J. Myanmar Acad. Arts Sci. 2020 **Vol. XVIII. No.5A**

-SEDIMENTOLOGY OF MOULMEIN LIMESTONE IN KAWKALUT-HNIDON AREA, KYAIKMARAW TOWNSHIP, MON STATE

Nandar Myint Maung[1], Day Wa Aung[2], and Tun Tun Zaw[3]

Abstract

The study area is situated in the southeastern part of Kyaikmaraw Township, Mon State. It lies between latitude 16º 20' 30'' N to 16º 23' 00'' N and longitude 97º44' 42'' E to 97º 47' 24'' E of one inch topographic map no. 94H/15. The present research mainly emphasized only on the carbonate sedimentology of the Middle to Late Permian Moulmein Limestone. Kawkalut-Hnidon Hills are composed of micritic limestone, fossiliferous limestone, dolomitic limestone and crystalline limestone. It was measured about 175 m and 200 m in thicknesss in details for microfacies analysis and were recognized into six microfacies; algal wackestone to packstone, dolomitic mudstone, mudstone, microbial grainstone, peloidal grainstone and peloidal packstone. These microfacies were grouped into three microfacies associations which represent three different depositional environments such as supratidal, intertidal and subtidal environments. The sequence stratigraphic interpretation of the Kawkalut section line indicates that eight metre-scale fourth–order shallowing upward parasequence cycles and three, metre-scale fourth–order deepening upward parasequence cycles. In the global Permian sea level, the slow falling of sea level also representing to Middle to Late Permian time which superimpose by lower order smaller cycles.

Keywords: Moulmein Limestone, Microfacies, Parasequence Cycles, Sea Level

Introduction

The research area is situated in the southeastern part of Kyaikmaraw Township, Mon State. It lies between latitude 16º 20' 30'' N to 16º 23' 00'' N and longitude 97º44' 42'' E to 97º 47' 24'' E of one inch topographic map no. 94H/15 and areas covering approximately 16 km^2 (6.25 square miles) (Fig.1). Physiographically, two different topographic units can be classified in the study area such as two isolated rolling hilly regions and flat alluvial plains (Fig.2). In the western part, Kawkalut Taung is about one mile long and 688 ft high above sea level. At the eastern part, Hnidon Taung is about 1.5 mile long and 802 ft high. Regionally, the investigated area lies on the southern part of Shan-Taninthayi Massif (Eastern Highlands), falls in the easternmost geotectonic belt of Burma and northern continuation of Taninthayi ranges. It belongs to the Moulmein Limestone of Middle to Late Permian age. Structurally, Hpa- pon fault and Three-pagoda fault are situated at the northern and southern part of the area and their trend is nearly NW-SE direction (Fig.3). Thin sections were prepared for petrography and get visual estimation of the constituent mineral grains. In addition to volume percent of rock constituents, it was done by using Terry and Chilinger’s reference chart (1955). And then, make analysis of petrofacies by using Folk (1959) and Dunham (1962) classifications, microfacies [Adams and Mackenzie (1984), Scholl (2003)] and finally interpret the depositional environment.

Stratigraphy

Maung Thein (2014) described “Moulmein Limestone” at Middle to Late Permian time is gradational contact with Taungnyo Formation. The present work deals with the rocks of the Moulmein Limestone.

[1] Dr, Lecturer, Department of Geology, Mawlamyine University
[2] Dr, Professor and Head, Department of Geology, University of Yangon
[3] Dr, Lecturer, Fepartment of Geology, Mawlamyine University

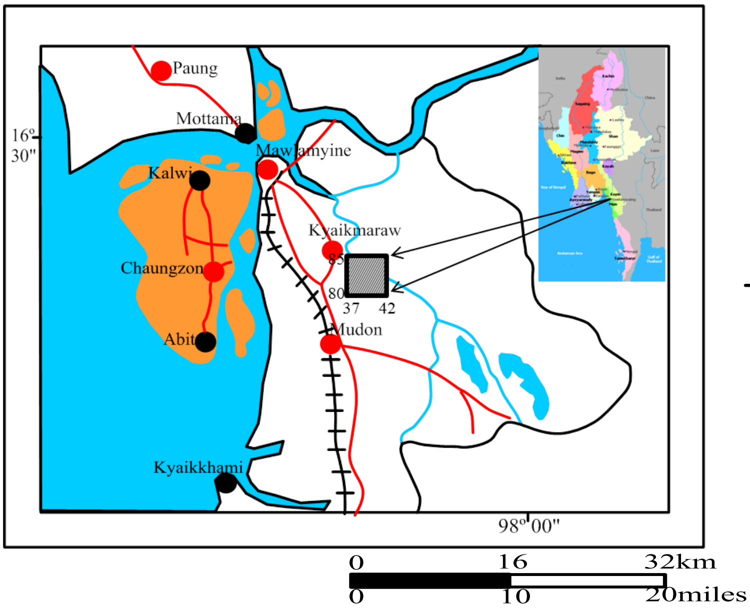


Figure 1 Location map of the study area

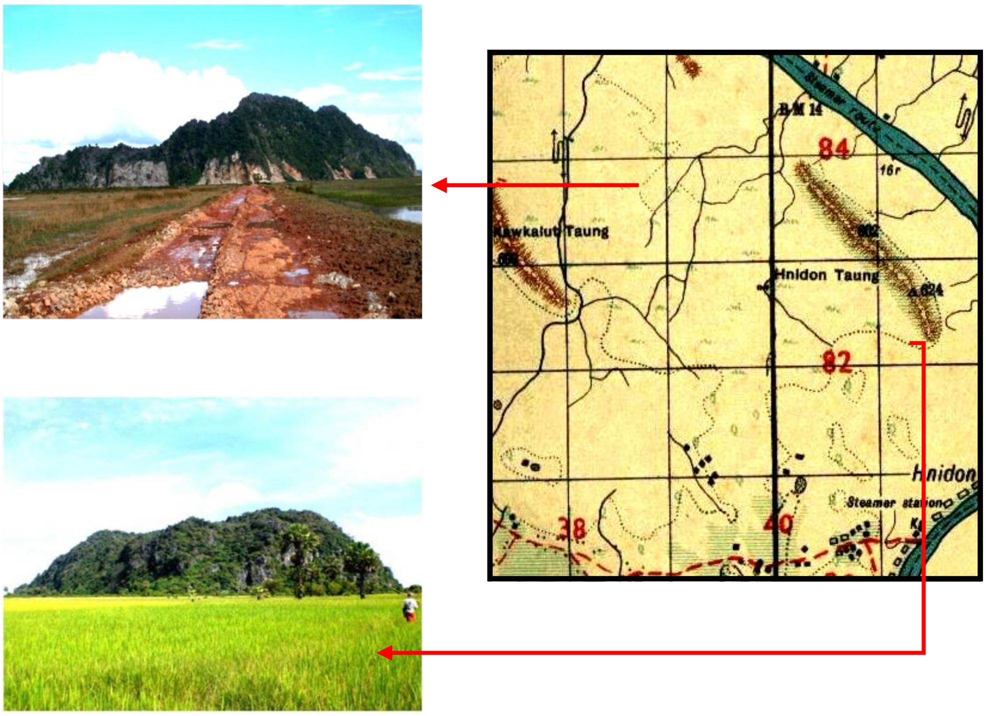


Figure 2 Kawkalut Hill (facing 75º) and Hnidon Hill (facing 5º) rising up in the alluvial land

Limestone of Kawkalut Hill

Kawkalut Hill Limestone is cropped out at the southeastern part of Kyaikmaraw Township and the eastern part of Taungnyo Range. It is exposed as isolated hill. Their trend is generally in NW-SE and dipping west with a dip amount of 50º to 75º.

In the lower part of Kawkalut Hill section line, light grey to dark grey-colored, thick-bedded, fine-grained micritic limestone are interbedded with fine-grained dolomitic limestone with wavy calcite veinlets (Fig.4). The middle part is mainly composed of dark grey-colored, fine-grained, micriticlimestones (Fig.5) are intercalated with medium-grained limestone. Micritic limestone with stromatolite is found in the middle part of Kawkalut Hill. The upper part consists of light grey to dark grey coloured, fine-grained fossiliferous limestone with rugose coral (Fig.6). The approximate stratigraphic thickness of Kawkalut Hill Limestone is about 574 ft (175m).

Limestone of Hnidon Hill

Sabe and Pagan Tunnels located at the northern and eastern part of Hnidon Hill. The trend of hill block is generally in NW-SE and dipping west with a dip amount of 25º.

At the southern part of Hnidon Hill, there is light grey-coloured, medium to thick-bedded, fine-grained micritic limestone in the lower and upper part interbedded with light grey to grey-coloured, fine to medium-grained dolomitic limestone. In the middle part, light grey to grey-coloured, medium to thick-bedded, fine to medium-grained limestone are interbedded with fine-grained micritic limestone with wavy laminations. The uppermost part is massive, grey to dark grey-coloured, fine-grained micritic limestone and dolomitic limestone (Fig.7). The approximate stratigraphic thickness is about 656 ft (200 m).

Carbonate Microfacies Analysis of Kawkalut and Hnidon Hills

Moulmein Limestone in the research area, the section lines can be categorized into (6) microfacies respectively.

Algal wackestone to packstone (microfacies -1)

Under the microscopic study, this microfacies consists of carbonated mud and some bioclasts. Allochembioclasts are included approximately 15 to 55 percents of the total rock volume. Bioclasts are algaes, stromatolite, foraminiferas, ostracods, gastropod, crinoids and unidentified shell fragments. Among them, densely radiating structure of tubules and shrubby plant forms of *Microbial* blue green algae and *Mizzia* green algae are found. Fragment of *Mizzia* green algal grain, outling of the grain with micritic sediment and infilling of original pores are sparry calcite cement. Laminated and contorted stromatolite (loferite) which preserved irregular lamination and elongate (birdseye or fenestral) pores (Fig.8). Crinoids showing the unit extinction (single crystal extinction), traces of pores structure and the axial canal and are surrounded by micrite envelope and filled with sparite. Foraminiferal tests show a variety of shapes and sizes. *Miliolina sp.* like tubular foraminifera is found. Micrite-walled endothyraceans were small Fusulinina, often with a well-developed inner fibrous layer. The rounded, circular-shaped exteriors of these grains made them easy to transport and orient, and as such they can be useful paleocurrent indicators. Thick-shelled gastropod, in which the original shell has been replaced by calcite and the internal are filled with algae and micrite. Orthochemmicrite are range from 15 to 40 percents and sparite is range from 25 to 50 percents of the framework. Peloids contain less than 5 percents of total rock volume.

Due to the presence of bioclasts (algae), micrite and sparite, the rock can be called biomicrite to biosparite using Folk’s classification (1959, 1962). The rock can also be called algal wackestone to packstone using Dunham (1962).

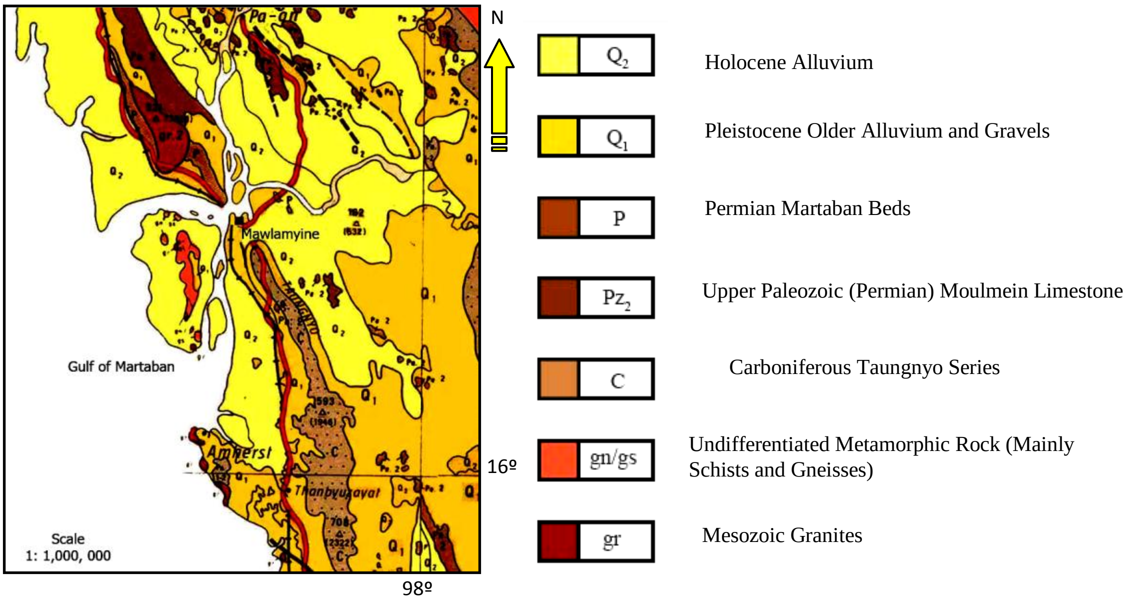


Figure 3 Regional Geological Map of the Study Area (From Geological Map of Myanmar, 1977)

Figure 4 Dolomitic limestone with wavy calcite veinlets in the lower part of Kawkalut Hill (Loc. 377829) (facing- west)

Figure 5 Fine-grained micritic limestone intercalated with medium-grained limestone in the middle part of Kawkalut Hill (Loc. 378828) (facing- southwest)

Figure 6 Rugose coral with fossiliferous limestone in the uppermost part of Kawkalut Hill (Loc.380826) (facing– northwest)

Figure 7 Massive nature of dolomitic and micritic limestone in the upper part of Hnidon Hill (Loc. 414823) (facing- west)

Dolomitic mudstone (microfacies-2)

Microscopically, allochems are very rare, and usually consists of brachiopod fragments, crinoids and algae. They are ranging from 3 to 5 percents of the total rock volume. Orthochemmicrite are 20 to 85 percents of the total volume of rock. These are made up of entirely of equant, granular, aphanocrystalline to cryptocrystalline mosaic of dense carbonate mud. Coarsely euhedral dolomites in micrite are also found. Microstalactitic or pendent fabrics were precipitated in the micrite (Fig.9). Dolomites are second in abundance. Dolomites place 15 to 75 percents of the total rock volume. Sparry calcite occurred from 3 to 5 percents of the rock.

Thus, the rocks of microfacies can be called dolomitic micrite (Folk, 1959, 1962). According to the limestone classification of Dunham (1962), the rock can be designated as dolomitic mudstone.

Mudstone (microfacies -3)

Microscopically, this mudstone facie is mainly made up of micrite. Bioclasts are included approximately 3 to 7 percents of the total rock volume. They are crinoids, ostracode, foraminifera and fossil fragments. Umbrella void in mudstone, the presence of some microcrystalline material on the roof of the cavities and calcite cements are filled with the fossil fragments and the remaining of geopetal pore space (Fig.10). Orthochem of micrite are range from 80 to 95 percents of the framework and sparites contain a little amount and which are filled in fossil fragments. Microstylolites are commonly observed in this microfacies. Dolomite contains 5 to 12 percents and calcite veinlets and selenites are present.

So carbonate mud are mainly present in this rock, the rocks can be called micrite by using the limestone classification of Folk (1959, 1962). According to Dunham's (1962), the limestone of this microfacies can be named as mudstone.

Microbial grainstone(microfacies -4)

Petrographically, allochem bioclasts range from 35 to 65 percents, peloids are less than 10 percents and orthochem of sparite are 25 to 65 percents of the total rock volume. Bioclasts are blue-green and green algae, brachiopod, echinoid plates, ostracode and foraminifera. The more irregularly shaped clumps of blue-green algae (*Microbial*) (Fig.11) and dasycladacean green algae (*Mizzia*) are the most common type among the bioclasts. Less complete fragments of brachiopod shell outline by micrite envelop and are smoothly curved and filled with blue-green algae. Gastropod test which shows the inside of the shell is filled with fine sediment of calcite. The original void space was partly filled calcisilt and remaining portion with coarse crystalline calcite. Little dolomites are found in some specimen. Five types of foram are found. Among them, Fusulinid foraminifer has the dark micrite wall.

Thus, the rock may be called as biosparite (Folk, 1959, 1962). According to Dunham's classification, it can be designated as bioclastic grainstone or microbial grainstone.

Peloidalgrainstone (microfacies -5)

Petrographically, allochem of bioclasts (algae) contain 13 to 23 percents, peloids are 17 to 55 percents and orthochem of sparite are 35 to 62 percents of the total rock volume. Bioclasts are algae, foraminifera, bryozoan and crinoid plates. Discoidal crinoid plates are thickest at their margins and the internal pores are completely filled with micritic carbonate giving the grains a characteristic dusty or speckled appearance. Grains that have micritic internal structure like pellet, but that has diverse and irregular shapes and sizes or vague remnants of internal fabric are generally termed peloids (Fig.12). Finely peloidal rock in which individual peloids are, for the most part, distinct and some peloids are less distinct and are considered under cements. These peloids must have been followed by relatively sparry calcite cementation. The peloids ranges from 0.1mm to 0.01mm in length, and width ranges from 0.15mm to 0.01mm.

Thus, the rock may be called as pel-sparite (Folk, 1959, 1962). According to Dunham's classification, it can be designated as peloidal grainstone.

Peloidalpackstone (microfacies -6)

According to the microscopic study, allochemical bioclasts consist of algae, echinoid plates, gastropod and foraminiferas which are 10 to 30 percents of the total rock volume. A variety of shapes and sizes of peloids are range between 15 to 65 percents. *Mizzia sp.* dasycladacean green algae and larger grains are pellet mud, which show the typical ellipsoidal shape in the middle part of the section line (Fig.13). The grains are peloids, probably algae in origin which shows some relict internal structure but with a variety of shapes and sizes. Many of the smaller grains are structureless. Uniformly grain size of peloids was associated with a lithified cyanobacterial mat in the upper part of the section line. A large echinoderm fragment with characteristic single crystal and the grain is surrounded by calcite overgrowths that formed in optical continuity with the grain which has irregular shape and lack of a central canal. Longitudinal section of gastropod, the exterior of the shell has been encrusted with calcite and the body chambered has been filled with micrite. The circular to cigar –shape cross-section of these spiral forms, the chamber structure and the microgranular walls with barely visible perforations all are the characteristic of small fusulinid foraminifera. Orthochem occupy 15 to 40 percents of sparry calcite and 10 to 35 percents of microcrystalline calcite. Dolomite contains 10 percents and calcite veinlets are present.

The rocks are made up of allochem grain of peloids and orthochem of sparry calcite and micrite. Therefore the rock can be named as pelmicrite to pelsparite (Folk, 1959, 1962) and peloidal packstone (Dunham, 1962).

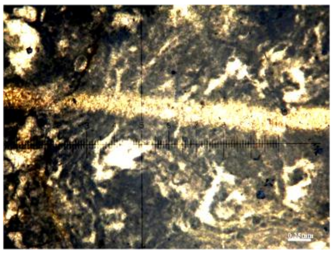


Figure 8 Laminated and contorted stromatolite (loferite) which preserved irregular lamination and elongate (birdseye or fenestral) pores in algal wackestone to packstone, PPL

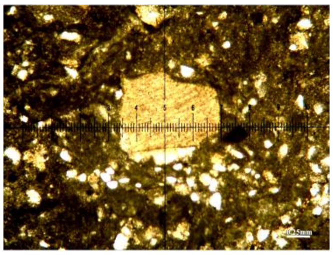


Figure 9 Microstalactitic or pendent fabric were precipitated in the micrite and anhedral to subhedral dolomite crystal in dolomitic mudstone, PPL

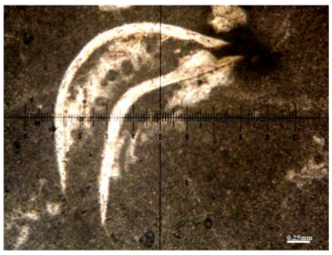


Figure 10 Umbrella void in mudstone, the presence of some microcrystalline material on the roof of the cavities and calcite cements are filled with the fossil fragments and the remaining of geopetal pore space, PPL

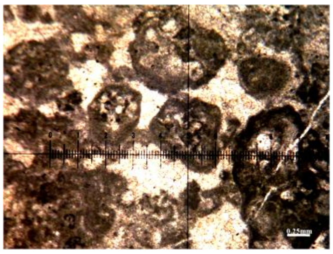


Figure 11 The more irregularly shaped clumps of blue-green algae in microbial grainstone, PPL

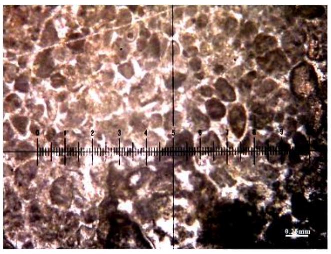


Figure 12 Grains that have micritic internal structure like pellet, but that has diverse and irregular shapes and sizes or vague remnants of internal fabric in peloidal grainstone, PPL

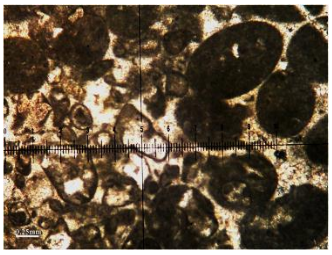


Figure 13 Larger loose grains are pellet muds, probably faecal in origin, show the typical ellipsoidal shape in peloidal packstone, PPl

Facies association and recognition of paleodepositional environment

Triangular plot of the rocks show that deposition had been taken place in the supratidal, intertidal and subtidal environments of Moulmein Limestone in Kawkalut and Hnidon Hill section lines (Fig. 14 and 15). Three major depositional environments are identified in the study area on the basis of grain types, physical and biogenic sedimentary structures, and vertical facies relationships as shown in table (1), (2) and (3). The possible depositional model of Kawkalut and Hnidon Hill is acquired by the study of microfacies and their respective association (Fig.16). Petrographic characteristics and depositional environments of the Kawkalut and Hnidon Hill Limestone are shown in (Fig.17 & 18).

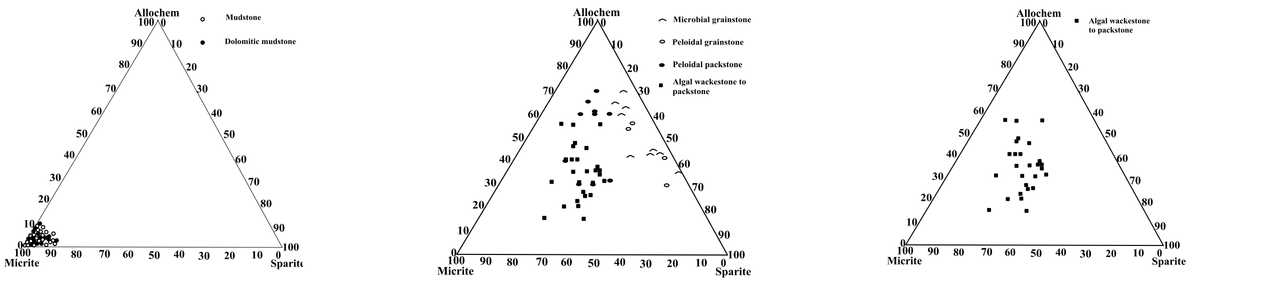


Figure 14 Triangular plot of supratidal, intertidal and subtidal environments of Moulmein Limestone in Kawkalut Hill section line (after Folk, 1959)

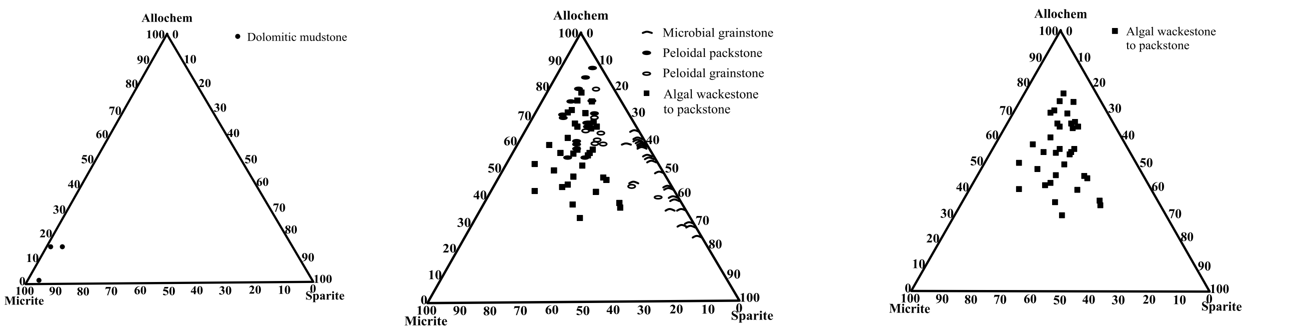


Figure 15 Triangular plot of supratidal, intertidal and subtidal environments of Moulmein Limestone in Hnidon Hill section line (after Folk, 1959)

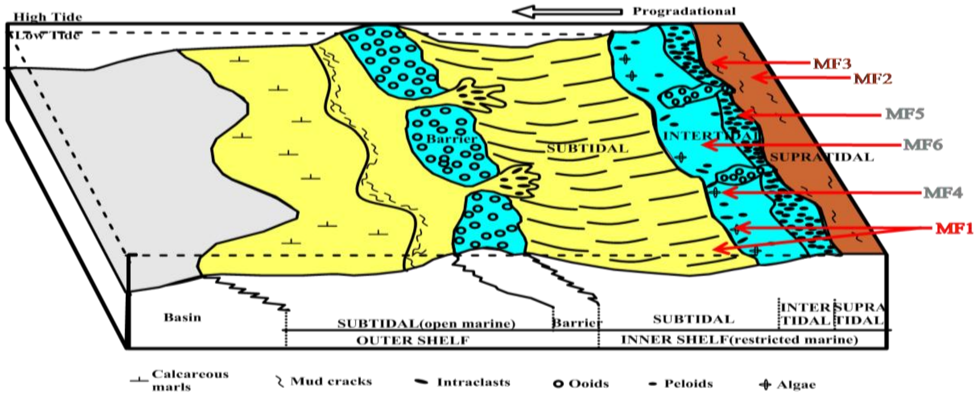


Figure 16 The possible depositional model of Kawkalut and Hnidon Hills Limestone

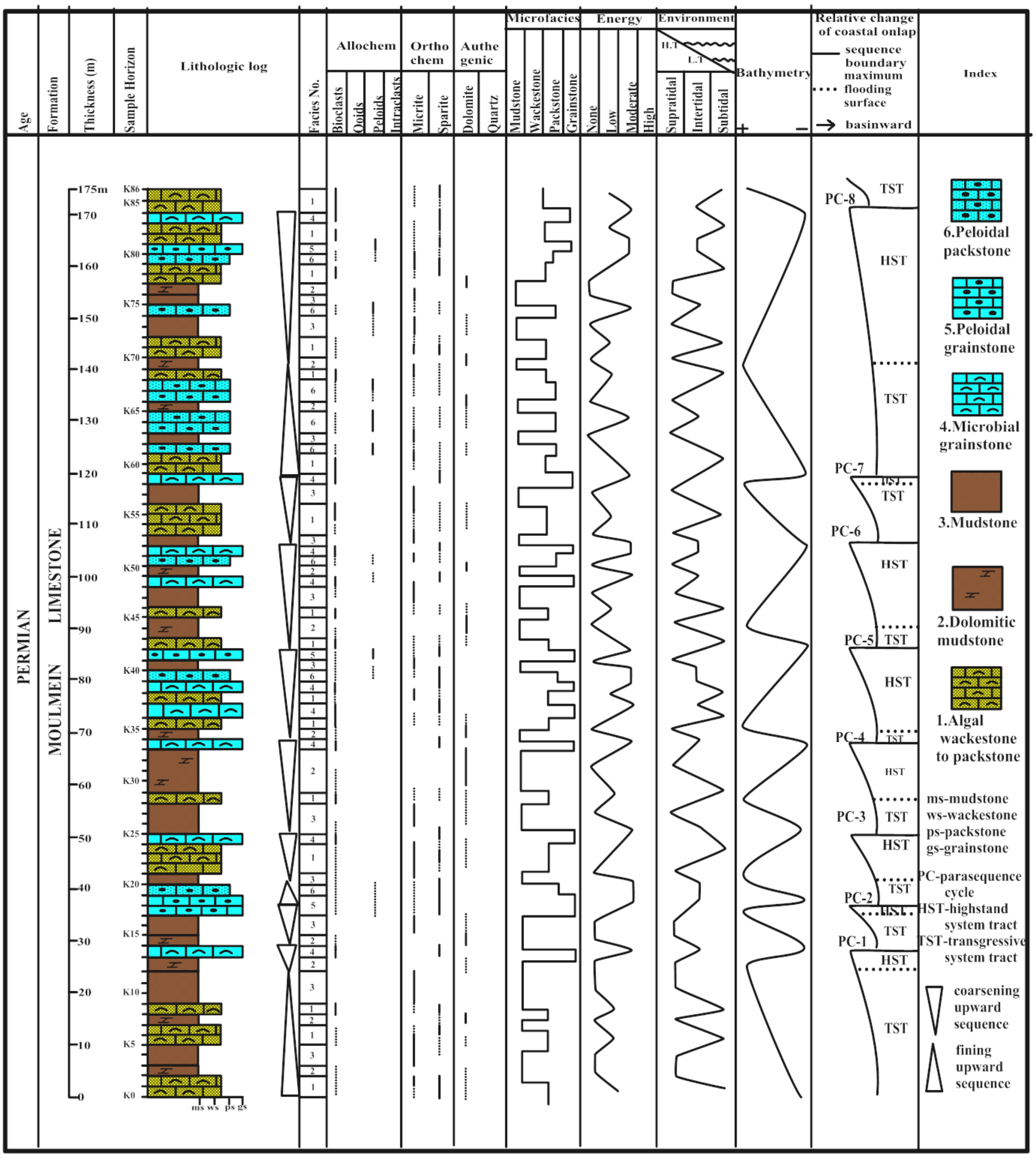


Figure 17 Petrographic characteristics and depositional environments of Moulmein Limestone at the Kawkalut Hill section (measured from Loc. 377830-378827)

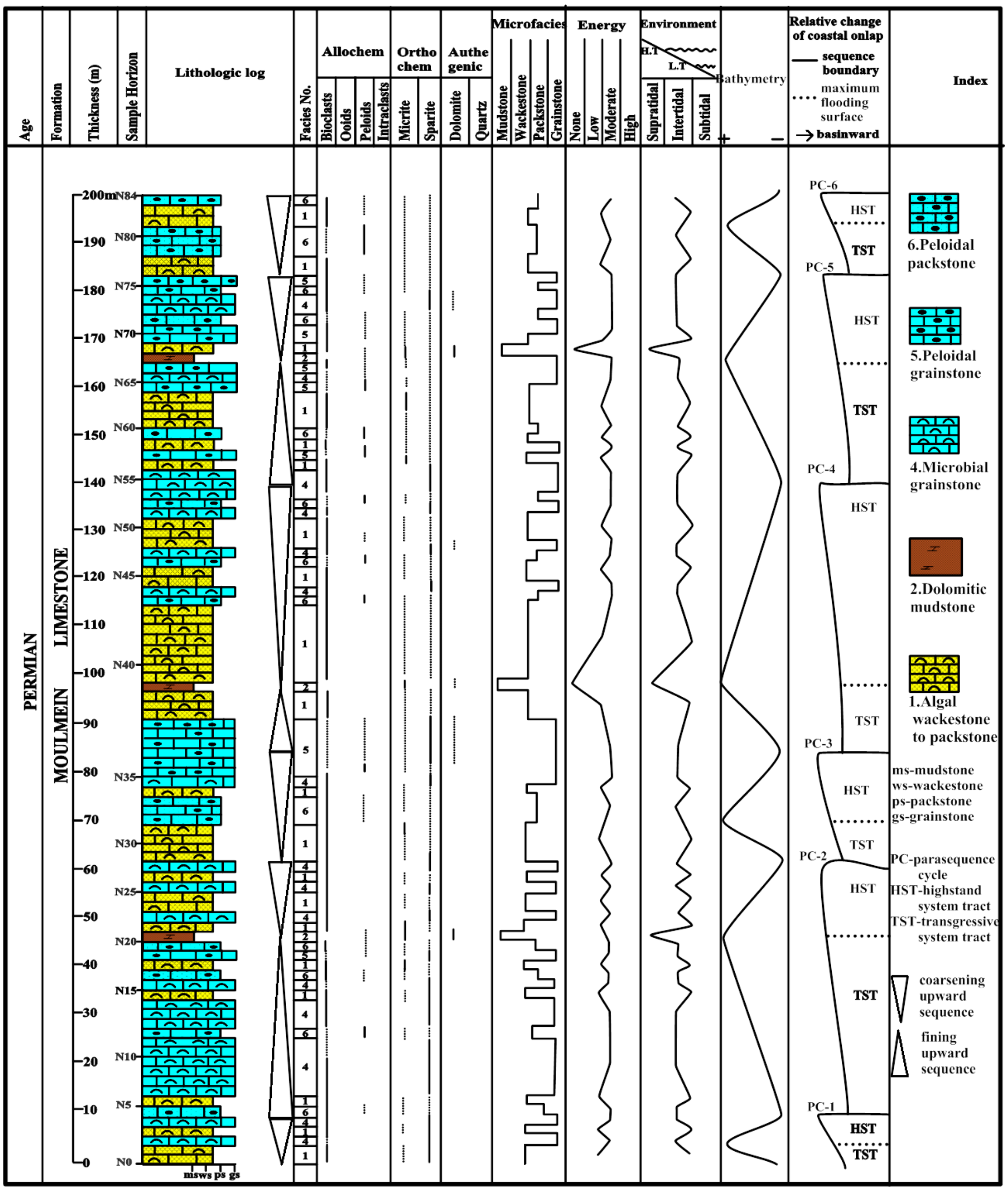


Figure 18 Petrographic characteristics and depositional environments of Moulmein Limestone at the Hnidon Hill section (measured from Loc. 377830-378827)

Table 1 Microfacies association and characteristic features of supratidal environment in Kawkalut and Hnidon Hill Section Lines

Supratidal	
Microfacies	**Characteristic features**
Dolomitic mudstone (microfacies- 2) Mudstone (microfacies- 3)	carbonate mud , high content of dolomite, dark colour, dolomite exhibit hypidiotopic to idiotopic fabric, gypsum (selenite), microstatitic or pendent cement, none energy, thick- bedded

Table 2 Microfacies association and characteristic features of intertidal environment in Kawkalut and Hnidon Hill Section Lines

Intertidal	
Microfacies	**Characteristic features**
Microbial grainstone (microfacies-4) Peloidal grainstone (microfacies-5) Peloidal packstone (microfacies-6) Algal wackestone to packstone (microfacies- 1)	Mostly bioclasts such as large brachiopod and gastropod, stromatolite, peloids, packstone, grainstone, moderate to high energy large

Table 3 Microfacies association and characteristic features of subtidal environment in Kawkalut and Hnidon Hill Section Lines

Subtidal	
Microfacies	**Characteristic features**
Algal wackestone to packstone (microfacies- 1)	Bioclasts, bryozoans, crinoids, stromatolite wackestone, lamination, low energy

Sequence Stratigraphy

Sequence Stratigraphic Interpretation of Kawkalut Hill Section Line

In this section line, eight, metre- scale fourth-order shallowing upward parasequence cycles and three, metre-scale fourth-order deepening upward parasequence cycles are recorded (Fig.17). The parasequence cycle boundaries PC-1 to PC-8 are tentatively defined at the changes of lithologic units. The PC-1, PC-3, PC-4, PC-6, PC-7 and PC-8 cycle boundaries are contact with microbial grainstone (MF-4). The PC-2 and PC-5 cycle boundaries are regarded by peloidal grainstone (MF-5). Dolomitic mudstone and mudstone are overlying on the cycle boundaries PC-1 to PC-8.

Maximum flooding surface (mfs) forms the boundary between the trangressive and highstand systems tract. In the study area, maximum flooding surfaces are defined by using argillaceous units (dolomitic mudstone and mudstone).

The transgressive systems tracts are noticed at the cycles PC-1 to PC-8. In the cycle PC-1, PC-3and PC-8, the transgressive systems tracts progressively fining upward and are composed of dolomitic mudstone and mudstone facies. These facies display retrogradational stacking pattern which suggested that the rate of sediment supply is less than the rate of accommodational space (Emery and Myers, 1996).

In the cycle PC-2, the transgressive systems tracts are dolomitic mudstone and mudstone facies. These mudstone facies display aggradational stacking pattern which suggested that the rate of sediment supply is equal to the rate of accommodational space.

In the cycle PC-4 and PC-5, this is made up of mudstone and dolomitic mudstone facies. The transgressive systems tracts of these cycles express progradational stacking pattern which indicate that the rate of sediment supply is greater than the rate of accommodation space.

In the PC-6, transgressive systems tract is characterized by algal wackestone to packstone and dolomitic mudstone facies. The transgressive systems tract of these cycle displays retrogradational stacking patterns repeatedly occurred. The rate of sediment supply is less than the rate of accommodation space.

The transgressive systems tract of PC-7 is collected of mudstone and algal wackestone to packstone facies. These cycles are occupied by progradational stacking patterns initially occurred and retrogradational stacking patterns are observed in later. The rate of sediment supply is greater than the rate of accommodation space in early stage and less in later stage.

The high systems tract of PC-1 consists of dolomitic mudstone and microbial grainstone facies. These grainstone facies represents cycle boundary. The highstand systems tract of this cycle, the progradational stacking patterns occurred which indicate that the rate of deposition is greater than the rate of accommodation space.

The high systems tracts of PC-2 and PC-7 consist of peloidal grainstone and microbial grainstone facies. These grainstones represent cycle boundaries. The highstand systems tract of this cycle, the progradational stacking patterns occurred which indicate that the rate of sediment supply is greater than the rate of accommodation space.

In the PC-3, highstand systems tract is characterized by algal wackestone to packstone and microbial grainstone facies. These grainstone represents cycle boundary. These cycles are occupied by retrogradational stacking patterns. These features indicate that the rate of sediment supply is less than the rate of accommodation space.

The highstand systems tract of PC-4 is composed of dolomitic mudstone and microbial grainstone facies. This grainstone represents cycle boundary 4. These cycles are occupied by progradational stacking patterns. This feature indicates that the rate of sediment supply is greater than the rate of accommodation space.

In the PC-5, highstand systems tract is characterized by algal wackestone to packstone, microbial grainstone, peloidal packstone, mudstone and peloidal grainstone facies. This grainstone represents cycle boundary 6. The highstand systems tract of these cycles initially display retrogradational stacking patterns repeatedly, and followed by progradational stacking patterns in later. Thus the rate of deposition is less than the rate of accommodation space in early stage, greater in later stage.

In the PC-6, highstand systems tract is characterized by algal wackestone to packstone, mudstone, microbial grainstone, dolomitic mudstone and peloidal packstone facies. This grainstone represents cycle boundary 6. These cycles are repeatedly occupied by retrogradational stacking patterns initially and progradational stacking patterns are observed in later. These features indicate that the rate of sediment supply is less than the rate of accommodation space in early stage and greater in later stage.

In the PC-8, highstand systems tract is characterized by algal wackestone to packstone, mudstone, peloidalpackstone, dolomitic mudstone, peloidalgrainstone and microbial grainstonefacies. This grainstone represents cycle boundary. This cycle is occupied by four repeated retrogradational stacking patterns. These features indicate that the rate of sediment supply is less than the rate of accommodation space.

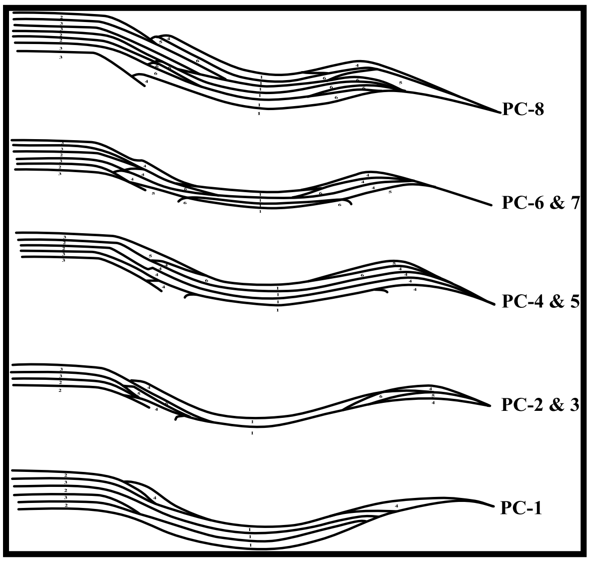
Stratal stacking patterns of KawkalutTaung related to shorelines trajectories can be observed in figure 19.

Parasequence Stacking Pattern

In the Middle to Late Permian time, global sea level history was also provided by the deposition of Moulmein limestone forming a peritidal carbonate platform giving a fashion of shorter sea level oscillation. The lacks of clastic strata and without pronounced drop in sea level are very strong support to the deposition in a stable sea level. In the global Permian sea level, the slow falling of sea level also representing to Middle to Late Permian time which superimposed by lower order smaller cycles.

Conclusion

From the present study, the limestones of Kawkalut and Hnidon Hills are composed of micritic limestone, dolomitic limestone, fossiliferous limestone and crystalline limestone according to field assessment. Microscopic analysis reveals the rock types of Kawkalut and Hnidon Hills are grouped into six microfacies. Dolomitic mudstone and mudstone are deposited in supratidal environment. Algal wackestone to packstone, microbial grainstone, peloidal grainstone and peloidal packstone are deposited in intertidal environment. Algal wackestone to packstone is deposited in subtidal environment. In sequence stratigraphic interpretation of the study area, eight, metre- scale fourth-order shallowing upward parasequence cycles and three, metre-scale fourth-order deepening upward parasequence cycles of Kawkalut Hill can be recognized. After the completion of Moulmein Limestone deposition, the slow falling of sea level also representing to Middle to Late Permian time which superimposed by lower order smaller cycles.



1.Algalwackestone to packstone
2.Dolomitic mudstone 3.Mudstone
4.Microbial grainstone 5.Peloidal grainstone 6.Peloidal packstone PC. Parasequence boundary

Figure 19 Stratal stacking patterns of Kawkalut trajectories (from Catuneanu et al. 2010)

Acknowledgements

Appreciation is due to Dr Aung Myat Kyaw Sein (Rector of Mawlamyine University) and Professor Dr Yin Yin Aye (Head of Geology Department, Mawlamyine University), for permission to carry out my research work.

References

Adams, A.E., and W.S. Mackenzie, (1984).*Atlas of sedimentary rocks under the microscope*, Longman Scientific & technical, John Wiley & Sons, Inc., 104 p.

Catuneanu, O., et. al., (2010).*Sequence stratigraphy*: common ground after three decades of development. First Break **28**, 21–34.

Dunham, R.J., (1962).*Classification of carbonate rocks according to depositional texture*, p. 108-121, in W.E. Ham, Ed., Classification of Carbonate Rocks: Tulsa, Okla, America Association of Petroleum Geologists, Mem., 1, 279 p.

Folk, R.L., (1959).Practical Petrographic Classification of Limestone.*Bull. Amer. Asso. Petrol. Geol.43*. 1-38.

Meyers,J., (1980). Compaction and Mississippian Skeletal Limestones, Southwestern New Mexico: *Jour, Sedi.Petrology*,v. 50, 457-474.

Oldham, T.(1856). Notes on the coal field and tin- stone deposits of the Tenasserim Provinces. Sel., Rec. Geol., Govt. India, 10: 31-67.

Scholle, P.A. and D.S. Ulmer- Scholle, (2003). *A color Guide to the Petrography of Carbonate Rocks: Grains, Texture, porosity, diagenesis,* AAPG Memoir 77,459 p.

Terry, R.D. and Chilinger, G.V., (1955). Summary of concening some additional aids in studying sedimentary formation by Shvetsov.M.S.:*Jour. Sed. Petrology,* v. 25, 229-234.

Tucker, M.E., (1991). *Sedimentary Petrology.* Blackwell Scientific Publications, 227 p.