Sedimentology of Natma Formation in Paluzawa Area, Kalewa Township, Sagaing Region

Zaw Lin Phyo[1] and Moe Zat[2]

Abstract

The present research would offer the sedimentology of the clastic sedimentary rock unit of Natma Formation (Middle Miocene) exposed in the southwestern Chindwin Basin, is situated in Kalewa Townships, Sagaing Region. The study is mainly focus on petrology, petrography and provenance study and outcrop-based sedimentary facies analysis. Natma Formation is mainly composed massive, medium to coarse-grained, occasionally pebbly sandstones and clays. Most of the Natma sandstones consist of quartz, feldspar, mica, rock fragments with chemical cements such as silica, calcite and iron oxide and fall in the field of subarkose, arkose and lithic arkose. As for the Diagenesis sequence, early diagenetic processes of formation of compaction and carbonate cementation and late diagenetic processes of hematite pigmentation are encountered. The paleocurrent and petrographic studies ensure the sediments to have derived from the acid igneous and low to medium to high-grade metamorphic rocks. The only possible area for the present existing sedimentary rocks is the Western Ranges and the nearby Igneous Belt of Myanmar. From facies analysis, the depositional environments can be deduced as fluvial environment. For more specific environment, individual facies combined into two facies association of braided channel bar and flood basin. At the starting of Middle Miocene time, the Natma Formation was deposited under meandering condition upon Letkat Formation.

Introduction

Location and Physiography

The research area, western part of the Southern Chindwin Basin is situated in Kalewa Township lays in topographic map no. 84 I/7. On the basis of landform characteristics, the area is not resistant to erosion than the adjacent units and therefore, it forms as broad valley nature (Fig. 1).

Aims and Objectives

The present project will attempt to carry out petrographic analysis, provenance study, and sedimentary facies analysis of the Natma Formation.

Materials and Methods

1. Field investigation was conducted mainly responsible for the detailed sedimentological measurements Natma Formation.
2. Petrological studies under polarizing microscope.
3. Naming of sandstones according to Sandstone Classification of McBride, 1963 and provenance by Dickinson, 1979.
4. 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”.

[1]Demonstrator, Department of Geology, Mawlamyine University
[2]Lecturer, Dr, Department of Geology, Mawlamyine University

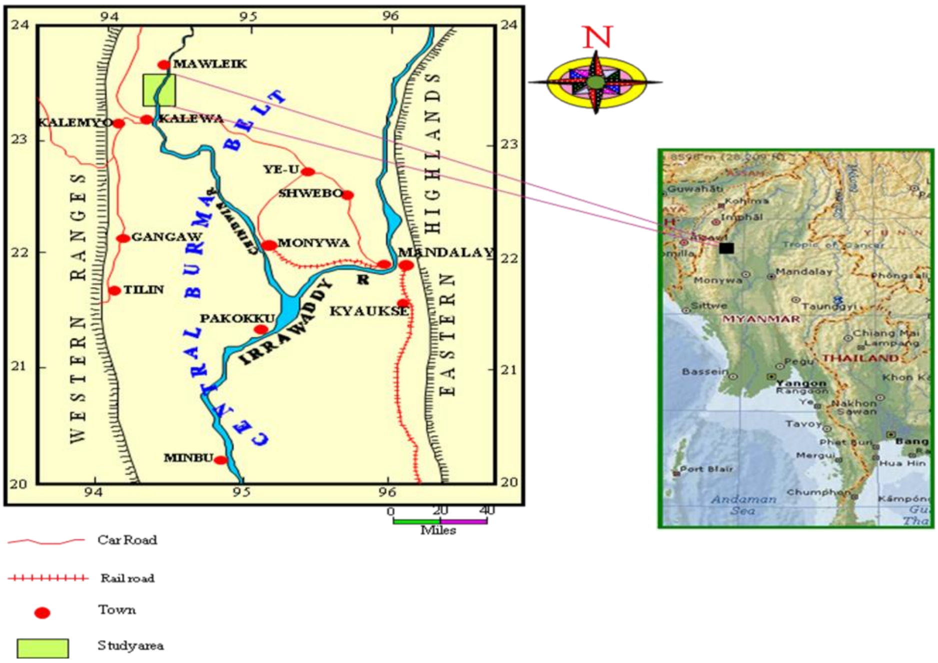


Figure (1). Location map of the study area

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, Middle Miocene rocks of Natma Formation are mostly cropped out along the central part which is overlain conformably by Early Miocene clastic sedimentary rocks of Letkat Formation and underlain conformably by Late Miocene clastic sedimentary rocks of Shwethamin Formation. The regional geology of the southern Chindwin Basin and its environs is shown in (Fig. 2).

Stratigraphy

General Statement of Natma Formation

Name Derivation

The term Natma Formation was first introduced by Goupta (1928), a series of soft, highly coloured clays and argillaceous sandstones formed at the vicinity of the Natma Village in the Lower Chindwin District.

Distribution

This unit is also well exposed along the Chindwin River just northeast of Paluzawa village, which itself is located in a broad valley underlain by the Natma Formation and the overlying alluvium.

Boundary Characteristics

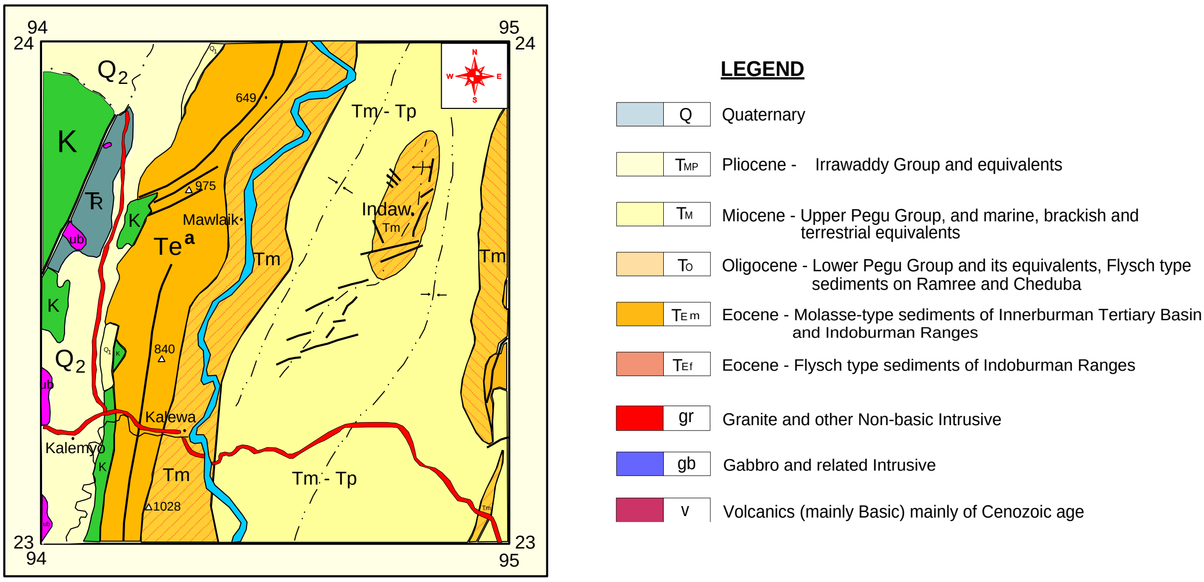
The Natma Formation is less prominent than the underlying Nwa Taung Sandstone of Letkat Formation and the overlying Shwethamin Sandstone. The contact between the Natma Formation and the overlying Shwethamin Sandstone is conformable and sharp.

Lithology

The Natma Formation comprises massive, medium to coarse-grained, occasionally pebbly sandstones and clays. The sandstones usually contain quartz pebble conglomerate lenses in their basal part in Natma area. Large-scale cross-stratification, mostly of trough type, mud clasts and wood chips are common features within these sandstones. Mudstones of this unit are dominantly of poorly bedded, yellowish brown weathering clays and well bedded yellowish brown weathering silty clays.

Fauna and Age

No fossils were collected from the Natma Formation. But the lithological and bedding characters pointed out that Natma Formation will be Late Miocene in age and correlated with Oligo-Miocene marine Pegu Group of the Minbu basin in the south.



Scale 1 : 100000

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

Petrography

Detailed Petrography of Natma Sandstones

These sandstones are mainly composed of quartz, feldspar, rock fragments, mica, accessory and heavy minerals are embedded in calcite cement. Sandstones of Natma Formation are mostly paraconglomeratic framework.

Natma sandstones comprise 70 to 80 % of the detrital grains and 20 to 30 % of cement (Fig. 3). These sandstones are mostly poorly to moderate sorted and subangular to subrounded in shape. The maximum grain size varies from 0.1 to 0.25 and the minimum grain size varies from 0.03 to 0.05 mm in diameter.

Detrital Fractions

Quartz

Detrital quartz constitutes 55 to 65 % of the total detrital fractions. Most of the quartz grains are elongated and subangular to subrounded in shape (Fig. 4). In the total quartz population, 90 to 95 % is monocrystalline quartz and 5 to 10% is polycrystalline quartz. Most of the quartz grains, which are derivatives of metamorphic show wavy extinction and the rest display nonundulatory extinction (Fig. 5). A few quartz grains are corroded and wedged apart by iron-oxide cement. Mineral inclusions are also observed.

Feldspar

Feldspar constitutes 30 to 40 % of the total detrital fractions. In the total feldspar grains, alkali feldspars are more common than plagioclase feldspar. Few of the feldspar grains are fresh and most are weathered grains. Some feldspar grains altered to clay mineral can be seen (Fig. 6). In these sandstones, orthoclase, plagioclase (Fig. 7) and microcline feldspar can be observed. Maximum grain size of feldspar is 0.25 to 0.3 mm whereas the minimum grain size is 0.05 to 0.08 mm in diameter.

Rock Fragments

The rock fragments consist of 5 to 10 % of the total detrital fractions, are of sedimentary, metamorphic and igneous rocks especially, chert fragments (Fig. 8). The conspicuous appearance of rock fragments compared to other detritus is the shape with better degree of rounding.

Mica

Mica comprises 1 to 2 % in all detrital frameworks. Both biotite and muscovite present but the former is more abundant. The size of mica grain ranges 0.1 to 0.25 mm in length and 0.08 to 0.1 mm in width. Some mica grains were bifurcated by the introduction of calcite cement, and some are distorted by the compaction.

Cement

The chemical cement takes up to 25 to 30 % of the total rock volume. The types of chemical cements are calcite and iron oxide.

Nomenclature

According to the sandstone classification of McBride (1963), most of the sandstones of Natma Formation can be named as subarkose, arkose and lithic arkose (Fig. 9).

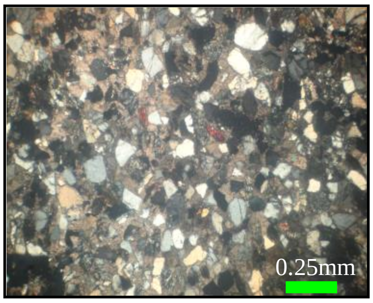


Figure (3). Photomicrograph showing the detrital grain and cement of the Natma Formation (between X.N) (Loc. 868018)

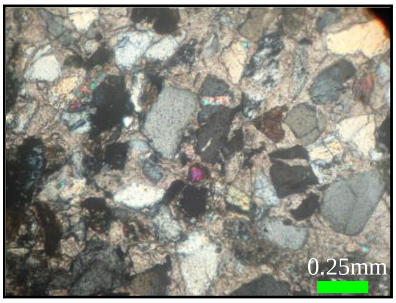


Figure (4). Photomicrograph showing subangular to sub-rounded in shape of quartz grains in Natma Formation (between X.N) (Loc. 875023)

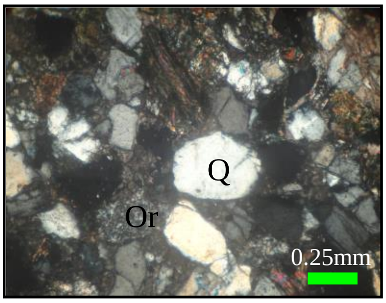


Figure (5). Photomicrograph showing the rounded quartz grain (Q) and weathered orthoclase (Or) (between X.N) (Loc. 888028)

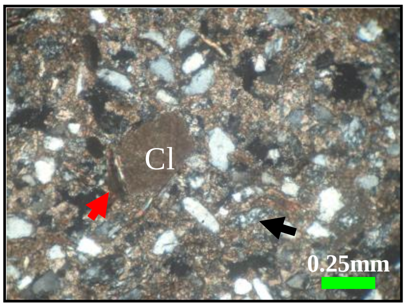


Figure (6). Photomicrograph showing alteration of feldspar grain to clay mineral (Cl), biotite mica (red arrow) and polycrystalline quartz (black arrow) (Qp) (between X.N) (Loc. 887027)

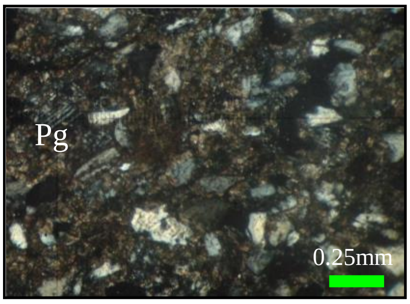


Figure (7). Photomicrograph showing plagioclase feldspar (Pg) grain embedded into calcite cement (between X.N) (Loc. 868018)

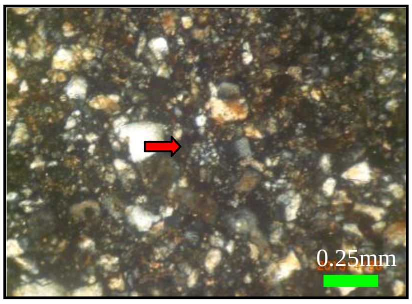


Figure (8). Photomicrograph showing chert fragment (red arrow) embedded in calcite cement (between X.N) (Loc.875023)

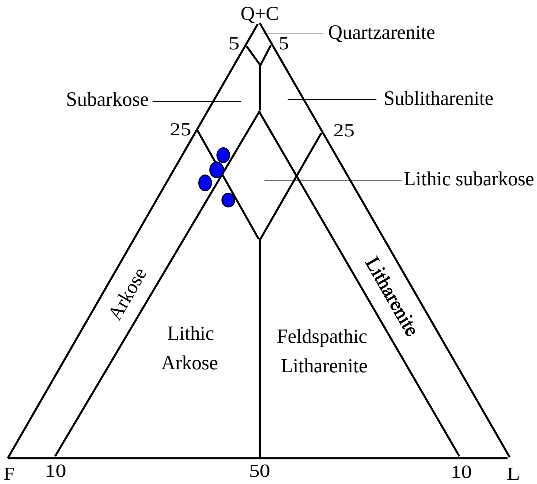


Figure (9). Ternary diagram (McBride, 1963) of Letkat sandstones showing apparent shift in composition from subarkose, arkose and lithic arkose.

Clastic Diagenesis

Diagenesis is the sum of those processes by which originally sedimentary clastic assemblages attempt to reach equilibrium with their environments (Burley, Kantorowitz & Waugh, 1985).

Diagenesis phases for the rocks constituted in the area can be categorized as two phases; the early diagenesis, for processes taking place from deposition and into the shallow burial realm and the late diagenesis for those processes affecting the sediments at the deeper levels and on uplift.

Early Diagenesis

The characteristic diagenetic features include; compaction and calcite cementation.

Compaction: The petrographic features such as the packing re-adjustments of the framework grains, grain bending and fracturing, and the pressure solution observed in the sandstones of the study area are the effects of compaction (Fig. 10). Compaction involves dewatering and a closer packing of grains. Further compaction through the overburden pressure results in local fracturing and bending of weak grains (Tucker, 1991). In compaction, sutured contacts formed between the grains if they are a similar solubility/hardness, and concavo-convex contacts formed where one grain dissolves preferentially (Tucker, 1991). Hence, quartz overgrowth and bending and splitting of mica flakes developed by the initial compaction are the early diagenetic features.

Carbonate cementation: Calcite is one of the most common cements in sandstones of the study area (Fig. 11). The source of the $CaCO_3$ may be the pore water itself, but in marine sandstones, much is probably derives from dissolution of carbonate skeleton grains (Tucker, 1991). The two main types of calcite cements are poikilotopic crystals and drusy calcite spar in which both are iron-rich cement. The precipitation of Fe-rich carbonate cements has been explained as a consequence of diagenetic origin and redox reactions in adjacent precipitation of (iron) carbonate cement (Almon and Davies, 1979; Curtis, 1983; Surdam et al. 1984).

Late Diagenesis

In the late diagenesis, the microscopic features of hematite pigmentation are also observed.

Hematite pigmentation: Many terrigenous types of sediment are colored red through the presence of hematite. The hematite typically occurred as a very thin coating around grains. It is also develop within biotite cleavage planes and in some cases replaces the biotite (Fig. 12). Iron is supplied by intrastratal dissolution of detrital silicates such as hornblende, augite, olivine, chlorite, biotite and magnetite (Tucker, 1991). The hematite is chiefly amorphous or consists of micron-size crystals. These features of the hematite, together with the absence of hematite coatings at grain contacts indicate a diagenetic origin (Tucker, 1991).

Figure (10). Photomicrograph showing the broken muscovite mica (arrow) by compaction effect (between X.N) (Loc. 841001)

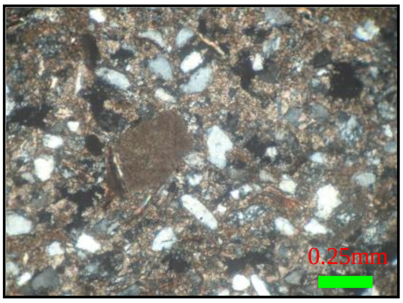


Figure (11). Photomicrograph showing the detrital grains are dissolution by calcite (arrow) (between X.N) (Loc. 833998)

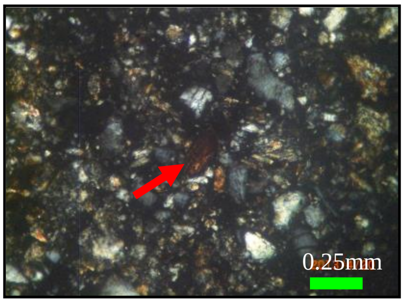


Figure (12). Photomicrograph showing the iron oxide (hematite) develop within biotite cleavage planes (arrow) (between X.N) (Loc.833998)

Provenance Study

Point counting data were recalculated to produce the grain parameters proposed by Dickinson (1970). The mean paleocurrent direction of the Miocene rocks exposed in the study area is 175º. This indicate that the possible provenance is situated somewhere in the NNW of the study area.

Moreover, petrographic and petrological criteria were used to determine the provenance. Triangular plots of QtFL and QmFLt were drawn from the point counting data. When QtFL diagram of Dickinson (1985) is applied, the data plot fall in the field of recycled orogenic and transitional continental and used QmFLt diagram, fall in the dissected arc, mix and transitional continental (Fig. 13).

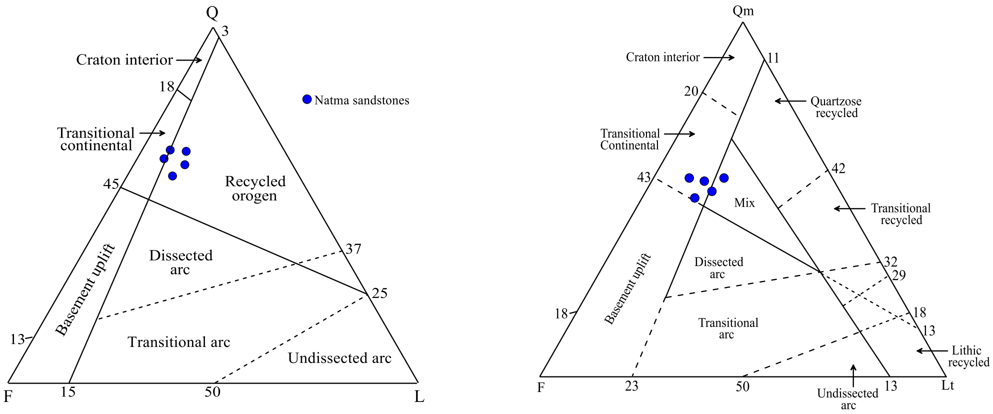


Figure (13). Triangular plots of QtFL and QmFL$_t$ showing the selected sandstone suitesderived from different types of provenances after Dickinson (1985)

Sedimentary Facies Analysis

General Statement

Sedimentary facies analysis has been carried out on two measured sections which are aligned nearly east-west across the regional strike of the Natma Formation exposed along the stream sections.

Lithofacies of Natma Formation

There are four lithofacies in Natma Formation. They are

1. Massive silty nodular clay with fine-grained sandstone facies (Fsc)
2. Medium to thick-bedded, coarse-grained to gritty trough–cross bedded sandstone with mud clast facies (St)
3. Thinly bedded siltstone or silty fine sandstone and shale facies (Fl)
4. Massive, variegated silty clay facies (Fm)

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

Description

This facies is mainly composed of whitish gray coloured thick-bedded shales with subordinated amount of silt and sand bands. The discontinuous sand lenses with micro cross-lamination, nodule silty shale and coal clasts (Fig. 14) are notably observed, intercalated in thick bedded clay unit. This facies is stratigraphically placed in the lower part of Natma Formation and vertically associated with coarse-grained to gritty trough cross-bedded sandstone facies.

Interpretation

Clay minerals remain in suspension in quite weak fluid flows and only settle out when the flow is very sluggish or the fluid still. Clay particles are therefore present as suspended load in most currents of water and air and are only deposited when the flow ceases (Tucker, 1988). Fine-grained sediments were deposited as overbank material during flood stages of the river, on the flood plain, in bays, swamps, marshes and crevasse splays. Thick-bedded shales were probably deposited by suspension in low energy environment and disperse over wide area by the basinal processes (Reading, 1996). Therefore, bluish gray shale with silt and sand bands facies represents the sediments deposited in backswamp of meandering river.

Medium to thick-bedded, coarse-grained to gritty trough–cross bedded sandstone with mud clast facies (St)

Description

This facies is mainly composed of buff colour, medium to thick-bedded, coarse-grained to gritty sandstone. The gravels are mostly subrounded to rounded and clear quartz grains. This unit is ranging from 0.1 to 0.4m in thickness. It consists of pebble-size mud clasts and medium to large-scale cross-bedding (Fig. 15). They are set in red ferruginous matrix. This facies is vertically associated with massive silty nodular clay with fine-grained sandstone facies.

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 pebbles are deposited in prograding gravelly and sandy distributary channel (Casshyap and Aslam, 1990). The deepest portions of the channels 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. 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, this facies can be interpreted as bar/channel lag deposit of the braided river.

Thinly bedded siltstone or silty fine sandstone and shale facies (Fl)

Description

This facies is mainly composed of bluish grey colour, brecciated shale and interbedded with siltstone or silty fine sandstones. The siltstones are yellowish white colour and small to medium scale horizontal scale cross laminations are occurred in them (Fig. 16). The sandstones are whitish grey colour and very fine-grained. These siltstone and shale beds are usually thin and are varying in thickness from 0.1m to 0.4m. The wavy bedding, scour and fill structures found in this unit. This facies is mostly associated with laminated gray shale facies and through cross-bedded sandstone with mud clasts facies.

Interpretation

Very fine sand and silt with clay and plant debris intercalations represent subaqueous levee deposits (Reineck and Singh, 1980). The wavy-bedding, scour and fill structures and burrows are the characteristic features of subaqueous levee deposits. 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. 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. Therefore, this facies can be interpreted as subaqueous levee deposits.

Massive, mottled and variegated silty clay facies (Fm)

Description

This facies is characterized by massive, buff colour clay and brownish, purplish to reddish mottled colours of massive variegated clays (Fig. 17). The thickness varies from 5m to 100 m. In this facies, silicified wood fragments are observed. It is well developed in the upper 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. 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. This facies is interpreted as the overbank deposit of river channel during flood period.

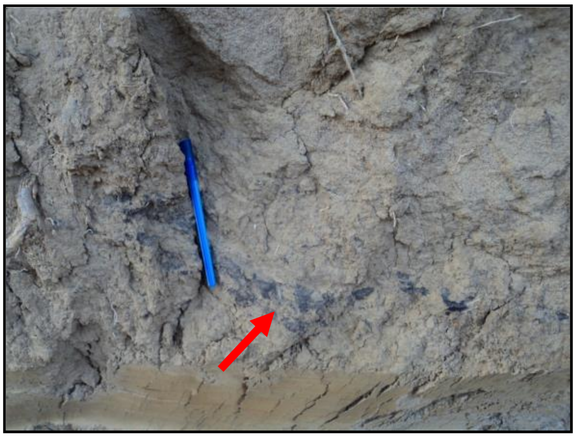


Figure (14). Photograph showing coal clasts (arrow) intercalated between bluish grey silty shale representing backswamp deposit (Loc.849999)

Figure (15). Pebbly large scale cross-bedding in Natma sandstones showing that downcurrent truncation of cross bed set of braided channel (Loc.866017)

Figure (16). Photograph showing thin-bedded fine sandstone with low angle stratification point out the levee deposit (Loc.887027)

Figure (17). Photograph showing mottled and variegated silty clay indicate semi-arid floodplain paleosols (Loc.885026)

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.

Braided channel bar facies association

This facies association is mainly found in the middle part of Natma Formation. It is composed of Medium to thick-bedded, coarse-grained to gritty trough–cross bedded sandstone with mud clast facies (St). Large-scale crude trough cross-bedding with eroded or incision association with abundant intraformational mud pebbles and coal clasts suggest eroding fluvial river channel of young stage and originated in the proximal region of a fluvial system.

Flood basin facies association

This facies association is mainly found in the upper part of Natma Formation. It is composed of massive silty nodular clay with fine-grained sandstone facies (Fsc), thinly laminated fine sandstone facies (Sl) and massive, variegated silty clay facies (Fm). Medium to thick bedded fine-grained materials developed which suggest that sediment load in the lower reaches of the rivers.

The principal environments and depositional faceis of meandering river model of Natma Formation is shown in figure (18).

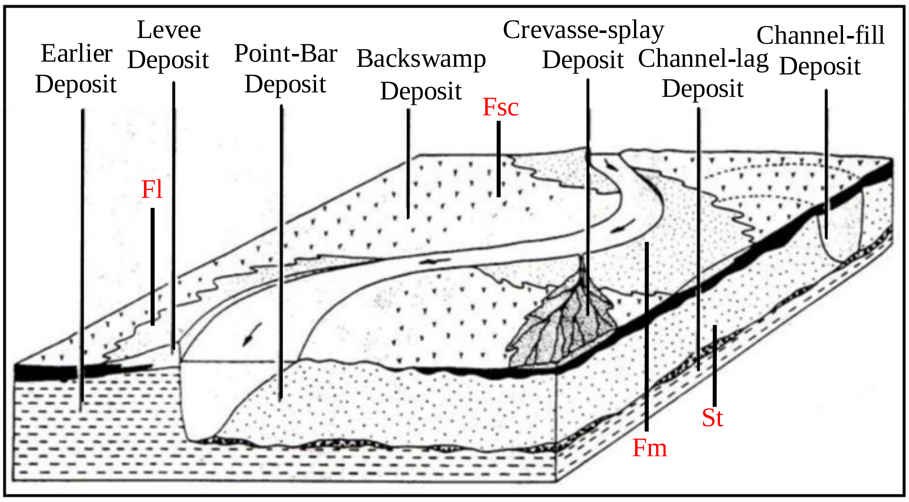


Figure (18). Principal environments and depositional faceis of meandering river model of Natma Formation (modified from Allen, 1964)

Discussion

The mean paleocurrent direction of the Middle Miocene rocks exposed in the study area is 175º. This indicate that the possible provenance is situated somewhere in the NNW of the study area.

Moreover, petrographic and petrological criteria were used to determine the provenance. Triangular plots of QtFL and QmFLt were drawn from the point counting data. When QtFL diagram of Dickinson (1985) is applied, the data plot fall in the field of recycled orogenic and transitional continental (Fig. 13).

The sandstones of the study area are mainly composed of quartz, feldspar and lithic fragments. Most of quartz grains are non-equidimensional, subangular to subrounded and an undulatory extinction. Such type of quartz derived probably acid plutonic igneous rock origin. Some quartz grains showing undulatory extinction are the derivation of metamorphic provenance. This indicates that the source area had once effected by a regional metamorphism.

Optically clear quartz with hexagonal outline (β quartz) found here are regarded as the volcanic origin (Blatt, 1980). The subsequent volcanic rock fragments are also involved in sandstones of the study area.

Rock fragments of chart and rounded quartz grains are also encountered. Hence, the provenance of the rocks of the study area also includes the pre-existing sedimentary rocks.

The presence of metamorphic rocks fragments like are indicatives of a source area affected by regional metamorphism.

The components of the acid plutonic igneous rocks such as biotite, muscovite and microcline are constituted in the sandstones of the study area.

Accordingly, the lithologic and petrologic characters strongly suggest that, the sediments of the study area for the most part belong to the acid plutonic igneous rock, low to high-grade metamorphic rocks and pre-existing sedimentary rocks.

Rapid erosion of uplift sources gives rise to a typical quartzo-feldspathic sand of classic arkose character (Dickinson, 1979).

In all likelihood, the only provenance of the rocks of the study area can be no other than the western ranges and the nearby igneous belt of Myanmar.

Acknowledgements

We wish to express our sincere gratitude to Dr Aung Myat Kyaw Sein, Acting Rector of Mawlamyine University, Dr Mi Mi Sein and Dr San San Aye, Pro-Rectors of the same University for their permission. We extend thank to Professors Dr Yin Yin Aye (Head) and Dr Ko Yi Hla of Geology Department, Mawlamyine University, for their advice and encouragement in preparing this paper.

References

Aung Khin and U Kyi, (1959). Geology of the Kalewa Coal Field (Northern Side Thitchauk).

Dickinson, W.R. (1985). Interpreting provenance relations from detrital modes of sandstones; In, Zuffa, G.G., eds.; Reading provenance from arenites, Dordrecht, Netherland, Riedel, p. 333-361.

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