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Palynostratigraphy and palaeoecological interpretation of Early Miocene sediments of Amarpur, Tripura, India

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ABSTRACT

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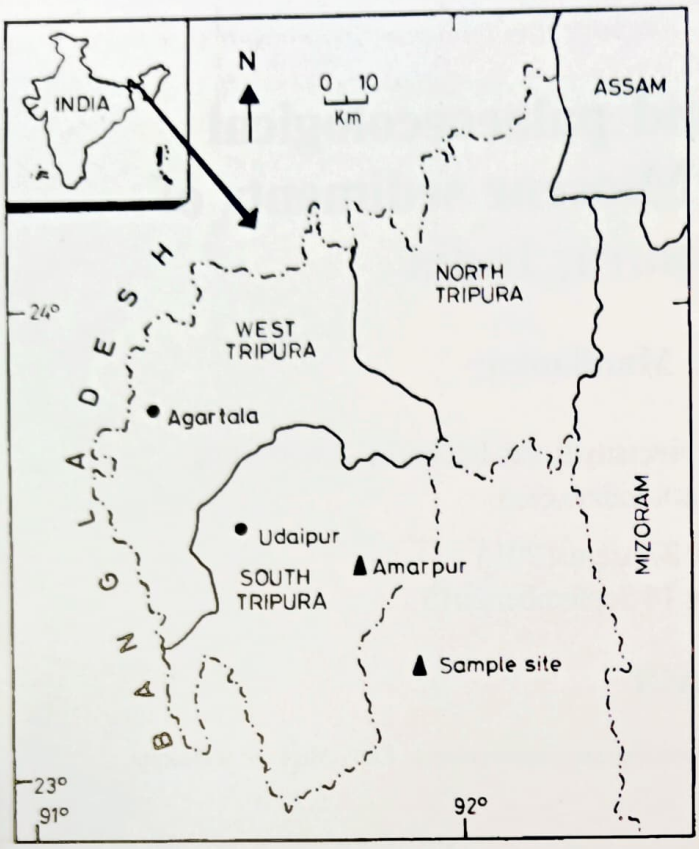
A rich and diversified palynofloral assemblage, comprising 97 genera and 124 species, has been recorded from the Middle Bhuban Formation of Amarpur, Tripura. The palynoassemblage is represented by dinoflagellate cysts (11 genera, 10 species), fungal remains (14 genera, 14 species), pteridophytic spores (16 genera, 32 species), gymnospermous pollen (4 genera, 9 species), angiospermous pollen (37 genera, 44 species) and reworked Permian and Cretaceous palynofossils (15 genera, 15 species). On the basis of frequency and distribution of palynofossils, three cenozones have been recognized. These are (in ascending order): *Pteridacidites vermiverrucatus* Cenozone, *Malvacearumpollis bakonyensis* Cenozone and *Albertipollenites crassireticulatus* Cenozone. The assemblage clearly indicates a tropical to subtropical, warm humid climate with high rainfall and sedimentation in a delta distributary channel with marine influence. The terrestrial elements of upland as well as lowland flora tend to merge with fresh water constituents. Dominant pollen genera of the assemblage (*Spinizonocolpites, Monocolpopollenites* and *Malvacearumpollis*) suggest brackish water mangrove swamp along the coastal line. Stratigraphically significant taxa, viz. *Clavaperiporites jacobii, Proteacidites triangulus, Spinizonocolpites echinatus, Pteridacidites vermiverrucatus, Retitrescolpites typicus, Malvacearumpollis bakonyensis* and *Albertipollenites crassireticulatus*, suggest an Early Miocene (Aquitanian-Burdigalian) age.

Key-words: Palynostratigraphy, palaeoecology, Bhuban Formation, Early Miocene, Amarpur, Tripura, India.

INTRODUCTION

Palynological investigation on the subsurface Surma-Tipam (LateTertiary) sediments of Tripura (Rokhia Borehole no.1, Gojalia Borehole no.1 and Baramura Borehole no.2, drilled by Oil and Natural Gas Corporation) has been carried out by Kar (1990). However, palynoflora from the Bhuban Formation (Early Miocene) of Amarpur, Tripura is not yet known (Text-figure 1). The main objective of the present study is therefore to record palynofossil assemblage and to establish a palynostratigraphic zonation based on their frequency and distribution at various levels of the stratigraphic succession studied. This helped in determining the age of the sediments and to bring out its relationship with stratigraphic sequences in other parts of Tripura basin. Botanical affinities of palynofossil species and present day distribution of their extant counterparts have been utilized to deduce palaeoclimate and depositional environment of the Bhuban Formation of Amarpur, Tripura.

The stratigraphic succession in Tripura basin begins with Surma Group which is divisible into Bhuban (Early Miocene) and Bokabil (Middle Miocene) formations. The Surma Group is overlain by Tipam Group with a



Text-figure 1. Map showing the location of the Amarpur area.

transitional contact and can be differentiated from the underlying Bokabil Formation by the occurrence of thick arenaceous sediments. This Group, exposed along both the limbs of Gojalia Anticline, is divisible into lower, Manu Bazar Formation and upper, Champanagar Formation. The Tipam Group is unconformably overlain by Dupitila Formation. The Dupitila Formation is unconformably overlain by alluvial sands and pebble beds of Middle Pleistocene-Recent age (Table 1, after Director General, Geological Survey of India 1974).

PALYNOFLORA

The palynofloral assemblage, recovered in this study, consists of 97 genera and 124 species belonging to algae (11 genera and 10 species of dinoflagellate cysts and sporadic occurrence of *Pediastrum* and *Botryococcus*), fungal remains (14 genera and 14 species), pteridophytic spores (16 genera and 32 species), gymnospermous pollen (4 genera and 9 species) and angiospermous pollen (37 genera and 44 species). Reworked Permian and Cretaceous palynofossils are represented by 15 genera and 15 species). The palynotaxa recognized here are given below and affinity and distribution of the important ones are shown in Table 2.

Algae: *Achomosphaera ramulifera* Evitt, *Areosphaeridium arcuatum* Eaton, *Botryococcus palanaensis* Sah & Kar, *Cleistosphaeridium diversispinosum* Davey et al., *Cordosphaeridium exilimurum* Davey & Williams, *Glaphyrocysta pastielsii* Stover & Evitt, *Homotryblium tenuispinosum* Davey & Williams, *Operculodinium centrocarpum* Wall, *Pediastrum* sp., *Polysphaeridium pastielsii* Davey & Williams, *Thalassiphora pelagica* Eisenack & Gocht.

Fungi: *Cervichlamydospora nigra* Kar et al., *Dicellaesporites elongates* Kumar, *Diporisporites*

Table 1. Generalized geological succession is in Tripura.

Group	Formation	Lithology
Recent	Recent	Alluvium represented by unconsolidated pale to dirty grey silt, sand, clay, silty clay, sandy clay, sometime with decomposed vegetable matters and yellowish brown coarse river sand, gravels and concretions.
		---------- Unconformity ----------
Dupitila	Dupitila	Earthy- brown to buff sandy clays with grayish brown to reddish brown sandy loam, mottled sandy clays, clayey sandstone, coarse to gritty ferruginous sandstone including lenticular bands, and pockets of bluish to grey plastic clays, white silica sand and laterites.
		---------- Unconformity ----------
Tipam	Champanagar	Massive medium to coarse, friable, sub-arkosic sandstone with occasional laminae of sandy – shale and abundant lumps of silicified fossil woods.
		---------- Contact gradational ----------
	Manu Bazar	Fairly bedded, fine to medium, subarkosic sandstone, including laminated layers and thick lenticular bands of sandy – shale, siltstone and sandy mudstone.
		---------- Contact transitional ----------
Surma	Bokabil	Thinly laminated and thinly bedded repetition of sandstone, siltstone/ shale alternation, shales, mudstone and ferruginous sandstone with irregular partings of fine to coarse sand and interstratified thick, occasionally lenticular horizon of medium to coarse, micaceous sandstone with mudstone.
		---------- Contact gradational to transitional ----------
	Bhuban	Indurated hard, compact, both massive and well bedded sandstone, dark to olive shale, sandy shale and siltstone repeatedly occurring in space. Base not seen

giganticus Kar, *Dictyostromata perfecta* Kar et al., *Fusiformisporites crabbii* Rouse, *Inapertisporites vulgaris* Sheffy & Dilcher, *Kutchiathyrites eccentricus* Kar, *Lirasporites elongates* Kar, *Lithomucorites miocenicus* Kar et al., *Multicellaesporites nortonii* Elsik, *Palaeogigaspora excellensa* Kar et al., *Palaeomycites globatus* (Sharma et al.) Saxena & Tripathi, *Phragmothyrites eocenicus* Edwards, *Pluricellaesporites planus* Trivedi & Verma.

Pteridophytic spores: *Cicatricososporites crassimurus* (Sah & Kar) Saxena, *Cheilanthoidspora monoleta* Sah & Kar, *Crassoretitriletes vanraadshooveni* Germeraad et al., *Cyathidites australis* Couper, *C. minor* Couper, *Dictyophyllidites cherrapunjensis* Kar & Kumar, *D. kyrtomatus* Kar & Kumar, *Gleicheniidites senonicus* Ross, *Hammenisporis aidaensis* (Kar) Saxena & Trivedi, *H. microverrucosus* (Kar & Saxena) Saxena & Trivedi, *H. multicostatus* (Kar & Saxena) Saxena & Trivedi, *H. susannae* (Van der Hammen) Saxena & Trivedi, *Intrapunctisporis apunctis* Krutzsch, *I. harudiensis* Kar, *Lycopodiumsporites globatus* Kar, *Laevigatosporites chatterjii* (Kar) Saxena & Trivedi, *L. levis* (Sah) Saxena & Trivedi, *Lycopodiumsporites speciosus* Dutta & Sah, *Lygodiumsporites lakiensis* Sah & Kar, *Osmundacidites cephalus* Saxena, *O. wellmanii* Couper, *Polypodiaceaesporites tertiarus* Dutta & Sah, *Polypodiisporites constrictus* Kar, *P. ornatus* Sah, *P. repandus* Takahashi, *Pilamonoletes excellensus* Kar, *P. moderatus* Kar, *Pteridacidites fistulosus* Sah, *P. tripuraensis* Kar, *P. vermiverrucatus* Sah, *Todisporites kutchensis* Sah & Kar, *T. major* Couper.

Gymnospermous pollen: *Abiespollenites absolutes* Thiergart, *A. cognatus* Kar, *Piceaepollenites excellensus* Kar, *P. alatus* Potonié, *P. naeraensis* Mathur & Mathur, *Pinuspollenites crestus* Kar, *Podocarpidites cognatus* Kar, *P. densicorpus* Kar, *P. khasiensis* Dutta & Sah.

Angiospermous pollen: *Acanthotricolpites brevicolpus* Kar, *Albertipollenites crassireticulatus* Dutta & Sah, *Bombacacidites bombaxoides* Couper, *B. triangulatus* Kar, *Chenopodiipollis miocenica* Kar & Jain, *Clavaperiporites jacobii* Ramanujam, *Compositoipollenites africanus* Sah, *C. conicus* Sah, *C. tricolporatus* Kar, *Dermatobrevicolporites dermatus* Kar, *Dicolpopollis kalewensis* Potonié, *Favitricolporites magnus* Sah, *Graminidites granulatus* Kar, *Hibisceaepollenites robustispinosus* Kar, *Lakiapollis ovatus* Venkatachala & Kar, *Magnamonocolpites miocenicus* Kar, *Malvacearumpollis bakonyensis* Nagy, *M. mammilatus* Kar, *Monocolpopollenites ovatus* Sah & Kar, *Myricipites singhii* Rao, *Neocouperipollis kutchensis* (Venkatachala & Kar) Kar & Kumar, *Operculosculptites baculatus* Kar, *Ornatetradites chandae* Rao & Ramanujam, *Palaeomalvaceaepollis mammilatus* Kar, *P. paucispinosus* Kar, *Paleosantalaceaepites minutus* Sah & Kar, *Pellicieroipollis langenheimii* Sah & Kar, *Periretitricolpites quambraensis* Jan du Chene et al., *Polyporina multiporosa* Kar, *Proteacidites triangulus* Kar & Jain, *Retipilonapites cenozoicum* Sah, *Retitrescolpites africanus* Sah, *R. crassimurus* Sah, *R. typicus* Sah, *Rhoipites kutchensis* Venkatachala & Kar, *Sonneratioipollis bellus* Venkatachala & Kar, *Spinizonocolpites echinatus* Muller, *Triangulorites bellus* Kar, *T. triradiatus* Kar, *Tricolporopilites pseudoreticulatus* Kar, *Trilatiporites noremii* Ramanujam, *T. retipilatus* Kar & Jain, *Trisyncolpites ramanujamii* Kar, *Verrutricolporites verrucus* Sah & Kar.

Reworked spores-pollen: *Callialasporites trilobatus* Dev, *Cannanoropollis obscures* Bose & Maheshwari, *Crescentipollenites fuscus* Bharadwaj et al., *Cuneatisporites rarus* Kar, *Densoisporites velatus* Weyland & Krieger, *Dulhuntyispora dulhuntyi* Potonié, *Faunipollenites varius* Bharadwaj, *Hindipollenites indicus* Bharadwaj, *Indotriradites korbaensis* Tiwari, *Klukisporites pseudoreticulatus* Couper, *Parasaccites korbaensis* Bharadwaj & Tiwari, *Platysaccus densus* Kar, *Potoniéisporites granulatus* Bose & Kar, *Scheuringipollenites tenuis* Tiwari, *Striatopodocarpites diffuses* Bharadwaj & Salujha.

PALYNOSTRATIGRAPHIC ZONATION

The palynoflora from Amarpur area in Tripura basin is characterized by well preserved palynofossils. First

and last occurrence of palynotaxa and their maximum development, decline, absence and restricted occurrence helped to divide the Bhuban Formation of the Amarpur area into three cenozones. These are (in ascending order): 1. *Pteridacidites vermiverrucatus* Cenozone; 2. *Malvacearumpollis bakonyensis* Cenozone; and 3. *Albertipollenites crasssireticulatus* Cenozone (Text-figure 2). A brief account of each cenozone is given below. For qualitative analysis, 100 specimens per samples were counted. Percentage of each palynotaxon was calculated and plotted under four categories, viz. rare (1-5 %), common (6 -9%), abundant (11-20%), and predominant (above 20%).

***Pteridacidites vermiverrucatus* Cenozone:** This cenozone is about 5.5 m thick. The significant taxa of this cenozone are *Pteridacidites vermiverrucatus, Osmundacidites wellmanii, Lycopodiumsporites globatus, Lygodiumsporites lakiensis, Dictyophyllidites kyrtomatus, Pilamonoletes excellensus, Hammenisporis susannae, Crassoretitriletes vanraadshooveni, Homotryblium tenuispinosum, Achomosphaera ramulifera, Botryococcus palanaensis* and *Pediastrum*. The important feature of this cenozone is the dominance of pteridophytic spores over the angiospermous pollen and fungal remains. *Pteridacidites vermiverrucatus* and *Homotryblium tenuispinosum* are about 20% in lower part and absent in the upper part of the cenozone. However, microthyriaceous fungal remains are abundant throughout the cenozone.

***Malvacearumpollis bakonyensis* Cenozone:** This zone has been recognized between 5 and 6 m. The characteristic palynofossils in this cenozones are *Crassoretitriletes vanraadshooveni, Clavaperiporites jacobii, Triangulorites bellus, Spinizonocolpites echinatus, Bombacacidites triangulatus, Dermatobrevicolporites dermatus, Compositoipollenites conicus, Retitrescolpites typicus, Pellicieroipollis langenheimii, Meliapollis quadrangularis, Hibisceaepollenites robustus, Retipilonapites cenozoicus, Neocouperipollis kutchensis* and *Malvacearumpollis bakonyensis*. The appearance of *Crassoretitriletes* and *Malvacearumpollis* is significant. Germeraad et al. (1968) studied distribution of the genus *Malvacearumpollis* which generally occurs in the Early Oligocene and reaches up to Miocene. Malvaceae is richly represented in the present day tropical to subtropical regions.

***Albertipollenites crassireticulatus* Cenozone:** The important taxa of this cenozone are *Acanthotricolporites brevicolpus, Triangulorites tetradites, Trisyncolpites ramanujamii, Graminidites granulatus, Dermatobrevicolporites dermatus, Favitricolporites magnus, Ornatetradites chandae, Podocarpidites cognatus, Pinuspollenites crestus, Compositoipollenites conicus, Polyporina multiporosa, Spinizonocolpites echinatus, Retipilonapites, Lithomucorites miocenicus, Palaeogigaspora excellensa* and *Albertipollenites crassireticulatus* which appear for the first time and are restricted to this cenozone whereas *Malvacearumpollis bakonyensis, Lycopodiumsporites globatus* and *Pteridacidites vermiverrucatus* are absent from this cenozone. There is relative increase in *Spinizonocolpites echinatus, Graminidites graminioides* and *Albertipollenites crassireticulatus*. From the fossil record, it seems that *Albertipollenites*, apparently referable to Gunneraceae (*Gunnera macrophyla*), plays an important role during Early Tertiary.

ENVIRONMENT OF DEPOSITION

The lithology of the Bhuban Formation of Amarpur area shows fresh water to brackish water deltaic deposition (Mandaokar 2015). The entire sequence has clay, shale, siltstone/ claystone and fine grained sandy grey shale association suggesting more or less stable condition. Clay/shale with distinct parallel ripples is suggestive of low energy and calm condition of deposition. The transgressive and regressive phases are identified in the succession on the basis of proportional distribution of marine phytoplanktons and land derived palynofossils. The dinoflagellate cyst show a remarkable change in quality and quantity from older to younger horizons. Chorate cysts, e.g. *Homotryblium tenuispinosum, Achomosphaera ramulifera, Cordosphaeridium exilimurum* along with *Glaphyrocysta pastielsii* and *Cleistosphaeridium*

Table 2. Distribution, habitat and extant comparable taxa of some palynofossils in Amarpur area, Tripura

Taxa	Affinity	Distribution and habitat
Fresh water & water edge elements		
Cyathidites australis	Cyatheaceae	Tropical-subtropical, characteristic elements of thick tropical forest.
Lygodiumsporites lakiensis	*Lygodium* Schizaeaceae	Tropical–subtropical, climbing fern associated with shrubby vegetation around thick forest.
Osmundacidites wellmanii	Osmundaceae	Tropical-subtropical, common in dense tropical forest.
Pteridacidites vermiverrucatus	*Onychium*, Adiantaceae	Subtropical, shade loving epiphyte on most moist bark and rocks.
Cicatricososporites crassimurus	Schizaeaceae	Tropical-subtropical, climbing fern associated with shrubby vegetation around thick forest.
Gleicheniidites senonicus	Gleicheniaceae	Tropical-subtropical, climbing fern associated with shrubby vegetation around thick forest.
Polypodiaceaesporites levis	*Microsorium punctatum* (Linn) Polypodiaceae	Humid subtropical climate, usually grow on tree trunk, low epiphytes/rocks.
Polypodiisporites miocenicus	*Polypodium* Polypodiaceae	Cosmopolitan, perennial fern.
Polypodiisporites constrictus	*Pyrrosia* (Mirble) Polypodiaceae	Cosmopolitan, montane forest, seasonally dry epiphytes & rocks.
Polypodiisporites ornatus	*Stenochlaena* Blechnaceae	Humid subtropical. perennial climbing fern. creeper on humus rich substratum in the forest of medium altitude.
Crassoretitriletes vanraadshoovenii	Schizaeaceae	Tropical-subtropical.
Hammenisporis susannae	*Ceratopteris* Ceratopteridaceae	Pan-tropical area, adaptation for floating aquatic environment.
Montane elements		
Clavaperiporites jacobii	Thymeleaceae	Cosmopolitan, montane elements, mostly woody in thick forest.
Proteacidites triangulus	Proteaceae	Cosmopolitan, climbers in evergreen forest.
Lowland elements		
Favitricolporites magnus	Rubiaceae	Cosmopolitan, fresh water element.
Monocolpopollenites ovatus	*Iguanura*, Arecaceae	Tropics of Malaya, low land evergreen vegetation.
Acanthotricolpites brevicolpus	Arecaceae	Tropical-subtropical, trees in rain forest.
Trisyncolpites ramanujamii	Caesalpiniaceae	Tropical-subtropical, generally woody climber in thick riverine forest.
Bombacacidites triangulatus	Bombacaceae	Tropical, swampy evergreen forest.
Lakiapollis ovatus	Durio type, Bombacaceae	Tropical, swampy evergreen forest.
Retipilonapites cenozoicus	*Potamogeton*, Potamogetonaceae	Cosmopolitan, perennial fresh water elements.
Periretitricolpites anambraensis	*Merremia*, Convolvulaceae	Warm tropical, climber of tropical forest.
Paleosantalaceaepites minutus	*Rhizophora-Bruguira* type	Tropical, mainly old world tree of back mangrove vegetation,
Rhoipites kutchensis	*Gluta*, Melanorrhoea, Anacardiaceae	Tropics of Indo-Malaya, trees of tropical forest.
Triangulorites triradiatus	*Epibolium* Onagraceae	Cosmopolitan, especially temperate to warm temperate, herb on moist places.
Spinizonocolpites echinatus	*Nypa fruticans*, Arecaceae	Tropics of south-east Asia and Australia, true mangrove palm.
Retitrescolpites typicus		Tropical, Malaysian tree in fresh water swamp.
Albertipollenites crassireticulatus	*Alchornea*, Euphorbiaceae	Tropical, element of open forest.
Tricolpites reticulatus	*Gunnera macrophylla*, Gunneraceae	Tropics of Malaysia, rhizomatic perennial herbs on marshy places.
Meliapollis quadrangularis	Clusiaceae	Tropical-subtropical, tree in fresh water swamp.
Ornatetradites chandae	Droseraceae	Tropical-subtropics, elements of open forest.
Neocouperipollis kutchensis	Arecaceae	Tropics of Indonesia, Philippines and Australia, dense evergreen forest of medium altitude.
Malvacearumpollis bakonyensis	Malvaceae	Cosmopolitan, tropical-subtropical, generally shrubs and trees in swamp areas.
Compositoipollenites conicus	Asteraceae	Cosmopolitan, especially temperate to warm temperate, herb on moist places.

diversispinosum, indicate a very shallow, near-shore marine depositional environment which was occasionally influenced by open marine conditions. Presence of gray shales in the lower most part of the succession also support this observation. This part of succession represents a major transgressive phase of sea in the area.

The regressive phase is pronounced at 10 m to 15 m level of this section. Palynological samples from this horizon yielded high amount of land derived elements,

e.g. pteridophytic spores, angiospermous pollen, fungal remains, cuticles, trachieds and woody material. A number of herbaceous taxa, viz. *Clavaperiporites jacobii* (Thymelaeaceae), *Chenopodiipollis miocenica* (*Chenopodium-Amaranthus*), *Proteacidites triangulus* (Proteaceae), *Retipilonapites cenozoicus* (Potamogetonaceae), suggest permanent water body nearby. Presence of fossil pollen comparable to extant plants, viz. *Rhoipites kutchensis* (*Gluta, Melanorrhoea* of Anacardiaceae), *Lakiapollis* (*Durio*), *Tricolpites crassireticulatus* (*Gunnera*), *Periretitricolpites anambraensis* (*Merremia* of Convolvulaceae), *Favitricolporites magnus* (Rubiaceae), *Trisyncolpites ramanujamii* (Caesalpiniaceae), *Paleosantalaceaepites minutus* (*Rhizophora, Bruguira* type/ Rhizophoraceae, collectively suggest swamp condition.

The palynofloral assemblage is characterized by the abundance of palm pollen, e.g. *Monocolpopollenites ovatus,* (Arecaceae) *Acanthotricolpites brevicolpus* (Arecaceae), *Spinizonocolpites echinatus* (Arecaceae), also indicates regression of sea in Aquitanian-Burdigalian time in the region. A few Permian to Early Cretaceous pollen grains e.g. *Faunipollenites varius, Crescentipollenites fuscus, Callialasporites trilobatus, Parasaccites korbaensis, Striatopodocarpites diffuses, Cuneatisporites rarus, Klukisporites pseudoreticulatus* possibly suggest that sediments were carried from inland and were deposited in the river mouth of delta. The well preserved palynomorphs in the middle part also suggest low energy and reducing environment. Significant increase in dinocyst population and a decline in terrestrial element in the interval of 15-20 m are interpreted as an indication of reappearance of minor transgressive phase and change toward comparatively higher energy and oxidizing environment in the succession. Younger horizons, exhibiting almost absence of biomass and increased sandy nature of sediments, suggest influx of terrestrial clastic material. The abundance of fresh water algae, *Pediastrum* in palynofloral assemblage indicates that there was a fresh water influx in the basin through river channel during the deposition of these strata. High incidence of fungal remains, consisting of spores, fruiting bodies and hyphae, is generally provided in deltaic substrate (Traverse 1988). Owing to undulating basement and heavy precipitation, lake/ pond developed on the eroded and depressed surface. The palynofloral assemblage of the younger horizons strongly suggest that deposition was in an estuarine environment at the top of a shallow basin.

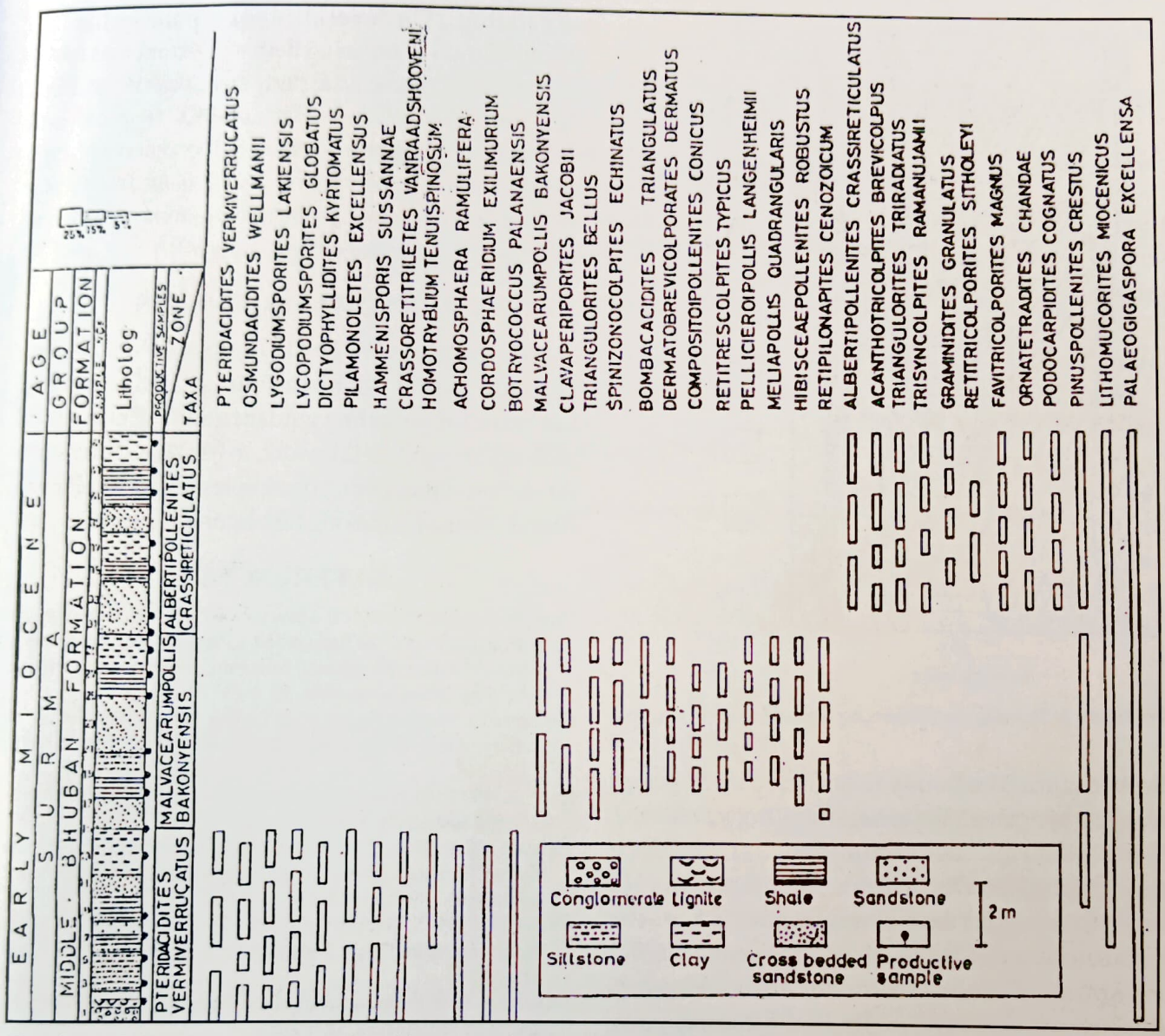
Together with the Tertiary palynofossils, some reworked Permian and Cretaceous palynofossils have also been recorded, viz. *Callialasporites, Klukisporites, Densisporites, Indotriradiates, Dulhuntyispora, Parasaccites, Cannanoropollis, Potoniéisporites, Platysaccus, Scheuringipollenites, Faunipollenites, Cuneatisporites, Crescentipollenites, Hindipollenites* and *Striatopodocarpites* etc. The occurrence of these palynofossils in the Miocene rocks is very important as these palynofossils suggest that sediments were carried from pre-existing inland Permian and Cretaceous sedimentary rocks and were redeposited in the river mouth of delta.

PALAEOECOLOGICAL IMPLICATIONS

For determining the palaeoecology, comparison between fossil and extant palynomorphs was made during assuming that the fossil taxa had more or less similar ecological preferences. Several ecologic and climatic indicators taxa recovered in the assemblage are shown in Table 2.

Fungal elements, consisting of spores, hyphae and microthyriaceous fruiting bodies, suggest present of mesophytic forest of tropical to subtropical climate with high rain fall (Selkrik 1975). Recovery of variety of fungal remains, e.g. *Diporisporites, Pluricellaesporites, Multicellaesporites, Lirasporis, Phragmothyrites, Kutchiathyrites, Cervichlamydospora, Dicellaesporites, Dictyostromata, Fusiformisporites, Lithomucorites, Palaeogigaspora, Inapertisporites, Palaeomycites* indicates warm and humid climate with heavy precipitation.

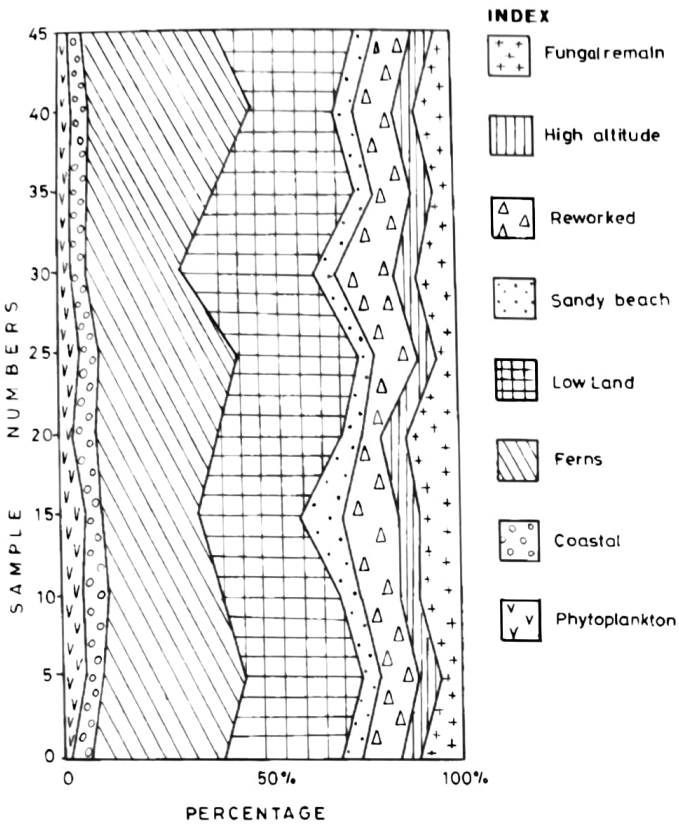
Pteridophytic spores belonging to Cyatheaceae (*Cyathidites minor, C. australis*), Pteridaceae (*P. vermiverrucatus*), Schizaeaceae (*Lygodiumsporites*



Text-figure 2. Showing the palynostratigraphic zonation for the Amarpur area

lakiensis, Cicatricososporites crassimurus, Crassoretitriletes vanraadshooveni), Osmundaceae (*O. wellmanii*), Gleicheniaceae (*G. senonicus*), Ceratopteridaceae (*Hammenisporis susannae*) collectively suggest warm and humid, tropical climate. Cyatheaceae and Schizaeaceae definitely indicate dense tropical forest of medium altitudes.

The pollen of Potamogetonaceae (*Retipilonapites*) suggest fresh water ponding condition. Pollen referable to Gunneraceae (*A. crassireticulatus*), Bombacacidites (*Tricolporopollis, Bambacacidites, Lakiapollis*), Rubiaceae (*Favitricolporites magnus*), Caesalpiniaceae (*Trisyncolpites ramanujamii*), Convolvulaceae (*Periretitricolpites anambraensis*), Anacardiaceae (*Rhoipites kutchensis*) is an indicative of lowland vegetation. The genera referable to the family Malvaceae (*M .bakonyensis*), typical back mangrove elements suggest deltaic condition (Text-figure 3). The existence of montane tropical flora is reflected by the pollen of Thymelaeaceae (*Clavaperiporites jacobii*), Proteaceae (*Proteacidites triangulus*), Podocarpaceae (*Podocarpidites cognatus, P. densus*). Arecaceae is a typical element of tropical climate and is restricted to tropical to subtropical



Text-figure 3. Showing the different ecological groups in the area.

climatic zone. The family is restricted by 5 species belonging to 5 genera and indicate truly tropical climate. The genera *Dicolpopollis* (*Calamus*), *Monocolpopollenites ovatus, Acanthotricolpites brevicolpus* suggest thick close evergreen forest. The rhizomatous palm genus *Nypa* (*Spinizonocolpites echinatus, Paleosantalaceaepites minutus, Neocouperipollis kutchensis*) indicates true mangrove vegetation. The overall above palaeoclimatic interpretation comparing between extant and fossil pollen taxa represent in the study area, it can be assumed that the palaeoclimate was mainly tropical and vegetation developed in warm humid condition with high precipitation. The palynotaxa also indicate fresh water swamp, lowland, mangrove and montane ecological habitat of the vegetation (Text-figure 3).

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