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Keywords	Facies, Sitha Formation, Stromatolite, Ordovician, Environment
Citation	
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Sedimentology of the Sitha Formation in the Sedaw–Kyaukchaw Area, Patheingyi and Pyin Oo Lwin Townships

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Abstract

The Sedaw-Kyaukchaw area forming a part of the western marginal zone of Eastern Highland lies to the east of the central Myanmar Tertiary Basin and is situated about 25 kilometers southeast of Mandalay in Patheingyi and Pyin Oo Lwin Township. Sitha Formation is well exposed in the east of Sedaw-Kaiktan village as distinct as Sedaw scarp line, especially between first and third Reversing on Mandalay-Pyin Oo Lwin railway station. Sitha formation is mainly composed of massive, thick-bedded, thin- to medium-bedded, bluish grey limestone with irregular silt partings. Primary sedimentary structures chiefly planar and trough cross stratification of small to medium scale, hummocky cross stratification and planar bedding are also abundant. Therefore seven lithofacies and six microfacies are studied. According to the lithofacies and microfacies characteristics, it indicated that the Sitha Formation was deposited in warm shallow marine, subtidal and intertidal environments. The occurrences of the various types of stromatolites and oncoid structures are abundant and characteristic, especially in the 1st reversing and northern part of the Sedaw Chaung. These structures are of the same characteristics in the middle Ordovician sequences of the Wunbye Formation of the Southern Shan State. Although it needs to be studied more, the two Formations of the Northern Shan State and Southern Shan State can be correlated not only on the basis of stratigraphy but also depositional facies.

Introduction

The Sedaw-Kyaukchaw area forming a part of the western marginal zone of Eastern Highland lies to the east of the central Myanmar Tertiary Basin and is situated about 25 kilometers southeast of Mandalay in Patheingyi and Pyin Oo Lwin Township. The Kachin-Shan-Tanintharyi Massif in which the present area situated is a distinct geotectonic domain (Maung Thein, 1973) forming the western part of the Eastern Highlands (Shan Massif), the Sino-Burma Ranges of Myanmar. The Shan-Burma Boundary fault lies along the western margin of the study area. It separate the Central Lowland from the Eastern Highlands. It is clearly seen from the Tertiary region as an abrupt change of more than 610m high, from the edge of Shan Massif to the neighboring alluvial plains of the Ayeyarwady and

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Sittaung. West of the fault, the exposures of the older metamorphic rocks mainly gneisses, schist, quartzite and basic intrusive are exposed in a linear belt trending generally in a north-south direction, extending from north of Mogok into the northern most region of Myanmar and toward south decreasing of the width of Shan Massif extend for a considerable part into the northwest of Thailand, limited to the east again by the intrusive granitic rocks.

Although various investigations were carried out in the surrounding and present area, detail analysis of the lithofacies and microfacies had not been done yet. The main purposes of the study area are to establish the stratigraphy and petrography and lithofacies of the Sitha Formation to interpret the depositional environment and geological history of the area. Several traverses were made across the regional structures.

The stratigraphic successions of different rock unit were established on the basics of lithological characteristic faunal content and their relative stratigraphic position in the sequence. The major ridges of the study area are generally north-south trend. The ridges are built up of the rocks of Sitha Formation and Si-baing Orthoquartzite Formation. This area is separated by Sedaw Chaung fault with other area. Topography depends upon the major structures and underlying bed rock.

The whole area consists of carbonate rocks of Paleozoic ranging in age from Cambrian to Permian which were deposited in the Myanmar-Malaysian Geosyncline (Kobayashi, 1964). To the east of Tonbo, the rocks of lower Paleozoic strata and the Thitsipin Formation are exposed repeatedly in the Sedaw scarp zone, Zebingyi Plain and Pyintha-Anisakan Plain, and within these segments some stratigraphic units are pinched out. The structure of the Sedaw scarp line is relatively complex, probably due to the major Shan-Burma fault zone.

Stratigraphy

Sitha Formation is well exposed at the east of Sedaw-kaiktan village as distinct as Sedaw scarp line, especially between first and third Reversing on Mandalay-Pyin Oo Lwin railway station. It is well exposed at the eastern slope and crestal portion of the Taungnima (1373') and Kyaukchaw Taung (1056'). The study area of Sitha Formation is underlying of late Cambrian Si-baing Orthoquartzite. The upper Ordovician strata of the Kyaingtaung Formation are missing in our study area. The Fourth

Reversing fault and eastern Taungnima fault are separated the Sitha Formation and the lower part of the Nyaungbaw Formation. This Formation is also faulted with Permian Thitsipin Limestone Formation. The following important fossils are present in the Sitha Formation.

Nautiloid, Cephalopods: *Actinoceras* sp., *Armenoceras* sp., *Ormoceras* sp., *Kionocera* sp., *Michelinoceras* sp., *Wutinoceras* sp. Bryozoans: *Diplotrypa* sp. Echinoids: *Crinoid Stems*, Gastropods: *Maclurites*, Brachiopod: *Orthis* sp., *Rafinesquina* sp. Sponge: *Receptaculites* sp.

These fauna assemblages indicate that the age of this unit is Middle Ordovician.

Sedimentology of the Sitha Formation

Lithofacies characteristics

Seven lithofacie have been defined on the basis of their lithological characters, textural information, sedimentary structures, bioturbation and taphonomy. Genetically related lithofacies are then grouped into larger, regionally correlative lithofacies associations based on stratigraphic relationships that reflect deposition in adjacent and gradational paleoenvironments.

Lithofacies A. Cross-laminated limestone lithofacies

These are irregular layers of limestone with numerous scour faces. Generally, it is intermingled and interlaminated with wavy and planar-beds (up to 15 cm) of silt (cm-mm) and shale. Lamination is common, although the limestone beds are bioturbated or modified by compaction. The silty limestones are yellowish to dark grey and the small scale planar and trough cross lamination (Fig. 1). Parallel lamination and hummocky cross stratifications structures (Fig. 2) are also characterized.

Present in this facies are minor intraclasts, bioclasts and shell fragments. Sometimes it is passing upward into burrowed limestone and cryptalgal laminate, supporting the interpretation of this facies as shallow subtidal environment (Osleger and Montanez, 1993).

Lithofacies B. Thin-to medium-bedded limestone with silt lamination lithofacies

This facies is associated with the thick-bedded to massive limestone and burrowed limestone of shallow subtidal lithofacies. The lower boundary of this facies is usually undulatory or erosional and the upper boundary is sharp or planar. They are laterally equivalent to wavy microbialite and sometimes overlain by cryptalgal laminite. The beds are mostly 5 to 30 cm thick, light grey to buff dark grey, fine-to medium-grained crystalline limestone. The limestone beds are mostly 5 to 20 cm thick and containing silt partings patches and silt lamination. Sometimes, the limestones are separated by very thin shales and/or silt lamination. The above features appear to indicate that the sediments probably accumulated in a shallow subtidal environment (Laporte, 1971).

Lithofacies C. Burrow limestone lithofacies

A characteristics lithological feature is the occurrence of small patches and lenses of buff colour siltstone in these limestones. Sometimes, the silt patches and tubes appear to be formally warm burrow tubes. "burrow limestone" (Fig.3). The limestones are compact, hard and splintery and are transverse by minute calcite vein. Locally, the limestones exhibit an indistinct phacoidal structure. Mostly the basal part of the facies is thick-bedded to massive. The upper and lower boundaries of this facies are sharp.

Horizontal burrows are more abundant than the vertical burrows. Burrowing is pervasive and disturbing original bedding. Heavily burrowed units are porous and vuggy, where as other units are only slightly burrowed and filled with dolomites. Texturally, they are mottled due to the presence of burrows.These burrowed limestones are mostly subtidal lithofacies and can be interpreted as deposits formed below fair weather wave base under normal marine conditions (Osleger and Reed, 1991).

Lithofacies D. Medium-thick-bedded to massive limestone with silt

This Lithofacies is composed mainly of medium to thick bedded, 30cm to 100cm, thick-bedded to massive, light-grey, whitish, and buff crystalline limestone (Fig.4 and 5). Also faint lamination and fossils are locally observed in the upper bedding plane. The limestones are mostly bioclastic, intraclastic packstone-grainstone and sometimes grading upward into micritic limestone.

Fragments of brachiopod shell are made up of laminae consisting of flattened fibres or prisms. The thick-bedded nature, moderate to high sparite to micrite ratio, the occurrence of burrows and the variety and large amount of fossil indicate that they were deposited in a shallow-subtidal environment of (Laport, 1971 and Tucker, 1990).

Lithofacies E. Oolitic limestone lithofacies

The oolitic limestones are medium-to thick-bedded and are associated with stromatolitic limestone. It can be clearly seen at the first reversing, northern part of margin zone and eastern highland in the study area. They are medium-to coarse-grained oolitic-intraclastic packstone-grainstone containing some bioclasts. Dolomitization is the most distinctive feature of this facies. Some are affected by selective dolomitization and others are completely dolomitized. Stylolites are common. It is important to note that ooids form the main characteristic element of this facies. The formation of ooids requires continually agitated water (Krumbein and Sloss, 1951).

Lithofacies F. Stromatolitic limestone lithofacies

The stromatolitic limestones are well abundant in the first reversing and northern part of this study area. These stromatolitic structures that have been previously termed fossil algae structure may be formed by a number of different process and organism. They can be assumed by the various forms. They are simplest form of planar stromatolites, laterally, linked hemisperoids (LLH), vertically stacked hemispheroids (VSH) and oncoids (spherical structure SS) type. LLH and VSH types are most abundant at the 1st reversing and near the contact between Sitha Formation and Si-baing Orthoquartzite in the northern part of the study area (Fig.6). Oncolitic are spherical unattached cryptagal structure (algal ball) often with concentric lamination. The stratification planes of the Sitha Formation are well marked and discernable from a distance. Oncoid spherical structure (SS) type is only found in the Sitha Formation in northern part of the study area.

Columnar stromatolites are interpreted to have aggraded vertically in response to available accommodation space. Stacked shallowing upward successions within each biostrome reflect repeated readjustment of base level (Sami and James, 1994). Also stromatolite bearing sequences are interpreted as of intertidal origin (Logan et al, 1964).

Microfacies Characteristics

Microfacies I. Biomicrite /Bioclastic-Wackestone

Megascopically, the rock is medium-bedded, dark grey, fossiliferous limestone. Bioclasts consist of brachiopods shells, cephalopod and gastropod, bivalves. Bioclasts are filled micrite and neospar. A limestone made up almost entirely of bivalve fragments preserved and thin micrite rims on the margins of the shell. These are micrite envelops and formed by micritization (Fig.7). The cement infilling the bivalve and between the shell is sparite. The quartz-silt grains are sub angular to rounded and scattered within the micrite (Fig.7).

The present of abundant bioclasts and bivalves are slow deposition in low energy environment, shallow waters with open circulation close to wave-base. This microfacies may be assigned to the Standard Microfacies 9 (Wilson, 1975 and Tucker, 1990).

Microfacies II. Biopelmicrite /Bioclastic, Pelletal Wackestone

Megascopically, the rock is medium-thick bedded grey to dark grey, with irregular silt parting and patches. Bioclast consists of brachiopod shell and fill with micrite. Peloids are circular to elliptical in cross section some are deformed and scattered in micrite. Neospar filled the voids and formed as secondary calcite veins (Fig .8). Oolites are small and filled with micrite. According to Blatt, Middleton and Murray (1980) peloids can be fecal pellets formed by carbonate mud ingesting organisms. The presence of bioclasts and the pellet reflect the slow deposition in low energy environment and microbial zone. This microfacies may be assigned to Standard Microfacies 20 and Standard Facies Belt 3 (Wilson, 1975 and Tucker, 1990).

Microfacies III. Pelsparite /Pelletal Packstone-Grainstone

Megascopically, the rock is thin-bedded, grey to dark grey fossiliferous limestone with silt parting. Bioclast consists of foliated branchiopod shell, trilobite. Bioclast are filled with micrite. The quartz silt grains are sub angular to rounded and scattered within the peloids. The pellets are pale-reddish brown to dark brown colour and have a spherical shape. The grain size ranges from 0.03 to 0.04 mm, with extremely uniform in shape and fairly uniform in size (Fig. 9). According to Blatt Middleton and Murray (1980), these peloids could be fecal pellets formed by carbonate mud ingesting organisms.

The distribution of the faecal pellet may indicate either that the related organisms leaved only in quiet water conditions or that the pellets were destroyed in agitated environment. The presents of faecal pellets deposited in shallow water with only restricted marine shoal environment. This microfacies may be assigned to the Standard Microfacies 16 and Standard Facies Belt 7and 8 (Wilson, 1975 and Tucker, 1990).

Microfacies IV. Oosparite /Dolomitic Oolitic Wackestone

Megascopically, the rock is thick bedded, dark grey to grey limestone associated with stromatolitic limestone. Bioclasts consist of trilobite skeleton, brachiopod shell fragment and echinoderm plate. The oolite fills by sparite. Most of oolite has suffered diagenetic alteration through dolomitization in the same time. The dominant size of oolite is commonly about 0.2-0.3mm (Fig. 10).

The present of abundant ooids are high-energy environment on oolite shoals, beaches and tidal bars. This microfacies may be assigned to the Standard Microfacies 15 and Standard Facies Belt 6 (Wilson, 1975 and Tucker, 1990).The excellent sorting in size and shape of oolite and absolutely mud free sediment indicates accumulation on bar or shoal where high energy currents, prevailed with corresponding saturation in calcium carbonate (Heath *et al*. 1967).

Microfacies V. Pelmicrite /Pelletal Wackestone

Megascopically, the rock is medium-bedded, grey to dark grey fossiliferous limestone with irregular silt parting and patches. The weather surfaces show sink holes and burrow structures. Bioclasts consist of brachiopod shell. Pellets are elongated and circular shape and filled with micrite. Irregular silt parting and worm burrowed-tubes filled with micrite. Pellet size average range from0.05-0.02mm in diameter (Fig. 10).

The presence of worm borrowed-tubes is deposited in open platform normal marine. The pelletal facies is identical to intertidal deposition. The microfacies may be assigned to the Standard Microfacies 9 and Standard Facies Belt 7 (Wilson, 1975 and Tucker, 1990).

Microfacies VI. Biosparite /Bioclastic Wackestone-Packstone

Megascopically, the rock is medium to thick-bedded grey to dark grey, with irregular silt parting, patches and fossiliferous. Bioclasts consist of gastropod, crinoids stem, trilobite, echinoderm plate and small thin shell bivalves, cystoid shells fragments fills micrite. Calcite veins are filled with neospars.

The presence of abundant bioclasts is deposited shallow waters with open circulation close to wave-base. This microfacies may be assigned to the Standard Microfacies 9 and Standard Facies belt 2and 4 (Wilson, 1975 and Tucker, 1990).

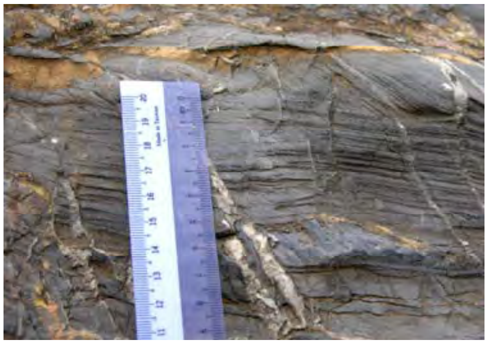


Fig. (1) Photograph showing planar-cross bedding in silt parting limestone of Sitha Formation from eastern part of Phayataung. (Grid. 763555)

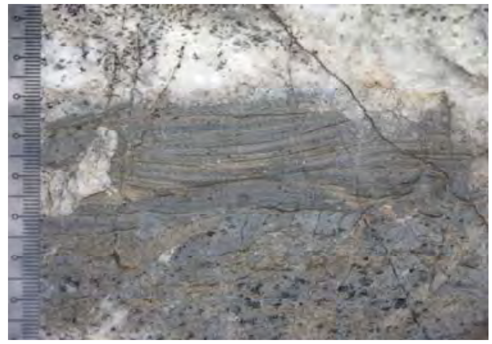


Fig.(2) Photograph showing Hummocky Cross-Stratification in silt parting limestone of Sitha Formation near mile post 16/4 on Mandalay-Pyinoolwin car-road. (Grid. 785493)

Fig. (3) Thick-bedded to massive burrow limestone of Sitha Formation near south of First Reversing. (Grid. 783528)

Fig. (4) Medium-to thick-bedded limestone of Sitha Formation near First Reversing. (Grid. 785546)

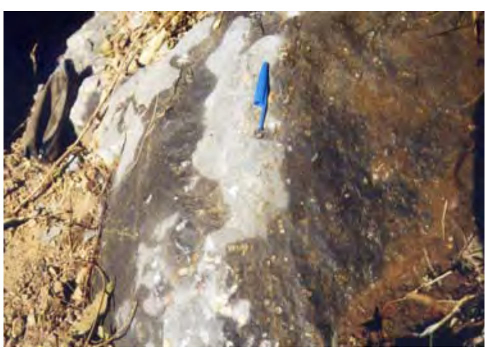


Fig. (5) Thick –bedded to massive limestone with numerous fossils.

Fig.(6) Stromatolitic limestone of (LLH and VSH) structures in Sitha Formation near First Reversing. (Grid. 785535)

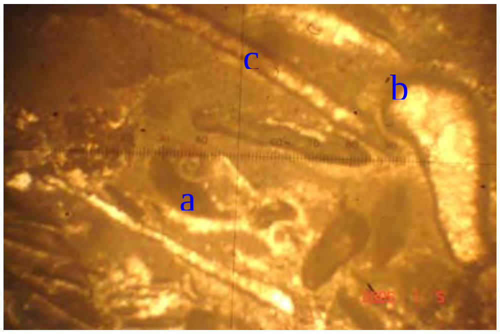


Fig. (7) Photomicrograph showing micritic enveloped (a), cephalopod fossils (b) and brachiopod shell fragment (c) in Sitha Formation under PPL, X-40.

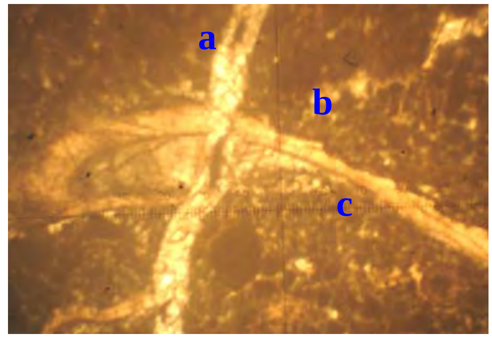


Fig.(8) Photomicrograph showing brachiopod shell fragment (a), secondary calcite vein (b) and pellet (c) of the Sitha Formation under PPL, X-40.

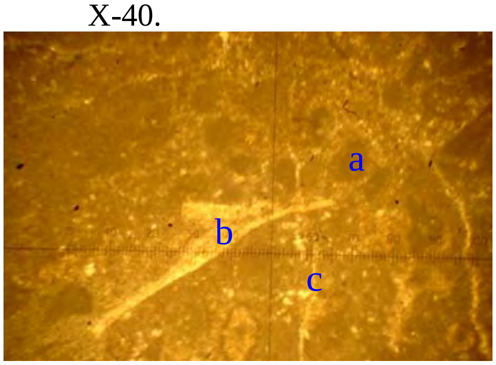


Fig. (9) Photomicrograph showing the pellets (a), cystoid (b) and minute calcite veins (c) of the Sitha Formation under PPL, X-40.

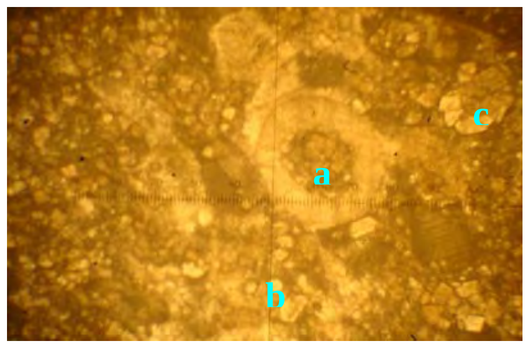


Fig. (10) Photomicrograph showing the ooid (a), dolomite (b) and grainbrackage (c) of the Sitha Formation under PPL, X-40. z

Depositional Environment of the Sitha Formation

Sitha formation is mainly composed of massive, thick-bedded, thin- to medium-bedded, bluish grey limestone with irregular silt partings. Primary sedimentary structures chiefly planar and trough cross stratification of small to medium scale, hummocky cross stratification and planar bedding are also abundant (fig. 11). It can be suggested that the depositional site of the Sitha formation not far away from the shore line. Moreover, it is supported by the argillaceous seams produced by the periodic influx of the terrigenous materials into a lime depositing environment (Wilson, 1975 and Tucker, 1999). In this Sitha Formation, burrowed limestones are also characteristics. According to Friedman and Sander, 1967, the occurrences of burrowed mottling and stromatolitic structure are very common in the intertidal environment.

Some LLH stromatolite structure, some burrow mottling and fossil diversity indicate that probably resulted from low intertidal to shallow subtidal. Various types of stromatolites are found such as LLH, VSH and SS type. The morphological variation of

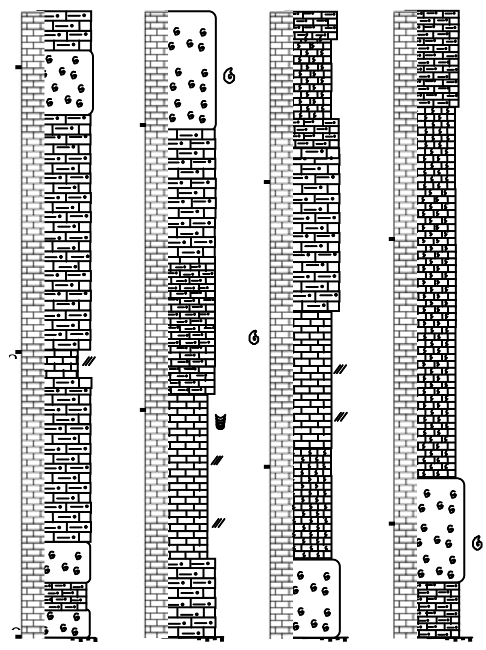


Fig.11 Section measurements of Sitha Formation from Phayataung and Fourth Reversing

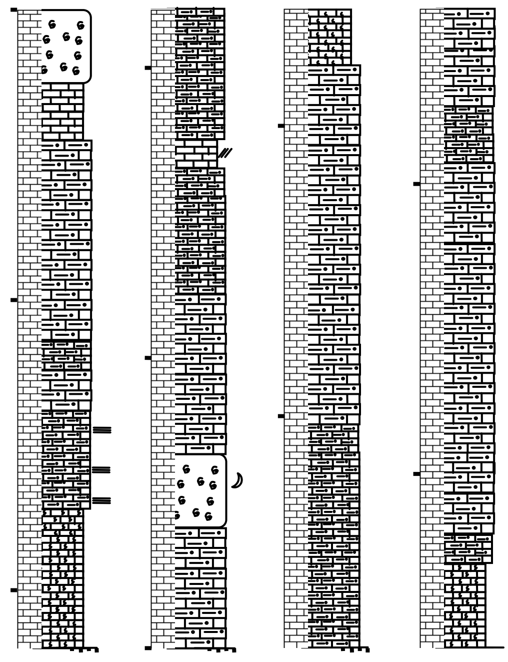
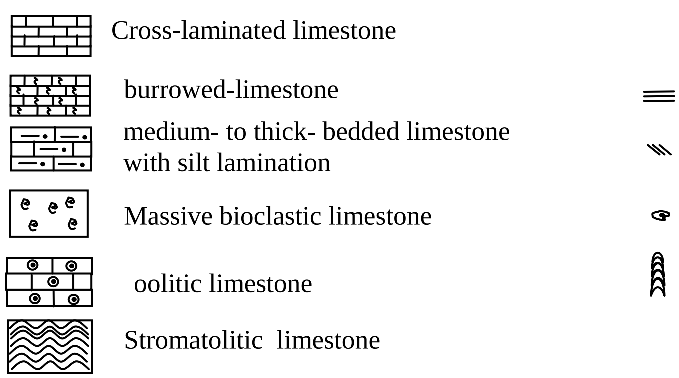


Fig. (12) Section measurements of Sitha Formation from Phayataung and Fourth Reversing

Explanation for Figure 12,



Cross-laminated limestone

burrowed-limestone

medium- to thick- bedded limestone with silt lamination

Massive bioclastic limestone

oolitic limestone

Stromatolitic limestone

Hummocky cross -stratification

parallel laminations

Planar cross- bedding

Gastropods

Cepholopods

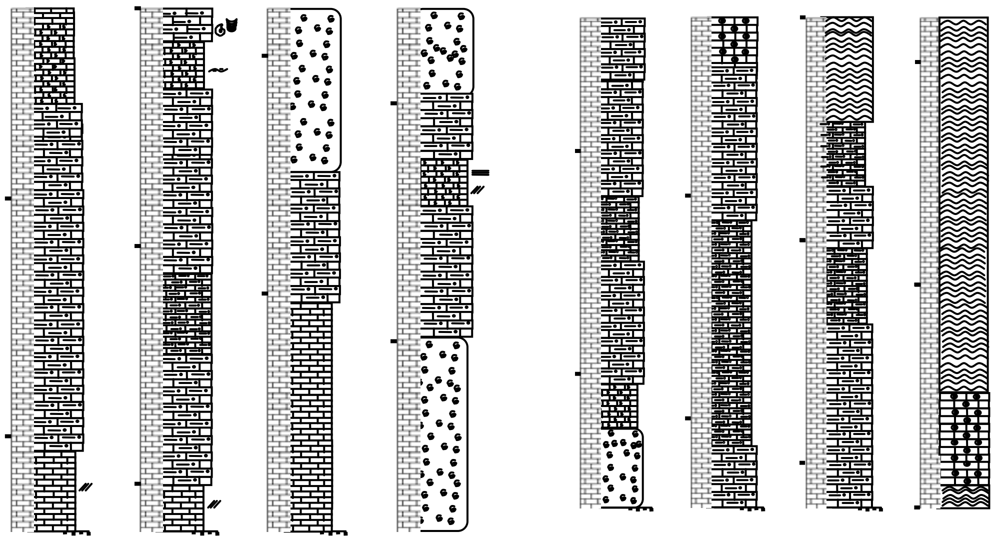


Fig.12 Continued

Some LLH stromatolite structure, some burrow mottling and fossil diversity indicate that probably resulted from low intertidal to shallow subtidal. Various types of stromatolites are found such as LLH, VSH and SS type. The morphological variation of microbialites depends largely on environmental factors such as water depth, tidal and wave energy, frequency of exposure and sedimentary rate (Tuckers, 2001). According to (Ginsburg, et.al 1969, Logan et al 1961), these stromatolites are characteristically developed in continuous mats of algal bound sediments from the marine, into mud flat environment mainly in the protected locations of re-entrant bays and barrier island ridges where wave action is usually slight. The oolitic limestone is associated with stromatolitic limestone. Oolitic may be found in shallow part of the open sea where wave or current action is sufficient to agitate the bottom. It originates through water movement on formed ooids are typically produced on the tidal bars (Wilson, 1975). The ooids grainstone deposited in tidal bars and shoals environment. Krumbein and Sloss (1963) also indicated that the oolites

Limestone are winnowed and cemented with sparite because the generation of the allochem types requires vigorous current and that the oolitic form where the oceanic water moving onto shallow banks are sufficienctly warmed.

Pettijon (1959) considered that the oolitic texture almost certainly is a primary features that the characteristic of shallow strongly agitated water. According to the Illing (1954) Oolitic accretion depends fundamentally on the movement of the sand grains under the impetus of marine current. The occurrences of burrowed limestone, wavy and planar-beddded limestone (skeletal packstone), columnar stromatolites, oncoid structures may be considered as the intertidal environment for the peritidal associations. Abundant fossils and micritic envelope suggest low energy intertidal environment. In some places, the stromatolites strctures are locally rare. The cryptalgal laminite and dolomitized calcareous siltstones contain abundant terrigenous detritus (silt-size quartz and muscovite) and carbonate mud. It is possibly accumulated on the supratidal area or elevated, well-drained area of tidal flat (Atiken, 1967).

Based on the above study of litholofacies and microfacies characteristics that the deposition of Sitha Formation can be characterized inter-tidal and sub tidal environment.

Discussion

In the middle Ordovician Sitha Formation of Sedaw area, the lithofacies and microfacies characteristics indicate that it was deposited warm shallow marine, subtidal and intertidal environments (Fig. 12). Moreover, the stromatolites are very abundant and oncoid structures are more characteristic. Also in the Southern Shan State of the middle Ordovician Wunbye Formation, the lithofacies, microfacies and stromatolitic structures are characteristics. So they can correlate not only with the stratigraphy but also with the depositional facies.

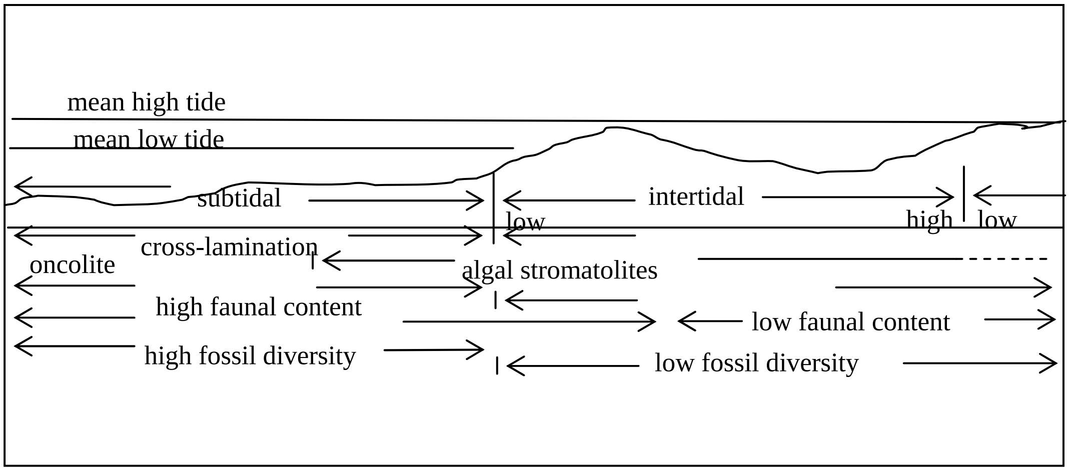


Fig (13) Sketch diagram of depositional environments of cross-laminated, oncolitic, stromatolitic, oolitic and bioclastic limestones of Sitha Formation in the present area.

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