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Research Article

DINOFLAGELLATE CYSTS FROM BILKHAWTHLIR- RENGTEKAWN IN KOLASIB DISTRICT, MIZORAM, INDIA: THEIR BIOSTRATIGRAPHIC AND PALEOENVIRONMENTAL IMPLICATIONS

***B. D. Mandaokar**
Birbal Sahni Institute of Palaeobotany, Lucknow-226007, India
**Author for Correspondence*

ABSTRACT
A rich and diversified palynofloral assemblage from Bhuban Formation exposed along road section on the northwest of Bilkhawthlir- Rengtekawn area, Mizoram has been investigated. The recovery of the palynomorphs belonging to pteridophytic spores and angiospermic pollen is extremely poor. Results indicate that the section consists of rich dinocyst assemblage showing significant variation in the palynofacies, helpful in interpretation of paleoenvironmental changes. The dominant dinoflagellate cysts are *Operculodinium, Homotryblium, Achomosphaera, Cordosphaeridium, Cleistosphaeridium, Chiropteridium, Polysphaeridium, Lingulodinium, Lejeunecysta, Selenopemphix, Cibroperidinium, Impagidinium, Nematosphaeropsis, Pentadinium, Sumatradinium, Thalassiphora, Hystrichokolpoma* etc. Associated palynofossils recorded from the sediments are *Pteridacidites, Striatriletes, Spinizonocolpites, Retitrescolpiles, Compositoipollenites, Malvacearumpollis* etc. Typical Permo-Triassic palynoassemblage having dominance of *Klausipollenites, Crescentipollenites, Faunipollenites, Alisporites, Falcisporites, Indotriradites, Densoisporites have* also been recorded from the sediments. On the basis of dinocyst assemblage an early Miocene age has been assigned. The depositional facies represent shallow marine transgressive environments in nature, reflect with sea level fluctuations. The studies show warm and humid climate. In addition to the above findings some stratigraphically reworked palynofossils are also recorded.

Key Words: *Palynology, Dinoflagellate, Bhuban Formation, Mizoram, India*

INTRODUCTION
The Territory of Mizoram covering an area of about 25,000 sq km and exposed over 5000 m thick has been studied, but for some reconnaissance geological survey, the area is practically unexplored for hydrocarbon. With the rapid growth of oil exploration a lot of subsurface data is continuously being generated from different prospective basins. During last twenty years the presence of dinoflagellate cysts were simply recorded from marine to transitional sediments by ONGC palynologists. However, the detailed studies on this group of microfossils began from Mizoram only after the publication of a series of papers by (Mandaokar, 2000, 2002, 2008 and Mandaokar and Kar, 2010).
Recently Mandaokar (2008) presented a detailed palynostratigraphic zonation for early Miocene transition in Mizoram. This scheme is based on spore- pollen, dinoflagellate cyst successions and documented marine section straddling the early Miocene boundary in southern Mizoram. Furthermore, by analyzing the distribution pattern of low and high latitude dinoflagellate taxa, the author observed that dinoflagellate cysts can be applicable for the recognition of changes in sea surface temperature. Moreover, some evidence was available that, in deeper marine deposits, changes in the distribution of dinoflagellate cysts derived from marginal marine environments. However, due to the condensed nature of the early Miocene transition sections in southern Mizoram, palynologically deduced sea level fluctuation are not accompanied by marked lithological changes. In order to validate the concept of the sensitivity of the dinoflagellate record in detecting Oligocene / Miocene sea level fluctuations, it is necessary to study time equivalent marginal marine sedimentary sequences in which sea-level change may be expected as expressed in lithological characteres

Geological Setting
Geologically Mizoram- Tripura depositional basin is a part of the larger Assam - Arakan basin. Argillaceous and arenaceous sediments occur here in alternation and forms N-S trending and longitudinally plunging

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anticlines and synclines (Ganju, 1975 and Ganguly, 1983). The strata generally trend NS with dipping 20° to 50°either eastward or westward and comprise interbedded sandstone with local lenses of conglomerate, siltstone, shale, mudstone with a few pockets of shell limestones, calcareous sandstone and intraformational conglomerate with occasional coaly stringer in basal part, while appearance of fossiliferous calcareous lenses in the upper part is noted (Karunakaran, 1974).

Table 1: Generalised stratigraphic succession in Mizoram (after Karunakaran, 1974 and Ganju, 1975).

Age	**Group**	**Subgroup**	**Formation**	**Thickness in meters**	**Lithology**
Recent	Alluvium				Silt, clay and gravel
		Unconformity			
Early Pliocene-Late Miocene	Tipam			+ 900	Friable sandstones with occasional clay bands
Conformable and transitional contact					
Miocene to Late Oligocene	S U R M A		Bokabil	+ 950	Shales with siltstones and sandstone
		Conformable and transitional contact			
		BHUBAN	Upper Bhuban	+ 1100	Arenaceous sandstones, shales and siltstones
			Conformable and transitional contacts		
			Middle Bhuban	+ 3000	Argillaceous with shales, silty shales and siltstones
			Conformable and transitional contact		
			Lower Bhuban	+ 900	Arenaceous with sandstones and silty shales
Unconformity obliterated by fault					
Oligocene	Barail			+ 3000	Shales, siltstones and sandstones
Lower contact not seen					

Lower Bhuban Formation

Lower Bhuban is the oldest exposed formation in Mizoram. The formation comprises of alternation of shale and sandstone. The shales are bluish - grey to greenish grey, laminated and exhibit spheroidal weathering, lenticular bedding is characteristic of sequence. Silts are thin bedded and microcross laminated. Ichnofossils are fairly common. The sandstone is grey, fine grained, silty with medium scale cross -stratification. Channel lag conglomerates with molluscan shells are fairly common and the sands display fining upwards sequence. The maximum thickness exposed on the eastern limb of Teidukhan anticline is 900 m.

Middle Bhuban Formation

It is predominantly an argillaceous sequence with subordinate, sandstones which occur as intercalations. The shales are grey to dark grey in colour, show spheroidal concretions. The sandstones are thin bedded to massive, ill sorted, silty, and are fine grained. Ripple laminations, lenticular bedding and flaser bedding are commonly observed in the sandstones. Small scale cross - stratification, current and interference ripples, and sandstone dykes have also been observed in the siltstone. The sedimentary structure indicates a west to south- westerly palaeocurrent direction for lower Bhuban. The maximum thickness of this formation measured on the eastern limb of lunglei anticline is 2840m.

Upper Bhuban Formation

The Upper Bhuban Formation is an alternating sequence of arenaceous and argillaceous elastics is almost equal proportions. The sandstones are thin bedded to massive grey, fine grained silty and ill sorted, clay pellets and lignite lenses are observed along bedding. Channel lag conglomerate wherever present certain fragments of claystones, shale and siltstone set in silty matrix. Some of these conglomerate bands also contain broken shells of mollusks. The sandstones mega ripples with wave lengths of several feet have been observed at places along with small to medium scale cross -stratification. The shales are bluish grey, thinly laminated splintery; fissile, micaceous with lenticular bedding formed of ripple laminated siltstone or very fine grained sandstone. The massive bedded siltstone show evidences of bioturbation now occurring in the form of sand filled tabular bodies. The thickness of this formation is 1080 m exposed in western limb of lungsen anticline.

MATERIALS AND METHODS

Samples for the present study were collected from sections exposed northwest of Mizoram. The section lies along the Bilkhawthlir- Rengtekawn road in the vicinity of Kolasib (Fig. l).

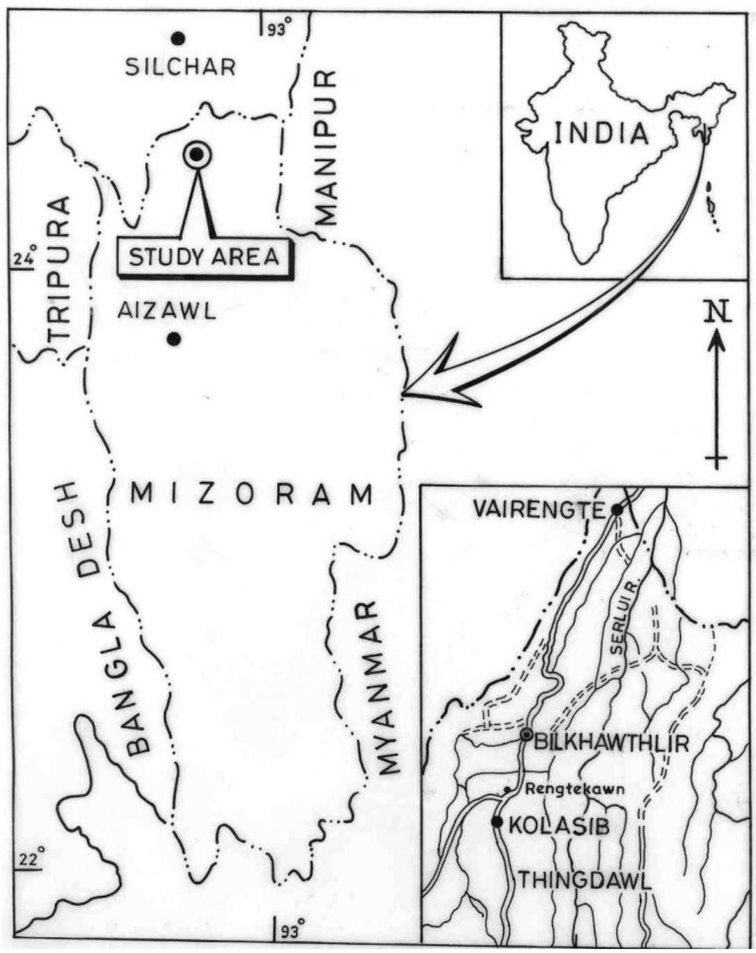

Figure 1: Showing the fossil locality of Bilkhawthlir – Rengtekawn area in Kolasib district

Out of 90 samples, 17 proved to be productive yielding of dinoflagellate cysts. For the recovery of dinoflagellate cysts, the samples were processed during standard palynological techniques. After HCL and HF treatment, the macerate was treated with 40% HNO3 for oxidation and washed using 25µ sieve. The water free residue mixed with polyvinyle alcohol was spread evenly on the glass cover. Permanent slides were preserved by fixing the oven dried cover slides using Canada balsam as the mounting media. Study and photography was carried out on Olympus BH2 microscope with contrast and automatic photo attachments. The illustrated dinoflagellate cysts are provided with the England Finder positions on the respective slides. The slides have been registered and deposited in the repository of the Museum Birbal Sahni Institute of Palaeobotany, Lucknow.

RESULTS

Dinoflagellate Assemblage

Fossil dinoflagellate cysts were recovered from all samples, except 2, 6, 10, 14, 18, 20 and 26. The cysts abundance is usually low, except in 28 and 58 (with 180 cysts per slides). Thirteen samples contain 12 -80 cysts per slides, and the remaining 18 contain fewer than 10 - 28 cysts per slides, less than ideal for quantitative studies. The total number of taxa recorded by 51 genera and 62 species but each samples contains relatively few. A low number of pollen spores are often associated with dinoflagellate cysts, in addition to abundant pollen and spores, with bisaccate pollen being dominant (table -2). The Check list of cyst taxa recorded from the assemblage in Table 2.

Dinoflagellate cysts.

Achomosphaera ramulifera (Deflandre, 1937) Evitt, 1963
Adnatosphaeridium vittatum Williams and Downie, 1966
Apteodinium spiridoides Benedek, 1972
Apteodinium maculatum Eisenack and Cookson, 1960
Apteodinium augustum Harland, 1979
Areoligera senonensis Lejeune - Carpentier, 1938
Chiropteridium lobospinosum Gocht, 1960
Chiropteridium galea Sarjeant, 1984
Cleistosphaeridium diversispinosum Davey *et al.*, 1966
Cordosphaeridium gracile Davey and Williams, 1966
Cordosphaeridium inodes Eisenack, 1963
Cordosphaeridium cantharellum (Brosius) Gocht, 1960
Cribroperidiniumgranomembranaceum Lentin and Williams, 1981
Cribroperidinium tenuitabulatum (Gerlach) Helenes, 1984
Dapsilidium pseudocolligerum Bujak *et al.*, 1980
Diphyes colligerum Cookson, 1965
Glaphyrocysta intricata Stover and Evitt. 1978
Glaphyrocysta exuberans Stover and Evitt, 1978
Homotryblium tenuispinosum Davey and Williams, 1966 a
Homotryblium plectilum Drugg and Loeblich,1967
Homotryblium vallum Stover, 1977
Hystrichokolpoma rigaudiae Deflandre and Cookson, 1955
Hystrichokolpoma cinctum Klumpp, 1953
Hystrichosphaeridium tubiferum (Deflandre) Davey and Williams, 1966b
Hystrichosphaeropsis sp.
Impagidinium dispertitum Cookson and Eisenack, 1965
Impagidinium patulum Stover and Evitt, 1978
Impletosphaeridium sp.
Lejeunecysta hyalina Sarjeant, 1984
Lejeunecysta cinctoria Lentin and Williams, 1981
Lingulodinium machaerophorum Wall, 1967
Melitasphaeridium choanophorum Harland, 1979
Membranophoridium aspinatum Gerlach, 1961
Nematosphaeropsis labyrianthus Deflandre and Cookson, 1955
Nematosphaeropsis lemniscata Bujak, 1984

Operculodinium centrocarpum Wall, 1967
Pentadinium laticinctum Gerlach, 1961
Polysphaeridium subtile Davey and Williams, 1966
Polysphaeridium zoharyi Bujak *et al.,* 1980
Selenopemphix coronata Bujak *et al.,* 1980
Selenopemphix nephroides Bujak *et al.,* 1980
Selenopemphix selenoides Bujak *et al.,* 1980
Spiniferites ramosus Davey and Williams, 1966
Spiniferites mirabilis Sarjeant, 1970
Spiniferites ellipsoideus Matsuoka, 1983
Sumatradinium hispidum Lentin and Williams, 1976
Thalassiphora pelagica Eisenack and Gocht, 1960
Thalassiphora patula Stover and Evitt, 1978
Tityrosphaeridium gracile Sarjeant, 1981
Tuberculodinium vancampoae Wall *and* Dale, 1971

Reworked pollen - spores

Alisporites grandis Dettmann, 1963
Caheniasaccites indicus Srivastava, 1970
Corisaccites alutas Venkatachala and Kar, 1966
Callialasporites dampieri Sukh Dev, 1961
Crescentipollenites fuscus Bharadwaj, 1974
Densipollenites invisus Bharadwaj and Salujha, 1964
Densoisporites sp.
Falcisporites stabilis Balme, 1970
Faunipollenites varius Tiwari *et al.,* 1989
Indotriradiates korbaensis Tiwari, 1964
Klausipollenites schaubergeri Jansonius, 1962
Osmundacidites sp.
Podocarpidites khasiensis Dutta and Sah, 1970

Tertiary pollen- spores

Pteridacidites vermiverrucatus Sah, 1967
Striatriletes susannae Kar, 1979
Compositoipollenites africanus Sah, 1967
Malvacearumpollis bakonyensis Nagy, 1962
Retitrescolpites typicus Sah, 1967
Polyadopollenites miocenicus Ramanujam, 1966
Spinizinocolpites echinatus Muller, 1968

Fungal remains

Alternaria type.
Cucurbitariaceites bellus Sah, Kar and Singh, 1972
Phragmothyrites eocenicus Kar and Saxena, 1976

SEDIMENTOLOGY AND BIOSTRATIGRAPHY

Sedimentological evidence indicates that the lower part of the Bhuban Formation is probably conformable transitional forms an underlying top sets sequence of a river dominant delta at the top of the Bhuban Formation to an inner neritic environments. The middle part of the formation could represent an open shelf environments and the upper part a near shore deposit. It is predominantly arenaceous and includes fine to very fine grained, compact, bluish ash. The lowermost assemblage is characterized by *Pteridacidites fistulosus*, *Polypodiisporites ornatus, Dictyophyllidites dulcis*. The *Pteridacidites fistulosus* zone is mostly based on spores (Mandaokar, 2008). The sedimentological evidence for the middle Bhuban Formation is interpreted as an outer shelf deposit, containing abundant of planktons whereas the upper alternating shale and siltstone contain fewer marine microfossils and could represent near shore deposits.

The base of the Bhuban Formation is closed to the Oligocene / Miocene boundary. Immediately above this boundary there is the first appearance of a typical warm water, Neogene fauna of foraminifera, mollusks and echinoderm (Jauhri *et al.,* 2003). The benthic foraminifera Soritidae is represented by *Pseudotaberina malabarica* species. Taberina occurring in the underlying middle Bhuban Formation and Upper Bhuban Formation. The *Tricolpites crassireticulatus* assemblage zone is characterized by an abundance of angiosperms pollen (19-28 %) which exceeds that of gymnosperm pollen (6 -8%) a sharp decreasing of *Betulapollenites* (down to 1 -3%) and the continuous occurrence of herbaceous pollen such as *Chenopodipollis* as well as microforaminifera.

Preservation is moderate in over half number of samples and poor in the remainder. *Polysphaeridium zoharyi* occurs almost continuously throughout the section and dominates many of the assemblage. Species of *Apteodinium* and *Pentadinium, Impagidinium* and *Operculodinium* are secondly important in terms of frequency of occurrence and relative abundance. Other common genera include *Chiropteridium, Cleistosphaeridium, Ligulodinium* and *Spiniferites*. Typical Palaeogene genera such as *Cordosphaeridium, Homotryblium, Membranophoridium* occur in the lower part of the section, where as some Neogene taxa such as *Hystrichosphaeropsis obscura* and *Melitasphaeridium choanophorum* occur in the upper part.

Impagidinium dispertitum-Hystrichokolpoma cinctum assemblage interval zone (Aquitanian- Burdigalian; 22.10 - 17. 95Ma) and *Cordosphaeridium cantharellum-Homotryblium vallum* interval zone (Aquitanian - Burdigalian; 17.95 - 16.40 Ma) that were first defined and named from the Bilkhawthlier - Rengtekawn of northern Mizoram were recognized in the lower and upper part of the Kolasib section, respectively, on the basis of occurrence and abundance of some important taxa. This zone is about 15 m thick and covers the topmost 1.3 m claystone. The rock samples of this zone are rich in organic detritus, pteridophytic spores, angiospermic pollen grains and dinoflagellate. The microplankton constituents are fair in number and variety. The zone is important by the incoming of some species for the first time in the sequence. These are *Impagidinium dispertitum, Impagidinium patulum, Spiniferites ellipsoideus, Achomosphaera ramulifera, Apteodinium cornutum, Areoligera senonensis* and *Adnatosphaeridium vittatum*.

The *Impagidinium dispertitum* - Hystrichokolpoma *cinctum* assemblage interval zone one is recorded from the lower Bhuban Formation. The assemblage is characterized by the presence of one of the eponymic species, *Impagidinium dispertitum* plus *Chiropteridium lobospinosum, Cleistosphaeridium diversispinosum, Cordosphaeridium gracile, Dapsilidinium pseudocolligerum*. *Homotryblium tenuispinosum, Membranophorum aspinatum, Hystrichokolpoma cinctum* and *Polysphaeridium subtile*. The diversity of dinoflagellate suddenly flared up at the beginning of assemblage one. The gradual increase of microplankton in higher zone suggests a shore deposits. The boundary between these two assemblages would be difficult to determine if based merely on the dinoflagellate data, because of the low abundance or lack of dinoflagellate cysts in more than half of the samples (Table -2). Poor presentation, which may have resulted in loss of some key species, also hinders recognition. The current placement of the boundary follows that of Mandaokar (2008). *Cordosphaeridium cantharellum- Homotryblium vallum* assemblage interval zone two (Aquitanian - Burdigalian; 17.95 - 16.40 Ma) characterized the upper Bhuban Formation. Species diversity is slightly higher-than in assemblage one, but cyst abundance is about the same one samples BI 46 has a high cyst r.a and low P/D r.a of sample BI 50, 76 % assemblage two is differentiated from the underlying assemblage one *Impagidinium dispertitum-Hystrichokolpoma cinctum* by the first occurrence of the species (Fig.2) *Cribroperidinium granomembranaceum, Hystrichosphaeropsis obscura, Lejeunecysta hyalina, Pentadinium laticinctum, Polysphaeridium subtile, Selenopemphix coronata, Sumatradinium hispidum, Thalassiphora pelagica, Tuberculodinium vancampoae, Hystrichosphaeropsis obscura* and *Melitasphaeridium choanophorum* occur in the upper part. The quantitative analysis revealed the dominance of *Spiniferites* (26%) and the subdominance of *Cordosphaeridium cantharellum* (9%) with the total absence of *Homotryblium vallum* which made its last appearance in assemblage two.

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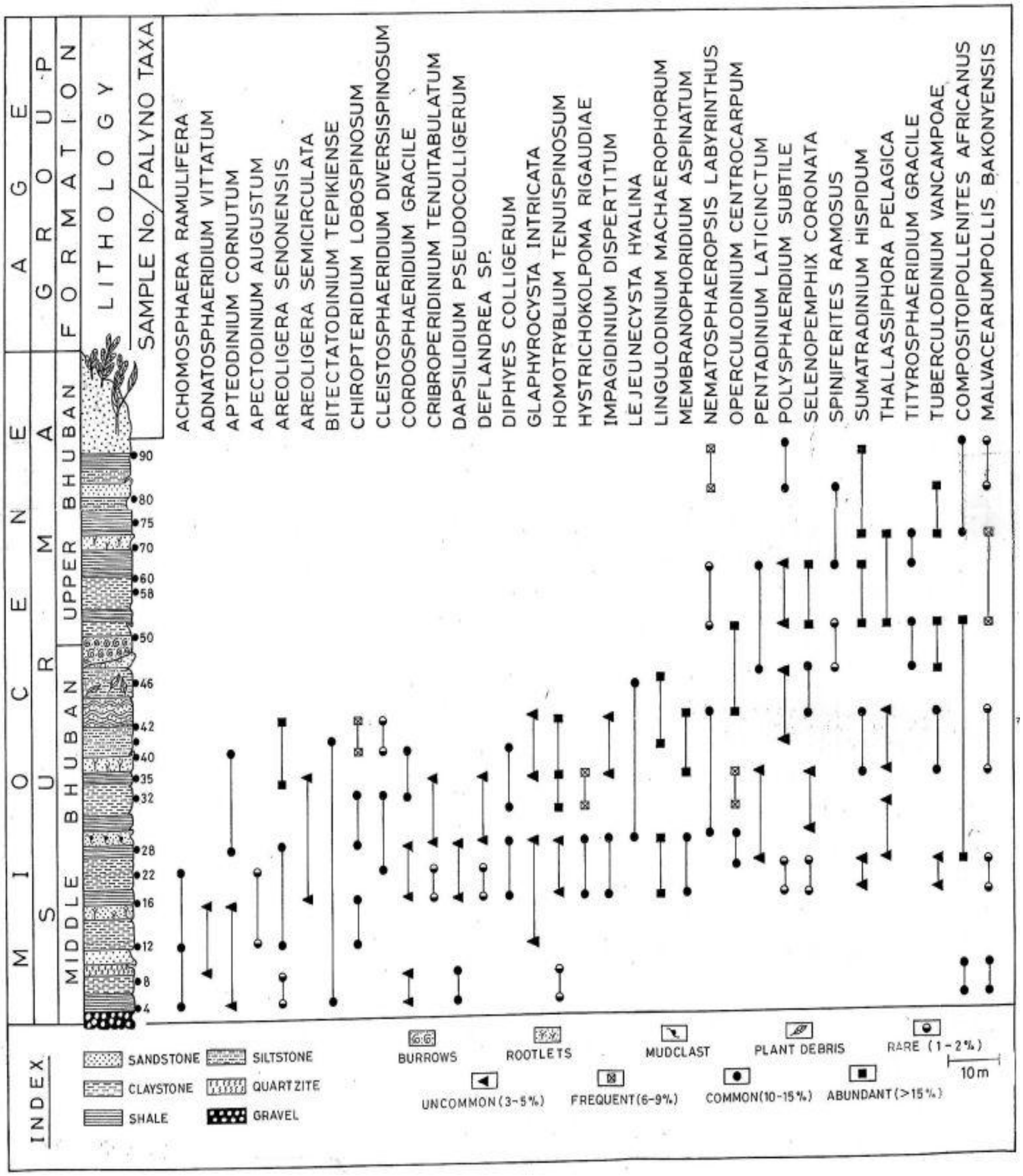

Figure 2: Relative abundance of selected taxa

The presence of low plant detritus, poor preservatives of spores and pollen grains together with consistent dinoflagellate cysts at the base of assemblage two and this marks the onset of true marine transgression in the area which continued throughout the Middle Miocene (Plate -I and II).

Paleoenvironmental Interpretation

The result achieved from the Bilkhawthlier - Rengtekawn section are an ideal for detailed environmental reconstruction, because the cyst assemblages are not diverse or abundant and provide evidence for interpreting some paleoenvironmental signals such as proximity to the coast, water salinity and temperature (Fig. 3).

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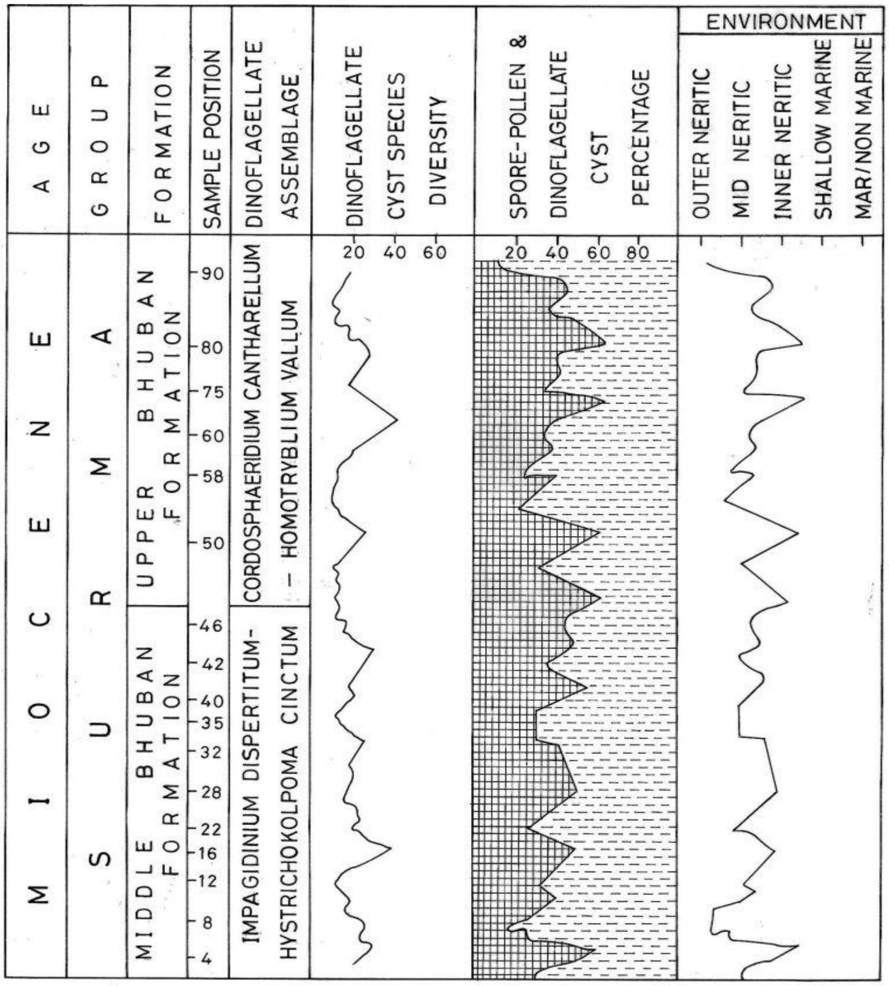

Figure 3: Showing dinoflagellate cyst events and palaeoenvironments

The environment might have been subject to slight sea level fluctuations recognized as three phases in ascending order. The first phase was a rising sea level with outer, inner neritic environments. Decreasing occurrence of terrestrial pollen spores at the top suggest shallowing nature. The second phase represented a falling sea level phase near shore conditions are indicated by the low species diversity and low numbers of dinoflagellate cysts and consequently high pollen spore/ less values of dinoflagellate cysts. The third was another episode of rising sea level with an outher, inner neritic environments. This is interpreted from the higher species diversity and relative abundance of dinoflagellate cysts.

The outer neritic oceanic cyst *Nematosphaeropsis labyrinthus* occurs in assemblage I and II and coeval assemblages from Pearl River Mouth and Yinggehai basins and South Carolina of USA. It is present in Miocene assemblages from Gulf of Mexico shelf, Goban Spur, Lemme section of Italy and Norwegian - Greenland Sea (Fig. 4). This suggests that the Bilkhawthlier - Rengtekawn area represents a near coast, inner neritic environments. The single occurrence of *Impagidinium* in samples BI - 48 of assemblage II may represent deeper water, since Impagidium is commonly recognized as an outer neritic to oceanic indicator (Wall *et al.*, 1977 and Harland, 1983).

Comparison with Coeval Assemblages

The comparison of the sections and a schematic intercorrelation with information from different section is given in (Fig. 4). It is remarkable that the comparison between the different section and present section is merely based on dinoflagellate biostratigraphy. *Polysphaeridium subtile* occurs almost continuously through

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out section and dominates many of the assemblages. Species of *Apteodinium*, *Pentadinium* and Operculodinium are secondly important in terms of frequency of occurrence of relative abundance. Other common genera *Chiropteridinium, Cleistosphaeridinium, Lingulodinium* and *Spiniferites*.

Dinoflagellate Cysts \ Localities	Bilkhawthlir Basin (Mizoram)	Pearl River Mouth basin (Mao & Lei, 1986)	Gulf of Mexico shelf (Duffield & Stein, 1986)	Offshore Louisiana (LeNoir & Hart, 1986)	Rockdall Plateau (Edwards, 1984)	Lemme Section of Italy (Powell, 1986)	The Norwegian Sea (Manum et al., 1989)	Cauvery Basin (Mehrotra & Singh 2003)
Achomosphaera ramulifera.	▲		◙	▲			◙	▲
Adnatosphaeridium vittatum.	◙	▲			◙	▲		
Apteodinium angustum.		◙	▲	◙		◙	◙	▲
Cordosphaeridium cantharellum.	▲		◙		▲		▲	
Cribroperidium tenuitabulata.	◙							▲
Cleistosphaeridium placanthum.	▲	▲	▲	▲	◙	▲	◙	
Dapsilidium pseudocolligerum.		◙				◙		◙
Diphyes colligerum.	◙		◙		▲	◙		
Glaphyrocysta intricata.	▲	◙			◙		▲	◙
Homotryblium tenuispinosum.			▲	◙		▲		
Hystrichokolpoma rigaudiae.	◙	▲			▲			▲
Hystrichosphaeridium rubiferum.	▲	◙	◙	▲	◙		▲	◙
Impagidinium dispertitum.			◙			▲		
Lejeunecysta cinctoria.	◙	▲			▲			▲
Nematosphaeropsis labyrinthus.		◙	▲		◙		▲	◙
Operculodinium centrocarpum.	▲		◙	▲		▲		
Polysphaeridium subtile.		◙						◙
Selenopemphix coronata.	◙	▲			▲		▲	▲
Spiniferites ramosus.	▲	◙		▲		▲		◙
Sumatradinium hispidum.	◙		▲		◙		◙	
Thalassiphora pelagica.		◙			◙		◙	▲
Tuberculodinium vancampoae.	▲			▲			▲	

Figure 4: Comparisons of Miocene assemblages of Bilkhawthlir – Rengtekawn section with coeval assemblages from elsewhere on the basis of common taxa ▲ and abundant ◙

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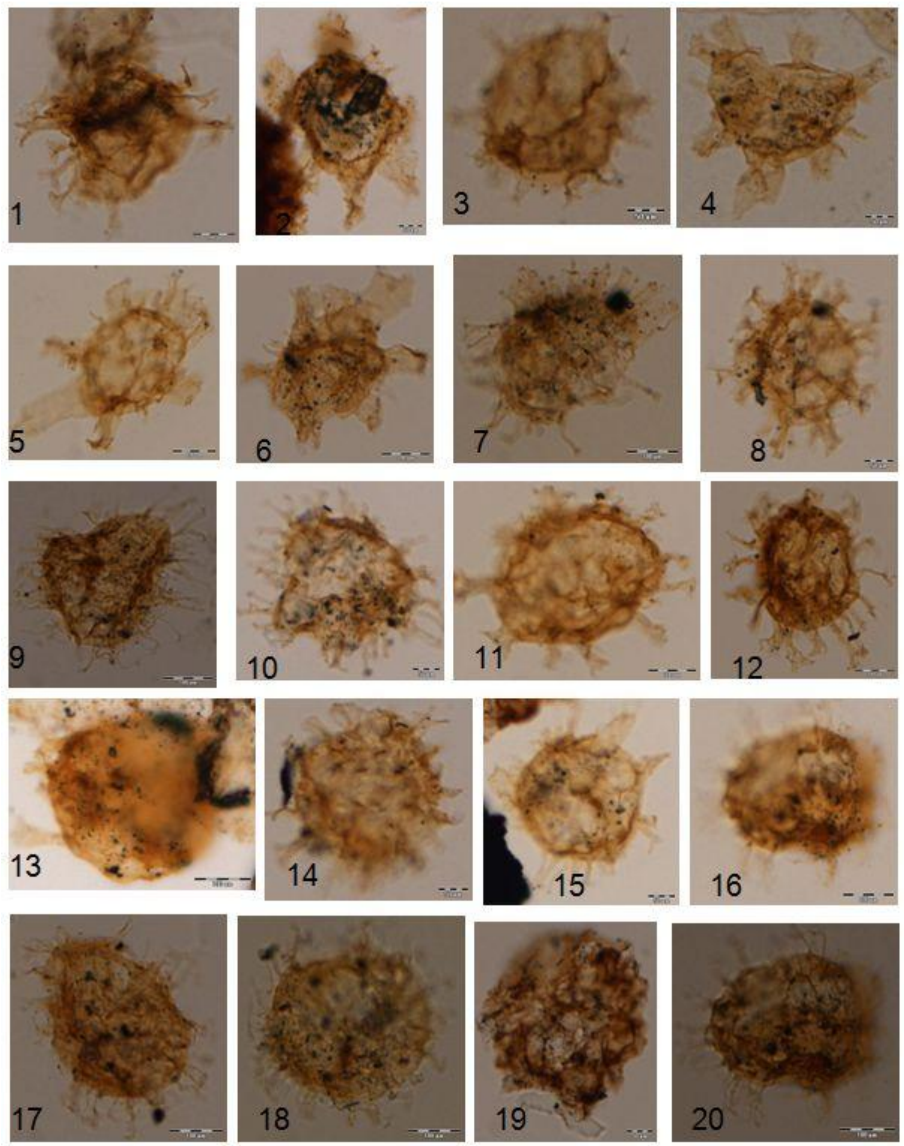
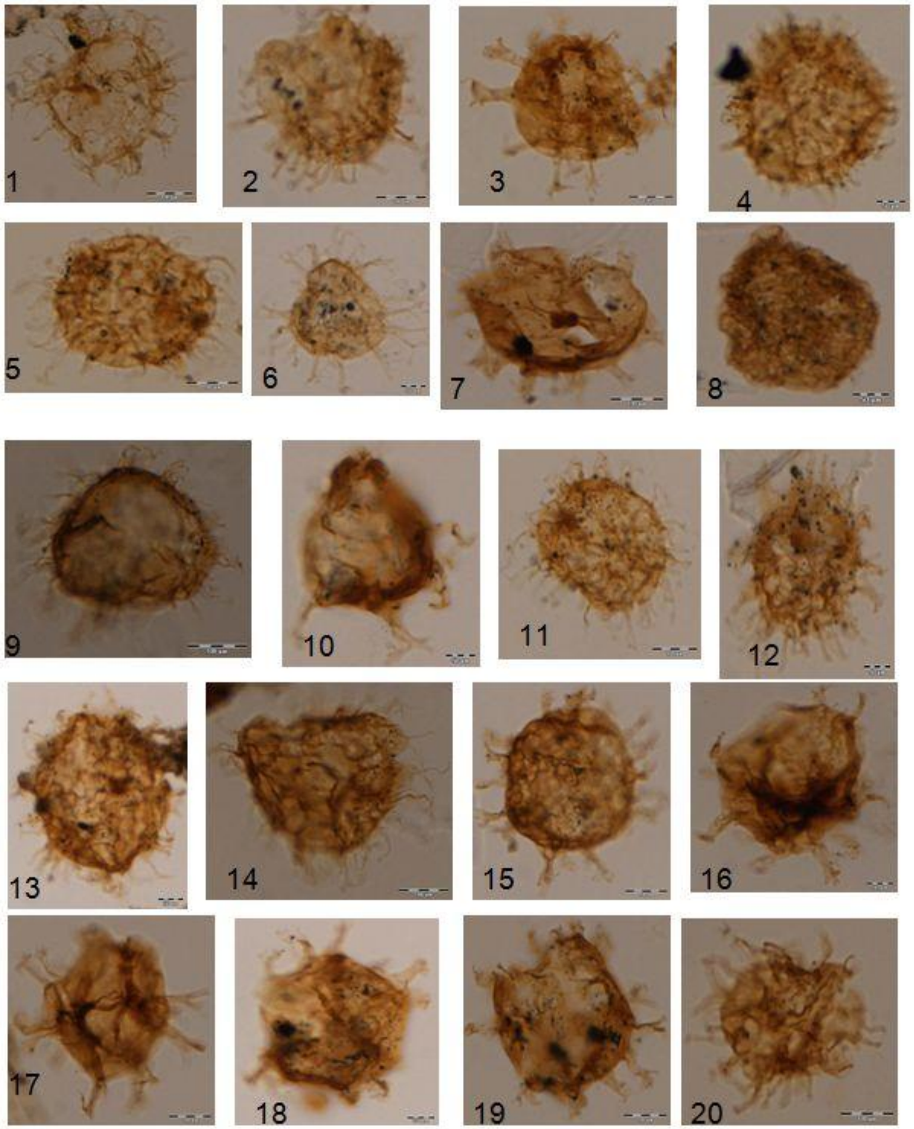
Plate: 1



Explanation of Plate -1

Fig.1. *Cordosphaeridium fibrospinosum*. Davey and Williams, Slide no. Bil/Reng.1/1
Fig.2. *Hystrichokolpoma rigaudae* Deflandre and Cookson, Slide no. Bil/Reng.1/2
Fig.3. *Areoligera senonensis* Mehrotra and Aswal, Slide no. Bil/Reng.1/1
Fig.4. *Cordosphaeridium exilimurum* Davey and Williams, Slide no. Bil/Reng.1/1
Fig. 5.*Florentinia mantelii* Davey and Williams, Slide no. Bil/Reng. 2/1
Fig. 6.*Florentinia cooksoniae* Duxbury, slide no. Bil/Reng.3/1
Fig .7. *Homotryblium pallidum* Davey and Williams, Slide no. Bil/Reng.3/1
Fig.8. *Hystrichosphaeridium salpiugophorum* Davey and Williams, Slide no. Bil/Reng.4/1
Fig. 9. *Hystrichokolpoma poculum* Maier, Slide no. Bil/Reng.5/1
Fig .10. *Spiniferites bulloideus* Sarjeant, Slide no. Bil/Reng.1/1
Fig.11. *Oligosphaeridium complex* (White) Davey and Williams, Slide no. Bil/Reng.6/1
Fig.12. *Areoligera digitata* Kar, Slide no. Bil/Reng.5/1
Fig. 13. *Operculodinium* sp. Slide no. Bil/Reng.8/1
Fig. 14. *Glaphyrocysta intricata* (Eaton) Stover and Evitt, Slide no. Bil/Reng.12/1
Fig. 15. *Hystrichokolpoma cincta* Klumpp, Slide no. Bil/Reng.2/1
Fig. 16. *Spiniferites ramosus* (Davey and Williams) Lentin and Williams, Slide no. Bil/Reng.12/1
Fig . 17. *Achomosphaera ramulifera* (Deflandre) Evitt, Slide no. Bil/Reng.14/1
Fig. 18. *Adnatosphaeridium multispinosum* Williams and Downie, Slide no. Bil/Reng.1/1
Fig. 19. *Samlandia chlamydophora* Eisenack, slide no. Bil/Reng.15/1
Fig. 20. *Litosphaeridium siphoniphorum* (Cookson and Eisenack) Davey and Williams, Slide no. Bil/Reng.12/1

Plate: 2



Explanation of Plate – 2.

Fig. 1. *Achomosphaera neptunii* (Eisenack) Davey and Williams, Slide no. Bil/Reng.1/1
Fig.2. *Areoligera digitata* Kar, Slide no. Bil/Reng.12/1
Fig.3. *Oligosphaeridium complex* (White) Davey and Williams, Slide no. Bil/Reng.10/1
Fig.4.*Operculodinium centrocarpum* (Deflandre and Cookson) Wall, Slide no. Bil/Reng.12/1
Fig.5. *Diphyes colligerum* Cookson, Slide no. Bil/Reng.14/1
Fig.6. *Glaphyrocysta kachchhensis* Jain and Tandon, Slide no. Bil/Reng.14/1
Fig.7. *Hystrichokolpoma eisenacki* Williams and Davey Slide no. Bil/Reng.12/1
Fig.8. *Sumatradinium* sp. Bil/Reng.15/1
Fig. 9. *Spiniferites mirabilis* Lentin and Williams, Slide no. Bil/Reng.14/1
Fig.10. *Dapsilidium* sp. Bil/Reng.10/1
Fig.11. *Spiniferites bulloideus* Sarjeant, Slide no. Bil/Reng.14/1
Fig.12.*Lithosphaeridium arundum* (Eisenack and Cookson) Davey and Williams, Slide no. Bil/Reng.15/1
Fig. 13. *Sumatradinium* sp. Slide no. Bil/Reng.12/1
Fig. 14. *Thalassiphora pelagic*a (Eisenack) Eisenack and Gocht, Slide no. Bil/Reng.14/1
Fig. 15. *Operculodinium robustum* Kar, Slide no. Bil/Reng.11/1
Fig. 16. *Spiniferites mirabilis* Lentin and Williams, Slide no. Bil/Reng.10/1
Fig. 17. *Cleistosphaeridium cephalum* Kar, Slide no. Bil/Reng.13/1
Fig. 18. Cf. *Perisselasphaeridium pannosum* Davey and Williams, Slide no. Bil/Reng.12/1
Fig. 19.*Homotryblium plectilum* Drugg and Loeblich, Slide no. Bil/Reng.10/1
Fig. 20. *Areoligera coronata* (Wetzel) Lejeune- Carpentier, Slide no. Bil/Reng.12/1

Typical Paleogene genera such as *Cordosphaeridium, Homotryblium, Membranophoridium* occurs in the lower part of the section, whereas some Neogene taxa such as *Hystrichosphaeropsis* and *Melitasphaeridium* occur in upper part. The present assemblages are quite similar to those of late Oligocene to early Miocene. Dinoflagellate cysts from South Carolina, USA (Edwards, 1986) with about 70% of the taxa shared and both having abundant *Homotryblium* and *Pentadinium*

DICUSSION

On the basis of quantitative patterns observed in the palynological record at Bilkhawthlir- Rengetekawn site in northern Mizoram, the sea level changes were restricted on the basis of ratios of oceanic versus neritic taxa and are of little significance due to the near absence of oceanic forms like *Impagidinium* and *Nematosphaeropsis* sp. In the encountered dinoflagellate cyst assemblages usually only a few taxa are quantitatively important. Extant representatives of the *Operculodinium* group (basically *O.centrocarpum, O. israelianum* and *O. psilatum*) occur in a wide variety of sedimentary settings, oceanic to restricted marine. Notably the distribution of *Operculodinium centrocarpum* is in any sense cosmopolitan, although it is often mentioned that high frequencies in more offshore settings are primarily due to transportation (Wall *et al.*, 1977). The other extant species are particularly known to be abundant in restricted marine settings. However, the surviving species (*Homotryblium plectilum, H. tenuispinosum and H. floripes*) went extinct during the middle Miocene. The distribution pattern of *Homotryblium* seems to indicative suitability preferable for low to mid latitude restricted marine to open marine inner neritic settings. The *Deflandrea* sp. went extinct during the Oligocene/ Miocene transition. However, the motile dinoflagellate stages that produced cysts assignable to *Deflandrea* may well represent heterotropic peridinioids. High frequencies of peridiniods are characteristic of areas with high primary production related to increased nutrient availability. Raised quantities of *Deflandrea* sp. may therefore be tentatively linked to such depositional settings; their motile stages may have grazed on diatoms and other autotropic phytoplankton. Extant representatives of *Spiniferites ramosus* have a rather cosmopolitan distribution and occur in both oceans and marginal seats today. However, available information suggests that the distribution of the motile stages that produce these cysts (*Gonyaulax spinifera* group) is mainly restricted to shelf areas (estuarine to neritic) and that the cysts are thus abundant in these settings, they may also reach high frequencies in more offshore settings due to transportation. Representative of other forms a large portion of the recovered assemblages. It was mentioned that certain other taxa also play an important role in the quantitative composition in some samples. The bisaccate pollen (*Podocarpidites khasiensis)* represent terrestrial elements because of their high buoyancy could be transported in large numbers to offshores even oceanic sites. Other pollen types especially spores are considered to be transported less far into the marine environments, river input may be the main transportation mechanism for these palynomorphs.

A perusal of geological and biostratigraphic studies on the Surma Group in Mizoram basin suggests that the Surma group is represented by two quite distinct depositional systems of different geological ages. In older age represents the metasedimentary succession comprising shale, siltstones, quartzitic sandstone and belong to lower Bhuban Formation (Early Miocene 22, 10 - 17.95 Ma). On the other hand, the younger depositional system characterizes the unmetamorphosed sedimentary succession comprising latest black shaly, calcareous silstones, shale and sandstone alternations and ranges in age from latest Permo -Triassic assemblages. The above two successions are separated by a major hiatus spanning approximately from late middle Aquitanian. The metasedimentary rocks of older age (Triassic) belong to Gondwana Group and initially deposited over the Bhuban Formation. Later on these sediments had undergone the process of varying degree of metamorphism due to various orogenic activities on the Indian craton or even sedimentary load. The metasedimentary rocks of Surma Group formed the floor for the subsequent deposition of unmetamorphed sedimentary sequence of latest Miocene. The lower Bhuban Formation after a major hiatus of about 600 Ma. Sedimentation is younger depositional system commenced during latest early Miocene and continued up to upper Bhuban Formation time.

The reworked palynomorphs belonging to the older rocks which have been recycled into younger rocks. Their presence is indicative of the paleogeographical conditions and provenance of the sediments could also be related to the regional tectonic movements during the time of deposition. The intiation of Surma sedimentation marks the beginning of a transgressive phase with its maximum in the middle Bhuban. This is indicated by the presence of dinoflagellate cysts. The shore line during this period had transgressed further inland towards northeast and sediments were deposited in the middle to outer shelf environments or may be even more open marine conditions. The regression phase began at the top of middle Bhuban and upper Bhuban.

Conclusion

1. The presence of dominant dinocyst genera like *Cordosphaeridium, Homotryblium, Membranophoridium, Hystrichosphaeropsis, Melitasphaeridium* indicates early Miocene in age.
2. The present sequence has been divided into two informal interval zones. These zones are 1. *Impagidinium dispertitum - Hystrichokolpoma cinctum* assemblage interval zone and 2. *Cordosphaeridium cantharellum-Homotryblium vallum* assemblage interval zones are marked where maximum changes in microfloral constituent are observed.
3. The occurrence of dinoflagellate cyst in the present sequence represents a warm, tropical–subtropical and shallow, inner neritic to inner outer neritic environments.
4. The presence of different dinoflagellate cysts, plant detritus, spore pollen at the base of *Impagidinium dispertitum - Hystrichokolpoma cinctum* assemblage and *Cordosphaeridium cantharellum-Homotryblium vallum* interval zone the gradual decline in dinoflagellate diversity high in the zones suggests near shore deposit.
5. There were three sea level fluctuations from outer inner neritic to near shore, back again to outer inner neritic and even later to inner outer neritic, then back again towards the end to near shore condition

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