tropical climate. *Polypodiaceae* (*Polypodiisporonites*) are cosmopolitan and perennial climbing fern, in a rainforest. *Dandotiaspora dilata* (*Matoniaceae*) suggests a shallow marine environment (Monga et al. 2015; Mathews et al. 2013). *Lycopodiales* (*Lycopodiumsporites*) are the climbing ferns associated with shrubby vegetation around a dense tropical forest of medium altitude. As well as the presence of fern spores indicate heavy rainfall and warm humid condition during the deposition of sediments. According to Morzadec-Kerfourn (1983), dinoflagellate *Operculodinium centrocarpum* indicates low salinity. The occurrence of Permo-Triassic acritarch (*Veryhachium*) has been marked in the sequence at the study area, which is considered to be reworked. The presence of acritarchs and dinoflagellate cysts are characteristic of shallow marine conditions. The conifer pollen, *Podocarpidites classicus* represent highlands or high-altitude provenance for the sediments from the surrounding areas or around the depositional terrain. The presence of less weathered Permian palynofossil, *Podocarpidites classicus* and *Platysaccus papilionis* from the Barail Group in the study area suggests Permian sources, probably be eastern Himalayas or Myanmar. Bisaccate pollen identical to the genus *Pinus* is commonly met in the Southeast Asian Oligo-Miocene sediments, in association with lesser frequencies of other gymnosperm pollen (Morley 1991).

Thus, from the above discussion on the palynotaxa, it can be concluded that the Barail Group was deposited in a swampy, deltaic, coastal to shallow marine environment. The climatic condition prevailed during the deposition of Barail Group was mainly warm and humid tropical to subtropical.

SUMMARY AND CONCLUSION

The palynofloral assemblage recovered from the Mariani-Changki Road section in Mokokchung District, Nagaland comprises of 42 species belonging to 35 genera. The palynoassemblage is dominated by the angiosperm pollen, followed by pteridophytic spores, acritarchs, gymnosperm pollen, and dinoflagellate cysts. Occurrence of coal bands and the presence of

carbonaceous shale point towards a reducing deltaic swampy setting or lagoonal depositional environment. Also, the presence of dinoflagellate cysts and spinose acritarchs, suggest marine sedimentary facies in a basin margin environment. Thus, a transition was observed in the deposition environments of sediments from shallow marine, deltaic, lagoonal to fluvial. The presence of a relatively higher frequency of the land-derived pollen and spores suggested a paralic condition of continental to shallow marine environment. The occurrence of *Meyeripollis naharkotensis, Polypodiisporonites oligocenicus,* suggested Oligocene age for the studied stratigraphic section. Abundant pteridophytic spores and the formation of coal in the study area reveal a tropical to sub-tropical climate with high humidity and heavy rainfall. Overall, the palaeoclimate during the Oligocene time (Barail Group of rocks) in the study area can reconstructed as tropical to subtropical with high humidity. From the palaeoecological analysis, we conclude that the palynoassemblage contains a variety of palynotaxa assignable to plants of various ecological communities such as lowland, freshwater, swamps, water edge, and sandy beach elements.

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