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Microfacies Types (MFT) and Palaeoenvironment of the Umlatodoh Carbonates in the Shillong Plateau of Meghalaya, NE India

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Abstract: One of the major marine transgressions in the Shillong Plateau is represented by the middlemost Umlatodoh Formation of the Sylhet Limestone Group during early Eocene. Based on 26 species of Larger Benthic Foraminifera (LBF) and eleven species of calcareous red algae and green algae, nine Tethyan MFT (microfacies types) viz, *Miliolid Packstone-Grainstone, Algal Packstone-Grainstone, Miliolid Grainstone, Larger Benthic Foraminiferal Grainstone, Green Algae Grainstone, Alveolina oblonga Grainstone, Oolitic Packstone-Grainstone and Micrite* have been identified for the Umlatodoh Limestone. These microfacies have contributed towards identification of a range of environments from low-energy, shallow neritic inner-shelf through shallow, reef shelf to more restricted environment represented by pure micrite. Petrographical characteristics indicate that these limestones are primarily microcrystalline allochemical rocks of biomicritic type and a mixture of packstone and grainstone. The foraminiferal assemblage associated with various species of coralline red algae and green algae suggests inner ramp, mud-free shallow neritic shelf carbonate sedimentation of the Umlatodoh Limestone showing depositions in calm water, low-energy conditions in the lower part changing to moderately high-energy conditions in the middle followed by low-energy restricted environment represented by micrite towards the upper part.

Keywords: Umlatodoh, Sylhet Limestone, Inner ramp, Shelf Carbonate, Meghalaya.

INTRODUCTION

A thick early Palaeogene carbonate succession termed the Umlatodoh Limestone Formation forming the middlemost unit of the Sylhet Limestone Group is well exposed in the Lumshnong area of Jaintia hills district, Meghalaya, NE India. Jaintia hills in Meghalaya exhibit huge deposits of the lower Tertiary within the Assam-Arakan basin. The larger foraminiferal assemblages from this Palaeogene sequence exhibit resemblance with both the Tethyan and Indo-Pacific provinces. Very well-preserved benthic foraminifera have been reported from the Palaeogene sequence of the south Shillong plateau. A very few publications related to stratigraphy, sedimentology, palynostratigraphy and algae of these limestones are available (Evans, 1935; Nagappa, 1959; Wilson and Metre, 1953; Pal and Dutta, 1979; Samanta and Raychaudhuri, 1983; Sarma and Ghosh, 2006; Jauhri and Agarwal, 2001; Jauhri et al. 2006; Dutta and Das, 2010). Based on 26 species of identified larger benthic foraminifera this study has added new data in the identification of carbonate MFT (Microfacies Types) and depositional environment of the Umlatodoh limestones exposed in the Lumshnong area which has escaped the attention of the previous workers. These rich assemblages of shallow neritic larger benthic foraminifera and calcareous algae identified in the carbonates and their microfacies types have also been used to interpret the depositional environment. Based on palaeontological data of the present study this Umlatodoh Limestone Formation is considered to be early Eocene.

The field study has been carried out in the two sections of Moiong limestone mine (no.1 and no.3) of Topcem Cement Limited in the Lumshnong area of Jaintia hills district, Meghalaya in January 2010. The Lumshnong area is situated on the south-eastern slope of the Shillong plateau on the Jowai-Badarpur road at a distance of 128 km to the southeast of Shillong township (Fig.1).

GEOLOGICAL SETTING

The Shillong plateau (Fig.1) in the northeast India is bounded to the south by E-W trending Dauki fault, to the north by Brahmaputra depression, to the west by N-S trending Jamuna fault and to the east it is covered by Tertiary sediments of upper Assam. This plateau is separated from

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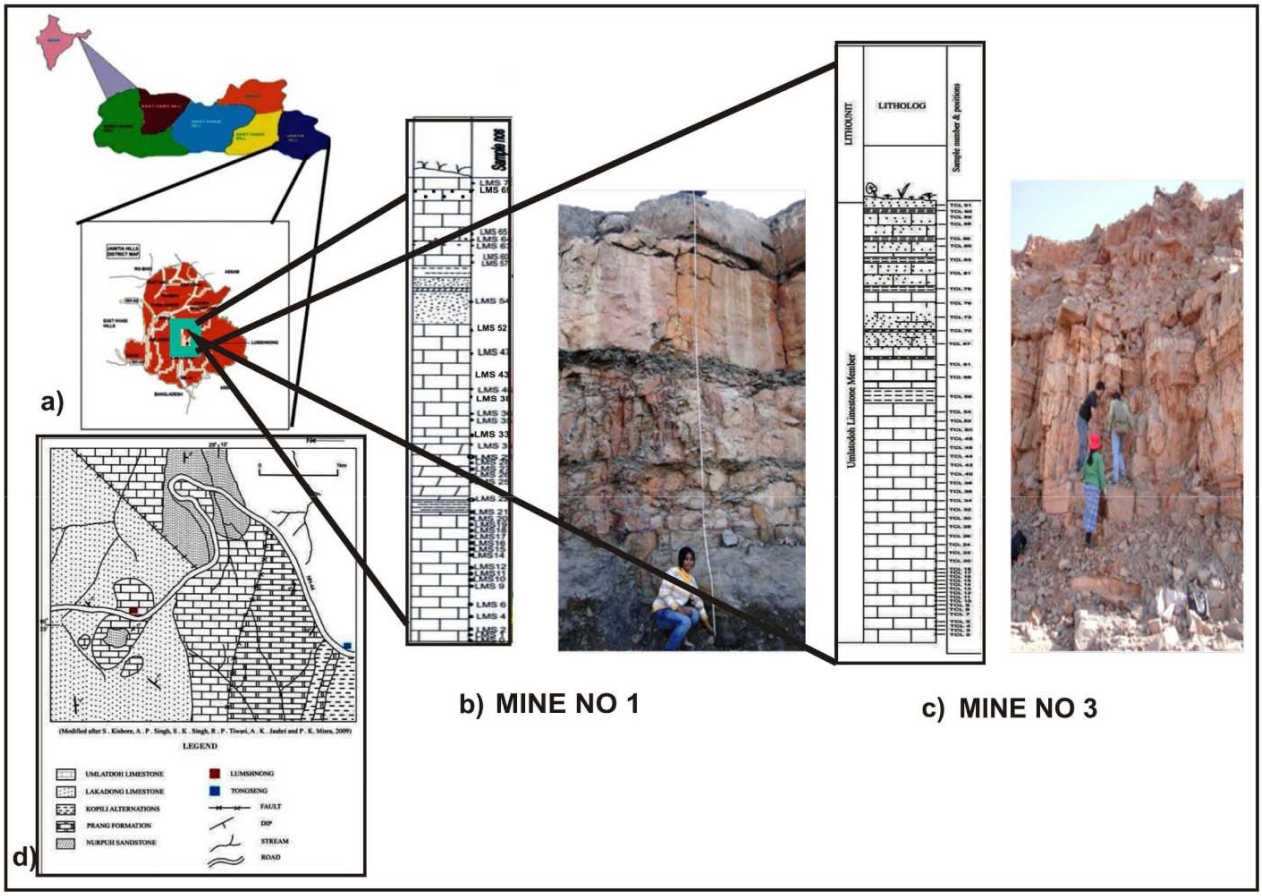

Fig.1. Showing **(a)** location of the Lumshnong, **(b)** lithological succession of mine no 1 in Topcem Cement Factory, **(c)** lithological succession of mine no 3 in Topcem Cement Factory, **(d)** geological map of Lumshnong area (*after* Kishore et al., 2009), Jaintia Hills, Meghalaya.

the Mikir hills in the north east by NE-SW trending Kopili fault system (Das Gupta and Nandy, 1982). The cause of formation of contrasting sedimentary rocks in the plateau is the marine transgression on the southern part of the plateau during the Cretaceous–Cenozoic times. Cenozoic transgression began in the early Palaeocene (Danian) in the Shillong plateau (Nagappa, 1959 and Garg and Jain, 1995).There were two transgressions of the southern sea, namely the Mahadek (= Maestrichtian) and the Langpar (Danian) seas (Dutta, 1968). This was again followed by a very large transgression during the upper Palaeocene when an arm of sea from the Eastern Tethys covered extensively the Shillong plateau via the Middle East, Pakistan and Tibet which is represented by the Lakadong limestone (Jauhri et al. 2006; Gogoi et al. 2009). Subsequently, two major marine transgressions covered the Shillong plateau during early Eocene which is represented by the Umlatodoh limestone and during middle Eocene to early upper Eocene that is represented by the Prang limestone (Spengler, 1923; Sander, 1962; Rama Rao, 1964; Hottinger, 1971; Sahni and Kumar, 1974; Rahaghi, 1983; Wan, 1991; Jauhri and Agarwal, 2001; Gogoi et al. 2009; Misra et al. 2011; Ghosh and Sarkar, 2013).

A few workers (Medlicott, 1871; Oldham, 1859; Evans, 1932; Ghosh, 1940; Wilson and Metre, 1953; Biswas, 1962; Murty et al. 1976; Dutta and Sah, 1970; Dasgupta, 1977; Dutta and Jain, 1980; Samanta and Raychoudhury, 1983; Murty, 1983; Jauhri, 1994; Garg and Khowaja-Ateequzzaman, 2000; Nandy, 2001; Sarmah and Borgohain, 2011) have worked on the stratigraphy, of the Shillong plateau. Stratigraphically the Umlatodoh limestone belongs to the Sylhet Limestone Group, which has been sub-divided into the Lakadong Formation in the lower part, Umlatodoh Formation in the middle and Prang Formation at the top (Dasgupta, 1977). Three limestone members are intercalated between two sandstone beds and the Sylhet Limestone Group is overlain by the Kopili Formation (sandstone and shale alteration) of late Eocene age (Table 1). The Umlatodoh Formation has been divided into the Umlatodoh limestone and the Narpuh sandstone. The Umlatodoh limestone is

Table.1. Stratigraphy of the Sylhet Limestone Group in the South Shillong Plateau (*after* Dasgupta, 1977)

	KOPILI FORMATION		Late Eocene
Sylhet Limestone Group	PRANG FORMATION		Middle Eocene
	Umlatodoh Formation	Narpuh Sandstone	Early Eocene
		Umlatdoh Limestone	
	Lakadong Formation	Lakadong Sandstone	Late Palaeocene
		Lakadong Limestone	

underlain by the Lakadong sandstone and is overlain by the Narpuh sandstone. Paleontological data especially the LBF data from the Umlatodoh carbonate succession are very scanty (Jauhri et al. 2006, Matsumaru and Sarma, 2010) in contrast to the Lakadong carbonates of the Sylhet Limestone Group. The appearance of larger foraminifera in the Umlatodoh carbonates indicates the initiation of marine transgression during Ypressian represented by the presence of porcellaneous-walled *Alveolina oblonga* (slide no. LMS 9 in mine no. 1 and TCL 8 in mine no. 3).

The Lumshnong area presents the most complete section of the entire Sylhet Limestone Group. The Umlatodoh limestones in the Lumshnong area comprise hard, massive and very thick foraminiferal-algal carbonates associated with dolomite, sandstone and shale sequence of early Eocene. In the area the beds exhibit a low dip of about 5° and the dip direction is S - SE. In mine no. 1, deposition starts with the limestone with a thin shale band within it. Limestone in the middle part (slide no.LMS 22 to LMS 32) becomes dolomitic limestone due to enrichment of magnesium. Towards the upper part, the lithology changes to sandstone (slide no.LMS 52 to LMS 58) with the second shale band above it followed by the deposition of carbonate sediments (from slide no.LMS 59). Current bedding (slide no. LMS 56) within the sandstone indicates high-energy conditions during deposition. In mine no. 3, the lower part of the succession is dominantly limestone with a shale band at a height of 59 feet (slide no. TCL 59) followed by high-energy conditions of deposition represented by sandstone showing current bedding (slide no.TCL 67 to TCL 78; slide no. TCL 75, height of 75 feet). Towards the upper part of the succession shale alterations are found within impure calcareous rocks.

MATERIALS AND METHODS

The Umlatodoh limestones in the Lumshnong area is characterized by limestone, dolomitic limestone, sandstone and thin shale bands. Field work was carried out in Topcem Cement factory in the Lumshnong area of Jaintia hills district, Meghalaya. The total height of the succession in Moiong mine no.1 is 72 feet (Fig.1b) and that of mine no.3 (Fig.1c) is 109.8 feet. In total, 37 thin sections from mine no.1 and 45 thin sections from mine no. 3 were prepared in the laboratory to carry out this study. Species diversities of foraminifera (Figs.2 and 3) and microfacies analysis were observed using Polavision microscope.

Volumetric percentages of each species of foraminifera in each slide were calculated using line counting method. Photomicrographs were taken using Motic MC camera and Leica DM 750P under 4X magnification. Samples of thin shale bands were macerated and a few ostracodes are picked from these shales. Microfacies types (MFT) are determined in thin sections on the basis of semi-quantitative-quantitative analysis of lithology, grain types, fossil assemblages and textures. Depositional environments are interpreted analysing the field data, palaeontological data, microfacies data and sedimentological data. All thin sections are housed in the Micropalaeontological Laboratory, Department of Applied Geology, Dibrugarh University, India.

BENTHIC FORAMINIFERAS

Benthic foraminiferas are considered as an important tool for studying the high resolution biostratigraphy of shallow marine carbonate sequences. Larger benthic foraminifera (LBF) are important contributors to modern and ancient tropical, shallow-marine sediments. Over the past 30 years, substantial literature on the ecology of modern LBF, especially in terms of their environmentally sensitive depth distribution, reproductive strategy and morphology, and the symbiotic relationship between many larger foraminifera and photosynthetic algae is available (Penney and Racey, 2004).

Based on 82 thin sections from both the mines, the Umlatodoh limestone reveals 26 species of benthic foraminifera belonging to 17 genera distributed among 7 families associated with various species of coralline red algae and green algae. *Quinqueloculina* sp is the most abundant species among the foraminifera to be reported in the limestone of both the studied sections. It is represented in the entire lithological succession. In mine no.1, the abundance of *Quinqueloculina* sp is followed by the abundance of *Alveolina oblonga* while in mine no.3, *Nummulites* sp is the second abundant species. The first appearance datum of *Alveolina oblonga* in both the sections is approximately 8 ft. Among the different types of

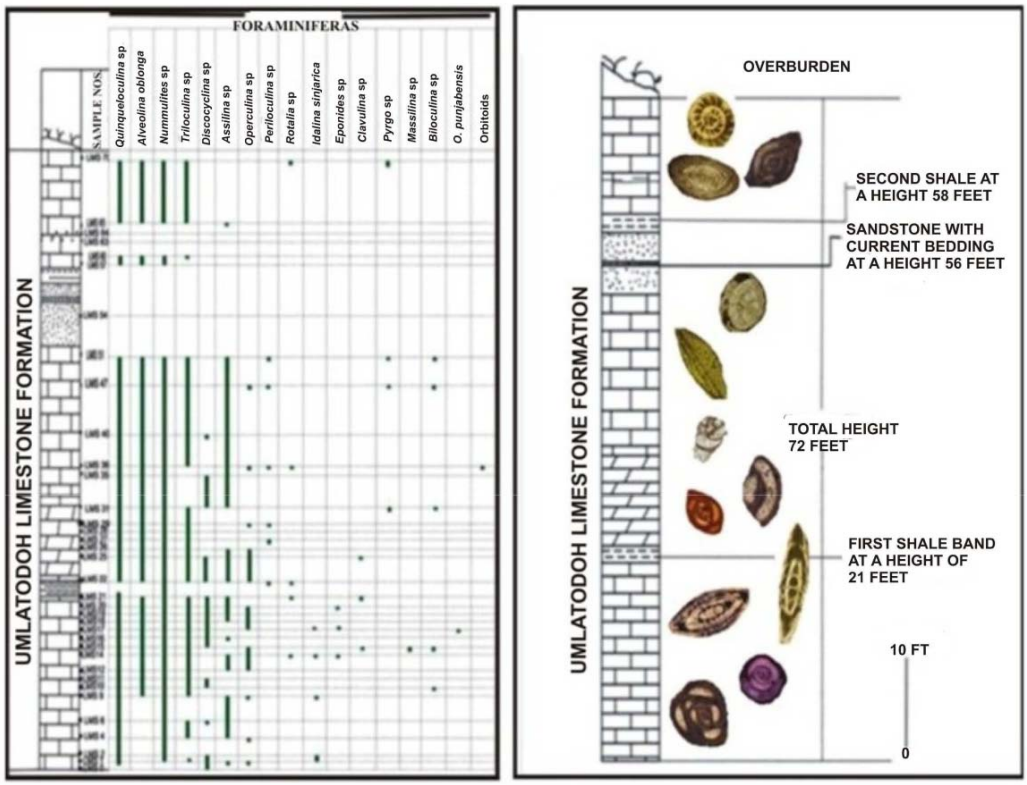

Fig.2. Foraminiferal species diversity of mine no. 1, Lumshnong area, Jaintia hills.

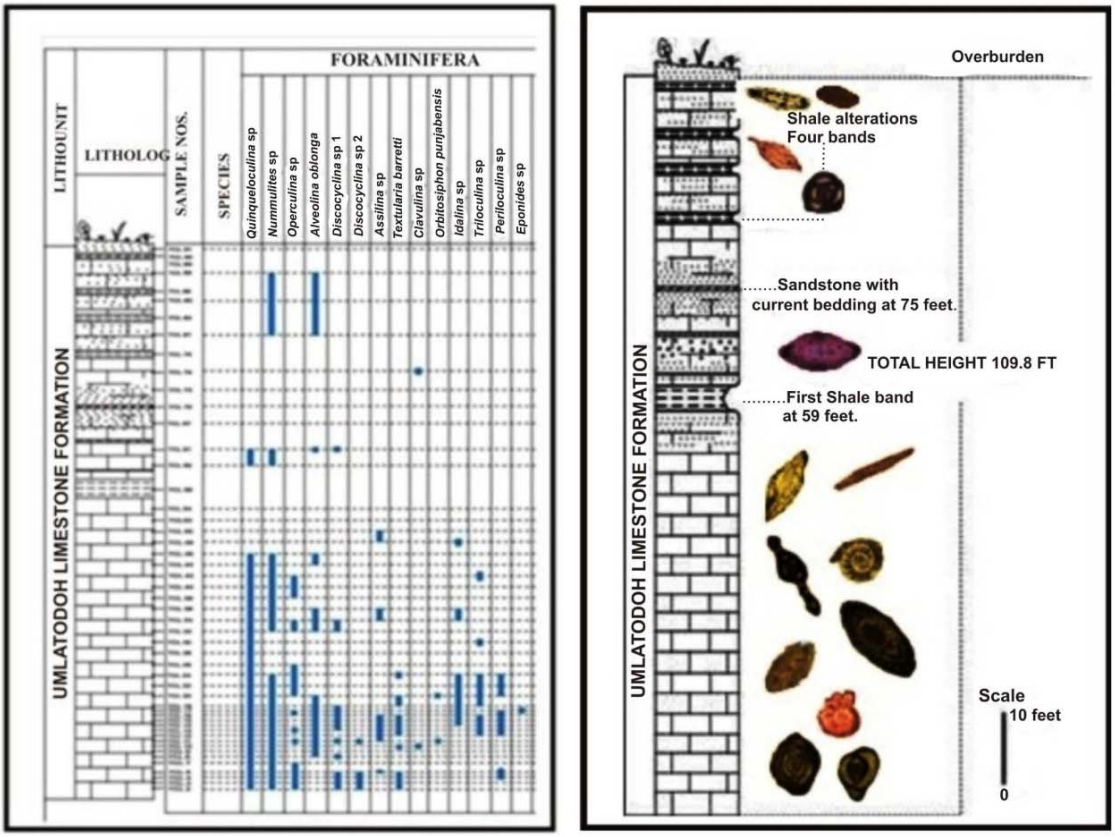

Fig.3. Foraminiferal species diversity of mine no. 3, Lumshnong area, Jaintia hills.

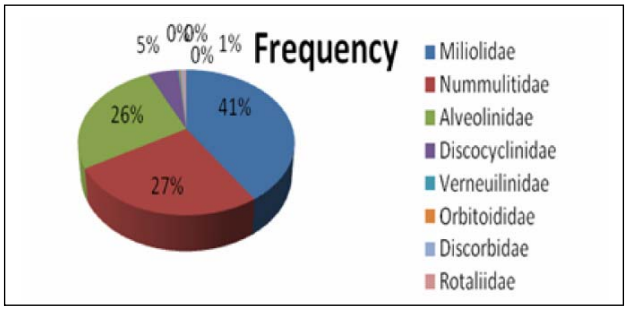

Fig.4. Frequency distribution of different families of foraminifera in mine no. 1, Topcem Cement Factory, Lumshnong area, Jaintia Hills.

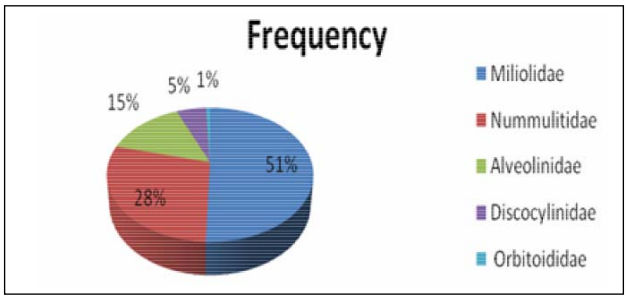

Fig.5. Frequency distribution of different families of foraminifera in mine no. 3, Topcem Cement Factory, Lumshnong area, Jaintia Hills.

foraminifera reported the least abundant are *Rotalia, Massilina, Biloculina, Periloculina, Orbitosiphon punjabensis* and *Orbitoides*. Majority of the reported species belong to the family Miliolidae constituting approximately 41% of the total population in mine no.1 while 51% in mine no.3 and is followed by Nummulitidae with approximately 28% in both the sections, Alveolinidae with 26% and 15% in mine no.1 and mine no.3 respectively, Discocyclinidae with 5% in both the sections and others are negligible compared to them (Fig. 4 & 5).

Distribution patterns of the foraminifera and algae species in the studied successions of mine no.1 and mine no.3 show variation. The lower part of the lithological succession is more abundant in *Quinqueloculina* sp and *Nummulites* sp compared to *Alveolina oblonga*, which appeared from a height of approximately 8 feet in both mine no.1and 3. This abundance of foraminifera have been noticed to the height of 40 feet (slide no LMS40) in the mine no. 1 and to 26 feet (slide no TCL26) in mine no. 3. This zone was the most favourable for the development of different foraminiferal species. *Alveolina oblonga* indicates Ypressian age. These foraminifera decrease towards the upper part of the lithological successions in both the mines, but there is a marked increase in size of each species. Moreover in slides LMS 27 to 29 of mine no. 1, *Alveolina oblonga* and *Nummulites* sp are comparatively larger than the other foraminiferas. These two are the only foraminifera species found to occur in the topmost part of the successions.

MICROFACIES TYPES (MFT), BIOTA AND PALAEOENVIRONMENT

The microfacies analysis (Fig.6) of the Umlatodoh limestone in Lumshnong area has followed the nomenclature of Dunham (1962), Embry and Klovan (1971) and Flugel (2004) for the microfacies of carbonate rocks. On the basis of 26 species of larger benthic foraminifera (LBF) and associated algae, nine Tethyan Microfacies Types have been established describing different depositional and palaeoenvironmental settings. This study presents new data on carbonate Microfacies Types (MFTs) establishing Miliolid Packstone-Grainstone MFT, Algal Packstone-Grainstone MFT, Miliolid Grainstone MFT, Nummulitic Grainstone MFT, Larger Benthic Foraminiferal Grainstone MFT, Algal Grainstone MFT, *Alveolina oblonga* Grainstone MFT, Oolitic Packstone- Grainstone MFT, and Micrite MFT.

Miliolid Packstone-Grainstone MFT (MFT 1, Fig.7)

This MFT in the lower part of the succession is dominated by miliolids (mainly *Quinqueloculina* sp and *Triloculina* sp). *Nummulites* sp, *Discocyclina* sp, *Pyrgo* sp and calcareous algae are also found in association with miliolids. Amongst the miliolids, *Quinqueloculina* sp is the most abundant. This microfacies in some part shows well developed calcite grains and in others micrite matrix. The matrix is also found to be locally ferruginous. The existence of abundant *Quinqueloculina* and other miliolids together with sedimentary textures suggest that this Packstone-Grainstone microfacies is related to low- energy, shallow neritic shelf shoal environment (Jauhri, 1994)

Algal Packstone-Grainstone MFT (MFT 2, Fig. 8a,b)

In these microfacies algae dominate over miliolid forams. This microfacies comprises of *Alveolina oblonga*, *Nummulites* sp, *Eponides* sp, *Discocyclina* sp, *Operculina* sp and microgastropods. *Halimeda* sp, *Indopolia satyavanti, Cymopolia mayaense, Neomeris* sp, *Griphoporella arabica* are the green algae associated with benthic foraminifera in this microfacies. Fragments of coralline red algae are also observed. The micritic matrix in this microfacies contains very fine grained calcite microspar. *Indopolia* has been reported from the shallow shelf, back-reef facies in Meghalaya (Jauhri et al. 2006), in Iraq (Elliott, 1968), Ras

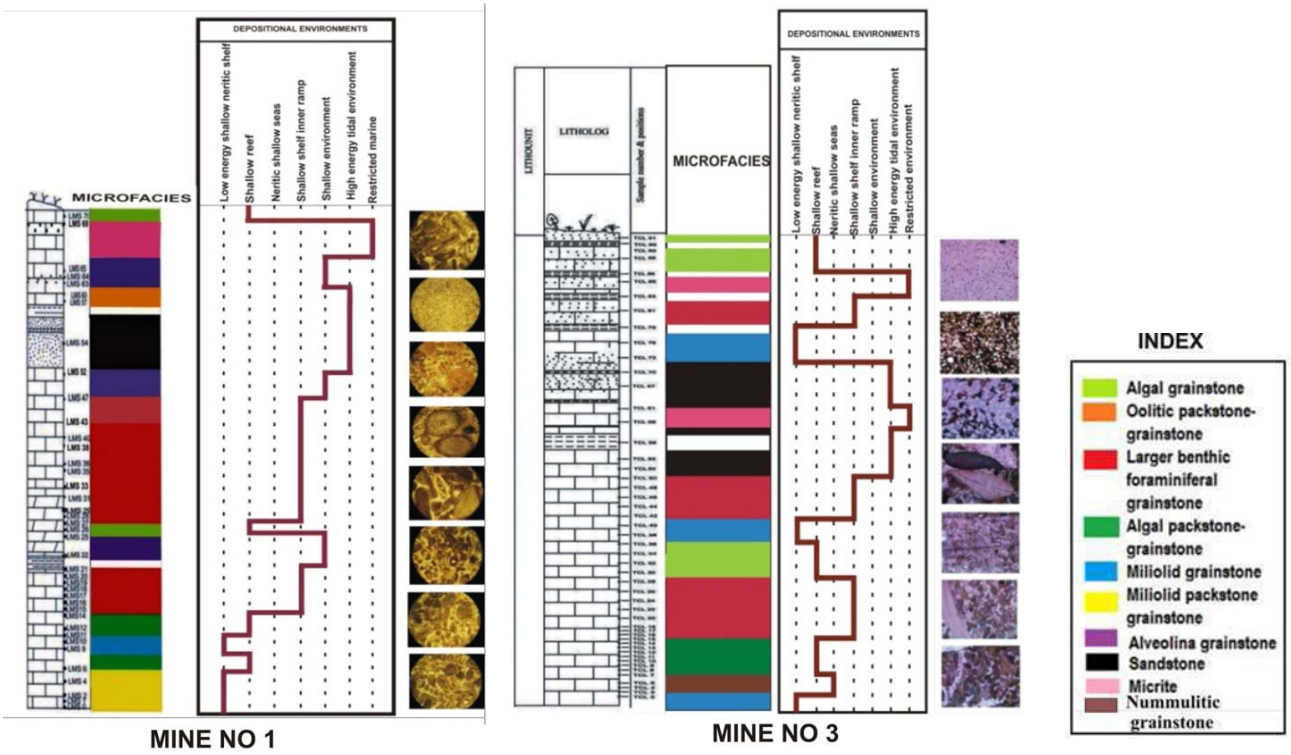

Fig.6. MFT types and different depositional environments in mine no. 1 and mine no. 3 of Topcem Cement Factory, Lumshnong area, Jaintia Hills.

Al Hamra, Oman (Racz, 1979), Greece (Deloffre et al. 1991) and Trichinopolly, south India (Misra et al. 2000). Cenozoic reefoidal limestones are commonly characterized by the genus *Halimeda*. Ghosh and Sarkar (2013) described *Halimeda* as more abundant in somewhat sheltered parts of the reef complex such as the inner part of the reef flat or the adjoining shallower portion of the lagoon, where water is moderately agitated and clear. The abundance of *Halimeda* and calcareous red algae suggests a shift from shallow neritic shelf to shallow reef environment.

Miliolid Grainstone MFT (MFT 3, Fig.9a, b)

Porcelaneous foraminifera such as miliolids (Austrotrillina, Pyrgo, Quinqueloculina and Triloculina) are the most abundant constituent along with *Alveolina oblonga,* calcareous algae, *Nummulites* sp and minor abundance of *Clavulina sp* and *Discocyclina* sp. The calcite grains show distinct three sets of cleavage. Fragments of corallinacea red algae are present. This MFT is mostly grain-supported matrix with micritic groundmass. The occurrence of perforate benthic foraminifera reflects that sedimentation took place in a shelf lagoon (Romero et al., 2002). This association together with red algae debris characterizes an inner-shelf depositional setting (Corda and Brandano, 2003).

Nummulitic Grainstone MFT (MFT 4, Fig. 10)

Nummulites are the dominant constituent of this microfacies. They are found in association with *Quinqueloculina* sp, *Triloculina* sp, *Periloculina* sp, *Operculina* sp, *Discocyclina* sp, *Assilina* sp and calcareous algae. Nummulitids are mainly found in the sediments of bioherm or sandbank facies and nummulitic reefs, commonly in neritic shallow seas.

Larger Benthic Foraminiferal Grainstone MFT (MFT 5, Fig. 11)

Nummulites sp, *Alveolina oblonga, Discocyclina* sp, *Assilina* sp and *Quinqueloculina* sp are the main constituent along with comparatively less calcareous algae. This microfacies texture show well developed larger calcitic grains. High taxonomic diversity of LBF with perforate walls, corallinacea, micrite matrix and stratigraphic position represents deposition on a shallower slope environment (Amirshahkarami et al. 2007). The larger benthic foraminifera and red algae association were identified as living in the ramp environment (Pomar 2001; Brandano and Corda, 2002; Corda and Brandano, 2003). Presence of these microfossils indicate shallow shelf inner ramp environment of deposition.

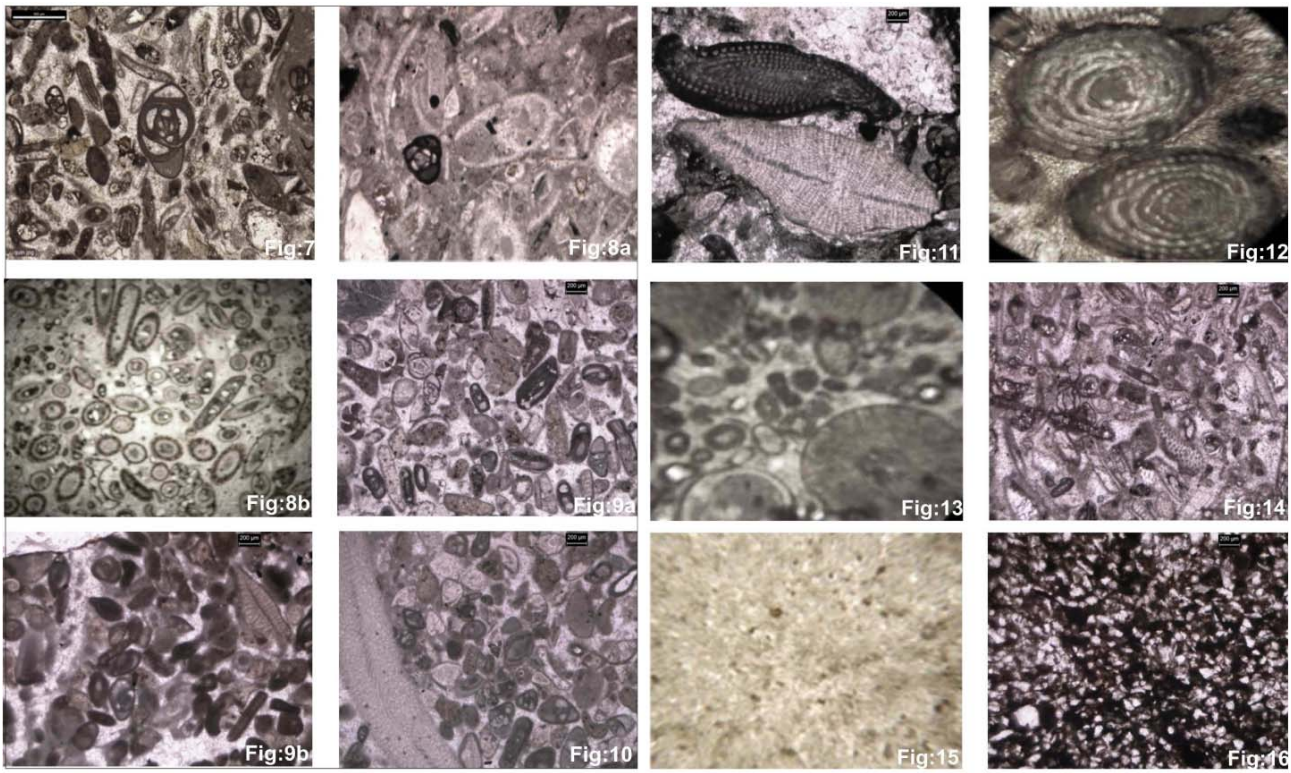

Fig.7. Miliolid Packstone – Grainstone (4X magnification), **Fig. 8a & 8b.** Algal Packstone- Grainstone (4X magnification), **Fig.9a & 9b**. Miliolid Grainstone (4X magnification), **Fig.10.** Nummulitic Grainstone. **Fig.11**. Larger Benthic Foraminiferal Grainstone (4X magnification), **Fig.12**. *Alveolina oblonga* Grainstone (4X magnification), **Fig.13**. Oolitic Packstone- Grainstone (4X magnification), **Fig.14**. Green Algae Grainstone (4X magnification), **Fig.15**. Micrite (4X magnification), **Fig.16**. Sandstone (4X magnification).

***Alveolina oblonga* Grainstone MFT** (MFT 6, Fig. 12)

Alveolina oblonga is the main constituent of this microfacies. The size of *Alveolina oblonga* is comparatively larger than those present in other microfacies. In this microfacies at a height of 47-52 ft, influx of clastic grains are more as this microfacies is succeeded by 8 ft thick depositis of arenaceous sediments. *Miliolids, Nummulites* sp, *Assilina* sp, *Discocyclina* sp and calcareous algae are found associated with *Alveolina oblonga.* Alveolina and miliolid persist in the shallow inner shelf or lagoon (Henson, 1950). Alveolina is distributed in back- reef, fore-reef and in quite water during the Eocene period (Ghose, 1977; Pautal, 1987). The presence of Nummulites and Discocyclina indicate the deposition of this microfacies near the shallow environment (Bartholdy, 2000).

Oolitic Packstone-Grainstone MFT (MFT 7, Fig. 13)

This microfacies is characterized by the presence of concentric and radial oolites. Abundance of oolites favours the deposition of this microfacies in the high- energy tidal environment.

Green Algae Grainstone MFT (MFT 8, Fig. 14)

Green algae are the main constituent of this microfacies. The microfacies texture is entirely grain supported. *Alveolina oblonga* and *Nummulites* are the only foraminiferal species found in association with these algae. Dominance of green algae suggests shallow reef facies.

Micrite MFT (MFT 9, Fig. 15)

Micrites are generally regarded as indication of low-energy restricted environment (Flugel, 2004).

DISCUSSION

Nine different Microfacies (MFT) Types (MFT 1 to MFT 9) identified in both the sections (mine no. 1 & mine no. 3) of the study area, suggests variation in the environment of deposition from the bottom to the top for the Umlatodoh limestone. The lowermost part of the Umlatodoh limestone is calcareous with fossil allochems mainly foraminifera and algae in micritic matrix. Presence of mud-free water in the basin of deposition and predominance of larger foraminifera

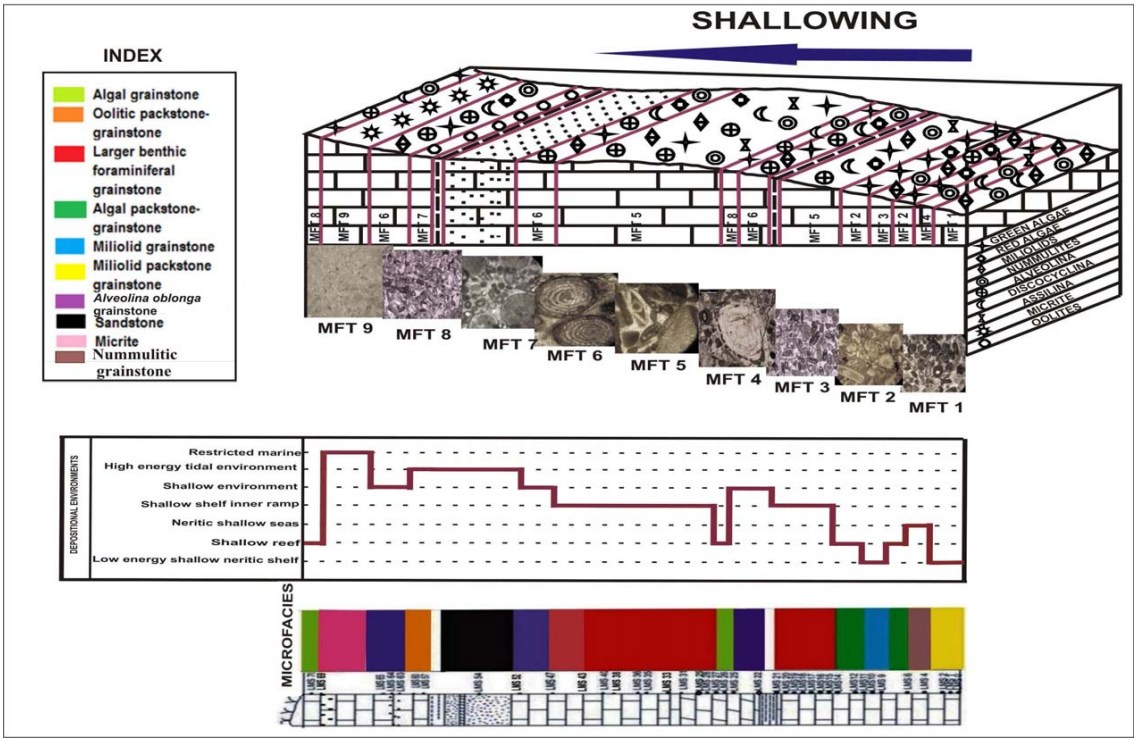

Fig.17. Sketch of microfacies model of shallow shelf inner ramp carbonate platform and the related depositional environment of the Umlatodoh limestone (mine no. 1) in Lumshnong area, Meghalaya plateau, NE India (modified after Mohammad et al., 2010).

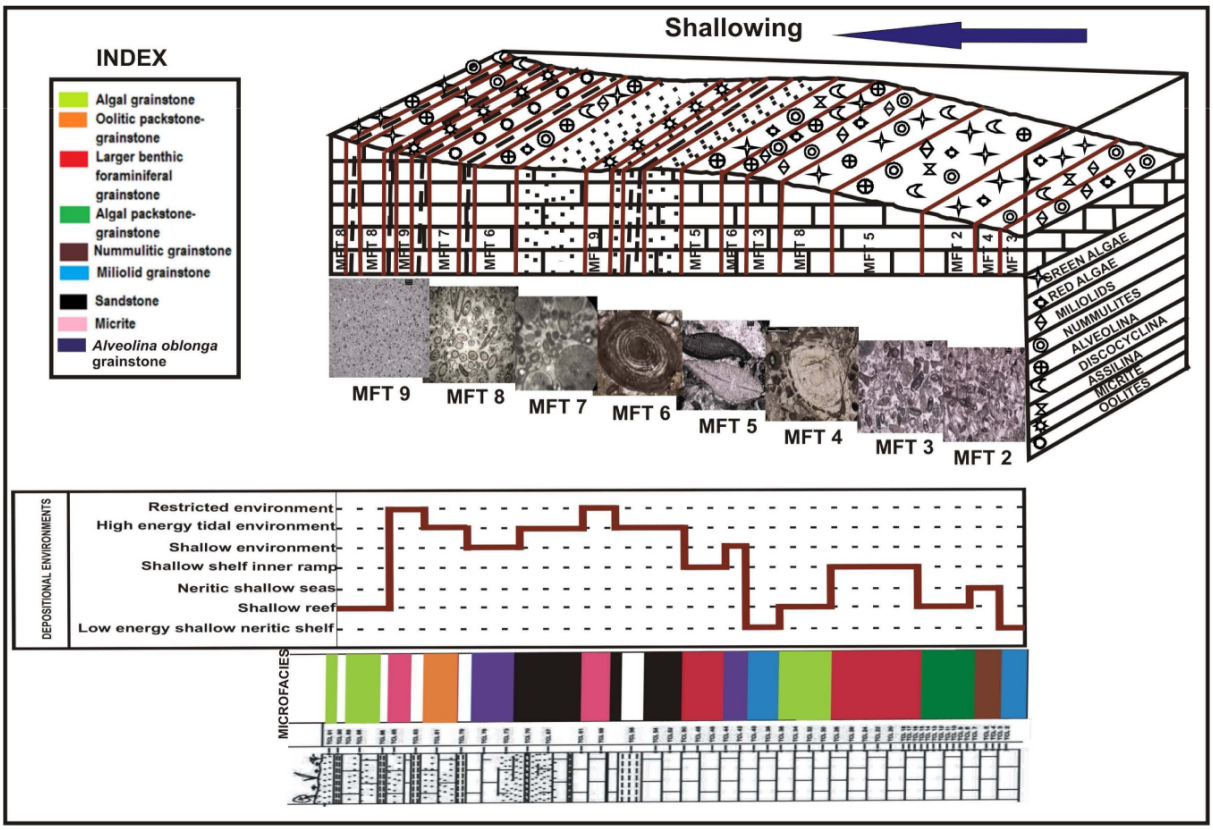

Fig.18. Sketch of microfacies model of shallow shelf inner ramp carbonate platform and the related depositional environment of the Umlatodoh limestone (mine no. 3) in Lumshnong area, Meghalaya plateau, NE India (modified after Mohammad et al., 2010).

and calcareous algae assemblage are indicative of low-energy, together with the different species of calcareous algae started depleting during this phase. Again this deposition was succeeded by the deposition of limestones indicating decrease in the influx of clastic grains. This marks the reappearance and replenishment of many foraminiferas and calcareous algae species. The lithological succession in mine no. 3 witnesses the deposition of four shale bands alternating with impure calcareous rocks at the top. The deposition starts with a decreasing energy condition of sedimentation. The clastic and calcareous ratio of the sediments is greatly reduced to produce calcareous rocks of mixed type. Then there were very short cycles of marine transgression and regression in which four shale bands were deposited.These shale bands were deposited in the sea level stand still conditions between a marine transgression and a regression. The abundant concentric and radial oolites towards the upper part indicate that sedimentation took place in a current or wave action dominated environment.

CONCLUSIONS

A study based on eighty two thin sections from the two lithological successions (mine no. 1 and mine no. 3) of Topcem cement factory, Lumshnong, Jaintia hills) has enabled establishment of nine Tethyan microfacies belonging to four sub-environments in the Umlatodoh limestone Formation of the Sylhet Limestone Group in Meghalaya. 26 species of larger benthic foraminifera (LBF) and eleven species of calcareous red algae and green algae have been identified.

Nine Tethyan MFT (microfacies types) viz, Miliolid Packstone-Grainstone, Algal Packstone-Grainstone, Miliolid Grainstone, Larger Benthic Foraminiferal Grainstone, Green Algae Grainstone, *Alveolina oblonga* Grainstone, Oolitic Packstone-Grainstone and Micrite have suggested four sub-environments from low- energy, shallow neritic shelf through shallow reef to moderately high-energy tidal to low-energy restricted environment. The depositional environment of the Umlatodoh Limestone (Fig.17 and Fig.18) Formation is interpreted as shallow shelf inner ramp carbonate platform with a gentle slope.

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