Structural Significances on Metamorphism of Taung Yin Area, Sagaing Township, Sagaing Region

Pyae Phyo Han[1], Myo Thant[2], Teza Kyaw[3] & Aung Khant Khant[4]

Abstract

The research area is located in east of the Shwebo to Mandalay railway line and northern part of Sagaing Township. The metamorphics of the present area are the continuation of Mogok Metamorphic Belt (MMB) that may be divided into two sequences, viz, Sagaing metamorphic and Minwun metamorphic. Sagaing metamorphic rocks are found in the region, east of the Sagaing Fault while the latter are exposed in the west of the fault. Structurally, metamorphic rocks along the MMB are highly foliated. Foliation planes often bear NNW–SSE-trending stretching lineations. The fold axes trend NW-SE and the axial planes plunge SW that indicate the compressional shear sense from NE-SW. Under microscope, mineral fishes show shear sense and quartz ribbon and mymerkite indicate metamorphic grade. Mineral fishes are elongate lozenge or lens-shaped single mineral crystals either tilted back against the sense of shear or sub-parallel to the C-surfaces. The mica, hornblende, feldspar and quartz fish in biotite-gneiss and hornblende-biotite gneiss indicate the N-directed shear sense. It can be concluded that the Sagaing Metamorphics in the present area may be metamorphosed by high grade with north-directed shear sense.

Key words : Mogok Metamorphic Belt, Sagaing Fault, mymerkite, mineral fish.

Introduction

The research area lies east of the Shwebo to Mandalay railway line and northern part of Sagaing Township (Fig-1). It lies between latitude N 22°15' - N 22°42' and longitude E 95° 57' - 96° 02' and in UTM map sheet No. 2295-16 and 2295-04. The study area is located at the western margin of the MMB that extends for over 1500 km along the western margin of the Shan-Thai Block. Rock units exposed in the study area are of NNW- SSE trending two metamorphic series, one is the Minwun Metamorphics and the other is the Sagaing Metamorphics, and overlying on them are Tertiary sediment (Kan Saw, 1975; Myint Thein et al., 1982).

General Geology

General Statement

The continuation of Mogok Metamorphic Belt (MMB) of the present area can be subdivided into two sequences, viz, Sagaing Metamorphics and Minwun Metamorphics. Sagaing metamorphics are found in the region, east of the Sagaing Fault while the latter are exposed in the west of the fault.

Sagaing Metamorphics

The name “Sagaing Metamorphic Sequence” was given by Kan Saw (1976). These metamorphic rocks found along the Sagaing ridge were also named “Sagaing Metamorphics” by Dr. Myint Thein, 1982.

Sagaing Metamorphic is exposed in the Tertiary sediments along the western bank of the Ayeyarwady River. The sequence is mainly composed of marble, calc-silicate and gneiss rocks with quartzo-feldspathic rocks. Most of these rocks are metasedimentary rocks. Some

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quartzo-feldspathic veins occur in these metamorphic rocks and they show concordant and discordant within the rocks.

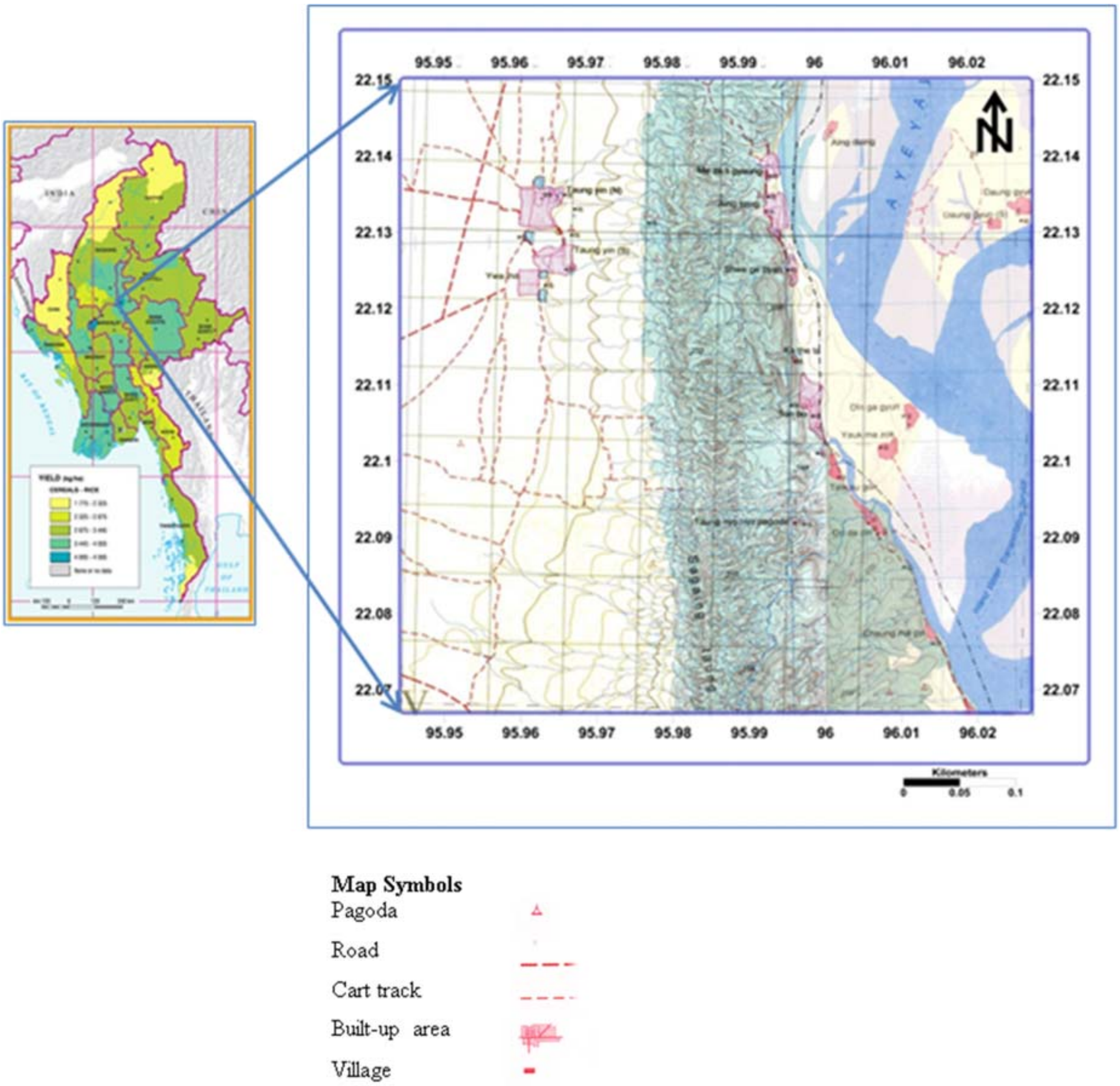

Figure (1). Location map of the study area.

Minwun Metamorphics

The Minwun metamorphics, consisting of low- to medium- grade metamorphic rocks of schist, gneiss, meta-igneous rocks, and metamorphosed limestones occur on the western flank of Sagaing Fault.

Serpentinite

A small body of serpentinite has been observed at east of Taung Yin village. They are bright green to dark green in color and highly deformed. The time of emplacement of serpentinite is post-Pliocene and is associated with the major lateral displacement of the Sagaing Fault (Myint Thein *et al.*, 1982).

Irrawaddy Formation

The sand rocks are found along the conspicuous erosional scrap with flat-top, facing eastward to the Ayeyarwady River. The wide exposures of Irrawaddy sandstones were exposed on the region east of Sagaing Fault from Htonbo to Mezaligyaung villages in the study area.

On the basis of facies change in lithology, this formation is subdivided into three members. They are

3. Gritty sandstone unit
2. Silty sandstone unit
1. Fanglomerate unit

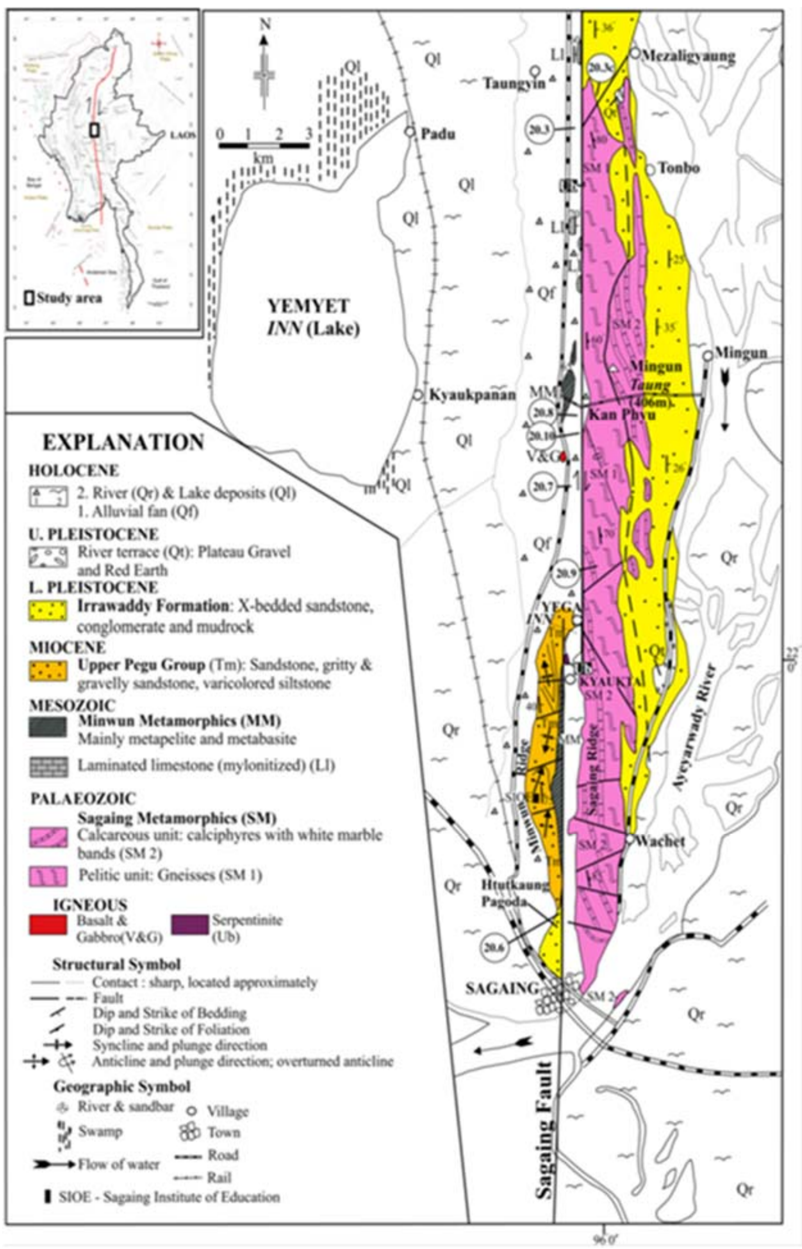

Figure (2). Geological map of the research area (Myint Thein, Kyaw Tint and Maung Maung (1978), Myint Thein *et al.*, 1982; Myint Thein 2009).

Structural significances

Mesostructural Study

Metamorphic rocks along the MMB are highly foliated. Foliation planes often bear NNW–SSE-trending stretching lineations. The deformation is not homogeneous along the belt. The most significant features of deformation can be seen in foliation planes of hornblende gneiss (Figure 3 A and B).

Ductile stretching, along a NNW–SSE direction, affecting the metamorphic rocks is observed at mesoscopic scale (Figure 4 A and B) as well as cross-cutting with the foliation planes.

Simple shear is also evidenced, in some localities, by drag-folded schistosity (Figure 5 A and B). The fold axes of drag folds run in NW-SE and the axial planes plunge SW. They indicate the compressional shear sense from NE-SW.

Minor fault planes dip NW and strike NE-SW which is affected from the NW-SE tensional shear sense. Moreover, NE–SW to ENE–WSW-striking faults were also affected by NNW–SSE-trending tensional deformation (Bertrand et al, 2003). These faults formed either during the ductile deformation at shallower structural level or just after the exhumation and cooling of the metamorphic rocks.

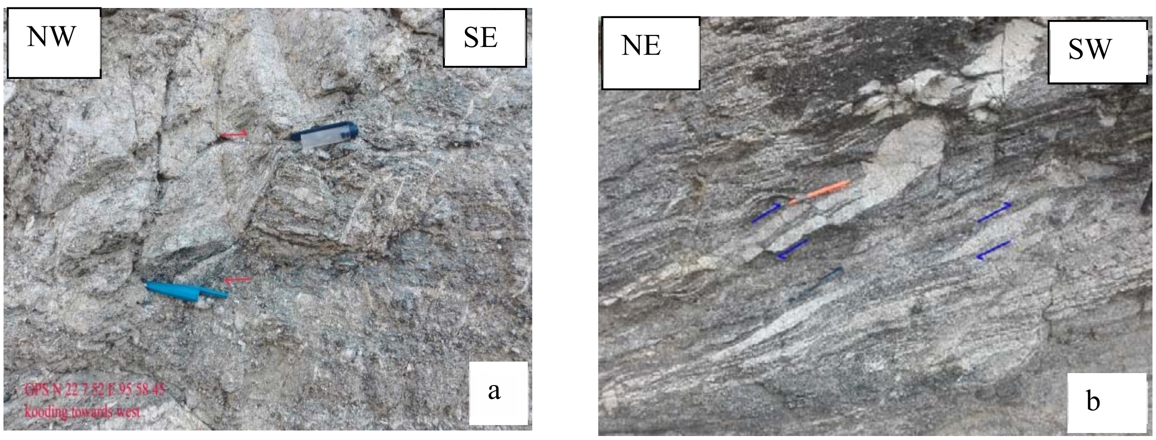

Figure (3). Field observations, in the Sagaing region with the NNW-SSE-trending Photo A and B; Shear plane parallel to foliation in hornblende gneiss (between Taung Yin and Aing Taing village).

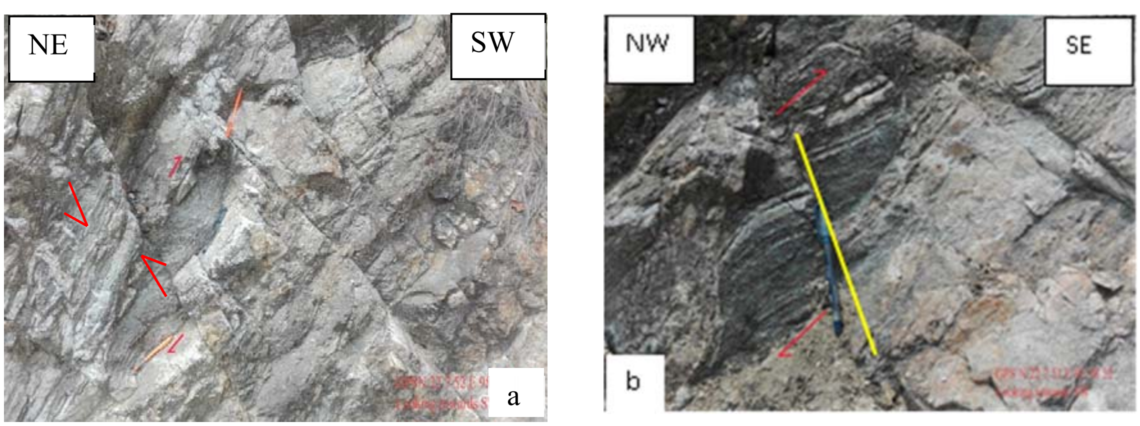

Figure (4). Field observations, in the Sagaing region, Photo A and B;Faults cross-cutting with the foliation planes which occur east of the Taung Yin village.

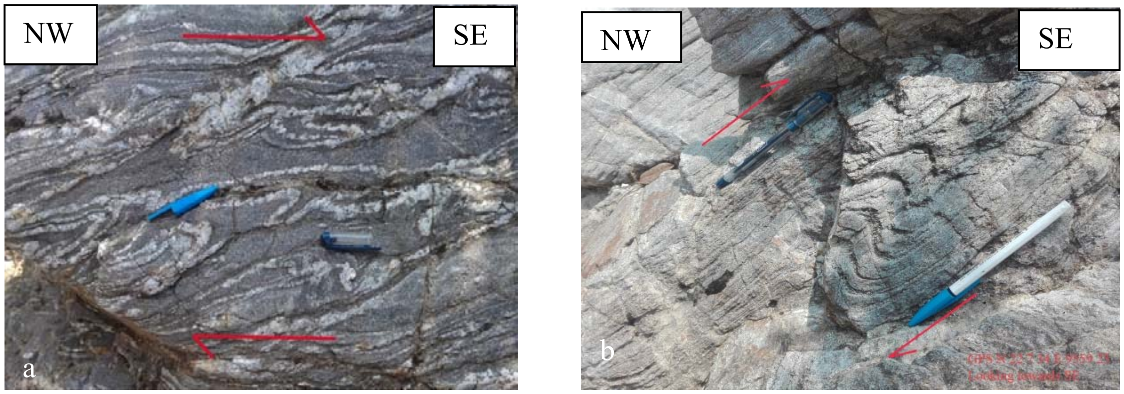

Figure (5). Field observations, in the Sagaing region, Photo A; Minor drag folds occur as west of the Shwe Ge Byan village and Photo B; Drag fold occurs as east of the Taung Yin village.

Microstructural Study

In this section, deformation microstructures that have been encountered in the thin sections are studied. According to our observations, porphyroclasts, mineral fish and quartz ribbon are found as following structures.

Porphyroclasts

Asymetric augen structures (Simpson and Schmid, 1983 and 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 quartz grains wrapped by tails of weaker minerals (i.e. micas) 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 (σ-clasts) refers to the shape of the tail which develops around the porphyroclast. The σ-clasts are unrotated clasts whose tail does not cross the foliation. Moreover, σ-clasts of the biotite gneiss indicate the simple N-directed, right-lateral shear sense (Figure 6). Such shapes are commonly observed in feldspar porphyroclasts.

According to Bose and Marques (2004), few major factors 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 porphyroclasts of feldspar in biotite-hornblende gneiss is rotated as clockwise that indicates the dextral shearing (Figure 7).

Myrmekites occur in biotite gneiss. Myrmekites are observed in feldspar and indicate the shear sense to the N (Figure 6). The ground mass are biotite, quartz and plagioclase. The porphyroclasts of feldspar in biotite –hornblende gneiss is rotated as clock wise that indicates the dextral shearing (directed to the N). The sense of the shear is determined by the rotation of the porphyroclasts (Figure 7). Quartz ribbons also occur in this unit. The ground mass of the unit is composed of hornblende, biotite, quartz and plagioclase. Hornblende and biotite (mafic minerals) are parallel to the foliation. Mineral fishs occur in the biotite gneiss and hornblende –biotite gneiss. The tails of mineral fish can interpret the shear sense. Rhombohedral (Mica) fish is found in the biotite gneiss. This mica shows the tails and indicates to the north shear sense (Figure 8). The ground mass of the unit are biotite, quartz and plagioclase. Hornblende fish are found in the biotite –hornblende gneiss. The ground mass are biotite, quartz and plagioclase. The end of the tails occurs biotite and quartz. This hornblende fish shows shear sense to the N (Figure 11).

Mineral Fish

Mineral fish (also referred as “displaced broken grains”) are elongate lozange or lens-shaped single mineral crystals either tilted back against the sense of shear or sub-parallel to the C-surfaces (Passchier and Trouw, 2005; Lister and Snoke, 1984). Trails of small micas fragments commonly extend into the matrix from the tips of isolated mica, feldspar, quartz and hornblende fish (Passchier and Trouw, 2005). The mica, hornblende, feldspar and quartz fish in biotite-gneiss and hornblende-biotite gneiss indicate the N-directed shear sense (Figure 8, 9, 10 and 11). Moreover, the mica fish in biotite gneiss displays simples shear sense as well as oblique sense to foliation. Metamorphic and foliated intrusive rocks along the MMB show similar shear deformation with oblique shear and cleavage planes (Bertrand and Rangin, 2003).

In addition, three broad morphologies of mineral fish are observed; (i) rhombohedral (mica), (ii) fish with small aspect ratio, group 5 (quartz and feldspar) and (iii) sigmoid (hornblende).

The rhombohedral fish (figure 8) indicates that can easily be attained by slip, starting from a position parallel to the foliation (Passchier and Trouw, 2005). K-feldspar fish in a quartz feldspar matrix (ten Grotenhuis *et al.*2003) in high grade rocks may also form by dynamic recrystallization along the rim (figure 9).

Quartz fish is the weaker phase in most deformed rocks, and special circumstances are needed to form quartz fish. Quartz fish form either by solution- precipitation without internal deformation or by intracrystalline slip with recovery and minor recrystallization (figure 10). Hornblende fish occurs in quartz matrix from high-grade biotite hornblende gneiss (figure 11).

Quartz ribbon

Quartz easily deforms by dynamic recrystallization which is a key mechanism for understanding deformation processes and the most important deformation mechanism in quartz.

Three sub-processes commonly occur depending upon temperature conditions and strain rate. They originate from two physical mechanisms which are namely the migration of existing grain boundaries and the formation of new grain boundaries (Stipp *et al.*, 2002). Stipp *et al.* (2002) proposed the classification based on observation from natural conditions that focuses on quartz dynamic recrystallization mechanisms and divides them in three sub-processes, namely bulging, subgrain rotation and grain boundary migration recrystallization.
Biotite-hornblende gneiss displays 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 ribbons are 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 occured in high-grade gneiss (500-700˚C) is probably formed by strong deformation followed by recovery and recrystallization (Passchier and Trouw, 2005) (Figure7). Thus, the quartz ribbon textures in biotite-hornblende gneiss are formed at high-grade due to grain boundary migration recrystallization process.

Myrmekite

Myrmekite textures occurred at the rim of K-feldspar crystals in biotite gneiss in which bulbous symplectite of vermicular quartz in K-feldspar (figure 6). It is common in high grade metamorphic rocks (above 600˚C) and igneous rocks, mostly as breakdown product of K-feldspar during progressive deformation and in that case 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).

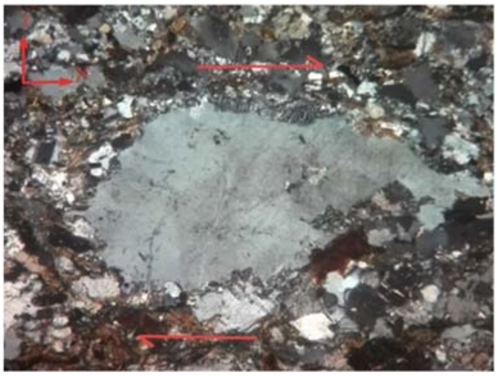

Figure (6). Myrmekite textures occurred at the rim of K-feldspar crystals in biotite gneiss

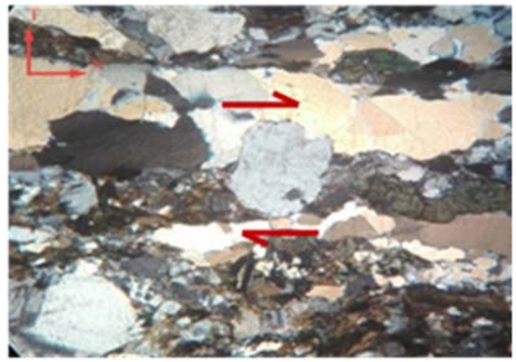

Figure (7). Biotite hornblende gneiss display quartz ribbon textures in quartz grains

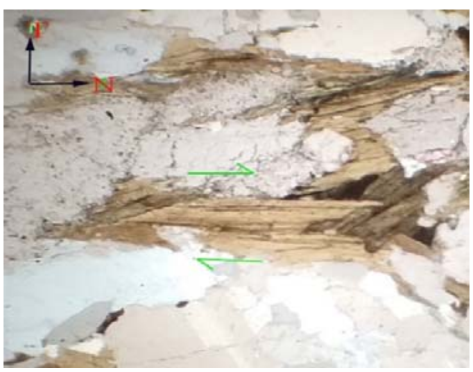

Figure (8). Rhombohedral Mica fish is found in biotite gneiss.

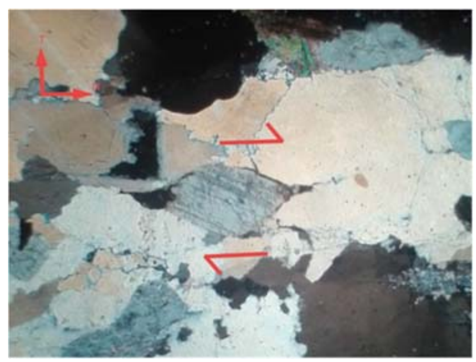

Figure (9) Feldspar fish with small aspect ratio, group 5 in biotite gneiss.

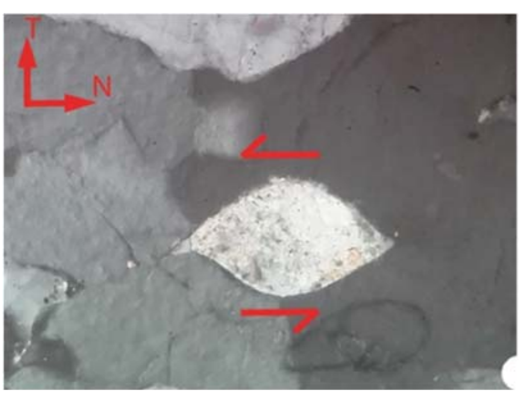

Figure (10). Quartz fish occur in quartz matrix from biotite hornblende gneiss.

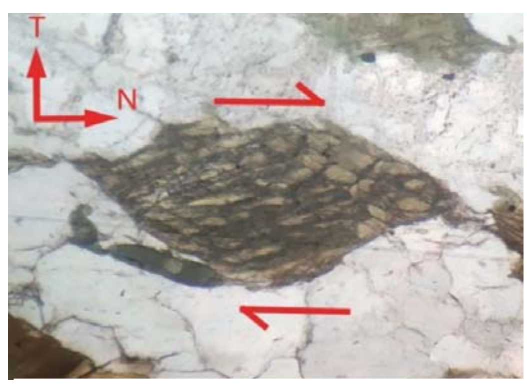

Figure (11). Hornblende fish occur in quartz matrix from biotite hornblende gneiss.

Conclusions

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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.Quartz ribbons occured in high-grade gneiss (500-700˚C) is probably formed by strong deformation followed by recovery and recrystallization . Thus, the quartz ribbon textures in biotite-hornblende gneiss are formed at high-grade due to grain boundary migration recrystallization process.

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References

Adamu,M. Lukaman, Rufai.A., Odoma, Tope.,S, Alege, 2018. Sedimentology and Depositional Environment of the Mid-Maastritchtian Ajali Sandstone inidah and Environs, Northern Anambra Basin, Northcentral Nigeria. *IOSR Journal of Applied Geology and Geophysiss , volume 6*.P38-50.

Aung Khin & Kyaw Win, 1969. *Preliminary Studies of the Paleogeography of Burma during the Cenozoic;* People's Oil Industry.

Bender. F.,1983. *Geology of Burma,* Gebrunder Borntraeger Berlin.

Chhibber. H., L., 1934. *The Geology of Burma,* Macmillan &Co.Ltd., London

Dickinson WR, Suczek CA.,1979. *Plate tectonics and sandstone compositions*. AAPG Bull .V.63, No.12.P 2164-2182.

Dickinson WR, Suczek CA.,1985. *Interpreation provenance relation from detrital modes of sandstones, provinces of Arenite*.P333-362

Folk, R. L., and Ward, W. C, 1957. Brazos River bar: A study in the significance of grain size parameters. /. Sediment. Petrol., 27:3.

Folk,R.L&Ward,W.C.,Brazos River Bar.,1957. *A study in the Significance of grain size parameter*.Jour Sed. Petrology. Vol.27.

Glenn.S., Visher 1969. Grain Size Distributions and Depositional Processes. *Journal of Sedimentary Pterology.*Vol,39. P1075-1105.

Khin Maung Myint, 1982. A Petrological study of the Okkan- Ainggyi Area, West of Kawlin, *M.Sc (Thesis),* Geology Department, Mandalay University.

Kyi Kyi Linn, 1996. Petrology of the Okahitkon Area, Kawlin Township. *M.Sc (Thesis),* Geology Department, Mandalay University.

Mitchell, A.H.G., 2012. *Geological Belts, Plate Boundaries, and Mineral Deposits in Myanmar*, Elsevier Inc., United States.

Okon, Emmanuel Etim and Essien,2015. Depositional Processes and Provenance Determination Using Grain Size Analysis and Heavy Mineral Assemblages of Surficial Sediment and Stream Sediment Samples from Iwere-lle and its Environs. *International Journal of Scientific & Engineering Research,* Volume 6.P12381245.

Omotone S.J.,Fadiya S.L., Adesiyan T.A.,2016. Sedimentological Study and Heavy Mineral Analysis of Sediment Sample from Well-S, Niger Delta, Nigeria. *Universal Journal of Geoscience*.P51-61.

Operanun, Oale and Paun,2007. *The Dynamic Significance of the Grain Size of Sediments Transported and Deposited by The Danube*.P111-119

Pettijohn,F.J., (1597). *Sedimentary Rocks*. 3rd edition, Harper and Row Press, New York.

Raymond, L.A., 1995. *Petrology: The study of Igneous, Sedimentary and Metamorphic rocks*. Wm. C. Brown Publishers.

Reineck and Singh., (1980). *Depositional Sedimentary Environment,* 2rd edition. Springer Verlagberlin, Heidelberg. New York.

Sahu, B. K., 1964. Depositional mechanisms from the size analysis of clastic sediments. J. Sediment. Petrol., 34 : 73-83.

Saravanan.S., and Chandrasekar.N.,2013. *Grain Size Analysis and Depositional Environmen.*P293-302.

Simon.J.,Blott and Kenneth Pye,2001. Gradistat; *A Grain Size Distribution and Statistics Package for the Analysis of Unconsolidated Sediments.* University of Landon, P1237-1248

Teza Kyaw, 2018. Determination on Igneous Activity based on Petrography and Petrochemical Characters of Kawline-Wela Area, Kawlin Township. *Univerities Research Journal,* Vol.11,P50-60.

Than Zaw., 1980. Stratigraphy and Sedimentation of the Sadawingyi Area, Kanbalu Township, *M.Sc (Thesis)*, Geology Department, Mandalay University, unpub.

Thet Tun, 1994. Petrology of Shangolon-Atetthitaya Area, Kawlin Township, *M.Sc (Thesis),* Geology Department, Mandalay University, unpub.

Tucker, M.E.,2001. *Sedimentary Petrology*, An introduction to the origin of sedimentary rocks. 2nd Edit, Blackwell Science, ltd, UK.

United Nations, 1979 a. Geology and Exploration Geochemistry of the Pinlebu-Banmauk Area, Sagaing Division, northern Burma, *Technical report 2*, New York.

United Nations, 1979 b. Mineral Exploration in Selected Areas, *Technical report 6*, New York.

Visher, 1696. Grain size distribution and sedimentary processes; Jour sed. Petrology. v.39p.1074-1106.

William,R.Dickinson.,1985. *Interpreting Provenance Relations from Detrital Modes of Sandstones.*USA.P333-361.

Williams, H., Turner, F. J., Gilbert, C. M., 1982. *An Introduction to the Study of Rocks in Thin Sections*, 2nd Edition, W. H. Freeman and Company, New York.

Winter, J. D., 2014. *An Introduction to Igneous and Metamorphic Petrology*, Prentice-Hall Inc., Upper Saddle River, New Jersey.