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# Depositional Environment and Palaeoecology of the Sylhet Limestone from Dillai Parbat, Karbi Anglong District, Assam, India

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## Abstract

The Dillai Parbat is known for its rich limestone deposits represented dominantly by wacke, grain and pack stones. In addition to that fine to medium grained sandstones and carbonaceous shale / shale are also present. Both epifaunal and infaunal forms of the microfossils have been observed. Plane/cross laminations, herringbone and hummocky cross stratifications are the sedimentary structures recorded in the study area. The sediments of the study area are intensely bioturbated which has imported a mottled character to it. Benthic forms of the identified microfossils include *Bolivina, Lagena, Anomalina, Rotalia, Pararotalia, Neoeponides, Spiroloculina, Quinqueloculina, Triloculina, Bolivina, Bulimina, Trifarina, Nummulites, Operculina, Cibicides. Globigerina and Globorotaloides* represent planktic forms of the microfossils. Mega fossils such as gastropods, echionoides and varieties of crabs have also been encountered. Trace fossils including *Skolithos verticalis, Palaeophycus tubularis* and *Thallasinoides* horizontalites have also been observed. Based on the above evidences a shallow marine warm water, rich in nutrients and oxygen within a lagoon /shallow marine environmental set up with fluctuating regime have been envisaged for these limestones.

*Keywords:* Depositional Environment, Palaeoecology. Shallow Marine, Environment, Dillai Parbat, Nagaland

## Introduction

Early Paleogene period had experienced many short and long duration changes in palaeoclimate, and reorganization of tectonic plates. During this period there was extensive development of shallow water carbonates globally. Important occurrence of limestones has been reported by many (Oldham, 1859; Evans, 1932; Nagappa 1956, 1959). The fossil assemblage of late Paleocene - Early Eocene shallow water carbonate is dominated by larger foraminifers which show changes in their morphology and abundance (Scheibner *et al.*, 2005; Zili *et al.*, 2009; Bhattacharya and Gogoi, 2018). The foraminiferal assemblage from Sylhet Limestone has also been reported by many (Pandey, 1981; Jauhri *et al.*, 2006; Gogoi *et al.*, 2009; and Bhattacharjya and Gogoi, 2018). According to Garg and Ateequzzaman, (2000) both the limestone and intermittent clastic facies were developed in this region which continued during Paleocene-Eocene time.

The Dillai Parbat limestones belong to the Eocene Sylhet Limestone Formation. They are inter-bedded with sandstones and shale and are rich in fossil contents both vertebrates and invertebrates. In addition to that many forms of trace fossils; not documented so far, have also been observed in these rocks. According to many (Zili *et al.*, 2009; Bhattacharya and Gogoi, 2018), these fossiliferous Eocene deposits have yielded both vertebrate and invertebrate faunas consisting of shark, ray, crocodile, conical tooth, gastropods and echinoderm spines. Based on the rich fossil assemblage they have not only suggested that these sediments were deposited in a shallow marine environment but also that during Eocene time Tethys was connected with other marine water bodies of the world.

In the present study for the first time an attempt has been made to infer the palaeoenvironment and palaeoecology on the basis of the foraminiferal assemblage and the trace fossils. As not much published literature is available on microfassils and the trace fossils assemblages of the study area, this study would enhance our understanding of the depositional environment and palaeoecology of Dillai Parbat limestones.

## Study Area

The Dillai Parbat limestone quarry (Fig.1a) is a part of Karbi-Anglong district of Assam and is bounded by 25°49'45” N and 26°01'00” N latitudes and 93°35'40” E and 93°35'50”E (SoI toposheet No. Nos.83F/12 and 83G/9). The limestone at Dillai Parbat limestone quarry, which lies on the south-eastern edge of the Karbi-Anglong Massif, belongs to the Sylhet limestone Formation. It overlies the Precambrian granite and granitic gneiss and is overlain by Oligocene Barail sediments. In Dillai Parbat quarry, limestones are highly weathered and at places exhibit brownish colour. The less weathered and fresh lime stones show grayish

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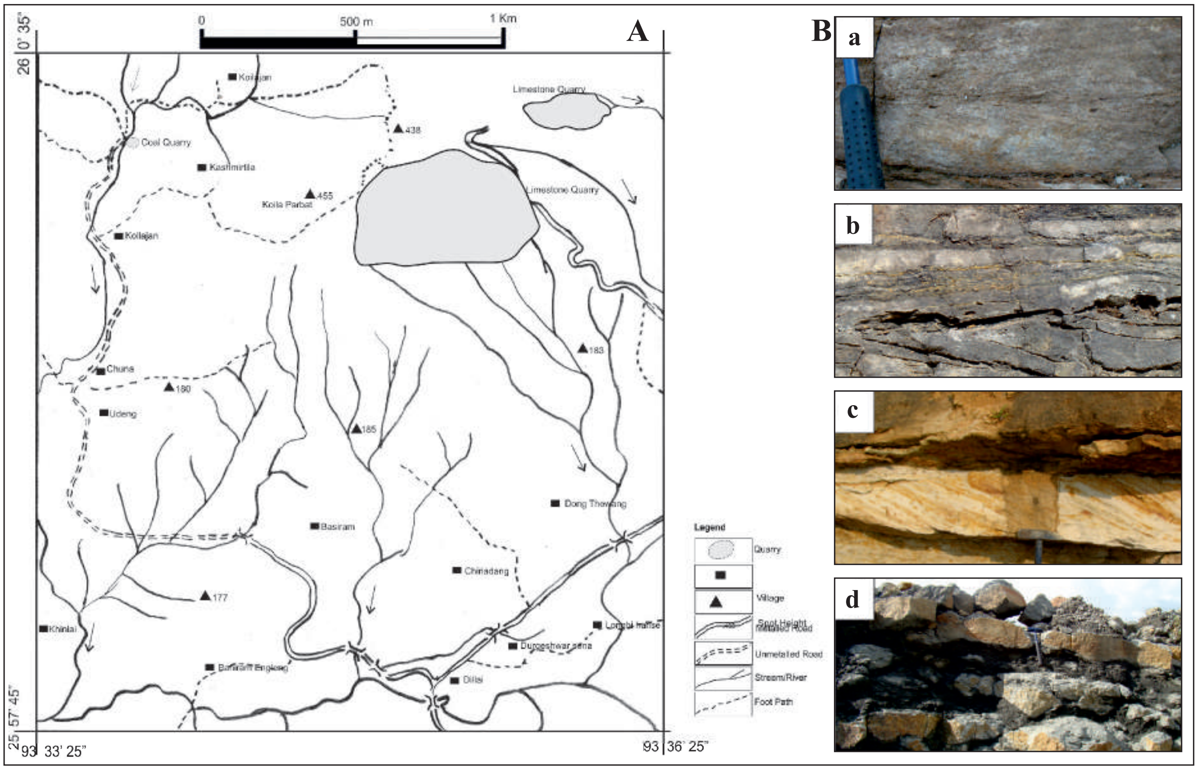


**Fig.1. A.** Geological map of the study area; **B.** Field photographs showing a) Herringbone cross stratification b) Hummocky cross stratification c) Cross stratification in clastic unit d) Alternating limestone and shale

colour. The Sylhet limestone of the study area is approximately 75m thick and is consisted of three horizons of limestone with intercalations of sandstone and shale. The grey colored Dillai limestones are hard and compact in nature. The beds are gently dipping with 8°-10° towards south and southeast. Sedimentary structures observed in the field include herringbone, hummocky, tabular cross and plane laminations (Fig.1b). The Sylhet limestones are rich in both vertebrate and invertebrate faunas and also trace fossils. Stratigraphic succession of the study area is given in Table 1 (Dasgupta, 1977).

## Material and Methods

Five vertical profile sections (VPS, Fig.2i-v) were constructed at suitable localities within the study area and sedimentary structures were photographed. Fresh samples of both limestones and sandstones were collected from the field and thin sections were prepared. Limestone, fine grained sandstones and carbonaceous shale samples were processed for separation of microfossils. After separating microfossils from the matrix, using binocular Leica microscope at the Department of Geology,

**Table 1:** Regional Stratigraphy of the Study Area (*After* Dasgupta, 1977)

| Age | Group | Formation | Lithology | Thickness (m) |
|---|---|---|---|---|
| Pleistocene<br>Recent<br>Plio-Pleistocene | Dihing Group | Alluvium | Boulder beds<br>Soft sandstone Clay | 400 to 800 |
| ~~~ Unconformity ~~~ | | | | |
| | | "Namsang Beds" Clay | Sandstones, conglomerates | |
| Mio-Pliocene | Dupitila Group | Dupitila Formation | Clays and sandstones | 1000 to 2800 |
| ~~~ Unconformity ~~~ | | | | |
| | | Lower<br>Formation | Sandstone and<br>conglomerates | 500 to 2800 |
| Miocene | Tipam Group | Girujan Clay<br>Tipam Sandstones | Sandstones and Clays | 1500-4100 |
| | Surma Group | | Sandstones and shale | 200-5500 |
| Oligocene | Barail Group | | Sandstones and shale | 1200 |
| Palaeocene-<br>Eocene | Jaintia Gropup<br>(Disang Group)<br>In Naga-patkoi | Kopili Shales<br>Sylhet limestones | Shales<br>Limestones and<br>Sandstones | 380-800 |

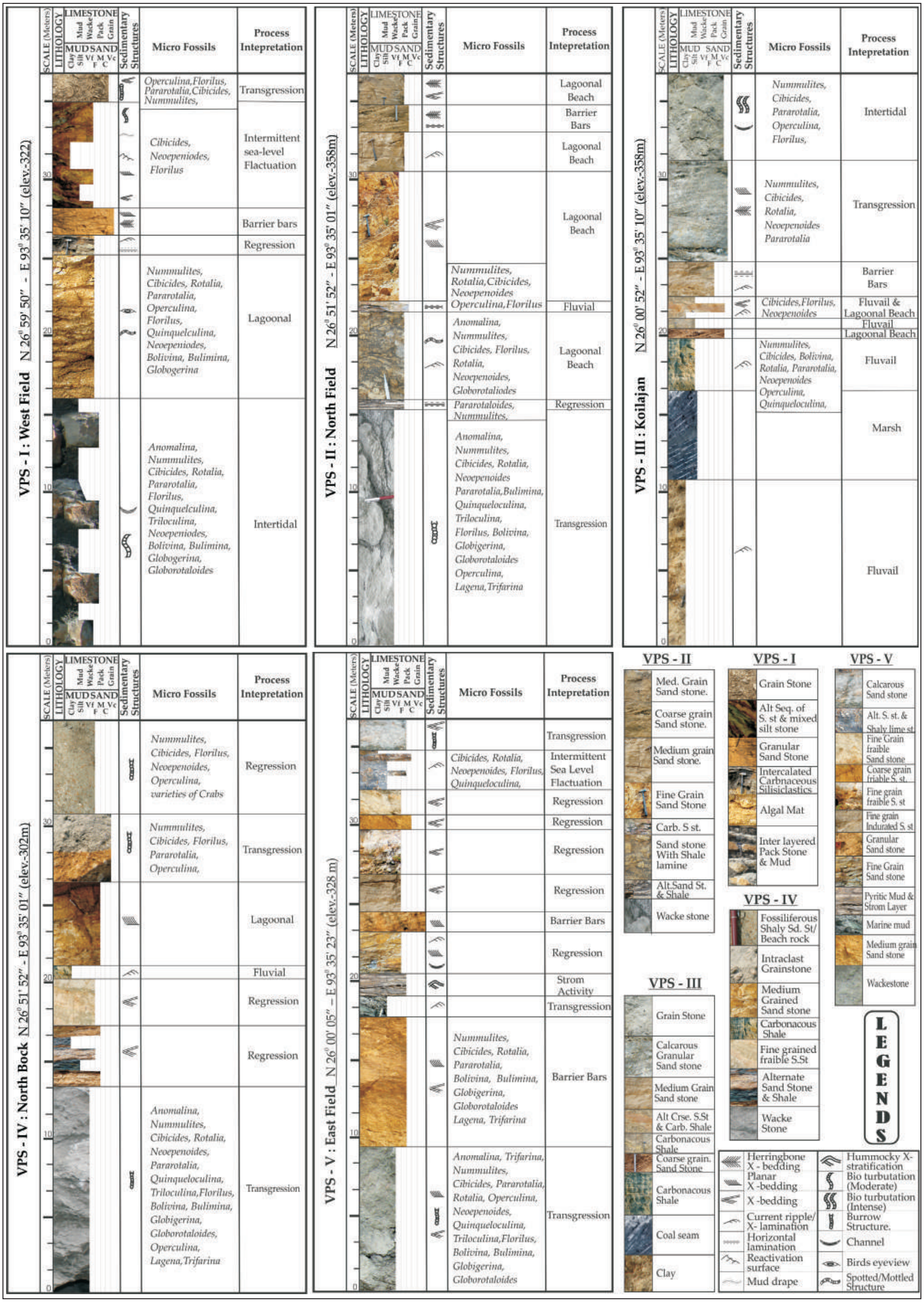


**Fig.2.** Vertical profiles sections (i,ii,iii,iv,v) constructed at various locations in the study area.

Nagaland University, microfossils were picked and mounted on the micro faunal slides. Microfossils from the mounted slides were identified and photographed using SEM at IIT, Bombay. Larger forms of microfossils have also been observed in the thin sections. Petrographic studies were carried out under the microscope and following Dunham (1962) and Embry and Klovan (1971) limestones of the study area were classified.

**Petrography**

Limestones are very common in shallow (<10 m; Prothero and Schwab, 2004) marine conditions. They also suggest that when temperature or alkalinity is slightly increased precipitation of carbonate takes place. Limestones of the study area is dominantly micritic in composition (<.004 mm) and is grouped under mud supported category (Dunham, 1962). In addition to micrite, sparry calcite has also been noticed. A mixed fabric, at places, involving micrite and sparry calcite were observed. Diagenetic calcite veins along with few quartz grains of angular to subangular shapes were also encountered. In most of the thin sections, distinctly dull calcite aggregate was seen. On the basis of the classification proposed by Dunham (1962, modified by Embry and Klovan, 1971), the limestone of the study area is classified as wackestone, grainstone and packstone (Fig.3a-d).

**Ichnology**

Trace fossils are the fossilised structures produced by the organisms (Bromley,1996). As they are produced in situ and have less chance for transportation, they provide important information on the hydrodynamic conditions as well as sedimentation (Ozukum *et al*., 2022). Good numbers of publications on trace fossils in recent times also signify their importance in interpreting the palaeoenvironment (Savrda and Bottjer,1986; Sudan *et al*., 2002; Srivastava *et al.,*2021). In the study area sediments are intensely bioturbated and at places bioturbation has provided a mottled texture to the sediments. Ichnospecies recorded from the limestones of the area include *Skolithos verticalis, Palaeophycus tubularis,* and *Thalassinoides horizontalis*. *Skolithos verticalis* is vertical in nature whereas *Palaeophycus tubularis,* and *Thalassinoides horizontalis* are horizontaly disposed. Trace fossils are recorded from fine grained sediments. Recorded ichnospecies belong to Skolithos and Cruziana ichnofcaies.

*Ichnogenus: Skolithos* Haldman (1840)
*Ichnospecies: Skolithos verticalis* Hall (1840); **Fig. 3e**

***Description***

They are cylindrical burrows and perpendicular to the bedding plane. Sediment fill are similar to the host sediments. It ranges in diameter between 5 and 7 mm. They appear as circular markings on the bedding surface.

***Remark***

According to Alpert (1974), *Skolithos verticalis* is short and small burrows which are perpendicular to the bedding plane and have been mainly reported from shallow water intertidal deposits. They are formed by the suspension feeders and have been reported from various shallow marine high energy environment (Seilachar, 1967; Fillion and Pickerell,1990; Pemberton *et al.*, 2001).

Ichnogenenus: *Palaeophycus* Hall (1847)
Icnospecies*: Palaeophycus tubularis* Hall (1847); **Fig.3f, g**

***Description***

*Palaeophycus tubularis* occurs as horizontally disposed un-branched straight/slightly curved burrow which are cylindrical in cross sections. Burrow walls are un-ornamented, and sediment fill and host rock is identical. Burrow diameter ranges between 1 to 1.3 cm and length is approximately 5 cm.

***Remark***

*Palaeophycus tubularis* is distinguished from other traces by its un ornamented smooth walls and have been reported from unconsolidated muddy horizons under shallow marine settings (MacEachern *et al.*, 2007).

Ichnogenus: *Thalassinoides* Ehrenberg (1994)
Ichnospecies: *Thalassinoides horizontalis* Myrow, 1995; **Fig.3e, h**

***Description***

*Thalassinoides horizontalis* is a three-dimensional horizontal unlined smooth burrow system. The three-dimensional burrow systems have horizontal tunnels which are straight/slightly curved and have almost constant diameter. Length of the horizontal burrows varies between 2 to 5 cm and diameter is less than 0.4 cm.

**Remark**

Traces of *Thalassinoides* have been reported from unconsolidated and muddy horizons with moderate energy under shallow marine settings (Pemberton *et al.*, 1992; MacEachern *et al.*, 2007; Sudan *et al*., 2002).

**Foraminifera**

In the present study foraminiferal assemblage have been extracted from both carbonates as well fine-grained siliciclastic sediments.

The identified microfossils represented by both benthic as well as planktic forms include Lagena, Globorotaloides, Neoepinoides, Florilus, Anomalina, Bolivina, Bulimina, Cibicides, Nummulites, Operculina, Pararotalia, Quinqueloculina, Spiroloculina, Trifarina, Triloculina, Globigerina, and Rotalia (Fig. 4A-B). In addition to that Bryozoa, Sclerites, Specules have also been recorded (Fig.4C). Their morphological types, mode of life, genera and suggested environments are given in Table 2.

**Palaeoenvironment and Palaeoecology**

The Eocene Sylhet Limestone deposits of the Karbi Anglong district of Assam exposed in and around Dillai have yielded both vertebrate and invertebrate faunas and also the well-preserved trace fossils. The vertebrate faunas are represented by gastropods, echinoderms and bivalves. The microfossils, recorded from the

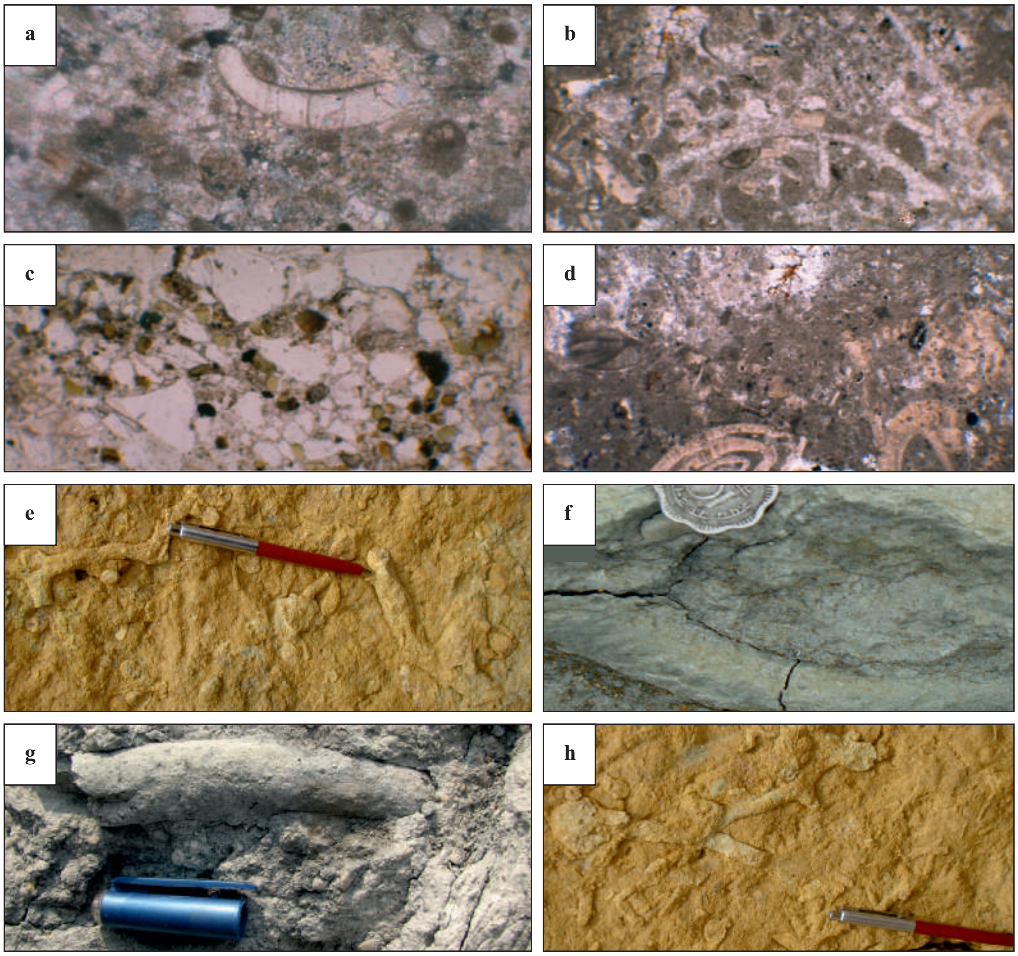

**Fig.3.** Photomicrographs of studied limestones **a)** Wackstone **b)** Packstone **c)** Grainstone **d)** Nummulites in wackestone; Trace fossils **e)** *Thalassinoides horizontalis* and *Skolithos verticalis,* **f)** *Palaeophycus tubularis,* **g)** *Palaeophycus tubularis* and **h)** *Thalassinoides horizontalis*

dominantly carbonate rocks, are represented by both benthonic and plantonic foraminifers. Foraminifers are good indicators of water level fluctuations, nutrients and availability of oxygen as they are very sensitive to changes in the environmental parameters. In the present study the foraminiferal assemblage is dominated by the benthic form, only two planktic foraminifers (*Globogerina* and *Globorotaloides*) were recorded form the sediments of the study area. As the foraminiferal assemblage from the study area is dominated by the benthic forms, interpretations are mainly based on them.

According to Morkhoven *et al*., (1986) and Murray (1991) benthic foraminifera are very useful indicators of the environmental settings. The benthic foraminiferal assemblage is dominantly by epifaunal forms and is represented by planoconvex, globular, trochospiral, rounded and flattened morphological types. Their epifaunal mode of life suggest that they either lived at sediment surface or in its uppermost layer (Singh *et al*.,2016) in nutrient poor environment (Thomos,1990). Infaunal foraminifers dominated by globular or flattened forms, points towards deeper layers of sediments. Many authors (Jorissen *et al*.,1992,1995; Coccioni and

**Table 2:** Habitat preferences of the identified microfossils from Dillai Limestones

| | | | |
|---|---|---|---|
| Globular | epifaunal | *Lagena* | Marine,shallow bathyl |
| Flattened tapered | infaunal-epifaunal | *Bolivina* | Marine, warm; inner shelf-bathyal |
| Rounded | epifaunal | *Rotalia* | Marine, temperate inner shelf- bathyal |
| rounded | epifaunal | *Pararotalia* | Marine,warm inner shelf |
| Rounded | epifauna | *Spiroloculina* | Marine-hypersaline; temperate warm, lagoon, inner shelf. |
| Elongated | epifaunal | *Quinqueloculina* | Marine-hypersaline, warm, marine shelf, rarely bathyal. |
| Rounded | epifaunal | *Triloculina* | Marine, hypersaline temperate-warm mainly hypersaline, lagoons or marine inner shelf |
| Elongated flattened | infaunal | *Bulimina* | Marine, temperate; inner shelf- bathyal |
| Elongated flattened | epifaunal | *Operculina* | Marine-slightly hypersaline; warm; inner shelf, lagoons. |
| | epifaunal | *Neoeponides* | Marine, shallow shelf |
| Plano-covex | epifauna | *Cibicides* | Warm, lagoons, shelf-bathyal. |
| Elongated flattened | infaunal | *Trifarina* | Marine, temperate, shelf and upper bathyal. |
| Rounded trochospiral | epifaunal | *Anomalina* | Marine, temperate, shelf and upper bathyal. |
| Rounded flattened | epifaunal | *Nummulites* | Marine, warm, lagoon to inner shelf |

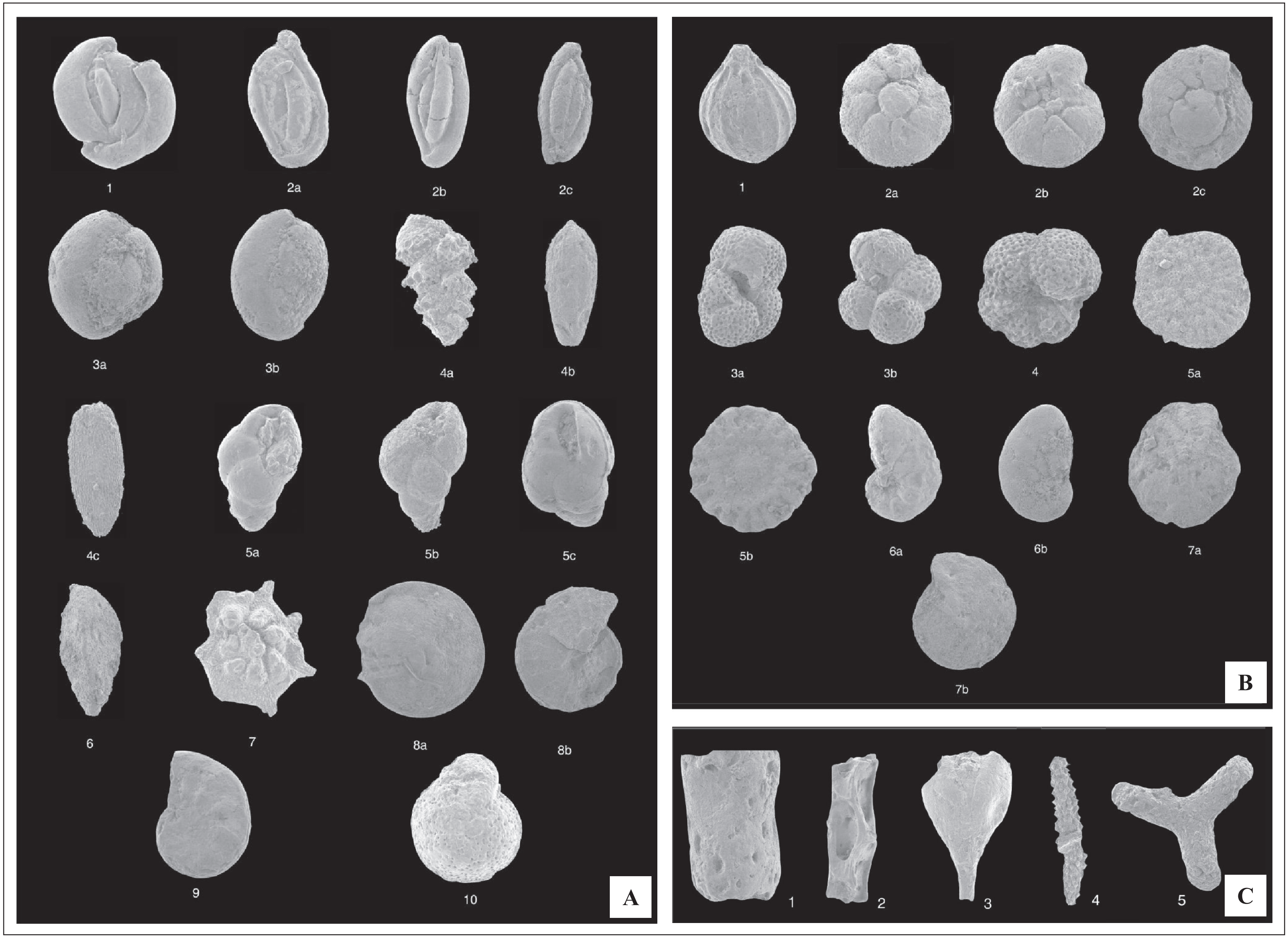


**Fig. 4.** SEM images showing microfossils **A)** Foraminifers (bentihic) : 1. *Spiroloculina* (X270); 2a,b,c. *Quenqueloculina* (X220, X220, X230); 3a,b. *Triloculina* (X250, X230); 4a,b,c. *Bolivina* (X300, X180, 160); 5a,b,c. *Bolimina* (X350, X300, X400); 6. *Trifarina* (X270); 7. *Pararotalia* (X270); 8a,b. *Numalites* (X130, X120); 9. *Operculina* (X100); 10. *Cibicides* (X270); **B)** Foraminifers (planktic): 1. *Lagena* (X450); 2a,b,c.*Rotalia* (X300, X300, X180); 3a-3b *Globorotaloides* (X370, X400); 4. *Globogerina* (X430); 5a,b, *Neoepenoides* (X220, X190); 6a,b *Florilus* (X270, X200); 7a,b. *Anamolina* (X130, X130); **C)** 1-3. Bryozoa (X350, X90, X220); 4. Sclerites (X120), 5. Specules (X250)

Marshili,2007) suggest that the presence of infaunal foraminifers points towards a high organic carbon fluxes. Dominant occurrence of epifaunal foraminifers largely suggests better oxygenated, oligotrophic environment with low organic carbon flux. Analysis of the microfossils suggests that a shallow marine warm and humid environments corresponding to the inner shelf/lagoonal environments prevailed during the deposition of the Sylhet limestones. Prothero and Schwab (2004) based on the presence of fossil fish assemblage, sedimentological features and invertebrate fossils have suggested that these sediments were deposited within a shallow marine environmental set up under tropical to temperate climate. In the present study, shallow bathyal environment is also suggested by the benthic assemblage with both warm and humid climate prevailed within a lagoonal-inner shelf marine environment. Lokho *et al.*,(2023) based on mega fossil echinoids occurrences have also suggested a warm shallow marine environment for the deposition of these sediments. The presence of sandstone alongwith limestone deposits not only suggests a shift in the depositional environment from a low energy to a higher-energy environment and sea level fluctuations but also a tectonically active area. Such geological sequence is common in costal/shallow marine environments experiencing changes in sea level or sediment supply (Prothero and Schwab, 2004). Also, the Eocene Sylhet limestone containing the large-sized *Nummulites* suggests adequate nutrition supply under the tropical climatic conditions within shallow marine environment (Pandey and Bhadu, 2010; Patra and Singh, 2015). Bhandari *et al*., (1973) and Dutta (1982) while working with Sylhet Limestone, also suggest that these rocks were deposited within shallow, open marine, warm water environment. The carbonate-shale alternations in association with the sedimentary structures suggest lagoonal to tidal environments. Algal mats and presence of larger foraminifera points towards the carbonate production under warm, humid tropical to subtropical climates (Andriansyah *et al.*, 2024; Khan *et al.*, 2025)

Presence of bryozoan remains and spicules also suggest that these carbonate sediments were deposited in shallow warm coastal waters. They have been reported from inter tidal zone to the continental shelves (Bone and James,1993). Calcareous skeleton of the bryozoa also contribute $CaCO_3$ sediments to the coastal area under warm conditions. Marine bryozoans have a wide range of habitats, from coastal areas to great ocean depths, but are most common just below the tidemarks (Bone and James,1993; Amini *et al.*, 2004).

Analysis of trace fossils present in the studied rocks (Skolithos verticalis, Thallasinoides horizontalis and Palaeophycus tubularis) suggests a shallow marine environment with fluctuating energy conditions. Presence of Skolithos verticalis ichnospecies suggests occasional increase in the energy conditions (Frey *et al*., 1990; MacEachern, *et al.,* 2007; Patel *et al.*, 2009). Low energy conditions of the environment is suggested by the horizontally disposed Thalassinoides horizontalis and Palaeophycus tubularis. Presence of Thalassinoides in these sediments suggests well-oxygenated bottom water (Ozukum *et al*., 2022). Presence of herringbone (Prothero and Schwab, 2004; Singh and Singh, 1995) and the hummocky cross stratifications (Harms *et al.*,1975) in the studied sediments also suggests a shallow marine environment as these sedimentological features have been reported by many from inter-tidal/shallow marine upper shoreface environment which had been frequented by low energy storms. Presence of algal mat also suggests the same (Logan *et al.*, 1964).

## Conclusions

Based on the analysis of micro faunal assemblages, sedimentary structures, lithology and ichnology a shallow marine warm water, with sufficient nutrient and oxygen within a lagoonal-inter tidal-inner shelf shallow marine environmental set up with fluctuating energy regime have been envisaged for the deposition of the Sylhet limestones. Presence of cross bedded sandstones between the limestone units may be attributed to the transgressive–regressive cycle owing to regional tectonics. Presence of the carbonate–shale alternations suggest their production in lagoonal and tidal environments. It is also concluded that the tropical to sub-tropical climatic conditions prevailed during their deposition.

## Authors' Contributions

**TSL:** Fieldwork, Investigation, Processing of samples and Initial Writing; **SKS:** Investigation, Processing of Samples and Draft Review.

## Conflict of Interests

Authors declare that there is no conflict of interest.

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