Palaeocene calcareous algae from Khasi Hills, Meghalaya

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Boruah P.K. & Dutta S.K. 2003. Palaeocene calcareous algae from Khasi Hills, Meghalaya. *Geophytology* 31(1 & 2) : 19-29

Palaeocene marine facies with calcareous algae occur in the Khasi and Jaintia Hills, Meghalaya. The quarries of Mawmluh-Cherrapunji Cement Ltd., situated on the southern Shillong Plateau, Meghalaya expose Palaeocene carbonate rocks. Rich occurrences of calcareous algae are found in the Lakadong Limestone Member (Thanetian) of the Sylhet Limestone Formation (Thanetian-Priabonian). A number of calcareous algal genera of the families Corallinaceae and Dasycladaceae occur in the Lakadong Limestone Member along with few corals, gastropods, bivalves, larger and smaller foraminifers. The crustose corallines chiefly include species of *Sporolithon, Lithothamnion, Mesophyllum, Lithoporella, Melobesia, Distichoplax* and the articulated corallines *Jania, Corallina and Rivularia.* The principal dasyclads are *Dissocladella* and *Cymopolia.* The Lakadong Limestone Member is characterized by *Distichoplax-Dissocladella* assemblage. Algal fragments, algal sticks and pellets along with variable contents of foraminifers are cemented by sparry calcite and formed largely skeletal grainstone carbonate facies, indicating high-energy, open marine platform environment of shallow depth, warm, humid, tropical climate.

Key- words – Calcareous algae, Palaeocene, Lakadong Limestone Member, Meghalaya.

INTRODUCTION

THE southwestern slope of the Shillong Plateau in the Khasi Hills represents one of the best Upper Cretaceous-Lower Tertiary sections in India. Thin cover of Lower Tertiary marine shelf sediments is well developed in the area around Cherrapunji, East Khasi Hills (Fig. 1). The Lakadong Limestone, the principal Upper Palaeocene carbonate strata is underlain by the Therria Formation and overlain by Lakadong Sandstone Member. Based on the palynological investigation, the coal-bearing sandstones in the area around Cherrapunji were considered as Lakadong Sandstone Member and to its north and around Laitryngew the sandstones were equated with the Therria Formation, both of them were considered as of Upper Palaeocene in age (Sah & Dutta, 1966; Dutta & Sah, 1970). Occurrence of the intervening limestone between Therria and Lakadong sandstones at 31/2 milestone along Shillong-Shella National Highway near Laitryngew (Fig.1) raised the question for its stratigraphical position. Later, it was concluded that the limestone could be equated with the Lakadong Limestone Member. The overlying sandstone is a continuation of Lakadong Sandstone Member of Cherrapunji area and is of Thanetian (Upper Palaeocene) age (Boruah & Dutta, 1990; Boruah, 1992).

Based on the findings of calcareous algae and coral an attempt is made here to find out the depositional environments of the Lakadong Limestone Member and to correlate the limestone exposed at milestone 31/2.

Oldham Medlicott (1869), LaTouche (1889), Palmer (1923), Ghosh (1940), Sen (1948), Biswas (1962), Evans (1964), Dutta and Sah (1970), Sah and Dutta (1966), Samanta (1968), Pandey (1978), Jauhri (1988) and others have contributed to the geology of Khasi – Jaintia Hills.

LITHOSTRATIGRAPHY

The studied sections show the following composite stratigraphical succession:

Group	Formation	Member	Age
Jaintia Group	Sylhet Formation	Lakadong Sandstone Member Lakadong Limestone Member	Thanetian (Upper Palaeocene)
	Therria Formation		Danian (Lower Palaeocene)
	Langpar Formation Mahadek Formation		Maastrichtian
---------- Nonconformity ----------			
	Basalt & Metamorphics		Pre-Upper Cretaceous

*Deceased

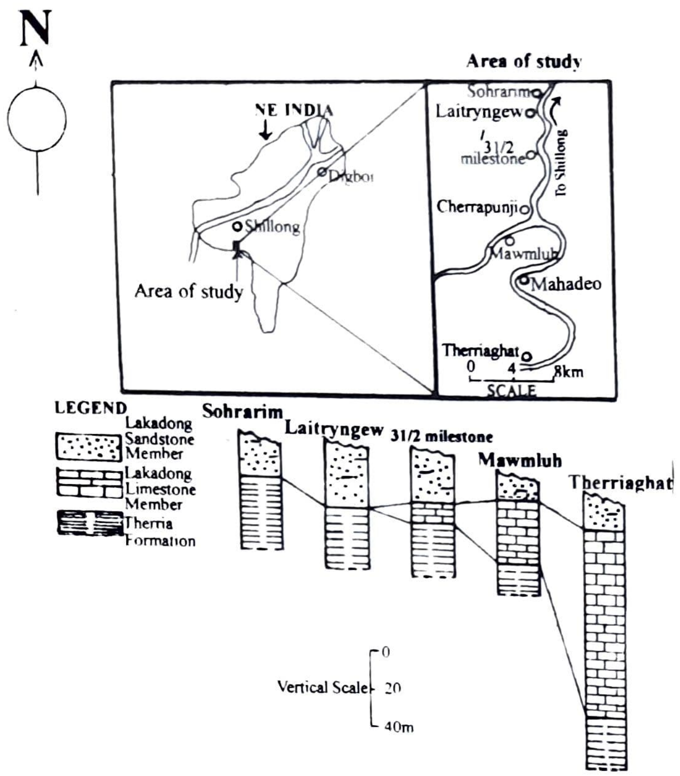

Fig. 1 : Vertical Profile Sections of the Area under study from Sohrarim to Therriaghat in Meghalaya, NE India.

Sylhet Trap

The trap is amygdaloidal and vesicular with intercalated ash-beds. The accepted age for thin trap is Pre-Upper Cretaceous (Krishnan, 1968). The best exposures are seen around Mawlong on the Shillong-Shella Road between 1/8 and 10 milestones and at Kendrang Falls along the Old Cherra-Shella road-section.

Mahadek Formation

The shallow marine beds of the Mahadek Formation show gentle southerly dip ranging between 5° to 7° (Jain *et al.*, 1975). The sandstone is glauconitic and both of quartzo-feldspathic arenite and wacke types. The lower part of the formation is gritty while the top of the sandstones are calcareous. The exposed stratigraphic thickness of the formation varies from 40m at 1023ft. Based on foraminifera (*Globotruncana stuarti, Guembelina plummerae, Orbitoides,* and *Siderolites calcitrapoides*), Nagappa (1959) proposed Maastrichtian age for the formation.

Langpar Formation

Lithologically feldspathic arenite and wacke, sandy claystones, sandy argillaceous biomicrite, calcareous shale, marl and mudstone represent the formation. Beds show almost horizontal (1° – 2°) dips, with the expression of cliff forming table land. On the basis of the occurrence of typical marine foraminifers (*Globigerina pseudobulloides, G. triloculinoides*) Nagappa (1959) correlated the Langpar Formation with the type Danian of Denmark.

Therria Formation

The Therria Formation comprises lower massive calcareous band, succeeded by fine-grained sandstones with interbeded thin shales. Around Cherrapunji the formation consists of well jointed (2-sets) coarse to fine grained, generally friable, sometimes ferruginous, hard and compact sandstones. The trace fossils are quite common and the beds show southwardly gentle dip ranging between 4° – 6°. The formation attains an average thickness of about 90m and extends up to about 5 km north of Laitryngew where it attains 15m of thickness. The basal part of the formation contains conglomeratic bands near Sohrarim. The age of the Therria Formation is considered to be Thanetian (Boruah & Dutta, 1991). The nummulitic Lakadong Limestone Member conformably overlies the Therria Formation.

Sylhet Limestone Formation

i) Lakadong Limestone Member

The Lakadong Limestone is light to dark grey in colour with gentle dip varying between 4° and 8° towards S and SE, and occasionally almost horizontal.

PLATE - 1 →

1. *Sporolithon* sp. B X25
2. *Sporolithon* sp. A X25
3. *Mesophyllum* sp. X40
4. *Lithoporella* sp. 25
5. *Sporolithon* sp. X25
6. *Amphiroa* sp. X25
7. *Lithothamnion* sp. A X25

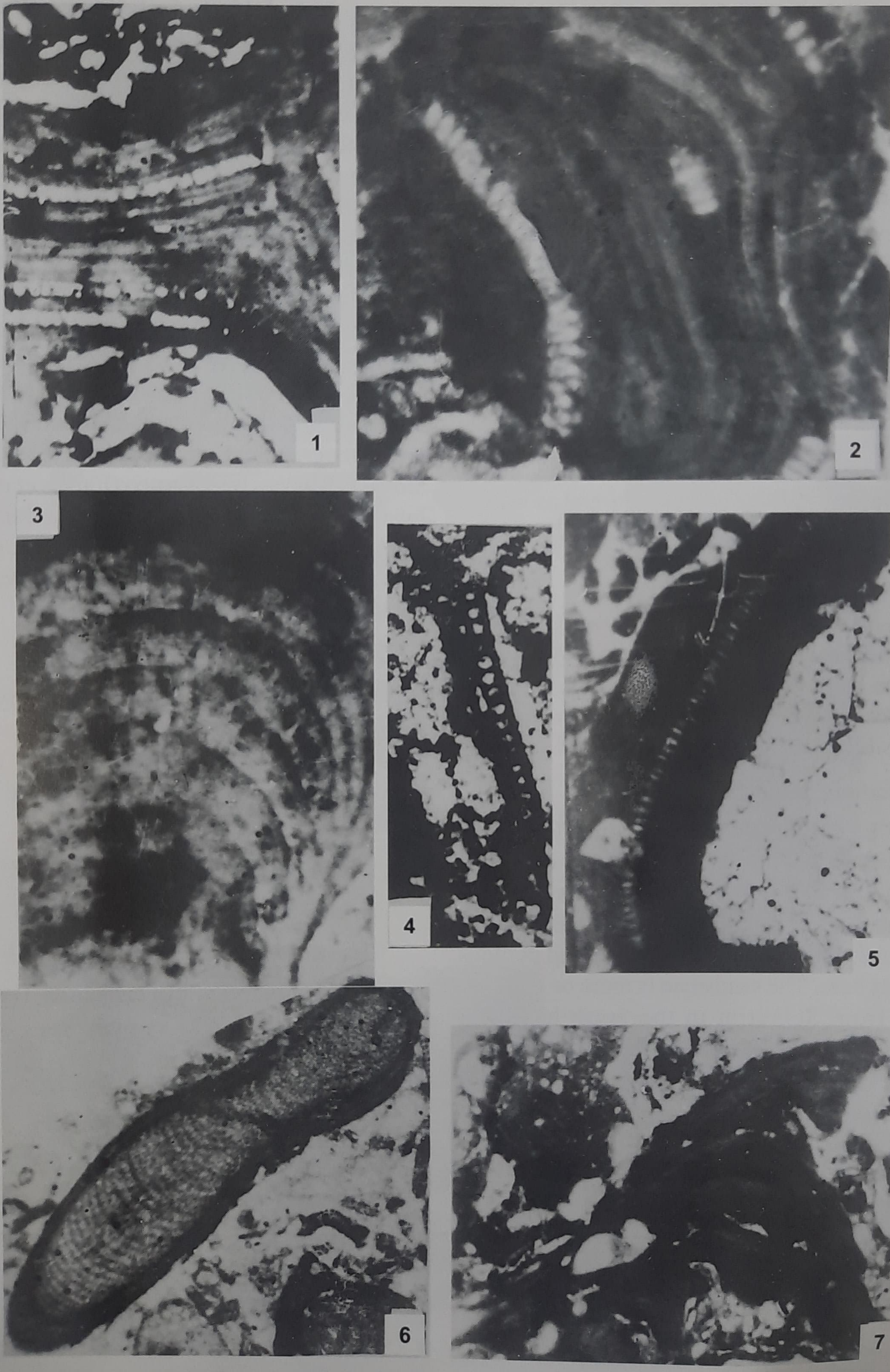

PLATE - 1

The exposed thickness of the Lakadong Limestone near Mawsmai village is about 20 to 25 m. The basal part and sporadically the middle of the limestone are dolomitic and light brown in colour. The exposed thickness of the dolomitic portion ranges up to 6 m. The limestone is compact, hard, fine grained and often grades upwards into the calcareous sandstone. The distribution of disseminated pyrite grains and specks at the contact with the overlying Lakadong Sandstone were noticed. The calcite crystals are more abundant in dolomite than in limestone. The limestone is rich in foraminifers, calcareous algae, few corals, gastropods, and bivalves. There are three foraminiferal-algal associations such as *Discocyclina – Ranikothalia* Association, *Glomalveolina primaeva – Distichoplax biserialis* Association and *Rotaliid – Miliolid* Association (Jauhri, 1988). The foraminiferal as well as spore-pollen assemblages indicate its age as Thanetian (Boruah & Dutta, 1991; Boruah, 1992). The typical foraminifers are *Nummulites thalicus, N. sindensis, Lockhartia heimei, Miscellanea miscella, M. meandrina, Discocyclina ranikotensis, Gypsina* sp. and some calcareous algae such as *Distichoplax biserialis, Lithothamniom andamanensis, Mesophyllum meghalayaensis,* etc.

ii) Lakadong Sandstone Member

The Lakadong Sandstone comprises coal, carbonaceous sand, argillaceous shales, clays and dominantly fine to coarse grained sandstones. The most significant characters of these sediments are workable coal seams, purple coloured sandstone and pyritous shale at its base. The sandstone is more or less continuous from Sohrarim in the north to Lower Cherrapunji in the south in the Cherrapunji Plateau, which laterally extends up to Therriaghat. The south-easterly dip of the beds varies between 3° to 8°. Based on the palynological investigations the age of the unit is considered as Thanetian (Boruah & Dutta, 1991; Boruah, 1992).

Use of Algae As Index Fossils

Many of the calcareous algal species on account of their limited vertical range and worldwide distribution have attained the status of index fossils particularly in the formations, where other diagnostic forms are often lacking and their abundance make them very important index fossils. The algal genus *Distichoplax* is found in the Tertiary sediments all over the world. It has been recognised by Eames *et al.* (1962) as an index fossil for the Palaeocene in the Tertiary stratigraphic correlation. Chatterji (1964) on the basis of *Distichoplax biserialis* (Diatrich) indicated the presence of marine Palaeocene in the Andaman Island. *D. biserialis* Pia has been reported from widely separated geographical areas such as Eastern Alps, Slovak, Pyrenees and Borneo (Eames *et al.*, 1962). Johnson (1954) tabulated the time distribution of the algal genera. However, until fossil algae of different ages are studied in many more areas, the value of algae in correlation will be limited.

PRESENT FINDING

The present study revealed a variety of algal forms. In addition, collection includes six specimens of coral belonging to the order Scleracitnia. The distribution of fossil algae and rock types are shown in figure 2.

LIST OF ALGAE RECORDED

Division-Rhodophyta Wettstein, 1901

Class-Rhodophyceae Rabenhorst, 1863

Order-Corallinales Silva & Johnson, 1986

Family-Sporolithaceae Verheji, 1993

Genus *Sporolithon* Heydrich, 1897

Sporolithon sp. A. (Pl. 1, Fig. 2)

Sporolithon sp. B. (Pl. 1. Fig. 1)

Sporolithon sp. (Pl. 1, Fig. 5)

PLATE - 2 →

1. *Amphiroa* sp. X 40
2. *Jania* sp. X 40
3. *Distichoplax raoi* and *Distichoplax biserialis* X 25
4. *Lithothamnion* sp. B X 25
5. *Dissocladella* sp. X 25
6. *Amphiroa* sp. X 40
7. *Mesophyllum* sp. (obliquely cross-section) X 25
8. *Corallina* sp. X 25

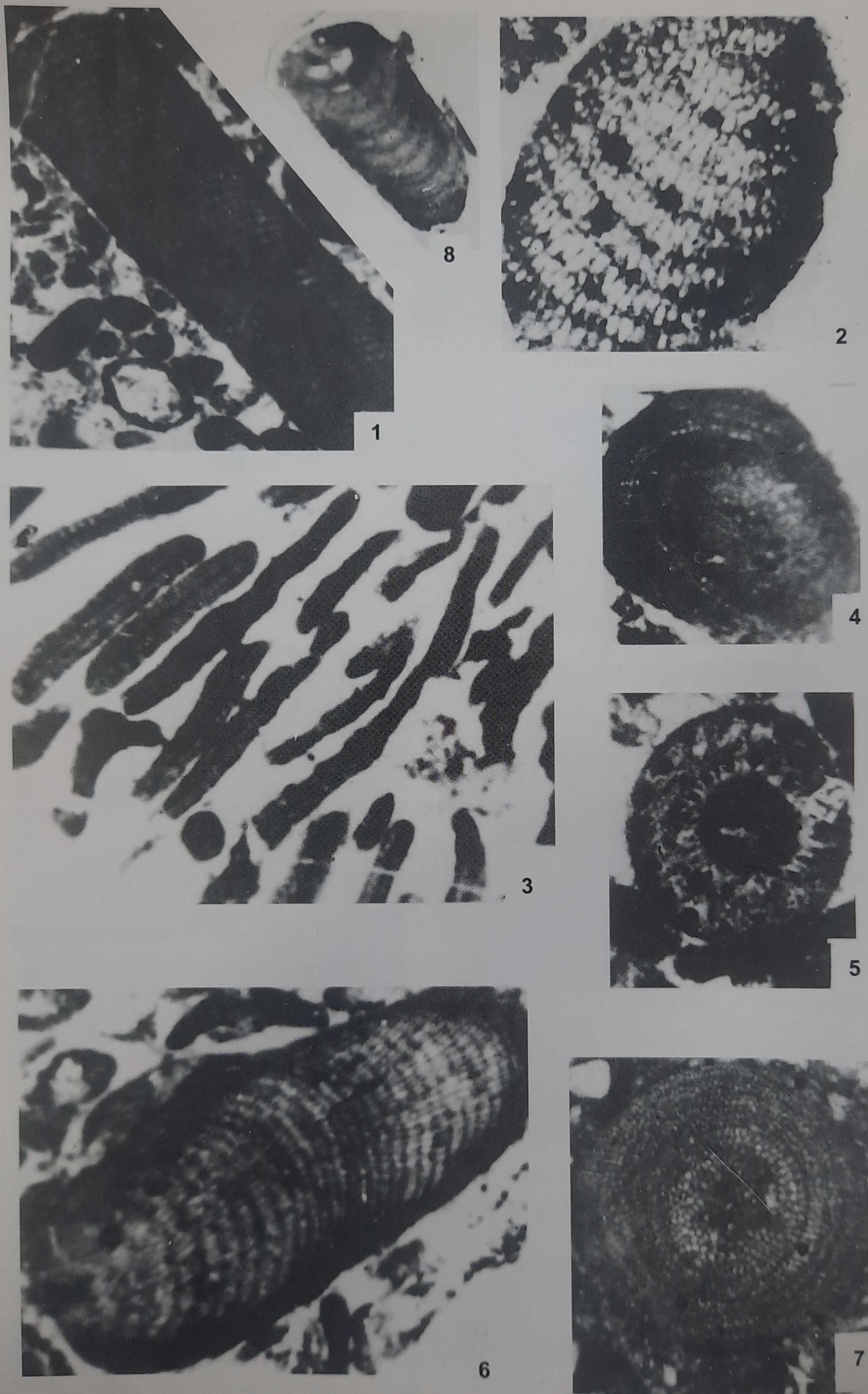

PLATE - 2

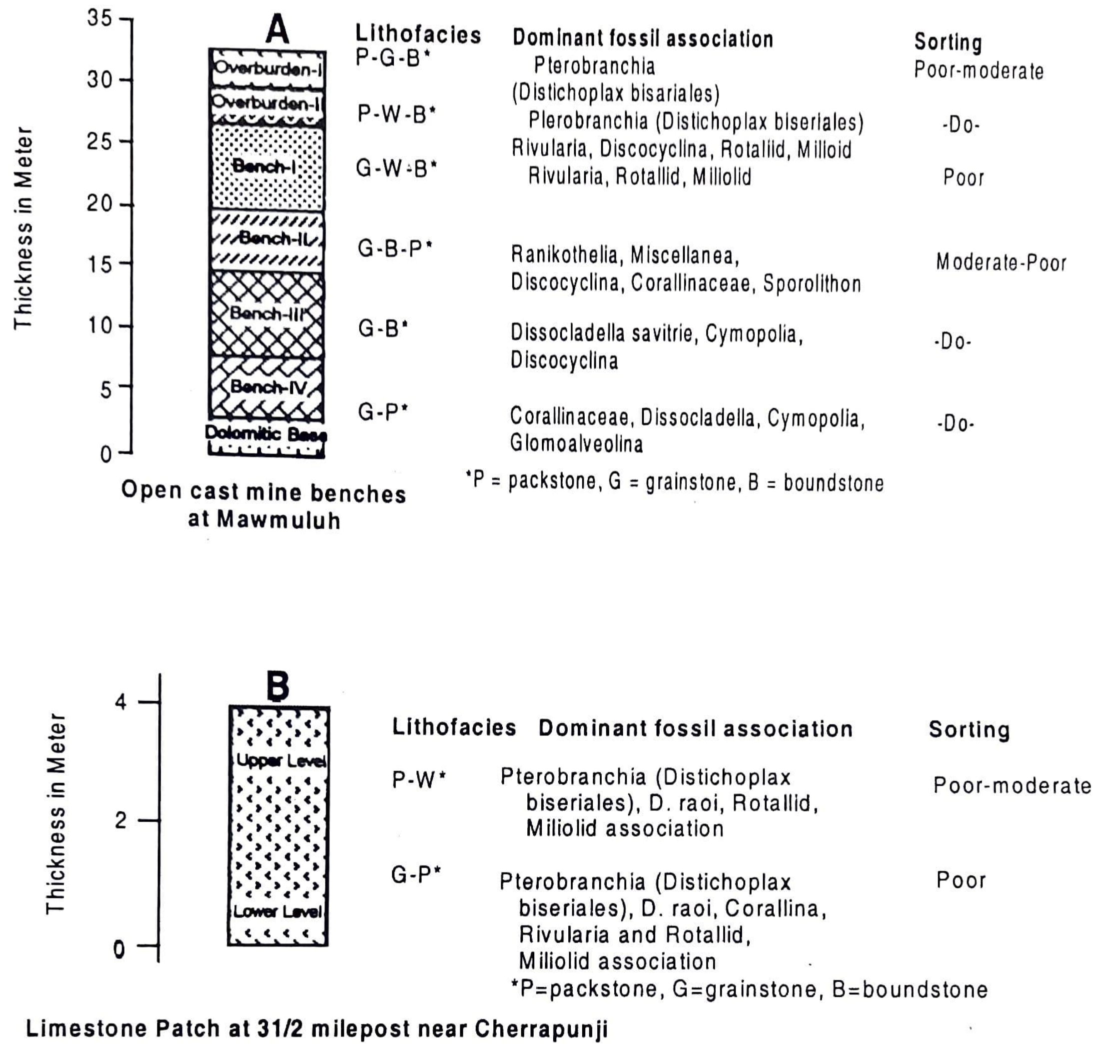

Fig. 2: Distribution of principal fossils and rock types of Lakadong Limestone Member at Mawmluh and 31/2 milepost near Cherrapunji

Family-Corallinaceae Lamouroux, 1816

Subfamily-Melobesioideae Bizzozero, 1885

Genus-*Lithothamnion* Heydrich, 1897

Lithothamnion sp. A. (Pl.1 Fig.7)

Lithothamnion sp. B. (Pl. 2 Fig. 4)

Genus *Mesophyllum* Lemoine, 1928

Mesophyllum sp. (Pl. 1, Fig. 3; Pl. 2, Fig. 7)

Subfamily-Mastophoroideae Setchell, 1943

Genus-*Lithoporella* (Foslie) Foslie, 1909

Lithoporella sp. (Pl. 1, Fig. 4)

Subfamily-Corallinoideae Areschoug, 1852

Genus-*Corallina* Tournefort, 1700

Corallina sp. (Pl. 2, Fig. 8)

Genus-*Jania* Lamouroux 1812

Jania sp. (Pl. 2, Fig. 2)

Genus-*Amphiroa* Lamouroux, 1812

Amphiroa sp. (Pl. 1, Fig. 6; Pl. 2, Fig. 1, 6)

Problematic ? Algal taxon

PLATE - 3

1. Radially fibrous coral sp.
2. *Placotrocus* sp.
3. *Placotrocus* sp.
4. *Placotrocus* sp.
5. *Balanophylia* sp.
6. *Dissocladella lakadongensis* Pal & Dutta X 40
7. Encrusting algal-foraminiferal forms X 40
8. *Lithoporella melobesioides* Foslie X 40
9. Gastropod shell from 31/2 milestone X 25

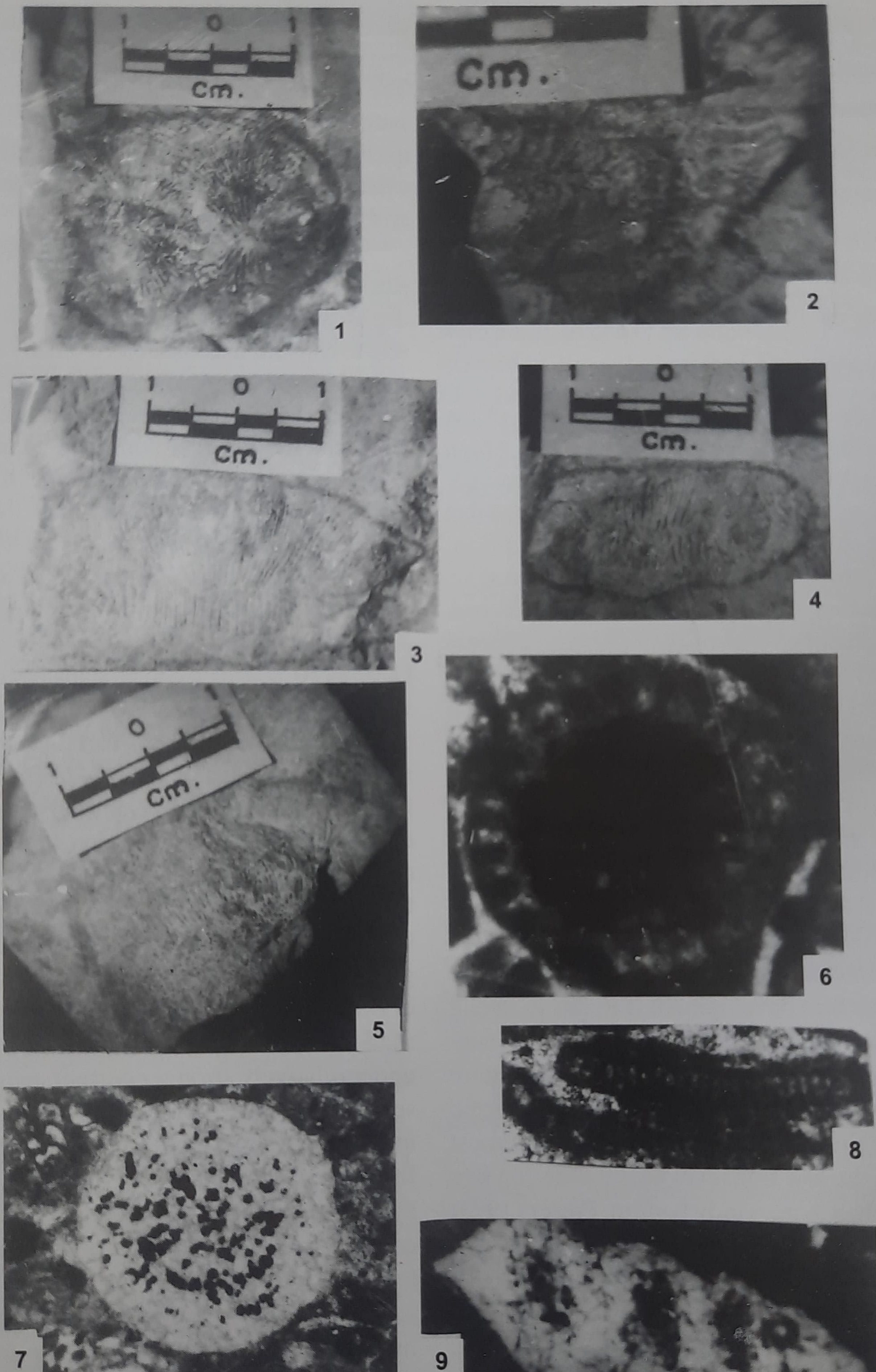

PLATE - 3

Distichoplax biseriales (Pl. 2, Fig. 3)

Distichoplax raoi Pl. 2, fig. 3

Division-Chlorophyta Pascher, 1914

Class-Chlorophyceae Kutzing, 1843

Order-Siphonales Wille, in Warming, 1884

Family-Dasycladaceae Kutzing, 1843

Genus-*Dissocladella* Pia, 1936

Dissocladella sp. (Pl. 2, Fig. 5)

PALAEOENVIRONMENT

One of the most important components of the carbonate sediments is the calcareous algae, which thrive well under warm marine environments throughout the geologic history. Greensmith (1985) found that the calcareous algae such as *Lithothamnion, Corallina, Lithophyllum* under family Corallinaceae are the product of shallow, warm marine conditions. The development of *Sporolithon* (*Archaeolithothamnium*) and *Lithothamnion* under tropical climate was suggested by Adey and Macintyre (1973) which is the chief genus in the seaward growth of the coral edge (Gardiner, 1903; Taylor, 1948). Adey and Macintyre (in Ghose 1977) found the growth of *Sporolithon* and *Lithophyllum* in intertidal zone. Foslie and Bosse (1904) observed shallow water accumulation of algal nodules in the Malaysian region. Johnson (1961) reported the same in the Bikini areas. The genus *Lithothamnion* is highly adaptable crustose form and their best development is in fair to strong circulated water (Gardiner, 1903). These studies suggest that for their metabolic processes algae require light and thus, their depth of occurrence is restricted to less than 200m of normal salinity which is almost equivalent to the low tide level where they can live freely or attached to the sandy bottom. Purser (1973) describes the clean washed foraminiferal, algal and coral sands from the extensive areas of Persian Gulf. The rise and fall in sea level due to Palaeocene oscillatory movement commenced the deposition of interbedded shale-carbonate-sandstone strata in Sylhet Limestone Formation, Meghalaya Plateau. The occurrence of algal ball and coralline algae together with foraminiferal assemblages in Lakadong Limestone bear the evidence of shallow, warm saline water conditions that prevailed during the Thanetian sea transgression. The underlying Therria and overlying Lakadong sandstones represent the regressive facies of the sequence. Dasgupta (1926) based on the lithofacies explained the development of this transgressive-regressive sequence in Meghalaya.

The genus *Rivularia,* recorded from the upper part of the limestone, is an important contributor to the deposits of modern tropical areas. These forms are able to colonise unconsolidated muddy bottom, which are unfavourable to family Corallinaceae. Wray (1964) suggested that Corallinaceae represents the reef facies while the *Rivularia* is dominant constituent in the Eocene reef-rock complex of Northeast India (Ghose, 1977). Articulate coralline algae like *Corallina, Amphiroa* and *Jania* are common in reef complex in which the *Corallina* and *Amphiroa* are distributed from cool temperate to warm tropical region while *Jania* is common in reef complex (Johnson, 1961). Gastropods, considered to be signatory of lagoonal environments (Bjorlykke, 1989), have been found in the upper part of the Lakadong carbonate facies supporting the development of lagoonal facies in the area. The family Dasycladaceae generally thrives under condition of relatively strong current action with little micrite accumulation (Greensmith, 1985). The relatively higher frequency of the family Dasycladaceae and Corallinaceae in the lower part was noticed to decline gradually towards the top of the facies. The occurrence of Dasycladaceae-Corallinaceae assemblage indicates shallow marine warm water conditions of deposition under relatively stronger current action. The widespread occurrence of Dasycladaceous algae are found in reefal body in Sirte basin of Libya (Berggren, 1974). In Northeast India the Dasycladacaen algae suggest the development of back-reef areas adjacent to reef core (Ghose, 1977) which might lie in the low-tide level down to 10m (Johnson, 1961). The *Lithothamnion* is an important rock builder of submerged shoal in the tropics down to about 100m (Gardiner, 1903). *Corallina* in the Lakadong limestone represents shallow exposed part of the facies. Algal-foraminiferal, biosparite/ biomicrite with reef building algae thrive under fore-reef side. The basinal water level fluctuation was marked by the presence of both the red and green algae, the latter can live in somewhat shallower depth by avoiding the blue short-wave light (Bjorlykke, 1989).

Both the algae and corals are coactive, and mutually assisting and play significant role in binding and encrusting (Longman, 1981). It is known to exist in the modern reefs of tropics living at depth less than 10m of marine water (Greensmith, 1985). The reported occurrence of *Gypsina* in the Lakadong Limestone (Nagappa, 1959) support the view of reef forming limestone, because the relation of *Gypsina* to the present day reef formation is commonly known from different parts of the world. In the modern seas, the encrusting foraminifers are indicative of reef-core and important constituents of foraminifera-algae reef complex. The occurrence of *Miscellanea* and *Lockhartia* indicates shallow-water (20-40m) condition (Levin, 1957) while the *Operculina* is suggestive of deeper parts of the lagoon (Gardiner, 1903). Abundant miliolids from upper-middle part of the limestone indicate clear and shallow water barrier-reef lagoons (Henson, 1950). *Orbitolites* in the Lakadong Limestone (Jauhri, 1988) is indicative of back-reef facies. The association of foraminifers such as *Ranikothalia, Discocyclina, Miscellanea,* corals such as *Placotrochus* and *Balanophylia* and other algal forms in the Lakadong Limestone indicates the development of shallow marine reef-complexes with normal salinity under less than 30m of depth in tropical climate.

PALAEOGEOGRAPHY

The area under present study was influenced by different phases of marine transgression and regression between Upper Cretaceous and Upper Eocene time, during which the sedimentary sequence comprising of Mahadek, Langpar, Therria, Sylhet and Kopili formations were deposited. The dawning of northward marine encroachment over the Archean gneisses and granites of Shillong Plateau is evidenced by the occurrence of Mahadek Formation during Maestrichtian epoch, which reached up to the point of 1023' waterfall near Upper Cherrapunji in the East Khasi Hills. The development of the Danian shallow marine environment is witnessed by the Langpar Formation that could be traced up to Sohrarim. Moreover, during the Late Palaeocene (Thanetian) two phases of sea regression with the intervening phase of sea transgression took place over the southern Shillong Plateau. The regressive facies are represented by the Therria Formation and the Lakadong Sandstone Member which as the product of near shore environment is clearly witnessed by the occurrence of coastal aspect of palm pollens (Dutta & Sah, 1970). The southward extension of both the rock units is Therriaghat. The northward transgression of the intervening Thanetian Sea is marked by the occurrence of Lakadong Limestone Member up to Cherrapunji. The second phase of Thanetian sea regression was followed by the Eocene sea transgression – regression events with some local phenomenon during which the calcareous sediments precipitated under shallow, warm, open marine to lower delta plain environments which could be followed up to Ishamoti in the Khasi Hills.

Based on the seismostratigraphic as well as the palynostratigraphic analyses it was suggested that the Palaeocene – Eocene marine encroachment was also extended up to the Upper Assam valley (Rath *et al.*, 1994; Bhuyan *et al.*, 1997) and for this reason the Langpar, Therria, Sylhet and Kopili formations have received much attention in the subsurface of Upper Assam Valley for delineating the ancient shore lines from the petroleum view point. In the sequence the Lakadong Limestone Member as principal Palaeocene carbonate facies plays significant role in the stratigraphy of this region.

CONCLUSION

Based on the occurrence of typical Palaeocene marker algae like *Distichoplax biserialis* the age of the limestone is considered as Thanetian (Upper Palaeocene). The genus *Ranikothalia* occurs as rock-forming element during the Thanetian age. In the present study, the rich assemblage of *Miscellanea, Ranikothalia,* and *Distichoplax* in the limestones both from 31/2 milestone and Cherrapunji-Mawmluh area (Lakadong Limestone Member) indicates their age as Thanetian and can be equated. Based on the development of algal association of *Distichoplax biserialis, Rivularia, Corallina* and foraminifers like

Ranikothalia, Miscellanea and Rotaliid-Miliolid association, the similar ecological conditions may also be suggested for the Lakadong carbonate facies.

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