Geology of the South Eastern Flank of Western Ranges, between N 17º 30′ and N 18º 15′, Hinthada District

Si Thu Soe[1], Soe Khaing Linn[2] and Saw Ngwe Khaing[3]

Abstract

The study area is located at the southeastern flank of the Western ranges. The study area is located about 42 km western part of Hinthada and 84 km from NNE of Pathein. The study area is extended about 90 km from north to south and 25 km from east to west. It is bounded by North latitude N 17º 30' to N 18º 15' and East longitude E 94º 50' to E 95º 5'. The total converges being about 2600 square kilometers. Topographically, the area can be divided into (1) mountainous unit (2) rolly hilling unit and (3) flat lowland unit. All streams are dendritically flowing from west to east. The study area and its environs are composed of rocks ranging from Upper Cretaceous to Recent. Undifferentiated Flysch Unit (Late Cretaceous to Paleocene), Paunggyi Formation (Paleocene), Undifferentiated Molassic Unit (Eocene to Early Oligocene), Okhmintaung Formation (Late Oligocene), Pyawbwe Formation (Early Miocene) and Irrawaddy Formation (Late Miocene to Pliocene) are well exposed in this area. Undifferentiated Flysch Unit indicates NNE-SSW strike direction with moderate to steep slope. Paunggyi Formation, Undifferentiated Molassic Unit and Okhmintaung Formation represent NNE-SSW in strike direction with gentle to moderate dips toward SE. Pyawbwe Formation and Irrawaddy Formation show gentle dip with the same strike direction. The bedding natures of the study area are shown NE-SW means striking and average dip amount 63.7º. Undifferentiated Flysch Unit and Undifferentiated Molassic Unit are highly deformed by the intense shear-folding processes.

Keywords: southeastern flank, dendritically, Flysch, Molassic, intense shear-folding processes

INTRODUCTION

The study area is located at the southeastern flank of the Western ranges. The study area is located about 42 km western part of Hinthada and 84 km from NNE of Pathein. It is also located at the western part of Laymyethna Town (Fig. 1). The study area is extended about 90 km from north to south and 25 km from east to west. It is bounded by North latitudes N 17º 30' to N 18º 15' and East longitude E 94º 50' to E 95º 15'. The study area lies on one inches topographic map Nos. 85L/16, 85N/4, 85 K/13, 85O/1, 85K/14 and 85O/2. The total converges being about 2250 square kilometers. The study area is located in the western part of the Pathein-Monywa car road. Hinthada-Ingabu-Myanaung-Kyangin railway is through across in the eastern part of the study area. It can be reached by car and cycle throughout the whole year and the accessibility is good. Tectonically and geomorphologically, Myanmar is subdivided into three main provinces (GIAC, 1999) which are N-S trending linear belts namely; Eastern highland containing east Kachin State, the whole Shan State, Kayin and Kayah State and Taninthayi Region. Central Lowland containing relatively low-lying area of Ayeyarwady, Chin Dwin and Sittaung drainage basins which are also called Central Myanmar Basin. Western Ranges containing Rakhine Yoma, Chin Hills, Naga Hills and Rakhine coast. Some workers also divided into four provinces separately as Rakhine coastal plain in the westernmost (Chhibber 1934, Tonish 1950 & Gorshkov 1959). The study area is located at the eastern flank of Western Ranges.

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The highest point of the area is Alan Taung, 518 m located at the central part of the study area. The remarkable height peaks of the study area can be range from north to south these are Kan gu Taung (427 m), Myin wa Taung (395 m), Le pet Taung (328 m), Kyi Taung (462 m), Alan Taung (518 m), Saing Taung (452 m), Modi Taung (489 m) are dominated along the western part. The general topographic trends are nearly N-S or NW-SE direction. Alluvial deposits are covered at the eastern part of the area. Topographically, the study area can be subdivided into three topographic units such as (1) mountainous region (2) rolling hilly unit and (3) flat lowland unit (Fig. 2).

(1) Mountainous Region

The western part of the study area is dominated by rugged and mountainous topography, with average elevation about 250 m and NW-SE to nearly N-S topographic trend. The highest peaks are Kan gu Taung (427 m), Myin wa Taung (395 m), Le pet Taung (328 m), Kyi Taung (462 m), Alan Taung (518 m), Saing Taung (452 m), Modi Taung (489 m) in this unit.

(2) Rolling and Hilly terrain

The middle portion of the study area is typified by the rolling and hilly topography with average elevation about 50 m. The hills are less rugged than the Mountainous terrain and the elongated small gullies are present in this unit.

(3) Flat low land Unit

The eastern portion of the study area, especially in the eastern part of Pathein-Monywa car road is generally characterized by flat, lowland topography with average elevation about 15 m., and many small streams and swamps are presence in this unit.

Drainage Systems

Drainage map of the study area is shown in figure (3). In the study area, main streams are flow from NW to SE direction. They are Pa daw Chaung, Ma mya Chaung, Ka nyin Chaung, The byu Chaung, Nan ga thu myauk Chaung, Nan ga thu taung Chaung, Gyat Chaung, Mezali Chaung and Thi da Chaung. These are observed as sub-angular to dendritic patterns. Chin Chaung and Kat Chaung are flowing from West to East and flowing into the Gyat Chaung. Other minor streams, such as Ye we Chaung, Kwin gauk Chauk, Legongyi Chaung and San Chaung are flowing from west to east. Myo daung Chaung is flowing into the Ka nyin Chaung from SW to NE direction. In the western part of the area, the short tributaries and steep sided, narrow V-shaped gullies are most common characters of the streams. All streams are sub-angular to dendritically flowing in the study area.

Methods of Study

Initially, desk study is made based on previous reports, theses and geological maps for literature survey. The lineation, general physiographic features, and different lithology units are studied on the aerial photos and satellite interpretation. General traverse to know lithological units, general trend and to observe and measure main outcrop with distinct structures. In detail traverses, recorded detail structural data information, systematic measurements of the beddings, lineation and structural features are also studied in these traverses. Oriented samples are collected in the field periods. In the laboratory study, various oriented rock samples are prepared as thin section (0.03mm). And then, these thin sections are studied on microscope and take the photomicrograph by Binocular microscope (MEIJI). The structural analysis is also mainly based on the interpretation of satellite TM-images and

black and white aerial photographs on the scale of 1:25,000. The structural data analysis was made by using Schmidt's net stereographic projections.

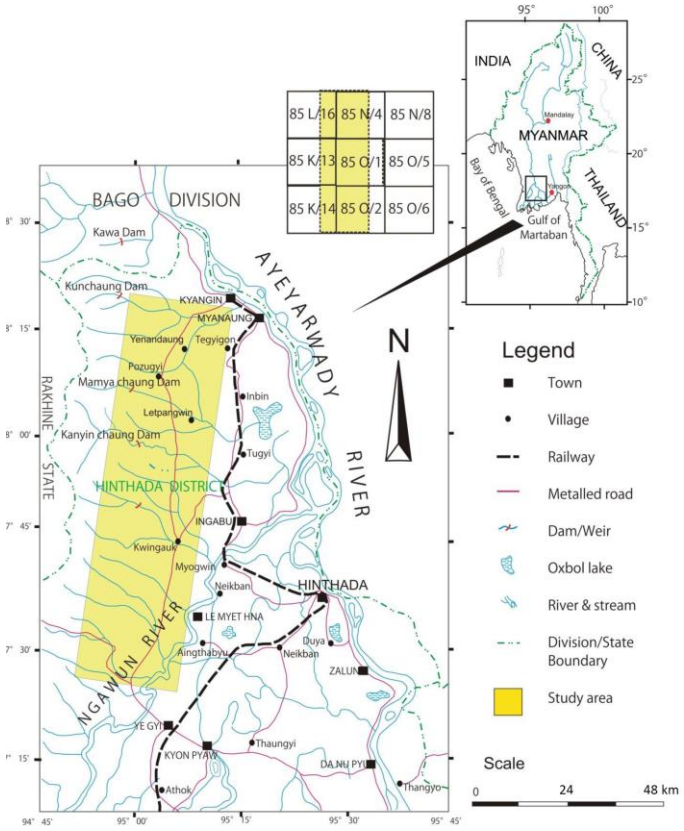
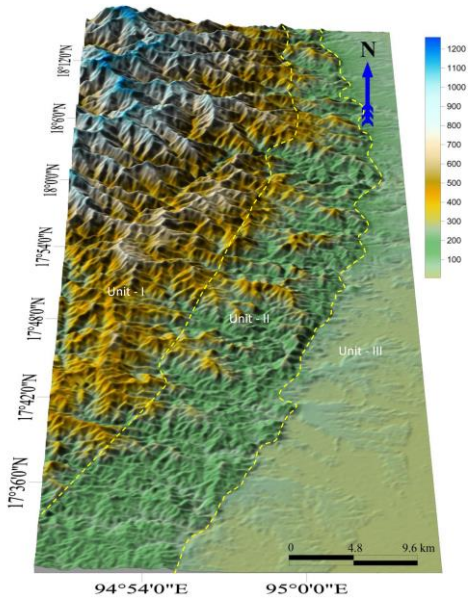


Figure (1) Location map of the Study area.



Unit - I Mountainous Region
Unit - II Rolling Hilly terrain
Unit - III Flat lowland

Figure (2) Physiographic units of the study area

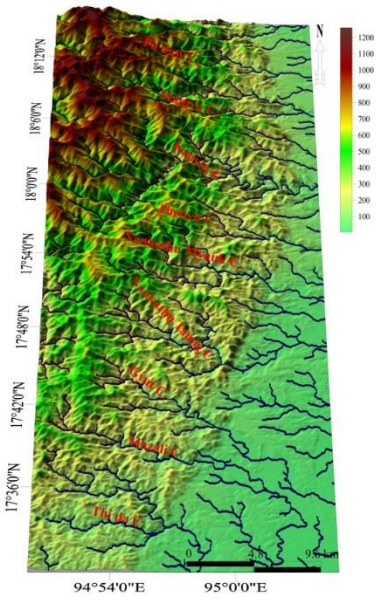


Figure (3) Drinage map of the study area (Based on DEM 30m)

Regional Geologic Setting

The Western Ranges or the Indo-Burman Ranges (Brunscheweiler, 1966), which include a long narrow range of folded mountains of the Naga Hills, the Chin Hills and the Rakhine Yoma (Fig. 4). The Western Ranges are composed mainly composed of a thick sequence of flysch-liked sediments and such subordinate rocks as quartzite, submarine mafic lava flow and *Globotruncana*-bearing micritic limestone of Middle Triassic to Eocene age (Win Swe, 1981), they are subjected to a low-grade regional metamorphism and locally associated with mafic to ultramafic rocks.

The Western Ranges can be divided into two parallel belts; (1) the western belt consists of flysch type sediments, largely of early Eocene age, all folded and thrust, and (2) the eastern belt is largely much older rocks (Mitchell, 1993). Uplift of the Western Ranges probably began in the late Eocene or early Oligocene (Mitchell, 1993).

East of the Western Ranges, the lowlands (Central basin) extends north-south as a broad fluvial plain, approximately 200 km wide and some areas are only a few tens of meters above sea level. The lowlands are divided into a western and an eastern part. Most of the filling (sandstone and shales) took place the eastern through. The total thickness of Tertiary and Quaternary sediments in the southeastern part of the lowlands could be in excess of 10 km (Rodolfo, 1969) and might reach 17 km (Mitchell, 1975).

At places along the western side of the lowlands, large east dipping thrusts have emplaced the Tertiary molasses over the Upper Cretaceous and Eocene flysch series of the Western Ranges (Mitchell, 1975).

In Chin Hills, narrow and discontinuous ophiolites are represented. The obduction of ophiolites on the Mesozoic sequences along the eastern marginal area of the Indo-Myanmar unit is also related to the plate collision between India and Asia (Win Naing, 2004).

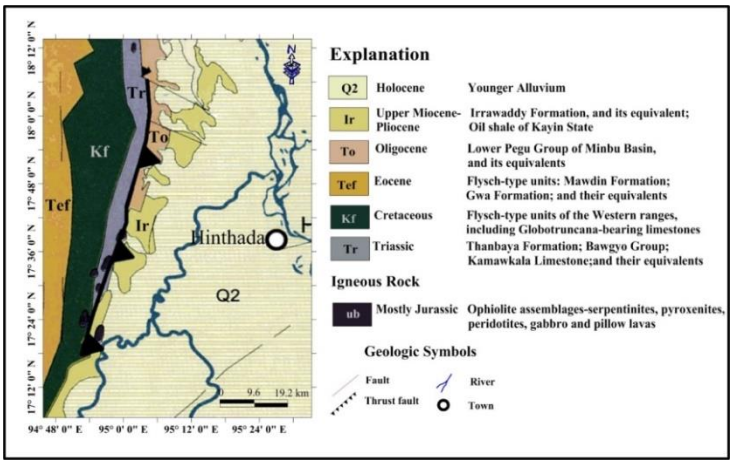


Figure (4) Regional geological map of the study area (Based on MGS, 2014)

Geology of the Study area

General Statements

In the study area, there are composed of six lithostratigraphic units. These are Undifferentiated Flysch Unit (Late Cretaceous to Paleocene), Paunggyi Formation (Paleocene), Undifferentiated Molassic Unit (Eocene to Early Oligocene), Okhmintaung Formation (Late Oligocene), Pyawbwe Formation (Early Miocene) and Irrawaddy Formation (Late Miocene to Pliocene). The oldest rock unit is Undifferentiated Flysch Unit (Late

Cretaceous to Paleocene) and which have been unconformably overlain by Paunggyi Formation (Paleocene). The youngest Formation is Irrawaddy Formation (Late Miocene to Pliocene) rest unconformable upon the Pyawbwe Formation (Early Miocene). There is also exposed ultramafic rock of serpentine (Late Cretaceous to Early Eocene).

Rock Sequence

Geological map of the study area is shown in figure (5). According to the geological map, the rock sequences exposed in the study area is described as follow:

Rock units	**Geological Age**
Sedimentary Rocks	
Alluvium	Holocene
Irrawaddy Formation	Late Miocene – Pliocene
~~ Unconformity ~~~~~	
Pyawbwe Formation	Early Miocene
~~ Unconformity ~~~~~	
Okhmintaung Formation	Late Oligocene
Undifferentiated Molassic Unit	Eocene – Early Oligocene
Paunggyi Formation	Paleocene
~~ Unconformity ~~~~~	
Undifferentiated Flysch Unit	Late Cretaceous – Paleocene
Igneous Rock	
Serpentinite	Late Cretaceous to Early Eocene

Rock Units of the Study Area

Undifferentiated Flysch Unit

In the study area, there are consisting of numerous flysch type sediments. Ba Than Haq (1972) defined as the Undifferentiated Flysch Unit in the Western Myanmar Region consisting Rakhine Yoma. Thin alteration sequence of thinly bedded slate with minor fine grained sandstone and pebbly greywacke along the western part of the area represent the Undifferentiated Flysch Unit of Late Cretaceous age (Aung Khin and Kyaw Win, 1969; Kyaw Win and Thit Wai, 1971) Localized shear metamorphism is occurred in this unit. The sequence of this unit can be recognized (1) pebbly greywacke, (2) sand/shale alteration, (3) Slate, (4) calc-slate, (5) phyllitic slate, (6) talc-chlorite phyllite (Fig. 6 & 7).

There is no fossil evidence within the area. Most of the previous workers have accepted that the Undifferentiated Flysch Unit is Late Cretaceous to Paleogene in age. Upper part of the unit is unconformably contact with Paunggyi Formation.

Paunggyi Formation

Paunggyi Formation is mainly composed of thick accumulation of grain-supported, sub-angular to sub-rounded rock materials with a wide range of variation in size, ranging from small pebbles to large boulder conglomerate (Fig. 8 & 9). Average elevation of this area is about 300 m above sea level which is lying on mountainous part of the region. This formation is lying unconformably on the Undifferentiated Flysch Unit.

The upper portion of the formation is locally characterized by grain-supported to matrix-supported, well rounded, large pebbles-sized quartz pebble conglomerate and matrix supported mud pebbles conglomerate.

There is no fossil evidence found in the study area, but foraminifera were recorded in the limestone of Paunggyi Formation (Theingi Kyaw, 2005). According to the Theingi Kyaw (2005), Paunggyi Formation is assigned to Late Middle Paleocene to early Eocene age. This formation is occurs along the eastern margin of the Undifferentiated Flysch Unit.

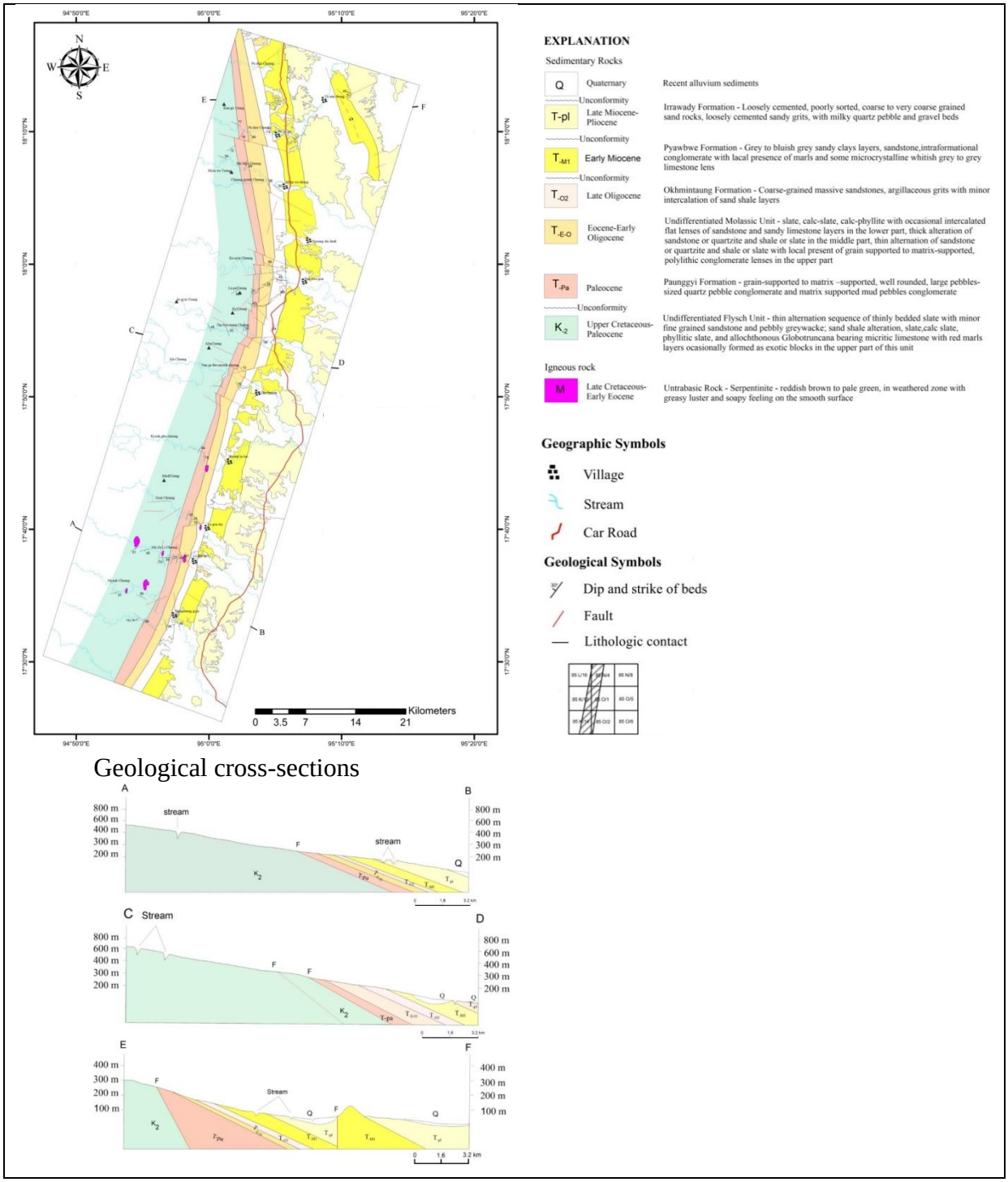


Figure (5) Geological map of the study area. Based on Saw Ngwe Khaing (2007), Lin Thu Aung (2008), Htun Linn Kyaw (2013), Naw Hnin Sandar Htun (2014), Tun Tun Min (2014) and present study data.

Figure (6) Undifferentiated Flysch Unit of thin bedded slate exposed at Chaung Chauk Chaung, west of Posugyi village near Ma Mya Dam. (Facing; 275˚)

Figure (7) Thin bedded slate of Undifferentiated Flysch Unit is underlying by the gravel bed as an unconformity, west of Myinwataung village. (Facing; 300˚)

Figure (8) Poorly sorted (pebble to large cobble size) rock materials firmly cemented by calcareous sandy matrix in Paunggyi conglomerate, west of Magyibingwin village. (Facing; 264˚)

Figure (9) Massive, thick bedded, quartz-pebble conglomerate in the Paunggyi Formation, SW of Kanyin Dam (Facing; 242˚)

Undifferentiated Molassic Unit

This unit is mainly composed of slate, calc-slate, calc-phyllite with occasional intercalated flat lenses of sandstone and sandy limestone layers in the lower part, thick alteration of sandstone or quartzite and shale or slate in the middle part, thin alteration of sandstone or quartzite and shale or slate with local present of grain supported to matrix-supported, polylithic conglomerate lenses in the upper part (Fig. 10). Thick bedded, medium to coarse grained, poorly sorted sandstone with subordinate shale layer are found in the uppermost part (Kyaw Win and Thit Wai, 1971).

One of the significant features is horizontal burrows present at the bedding plane surface of the fine sandstone (Fig. 11). The approximate width of burrows range occurs from 4 to 5 mm. The Undifferentiated Molassic Unit overlies the Paunggyi Formation

conformably. This unit gradually changes upward into Okhmintaung Formation of the Late Oligocene. The age of the Undifferentiated Molassic Units can be recognized as Eocene to Early Oligocene (Saw Ngwe Khaing, 2007; Lin Thu Aung, 2008).

Figure (10) Sandstone and Shale interbedded of the Undifferentiated Molassic Unit, SW of Wadawgwin village. (Facing; 160˚)

Figure (11) Sandstone with shale intercalation of Undifferentiated Molassic Unit, and inclined burrows, W of Myinwataung. (Facing; 154˚).

Okhmintaung Formation

"Okhmintaung Sandstone" is first proposed by Lepper (1933) for the sandy unit of Okhmintaung Hill (N19˚ 33' & 94˚ 54') in Magway Region. The lithostratigraphic unit "Okhmintaung Formation" is later used by Aung Khin and Kyaw Win (1969).

Okhmintaung Formation is mainly made up of poorly sorted, coarse-grained, massive sandstone, argillaceous grits with minor intercalation of sandy shale layers and occasional flat lenses of grain-supported polylithic conglomerate and clay-pebble conglomerate. Sandstone concretions are common in this formation (Fig. 12 & 13).

The lower boundary of Okhmintaung Formation is overlain by the Undifferentiated Molassic Unit conformably. Upper boundary of this formation is unconformable with the Pyawbwe Formation. The age of the Okhmintaung Formation is assigned to the Late Oligocene (Aung Khin & Kyaw Win, 1969).

Figure (12) Horizontal burrow present at the bedding plane surface of the sandstone unit exposed at near the Kanyin Dam Spillway. (Facing; Plan View)

Figure (13) Grey to bluish grey colour of the Okhmintaung Formation, with ripple marks, at Myotaung Chaung (Facing; 160˚)

Pyawbwe Formation

The name "Pyawbwe Clay" was first introduced by Lepper (1933) in which comprising of argillaceous unit. It is the oldest of Upper Pegu Group. This unit is well exposed near Pyawbwe village (N 20˚ 1' & 94˚ 8' E) in Magway Region. Later, Aung Khin and Kyaw Win (1969) proposed into lithostratigraphic unit, "Pyawbwe Formation".

Pyawbwe Formation is relatively quite softer than the other units. Therefore, it has the rolling topography. This formation is mainly composed of thick accumulation of fine clastic sediments composed mainly of grey and bluish grey sandy clay layers, sandstones and limestone body lenses can be designated as Pyawbwe Formation (Fig. 14 & 15).

This formation is unconformably overlain upon the Okhmintaung Formation and upper boundary is gradually changed into Kyaukkok Formation. The age of the Pyawbwe Formation is regarded as Early Miocene (Lin Thu Aung, 2008).

Figure (14) Grey to bluish grey clay layers of the Pyawbwe Formation, near the Mamya Dam Spillway. (Facing; 319˚)

Figure (15) Miocene Limestone of Pyawbwe Formation exposed at Tontaung. (Facing; 170˚)

Irrawaddy Formation

Irrawaddy Formation is rest upon the upper surface of the Obogon Formation. On the basic of loosely consolidated sandrocks with abundant silicified fossil woods, it was first assigned as "Fossil Wood Group" by Theobald in 1873. In 1875, Noetling gave the name "Irrawaddy System" to this type of lithology. Later, Pascoe (1959) has modified it and use "Irrawaddy Sandstone". The lithostratigraphic name "Irrawaddy Formation" was proposed by Aung Khin and Kyaw Win (1969). The Irrawaddy Formation is well recognized by loosely cemented sandy grits, with milky quartz pebbles and gravel beds and subordinate sandy shales with thick to very thick bedded nature (Fig. 16 & 17). The formation is regarded as Late Miocene to Pliocene in age (Aung Khin & Kyaw Win, 1969).

Alluvium

The flat lowland region of the eastern part of the study area has been observed the alluvial deposit (Fig. 18).

Serpentinite

In the study area, the ultrabasic rocks of serpentine bodies are exposed as linear bodies (Fig. 19). The serpentinites are exposed near the boundary with tectonic contact (near the contact of regional thrust faults) and metamorphic rocks (Kyaw Htun 1999 and Tun Tun Min, 2014) and highly sheared deformation. They show reddish brown to pale green in

weathered zone with greasy luster and soapy feeling on the smooth surface (Fig. 20). On the fresh surface the color is usually dark greenish to deep green.

Figure (16) Loosely cemented, wavy irregular bedding surfaces with local scouring and nearly horizontal beddings characters of gravel beds occurs in the Irrawaddy Formation, south of Pandaw Gyi village. (Facing; 20˚)

Figure (17) Loosely cemented sandstone with planar cross stratification of the Irrawaddy Formation, west of Banbwekon village. (Facing; 45˚)

Figure (18) Alluvial deposit of flat low lying plain southeast of Myama Dam. (Facing; SW)

Figure (19) Outcrop nature of the serpentinite exposed at the southern part of the study area, north of

Figure (20) Reddish brown to pale green serpentinite rock body, west of Legongyi village (Facing; 350˚)

Wadawgwin village. (Facing; 220˚)

Attitudes of beds

Field measurement indicates that the rocks exposed in the study area and its environs can be organized into the three different categories, according to the attitude of beds.

The Undifferentiated Flysch Unit represents the first category and their beds generally indicate NNE-SSW in strike-position with moderate to steep dips towards SE (Fig. 21). Some exceptions show NW-SE striking of beds due to local folding and faulting.

The Early Tertiary Formations such as Paunggyi Formation, Undifferentiated Molassic Unit and Okhmintaung Formation represent the second category. These formations commonly show NNE-SSW in strike direction with gentle to moderate dips toward SE (Fig. 22, 23 & 24).

The Late Tertiary formations such as Pyawbwe Formation and Irrawaddy Formation characterized by NNE-SSW general strike direction with gentle dips toward SE (Fig. 25).

The stereoplot analyses of the contour diagram for bedding nature of the study area are shown NE-SW means striking and average dip amount 63.7º (Fig. 26).

Figure (21) Undifferentiated flysch Units shows moderate to steep inclination of beds at the Ma za li Chaung area, west of Legongyi village (Facing; West).

Figure (22) Paunggyi Formation shows moderate inclination (25˚/197˚) of bed, west of Myinwataung (Facing; East).

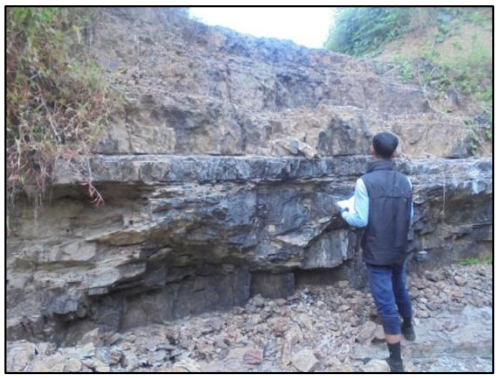


Figure (23) Undifferentiated Molassic Units shows moderate to gentle bed

Figure (24) Moderate dipping nature of the thick bedded sandstone with

inclination at near the Pathein-Monywa Car Road, north of Magyibingwin village (Facing; 10º).

shale intercalation of Okhmintaung Formation, west of Banbwekon village (Facing; 50˚).

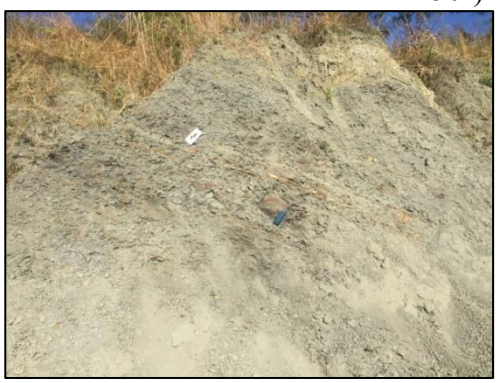


Figure (25) Moderate to gentle dipping nature of the Pyawbwe Formation, near the Mamya Dam Spillway (Facing; NW).

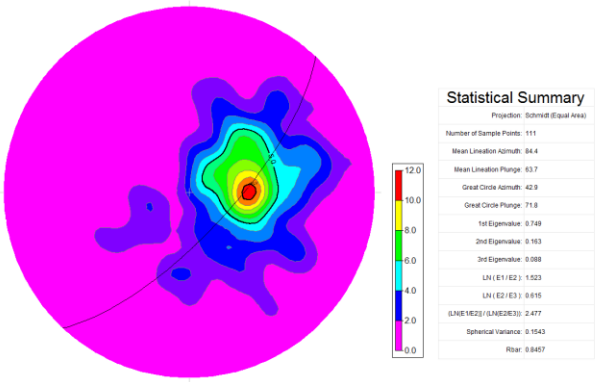


Figure (26) Stetroplot analysis of the bedding nature of the study area.

CONCLUSION

The study area is located about 42 km from western part of Hinthada. It is bounded by the North latitudes N 17º 30' to N 18º 15' and East longitude E 94º 50' to E 95º 5'. Tectonically and geomorphologically, Myanmar is subdivided into three main provinces which are N-S trending linear belts namely; Eastern highland, Central Lowland and Western Ranges. The study area is located at the eastern flank of Western Ranges.

The highest point of the area is Alan Taung, 518 m located at the central part of the study area. The general topographic trends are nearly N-S or NW-SE direction. Alluvial deposits are covered at the eastern part of the area. Topographically, the study area can be subdivided into three topographic units such as: (1) mountainous region (between 200 m to 500 m above sea level) (2) rolling hilly unit (100 to 200 m above sea level) and (3) flat lowland unit (less than 100 m above sea level). In the study area, main streams, Padaw Chaung, Mamya Chaung, Kanyin Chaung, Tha byu Chaung, Nangathu-myauk Chaung, Nangathu-taung Chaung, Gyat Chaung, Mezali Chaung and Thida Chaung flow from NW to SE direction. In the western part of the area, the short tributaries and steep sided, narrow V-shaped gullies are the most common characters of the streams. All streams are sub-angular to dendritically flowing in the study area.

In the study area, there are six lithostratigraphic units. They are Undifferentiated Flysch Unit (Late Cretaceous to Paleocene), Paunggyi Formation (Paleocene), Undifferentiated Molassic Unit (Eocene to Early Oligocene), Okhmintaung Formation (Late Oligocene), Pyawbwe Formation (Early Miocene) and Irrawaddy Formation (Late Miocene to Pliocene). There are also exposed the untramafic rock, serpentenite (Late Cretaceous to Early Eocene).

Thin alteration sequence of thinly bedded slate with minor fine grained sandstone and pebbly greywacke along the western part of the area represents the Undifferentiated Flysch Unit of Late Cretaceous age. Paungyi Formation is composed of thick accumulation of grain-supported, sub-angular to sub-rounded rock materials with a wide range of variation in size, ranging from small pebbles to large boulder. Undifferentiated Molassic Unit is mainly composed of slate, calc-slate, calc-phyllite, thick alteration of sandstone or quartzite and shale or slate, thin alteration of sandstone or quartzite and shale or slate with local present of grain supported to matrix-supported, polylithic conglomerate lenses. Okhmintaung Formation is mainly made up of poorly sorted, coarse-grained massive sandstone, argillaceous grits with minor intercalation of sandy shale layers. Mainly grey and bluish grey sandy clay layers, sandstone and intra-formational conglomerate can be designated as Pyawbwe Formation. Irrawaddy formation is most widely distributed in the eastern part of the study area. The formation is well recognized by loosely cemented sandy grits, with milky quartz pebbles and gravel beds and subordinate sandy shales with thick to very thick bedded nature.

Undifferentiated Flysch Unit exposed as NNE-SSW strike with steep to moderate slope. Early Tertiary formations are shown NNE-SSW strike direction with moderate to gentle dips toward SE. Late Tertiary formations are characterized by NNE-SSW general strike direction with gentle dips toward SE. The stereoplot analyses of the contour diagram for bedding nature of the study area are shown NE-SW means striking and average dip amount 63.7º. Undifferentiated Flysch and Undifferentiated Molassic Units are highly deformed by the intense shear-folding processes.

Acknowledgements

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