SEDIMENTARY FACIES ANALYSIS OF MIOCENE CLASTIC STRATA IN KALEWA-MAWLEIK AREA, SAGAING REGION

Moe Zat[1], Kyi Kyi Maw[2], Yi Lar Tun[3], Zaw Htaik[4] and Aye Aye Min[4]

Abstract

The present study would offer the Sedimentary Facies of Miocene clastic sedimentary rock units of Letkat Formation (Early Miocene), Natma Formation (Middle Miocene) and Shwethamin Formation (Late Miocene) exposed in the southwestern Chindwin Basin, situated in Kalewa-Mawleik Townships, Sagaing Region. The study is mainly focus on outcrop-based sedimentary facies analysis. Eight lithofacies of Letkat Formation such as Trough cross-stratified sandstone (St) with basal erosional surface facies (Se) and lags (F.1), Pebbly gritty sandstone facies (Gm) (F.2), Sand-mud interlayer facies (Fl) (F.3), Thinly laminated fine sandstone facies (Sl) (F.4), Planar cross-stratified sandstone facies (Sp) (F.5), Horizontal to low-angle stratified sandstone facies (Sh) (F.6), Massive, variegated silty clay facies with fine-grained sandstone facies (Fsc) (F.7) and Bluish grey silty shale with silt and sand lens facies (Fsc) (F.8), five lithofacies of Natma Formation such as Massive nodular clay with fine-grained sandstone facies (Fsc) (F.1), Medium to thick-bedded, coarse-grained to gritty trough–cross bedded sandstone (Gt) with basal erosional surface (Se) facies (F.2), Planar cross-stratified sandstone facies (Sp) (F.3), Thinly bedded siltstone or silty fine sandstone and shale facies (Fl) (F.4) and Massive, variegated silty clay facies (Fm) (F.5) and six lithofacies of Shwethamin Formation such as Gritty to pebbly sandstone facies (Gm) (F.1), Trough cross-bedded sandstone facies (St) (F.2), Planar cross-bedded sandstone facies (Sp) (F.3), Horizontal laminated sandstone facies (Sh) (F.4), Thinly laminated fine sandstone and siltstone facies (Fl) (F.5) and Massive, variegated silty clay facies(Fm) (F.6) were deposited in braided river environment. For more environmentally specific, individual facies is needed to combine together into facies associations to define environment. At least five lithofacies association can be established in the Miocene sequence of the research area which are Sandy Fluvial Channel Facies Association (CH), Sand Bar Facies Association (SB), Gravel Bar Facies Association (GB), Overbank Fines Facies Association (OF) and Laminated Sand Sheet Facies Association (LS).

Keywords: Facies, Letkat Formation, Natma Formation, Shwethamin Formation

Introduction

1.1 Location and Physiography

The research area, southern part of Chindwin Basin is situated in Kalewa-Mawleik Township lays in topographic map no. 84 I/6, I/7 and I/8.

On the basis of landform characteristics, the research area forms as strike ridges and valley intervening between the two ridges-forming units (Figure.1).

Aims and Objectives

The present project will attempt to carry out sedimentary facies of Miocene clastic strata in Kalewa-Mawlaik area.

Materials and Methods

1. Field investigation was conducted mainly responsible for the detailed sedimentological measurements Miocene Formations.

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

2. Analysis outcrop-based sedimentary facies of rock units recognizing the evolution of the depositional system.

Previous Work

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.

In 1972, Dr Win Swe, U C. Thacpaw, Daw Nay Thaung Thaung and U Kyaw Nyunt also studied "Geology of Part of the Chindwin Basin of the Central Belt, Burma".

Regional Geologic Setting

The research area is situated in the western part of the Southern Chindwin Basin which is a part of the Central Myanmar Tertiary Basin lying between the Western Ranges (Indoburman Ranges) in the west and Wuntho Igneous Massif in the east.

Regionally, the research area is mainly composed of clastic sedimentary rocks with a general trend of nearly N-S direction. In this area, Miocene rocks of Letkat, Natma and Shwethamin Formations are mostly cropped out along the middle part which is overlain unconformably by Late Eocene clastic sedimentary rocks of Yaw Formation and conformably by Miocene-Pliocene clastic sedimentary rocks of Irrawaddy Formation.

In the Miocene Formations, the rocks are distributed especially along the ridges of Kalewa-Mawlaik and some are along the stream section and the car-road section. The regional geology of the southern Chindwin Basin and its environs is shown in (Figure. 2).

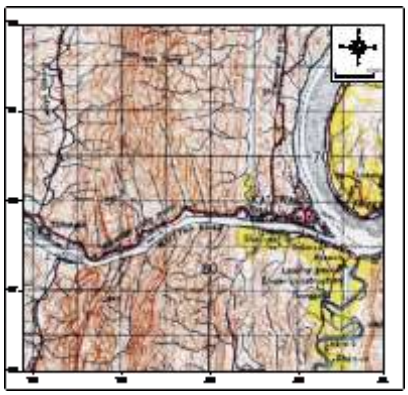


Figure 1 Location and Physiographic feature of the research area

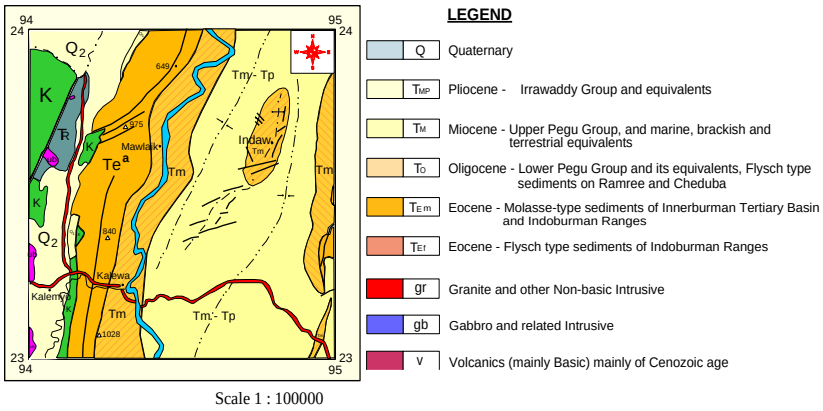


Figure 2 Regional geologic setting of the study area (From Geological Map of Myanmar, 1977)

Stratigraphy

General Statement

The study area, western part of the southern Chindwin Basin is underlain by thick succession of Plaeogene-Neogene clastic sedimentary strata. The exposed rock units are Letkat Formation (Early Miocene), Natma Formation (Middle Miocene) and Shwethamin Formation (Late Miocene). The stratigraphic succession is shown in Table (1).

Sedimentary Facies Analysis of Miocene Formations

Sedimentary Facies Analysis of Letkat Formation (Early Miocene)

1. Trough cross-stratified sandstone (St) with basal erosional surface (Se) facies

Description

The lower part of the Letkat Formation is commonly started with very thick to massive, large scale trough cross-bedded fine to medium grained sandstones with sharp, deep and broad basal erosion surfaces scoring into the underlying Yaw Formation (Figure.3). This facies consists of fine to medium-grained, medium-bedded, light gray colored sandstones with mud drapes and clasts. Small to large-scale trough cross-beddings and mud clasts are the dominant sedimentary structures.

Table 1 Stratigraphic Sequences of the Western Part of Southern Chindwin Kalewa Area

Age	Stratigraphic Units	Dominant Lithology	Maximum Thickness (m)	Depositional System
Late Miocene	Shwethamin Formation	Sand, minor silty shale	200	Fluvial system
Early Miocene	Natma Formation	Shale, silty shale, minor sand	340	Fluvial system
Early Miocene	Letkat Formation	Sand, subordinate pebble-conglomerate, minor silt/clay	?	Fluvial system

Interpretation

Very large-scale trough cross-bedded sandstones free from mud drapes in their foreset stratifications and the occurrence of intraformational mud clasts are commonly found in the basal part of the fluvial channels. The erosional base with clasts and detrital coal clasts-supported conglomeratic sandstones can be regarded as channel floor and basal deposits (Miall, 1987). Mud clasts present at the base of the trough cross-bedded sandstone reveal as the basal portion of a sandy fluvial channel.

Therefore, this facies pointed out that it had deposited in the distributary channel of fluvial environment.

2. Pebbly gritty sandstone facies (Gm)

Description

This facies is mainly composed of medium to gritty, medium to thick bedded, light grey to yellowish grey colored pebbly gritty sandstones. Low angle cross-beddings are common in the gritty sandstone. Pebbles are scattered through the sand (Figure.4) and more typically at the top of the bed. Mostly, pebbles are more or less parallel to the large scale low angle cross-bedding.

Interpretation

Mostly, the pebbles are deposited in prograding gravelly and sandy distributary channels (Casshyap and Aslam, 1990). Low angle cross-beddings are produced by migration of bars with low channelward dipping slopes (Reineck and Singh, 1980). Clast-support rounded conglomerates

found in association with lithofacies; St and Sh suggest gravel bedforms or gravel bars of a high gradient, proximal bed-load braided river deposits (Reading, 1996).

Therefore, this facies can be interpreted as bars or channel lag deposit of the braided river.

3. Sand-mud interlayer facies (Fl)

Description

This facies is mainly composed of fine to medium-grained, thin to medium-bedded, light gray to gray colored sandstones and bluish gray colored shale. Parallel lamination, interlayering of sand-shale and small scale cross-lamination are the dominant sedimentary structures (Figure.5). Approximate sand-shale ratio is 3:2 in average.

Interpretation

The interlaying of sand-shale and the small scales cross-stratification indicate that the flow velocity generally fluctuated and were lower than those flow responsible for deposition of sand (Wood and Hopkins, 1989). In high-energy tidal environments, mud settles during slack water time, at high and low tide stands, when the current inverts its direction and its strength becomes insufficient to transport sand (Ricci Lucchi, 1995).

Therefore, the above listed documentation pointed out that the sand–mud interlayer facies had deposited in the overbank or waning flood deposit of fluvial channel.

4. Thinly laminated fine sandstone facies (Fl)

Description

This facies is mainly composed of thin to medium bedded, thinly parallel and wavy laminated fine sandstones with very thin carbonaceous laminations and minor ripple cross-laminations (Figure.6). Some place is scoured by a broad and shallow sandy minor channel with coal fragments as a basal lag.

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). 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 crevasse splay or planar bed flow (lower and upper flow regime) of fluvial channel.

5. Planar cross-stratified sandstone facies (Sp)

Description

This facies is mainly composed of medium to thick-bedded, fine to medium-grained, sandstones with single sets of medium to large-scale planar-tabular cross-stratifications (Fig.6). Foresets are straight with sharp, angular lower contacts with inclined angle at 15° -30°.

Interpretation

Planar cross-bedding is commonly found in migrating straight crested subaqueous dunes of the active fluvial river channel (Miall, 1987). Large-scale single sets of planar cross-bedding also represent cross channel bars and associated with planar or horizontally stratified sandstone facies (Sh) suggesting sand flat accretion (Cant & Walker, 1978).

Therefore, this facies can be interpreted to have been deposited under transverse bars or dunes (lower flow regime) of fluvial river channel.

6. Horizontal to low-angle stratified sandstone facies (Sh)

Description

This facies is mainly composed fine to medium-grained, light grey to yellowish grey colored sandstones with horizontal to low-angel thinly parallel and wavy laminated fine sandstones with very thin carbonaceous laminations (Figure.7). Laminations are horizontal or have low dip angle (<10°) with parting lineation or plane bed stratification.

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). Low-angle cross-bedding (angle of dip 5°-10°) is very common in the ephemeral stream deposits and can be considered as a characteristic bedding of shallow or ephemeral stream deposits (Picard and High, 1973). Thick sequence of this facies also represents poorly channelized laminated sand sheet deposits (Miall, 1985).

Therefore, this facies can be interpreted to have been deposited under planar bed flow (lower and upper flow regime) or anti-dunes of fluvial environment.

7. Massive, variegated silty clay facies (Fm)

Description

This facies is characterized by massive, buff color clay and brownish, purplish to reddish mottled colors of massive variegated clays with calche nodules (Figure.8). The thickness varies from 5m to 40m. In this facies, silicified wood fragments are common. It is well developed in the upper portion of Letkat Formation.

Interpretation

Fine-grained sediments are deposited as overbank material during flood stages of the river, on the flood plain, in bays, swamps, marshes and crevasse splays. The variegated clay with calche nodules, closely linked to the fluvial depositional system, has long been regarded as fluvial paleosols. It is a characteristic pedogenic feature of alluvial soil derived from the shallow burial early diagenetic alteration of fluvial flood plain deposits under semi-arid condition (Bowen & Kraus, 1993).

The presence of calche nodules suggest that the sediment was deposited in swampy deposits at basin margin.

8. Bluish grey silty shale with silt and sand lens facies (Fsc)

Description

This facies is mainly composed of gray and yellowish grey colored thick-bedded shales with subordinated amount of silt and sand lens (Fig.9). The discontinuous sand lenses with micro cross-lamination and coal clasts are notably observed, intercalated in thick bedded clay unit.

Interpretation

Thick-bedded shales were probably deposited by suspension in low energy environment and disperse over wide area by the basinal processes (Reading, 1996). Organic content and the

association with dull coal, indicate an extremely low rate of sedimentation and an anoxic environment of deposition. Micro cross-laminated and fairly persistence thin sand layers are characterized by storm surged current (Reineck and Singh, 1980). The silty, parallel and lenticular laminations occurred in this shale facies indicate the depositional site near to the delta front.

Therefore, these facies can be deposited when the transgression took place in the depositional site, where there again have a deeper environment.

Sedimentary Facies Analysis of Natma Formation (Middle Miocene)

1. Massive silty nodular clay with fine-grained sandstone facies (Fsc)

Description

This facies is mainly composed of whitish gray colored thick-bedded shales with subordinated amount of silt and sand bands. The discontinuous sand lenses with micro cross-lamination, nodule sitly shale (Figure.10) and coal clasts are notably observed, intercalated in thick bedded clay unit.

Interpretation

Clay particles are therefore present as suspended load in most currents of water and air and are only deposited when the flow ceases (Trucker, 1988). Thick-bedded shales were probably deposited by suspension in low energy environment and disperse over wide area by the basinal processes (Reading, 1996). The nodular shale is a result of dehydration process. Organic content and the association with dull coal, indicate an extremely low rate of sedimentation and an anoxic environment of deposition.

Therefore, these facies can be deposited when the transgression took place in the depositional site, where there again have a deeper environment.

2. Medium to thick-bedded, coarse-grained to gritty trough–cross bedded sandstone (Gt) with basal erosional surface (Se) facies

Description

This facies is mainly composed of buff color, medium to thick-bedded, coarse-grained to gritty, medium to large-scale trough cross-bedded sandstone with sharp, deep and broad basal erosion surfaces scoring into the underlying silty shale. It consists of pebble-size mud clasts, coal clast and medium to large-scale cross-bedding (Figure.11). They are set in red ferruginous matrix.

Interpretation

The coarser and poorly sorted sediments than the adjoining deposits indicated that the deposition took place as channels fills where the various kinds of cross-beddings can be occurred. The deepest portions of the channles are floored either by a coarse lag deposit or by large sand waves (Hubbard, 1971 Oertel, 1973; Kumar and Sanders, 1974). Gravels may occur in cross bedded units representing bar deposits in gravelly braided rivers or as gravel lags, thin layers of coarse debris lying on the erosional scours at the bottoms of the river channels.

Therefore, this facies can be interpreted as bar/channel lag deposit of the braided river.

3. Planar cross-stratified sandstone facies (Sp)

Description

This facies is mainly composed of medium to thick-bedded, medium-grained, sandstones with single sets of medium scale planar-tabular cross-stratifications. Foresets are straight with sharp, angular lower contacts with inclined angle at 15° -30° (Figure.12).

Interpretation

Planar cross-bedding is commonly found in migrating straight crested subaqueous dunes of the active fluvial river channel (Miall, 1987). Large-scale single sets of planar cross-bedding also represent cross channel bars and associated with planar or horizontally stratified sandstone facies (Sh) suggesting sand flat accretion (Cant & Walker, 1978).

Therefore, this facies can be interpreted to have been deposited under transverse bars or dunes (lower flow regime) of fluvial river channel.

4. Horizontal to low-angle stratified sandstone facies (Sh-Sl)

Description

This facies is mainly composed fine to medium-grained, light grey to yellowish grey colored sandstones with horizontal to low-angel thinly parallel and wavy laminated fine sandstones with very thin carbonaceous laminations. Laminations are horizontal or have low dip angle (<10°) with parting lineation or plane bed stratification (Fig. 13).

Interpretation

Low-angle cross-bedding (angle of dip <10°)) is very common in the ephemeral stream deposits and can be considered as a characteristic bedding of shallow or ephemeral stream deposits (Picard and High, 1973). In fluvial channel, these stratifications can be observed in wash-out dunes, anti-dunes, and commonly found in laminated sand sheets (Miall, 1978).

Therefore, this facies can be interpreted to have been deposited under planar bed flow (lower and upper flow regime) or anti-dunes of fluvial environment.

5. Thinly bedded siltstone or silty fine sandstone and shale facies (Fsc)

Description

This facies is mainly composed of bluish grey color, brecciated shale, and variegated shale and interbedded with siltstone or silty fine sandstone and plant debris intercalation (Fig.14). The siltstones are yellowish white color and small to medium scale horizontal scale low-angle laminations are occurred in them. The sandstones are whitish grey color and very fine-grained.

Interpretation

Very fine sand and silt with clay and plant debris intercalations represent subaqueous levee deposits (Reineck and Singh, 1980). The sandstone beds with sharp or loaded bases were rapidly emplaced probably during periods of high fluvial discharge (Wood and Hopkins, 1989). The general sharp base nature of the shale beds indicate that deposition of mud from suspension may have occurred predominantly during periods of interflood quiescence rather than the waning flood stage.

In this facies, very fine sand and silt with clay and plant debris intercalations represent subaqueous levee deposits (Reineck and Singh, 1980).

6. Massive, variegated silty clay facies (Fm)

Description

The variegated clays are observed as the multicolor of mottled ash gray to greenish grey in chocolate brown to reddish brown matrix of sandy and silty clay with disseminated small carbonate nodules (Figure.15). In this facies, silicified wood fragments are common. It is well developed in the middle portion of Natma Formation.

Interpretation

Fine-grained sediments are deposited as overbank material during flood stages of the river, on the flood plain, in bays, swamps, marshes and crevasse splays. The variegated clays are interpreted as semi-arid floodplain paleosols formed during lower water table at relative base-level fall or indicating that the rated of basin subsidence was less than the rate of deposition.

Therefore, extensive occurrence of paleosol formation in the upper part of Natma Formation may reflect prolong exposed floodplains of non-depositional in a mixed-load meandering river system under semi-arid climate.

Sedimentary Facies Analysis of Shwethamin Formation (Late Miocene)

1. Gritty to pebbly sandstone facies (Gm)

Description

This facies is mainly composed of medium to gritty, medium to thick bedded, light grey to yellowish grey colored pebbly gritty sandstones with erosional base (Fig.16). Pebbles are scattered through the sand and more typically at the top of the bed. Wood fragments are also occurred in the basal part of this formation.

Interpretation

Gravels are more abundant and comprise main deposits of channels and bars (Tucker, 2003). Mostly, the pebbles are deposited in prograding gravelly and sandy distributary channels (Casshyap and Aslam, 1990). The erosional base with mud clasts and detrital coal clasts-supported conglomeratic sandstones can be regarded as channel floor and basal lag deposits (Miall, 1978).

Therefore, this facies is a characteristic of the channel lag deposit of the braided river formed during high stage of river with turbulence and erosive current.

2. Trough cross-bedded sandstone facies (St)

Description

This facies consists of medium-grained, medium to thick-bedded, light gray colored sandstones with mud drapes and clasts. Small to large-scale trough cross-beddings (Figure.17) and mud clasts are the dominant sedimentary structures. The paleocurrent direction measured from cross-bedding is 190°.

Interpretation

The small scale cross-laminated fine to medium-grained sandstones is the lower flow regime structures of sandy fluvial channel and they are found as (Miall, 1972: Reading, 1996). Very large-scale trough cross-bedded sandstones free from mud drapes in their foreset stratifications and the occurrence of intraformational mud clasts are commonly found in the basal part of the fluvial channels. Wavy or erosive base upon which the present of mud drapes and clasts

is the deposition taken place in a channel area where the basal erosion can occur (Reineck and Singh, 1980).

Therefore, this facies pointed out that it had deposited in dunes of a fluvial channel.

3. Planar cross-bedded sandstone facies (St)

Description

This facies is characterized by medium to thick-bedded, medium to coarse-grained sandstones with single sets of large scale planar cross-stratifications (Figure.18). In some outcrops, pebbles and grains are arranged in cross-beds.

Interpretation

Planar cross-bedding is commonly found in migrating straight crested subaqueous dunes of the active fluvial river channel (Miall, 1987). Large scale single sets of planar cross-bedding also represent cross channel bars and associated with planar or horizontally stratified sandstone (Sh) suggesting sand flat accretion (Reineck and Singh, 1980).

Therefore, this facies can be interpreted to have been deposited under transverse bars or dunes (lower flow regime) of fluvial river channel.

4. Horizontally laminated sandstone facies (Sh)

Description

This facies is characterized by thick-bedded to massive, fine to medium-grained, light grey to buff color sandstone (Figure.19). Horizontal laminations with parting lineation or plane bed stratifications are found in this facies. It is vertically associated with trough cross-bedded sandstone facies (St).

Interpretation

Low-angle cross-bedding (angle of dip 5°-10°) is very common in the ephemeral stream deposits and can be considered as a characteristic bedding of shallow or ephemeral stream deposits (Picard and High, 1973). In fluvial channel, these stratifications can be observed in wash-out dunes, anti-dunes, and commonly found in laminated sand sheets (Miall, 1978).

Therefore, this facies can be interpreted to have been deposited under shallow, high-energy (upper flow regime) flow conditions during which sediments was aggraded vertically.

5. Thinly laminated fine sandstone and siltstone (Fl)

Description

This facies is mainly composed yellowish grey colored fine-grained and buff colored siltstone with thinly lamination (Figure.20). Mica and carbonaceous matters are present in laminations. Some place is scoured by a broad and shallow sandy minor channel with coal fragments as a basal lag.

Interpretation

Thick sequence of this facies also represents poorly channelized laminated sand sheet deposits (Miall, 1985). Thinly laminated fine sandstones and siltstones represent the characteristic of crevasse splay sandstone. 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. Massive silty clay facies (Fm)

Description

This facies is characterized by massive, grey to buff color clay and brownish, purplish to reddish mottled colors of massive variegated clays (Figure.21). In this facies, silicified wood fragments and load cast nature are common. It is well developed in the upper portion of Natma Formation.

Interpretation

The variegated clays are interpreted as semi-arid floodplain paleosols formed during lower water table at relative base-level fall or indicating that the rated of basin subsidence was less than the rate of deposition. When a mud is deposited in water it has a high water content which is lost as the sediment compacts and cements into a mudrock.

So, this facies is interpreted as swampy deposits at basin margin and interdistributary bay deposits on delta plain (Coleman and Gagliano, 1965).

Lithofacies Association of Miocene Formations

1. Sandy Fluvial Channel Facies Association (CH)

This lithofacies association is characterized by the lithofacies Se, St, Sp, Sh, Sr and the minor or subordinate facies (Fsc, Fl and Fm) of waning flood and overbank fines. It usually starts at the base with erosional concave-up, crude cross-bedded, gritty to pebbly sandstones (lithofacies Se) and associated lag deposits of Letkat, Natma and Shwethamin Formations. It is overlain by medium to large-scale trough cross-bedded coarse sandstone (St) with thickness vary from 1m to 5m gradually upward decrease in grain size and scale of primary structures; Sp, Sh, Sr in descending order. The upper part again overlain by the fine facies, Fsc, and Fm show the overall fining upward facies trend. In the lower part of the formations, this faces association is always found in association with sandy and gravelly bedforms (SB and minor SG). The middle part of the formations show thin facies associations of CH and thick LS. The upper part of the formations is mainly composed of thin CH which is intercalated within the thick overbank-floodplain fines (OF).

This facies association is commonly found in associated with sandbars and minor gravel bars in the lower part suggesting the coarse grained bedload braided river system. It gradually passes upward to the mixed-load meandering river systems in the upper of the formation (Miall, 1985).

2. Sand Bar Facies Association (SB)

It is mainly comprised of Sp, Sh-Sl, St, Se and the subordinate facies of Sr, Fl and Fm. This facies association is significantly decreased upward in their scale and population throughout the vertical sequence of the Letkat and Shwethamin Formations. It is commonly associated with CH, GB and OF facies association.

This facies association can be interpreted as fluvial sandbars of varying types of the channel-fill complexes (e.g., dunes and transverse bars) and it also represents the crevasse channels and splay deposits (Miall, 1985).

The middle part of the formation is mainly dominated with thick multi-storey SB mainly composed of the coarse grained and large-scale co-sets of Sp, Sh-Sl, and St, Se lithofacies found in association with CH and minor GB suggesting a proximal braided river channel with sandy braided bars; transverse bars and downstream accretion sand bars (Cant & Walker, 1978; Reineck & Singh, 1980). The occurrence of bars more than 10m thick and large sand waves or sand-flats indicate that the river channels were large and had an extensive catchment area (MacCarthy, 1990). The scale of the sandbars decrease upwards in the sequence also reflect the overall upward fining fluvial system which could have resulted from and increased subsidence rate in the basin (Blair, 1986) and associated increased in relative sea-level as well as a reduction in sediment supply from the source areas.

3. Gravel Bar Facies Association (GB)

The facies association GB (gravelly bars and bedforms) is commonly found in association with the facies association (SB) sand bedforms) and CH (sandy braided river channels) interbedded in the lower part of Letkat Formation. Pebbly gritty sandstones with varying proportion of gravels (granule to pebble sizes) are included in this facies association. Associations of massive or crudely bedded, pebble-clast-supported conglomerates (Gm and Gp with subordinate lithofacies; Gt, St, Sp) are interpreted as gravel has deposited in a low sinuosity gravelly braided river (Miall, 1978; MacCarthy, 1990).

In the downstream or the middle reaches of braided rivers, gravel beds grade into the small babbles and sand beds. In the lower, more active channels, bar gravel dominate, whereas sands and pebbly sands are common at higher topographic elevation (South Saskatchewan). As a result of downstream and laterally migrating sand and gravel bars, planar and trough cross-bedding are dominant.

4. Overbank fines Facies Association (OF)

The overbank fine (OF) lithofacies associations represents natural levees, inter-fluvial overbank, flood plains and fluvial-floodplain paleosols in the facies analysis of the Fluvial Letkat, Natma and Shwethamin Formations. It is mainly composed of mudstone and siltstone lithofacies and found in association with minor interbeds of fine sand lithofacies; Sl, Sh, Sr. Carbonaceous matters and carbonate nodules or calche nodules are frequently observed.

This facies association is rarely observed in the lower part, subordinately occurred in the middle part, and well developed in the upper portion of the Letkat Formation. In the upper part of the formation, OF is interbedded with the lithofacies associations; SB of crevasse splays sands, SL of laminated sand sheets, and CH of sandy channels (Fig. 73).

OF in the lower part is dominated with light greenish grey mudstone/siltstone facies with carbonaceous matters and carbonized fossil-wood fragments. Whereas in the upper part is characterized by brownish, purplish to reddish mottled colours of thick variegated clays with desiccation cracks, calche nodules, and silicified wood fragments suggesting that the closer to the top of profile, the nearer to surface condition and thereby the more intensive the soil formation process (Kraus and Brown, 1985). The variegated clay of the upper part is interpreted as semi-arid floodplain paleosols formed during lower water table at relative base-level fall or indicting that the rate of basin subsidence was less than the rate of deposition.

5. Laminated Sand Sheet Facies Association (LS)

This facies association is mainly composed horizontal to low angle cross-stratified sandstone facies Sh-Sl with minor lithofacies of Sp, St and Sr. It is best developed in the middle

and the upper part of the Letkat Formation commonly associated with the lithofacies associations; CH and OF.

In the middle of the formation, thick cyclic sequences of LS (10-15m) associated with shallower and broad sandy fluvial channel elements (CH) are interpreted to have deposited under shallow, high energy poorly channelized sheet deposits occurring as channel fill or bar tops (North and Taylor, 1996).The upper part of the formation contains the interbedded sequences of LS and OF suggesting flash-flood or generally unconfined sheet flood deposits, i.e., crevasses sand sheets deposition into the flood plains during highest stage of river (Miall, 1985).

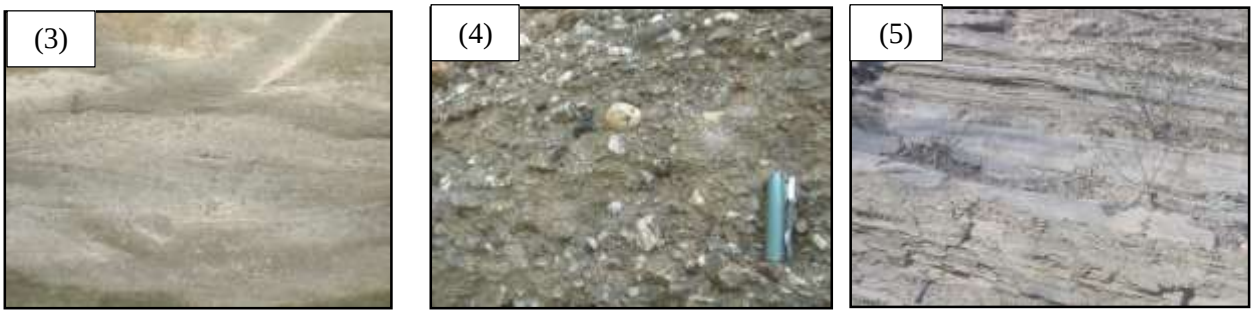


Figure 3 Photograph showing large scale trough cross-bedding showing that downcurrent truncation of cross bed set confined active large scale fluvial channel

Figure 4 Photograph showing pebbles, conglomerates and coal scatter embedded in Lower Letkat Sandstone point out that bar/channel lag deposit of braided river

Figure 5 Photograph showing sand-mud interlayering nature; light color representing sand beds with sharp or loaded bases which were rapidly emplaced, probably during periods of high fluvial discharge

Figure 6 Photograph showing a fluvial sequence developed on a sharp channeled base little fining upward trend and may contain a scour surface (arrow) indicating that it is an amalgamated sandbody

Figure 7 Photograph showing thick-bedded truncated set of medium to large-scale planar cross-stratified sandstone (Sp) of the lower part of Letkat Formation

Figure 8 Photograph showing thick-bedded, low-angle (<10º) stratified medium-grained sandstone body which representing high energy (upper flow regime) condition

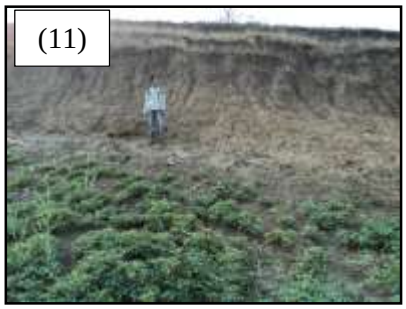
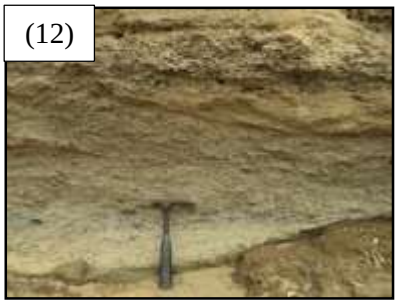


Figure 9 Photograph showing variegated clays with calche nodules indicating that the non-deposition in mix-load meandering river system under semi-arid climate

Figure10 Photograph showing thick bedded bluish grey silty shale resting between trough cross-bedded sandstone of Letkat Formation pointing out the transgression took place in the depositional site

Figure11 Photograph showing thick bedded nature of bluish grey shale with a few isolated cobbles in Natma Formation indicating flood sequence from braided river



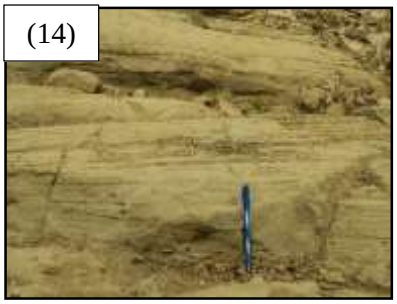


Figure 12 Photograph showing pebbly gritty sandstone laying the silty grey shale which is pointing out the protruding in a gravelly braided river

Figure 13 Photograph showing medium planar cross-stratified, fine to medium-grained sandstone deposited in the lower flow regime found in fluvial channel

Figure14 Photograph showing horizontal to low-angle (<10º) stratified medium-grained sandstone body which representing high energy (upper flow regime) condition

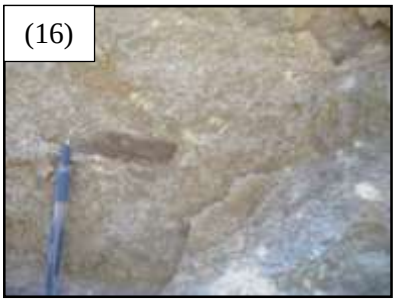


Figure 15 Photograph showing the variegated clay with calche nodule, which is a characteristic of fluvial deposition system as paleosols

Figure 16 Photograph showing silicified wood fragments in the basal part of gritty sandstone indication channel lag deposit

Figure 17 Photograph showing large-scale trough cross-bedding point out the down current truncation of cross-bed set confined active large scale fluvial channel

Figure 18 Photograph showing medium to thick-bedded, medium to coarse-grained sandstones with single sets of large scale planar cross-stratifications in Shwethamin sandstone

Figure 19 Photograph showing medium-bedded horizontal to low-angle stratified medium-grained sandstone overlying the trough cross-bedded sandstone indicating the fluvial channel environment

Figure 20 Photograph showing parallel continuous laminated fines sandstone indicating the waning floods deposits

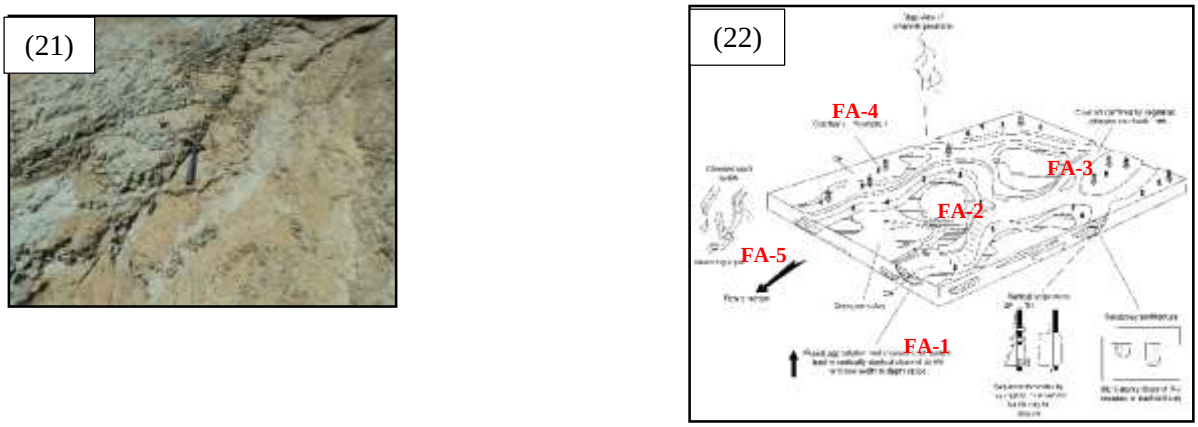


Figure 21 Photograph showing thick-bedded variegated silty shale with numerous calche nodules representing the characteristics pedogenic features of the semi-arid climate

Figure 22 Generalized lithofacies association in braided river model of Letkat Formation of the study area

This predominance of this facies association over the others is one of the most outstanding features used to distinguish the ephemeral-fluvial river deposits of semi-arid region form the perennial river deposits of humid-region and it is also a characteristic of an aggrading fluvial river system (North and Taylor, 1996) developed during initial relative base-level rise.

Conclusions

The present study would offer the sedimentological outcrop-based sedimentary facies analysis of the clastic sedimentary rock units of Letkat Formation, Natma Formation and Shwethamin (Late Eocene) exposed in the southwestern Chindwin Basin, situated in Kalewa-Mawleik Townships, Magway Region.

During Early Miocene, Letkat Formation was deposited in a fluvial-river system of the lowstand systems tract deposits (LST) deeply incised into the underlying Yaw Formation during relative sea-level fall, also be regarded as an incised fluvial channel-fill (IVF). The fluvial sequence of the lower part Letkat Formation is characterized by high bed-load gravelly and sandy, multi-

story sand bodies of braided channel-complexes with general lack of the overbank fines. The middle part of the formation is constructed with the shallow and broad amalgamated sandy channels with thick laminated sheets (LS) probably deposited as a result of unconfined sheet flooding. The upper part is becoming dominated with thick overbank-floodplains fines (OF) interbedded with the isolated major channels, minor channels or crevasse channels, and thin crevasse splays or laminated sand sheets. The lower part Natma Formation is becoming dominated with thick overbank-floodplains fines (OF) interbedded with the isolated major channels, minor channels or crevasse channels, and thin crevasse splays or laminated sand sheets in the fluvial system. The upward change in sand-body architectures within the sequence and lateral interconnected and amalgamated channel and meander belt systems with poorly preserved floodplain deposits. The lower part of Shwethamin Formation is characterized by high bedload gravelly and sandy, multi-story sand bodies of braided channel-complexes. The middle part is constructed with the shallow and broad amalgamated sandy channels whereas the upper part is dominated with thick overbank-floodplains fines.

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References

Anderton, R. (1985), Clastic facies models and facies analysis. In: Sedimentology: Recent Developments and Applied Aspects (Ed. by P.J. Brenchley and B.P.J. Williams), pp.31-47. Spce. Publ. Geol. Soc. London, 18-25.

Miall, A.D., (1977), "Analysis of Fluvial Depositional System", American Association of Petroleum Geologists, Fall Education Conference (1981).

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

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