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# Age and depositional environment of the Upper Bhuban Formation of Champhai area (Eastern Mizo hills) India—A palynological approach

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**ABSTRACT**

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Palynological analysis of outcropping claystone, shale and alternation of sandstone –siltstone, Upper Bhuban Formation from Champhai, eastern Mizoram, India has been attempted. In all total 47 genera and 60 species are recognised in the assemblage. Of these 8 genera and 11 species are represented by pteridophytic spores and 27 genera and 35 species belong to angiospermic pollen, 6 genera and 6 species to gymnospermous pollen, fungal remains are also encountered. Some significant constituents of the assemblage are *Dictyophyllidites, Pteridacidites, Polypodiisporites, Lycopodiumsporites, Compositoipollenites, Polygonacidites, Malvacearumpollis, Hibisceapollenites, Cupuliferoipollenites, Alnipollenites, Engelhardtioidites, Pinuspollenites, Piceaepollenites* and *Podocarpidites.* Quantitative dominance of angiospermous pollen is a conspicuous feature of the assemblage. The recorded palynological assemblage indicates the prevalence of wet semi evergreen type of vegetation with warm and humid tropical-temperate climate with plenty of rainfall during sedimentation. On the basis of comparison of the present assemblage with the palynoassemblages known from Indian Tertiary sediments. An Upper Miocene age has been assigned to the Tertiary sediments of Champhai area of Mizoram.

**Key-words**—Palynology, Upper Bhuban Formation, Miocene, Champhai, Mizoram, India.

## भारत के चम्फ़ई क्षेत्र (पूर्वी मिज़ो पर्वत श्रेणियों) के उपरि भूबन शैलसमूह की आयु तथा निक्षेपणीय पर्यावरण—परागाणविक दृष्टिकोण

भगवानदास दोमाजी मंडावकर

**सारांश**

भारत के पूर्वी मिज़ोरम के चम्फ़ई क्षेत्र में अनावरित उपरि भूवन शैलसमूह से प्राप्त मृत्तिकाश्म, शेल तथा बालुकाश्म-पांशु प्रस्तर के एकान्तरण का परागाणविक विश्लेषण का प्रयास किया गया है। कुल 47 वंश एवं 60 प्रजातियों को इस समुच्चय से अभिज्ञात किया गया है। उनमें से 8 वंश एवं 11 प्रजातियाँ टेरिडोफाइट बीजाणुओं को निरूपित करती हैं, 27 वंश एवं 35 प्रजातियाँ आवृतबीजी परागकणों से सम्बन्धित हैं, 6 वंश एवं 6 प्रजातियाँ अनावृतबीजी परागकणों की हैं तथा इनमें कवकी अवशेष भी मिलते हैं। इस समुच्चय के कुछ मुख्य घटक-*डिक्टियोफिल्लीडाइटीज़, टेरिडेसीडाइटीज़, पोलिपोडीआइस्पोराइटीज़, लाइकोपोडियमस्पोराइटीज़, कम्पोज़ीटोईपोलेनाइटीज़, पोलीगोनेसीडाइटीज़, माल्वेसीरम्पोलिस, हिबिस्सीपोलेनाइटीज़, क्यूपुलीफिरोइपोलेनाइटीज़, एल्नीपोलेनाइटीज़, एन्गलहार्डटीओडाइटीज़ पाइनसपोलेनाइटीज़, पिसीयापोलेनाइटीज़* तथा *पोडोकार्पीडाइटीज़* हैं। आवृत्तबीजी परागकणों की मात्रात्मक प्रचुरता इस समुच्चय का सुस्पष्ट लक्षण है। अभिलिखित

परागाणविक समुच्चय अवसादन के दौरान प्रचुर वर्षा से उष्ण एवं आर्द्र उष्णकटिबंधीय-शीतोष्ण जलवायु के साथ आर्द्र सदाहरित प्रकार की वनस्पति की व्यापकता का संकेत करता है। वर्तमान समुच्चय की भारतीय टर्शियरी अवसादों से ज्ञात परागाणु समुच्चयों से तुलना करने के आधार पर मिजोरम के चम्फ़ई क्षेत्र के टर्शियरी अवसादों की उपरि मायोसीन आयु निर्धारित की गई है।

**संकेत-शब्द**—परागाणु विज्ञान, उपरि भूबन शैलसमूह, मायोसीन, चम्फ़ई, मिज़ोरम, भारत।

## INTRODUCTION

THE union territory of Mizoram, covering an area of about 25,000 sq km and exposing the sediments of the Tertiary Sequence which are 5,000 m thick. The entire terrain is mountainous and consists of synclinal valleys between two ranges. Mizo folded belt is composed of a series of longitudinal folds arranged en-echelon. The anticlines are long, narrow and tight but the intervening synclines are broad and gentle. Along the length of structures several reversals in the direction of plung are observed. The structures are offset by numerous faults and thrusts (Ganju, 1975). The stratigraphic succession exposed in these structures belongs to Surma and Tipam groups. Owing to the inaccessibility of the terrain, the geological investigation in Mizo hills is meagre. The early work was done by La Touche (1891), Hayman (1937) and Frankline (1948). Das Gupta (1948) reviewed the geology and petroleum prospects of Lushai hills and concluded that in general the area was unattractive. The palaeontological studies (Das Gupta, 1982; Sinha *et al.,* 1982) indicated that the lower age limit of Bhuban Sequence in Mizoram goes down to Oligocene. The fossils for above palaeontological studies were made only from upper horizon of Bhuban Sequence and they concluded Bhuban succession is homotaxial with Barail unit.

A little amount of palynological studies is known from the Hait and Banerjee (1994) which has not been successfully applied in deducing palaeoclimate and environment of deposition. Mandaokar (2000) studied the palynofloral sequence from the western flank of Aizawl Town, Ramrikawn, near Chandmari, Mizoram. The palynoflora suggest an early Miocene age for the sediments. Mandaokar (2002a) worked on palynological study of early Miocene sediments of Aizawl basin Dulte Formation, Surma Group, Mizoram is presented. Mandaokar (2002b) also carried out palynological studies from Keifang Formation, Mizoram. The palynoflora suggest an early Miocene in age.

Geological Survey of India published in a brochure of (1974) opined an Oligocene age equivalent to Barails of Assam for the exposures at Aizawl-Champhai Road, Mizoram. The geologists of Oil and Natural Gas Commission (Shrivastava *et al.,* 1979) and Jokhan Ram & Venkataraman (1984), on the other hand, are of opinion that these rocks are a part of Surma Group. Hait and Banerjee (1994) worked on two samples of Lignite from Mizoram and assigned a lower Miocene and Upper Miocene age for the sediments. Tiwari and Mehrotra (2002), advocated an Oligocene age for the same sediments. Agarwal and Mandaokar (2002), on the other hand suggested an early Miocene age for the Mizoram outcrop. Mehrotra and Mandaokar (2002) described Leguminous fruit from Mizoram and assigned a Lower Miocene age. The present palynological investigation was undertaken to solve the age controversy of these outcrops.

## MATERIAL AND METHODS

The area of investigation is located in the eastern flank of Aizawl hills. The Champhai locality lies about 23° 29' 06"N; 93° 16' 45"E. (Fig. 1). The area comprises a repetitive succession of argillaceous and arenaceous strata, which are present in a series of north- south trending en-echelon anticline and syncline. Lithologically the area is covered by unconsolidated alluvium comprising coarse grained, friable felspathic sandstone, reddish pink clays, carbonaceous shale, stringent

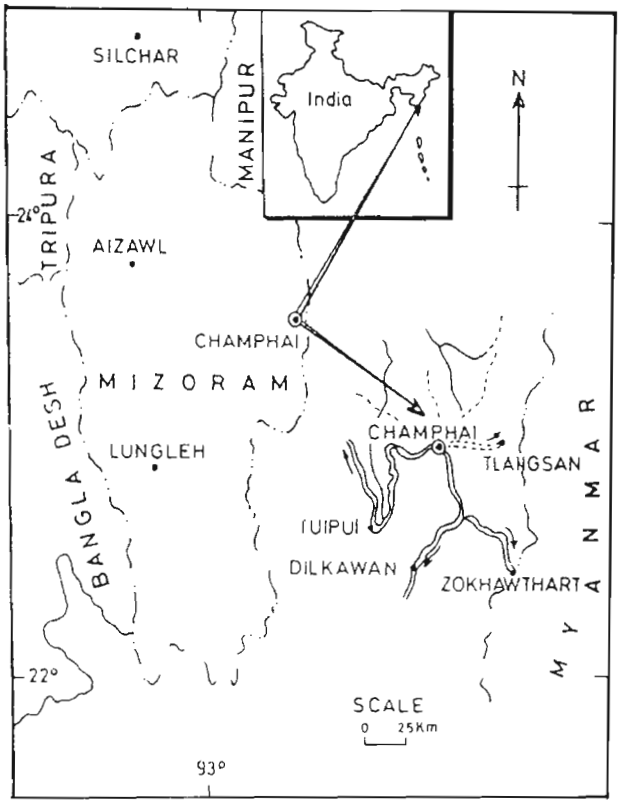


Fig. 1—Showing geological location of Champhai area

| Age | Group | Sub Group | Formation | Thickness | Lithology |
|---|---|---|---|---|---|
| Recent | Alluvium | | | | Silt, Clay & gravel |
| | | Unconformity | | | |
| Early Pliocene- Late Miocene | Tipam | | | + 900 m | Friable sandstone with occasional clay bands |
| | S | Conformable and Transitional contact | | | |
| | U | Bokabil | | + 950 m | Shale with siltstone and sandstone |
| Miocene | R | Conformable and Transitional contact | | | |
| | M | B | Upper Bhuban | + 1100m | Arenaceous with sandstone,shale & siltstone |
| to | A | Conformable and Transitional contact | | | |
| | | H U | Middle Bhuban | + 3000m | Argillaceous with shales, Silty-shales & siltstones |
| | | B | Conformable and Transitional contact | | |
| Upper Oligocene | | A N | Lower Bhuban | +900m | Arenaceous with sandstones & silty shales. |
| | Unconformity obliterated by fault | | | | |
| Oligocene | Barail | | | +3000m | Shale,Siltstones& Sandstone |
| | Lower contact not seen | | | | |

Fig. 2—Generalised stratigraphic succession of Mizoram (after GSI, 1974; Ganju, 1975).

of lignite and siltstones. For this purpose thirty samples were collected from claystone, dark to black splintery shale's with siltstone from Champhai. The samples were treated with usual maceration technique by using with HCL, HF and $HNO_3$ followed by 5% solution of KOH. The slides were prepared in polyvinyl alcohol and mounted in Canada balsam. An Olympus BH2 microscope has been used for encounting spore pollen and photography. The residual material, slides and negatives have been deposited in the museum of B.S.I.P. Lucknow.

## GEOLOGICAL BACKGROUND

Geologically, Mizoram is a part of Tripura-Mizoram miogeosyncline which constitute a part of Assam- Arakan geosynclinal basin. The Mizoram hills (Lushai Hills) considered to be forming an integral part of the mobile belt constituted very tight, elongated asymmetrical, N-S trending anticlines alternating with broad saucer shaped synclines showing a slightly arcuate and convex westward submeridional trends (Shrivastava *et al.*, 1979). The hills ranges mainly comprise of compact and resistant older units exposed in the anticlinal crests, whereas, of the valley are composed of younger and softer formation exposed in the synclinal troughs (Ganguly, 1975). The region is exposed mainly by geosynclinal molasse sediments of Neogene age, comprising poorly fossiliferous succession of alternating shales, mudstones, siltstone and sandstones in varying proportions. The generalised stratigraphic succession worked out by G.S.I. (1974) and Ganju (1975) is shown in Fig. 2.

The silty clays, shales are extremely rich in palynological fossils. The assemblage comprises 47 genera and 60 identifiable species. The excellently preserved, spores of pteridophytes and pollen grains of angiosperm, gymnosperm and fairly sizeable number of fungal fruiting bodies were recovered. The angiosperm pollen grains constitute the predominent elements of Champhai palynoflora. The gymnosperm pollen grains encountered in large numbers. Some genera like *Polypodiisporites, Pteridacidites, Malvacearumpollis, Compositoipollenites* and *Hibisceaepollenites* show a wide morphological variations. These genera and species are listed in Fig. 3.

**Pteridophytic spores**

*Cyathidites minor* Couper, 1953
*Deltoidospora halli* Miner, 1935
*Dictyophyllidites granulatus* Saxena, 1978
*Intrapunctisporis intrapunctis* Krutzsch, 1959
*Lycopodiumsporites globatus* Kar, 1985
*Polypodiaceaesporites levis* Sah, 1967
*Polypodiaceaesporites tertiarus* Dutta & Sah, 1970
*Polypodiisporites ornatus* Sah, 1967
*Pteridacidites africanus* Sah, 1967
*Pteridacidites rotundus* Sah, 1967
*Pteridacidites vermiverrucatus* Sah, 1967

**Gymnosperm pollen**

*Abiespollenites cognatus* Kar, 1985
*Cedripites nudis* Sah & Dutta, 1970
*Laricoidites* sp.
*Piceaepollenites naeransus* Mathur & Mathur, 1969
*Pinuspollenites crestus* Kar, 1985
*Podocarpidites ellipticus* Cookson, 1947
*Podocarpidites khasiensis* Dutta & Sah, 1970

**Angiosperm pollen**

*Alnipollenites verus* Potonie', 1931
*Araliaceoipollenites psilatus* Dutta & Sah, 1970
*Chenopodipollis miocenica* Kar & Jain, 1981
*Compositoipollenites africanus* Sah, 1967
*Compositoipollenites tricolporatus* Kar, 1985
*Cupuliferoipollenites ovatus* Venkatachala & Kar, 1969
*Cupuliferoipollenites pusillus* Potonie', 1951
*Dicolpopollis fragilis* Salujha Kindra & Rehman, 1972
*Dicolpopollis proprius* Salujha, Kindra & Rehman, 1972
*Engelhardtioidites minutiformis* Ramanujam & Reddy,1984
*Engelhardtioidites parvus* Sah & Dutta, 1966
*Favitricolporites eminens* Sah, 1967
*Graminidites granulatus* Kar, 1985
*Hibisceaepollenites splendus* Kar, 1985
*Ilexpollenites deliciosus* Sah, 1967
*Inaperturopollenites* sp.
*Juglanspollenites horniana* Raatz, 1937
*Malvacearumpollis bakonyensis* Nagy, 1962
*Monoporopollenites grameneoides* Meyer, 1956
*Pachydermites diederxi* Germeraad, Hopping & Muller, 1968
*Paleosantalaceaepites primitiva* Biswas, 1962
*Polygalacidites clarus* Sah & Dutta, 1966
*Polyporina globosa* Sah, 1967
*Potamogetonacidites cenozoicus* Sah, 1967
*Retipilonapites cenozoicus* Sah, 1967
*Retitrescolpites crassimurus* Sah, 1967
*Retitrescolpites oblongus* Sah, 1967
*Retitrescolpites splendens* Sah, 1967
*Retitrescolpites typicus* Sah, 1967
*Retitricolporites guianensis* Germeraad, Hopping & Muller, 1968
*Rhoipites anacardiodes* Ramanunam, 1966
*Rhoipites bradleyi* Wodehouse, 1933
*Sparganiaceaepollenites polygonalis* Thiergart, 1937
*Tricolpites crassireticulatus* Dutta & Sah, 1970
Tricolpites reticulatus Cookson, 1947
*Umbelliferoipollenites constrictus* Venkatachala & Kar, 1969

**Fungal remains**

*Dicellaesporites elongatus* Kumar, 1990
*Dicellaesporites minutus* Kar & Saxena, 1976
*Exesisporites verrucatus* Kumar, 1990
*Fusiformisporites acutus* Kumar, 1990
*Fusiformisporites crabbi* Rouse, 1962
*Gelasinosphaera* sp.
*Inapertisporites kedvesii* Elsik, 1968
*Inapertisporites variabilis* Van der Hammen, 1954
*Multicellaesporites nortonii* Elsik, 1968

**Insertae Sedis**

*Amorphous matter*
*Fibrous tissue*
*Leaf tissue*
*Woody tissue*

Fig. 3—Palynological check list in Champhai area

## AGE OF THE SEDIMENTS

The result of the traversing taken by geologists of Geological Survey of India along Aizawl-Champhai road have not been published so far. However, a reference about such a work is outlined in a brochure circulated on 125th anniversary of G.S.I. where a sequence of shale, sandstone, siltstone classified as Barail and Bhuban rocks. The occurrence of Barail in Mizoram is rather controversial. The worker of G.S.I. (1974) hold the view that the rock succession exposed in the eastern most part of the Mizoram state around Champhai can be equated with Barail Group on the basis of lithological contrast it bears with the overlying Surma Group of central Mizoram. The geologists of Oil and Natural Gas Commission (Shrivastava *et al.* 1979) and Jokhan Ram & Venkataraman (1984), on the other hand, are of opinion that these rocks are a part of Surma Group.

A review of the data obtained from Bhuban Formation eastern Champhai, Mizo hill clearly demonstrates a number of taxa in common with those from Maibong (Mandaokar, 1990). Palynological study of lignite samples (MIZ/L1; MIZ/L2) from two different localities of Mizoram, Eastern India has been made by Hait & Banerjee (1994). The analysis suggests a tropical to subtropical, humid and near shore environment viz., *Bombacacidites*, *Margocolporites, Pachydermites, Retitrescolpites, Nyssapollenites, Meliapollis,* etc. A lower Miocene age of MIZ/L1 is suggested. The MIZ/L2 assemblage is dominated by fresh water temperate taxa, no brackish water taxa are represented in this assemblage viz., *Querocopollenites*, *Alnipollenites, Compositoipollenites, Juglanspollenites* and *Graminidites* are encountered in MIZ/L2. Upper Miocene age suggested on the basis of the similarity of the assemblages with Tipam Sandstone and Girujan Clay palynomorphs (Shrivastava *et al.,* 1979; Banerjee & Uniyal, 1980).

An extensive search was made (Tiwari & Mehrotra, 2002) for plant impressions from the Palaeogene of Mizoram to

| Palynotaxa | Botanical Affiliations | Habitat |
|---|---|---|
| **Pteridophytes** | | |
| *Lycopodiumsporites* | Lycopodiaceae | Cosmopolitan |
| *Polypodiaceaesporites* | Polypodiaceae | Cosmopolitan |
| *Pteridacidites* | Pteridaceae (pteris) | Cosmopolitan |
| **Angiosperm pollen** | | |
| *Alnipollenites* | Betulaceae | Terrestrial-temperate |
| *Araliaceoipollenites* | Araliaceae | Terrestrial-tropical |
| *Compositoipollenites* | Asteraceae | Terrestrial-Cosmopolitan |
| *Cupuliferoipollenites* | Fagaceae (*Castanea*) | Terrestrial- temperate |
| *Dicolpopollis* | Arecaceae (*Calamus*) | Tropical- Coastal |
| *Engelhardtioidites* | Juglandaceae (*Engelhardtia*) | Terrestrial- Temperate |
| *Graminidites* | Poaceae | Cosmopolitan |
| *Juglanspollenites* | Juglandaceae (*Juglans*) | Terrestrial- Temperate |
| *Malvacearumpollis* | Malvaceae | Tropical- subtropical |
| *Monoporopollenites* | Poaceae | Cosmopolitan |
| *Polygalacidites* | Polygalaceae | Cosmopolitan |
| *Polyporina* | Chenopodiaceae | Tropical-Temperate |
| *Plumbaginacipites* | Plumbaginaceae | Tropical-Temperate |
| *Retitricolporites* | Tiliaceae | Marshy-tropical |
| *Retitrescolpites* | Oleaceae | Tropical-Temperate |
| *Retipilonapites* | Potamogetonaceae (*Potamogeton*) | Aquatic |
| *Rhoipites* | Anacardiaceae | Terrestrial-Temperate |
| *Sparganiaceaepollenites* | Sparganiaceae (*Sparganum*) | Fresh water- Temperate |
| *Tricolpites* | Clusiaceae | Tropical-temperate |
| **Gymnosperm pollen** | | |
| *Podocarpidites* | Podocarpaceae | Tropical-Temperate |
| *Pinuspollenites* | Pinaceae | Terrestrial-Temperate |
| *Piceapollenites* | Pinaceae | Terrestrial-Temperate |
| **Fungal remains** | | |
| *Exesisporites* | Microthyriaceae | Tropical-subtropical |
| *Fusiformisporites* | Microthyriaceae | Tropical-subtropical |
| *Gelasinosphaera* | Microthyriaceae | Tropical- subtropical |

Fig. 4—Summary of occurrence and botanical affinities of palynomorphs recorded in present paper.

reconstruct the palaeoenvironment of area. Leaf, fruit and seed impressions were collected from three fossiliferous localities situated near Champhai-Aizawl road, Mizoram. Megafossils viz., *Podocarpus oligocenicus, Vernonia palaeoarborea, Dicotylophyllum mizoramensis, Leguminocarpon mizoramensis, Terminalia precatappa* and *Corpolithus* sp. indicate Oligocene age belonging to Barail Group Agarwal and Mandaokar (2002) have identified as a fossil leaf impression as *Phyllanthus* of family Euphorbiaceae from Mampui area, Mizoram state of Eastern India. The leaf impression belongs to the Middle Bhuban Formation of Surma Group. Mehrotra and Mandaokar (2002) also described a new Leguminous fruit from the Middle Bhuban Formation of Surma Group, Aizawl Basin, Mizoram. The present fossil fruit has been collected from the silty sandstone and is Lower Miocene in age.

Mandaokar (2002a, b) carried out palynological studies from Keifang and Dulte formations, Aizawl Basin, Mizoram. The significant elements of the palynoassemblage are *Pteridacidites, Striatriletes, Compositoipollenites, Ctenolophonidites, Polyporina, Graminidites,* etc. The shale contains abundant plant remains and white gastropod shells. The alternation of shale - siltstone, sandstone - claystone, shale - sandstone ratio and palynoflora suggest an Early Miocene age. The key taxon *Hibisceaepollenites* indicate an Early Miocene age. It is also a dominant element in Khari Nadi Formation, Kachcch (Kar, 1985), Surma Group, Meghalaya & Assam (Rao *et al.,* 1985) but it is poorly represented in Mizoram Basin. *Pteridacidites* and *Compositoipollenites* have been recorded from Miocene sediments of Rusizi Valley, Burundi (Sah, 1967). Asteraceae and Pteridaceae are regarded as young families with their first occurrence dating back to Miocene.

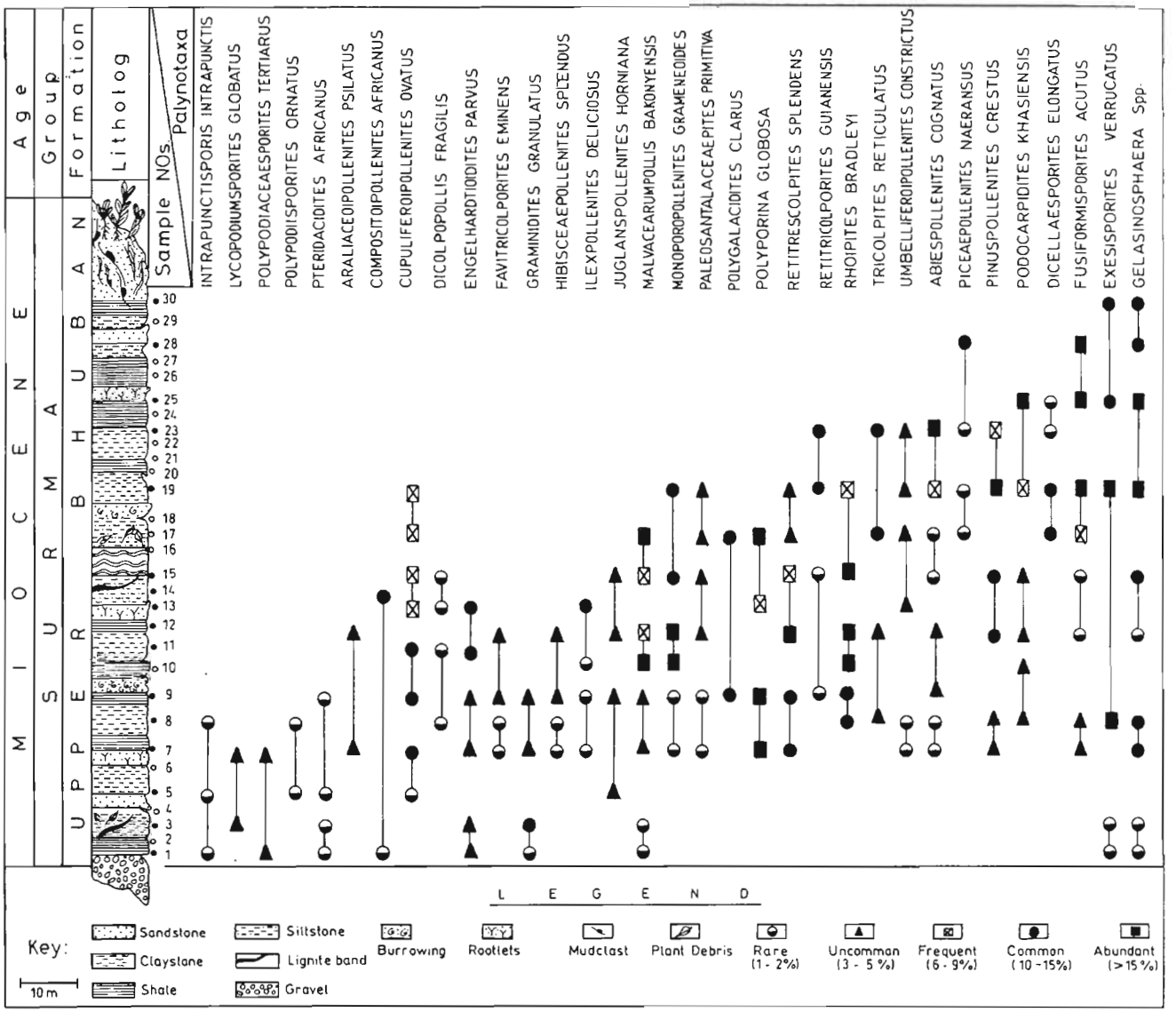


Fig. 5—Quantitative results and distribution of spore-pollen.

The distinctive pollen grains of *Malvacearumpollis* (Sah, 1967) is also significant. There is no fossil records of Malvaceae family from sediments older than Early Eocene. *Retitrescolpites* (Sah, 1967) has undoubted Oleaceous affinities. The geological history of the family dates back to Eocene and it became fairly widespread only during the Miocene.

The genus *Podocarpidites* (Potonié, 1958) is known to occur sporadically from Eocene and more commonly from Oligocene and Miocene. *Umbelliferoipollenites* is represented here by family Apiaceae also reported from Upper Miocene of Spain and Pliocene of Portugal. The pollen grain referred to *Polyporina* probably represent the chenopods. They are fairly common, which might indicate partly halophytic condition near the site of deposition. A recent palynological study of the Ramrikawn Aizawl District, Mizoram (Mandaokar, 2000), also provide cogent evidence that the palynoflora varies from Early Miocene to Upper Miocene in age.

The significant data obtained from Upper Bhuban Formation eastern Champhai, Mizo hills clearly demonstrates a number of taxa viz., *Pteridacidites, Compositoipollenites, Polyporina, Graminidites, Hibisceaepollenites, Retitrescolpites, Umbelliferoipollenites, Cupuliferoipollenites, Alnipollenites,* etc. which is dated as Early Miocene in age. The majority of the taxa are known from Eocene although some of them have been reported from sediment ranging in age from Palaeocene to Miocene. Therefore the present finding from Champhai area indicates that these taxa might have evolved in the Early Miocene in age but flourished only during the Upper Miocene. Further support is provided by O.N.G.C. (Shrivastava *et al.*, 1979) who have carried out

detailed work on the stratigraphy of Eastern Mizo Hills and they suggested an Upper Miocene age.

## BOTANICAL AFFINITIES

The botanical alliances of the dispersed palynotaxa are mainly with the ferns, among which several families including Polypodiaceae, Pteridaceae, Matoniaceae are represented. A variety of angiospermous and gymnospermous groups are also represented. Despite the evidently close stratigraphic association with shallow water deposits, the palynoflora contain no obvious forms of marine derivation. The assemblage appears to represent the autochthonous products of tropical fresh water swamps vegetation to low diversity. The present palynoassemblage shows difference from the assemblage described by Hait & Banerjee (1994) in the presence of gymnospermous pollen grains viz., *Podocarpidites, Pinuspollenites, Abiespollenites, Cedripites, Laricoidites* and *Piceapollenites*. On the other hand some of the angiospermous genera recovered by them was viz., *Ouerocopollenites, Retitricolpites, Foveotricolporites, Meliapollis, Nyssapollenites, Psilatricolporites, Zonocostites, Bombacacidites, Margocolporites, Palaeocoprosmadites, Nymphaeacidites, Betulaepollenites, Maculosporites, Tritriopollenites, Caryapollenites*, etc. was not found in the present assemblage. Hait & Banerjee (1994) also presented a table showing the botanical affinities of the different taxa however for the sake of convenience the palynoflora have been grouped on the general habitat are shown in the figure with botanical affinities (Fig. 4).

The palynoflora recorded in the present area were derived from essentially terrestrial and swampy inland vegetation growing in moist shady low lands and cool uplands in a subtropical to temperate climate. High altitudinal cold- loving plants emerges in the area suggest the existence of elevated topography in the surrounding deposition of the sediments. This interpretation is indicative of orogenic activity in the northern parts of the area, and consequently regression of the sea south words. Banerjee (1968) has discuss the change of topography in Middle Miocene times possibly due to this phenomenon of orogenic activity, while dealing with the significance of saccate conifer grains in the Tertiary of Assam and Siwalik palynoflora of Punjab. The presence of dominantly representative of herbaceous plants suggest drier climatic conditions which favoured the growth of grasses (*Graminidites, Monoporopollenites*), Chenopods (*Polyporina*), *Potamogeton, Retipilonapites* and *Polygalacidites* are commonly recorded in the area. During Pliocene and younger period, the swampy elements become more dominant in the vegetation. The coastal and marine element disappeared completely in this period which indicates that the sea had regressed much further to the south of Mizoram area by this time. During Palaeogene period the land in the northeast and northwest, the vegetation grew was not elevated but flat and low topography whereas in Neogene period the vegetation grew on much elevated land mass near the area of deposition.

## PALAEOCLIMATE AND DEPOSITIONAL ENVIRONMENT

The palynofossils are reliable indicators of past climate particularly when they are related and referable to modern taxa. Environmental interpretation deduced from individual taxa become more convincing when the floristic complex includes number of taxa with similar ecological requirements, thereby highlighting a characteristic natural biome and environment.

The characteristics palynoassemblage of Mizoram Lignite MIZ/L1 and MIZ/L2 Hait & Banerjee (1994) have revealed the influence of distinct ecological and climatic factors. The analysis suggests for tropical to subtropical humid and near shore environment of deposition for the MIZ/L1, Suangpuilawn village. The MIZ/L2, Champhai palynoassemblage do not contain gymnospermous pollen and *Cicatricosisporites*. These palynoassemblage is dominated by fresh water, temperate taxa, no brackish water and tropical to subtropical taxa are rarely represented. These accounts indicates dry and temperate environment for MIZ/L2 assemblage.

An overwhelming majority of the taxa with recognizable botanical affinities indicate the presence of either exclusively terrestrial, tropical to temperate families in the palynoflora. The occurrence of such families are Polypodiaceae, Araliaceae, Oleaceae, Anacardiaceae, Juglandaceae, Betulaceae, Fagaceae *etc.*, unequivocally points towards heavy precipitation. The epiphyllous fungi *Gelasinosphaera, Exesisporites, Fusiformisporites* recorded along with spore-pollen complex indicate warm and humid climate. The records of pollen types affiliated to Pinaceae and Podocarpaceae amply bear testimony to the prevalence of high land area. On the basis of present palynofossils it seems that the climate during the Neogene of Mizoram was of tropical humid type with plenty of rainfall. The modern climate of the Mizoram is also of the same kind. One is tempted to presume that perhaps there had not been much change in climate of this region since Neogene time. There were probably a number of fresh water ponds dotting the landscape as evidenced by the occurrence of pollen grains of Potamogetonaceae.

## PALYNOLOGICAL COMPARISON

During the last four decades significant contributions to the Tertiary palynostratigraphy of Kachchh, Meghalaya, Mizoram, Assam, Bengal, Tripura and South India have been made. A comparison of the present palynoassemblage with those known from the above areas has been attempted below.

### *Western India (Kachchh)*

Kar (1985) described spore-pollen from Khari Nadi Formation. Miocene Kachchh. This formation is composed of laminated mottled to variegated siltstone with occasional band of grey-brown and gypseous claystones. This assemblage is not much comparable except some gymnospermous pollen genera like *Abiespollenites, Podocarpidites, Pinuspollenites* and *Piceaepollenites*. The other palynomorphs like *Cordosphaeridium, Operculodinium, Aplanosporites, Tuberculodinium, Azolla, Biretisporites, Striatriletes, Khariasporites, Cingulatisporites, Laevigatosporites, Psiloschizosporis, Polyadopollenites,* etc. are absent from the present asemblage.

### *Northeast India*

The tropical to temperate palynoassemblage from Champhai Mizoram can be compared with the Bengal Palynozone V (Baksi, 1972). The palynozones of Bengal basin contains Hystrichosphaerides and dinoflagellate, in addition to brackish water, back mangrove taxa indicating more marine influence. Only gymnospermous pollen grains occur in low frequency in both the assemblages. The palynoassemblage recorded from Mizoram compared well with Meghalaya in the presence of *Rhoipites, Araliaceoipollenites, Tricolpites, Polygonacipites* and *Alnipollenites* (Nandi & Sharma, 1984). The present assemblage is also compared with those recorded by (Salujha *et al.,* 1972, 1973). Singh *et al.* (1986), studied Lower Miocene (Surma) sediments exposed along Sonapur-Badarpur road section Meghalaya. The above assemblages are found to be closely comparable to one another.

The genera *Alnipollenites, Compositoipollenites, Juglanspollenites* and *Graminidites* recorded in Champhai are also found in Tipam Sandstone and Girujan Clay of Upper Miocene age, Assam (Banerjee *et al.,* 1973; Banerjee & Uniyal, 1980; Singh & Saxena, 1984). The occurrence of gymnospermous pollen grain and high frequency of angiospermous grains in all the assemblage indicate similarity to the present assemblage. The palynological assemblage described by Kar (1990) is not much comparable to the present assemblage as the former has plenty of reworked Permian pollen.

The present assemblage has also been compared with known palynofloral assemblage of Tipam-Surma sediments from Naharkotiya - 1, Assam (Sah *et al.,* 1980) and Rokhia bore hole-1 and Baramura bore hole no. 2, Tripura, (Kar, 1990). Many palynofossils have been found to be common in between the two assemblage e.g. *Podocarpidites, Piceaepollenites* and *Pinuspollenites*. Gymnospermous pollen grains are found in abundance in Tipam-Surma sediments of Kharsang-2 and 3 bore hole of Arunachal Pradesh, however they are poorly represent in Duarmara-2 and Naharkotiya bore hole no. 263 and 268. The Kharsang palynofloral assemblage exhibits abundance of *Compositoipollenites, Polypodiisporites, Polypodiaceaesporites,* etc. Girujan palynological assemblage recorded by earlier workers (Sah & Kar, 1972; Singh & Saxena, 1984) are not much comparable with the present assemblage.

Hait & Banerjee (1994) reported rich palynological assemblage from Mizoram. The localities included MIZ/L1 near the Suangpuilawn village 23°55'N; 93°00' E about 20 Km north east of Aizawl and MIZ/L2 is from around Champhai 23°29' N; 93°18' E. The palynoflora comprises 50 genera and 36 species including pteridophytic spores and angiospermous pollen and fungal remains. On the basis of these taxa Upper Miocene age have been proposed. The important palynofloral elements present in the Miocene sediments of Champhai and Suangpuilawn are absent in the present assemblage are viz., *Ouerocopollenites, Retitricolpites, Foveotricolporites, Meliapollis, Nyssapollenites, Psilatricolporites, Zonocostites, Bombacacidites, Margocolporites, Palaeocoprosmadites, Nymphaeacidites, Betulaepollenites, Maculosporites, Tritriopollenites, Caryapollenites, Laevigatosporites, Palmaepollenites, Clavapalmaedites, Lacrimasporonites, Alternaria type, Dyadosporites,* Mycrothyriaceous fruit body and fungal polyad.

The present palynoassemblage is comparable with those from Champhai and Suangpuilawn, Mizoram in having following palynotaxa in common viz., *Lycopodiumsporites, Pteridacidites, Retipilonapites, Dicolpopollis, Tricolpites, Araliaceoipollenites, Cupuliferoipollenites, Foveotricolporites, Rhoipites, Retitricolporites, Retitrescolpites, Compositoipollenites, Graminidites, Sparganiaceaepollenites, Malvacearumpollis, Chenopodipollis, Polyporina, Juglanspollenites, Polygonacipites, Alnipollenites, Pachydermites, Fusiformisporites, Gelasinosphaera, Multicellaesporites, Exesisporites,* etc. Thus these two palynoassociations are homotaxial and come close to one another.

Mandaokar (2002a, b) studied detailed palynology and palaeoecology of the early Miocene sediments of Dulte and Keifang Formation, Mizoram. Thecommon constituents of Dulte and Keifang Formation and present palynoassemblage are viz., *Lycopodiumsporites, Pteridacidites, Cyathidites Pinuspollenites, Podocarpidites, Araliaceoipollenites, Retipilonapites, Dicolpopollis, Tricolpites, Araliaceoipollenites, Cupuliferoipollenites, Foveotricolporites, Rhoipites, Retitricolporites, Retitrescolpites, Compositoipollenites, Graminidites, Malvacearumpollis, Chenopodipollis, Polyporina, Juglanspollenites, Umbelliferoipollenites, Polygonacipites, Fusiformisporites, Gelasinosphaera, Multicellaesporites,* etc. Thus these two palynological assemblages mentioned above show many common elements.

*South India*

The palynoasemblages are closely comparable to the Neogene palynoflora of South India in the occurrence of stratigraphically important palynotaxa like *Compositoipollenites, Malvacearumpollis, Dicolpopollis, Graminidites, Polygonacidites, Pteridacidites, Lycopodiumsporites, Polypodiisporites,* etc. (Ramanujam & Rao, 1978 ; Ramanujam, 1995). Rao (1990, 1996) studied the palynostratigraphy of Arthungal bore hole in the Alleppey District and recognised three palynozones. Of these the upper most *Malvacearumpollis bokonyensis* cenozones consist of *Pteridacidites*, *Chenopodipollis* and *Compositoipollenites* are comparable with present Mizoram assemblage. The high sculptural fungal spores recovered in the present assemblage are comparable to Miocene Quilon beds of Kerala South India (Kumar, 1990) also suggest Neogene age of sediments. Ramanujam (1982) stated that spore types with highly sculptured wall are encountered consistently in Neogene sediments and forms like *Exesisporites, Fusiformisporites, Inapertisporites* and *Gelasinosphaera* may be stratigraphically significant elements. A close comparison with the present assemblage indicates close similarity.

## DISCUSSION

The palynological assemblage studied by Hait & Banerjee (1994), and Mandaokar (2000, 2002a, b) are well diversified and show some well preserved forms. The present assemblage comprises a number of genera and species. Most of their botanical affinities are provided in by Fig. 4. The important palynofloral elements, quantitative results and distributions of spore-pollen are shown in Fig. 5. It appears that the swampy vegetation was dominated by ferns, among which the families Polypodiaceae, Pteridaceae and Matoniaceae are significant. However, the majority of the fern spores present are from current evidence, attributable to living species or genera, in some cases unequivocally even to particular families. The Lycopods were evidently only minor component of the peat forming vegetation.

Palm pollen of the distinctive *Calamus* type is consistently represented in the studied assemblage. The characteristic dicolpate fossil pollen grains have been recorded from India both from Palaeogene and Neogene strata. The Palaeogene records of *Dicolpopollis* are from Palaeocene of Garo Hills, Meghalaya (Salujha *et al.*, 1972,1973). The significant Neogene records of this taxon are from Miocene deposit of Tripura (Salujha *et al.*, 1980; Salujha & Kindra, 1984). Dicolpate pollen types are found in some members of Araceae and Arecaceae. The modern *Calamus* species are climbing or straggling rattan palms mostly confined to riparian margin of peat-swamps beyond the saline influence in tropical regions with high precipitation (Haseldonckx, 1977). Similar ecological scenario was also prevalent in the Champhai area of Mizoram Basin during Miocene epoch.

The angiosperms constitute the largest contingent of Champhai palynoflora are represented by the pollen of monocotyledonous and dicotyledonous. The monocotyledonous are represented by the pollen of Potamogetonaceae *(Retipilonapites)*, Arecaceae *(Dicolpopollis)* and Poaceae *(Monoporopollenites, Graminidites)*. Of these the pollen of Arecaceae are sporadically represented and show significant resemblance with the pollen of modern palms viz., *Cocos*. Pollen grains refereble to the dicotyledons are Oleaceae *(Retitrescolpites)*; Araliaceae *(Araliaceoipollenites)*; Asteraceae *(Compositoipollenites)*; Polygalaceae *(Polygonacidites)* and Chenopodiaceae *(Polyporina)*. On the whole, angiosperm pollen of arborescent plants predominates over of herbaceous ones. The palynoflora recorded in Champhai area were derived from essentially terrestrial and swampy inland vegetation growing in moist shady low lands and cool uplands in a subtropical to temperate climate. High altitude cold-loving plants recorded in this area suggest the existence of elevated topography in the surroundings during deposition of the sediments. This is interpreted as indicative of orogenic activity in the northern parts of the area, and consequently regression of the sea south wards (Banerjee 1968).The amorphous matter, leaf tissue and woody fragments occur frequently in reduced environments. The evidence suggests that the spore-pollen were autochthonous drawn from a tropical fresh water swamp vegetation which was relatively low in diversity.

The stratigraphically important palynotaxa are *Polypodiisporites, Pteridacidites, Compositoipollenites, Malvacearumollis, Hibisceaepollenites, Alnipollenites, Cupuliferoipollenites, Graminidites,* etc. These palynomorphs together with the pollen of Oleaceae, Asteraceae and Malvaceae recorded in the Champhai could be assigned an Upper Miocene age.

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