Sedimentary Facies Analysis and Sequence Stratigraphy of Late Eocene Yaw Formation in Kalewa-Mawleik Area, Sagaing Region

Moe Zat[1], Day Wa Aung[2], Kyi Kyi Maw[3], Tun Tun Zaw[4], Nandar Myint Maung[4]

Abstract

The study area situated in Kalewa and Mawleik Townships in Sagaing Region, in the Southern part of Chindwin Basin is mainly composed of the Eocene to Miocene clastic sedimentary rocks. Sedimentary facies analysis and sequence stratigraphic implications were conducted in the present study. By the facies analysis sedimentary facies such as Bluish grey nodular shale facies, Heterolithic facies, Trough cross-stratified sandstone with mud clast facies, Rippled sandstone facies, Thinly laminated fine sandstone facies, Large-scale horizontal to low-angle stratified sandstone, Fine-grained sandstone with slump structure facies, Hummocky cross-stratified sandstone facies and Coal seam, carbonaceous shale or coaly shale with fine sand and silt alternation facies were recognized. These recorded facies representing five facies associations deposited in prodelta/offshore, lower shoreface, delta front, delta plain, tidal flat and flood plain areas of a deltaic system. In the stratigraphic sequence of the area, Yaw Formation commenced deposition as shallow marine prodelta clays on the fluvialtile Pondaung sandstone as the transgression taken place rapidly as forced transgression. A deltaic sequence can be divided into two transgressive-regressive cycles during the deposition of the Yaw Formation. The Transgressive Systems Tract and Highstand Systems Tract characterized by the retrogradational and progradational parasequences indicating the sea level changing through the Late Eocene time. The uppermost horizon of the Yaw Formation unconformably overlain by thick-bedded fluvial sandstone of the Letkat Formation showing with erosional features characteristic of incised fluvial channels can also be regarded as a sequence boundary.

Keywords: Facies, Sequence Stratigraphy, Transgression

Introduction

Location

The study area, western part of the southern Chindwin Basin is situated in Kalewa and Mawleik Townships, Sagaing Region. It is bounded between Latitude 23º10′00″N to 23º40′00″N and Longitude 94º15′00″E to 94 º30′00″E covering parts of the one-inch topographic map sheets no. 84 I/6, 84 I/7 and 84 I/8 of Myanmar Survey Department (Fig. 1 Figure).

Aims and Objectives

The present project will attempt to carry out sandstones composition and provenance study of Late Eocene - Miocene sandstones of Southwestern Chindwin Basin.

Methods of Study

The present study is mainly based on field investigations and employs the following methods to achieve the objective of the project. Field investigation was conducted mainly responsible for the detailed sedimentological measurements, taking photographs and logging together with the sample collection along the selected stream sections crossing the continuously exposed sequences of the Yaw Formation.

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

Previous Work

Chhibber (1934) and Tainsh (1950) also made brief discussions on the geology of the Upper Chindwin area.

Aung Khin and Kyaw Win (1968, 1969); MOGE (1977), Than Htut and Chit Saing (2003) outlined the paleontology and stratigraphy of Eocene to Pleistocene units of Chindwin Basin.

Dr Win Swe, U C. Thacpaw, Daw Nay Thaung Thaung and U Kyaw Nyut (1972) outlined Geology of Part of the Chindwin Basin of the Central Belt, Burma.

Myo Thant (2005) carried out his PhD Thesis the title of "Sedimentology and Sequence Stratigraphy of the Upper Cretaceous – Lower Tertiary Units of the Kalewa-Mawleik Area".

Kyaw Linn Oo (2008) carried out his PhD Thesis the title of "Sedimentology of Eocene-Miocene Clastic Strata in the Southern Chindwin Basin".

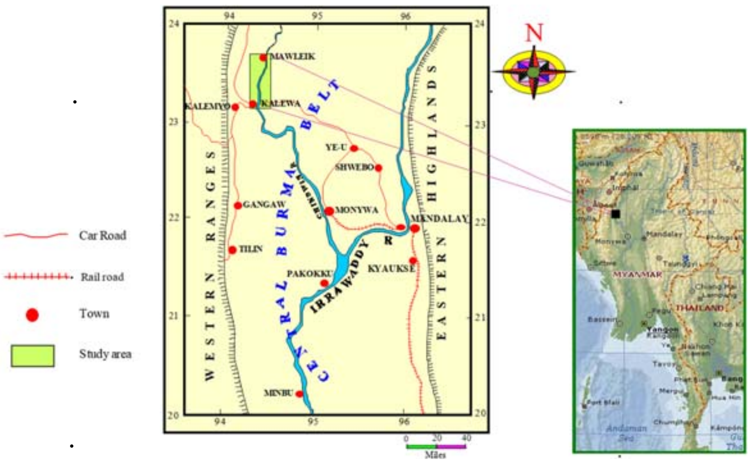

Figure (1). Location Map of the Research

Regional Geologic Setting

The present investigation area is situated in the western part of the Southern Chindwin Basin which is a part of Central Myanmar Tertiary Basin, lying approximately between Latitude 22˚00´N to 26˚00´N and Longitude 94˚00´E to 95˚00´E. It lies between the Western Ranges (Indoburman Ranges) in the west and Wuntho Igneous Massif in the east.

Chindwin Basin is filled with thick piles of Tertiary clastic sedimentary rocks of about 10 km and estimated to have covered the areas of 4600 square kilometers. The eastern flank of the basin is generally thinned out towards east and bounded by the northeast striking regional thrust faults against the basement high, Wuntho massif.

Regionally, the research area is mainly composed of clastic sedimentary rocks with a general trend of nearly N-S direction (Figure.2). In the area, Late Eocene rocks of Yaw Formation are overlain unconformably by Miocene clastic sedimentary rocks of Letkat Formation, Natma Formation and Shwethamin Formation. Upper Miocene-Pliocene rocks of Irrawaddy Formation are restricting distributed in the basin overlying the older Formations with an unconformity.

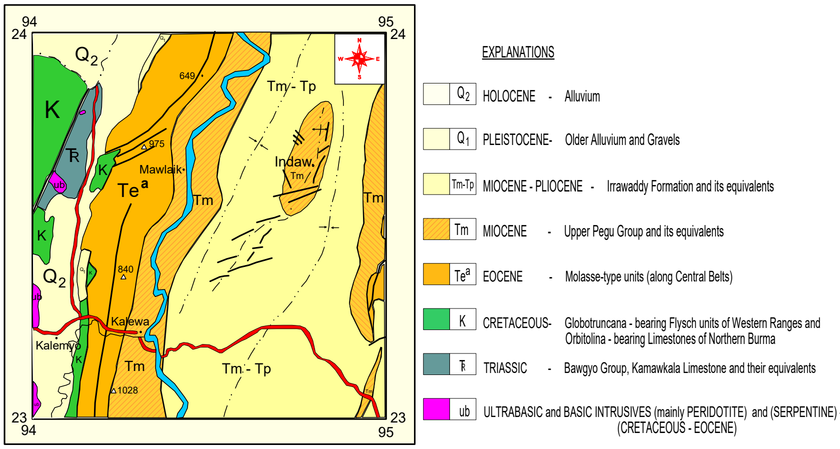

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Figure (2). Regional geologic setting of the study area
(From Geological Map of Myanmar, 1977)

Stratigraphy

Name Derivation

The term "Yaw Shale" was first introduced by Cotter (1912), where the beds are typically developed at the Yaw Chaung section in Pakokku district. Later, these shales were renamed "Yaw Formation" in 1969 by Aung Khin and Kyaw Win, for a formal lithostratigraphic unit.

Distribution

The Yaw Formation is occupied in the low lying areas and intervening between the two ridge-forming units; Pondaung Formation and Letkat Formation. This Formation is less resistant to erosion than the adjacent units in the area, and therefore, it forms strike valleys. It is well exposed in the Myittha Chaung, southwest of Kalewa.

Lithology

Yaw Formation is mainly characterized by thick sequence of blue grey nodular shale to thinly laminated silty shale with silt-lenticles interbedded with lenticular, wavy and flaser bedded heterolithic units and thin to medium-bedded, fine-grained, ripple cross-laminated sandstones. Coal seams are cyclically intercalated with sandstones in the Yaw Formation and thickness varies from about an inch to a few feet with the majority being one to two feet.

Boundary Characteristics

The lower boundary with conformably the Pondaung Formation is a distinct lithological break (Bender, 1983) and there is abrupt change in lithology.

The upper boundary with the Letkat Formation can be clearly be defined by the presence of the bluish grey to dark grey, soft, carbonaceous shale which is overlain by yellowish-grey to greenish grey moderately hard, medium-grained, current bedded Letkat sandstones with basal conglomerate band. This band is indicating a time breaks between Yaw and the overlying Letkat Formation.

Fauna, Age and Correlation

In the research area, microforaminifera species are not seen but the lithological character, the abundant of coal seams and molluscan fauna of ***Turritella sp.*** indicate Late Eocene age and strong brackish to very shallow marine conditions. This Formation can be tentatively correlated with the Yaw Formation of Minbu Basin and the northern Chindwin Basin (Aung Khin and Kyaw Win, 1969).

Sedimentary Facies Analysis

1. Bluish grey nodular shale facies

Description

The lower part of Yaw Formation is always started with thick bluish grey shale facies. This facies characterizes thick sequence of shale (up to 30m thick) which exhibits light grey to bluish grey colored shale with subordinated amount of fine sand intercalations and streak sand lens (Figure.3). Shales are generally less fissile, sub-conchoidal fracture, nodular type and bioturbated (Figure.4). It is gradationally increased in silt and fine sand content upward to form light bluish grey shale with very thin silt and paper-thins fine sand laminations with more fissile. Thin sand beds and fossils-hatch beds are also noted in this unit (Figure.5).

Interpretation

The fine-grained muddy sediments are the prodelta deposits, which are closely related to Prograding deltaic system (Reineck and Singh, 1980). In offshore area, the sediments concentration is too low and the slack water period too short to allow for the deposition of more than a fraction of a millimeter of mud (Blatt et al. 1980).Extremely slow rates of sedimentation, burrowing is very intensive as organisms have sufficient time for bioturbation (Reineck and Singh, 1980). Shepard (1956) noted that the shelf mud shows extensive mottling and homogenous beddings. The occurrence of a fossil conglomerate band indicates a storm-surged lag deposited on the shelf environment.

Therefore, the above points noted that the depositional environment of this shale unit can be assigned as the indicator of increasing sea-level of prodelta/shelf mud area.

2. Heterolithic Facies

Description

This facies comprises flaser bedding, lenticular bedding with the various portions of sand and mud as heterolithic type. This facies shows characteristic facies transition from lenticular bedding through wavy bedding to flaser bedding with upward increasing sand content and bed thickness observed throughout the vertical sequence of the Yaw Formation (Figure.6). In some horizon, the senses show small-scaled load structures observed as syn-sedimentary deformation features (Figure.7). Wavy bedding or interlayered sand/mud facies shows thin wavy mudstone layers alternating with thin ripple-bedded sandstone layers (Figure.8). This facies is commonly associated with bluish grey nodular shale facies and rippled sandstone facies.

Interpretation

The heterolithic facies with characteristic sandier up and thickening upward facies trend suggest influence of tidal action, shallowing upward, and prograding nature commonly found in a prodelta front setting. Typical lenticular bedding with flat disconnected and connected fine sand and silt lenses termed separated or starved ripples or isolated ripple train (Reineck and Singh, 198)).Thinly bedded nature of interlayered sand and mud is commonly deposited in the low energy environment of intertidal to subtidal area (Casshyap and Aslam, 1990). Association of lenticular-wavy-flaser bedding are common in tidal flat and delta front sediments, where there are fluctuations ion sediment supply or level of current or wave activity (Tucker, 1982).

Therefore, the associated facies clearly support that this facies can be regarded the sediments were deposited in the tidal flat of delta front setting.

3. Trough cross-stratified fine-grained sandstone with mud clasts facies

Description

This facies consists of fine to medium-grained, medium to thick-bedded, gray to yellowish gray colored sandstones with an erosional base. Small to medium scale trough cross-beddings and mud clasts are the dominant sedimentary structures of this facies (Figure.9). Intraformational mud pebbles and coal clast are present (Figure.10). Thickness of beds may vary from 8 inches to 2 feet can be noted. The associated flaser show bi-directional paleocurrent whereas the trough cross-bedding show to basinward direction 150º-180º degrees in Myitta Chaung section. This facies is vertically associated with bluish gray shale facies and hummocky cross-stratified sandstone facies.

Interpretation

Trough cross-stratifications are formed when ripples migrated back up the slip face and across the top of the larger sand wave, during the period reversed flow (Hubbard et al., 1978). The coarser and poorly sorted sediments than the adjoining deposits indicate that the deposition took place as channel fills where the various kinds of cross-beddings can be occurred. The trough cross-bedded sandstone with mud clast facies is deposited in distributary channels of the delta plain environment. Wavy or erosive base upon which the present of mud clasts is the deposition taken place in a channel area where the basal erosion can occur (Reineck and Singh, 1980).

Therefore, the presence of mud pebbles at the base of this facies pointed out that this facies had deposited in the channel of intertidal flat area or distributaries channel of delta plain area.

4. Rippled sandstone facies

Description

This facies is mainly composed of thin to medium-bedded, fine-grained, light gray to gray colored sandstones with small to medium scale current and wave ripples bedforms are observed on the upper bedding surfaces of the sandstones interbedded with thin shale (Figure.11). The rippled sandstones show small-scale current of undulatory ripples which have projections in the down-current direction (Figure.12). This facies is vertically associated with heterolithic facies and trough cross-bedded sandstone with mud clasts facies.

Interpretation

The rippled sandstones with interbedded mudstones represent alternate changes from low energy to higher energy wave and current conditions. The asymmetrical and symmetrical ripples were formed on sand dominated intertidal flats by relatively weak tidal currents and wave action (Reading, 1981).Reineck and Singh (1980) stated that these small ripples beddings are abundantly developed in sandy intertidal flats and shoals. Besides, the weakest bioturbation zone in the intertidal area is the sand flat.

By the evidence of above mentioned characteristics, the depositional environment of this facies can be regarded as sandy intertidal flat and that features also occur in subtidal environment.

5. Thinly laminated fine sandstone facies

Description

This facies is mainly composed thin to medium bedded, thinly parallel and wavy laminated fine sandstones with very thin carbonaceous laminations and minor ripple cross-laminations (Figure.13). The laminated fine sandstones are commonly interbedded with dark bluish gray, less fissile and blocky (Figure.14).This facies is underlain by the organic-rich facies with some sulphurous dull coal seams and thick bluish grey shale facies.

Interpretation

Laminae in the shallow marine environments are produced by seasonal fluctuations in sediment supply or periodic stirring of the bottom by wave action (Blatt et al., 1980).Parallel and subparallel laminations were formed by the alternation to thin sedimentary layers of differing composition of sediments (Bates and Jackson, 1983).Sharp base with fining upward and thinly laminated fine sandstone beds overlying thick unit of laminated shale represent the characteristic of a crevasse splay sandstone as well as carbonaceous silt and mud of interdistributary bay sediment deposited in delta plain environment (Coleman & Prior, 1980; Allen, 1987).

Therefore, this facies was deposited in crevasse splay of delta plain environment.

6. Large-scale horizontal to low-angle stratified sandstone

Description

This facies is mainly composed of fine to medium-grained, medium to thick-bedded, and greenish grey colored sandstones with horizontal to low-angle stratification (<10) (Figure.15). It is overlying on the flaser bedded fine sandstone found in the upper part of the Yaw Formation.

Interpretation

Large-scale parallel and low-angle stratified sandstone is a product of wave built features found in beach and shore-face deposits associated with active delta lobes (Allen, 1987). In fluvial channel, this type of stratification can be observed in wash-out dunes, antidunes, and commonly found in laminated sand sheets (Miall, 1978).

Therefore, this facies was deposited in shallow, upper flow regime of antidune in delta front environment.

7. Fine-grained sandstone with slump structure facies

Description

This facies is mainly composed of fine-grained, thin to medium bedded, light gray to gray colored sandstones with the dominant sedimentary structure of convolute laminations (Figure.16). Laminae may be intensively folded and remarkably continuous (Figure.17). This facies is stratigraphically placed at the middle part of the Yaw Formation. and vertically associated with trough-cross bedded sandstone with mud clasts facies and laminated gray shale facies.

Interpretation

Convolute bedding is produced by differential liquefaction of a sedimentation unit (Williams, 1960). Convolute bedding develops from the deformation of ripple marks (Kuenen, 1953a).

Convolute bedding is formed from the shearing action of the current flowing over a sediment layer acting as a cohesive layer (a result of compaction after deposition). Williams (1960) described convolute bedding is rather a common feature on the steeper slopes of sand bars in tidal environments resulted by liquefaction.

Therefore, the above listed documentation pointed out that this facies had deposited in intertidal flats environment.

8. Hummocky Cross-stratified Sandstone Facies

Description

This facies is composed of fine-grained, medium bedded, light gray to greenish gray colored sandstones. The low angle cross-stratification with maximum angle of 10˚ to 15˚ is well marked (Figure.18). Small scale wave ripple are found at the surface of the hummocky cross-stratified beds. The trough cross-bed set with concave and convex bounding surface intercalated in low angle swale lamination are also noted. The strata of this facies always display the swale and hummock appearances with the concave upward cross-bed sets.The lower portion of this unit is characterized by bioturbated shales unit, whilst the upper part is small to medium scale trough cross-laminated sandstone unit are noted.

Interpretation

Hummocky cross-stratification originates from laminae draping shallow and very low angle truncation (Midtgaard, 1996). Hummocks formed during storm condition, ripple during fair weather, when normal waves reworked the storm (Ricci Lucchi, 1995). Hummocky cross- stratification is formed under combined flows conditions which involving unidirectional offshore moving currents and oscillatory currents (Dyson 1983; Swift et al. 1983; Snedden et al. 1988). The upward concave of the sandstone beds containing low angle cross- stratification of hummocky cross-stratification can be interpreted as near shore sand bar deposit (Katsura et al., 1984).

According to Reading (1981), the medium-grained sediments with high-energy bed forms and internal structures characterized that the depositional environment of hummocky cross-stratified facies is subtidal to offshore area.

9. Coal seam, carbonaceous shale or coaly shale with silt and sand alternation facies

Description

This facies is dominated in the lower and upper part of Yaw Formation, mainly composed of dark gray to black carbonaceous shale or coaly shale with silt and fine sand laminations (Figure.19). Most of the shales are fissile due to the presence of streak sand. Sulphurous dull coal seams (0.5 to 2 m thick) are occasionally noted (Figure.20). This facies is vertically associated with lenticular bedded sandstone facies and trough cross-bedded sandstone with mud clasts facies and bluish gray shale facies.

Interpretation

The organic matters such as plant remains, coal chips associated with clays reflects the peat deposition in delta plain environment where the clastic sediment only occasionally occurs (Reineck and Singh, 1980). The thin streak sand (or) thinly laminated silt is the indicator of the floods generated nature in poorly drained swamp (Coleman, 1968). The high preserved organic content and the association with dull coal, indicate an extremely low rate of sedimentation and an anoxic environment of deposition (Middleton, 1965).

Therefore, the above listed documentation pointed out that the carbonaceous shale and coal are thought to have been deposited in a delta plain swampy environment.

Figure (3).Thick bedded bluish grey shale of pordelta faces association found the lower part of Yaw Formation suggests shallow marine condition

Figure (4). Nodular character thick-bedded bluish gray shale indicate as a result of dehydration

Figure (5). Thin sand beds and fossils-hatch beds are thought to be the deposition of storm generated deposits accumu-lated in deeper basin

Figure (6). Heterolithic facies of lenticular silt-laminated mudstone thickening up to flaser bedded sandstone facies shows gradual change of the prodelta to distal mouth bar facies association

Figure (7).Small-scale synsedi -mentary slump features of contorted silt laminations and load cast ripples suggesting the prodelta-delta front environment

Figure (8). Interlayered sand-mud bedding with oscillation wave ripples, representing wavy tidal bedding found in the intertidal flats of the lower tidal plain or at the base of the delta front sand bars

Figure (9).Wavy/erosional surfaces of micro cross-laminated fine-grained sandstone with mud pebbles indicating the basal erosion in a channel area

Figure (10). Basal part of the trough cross-bedded sand-stone contain coal clasts and mud drapes representing channel scoring and basal lag

Figure (11). Wavy base of ripple bedforms are observed on the upper bedding surfaces of the sandstones interbedded with thin shale

Figure (12). Linguoid ripple on the bedding plane of sandstones with current direction 170º, associated with the tidal flat facies indicate the tidal channel paleocurrent direction

Figure (13).Wavy continuous thin carbonaceous silt and mud indicate interdistributary bay in delta plain environment

Figure (14). Thinly laminated fine sandstone lying between bluish grey shale showing a characteristic of crevasses splay deposit

Figure (15). Thick-bedded, horizontal to low-angle stratified sandstone body which representing high-energy condition of active delta lobe

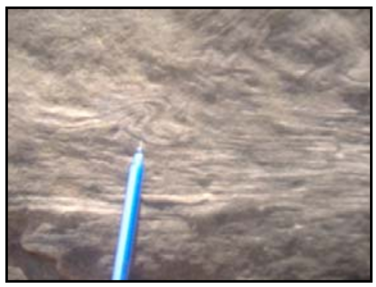

Figure (16). Convolute laminations in fine-grained sandstone suggest rapid vertical sediment aggradation during high sand supply under slower current velocity

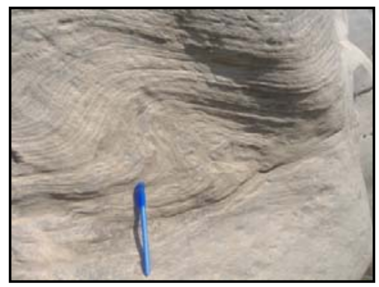

Figure (17). Cross-bedded sands at the base and convoluted, deformed laminations above point out that deformation took place when the sediment was water saturated phase

Figure (18). Hummocky cross-stratification in fine-grained sandstone indicates the very low angle concave and convex cross-lamination which are formed during storm condition

Figure (19). laminated shaly coal with fine silt laminations commonly found in the interdistributary-bay and marsh of lower delta plain

Figure (20). Sulphurous bituminous coal bed representing lower delta plain coal zone and higher sulphur content is introduced as a result of transgression

Lithofacies Association

In clastic facies analysis, individual facies are process related and are usually not environmentally specific. Facies associations are environmentally specific. Therefore, in clastic facies analysis, individual process (facies) is needed to be combined together into facies associations to define environment.

1. **Prodelta/Offshore Facies Association (FA-1)**

This facies association is mainly found in the lower part of Yaw Formation. It is composed of thick sequence of bluish grey nodular shale (F-1) with minor interbed of thin silty fine sandstone, marl and fossil band. Carbonaceous shale with thin parallel silt lamination (F-9) and lenticular bedding (F-2) are observed in the upper part of the facies association.

The prodelta environment is the most seaward part of the delta where energy environment low and thick bedded accumulation of finer particles settles out from suspension (Figure.3). In the prodelta environment, the low hydrodynamic condition inhabits the intense bioturbated sediment. Thin sand beds and fossils-hatch beds are thought to be the deposition of storm generated deposits accumulated in deeper basin area (Reineck and Singh, 1980) (Figure.5). The phosphates deposition indicates the slow sedimentation in deeper area of higher sea level position. The erosive base upon which mud pebbles point out that storm surged lag deposit or transgressive lag deposit in offshore area (Reineck and Singh, 1980). The typical coarsening upward sequence reflects that the shore line had prograded across the muddy shelf (Reading, 1981).

Therefore, the prodelta/offshore environment is mainly composed of the thick-bedded shale and bioturbated sediments.

2. **Delta Front Facies Association (FA-2)**

The delta front facies association mainly consists of thin to medium-bedded sand of delta front, the cross-bedded sandstone of distributary mouth-bar (F-2) and (F-4), Large-scale horizontal to low-angle stratified sandstone (F-6), and the bioturbated shale (F-1). The proportion of bioturbation is also flourishing. Sometimes, the storm deposits also associated with these sand beds how typical high-energy zone.

The delta front environment is the protrusion of distributary channels to the opening of seaward limit shows the sand deposition on outer delta plain. Thin to medium bedded sandstone associated with internally parallel lamination was indicate the storm wave base and fair-weather wave base condition (Walker, 1992). The bioturbations are also flourishing. The lenticular laminated bluish grey shale unit with abundant small-scale contorted laminae, load casting and slumping structures of silt laminae in muddy substrate also support the characteristic of prodelta deposits (Figure.7). High pore water content in rapidly accumulated mud in prodelta and/or muddy intertidal channel may cause large amount of distorted bedding (Figure.7) (Coleman & Prior, 1980). This facies association is laterally associated with prodelta/offshore facies association of shallow water.

Therefore, the delta front environment is mainly composed of medium-bedded rippled sand and heterolithic units.

3. **Lower Shore Face/Subtidal Facies Association (FA-3)**

Hummocky cross-stratified sandstone facies (F-8) and rippled sandstone facies (F-4) can be grouped as a lithofacies association named subtidal facies association.

The primary structures included in these three lithofacies such as hummocky cross-stratification (Figure.18) and ripples (Figure.11) believed to have been formed in the high energy environment. The bidirectional nature of the bed form distribution reflects the opposition name and tidal facies (Hubbart et al., 1979).

The particular depositional environment is the place under the mean low water line where these sedimentary structures can form.

4. Delta Plain Facies Association (FA-4)

Delta plain facies association mainly consists of flaser/lenticular and sand-mud interlayer facies (F-2), trough cross-bedded sandstone with mud clast facies (F-3), bluish gray shale facies (F-1), rippled sandstone facies (F-4), thinly laminated fine sandstone facies (F-5), fine-grained sandstone with slump structure facies (F-7) and Coal seam, carbonaceous shale or coaly shale with silt and sand alternation facies (F-9) of can be grouped as delta plain facies association.

The delta plain facies association mainly consists of distributary channel sands, delta plain mud, crevasse sands, and sand-mud interlayer deposits. The deposition of cross-bedded sandstone with mud clasts is the typical delta plain deposits, which is always associated with delta plain mud. The presence of the bidirectional trough cross-beddings are indications of tidal current facies (Reineck and Singh, 1980) (Figure.7). The sedimentary structure of large scale cross-bedded sandstone with unidirectional cross-bedding bed shows that the deposition took place a channel of delta plain. The crevasse deposits are formed by the breaching of channel banks and deposited on the delta plain mud (Figure.14). The sand-mud interlayer deposits are formed by the overbanking of the suspension mud deposited on the delta plain sand during flooding condition (Wood and Hopkins, 1989) (Figure.8).

Therefore, the major depositional site of the lithofacies association is the delta plain area.

5. Tidal Flat Facies Association (FA-5)

Tidal flat facies association are documented by bluish gray shale facies (F-1) flaser/lenticular bedded and sand-mud layered facies (F.2) and trough cross-bedded sandstone with mud clast facies (F-3).

The sedimentary structures of flaser and lenticular bedding are the criteria for interpreting flat and shallow subtidal facies (Klein, 1977) (Fig.60 and 62).The flaser beddings, lenticular bedding, sand interlayered sand-mud beddings reflects that the depositional environment is the mixed intertidal flat area (Reineck and Singh, 1980). Mainly thick mud layers with thin sandy intercalation noted that this facies deposited on the mud flat of tidal flat environment (Reineck and Singh, 1980). The trough cross-laminae indicate a peculiar indicator of the tidal environment (Franco Ricci Lucchi, 1995).

Therefore, the major depositional site of the lithofacies association is the tidal flat area.

6. Floodplain Facies Association (FA-6)

The floodplain facies association is documented by the presence of the silty shale and mud deposition (F-1). The crevasses splays (F-5) acquire the minor amount of sand. The main shale deposition took place at the higher stage of water level. In the flood plain, the plant remains, wood debris are also observed. Moreover, the higher frequency of flood plain indicates the river type to be of highly meandering.

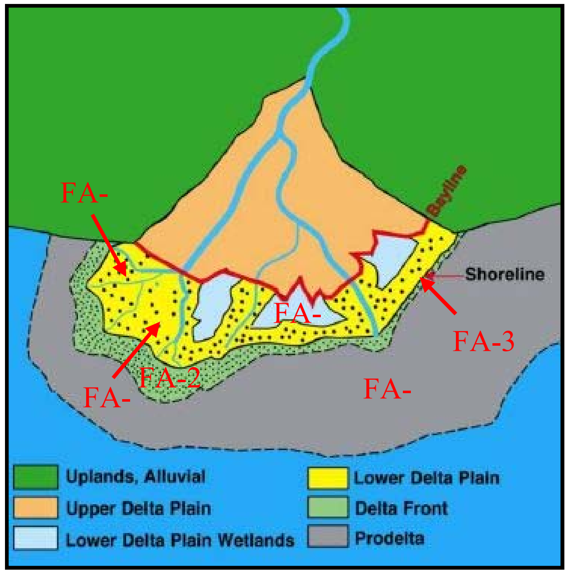

Figure (21). Generalized lithofacies association in fluvial-tide dominated deltaic model of Yaw Formation

Sequence Stratigraphy

1. Introduction

Sequence stratigraphy is the study of genetically related facies within a framework of chronostratigraphically significant surface (Van Wagoner et al., 1990).

Global eustatic sea-level changes which drive the episodic deposition that leads to the formation of sequences. Therefore, the tectonic and sea-level govern the sequence development in which sedimentation pattern in each sequence with one another would be different.

2. Sequence Stratigraphic Implication

In the present study area, the study of sequence is mainly based on the sedimentary facies analysis.

Firstly, the section measurements were done in well-exposed areas where the representative rock units exposed area. Then, the section compilation, petrographic analysis and sedimentary facies analysis was carried out leading to be done the sequence stratigraphic analysis.

3. Sequence Boundary between Fluvial Pondaung and the overlying Deltaic Yaw Formation

In the stratigraphic sequence of the study area, the Yaw Formation itself is commencing deposition as shallow marine shelf/prodelta clays on the fluvial Pondaung sandstone. It is denoted that the transgression taken place rapidly without interfiguring facies on the Fluvial Pondaung sandstone. Therefore, the Yaw Formation representing the rapid transgression resemblance to forced transgression.

The uppermost part of Pondaung Formation representing the laterite horizon and overbank floodplain paleosol also indicated the sequence boundary characteristic but to combine with Yaw Formation (Figure.22). When longer period of uninterrupted alteration occurred on the overbank-flood plain paleosoil facies, semi-lithified firm-ground (highly ferruginous horizon) was developed, key to the sub-aerial erosion surface of Emergent

Surface (ES) (Reading, 1996). This horizon represents a *Hiatus* indicating that the floodplain had been abandoned in a state of non-deposition for tens of thousands of years at the times of tectonic quiescence and stable base level during the end of Late Middle Eocene.

The earlier phase of marine transgression or the slow rate of marine flooding was occurred at the beginning of Late Eocene, mainly responsible for the deposition of marginal marine (deltaic) sediments of the Yaw Formation. It is documented by the trace fossil assemblages colonized over the ferruginous horizon as well as lower delta plain coal zone observed in the lowermost part of the Yaw Formation. It also represents Transgressive Surface (TS) or Marine Flooding Surface (FS).

It is also here interpreted as the highly matured paleosol horizon or the Emergence Land Surface (ES) coupled with the overlying Transgressive Surface or Marine Flooding Surface (FS) forming as an amalgamated co-planar surface called ES-FS separating the Pondaung Formation (late Middle Eocene) from the overlying Yaw Formation (Late Eocene).

4. **Sequence Stratigraphic Implication of Yaw Formation**

Deltas are excellent depositional systems for testing sequence stratigraphy due to their sensitivity to controls on sedimentation such as variations in eustatic sea-level, subsidence rate and sediment supply (Hadley and Elliott, 1993). A deltaic sequence of the Yaw Formation can be divided into at least two cycles of Transgressive System Tract (TST) and Highstand System Tract (HST) deposits characterized by the retrogradational and progradational parasequences sets.

The Lowstand Systems Tract (LST) of Yaw Sequence cannot be observed in this area became the LST deposit formed as a Lowstand Prograding Wedge on the sequence boundary. Therefore, Lowstand Prograding Wedge Systems Tract (LPWST) of Yaw should be placed in the area far south of the present study area.

The Transgressive System Tract (TST)

The lowermost part of the Yaw Formation immediately overlying the sequence boundary on the fluvial Pondaung Formation shows characteristics of marine invasion as documented by the occurrence the highly ferruginous horizon and the development of thick and laterally extensive lower delta plain sulphurous coal zone. It comprises of thin to medium bedded sulphurous dull coal seams which are intercalated within the alternation unit of shaly coal or coaly shale with thin silty fine sands. It points out the fact that there was a considerable amount of clastic influx by the fluvial-dominated distributary channels while accumulation of organic matter was favored during relative sea-level rising (Figure.19).

The accumulation of the lower delta plain organic-rich lithofacies observed in the Transgressive System Tract of the Yaw Formation can be explained by a model proposed by Bohacs & Suter (1997) (Figure.23). During Transgressive System Tract (TST) and early Highstand System Tract (HST), coaly organic-rich rock accumulation and preservation is favored by increased accommodation due to rising sea level and high ground water table, and low rate of clastic influx.

The Highstand System Tract (HST)

The Highstand System Tract deposits of the Yaw Formation can be characterized by a progradationally stacked parasequences dominated by a gradational, coarsening upwards delta front facies sequences, which may be capped by lower delta plain deposits (Figure.24). Progradational parasequence sets are considered to reflect HST deposition (Hadley and Elliott, 1993).

The progradationally stacked parasequences comprise delta-front and delta plain facies associations and are bounded by the inferred maximum flooding zone in the depositional dip section under consideration. The lower delta front facies associations and widespread, but the overlying delta plain facies tends to be absent down-dip (Figure.25). The occurrence of delta plain facies association over delta front facies association in the HST deposits is interpreted to reflect the continuation of the underlying progradational trend, rather than a basinward shift of facies caused by a fall of relative sea-level.

The next cycle of transgressive system tract is possibly represented by thin, retrogradationally stacked parasequences mainly composed of shelf-prodelta facies associations overlying the lower progradational parasequence of delta front facies association.

5. Sequence Boundary between Deltaic Yaw and the overlying Fluvial Letkat Formation (Type-I, Fluvial Incised Valley-Filled (IVF))

The upper part of Yaw Formation, the progradational parasequence of the highstand system tract deposit (distributary mouth bar facies associations) is always capped with an aggradational parasequence which marked by thin lower delta plain carbonaceous shale and coal seams.

The boundary between thick bedded to massive fluvial sandstones of the Letkat Formation and the underlying carbonaceous shales of the Yaw Formation is sharp and erosional showing the characteristic of an Incised Fluvial Channel. It can also be regarded as a phenomenon of basinward shift in facies and facies dislocation between the two formations or a Type I sequence boundary of Vial (1977).

Deep and broad fluvial channel incision is well documented by 1) abundant mud pebbles and coal fragments in the basal part of the large-scale trough cross-bedded sandstone; and 2) thick coal clast-support conglomeratic sandstone horizon at the base of the channelized-sandstone occurs as a basal conglomerate bed (Figure.25).

Conclusion

The study area situated in Southern part of Chindwin Basin is mainly composed of the Eocene to Miocene clastic sedimentary rocks and nine lithofacies of bluish grey nodular shale facies, heterolithic facies, trough cross-stratified sandstone with mud clast facies, rippled sandstone facies, thinly laminated fine sandstone facies, large-scale horizontal to low-angle stratified sandstone, fine-grained sandstone with slump structure facies, hummocky cross-stratified sandstone facies and coal seam, carbonaceous shale or coaly shale with fine sand and silt alternation facies were recognized. These recorded facies representing five facies associations deposited in prodelta/offshore, lower shoreface, delta front, delta plain, tidal flat and flood plain areas of a deltaic system. In the stratigraphic sequence of the area, Yaw Formation commenced deposition as shallow marine prodelta clays on the fluvialtile Pondaung sandstone as the transgression taken place rapidly as forced transgression. A deltaic sequence can be divided into two transgressive-regressive cycles during the deposition of the Yaw Formation. The Transgressive Systems Tract and Highstand Systems Tract characterized by the retrogradational and progradational parasequences indicating the sea level changing through the Late Eocene time. Lowermost part of the Yaw Formation immediately overlying on the sequence boundary between the Pondaung Formation shows characteristics of transgression whereas HST developed in the Yaw Formation characterized by progradational parasequences forming with delta front and delta plain facies bordered by inferred maximum flooding zone. The depositional setting indicating the relative sea-level falls whilst the next transgression favored the deposition of shelf prodelta facies on the progradational parasequences. The uppermost horizon of the Yaw Formation unconformably overlain by thick-bedded fluvial sandstone of the Letkat Formation showing with erosional features characteristic of incised fluvial channels can also be regarded as a sequence boundary.

Figure (22). Uppermost paleosol horizon (arrow) of Pondaung Formation pointing out the sub-aerial erosion surface of Emergent Surface (ES)

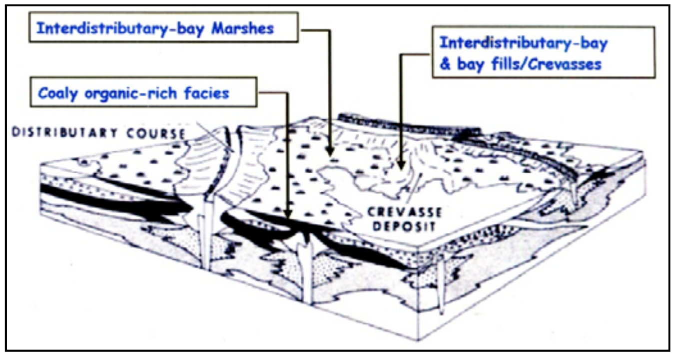

Figure (23). Lower delta plain environments and distribution of paralic coaly rocks within the depositional sequence model of Yaw Formation (Modified after Bohacs & John Suter, 1997)

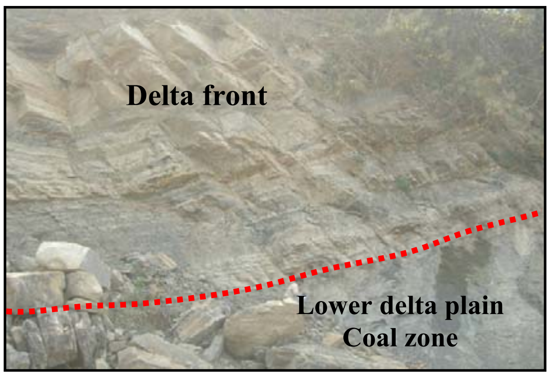

Figure (24). Progradationally stacked para-sequences dominated by a gradational, coarsening upwards delta front facies sequences, capped by lower delta plain deposits

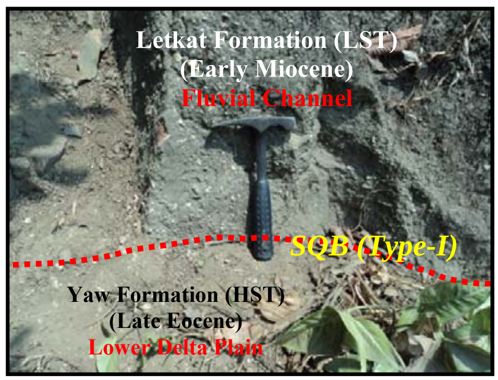

Figure (25). Basal part of Letkat Formation indicating a characteristic of incised fluvial channel cutting into the underlying Yaw Formation, suggesting an evidence of Type-I Sequence Boundary between them

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