Study on Structural significances of Sagaing Metamorphics and Minwun Metamorphics, Exposed in Taungnyo–Wachat Area, Sagaing Region

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Abstract

The study area lies between N 21˚ 52′ to N 21˚ 59′ and E 95˚ 56′ to E 96˚ 00′ in one inch topographic map of 84 O/13 and 93 C/1. That covers about 14 square miles. Two metamorphic series are exposed in the study area, one on the Minwun range is Minwun metamorphics and the other at the Sagaing ridge is Sagaing metamorphics. The Minwun range and Sagaing ridge are separated by Sagaing fault. The Sagaing metamorphics are composed of diopside-calc silicate rocks, marbles: white marble, phlogopite-diopside-forsterite marble, and gneisses: hormblende biotite gneiss, garnet biotite gneiss. Minwun metamotphics are composed of chlorite schist, garnet muscovite schist and antinolite schist. Two types of metamorphism can be recognized in the study area; regional metamorphism and dynamic metamorphism. Quartz ribbon and myrmekite are formed due to the high-grade metamorphism. The distinctive microstructures: rotation of garnet, augen shape hornblende porphyroclast and mineral fishs are used to postulate the shear sense indicators. Domino boudin occurs in Sagaing metamorphics that indicated N to S right lateral sense of shearing. Rotation of garnet porphyroclasts , σ clast of hornblende porphyroclast and mineral fish occur in the Mniwun metamorphics that indicated N to S sense of shearing. Thus, Sagaing metamorphics and Minwun metamorphics are formed high-grade metamorphism base on microstructures, and shear sense indicators of these metamorphics indicates N-S sense of shearing..

Keywords : Sagaing metamorphic, Minwun metamorphic, myrmekite, Quartz ribbon

Introduction

The study area lies between latitude N 21° 52' to N 21° 59' and longitude E 95° 58' to E 96° 00' of one inch topographic map of 84-O/13 and 93-C/1. That covers about 14 square miles. The study area (Figure.1), north of Sagaing lies within the eastern margin of the Burma (Myanmar) Plate and western margin of Sundaland, shearing past each other along the Sagaing Fault (Win Swe 1970). It is 1500 km long, major right-lateral strike-slip structure , which is also thought to represent the present plate boundary between the Burma and the Sunda plates (Myint Thein et.al., 2017).

Previous Works

La Touche (1913), in the Memoir of the Geological Survey of India, generally investigated the first geological information. He assigned that the Sagaing metamorphics was the southern continuation of the Mogok Series which was also regarded as Archean in age. Chhibber (1934) considered that the age of the metamorphic rocks of the Sagaing hills are the same as those of the Mogok Stone Tract which is Precambrian in age. Win Swe (1972) studied and systematically mapped a major right lateral strike-slip fault between Sagaing and Yelamaw village for a distance of 36 miles. He studied effects of and evidences for the Sagaing fault and made some comprehensive reports. Maung Maung (1979) studied the southern part of Sagaing hills and firstly proposed the term “Kyaukta Formation” for the older sedimentary unit in this area. He suggested that the Kyaukta Formation may also be the southernmost continuation of the Male Formation. Myint Thein et al. (1982) proposed the

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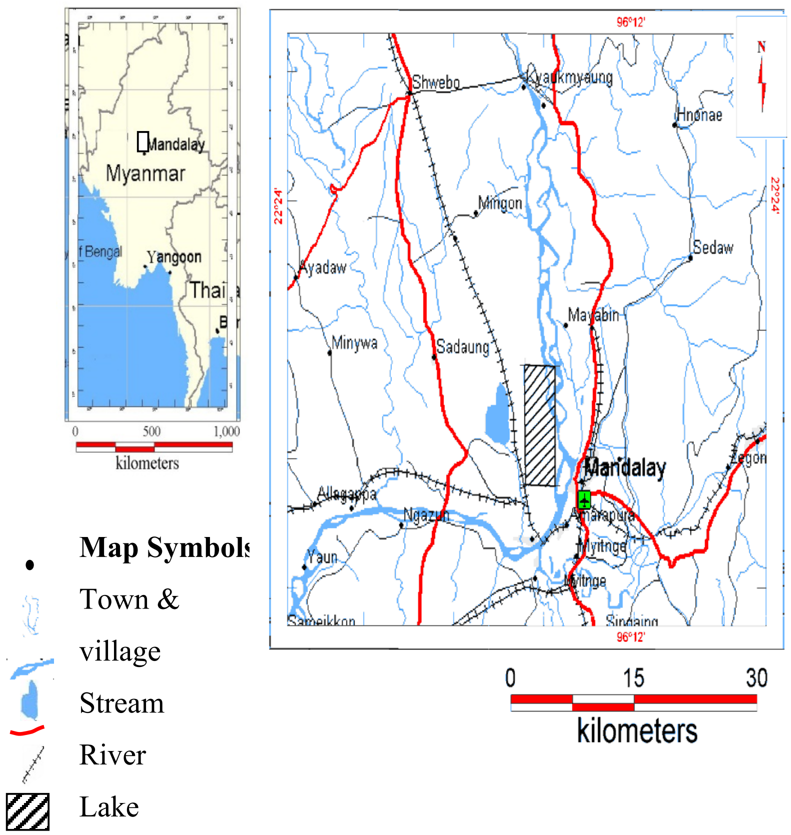

Figure (1). Location map of the study area.

Geology of the part of the eastern margin of the Central Burma Belt between Sagaing and Tagaung. The metamorphic rocks belong to Mogok Series in which establishment of the petrographic units and determination on age of metamorphism as pre-Tertiary. Me Me Aung (2007) studied "Petrographic Criteria and Petrogenetic Significance of the Metamorphic Rocks of the Sagaing Area" in which she proposed the metamorphic grade, the metamorphic facies and facies association and PTt (pressure-temperature-time) of that area.

General Geology

General Statement

The rock units in the study area can be subdivided into two sequences, Sagaing Metamorphics and Minwun Metamorphics. The Sagaing Metamorphics comprise of calcareous and pelitic classes and the Minwun Metamorphics comprise of basic and pelitic classes.

Sagaing Metamorphics

The name as "Sagaing Metamorphic Sequence" was given by Kan Saw (1976) for the metamorphic rocks found along the Sagaing ridge. Myint Thein, (1982)were also named "Sagaing Metamorphics" by. The Sagaing Metamorphics are mainly composed of diopside calc-silicate rocks, marbles: white marble, phlogopite-diopside-forsterite marble, and gneisses: hornblende biotite gneiss, garnet biotite gneiss. The whole sequence of the Sagaing metamorphics trending in NNW-SSE direction has a general dip NNE with moderate inclination of 20°- 60°. Due to their resistance to denudation, marbles occupies the higher altitude than the other lithologies.

Diopside calc-silicate rocks

This unit is well exposed at the east of Taungphila taung. The calc-silicate rocks are dark green in fresh and grey in weathered surface, hard and compact which occasionally display rib-and-furrow structures. It mainly consists of quartz, calcite and such as diopside. In this unit, calc-silicate rocks are found with the intercalated gneiss layers that are highly contorted into small folds (Figure.2). Moreover, marbles are also intercalated in calc-silicate. The calc-silicate rocks generally trend N-S and dipping eastwards about 40° to 70°.

White marble

White marble is well exposed around the Taungphila and Nangaing pagoda, especially near the gate of Ponnyashin pagoda. This unit is mainly composed of white marble with subordinate amount of other marble and calcsilicate rocks. These marbles show dark grey on weathered surface and a milky white colour on fresh surface that forms small sink holes and solutions pits. It is composed almost wholly of coarse grained, well crystaline calcite with minor amount of graphite and phlogopite that shows massive nature (Figure .3). This unit has a general strike of NE-SW direction with dips of 20° - 40° towards east.

Phlogopite-diopside-forsterite marble

This unit is well exposed north of the Padamyasedi, sides of the car road from Taungphila to Padamya pagoda, eastern part of Yega Lake and around the East of Taungnyo village (Figure.4). This marble unit is composed of phlogopite, diopside, forsterite and calcite. Phlogopite, diopside, forsterite segregation are abundant in this unit. This unit occurs as hard and compact and displays light green to green color on fresh surface, with white spots and dark colour on the weathered surface.

Hornblende biotite gneiss interbedded with garnet biotite gneiss

Hornblende biotite gneiss cropps out at the northern part of the Padamyasedi and in the east of Taungnyo village, and environs of the Wachet village. Hornblende biotite gneiss are hard, compact and highly jointed showing well banded gneissose texture due to alternative arrangement of quartz-feldspar rich (felsic) layers and hornblende-biotite rich (mafic) layers (Figure .5). Their foliation is striking NW-SE in direction with 20°-40° dip eastward. Occurrence of both crosscutting (discordant) and sub-parallel to foliation (concordant) quartzo-feldspathic veins are common throughout the unit which is chiefly composed of quartz, feldspar, hornblende, and biotite.

Garnet biotite gneiss is well exposed around the Wachet village, along the foot path from Yega to Arlaung village and eastern part of East Taungnyo village (Figure 6). This rock unit is mainly composed of feldspar, quartz, biotite, garnet and other accessory minerals that show gneissose texture. Foliation in hand specimen is well marked by platy brown biotite layers in whitish, quartzo-feldspathic groundmass. On the weathered surface, it is readily disintegrated into loosed fragments. Foliation is striking in NW-SE in direction with 20° to 40° eastward dip.

Figure (2). Highly jointed diopside calc-silicate rocks exposed east of Taungphila.

Figure (3). White marble exposed at around the Taungphila.

Figure (4). Phologopite diopside forsterite marble exposed at the north of Padamya Sedi.

Figure (5). Highly jointed hornblende biotite gneiss showing gneissose texture exposed at the north of the Padamya .pagoda.

Figure (6). Highly jointed garnet biotite gneiss showing gneissose texture exposed west of Wachat village.

Minwun Metamorphics

Minwun metamorphics can be grouped into three types as follows; (1) Chlorite schists, (2) Actinolite schists and (3) Garnet muscovite schists.

Chlorite Schist

Chlorite schist is well exposed in the northern and central parts of the Minwun range; especially between Bawdimandai pagoda and Salin Pagoda, and near the Kyaukta village. Chlorite schist is exposed in contact with serpentinite body on the western bank of Yega Lake. The chlorite schist is strongly foliated, light green to green colour, fine grained rocks. The foliation is trending in NW-SE with about 40° east dips.

Actinolite Schist

Actinolite schist is well exposed at the side of the car tracks to the east of Taungnyo village and eastern flank of the Bawdimandai Pogoda. This rock is mainly composed of quartz, feldspar, actinolite, hornblende and other accessory minerals. On the fresh surface, it shows a light green colour (Figure7) and segregation of wellformed fibrous to sometimes acicular actinolite crystals are observed.

Garnet-muscovite Schist

Garnet-muscovite schist is well exposed in the central part of the Minwun range and sides of car-track from east of Taungnyo. It is light grey to whitish in colour, medium to coarse-grained and chiefly composed of muscovite, quartz, feldspar, garnet and other accessory minerals (Figure 8). Abundance of muscovite with garnet porphyroblasts renders this rock easily recognizable in the field. Foliation is due to segregation of thin layers alternately rich in mica and in quartz - feldspar. The strike is NW-SE with 30°to 50° east dipping.

Amphibolite

Amphibolite is well exposed around the Minwun range and throughout the west side of the Sagaing Fault. This rock is highly jointed, coarse grained, dark green to black on fresh surface (Figure 9). It is chiefly composed of amphibole mineral (especially Hornblende), plagioclase, quartz and other accessory minerals. This unit strikes in NNW-SSE direction with dips of 40° to 60° towards east. Moreover, the highly jointed and dark green colour, banded amphibolite is found at the central part of the Minwun ranges especially near the Salin Pagoda.

Serpentinite

A small body of serpentinite has been observed at the west bank of Yega Lake. Serpentinite bodies are found along with the older Minwun metamorphic, Kyaukta Formation and Irrawaddy Formation along the Sgaing Fault. In outcrop, the serpentinite is in contact with chlorite schists in the southern end and with sandstone of the Kyaukta formation in other parts. They are bright green to dark green in color and highly deformed (Figure.10). The time of emplacement of serpentinites is Post-Pliocene that is associated with the major lateral displacement of the Sagaing Fault (Myint Thein et al., 1982).

The evidence of no contact aureole and cross cutting relationship in adjoining chlorite schist and overlying upper Miocene sediments, and the change from serpentinites to chlorite schist is transitional indicate a normal mineral paragenesis sequence for most metamorphosed ultrabasic rocks (Me Me Aung, 2007).

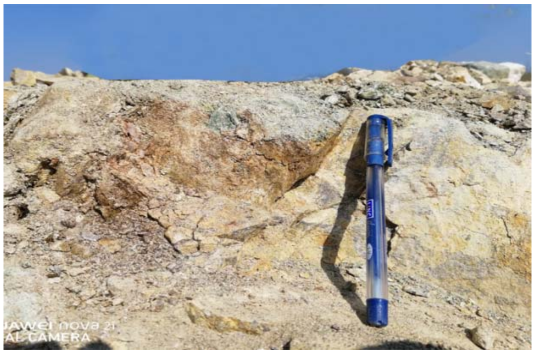

Figure (7). Actinotlite schists exposed at north–east of the Taungnyo village.

Figure (8). Garnet muscovite schist exposed in the central part of the Minwun range.

Figure (9). Highly jointed amphibolite that is well exposed near the cart track at south-east of Taungnyo

Figure (10) Serpentinite outcrop at the west of the Yega Lake.

Structural Significance

Mesostructural Analysis

Asymmetric Boudins

Biotite gneiss shows asymmetric boudins occur in the Sagaing Metamorphics that indicate S to N right- lateral sense of shearing (Figure 11). Two types of asymmetric boudins can be distinguished shear band boudins and domino boudins. Shear band boudins have a long, curved lenticular shape and large relative displacement and synthetic drag on an inter-boudin surface that is gently inclined to the boudin exterior surface. Domino boudins have an angular shape, an inter-boudin surface steeply inclined to the boudin exterior surface with small relative displacement and unique antithetic flanking folds instead of synthetic drag (Passchier and Trouw, 2005).

Figure (11). Biotite gneiss shows asymmetric domino boudins.

Microstructural Analysis

The deformation microstructures that have been encountered in the thin sections are analyzed. The most distinctive structure; rotation of garnet, augen shaped hornblende porphyroclast and mineral fishs are used as shear sense indicator. The rotation of garnet porphyroclast occurs in garnet muscovite schist. The sense of shear is determined by the rotation of porphyroclast. The rotation of garnet porphyroclast indicates N to S left sense of shearing associated with muscovite, quartz. The hornblende porphyroclast occurs in amphibolite. The tails of the hornblende porphyroclast that indicate N-S left- lateral sense of shearing (Figure 12). Two types of mineral fish occur in garnet muscovite schist; (i) lenticular (mica and garnet) and (ii) rhombohedral (feldspar). They show N -S to left- lateral sense of shering. Quartz easily deforms by dynamic recrystallization which is a key mechanism for understanding deformation processes and the most important deformation mechanism. Quartz ribbon occurs in garnet biotite gneiss in which quartz grains are formed by the strong deformation followed by recovery and significance grain boundary migration. Myrmekitie occur in hornblende-biotite gneiss. It is common in high grade metamorphic rocks.

Asymetric augen structures (Simpson and Schmid, 1983, Bose and Marques, 2004) are large and flow-resistant grains, also named as porphyroclasts occurring within a more ductile and fine-grained matrix. They are typically feldspars, garnets or hornblende grains wrapped by tails of weaker minerals or finer grained recrystallized material of the same mineral as the prophyroclast. This fine-grained material within the tails is usually the product of dynamic recrystallization but pressure solution may also be involved. These tails are used as shear sense indicators and are considered as reliable criteria. The porphyroclast-tail geometry (□ -clasts) refers to the shape of the tail which develops around the porphyroclast. The □ -clasts are unrotated clasts whose tail does not cross the foliation. Moreover, □ -clasts of the amphibolite indicate the simple N-directed, right-lateral shear sense (Figure 13). Such shapes are commonly observed in hornblende porphyroclast.

Myrmekite

Hornblende-biotite gneiss display myrmekite textures that occurred at the rim of the K-feldspar in which bulbous symplectite of vermicular quartz in K-feldspar (Figture 14). It is common in high grade metamorphic rocks and igneous rocks, mostly as breakdown product of K-feldspar during retrograde metamorphism. Myrmekite may develop at stress concentration sites during progressive deformation and in that case can serve as a shear sense indicator (Passchier and Trouw, 2005). Although P, T and the chemical conditions govern the replacement reaction, because of additive shear it concentrates along the edges facing incremental shortening direction of the K-feldspar (Zachar and Toth, 2001).

Figure(12).Rotated porphyroclast of garnet indicate N to S left sense of shearing.

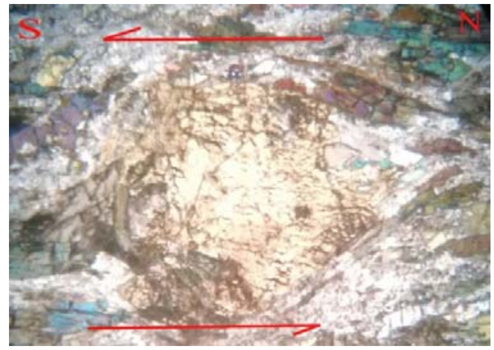

Figure (13). Augen shape hornblende porphyroclast occurs in amphibolite that indicates N-S left-lateral shear sense.

Figure (14). Photomicrograph of hornblende- biotite gneiss display myr-mekite textures.

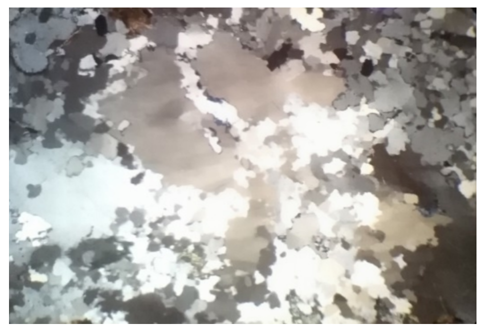

Figure (15). Grain boundary migration of quartz in biotite gneiss.

Quartz ribbon

Grain boundary migration recrystallization (GBM) is observed in hornblende biotite gneiss exposed at the Wachet Village. This domain is characterized by highly amoeboid grain shapes (Figure 15). Grain boundary migration recrystallization (GBM) evidences for even higher temperature where quartz grains are larger displaying even more amoeboid shapes and grain boundaries which are not always detectable. Grain boundary pinning is weak and for the highest temperature conditions, chessboard patterns are observed.

Garnet biotite gneiss display quartz ribbon textures in which quartz grains are single crystals with an elongate shape with lack intracrystalline deformation structures. Moreover, equidimensional feldspar grains are common in these rocks. Quartz ribbon occurred from low- to high grade quartzo-feldspathic rocks. This quartz ribbon may be formed from high grade because monocrystalline quartz ribbons in high grade gneiss are probably formed by strong deformation followed by recovery and significant grain boundary migration (Mandal et al., 1997). Quartz ribbons occur in high-grade gneiss (500-700°C) is probably formed by strong deformation followed by recovery and recrystallization (Passchier and Trouw, 2005) (Figure 16).

Mineral fish

In the studied thin-sections, mica, garnet and feldspars show the characteristic fish shape. Mica fish, garnet fish and feldspar fish are found in garnet muscovite schist (Figure 17, 18, 19). Two broad morphologies of mineral fish are observed; (i) lenticular (mica and garnet) and (ii) rhombohedral (feldspar). The lenticular mica fish indicates that the removal of small recrystallized or cataclastically torn-off grains along the upper and lower parts whereas elongated garnet fish formed crystaplastic deformation at higher temperature.The rhombohedral feldspar fish indicates that it may be formed by internal deformation in high-grade quartzofeldspathic rocks (Passchier and Trouw, 2005).

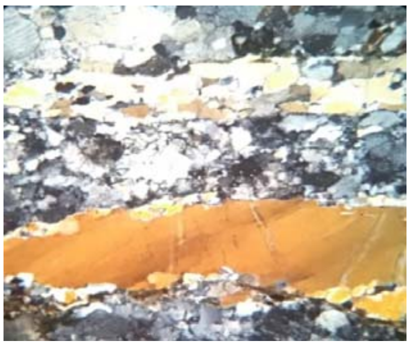

Figure (16). Photomicrograph of biotite gneiss display quartz ribbon.

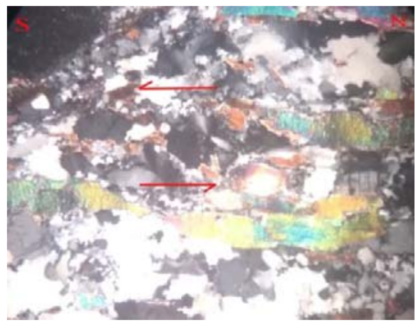

Figure (17). lenticular mica fish occurs in mica schist (N to S left-lateral sense of shearing).

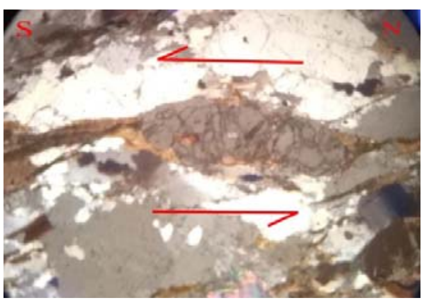

Figure (18). Lenticular garnet fish occurs in mica schist (N to S left-lateral sense of shearing)

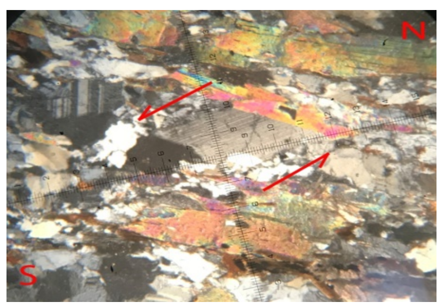

Figure (19). Rhombohedral feld-spar fish occurs in mica schist (N to S left-lateral sense of shearing).

Discussion

The study area, north of Sagaing lies within the eastern margin of the Burma (Myanmar) Plate and western margin of Sundaland, shearing past each other along the Sagaing Fault (Win Swe 1970). It is a major right-lateral strike-slip structure 1500 km long , which is also thought to represent the present plate boundary between the Burma and the Sunda plates (Myint Thein et.al 2017).

Rock units exposed in the study area are of NNW-SSE trending two metamorphic series, one on the Minwun range is Minwun metamorphics and the other at the Sagaing ridge is Sagaing metamorphics (Kan Saw, 1975). The Minwun ridge and Sagaing ridge are separated by Sagaing fault. The east side of the fault is Sagaing Metamorphics in which marbles, calcsilicate and gneisses which are covered by Irrawaddy Formation and also capped by Quaternary terrace deposits. The Sagaing metamorphics are the western most outcrop of the Mogok series on Precambrian age (Chibber, 1934).

The Sagaing Metamorphics are composed of diopside-calc-silicate rocks, marbles; white marble, phlogopite-diopside-forsterite marble, and gneisses; hornblende biotite gneiss, garnet biotite gneiss. Diopside-calcsilicate rocks are dark green in fresh and grey in weathered surface, hard and compact which occasionally display rib-and-furrow structures. It mainly consists of quartz, calcite and calc-silicate minerals such as diopside. White marble is mainly composed of white marble with subordinate amount of other marble and calcsilicate rocks. It show dark grey on weathered surface and a milky white colour on fresh surface that forms small sink holes and solutions pits. It is composed almost wholly of coarse-grained, well crystalline calcite with minor amount of graphite and phlogopite that shows massive nature. Phlogopite-diopside-forsterite marble is thick bedded to massive, hard and compact that is mainly composed of phlogopite, diopside, forsterite and calcite. Phlogopite, diopside, forsterite segregation are abundant in this units. Hornblende biotite gneiss is hard, compact and highly jointed showing well banded gneissose texture. The unit is chiefly composed of quartz, feldspar, hornblende, and biotite.

Schists in the Minwun range can be grouped into three types; chlorite schist, actinolite schist, garnet muscovite schist. Chlorite schist is strongly foliated, light green to green colour, fine grained rocks. This rock is chiefly composed of quartz, feldspar, chlorite and other accessory minerals. Actinolite schist is mainly composed of quartz, feldspar, actinolite, hornblende and other accessory minerals. Garnet muscovite schists is light grey to whitish in colour, medium to coarse-grained and chiefly composed of muscovite, quartz, feldspar, garnet and other accessory minerals.

Amphibolite is highly jointed, coarse grained, dark green to black on fresh surface. It is chiefly composed of amphibole mineral (especially Hornblende), plagioclase, quartz and other accessory minerals. Serpentinite bodies intruded into the older Minwun metamorphic, Kyaukta Formation and Irrawaddy Formation along the Sgaing Fault. They are bright green to dark green in color and highly deformation.

Grade of metamorphism is defined on the basic of appearance of Ca-Mg silicate minerals, such as hornblende, diopside and forsterite. In accordance with general sequence described by Eskola (1922) and refined by Bowen (1940) and Tilley (1951), diopside + forsterite zone is higher in grade than diopside or forsterite zone .Phlogopite- diopside - forsterite marble exposed at the eastern part of Yega Lake whereas phogopite diopside marble exposed at Padamyasedi. Therefore, the metamorphic grade of the Sagaing metamorphics increases towards the west.

Bertrand et al. (2001) gave 40Ar/39Ar date on the phlogopite of the northeastern Shan Plateau border in mogok area (GPS; 21° 56' 30" -95° 58' 57") as 19.8±0.3Ma. Moreover, it can be concluded that the Sagaing metamorphics were metamorphosed from sedimentary sequence of dolomite and siliceous limestones and pelitic rocks during Tertiary period.

According to Bose and Marques (2004), few majors factor control tail geometry among which the degree of adherence of the inclusion to the matrix and the rheological behavior of the mantle relative to the matrix. In case no tail is present around the prophyroclast, shearing sense may still be given if the porphyroclast has been rotated. In such case, the sense of shear is determined by the sense of rotation of the propyroclast. In present study, the pophyroclasts of garnet in garnet muscovite schist is rotated as an anticlockiswise that indicate N to S left sense of shearing.

Quartz easily deforms by dynamic recrystallization which is a key mechanism for understanding deformation processes and the most important deformation mechanism in quartz. Stipp et al. (2002) proposed another classification based on observation from natural conditions. This system focuses on quartz dynamic recrystallization mechanisms such as grain boundary migration recrystallization.

Biotite gneiss shows asymmetric domino boudins occur in the Sagaing Metamorphics that indicate S to N right- lateral sense of shearing .The sense of shear is determined by the sense of rotation of propyroclast. The pophyroclasts of garnet in garnet muscovite schist is rotated as an anticlockiswise that indicate N to S left-lateral sense of shearing. Asymetric augen structures are large and flow-resistant grains, also named as porphyroclasts occurring within a more ductile and fine-grained matrix.The hornblende grains wrapped by tails of weaker minerals or finer grained recrystallized material of the same mineral as the prophyroclast. This fine-grained material within the tails is usually the product of dynamic recrystallization but pressure solution may also be involved. These tails are used as shear sense indicators. The □ -clasts of the amphibolite indicate the simple N-S left-lateral shear sense. Such shapes are commonly observed in hornblende porphyroclast.

Myrmekite is common in high-grade metamorphic rocks (above 600°C), mostly as breakdown product of K-feldspar during retrograde metamorphism. Myrmekite may develop at stress concentration sites during progressive deformation and in that case can serve as a shear sense indicator. Quartz easily deforms by dynamic recrystallization which is a key mechanism for understanding deformation processes and the most important deformation mechanism. Quartz ribbon may be formed from high grade because monocrystalline quartz ribbons in high grade gneiss are probably formed by strong deformation followed by recovery and significant grain boundary migration .Two broad morphologies of mineral fish; (i) lenticular (mica and garnet) and (ii) rhombohedral (feldspar) occurs in garnet muscovite schist. The lenticular mica fish indicates that the removal of small recrystallized or cataclastically torn-off grains along the upper and lower parts whereas elongated garnet fish formed crystaplastic deformation at higher temperature. The rhombohedral feldspar fish indicates that it may be formed by internal deformation in high-grade quartzofeldspathic rocks.

Quartz ribbon and myrmekite are formed due to high-grade metamorphism. Domino boudin occurs in Sagaing Metamorphics that indicate S to N right-lateral sense of shearing. Rotation of garnet propyroclast, -clasts of hornblende porphyroclast and mineral fish occur in the Minwun Metamorphics that indicate N to S sense of shearing.

Acknowledgement

I would like to express my thanks to supervisor Dr.Thura Oo, Rector, Monywa University, for his enthusiastic guidance, valuable criticism and close supervision.

I am deeply indebted to Dr Zaw Myint Ni, Professor and Head, Department of Geology, Monywa University, for his kind permission and advice to carry out this research work.

I am greatly indebted to Dr. Myat Khine,Professor, Department of Geology, Monyea University in this paper for his encouragement, valuable advice and fruitful suggestion..

I wish to express my gratitude to all of my teachers, Department of Geology, Monywa University, for their valuable discussion and suggessions.

References

Aung Khin and Kyaw Win, 1968; Preliminary Studies of the paleogeography of Burma during the Cenozoic Union of Burma, Jour. Sci E Tench., V.1., n.2.

Bertrand, G., Rangin, C., Maluski, H., Tin Aung Han, Myint Thein, Ohn Myint, Win Maw, San Lwin, 1999; Cenozoic metamorphism along the Shan Scarp (Myanmar): evidences for ductile shear along the Sagaing fault or the northward migration of the eastern Himalayan syntaxis. *Geophysical Research Letters 26, 915–918.*

Bertrand, G., Rangina, C., 2003; Tectonics of the western margin of the Shan plateau (central Myanmar): implication for the India–Indochina oblique convergence since the Oligocene, *Journal of Asian Earth Sciences 21 1139–1157.*

Chhibber, H. L., 1934; *Geology of Burma*, Mac-Millan, London.

Davis, G.H., Reynolds, S.J., Kluth. C. F; *Structural Geology of Rocks and Regions*, Third Edition.

Kan Saw, 1976; Geology of the northern Mingun-Kabwet area. Univ. of Mandaly*, Master thesis.*

Maung Maung, 1980; Field guide book for Geology of the Sagaing-Minwun area, unpublished field report. MU.

Passchier, C W, Trouw, R A. J, 2005*; Microtectonics* ;2nd , Revised and Enlarged Edition.