



PALYNOFLORA FROM THE KEIFANG FORMATION (EARLY MIOCENE) MIZORAM, INDIA AND ITS ENVIRONMENTAL SIGNIFICANCE

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ABSTRACT

Palynological studies from the Keifang Formations, Aizawl, Mizoram have been carried out, and the results are presented herein. The Keifang sediments show cyclic alternation of light and dark grey shales with interbedded siltstone, sandstone, packstone and minor mudstone. The palynofloral assemblage consists of 45 genera and 60 species. The qualitative analysis of the assemblage reveals that *Polypodiaceae*, *Lycopodiaceae*, *Cyatheaceae*, *Podocarpaceae*, *Pinaceae*, *Palmae*, *Oleaceae*, *Malvaceae*, *Compositae* are representative of warm, humid climate with high rainfall during the time of deposition. Ecological analysis of the assemblage shows several palynooassociations of the low lands, fresh water, swamp and water edge, mangrove, sandy beach and back mangrove. The vegetation clearly points toward coastal, tropical-moist conditions during early Miocene of Mizoram.

Key words: Palynology, Keifang Formation, Miocene, Mizoram, India.

INTRODUCTION

The union territory of Mizoram, covering an area of about 25,000 sq. kms., exposes the sediments of the Tertiary sequence which are 5,000 m thick. The Mizo belt forms a part of the Arakan-Yoma belt. The latter evolved from an arc-trench type subduction and subsequent continental accretion. The entire mobile belt has been divided into five geotectonic provinces. A series of transverse faults have segmented the regional structure into several crustal blocks. The entire terrain is mountainous and characterised by a series of anticlinal and synclinal folds testifying to the first natural order of topography (Jokhan Ram and Venkataraman, 1984).

A little amount of palynological information is known from the Tertiary sediments of Mizoram (Hait and Banerjee, 1994) which has not been successfully applied in deducing palaeoclimate and environment of deposition. The Tertiary palynofossil locality in Mizoram are shown in fig.1. The present contribution deals with the palynology of the Keifang Formation with the objectives to study the palynoflora, to interpret the depositional environment and to determine the biostratigraphic potential of the palynofossils.

The area of investigation is located in the eastern flank of Aizawl hills. The Keifang Formation is exposed about 90 km northeast of Aizawl town (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 Keifang Formation is dominated by massive claystone, dark grey to black splintery shales and sandstone. For the recovery of palynofossils, the samples were treated with HCl, HF and HNO₃ followed by 10% solution of KOH. The slides were prepared in polyvinyl alcohol and mounted in canada balsam. The material

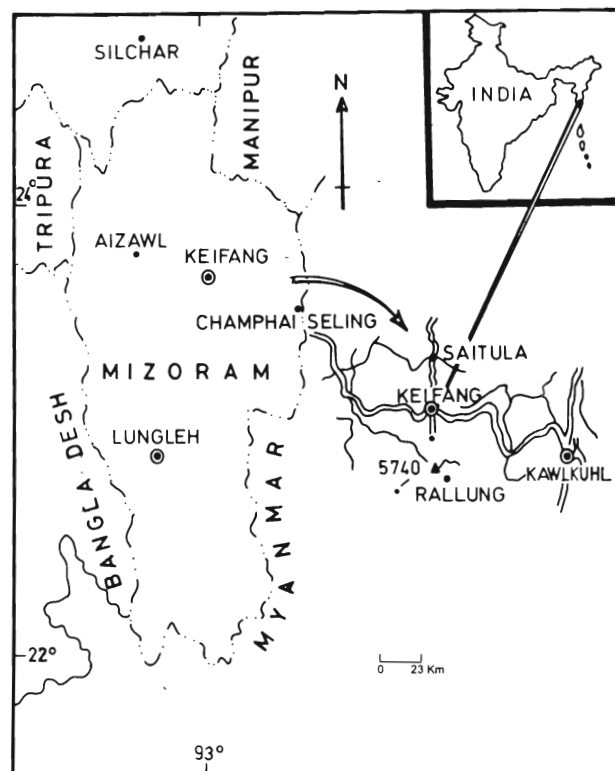


Fig.1. Showing location map of the Keifang area, Mizoram.

slides and negatives of the figured specimens have been deposited in the repository of BSIP, Lucknow.

REGIONAL SETTING

The earlier reports about of geology of Mizoram are by La Touche (1891), Hayman (1937), Franklin (1948) and Das Gupta (1948). These reports were followed by the geologists of G.S.I. and O.N.G.C. (Ganguly, 1975; Ganju, 1975; Das Gupta, 1977; Shrivastava *et al.*, 1979; Nandy, 1980, 1982; Jokhan Ram and Venkataraman, 1983, 1984). The sediments of Mizo hills have exposed a thick succession of the Surma Group, the Bhuban subgroup, the Keifang Formation in the Aizawl Basin, Mizoram State. In the eastern part of Mizoram, the Bhuban subgroup is subdivided on the basis of lithology into two formations, i.e Dulte and Keifang (Shrivastava *et al.*, 1979). These, however, have not been correlated with the subdivisions of lower, middle and upper Bhuban formations in western Mizoram. Therefore, the stratigraphic equivalence of the subdivisions of eastern Mizoram with those of western Mizoram still remains to be established. The Keifang Formation is dominantly arenaceous and is confined to the core of Tuivawl syncline. The sandstone is massive to bedded, grey with interbeds of grey claystone. The computed thickness of this formation is 1890 m. The stratigraphic succession of the Keifang Formation is given in table 1 (Shrivastava *et al.*, 1979).

KEIFANG FORMATION

The upper subdivision of the Bhuban subgroup exposed along the Seling-Champhai road section, having a predominantly arenaceous fraction, is informally proposed as the Keifang Formation after Keifang village. Its type section extends from Tuivawl river towards Keifang for a distance of nearly 10 kms along the road in the strike direction.

The Keifang Formation is virtually confined to the core of the Tuivawl syncline. Compared to the rest of the area, the terrain is less undulatory probably due to the predominance of sandstones, resisting the process of valley formation. The formation is predominately arenaceous with minor claystone and sandstone alternations (massive to bedded) showing grey to yellowish weathering. The sandstone is fine grained, hard, compact and micaceous. The claystone is bedded to thinly bedded, greenish grey to grey, moderately hard and often with lamination of silt alternating with sandstone.

PALYNOFLORAL COMPOSITION

The palynoflora from the Keifang Formation is composed of algal cysts, fungal remains, pteridophytic spores, gymnospermous and angiospermous pollen along with fibrous tissues and amorphous organic matter. The palynological assemblage comprises 45 genera and 60 species. The high percentage of angiospermous pollen taxa is noticeable. The palynoflora recovered from a variety of sediments comprising a mixture of shale-siltstone-clay, siltstone-sandstone alternation and mudstone units is listed in table 2.

QUANTITATIVE ANALYSIS

Quantitative analysis of the palynoflora reveals 45 genera and 60 species in the percentage count of the palynoassemblage. The percentage was calculated by counting 100 determinable species per samples. The frequencies of individual species have been given in the fig. 2.

The spore-pollen frequency in different levels of the Keifang Formation clearly indicates that vegetational pattern was more or less uniform throughout the deposition of the beds in the

Table 1: Generalised stratigraphic succession of the exposed sediments of the Keifang section (after Shrivastava *et al.*, 1979).

Group	Sub-group	Formation (Informal)	Lithology	Thickness in ft (metres)
S U R M A	B H U B A N	K E I F A N G	Predominantly arenaceous, comprising massive to bedded sandstone, minor claystone and sandstone-claystone alternations. Sandstone : massive to bedded, greyish, weathering to yellowish, fine grained, hard, compact and micaceous. Claystone: greenish grey to grey, moderately hard, micaceous, bedded to thinly bedded alternating with sandstone, and often with thin silty laminations and microcross laminations.	6200 ft (1890m)

Table 2: Palynofloral assemblage from the Keifang area, Mizoram, India.**Algal remains**

Oligosphaeridium complex Davey & Williams, 1966
Operculodinium centrocarpum Wall, 1966

Pteridophytic spores

Cyathidites minor Couper, 1953
Dictyophyllidites granulatus Saxena, 1978
Intrapunctisporis intrapunctis Krutzsch, 1959
Lycopodiumsporites lobatus Kar, 1985
Lygodiumsporites lakiensis Sah & Kar, 1969
Osmundacidites wellmanii Couper, 1958
Polypodiaceasporites chatterjee Kar, 1985
Polypodiaceasporites levis Sah, 1967
Polypodiaceasporites haardtii Potonié & Venitz, 1934
Polypodiaceasporites intrapunctis Rao & Ramanujam, 1982
Polypodiisporites miocenicus Rao & Ramanujam, 1982
Polypodiisporites ornatus Sah, 1967
Polypodiisporites mawkmaensis Dutta & Sah, 1970
Pteridacidites triangulatus Sah, 1967
Pteridacidites africanus Sah, 1967
Pteridacidites rotundus Sah, 1967
Todisporites major Couper, 1953

Angiospermous pollen

Alnipollenites verus Potonié, 1931
Araliaceipollenites psilatus Dutta & Sah, 1970
Chenopodiipollis miocenica Kar & Jain, 1981
Compositoipollenites serratus Sah, 1967
Compositoipollenites tricolporatus Kar, 1985
Cupuliferoipollenites ovatus Venkatachala & Kar, 1969
Cupuliferoipollenites pusillus Potonié, 1951
Dicolpopollis fragilis Salujha, Kindra & Rehman, 1973
Dicolpopollis propius Salujha, Kindra & Rehman, 1973
Engelhardtoidites minutiformis Ramanujam & Reddy, 1984
Engelhardtoidites parvus Sah & Dutta, 1966
Ericipites longisulcatus Wodehouse, 1933
Favitricolporites eminens Sah, 1967
Graminidites granulatus Kar, 1985
Hibisceapollenites splendidus Kar, 1985
Ilexpollenites rarus Sah, 1967
Ilexpollenites deliciosus Sah, 1967
Impatiensidites brevicolpus Sah, 1967
Jacobipollenites magnificus Ramanujam, 1966
Malvacearumpollis bakonyensis Nagy, 1962
Monoporopollenites gramineoides Meyer, 1956
Pachydermites diderixi Germeraad, Hopping & Muller, 1968
Polygalacidites clarus Sah & Dutta, 1966
Polyporina multiporosa Kar & Jain, 1981
Polyporina globosa Kar, 1985
Plumbaginacipites neyveli Navale & Mishra, 1979
Retipilonapites arcotense Ramanujam, 1966
Retitrescolpites typicus Sah, 1967
Rhoipites bradleyi Wodehouse, 1933
Sapotaceoidaepollenites obscurus Sah, 1967
Tricolpites crassireticulatus Dutta & Sah, 1970
Tricolpites medius Sah, 1967
Tricolpites retipilatus Kar & Jain, 1981
Umbelliferoipollenites constrictus Venkatachala & Kar, 1969

Gymnospermous pollen

Abiespollenites cognatus Kar, 1985
Podocarpidites ellipticus Cookson, 1947
Podocarpidites khasiensis Dutta & Sah, 1970
Piceapollenites excellens Kar, 1985

Fungal remains

Diporisorites curvatus Ramanujam & Rao, 1978
Exesisporites neogenicus Elsik, 1969
Fusiformisporites crabbi Rouse, 1962
Inapertisporites kedvesii Elsik, 1968

Incertae Sedis

Fibrous tissue
 Leaf tissue
 Woody tissue

sequence, although it is fairly certain that some changes in the vegetational pattern might have occurred above the three-meter level. The sediments are highly burrowed, and made up of shaly mudstones, lignite stringers and siltstones within the lower part of the Keifang Formation, where the basal (?) exposures are present. At the middle level of the quarry, a gradational change in the Keifang Formation from the pure grey shales to burrowed shaly claystones and finally to pure sandstones indicates a shallowing upwards sequence (fig.2). The sandstones are usually massive in appearance and often show dense mudclasts, with ostracodes indicative of outer-shelf environment. The middle and inner-shelf siltstones usually contain abundant gastropods, bivalves and broken microbored coralline algal fragments, transported from high energy environments.

At present, very little is known about the Tertiary palynoflora of Mizoram. Mandaokar (2000) studied the palynofloral sequence from the western flank of Aizawl town, Ramrikawn near Chandmari, Mizoram. Further contributions on the palynological study of the Tertiary sequence have not so far been published. Therefore, the nearest floristic composition that can be compared with are those described from the Dulte Formation, Aizawl Basin, Mizoram (Mandaokar, *in press*). A comparative study shows differences in the nature of the flora. Although there are common floral elements in both the assemblages in the Keifang assemblage, ferns are the dominant constituents which are less represented in the Ramrikawn palynoflora. The grasses are rather scant in the Keifang assemblage, whereas they form a dominant group in the Ramrikawn flora. The frequency differences have been noticed in the case of *Podocarpaceae*, *Pinaceae*, *Compositae*, and *Cyperaceae*. Detailed field mapping shows that the deposition of the Keifang Formation took place in a northeast trending turbidite. The presence of low frequency difference of *Podocarpidites*, *Abiespollenites* was noted in the outcrops as a rapid but gradational vertical change from siltstone to claystone. The presence of angiosperm pollen, e.g. *Compositoipollenites*, *Graminidites*, *Monoporopollenites*, implies that forests in low lands were interrupted by lake with extensive surrounding

wetlands. Most of the near-shore and inner-to-Middle-shelf sediments also show evidence of thick-walled, winged pollen grains that have been transported from the elevated areas which were not far away from the site of deposition. The fibrous tissue and skeletal fragments indicative of shallow water, moderate to high energy settings, were often transported to inner-shelf environments.

ECOLOGICAL INTERPRETATION

The assemblage indicates that the Keifang palynoflora was terrestrial and is composed of the tropical, subtropical and temperate elements. The habitat of the families of the Keifang palynoflora has been listed in table 3. Rao and Ramanujam (1982), Ramanujam (1987) and Rao (1995) have also utilised the flora to interpret the palaeoclimate. Of the 17 families, 10 are characteristic of tropical

climate, 5 families are restricted to subtropical-tropical conditions and two families pertain to tropical-temperate climatic conditions. The presence of spores of *Lycopodiaceae*, *Polypodiaceae*, *Schizaeaceae*, *Osmundaceae*, *Caesalpiniaceae*, *Oleaceae* and *Malvaceae* clearly indicates the prevalence of tropical humid condition at the time of deposition. The present-day climate of Mizoram is also of the tropical humid type with heavy precipitation. The presence of microthyriaceous fungal spores (*Diporisorites*, *Fusiformisporites*, *Inapertisporites*) and tropical epiphyllous fungi indicates the existence of a terrestrial plant ecosystem and supports an interpretation of warm and humid climate with heavy rainfall.

AGE OF THE SUCCESSION

A well-preserved sequence of the Tertiary strata

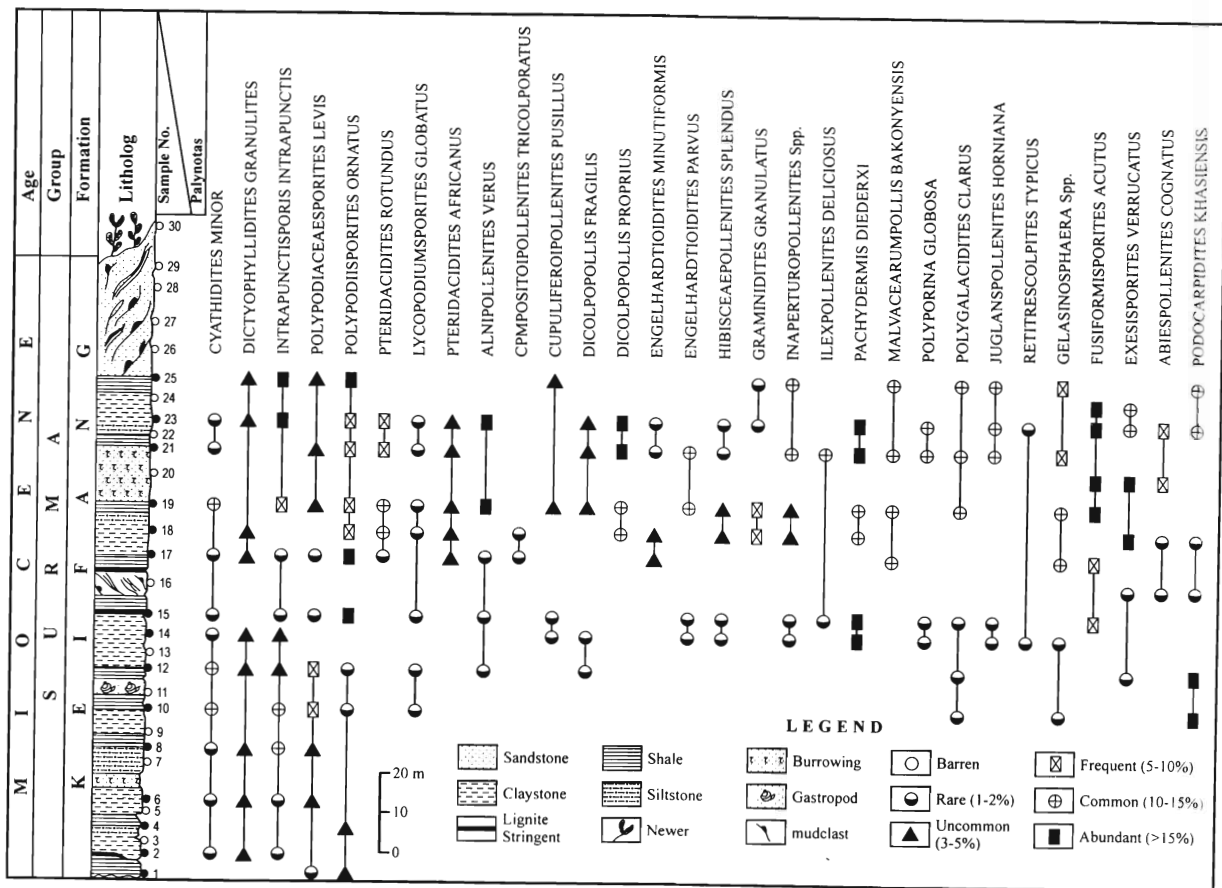


Fig.2. Floral distribution tied with the lithologic column of the Keifang Formation.

can be seen in the foothills of Keifang, Mizoram. The sequence has been of much interest to palaeobotanists, palaeontologists and geologists. The ill-preserved bivalves, barnacles, fish teeth, gastropods observed within the Keifang Formation have the potential of providing age- constraint to the sequence. Microfaunal studies are yet to be carried out.

Shrivastava *et al.* (1979) suggest that the total 1890 m thick sequence of the Keifang Formation exposed from west to east in the Tuivawl syncline, are lithologically identical with the Middle Bhuban and is mainly arenaceous. Further, it does not present any diagnostic variation in the sand-shale ratio on which it can be further subdivided into rock units which could be equated with the sand-dominated Lower Bhuban and the Barails of the type area along the Silchar-Imphal-Manipur road about 110 Km north where the latter rock units are well represented. The sediments of eastern Mizoram could be considered equivalent to the Bhuban subgroup which can be further subdivided into the lower argillaceous Dulte Formation and the upper arenaceous Keifang Formation.

A comparison of the present palynoflora with those from the Tertiary sediments of Assam, Meghalaya and Arunachal Pradesh reveals that the Keifang assemblage is closely similar to those assemblages which are characteristic of the Miocene sediments of these regions. Mandaokar (2000) was able to deduce the age of the marine succession in western Mizoram as early Miocene (Aquitanian-Burdigalian) on the basis of palynoflora. Mandaokar (*in press*) also made some interesting and significant palynological observation on the Dulte Formation of Aizawl district, Mizoram and suggested an early Miocene age for it. *Malvacearumpollis*, *Pteridacidites*, *Compositoipollenites* are some common early Miocene elements.

ENVIRONMENT OF DEPOSITION

The Keifang Formation represents a predominantly fine-grained depositional system characterised by laminated alternation of sandstone-siltstone and mudstones with a range of coarser sediment flow deposits (Shrivastava *et al.*, 1979).

The Tertiary sediments of the present sequence consist of pteridophytic spores, gymnospermic pollen, angiospermic pollen, fungal remains and dinoflagellate cysts. Palynological data were thoroughly scrutinized and palaeoenvironmentally significant taxa were selected and segregated for identifying several habitats, including montane, lowlands, fresh water swamp and water edge, mangrove and swampy beach-coastal elements. The botanical affinities of the palynotaxa of the Keifang Formation are given in the table 3.

Table 3: Botanical affinities of palynotaxa.

Name of Taxa	Botanical affinities
Montane elements	
<i>Podocarpidites</i>	Podocarpaceae
<i>Piceapollenites</i>	Pinaceae
Low land elements	
<i>Compositoipollenites</i>	Asteraceae
<i>Favitricolporites</i>	Vitaceae
<i>Retitrescolpites</i>	Oleaceae
<i>Tricolpites</i>	Gunneraceae
<i>Rhoipites</i>	Anacardiaceae
Sapotaceoidaepollenites	Sapotaceae
Fresh water swamps and water edge elements	
<i>Osmundacidites</i>	Osmundaceae
<i>Pteridacidites</i>	Adiantaceae
<i>Polypodiaceasporites</i>	Polypodiaceae
<i>Polypodiisporites</i>	Polypodiaceae
Mangrove elements	
<i>Malvacearumpollis</i>	Malvaceae
Sandy beach-coastal elements	
<i>Spinizonocolpites</i>	Arecaceae
<i>Palmaepollenites</i>	Arecaceae
<i>Graminidites</i>	Poaceae
<i>Polyporina</i>	Chenopodiaceae

Considering the modern affinities of the recorded palynotaxa and their distributional pattern, it is evident that the Keifang Formation was deposited under brackish water to shallow marine environments. The total percentage of dinocysts in the palynoassemblage is very low, which indicates brackish water environment. The pteridophytic spores represented mainly by *Todisporites*, *Foveotriletes*, *Lygodiumsporites*, *Osmundacidites*, *Pteridacidites* and *Polypodiaceasporites* are dominant and restricted to fresh water flood plains through time. Abundant terrestrial plant debris indicate both a good vegetal source area and a substantial fluvial input to the basin. Spore-pollen

assemblage from the Keifang Formation records a diverse land vegetation developed in a humid tropical to subtropical climate. Poor representation of gymnospermous pollen grains reflects the paucity of montane plants nearby. It also indicates that the taxa were growing mostly along the depositional sites. Montane flora mostly represented by gymnospermous taxa exhibits its maximum abundance in the Keifang Formation. It depicts the occurrence of higher lands around the depositional sites. The presence of fungal spores, viz. *Exesisporites*, *Diporisporites*, *Fusiformisporites* and *Inapertisporites* throughout the succession indicates a warm, humid climate. The occurrence of angiosperm pollen *Compositoipollenites*, *Polyporina*, *Graminidites*, *Retitrescolpites*, *Favitricolpites*, etc. represents the floral elements of lowland vegetation.

DISCUSSION

The palynoflora of the Keifang Formation consists of 45 genera and 60 species. Of these, 4 genera and 4 species belong to fungi, 10 genera and 17 species belong to pteridophytes, 3 genera and 4 species belong to gymnosperms and 26 genera and 33 species to angiosperms. Besides, dinoflagellate cysts have also been recorded. Palynological analysis has been supported by the study of several tissues such as fibrous, leafy and woody tissue which help to reinforce palaeobotanical interpretation. Though these tissues are well preserved, they are not identifiable to the appropriate generic level. Diessel (1986) introduced two types of petrographic indices of coal (GI=Gelification Index and TPI= Tissue Preservation Index) and related these indices, by comparison with sedimentological aspects of strata, to prevailing swamp types (dry forest swamp, wet forest swamp, fen and marsh vegetation). The gelification and tissue preservation values were also used to define depositional environments such as upper delta plains, lower delta plains, mangrove, back barrier, etc. It appears to be applicable to strata of other geological ages (Kalkreuth *et al.*, 1991). Thus, tissue preservation in these palynoassemblages also supports the occurrence of the forest fire at the time of deposition, and allows to infer a fluvio-marine conditions where the surrounding area sustained a

thick vegetation.

It is possible to attempt a reconstruction of general environmental condition that existed at the time of deposition. The topography was low, relatively flat, close to sea and swampy. Swampy conditions which probably prevailed over the area, are indicated by the presence of *Graminidites* which normally inhabits swampy areas and stream borders. Pollen grains of *Arecaceae*, *Oleaceae*, *Compositae*, etc are present. The spores of *Polypodiaceasporites* are common among the pteridophytic elements. In the Keifang Formation, *Piceapollenites* species form the bulk of the assemblage, whereas the angiospermous flora is subordinate. From the recorded palynofloral data, it is evident that during the time of deposition, the vegetation was temperate to subtropical in nature.

The site of deposition was a nearshore area which is evidenced by presence of the elements such as *Nypa* (*Spinizonocolpites*) and other arecaceous pollen. Ferns and low land flora also thrived near the coast and their spore-pollen were carried to the depositional site by water channels. Presence of dinoflagellate cysts indicates marine influence. Temperate elements (*Piceapollenites*) suggest that elevated area was not far away from the site of deposition. The overall vegetational composition indicates a coastal, tropical moist vegetation during the early Miocene in Mizoram.

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