SEQUENCE STRAGRAPHY OF TAUNGNYO FORMATION IN THE SOUTHERN PART OF MAWLAMYINE AREA, MON STATE

Moe Moe Lwin[1], Day Wa Aung[2] and Ko Yi Hla[3]

Abstract

The study area is situated in Mawlamyine and Mudon Townships, Mon State. It is mainly composed of Early Carboniferous to Early Permian clastic sedimentary rocks comprising shales, mudstones, pebbly mudstones, sandstones, gritty sandstones, conglomerate and pebbly greywacke. Nine lithofacies of Taungnyo Formation are recognized; (1) dark grey color thick-bedded mudstone facies, (2) dark color pebbly sandstone facies, (3) dark color pebbly mudstone facies, (4) conglomeratic gritty sandstone facies,(5) gritty sandstone facies ,(6) medium to thick-bedded sandstone facies, (7) thin to medium-bedded sandstone facies, (8) thin-bedded sandstone with shale interbeddedfacies and (9) sandstone and mudstone interbeddeddfacies. It is divided into three lithofacies associations; (1) pebbly greywacke-pebbly mudstone-shale association which represents upper and lower fan sequence ,(2) conglomerate-gritty sandstone-sandstone-shale association represented upper fan and mid fan sequence and (3) sandstone-shale association representing mid fan channel and basin plain of lower fan sequence. By studying the rocks of Taungnyo Formation it is characterized by high velocity turbidity current, low density turbidity current, fine-grained sandstone with low velocity and coarse-grained sandstone with high velocity turbidity current of submarine fan environment. Taungnyo Formation was formed as a submarine fan and taken place in the deep sea. This is forming as a sand-rich and mixed sand-mud turbidite system. Growth and deposition of a turbidite system are intimately tied to a cycle of eustatic or relative sea-level change. During a maximum regression, the shore line moved basinward and the fluvial system placed on the exposed shelf area and most of the sediments were deposited in continental slope area. This regression is also coincided with the global sea level drop.

Keywords: Taungnyo Formation, turbidite system, maximum regression, Sequence

Introduction

Location, size and accessibility

The study area is located in Mawlamyine and Mudon Townships, Mon State. It is bounded by Latitudes 16 d 21 ′ N to 16 d 30′ N and Longitudes 97 d 38 ′ E to 97 d43′ E, and are located partly in one inch topographic maps No. 94 H/ 10, 11and 15. It can be easily accessed by car (Fig 1).

Physiography

The Taungnyo range can be physiographically divided into two divisions such as the hill ranges of southeasternly trending Taungnyo range in the middle and the rest is young flat alluvial plain. The eastern and western parts of the ranges are also covered by alluvial plains of Mawlamyine, Kyaikmaraw and Mudon Townships. Isolated hill blocks of Moulmein Limestones also stand out in the low lying alluvial plain on both sides of the Taungnyo range. Regional structural trend is NNW-SSE direction (Fig. 2).

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

Regional geologic setting

The study area is located in the central portion of Mon State occupies Shan-Taninthayi block. In this area, clastic sedimentary rocks were folded and it is conformably overlain by Moulmein Limestones in both eastern and western part of the range. Regional structural trend of these rocks is NNW-SSE direction and has been stratigraphically correlated with Lebyin Group of Southern Shan State. The Taungnyo Group and Mawchi Series were regareded as homotaxial and part of Mergui Series which is ranging in age from Silurian to Lower Carboniferous (Haq and Thein, 1969). The fauna found in Zwegabin range, south of Hpa-an reveals that the age of fossils-bearing sandstones of Taungnyo Group is Upper Carboniferous (Brunnschweiler, 1970). Generally Taungnyo Series is resting conformably on Mergui Series and overlain by Moulmein Limestones exposed along the eastern and western part of Taungnyo range (Brunnschweiler, 1970). Regional geological map of the study area is shown in Fig (3).

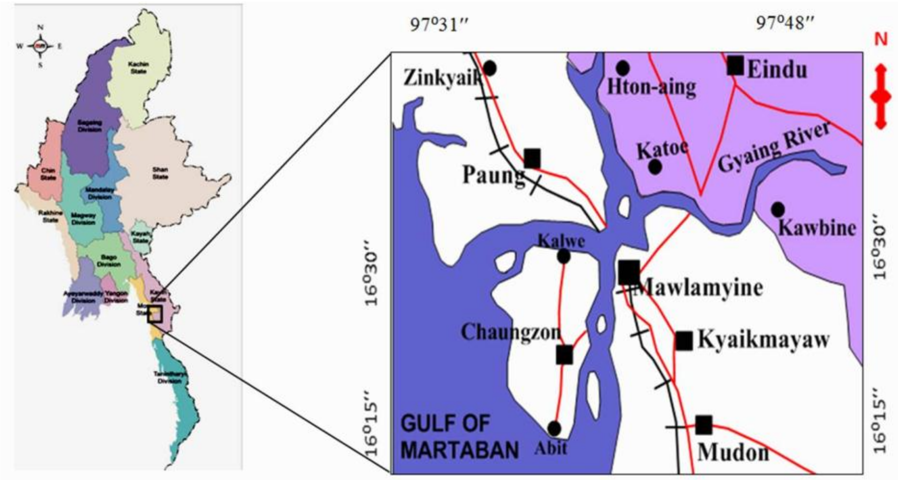

Figure 1 Location map of the study area.

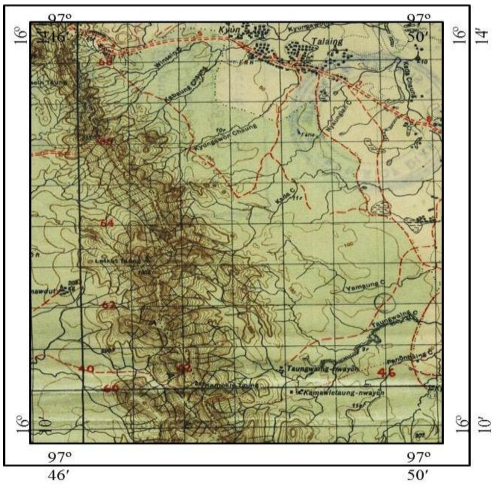

Figure 2 Topographic map of the study area.

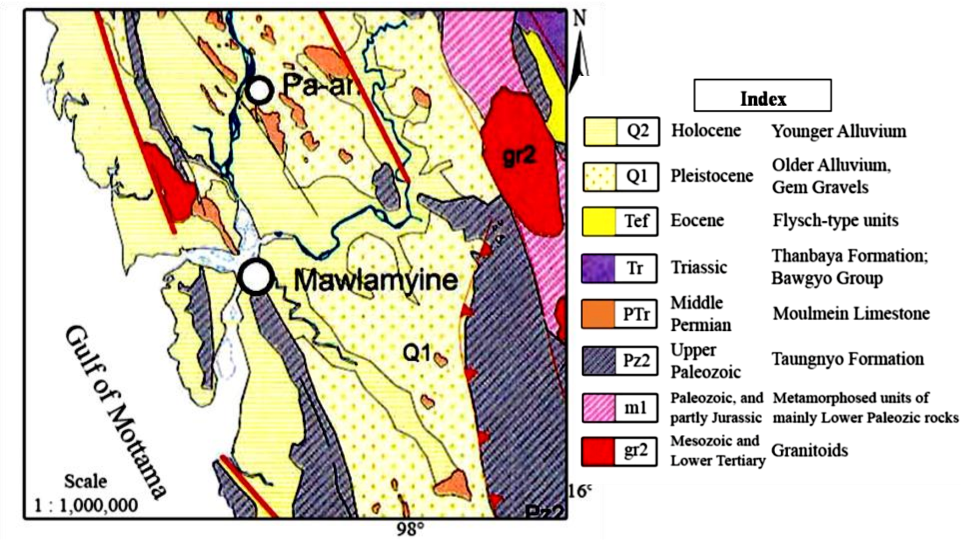

Figure 3 Regional Geological Map of the Study Area.(From Geological Map of Union of Myanmar, 2014)

Stratigraphy

The study area lies in a part of Shan-Taninthayi Block. It is composed of clastic sedimentary rocks of Early Carboniferous to Early Permian Taungnyo Formation which is overlain by Moulmein Limestone. According to the lithologic characteristics and bed thickness, the Taungnyo Formation is divisible into three different subunits such as unit 1, 2 and 3.The stratigraphic succession is shown in Table (1).

Table 1 Stratigraphic succession of Taungnyo Formation.

	Age	Subunits	Dominatlithology
Taungnyo Formation	Early carboniferous to Early Permian	Unit 1	Thin to medium-bedded, coarse-grained sandstone interbedded with shale and mudstone
		Unit 2	Medium to thick-bedded, medium to coarse-grained sandstone interbedded with shale and mudstone, paddy mudstone, pebbly mudstone, pebby sandstone, grit and conglomerate
		Unit 3	Thick-bedded to massive fine to medium-grained sandstone with shale and mudstone

Sedimentology

Facies analysis

There are nine lithofacies were differentiated on the basis of grain sizes, lithology and sedimentary structures. They are; (1) dark grey coloured thin-bedded to massive mudstone facies(Fig. 4), (2) dark grey coloured pebbly sandstone facies(Fig. 5), (3) dark greycoloured pebbly mudstone facies(Fig. 6), (4) conglomeratic gritty sandstone facies(Fig. 7), (5) gritty sandstone facies (Fig. 8), (6) medium to thick-bedded sandstone facies(Fig. 9), (7) thin to medium-bedded sandstone facies(Fig. 10), (8) fine-grained laminated sandstone with shale intercalated facies(Fig. 11), and (9) thin to medium-bedded sandstone and mudstone interbedded facies(Fig. 12).

Facies (1) Dark grey coloured thin-bedded to massive mudstone facies

Description

This facies is mainly consisting of grey to dark grey coloured mudstone. In some localities dark grey coloured mudstone consists of laminations (Fig.4). In some grey coloured mudstone abundant fossilized brachiopod shell as living position are well preserved. Sometime, pyrite occurs in this facies. This facies is vertically associated with thick-bedded to massive sandstone facies and fine-grained sandstone interbedded with shale facies and thin to medium-bedded sandstone. It is similar with Bouma's $T_{\mathbf{a}}$ division.

Interpretation

Dark grey coloured mudstone in this facies was deposited in low energy environment where the finer particles settle out of suspension (Reineck and Singh, 1980). The pyrite associated with dark grey shale display the reducing environment far enough from shore lines and has settle on the sea floor. This facies may be deposited in the basin floor of the lower fan environment.

Facies (2) Dark grey coloured pebbly sandstones facies

Description

This facies is composed mainly of medium to thick-bedded and massive dark grey coloured pebbly sandstones (Fig 5). Pebbles are subangular to well rounded, and sizes range from 1cm to 5cm in diameter. They are vertically associated with dark grey coloured sandstones, pebbly mudstones and gritty sandstones. This facies is similar to Bouma's T_a division.

Interpretation

The sandstone wih pebbles is the deposit of high density turbidity current (Lowe, 1982). During river floods or slump and slide, main long distance transport took place debris flow and high concentration turbidity current (Walker, 1987). The observed character of this facies could be assigned to a gravelly high density turbidites. Pebbly wacke and massive sandstones are deposited near the mouth of the submarine canyon according to Stanley & Kelling, 1967.

Facies (3) Dark grey coloured pebbly mudstones facies

Description

This facies is consisted mainly of grey to dark grey coloured, fine-grained, thin to medium-bedded and thick-bedded to massive pebbly mudstones (Fig 7). This facies is vertically and laterally associated with thin to medium-bedded gritty sandstones, medium to thick-bedded dark coloured pebbly sandstones and thin to medium-bedded mudstone. Pebbles are subrounded to well rounded and size ranging from 1cm to 3cm in diameter. Some pebbly mudstone deposits possess large rock blocks with sizes ranging from about cobble to boulder. Clasts are randomly oriented. This facies is similar with Bouma's T_a division.

Interpretation

These pebbles are carried by rivers as bed load and moved on the muddy surface (Stanley, 1969) when increase rates of deposition during flood periods possibily cause to a trigger failure and moving masses downward on the very steep side to be an unstable area. The deposit shows no internal evidence of slump (Walker, 1992) also observed in various continental margins may be the deposits of submarine canyon especially in the mouth (Gorsline, Emery, 1959). Thus, pebbly mudstone deposits represent high velocity plastic mass-flow downslope movement under the influence of gravity (Crowell, 1957).

Facies (4) Conglomreatic gritty sandstone facies

Description

This facies is mainly composed of white to light grey and buff to reddish brown colored, coarse to very coarse-grained, medium to thick-bedded conglomeratic gritty sandstones (Fig 8). Observed internal structure is only graded bedding. This facies is vertically associated with medium to thick-bedded sandstone and gritty sandstone. They are clast supported conglomrerate and having different rock types and pebble size ranges from 0.3 cm to 10 cm in diameter.

Interpretation

This facies was deposited in the braided channel of upper fan. This interval is composed of graded conglomerates and sandstone resembling the graded stratified conglomerate facies of Walker (1975, 1977) and Hein &Walker, (1982). The coaser sediments may be restricted to thalweg channels. In such area (braided channels of upper fan), gravels and boulder may be deposited (Haner, 1971, Clearly & Condly, 1974). Therefore, the area of deposition of conglomerate may be upper fan valley and channel.

Facies (5) Gritty sandstone facies

Description

This facies is consisted of coarse-grained, white to light grey, light grey to buff colored, thin to medium and medium to thick-bedded gritty sandstones (Fig 9). This facies is vertically and laterally associated with conglomeratic gritty sandstones, medium to thick-bedded sandstone, dark grey coloured pebbly mudstones and shale. Recognized internal structures of this facies are lamination, mud drapes, graded bedding, small scale planar and trough cross bedding. This facies is similar with Bouma's T_{a-c} division.

Interpretation

The facies is assumed to be deposited in the braided channel of mid fan area. Gritty sandstone (show normal graded bedding) interval has been deposited from dispersed pressure and or turbulent suspension. Cross-strification and flat-layered gritty sandstone and thick-bedded sandstone reflect traction sedimentation beneath high density flow (Reading, 1986). This facie is probably deposited in braided channel of middle fan submarine environment (Walker, 1982).

Facies (6) Medium to thick-bedded sandstone facies

Description

This facies is mainly composed of buff to light grey, medium to coares-grained, medium to thick-bedded sandstone (Fig 10). In some locality, sandstones grade upward into masssive character. It is vertically associated with thin to medium-bedded sandstones, gritty sandstone and buff to light grey shale. Laminations, ripples, low angle planar cross-bedding and mud drapes are observed as internal structures. This facies is similar to Bouma's T_{b-d} division.

Interpretation

Thick-bedded to massive sandstone can be recognized in many places and probably indicate channel filling and suggest the possibility of gradual lobe shifting with lobe margin replacing lobe center depositional environment of mid fan (Mutti, Ricci and Lucchi,1972). Due to lateral shifting of a lobe in the mid fan region, it is possible that thickening and coarsening upward sequence are repeated (Mutti, Ricci and Lucchi, 1972).

Facies (7) Thin to medium-bedded sandstone facies

Description

This facies is mainly consist of buff to white coloured, fine to medium-grained and thin to medium-bedded sandstone (11). Laminations, planar cross beddings, and rip-up mud clasts and ripple boundings are observed as internal structures. It is vertically associated with medium to thick-bedded sandstones, fine-grained thin-bedded sandstone with shale intercalation and light grey to buff and reddish colored shale. This facies is similar with Bouma's T_{b-c} division.

Interpretation

Thining upward and finer grained are recorded, similar to fluvial deposits in abondoned channel of mid fan environment (Mutti, Ricci and Lucchi, 1972). Evenly laminated sand can be produced in the plane-bed phase of high flow regime (Reneick and Singh, 1980). This facies is deposited probably in braided channel of mid fan lobe.

Facies (8) Fine-grained laminated thin-bedded sandstone with shale intercalated facies

Description

This facies consists of buff to light grey color, very fine to fine-grained, thin-bedded sandstones and shale intercalation (Fig 12). Laminations, small scale ripples, ripped-up mud clasts and cross bedding are recognized in this facies. It is vertically associated with buff to light grey shale and thin to medium-bedded sandstone. This facies is similar with Bouma's base missing $T_{\mathbf{c-d}}$ division.

Interpretation

This facies would be deposited in the incised channel deposits of new supra fan lobe as proposed by Walker (1982). Low-density flows are generally thought to transport largely clay and silt-sized particles. Mixed sand-mud depositional system consists of well developed channel-levee systems and deposition lobes. Thin-bedded sandstone intercalated with poorly sorted clayey silt and mud layers are fan valley similar to channel levee of the lower fan environment.

Facies (9) Thin to medium-bedded sandstone and mudstone interbeddedd facies

Description

This facies is mainly composed of white to light grey colour, fine to medium-grained thin to medium-bedded sandstone with shale interbedding (Fig 13). Laminations and ripped-up mud clasts are recognized as sedimentary structures. This facies is vertically associated with mudstone facies, thin to medium-bedded sandstone facies, medium to thick-bedded sandstone facies and gritty sandstone facies). This facies is similar to Bouma's $T_{\mathbf{b-d}}$ interval.

Interpretation

Interbedding of mudstone and thin, fine-grained turbidites and thinning upward succession was compared with channel fills on the delta plain and was interpreted as the fills of submarine channel. This facies is characterized by monotonous alternation of sharp-based sandstones and interbedded mudstone of Walker (1992). The overbank flow from the channel contains fine silt and mud which spread out as a fine-grained turbidity current away from the channel to form a submarine channel levee.

According to Walker's (1978) facies models and sub marine fan environment, faciesF2, F3 and F4 were deposited with high density grain flow in feeder channel of upper fan.FaciesF5, F6, F7 and F9 were deposited in the incised channel, on channel margins or on levee and on lobe area of a channel margins in the mid-fan region.FaciesF1 and F3 were deposited in basin floor and levee area of lower fan (Fig 13). There are three facies associations termed, conglomerate-gritty sandstone-sandstone-shale association, pebbly greywacke-pebbly mudstone-shale association and sandstone-shale association.

Figure 4 Lamination in dark grey colour thick-bedded to massive mudstone.

Figure 5 Nature of dark grey coloured pebbly sandstone facies showing various size of pebbles.

Figure 6 Rounded sandstone pebble embedded in thick-bedded to massive dark color pebbly mudstone.

Figure 7 Nature of medium to thick-bedded conglomeratic gritty sandstone.

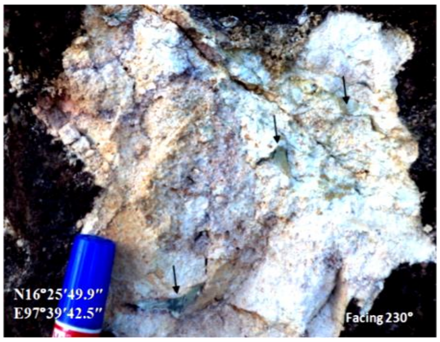

Figure 8 Mud clasts (arrows) in medium to thick-bedded gritty sandstone.

Figure 9 Nature of thick-bedded to massive sandstone facies.

Figure 10 Nature of mediun to thick-bedded sandstone facies.

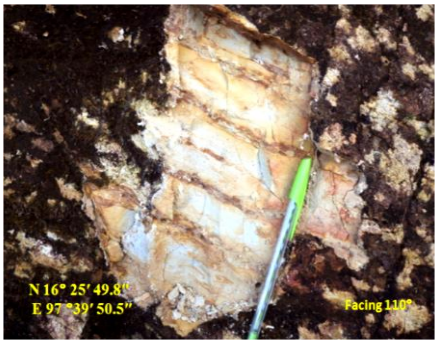

Figure 11 Nature of mudstone and thin-bedded sandstone intercalation facies.

Figure 12 Nature of thin to medium-bedded sandstone interbedded with mudstone facies.

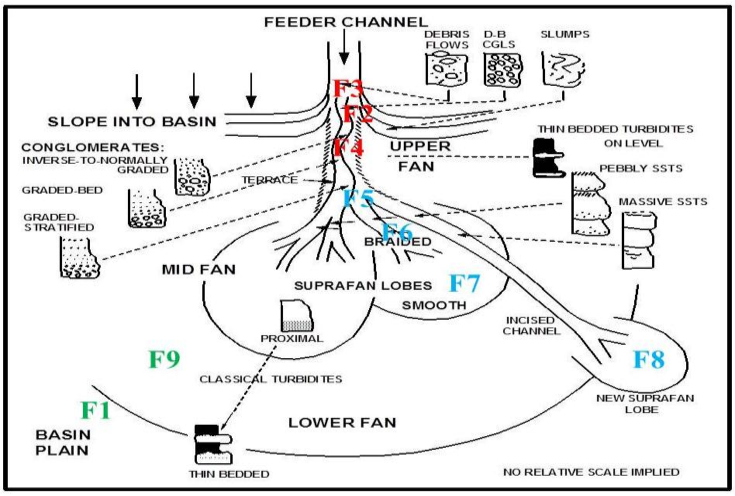

Figure 13 Facies analysis and depositional environment of the rocks of Taungnyo Formation in submarine fan model (Walker, 1978).

Sequence stratigraphy

Relative sea-level order and cycle

The study area is mainly composed of clastic sedimentary rocks of Early Carboniferous to Early Permian age. So duration of the deposition of Taungnyo Formation is about 90 million year by geological age. There are four orders of stratigraphic cycles are depicted (Duval et al., 1992) (Fig. 14). The continental encroachment cycle is defined by the very largest scale (> 50 million years). So, sea level cycle order of Taungnyo Formation is related to first order according to stratigraphic cycle. First-order continental encroachment cycles are considered to be controlled by tectono-eustasy, i.e. changes in ocean basin volume related to plate tectonic cycle (Pitman, 1978).

Sequence stratigraphic implication and general statement

The facies study of Taungnyo Formation revealed that the majority of depositional facies is sediment gravity flow in origin.This leads to conclude that TaungnyoFormation is accumulated as sand-rich and mixed sand-mud turbidite system. Although, the lower boundary of the Taungnyo Formation is not observed in the study area, the upper boundary with Moulmein limestone is an unconformity existed as a sequence boundary. In the Early Carboniferous to Early Permian age, the deposition of Taungnyo Formation taken place in the deep sea. During a maximum regression, the shore line moved basinward and the fluvial system placed on the exposed shelf area and most of the sediments were deposited in continental slope area. Moreover, the presence of high content of extrabasinal grains indicates that the deposition taken place in regressive phase (Zuffa, 1980) (Fig 15).This regression is also coincided with the global sea level drop (Fig 16).

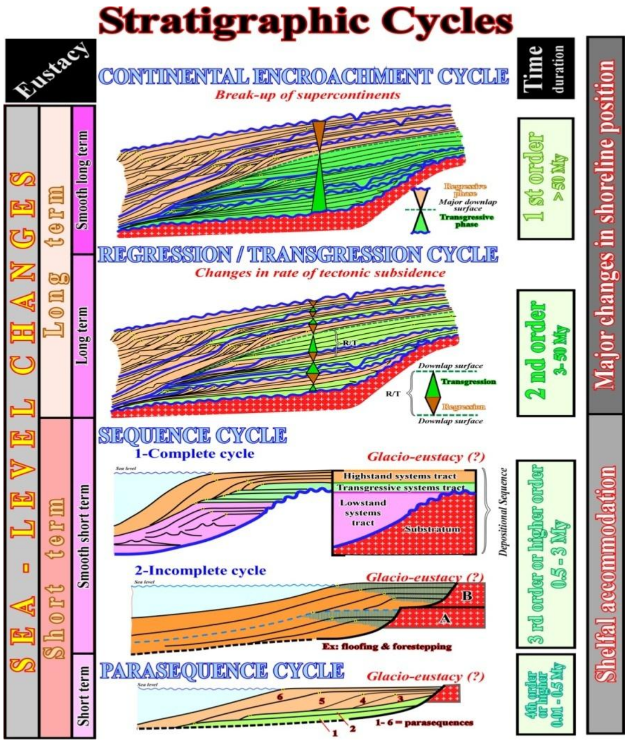

Figure 14 Hierarchy of stratigraphic cycle. (After Duval et. al., 1992)

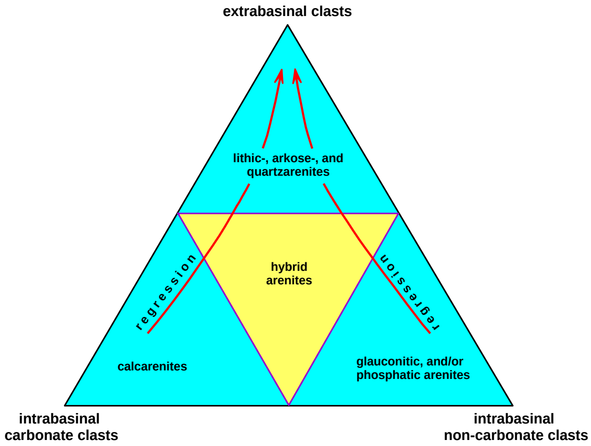

Figure 15 Triangle showing possible changes in the proportion of extra-basinal and intra-basinal, framework grain composition of sandstones due to changes in the relative sea level (after Zuffa, 1980).

Sand-rich fan and ramp systems are dominated by up-dip channel sand bodies pass down-dip into channelized fan lobes (Reading and Richards, 1994).The systems are largely dominated by massive to internally graded high-density turbidites, with only thin-bedded turbidites forming fanabandonment and fringe deposits. Mid fan deposits are dominated by abrupt changes from shale into thick, amalgamated sandstones.

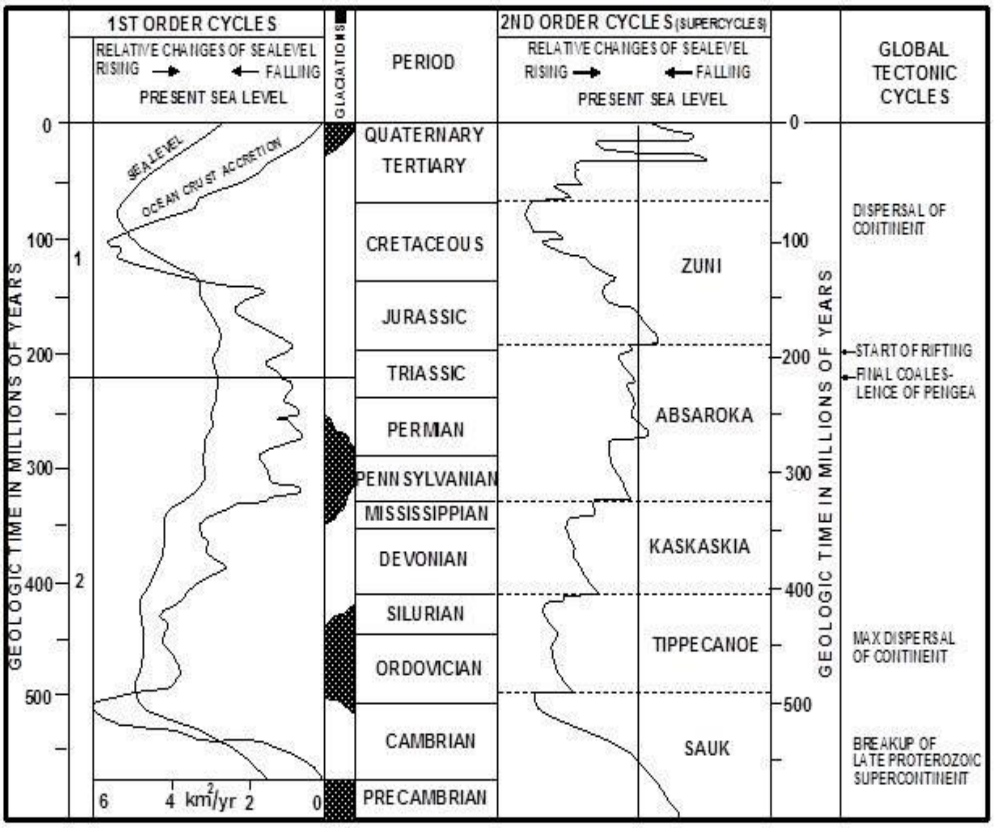

Figure 16 Eustatic sea level variation during the Phanerozoic (after Walker, 1992).

Lowstand System Tract

It is a basal system tract in a type 1 depositional sequence. In the stratigraphic sequence of the study area, Taungnyo Formation was deposited as submarine fan environment. The lower part of the formation is characterized by high velocity gravel rich deposits such as gritty sandstones and pebbly mudstone. It is a characteristic feature of LST deposits may result in low sinuosity (braded) channel. Gravel rich slpoe apron are derived from reworking, mass wasting and catastrophic submarine rock fall avanlanches associated with high-angle slope and scarps. Sediments are often poorly sorted prior to deposition. These coares-grained facies commonly interbedded with turbidite sandstone and mudstone (Surlyk, 1978; Ineson, 1989).

When relative sea-level falls at the offlap break, the river incise into the previously deposited topsets; the alluvial plain, coastal plain and/or shelf deposits of the previous sequence. These rework sediments and fluvial load from the hinterland are deliverd directly onto the previous high stand clinoform slope. This is an inherently unstable situation, the sedimentation processess are dominated by large-scale slope failure resulting in bypass of the slope and deposition of submarine fan in the basin. These process continue to dominate the sedimentary record while relative sea-level is falling and the river system is forced incise.

The rate of rises of relative sea-level is initially low and together with the limited topset area of the prograding system. This will be outpaced by sediments supply next system tract (transgression) will be formed (Fig 17).

Trangressive System Tract

It is deposited during relative sea-level rise when topsetaccomodation volume is increasing faster than the rate of sediment supply. Thetransgressive system tract passess distally into a condensed section characterized by extremely low rates of deposition and the development of condencedfacies such as glauconitic, organic rich and/or phosphaticshales or pelagic carbonates. Highstand system tract of Taungnyo Formation in this study area is characterized by high-velocity turbulence gravity flow deposits as pebbly mudstone. The depositional product of these systems reflects a wide variety of mass flow processess and includes non-channelized chaotic boulder/cobble beds and intraformational rotational slump of fine-grained interbedded sandstones and mudstones with exotic clasts.

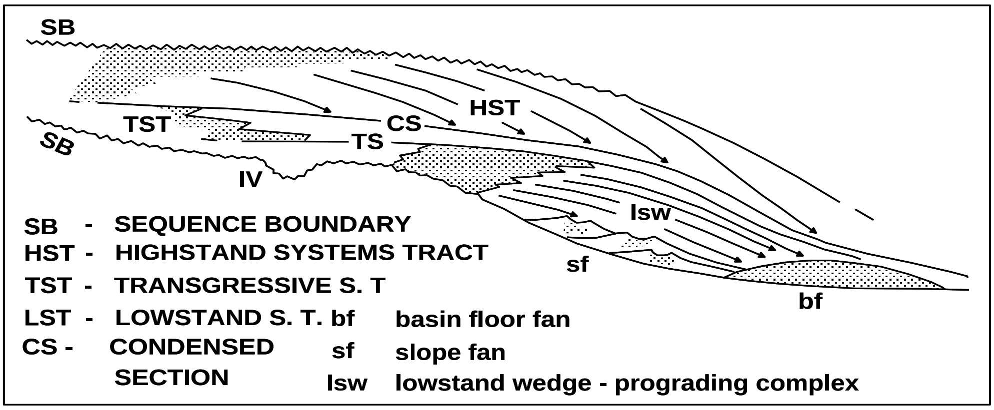

Figure 17 Submarine fans in a sequence stratigraphic context (After Walker, 1992).

Acknowledgements

We are deeply thankful to Professor Dr Aung Myat Kyaw Sein, Rector, University of Mawlamyine for his kind permission to carrry out this research. I sincerely thanks to Dr Yin Yin Aye, Professor and Head of Geology Department, University of Mawlamyine for her kind permission of our researchworks.

References

Bouma, A.H, (1962) Sedimentology of some flysch deposits: A graphical approach to facies interpretation. Elsevier, Amsterdam, 168 p.

Brunnschweiler, R.O., (1970) Contributions to the post-Silurian geology of Burma (Northern Shan State & Karen State); Geol. Soc. Australia.

Emery, D. and Myers, K. J. (1996) Sequence stratigraphy, editors: Oxford, Blackwell Science, 297 p.

Galloway, W.E. (1989) Genetic stratigraphic sequences in basin analysis: architecture and genesis of flooding surface bounded depositional units. Am. Assoc. Petrol. Geol. Bull., 73, 125-142.

Kolla, V. and Perimutter, M.A. (1993) Timing of turbidite sedimentation on the Mississippi fan. Am. Assoc. Petrol. Geol. Bull., 77, 1129-1141.

Kyaw Min., (1997) Geology of Taungnyo Area, Mawlamyine, Mudon and Kyaikmayaw Townships. M.Sc. Thesis. University of Mawlamyine.

Leicester, P., (1930) Geology of Amherst district Rec-Geol. Surv. India, V.63, Pt.1 (Dir Gen. Rep).

Lowe, D.R. (1979) Sediment gravity flows: their classification and some problems of application to natural flows and deposits. In: Geology of Continental Slopes (ed. by K.J. Doyle & O.H. Pilkey). Special Publication, Society of Economic Paleontologists and Mineralogists, Tulsa, 27, 75-82.

Lowe, D.R. (1982) Sediment gravity flows II: depositional models with special reference to the deposits of high density turbidity currents. J. Sediment. Petrol., 52, 279-297.

Middleton, G.V. and Hampton, M.A. (1973) Sediment gravity flows: mechanics of flow and deposition. In: Turbidites and Deepwater Sedimentation (ed. by G.V. Middleton & A.H. Bouma). Society of Economic Paleontologists and Mineralogists, Los Angeles, pp. 1-38.

Posamentier, H.W. and Vail, P.R. (1988) Eustatic controls on clastic deposition I. – sequence and systems tract. Models. In: Sea-level Changes: An Integrated Approach (ed. by C.K. Wilgus, B.S. Hastings, C.G. St. C. Kendall, H.W. Posamentier, C.A. Ross & J.C. Van Wagones). Special Publications, Society of Economic Paleontologists and Mineralogists, Tulsa, USA, 42, 109-124.

Reading, H.G., (1981) Sedimentary Environments and Facies: Oxford Blackwell Sci- Publications.

Reading, H.G. and Richards, M. (1994) Turbidite systems in deepwater basin margins classified by grain-size and feeder system. AAPG Bulletin 78, 792 - 822.

Reineck, H.E., and Singh, I.B., (1980) Depositional Sedimentary Environment: Springer- Verlag, N.Y.

Time and Facies. American Association of Petroleum Geologists Methods in Exploration Series, Tulsa, 7, 55 pp.

Walker, R.G. (1978) Deep water sandstone facies and ancient submarine fans: models for exploration for stratigraphic traps. Am. Assoc. Petrol Geol. Bull., 62, 932-966.

Walker, R.G. (1992) Turbidites and submarine fans. In: Walker, R.G. & James, N.P. (eds) Facies models – response to sea-level change. Geological Association of Canada, 239 – 263

Zuffa, G.G. (1980) Hybrid arenities: their composition and clasification. Journal of Sedimentary Research 50, 21-29.