Metamorphic Facies and Retrograde Metamorphism of the Myogyi Area, Ywangan Township, Southern Shan State

Aye Aye Mar*, Naing Lin, Marlar Aye Shwe*****

Abstract

The regionally metamorphosed rocks that are occurred in the study area have undergone deformation during Charnian orogenic event resulting that have been eroded to expose the metamorphic rocks. The major rock units in the study area are mainly composed of metasedimentary rocks of metapelite (Slate, Phyllite and Schist) and metapsammite (Quartzite and Metagreywacke). The texture of the rocks changes from Slates and Phyllites in the Chlorite zone to Mica - Schists in the Biotite zones, to Garnet -Mica Schists in the Garnet zone. The metamorphic facies series of regional metamorphism are characterized by the presence of garnet and chloritoid in the intermediate grade mineral assemblages indicating that the conditions of metamorphism in Barrovian Facies Series of metamorphic rocks. The greenschist facies for Phyllite and Mica - Schist and the epidote amphibolite facies for Garnet - Mica schist occurred in the study area. In the study area, the garnet porphyroblasts are often rimmed by small amounts of chlorite and quartz, indicating that limited quantities of water were available for the reverse of the reaction given above to proceed during cooling. The chlorite rims on the garnet porphyroblasts indicate the retrograte metamorphism.

Key words: Charnian orogenic event, metapelite, metapsammite, chloritoid

Introduction

The regionally metamorphosed rocks occurred in the study area have undergone deformation during Charnian orogenic event resulting that have been eroded to expose the metamorphic rocks (Ko KO Myint, 1989). The major rock units in the study area are mainly composed of metasedimentary rocks of metapelite (Slate, Phyllite and Schist) and metapsammite (Quartzite and Metagreywacke).

The texture of the rocks changes from Slates and Phyllites in the Chlorite zone to Mica - Schists in the Biotite zones, to Garnet -Mica Schists in the Garnet zone. The metamorphic facies series of regional metamorphism are characterized by the presence of garnet and chloritoid in the intermediate grade mineral assemblages indicating that the conditions of metamorphism in Barrovian Facies Series of metamorphic rocks.

* Associate Professor, Geology Department, Yadanabon University

** Professor, Dr, Geology Department, Yadanabon University

*** Lecturer, Dr, Geology Department, Yadanabon University

Metamorphic Facies

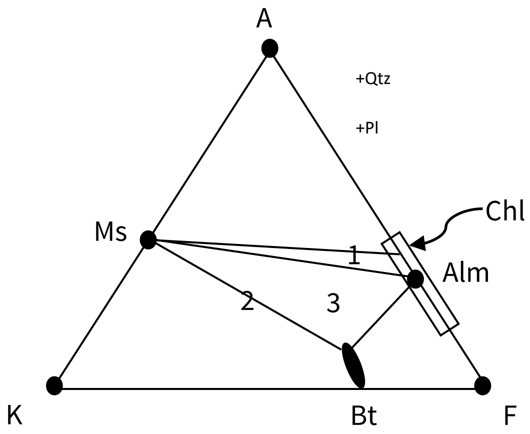
The determination of metamorphic facies was done on the basic of diagnosic mineral assemblages and index minerals. The constituents of mineral assemblages in metapelitic rocks are as follows:

(1) Chlorite + quartz+ feldspar + muscovite + biotite ± pyrophyllite ± chloritoid ± pyrite

(2) Biotite + quartz+ K-feldspar + albite + muscovite

(3) Garnet + biotite + muscovite + chloritoid + quartz + albite

The above mineral assemblages for metapelites are illustrated in AKF diagram (Figure 1) and the representative facies diagram for this area is shown in figure (2) .



Qtz = quartz, Ms = muscovite,

Chl = chlorite, Pl = plagioclase

Alm = alamadine garnet, Bt = biotite

Figure (1) AKF diagram for mineral assemblages of metapelites in the study area

In the present area the occurrence of chlorite + quartz + feldspar + muscovite + biotite mineral assemblage in Chlorite Phyllite and biotite + quartz + albite + muscovite mineral assemblage in Mica - Schist point toward the lower greenschist facies and garnet + biotite + muscovite + chloritoid + quartz + albite mineral assemblage in Garnet - Mica schist represents the upper greenschist facies to the epidote-amphibolite facies.

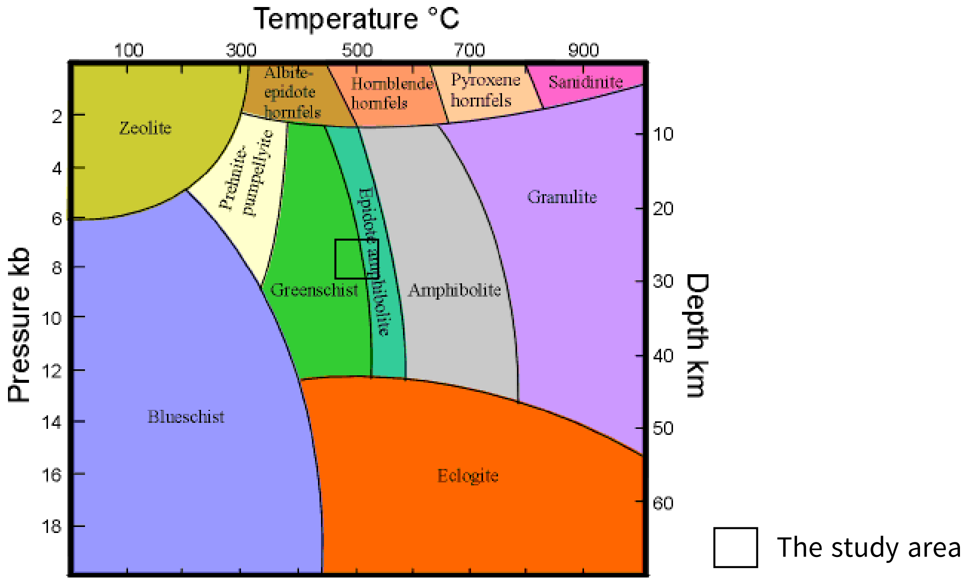


Figure (2) Metamorphic Facies recognized in the study area (Source; ees.2.geo.rpi.edu)

Metamorphic Zone

Chlorite Zone

Phyllite - In the study area, chlorite zone is defined by the occurrence of chlorite + quartz+ feldspar + muscovite + biotite + pyrophyllite mineral assemblage in Chlorite Phyllite. The lowest grade rock, Chlorite Phyllite is difficult to study under the microscope, but it is chiefly composed of chlorite and muscovite with variable amount of quartz, feldspar, pyrophyllite and accessories such as pyrite and iron oxides. This mineral assemblage in the study area is alike to those of the Barrovian chlorite zone. Winkler (1979) mentioned pyorphyllite is a widespread mineral in Slates and Phyllites. In some pelitic rocks, pyophyllite and (phengite) sericite are the only sheet silicates, but more commonly chlorite is also present and the amount of pyophyllite is subordinate. The stabitity field of pyrophyllite reaches 345±10 °C at 2kb and 375±10 °C at 3kb.

Metagraywackes - It retains the clastic sedimentary textures and contains quartz, feldspars and rock fragments with laumontite ($CaAl_2Si_4O_{12}{\cdot}4H_2O$), prehnite [$Ca_2Al_2Si_3O_{10}(OH)_2$] or pumpellyite [$Ca_4(Mg,Fe)(Al,Fe^{+3})_5Si_4O_{23}(OH)_3{\cdot}2H_2O$ in the recrystallized feldspars (Alexander Lewerentz, 2018). The rocks have the following mineral assemblages: quartz, albite, laumontite, chlorite, sericite, hematite.

Biotite zone

Metapelitic rocks from the biotite zone are Mica - Schists characterized by the preferred orientation and crenulation cleavage. They represent the regional schistosity. Winkler (1979) pointed out the biotite coexisting with phengite ± chlorite and quartz corresponds to the beginning of Barrovian's biotite zone in metapelites. The mineral assemblage is Chl + Ms + Bt + Qtz + Pl with opaque accessory minerals. The chemical reaction considered in pelitic rocks is Kfs

+ Chl = Bt + Ms + Qtz + H_2O, whereas the chemical reaction considered in metapelitic rocks is Phe + Chl = Bt + Ms + Qtz + H_2O. Bucher and Grapes (2011) stated that the low grade assemblage K-feldspar + chlorite are replaced by biotite + chlorite over a temperature interval of about 40°C. The reaction has equilibrium conditions of 420°C about 2kb along the orogenic intermediate-pressure metamorphism path.

Garnet zone

Metapelitic rocks are typically foliated, fine- to medium-grained, Garnet - Mica schists. The mineral assemblage is Qtz + Ms + Grt + bit + Cld. Garnet occurs as anhedral to euhedral porphyroblasts, which contain mineral inclusions. Sector zoned (hourglass structure) chloritoid randomly distributed overgrows the schistosity of the rock. The occurrence of chloritoid in this metamorphic zone can be also related to Al-rich pelites and probably near the biotite zone. The chemical reaction considered in metapelitic rocks is Chl + Ms = Grt + Bt + Qtz + H_2O. Bucher and Grapes (2011) mentioned the first garnet appears in metapelites at temperature of around 450°C. According to Winkler (1979), Bucher and Grapes (2011) and on the basis of previous works, the present observations, the aspects of metamorphic facies, zone, the representative rocks and mineral assemblages in metapelites of the study area are greenschist facies for Phyllite and Mica - Schist, epidote amphibolite facies for Garnet - Mica schist.

Quartzite - Quartz occurs as xenoblastic grain. The quartz grains are fractures and their margins are granulated. They show undulatory extinction. The quartz grains have suture boundary. Muscovite occurs either as scaly aggregates or as disseminated flakes in the granoblastic matrix. The rocks have the following mineral assemblages; quartz, albite, biotite, muscovite, graphite.

Type of Metamorphism

In general, the changes in mineral assemblage and mineral composition that occur during burial and heating are referred to as prograde metamorphism, whereas those that occur during uplift and cooling of a rock represent retrograde metamorphism If thermodynamic equilibrium was always maintained, one might expect all the reactions that occur during prograde metamorphism to be reversed during subsequent uplift of the rocks and reexposure at Earth's surface. However, the factors mitigate against complete retrogression of metamorphic rocks during their return to Earth's surface. First is the efficient removal of the water and carbon dioxide released during prograde devolatilization reactions by upward migration of the fluid along grain boundaries and through fractures. Because almost all the water released during heating by reactions—such as when chlorite ($Fe_9Al_6Si_5O_{20}(OH)_{16}$) reacts with quartz ($4SiO_2$) to yield garnet ($3Fe_3Al_2Si_3O_{12}$) and water ($8H_2O$)—is removed from the site of reaction. Thus, garnet can be preserved even though it is thermodynamically unstable at such low temperatures and pressures. During cooling, reaction kinetics become sluggish, and metastable mineral assemblages and compositions can be preserved well outside their normal stability fields. Thus, prograde reactions are generally more efficient than retrograde reactions, and metamorphic assemblages indicative of even extremely high temperatures or pressures or both are found exposed throughout the world.

It is common, however, to find at least some signs of retrogression in most metamorphic rocks. In the study area, the garnet porphyroblasts are often rimmed by small amounts of chlorite and quartz, indicating that limited quantities of water were available for the reverse of the reaction given above to proceed during cooling (Figure 3). The chlorite rims on the garnet porphyroblast indicate to the retrograde metamorphism (Figure 4). During retrograde metamorphism, bi, chl and ilmenite become more Mn rich owing to garnet breakdown (Kurt Hollocher, 1987). Retrograde features such as the reaction rims yield information on pathways of fluid migration through the rocks during uplift and cooling. The retrograde metamorphism, further decompression and cooling occur at a slow rate, implying further erosion after the tectonic event. The development of euhedral garnet porphyroblast with few inclusion probably reflects slow growth (Barker, 1998) (Figure 5). The fractures in garnet porphyroblasts of the Garnet - Mica schist indicate the prekinematic porphyroblasts (Figure 6). Most garnet porphyroblasts are intensity fractured, with fracture filled by quartz. Garnet porphyroblasts cut by quartz veins displaying truncated (Figure 7 a, b).

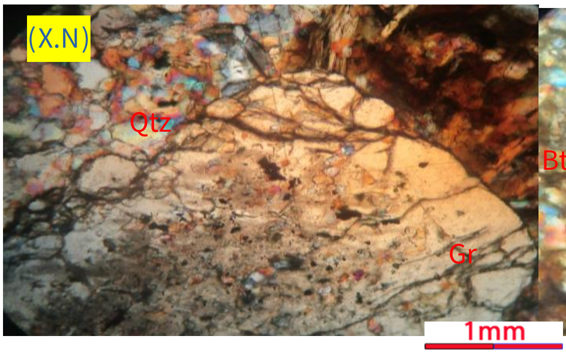


Figure (3) Garnet (Gr) porphyroblasts are often rimmed by small amounts of chlorite and quartz (Qtz)

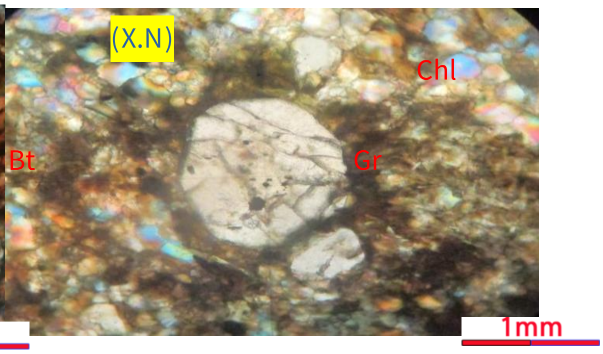


Figure. (4) Chlorite (Chl) rims on garnet (Gr) porphyroblast

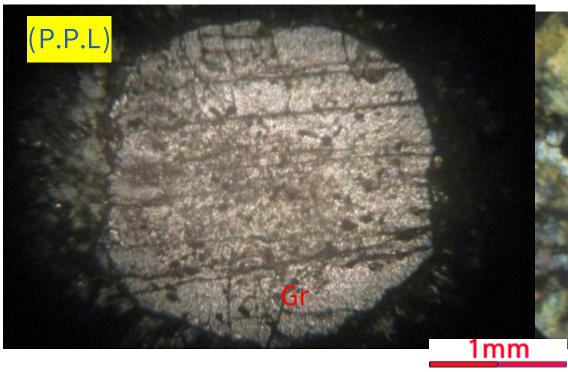


Figure (5) The euhedral garnet porphyroblast

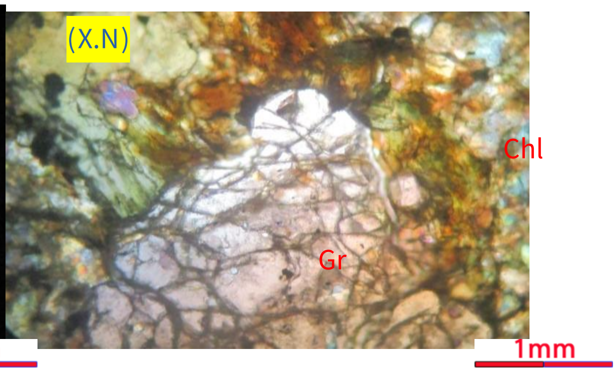


Figure (6) The fractures occur in garnet (Gr) porphyroblast

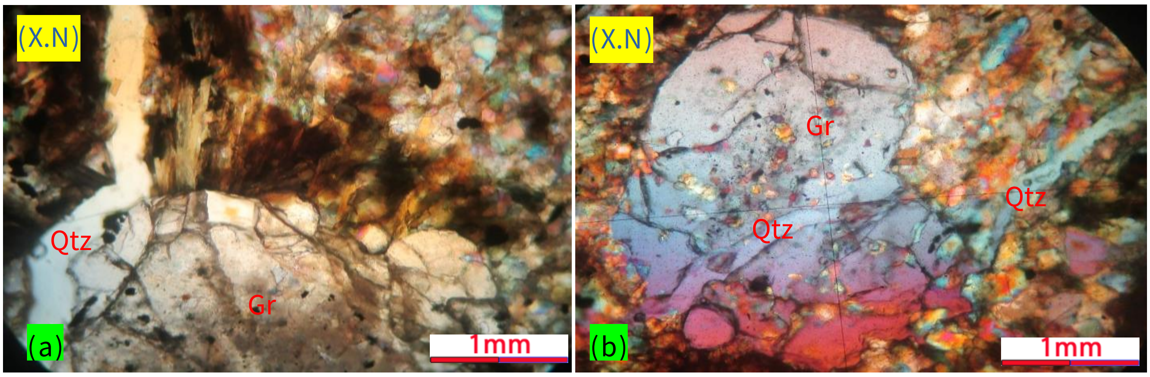


Figure (7 a, b) Truncated garnet (Gr) by quartz (Qtz) veins in the Garnet - Mica schist

In the garnet isograd, garnet grew by the reaction chloritoid+ chlorite+ quartz⇌ garnet+ H_2O. With increasing grade the mineral compositions are displaced towards lower Mn/Fe and higher Mg/Fe ratios. There are the distinct types of garnet zoning reversals in these samples. These rocks contain mineral assemblage such as quartz + biotite + muscovite + garnet + chloritoid, with minor plagioclase and K-feldspar, and Fe-Ti oxides as the main accessory phases. In the Garnet - Mica schist, it is clear that certain exchange reactions operated in a retrograde sense even when the net-transfer reactions were frozen in prograde metamorphism. Systematic hydration of the progate assemblage by a influx of H_2O produced the retrogate muscovite (Kurt Hollocher, 1987). Raction texture occurs at the corroded margin of crystals, from the corrosive rimming of garnet porphyroblast by finer grained aggregates of quartz and other minerals that indicate partial removal of crystalline materials by reaction (Figure 8).

The large garnet porphyroblasts contain inclusions of chloritoid, quartz and magnetite (Figure 9). The garnet therefore holds evidence of an earlier metamorphic assemblage. Retrograde reactions may completely destroy prograde minerals like garnet. However, relics of them may survive trapped inside other minerals, like chloritoid, chlorite, biotite, quartz and magnetite (Figure 10 a, b). The garnet porphyroblasts were completely lost from the assemblage, but a few grains remain inside these quartz crystals where they were protected from reaction. Garnet porphyroblasts in a Garnet - Mica schist that have been retrograded along its rim and fractures to a mixture of chloritoid, quartz and chlorite (Figure 11). It indicates partially retrograded garnet in Garnet - mica schist. An important part of the garnet solid solution, the retrograde reaction was: garnet + biotite + ilmenite + H_2O = chlorite + muscovite + chloritoid + quartz. The chloritoid, quartz and chlorite grew after foliation development. At lower temperature, water gained access to the rock and partially retrograded the garnet margins to a mixture of chloritoid, chlorite, quartz and magnetite (Figure 12).

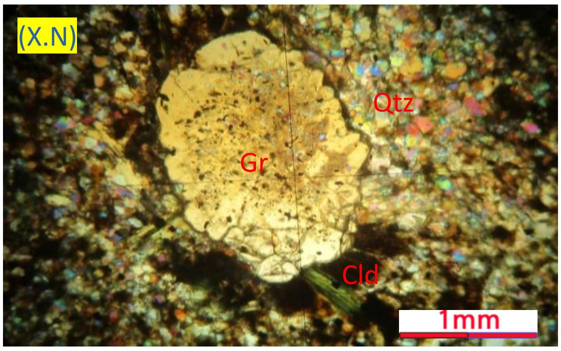


Figure (8) The corrosive rimming of garnet (Gr) porphyroblast by finer grained aggregates of quartz (Qtz) and minerals

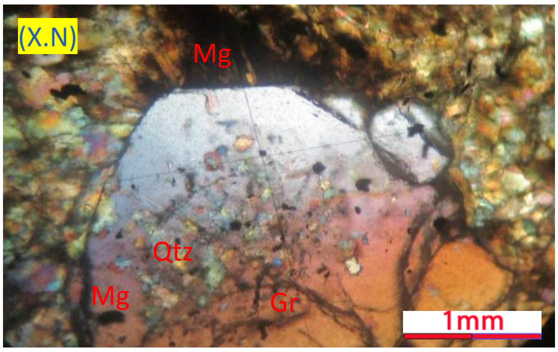


Figure (9) The large garnet (Gr) porphyroblasts contain inclusions of chloritoid, quartz (Qtz) and magnetite

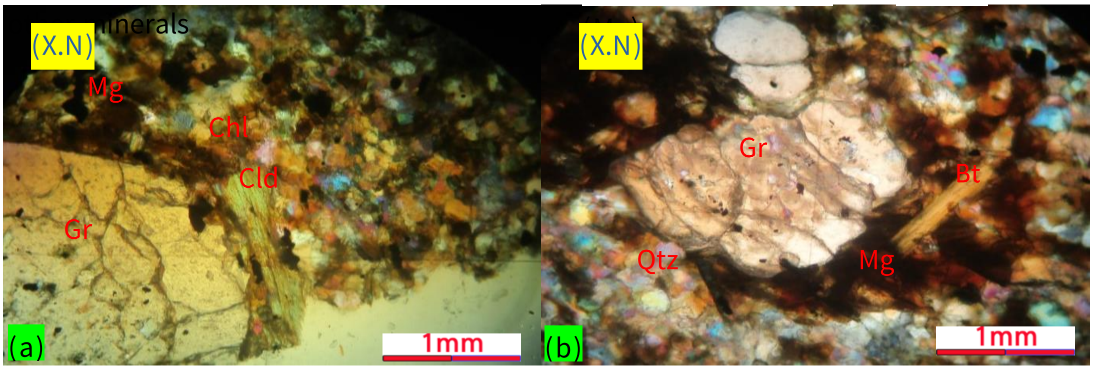


Figure (10 a, b) The garnets (Gr) survive trapped inside chloritoid (Cld), chlorite (Chl), biotite (Bt), quartz (Qtz)and magnetite (Mg) minerals

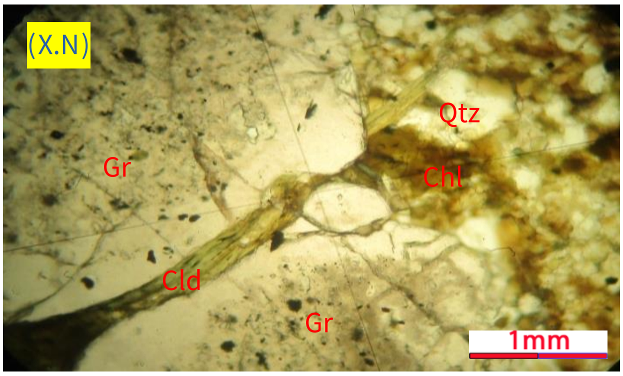


Figure (11) The mixture of chloritoid (Cld) , quartz (Qtz) and chlorite (Chl) occurs at garnet (Gr) margin

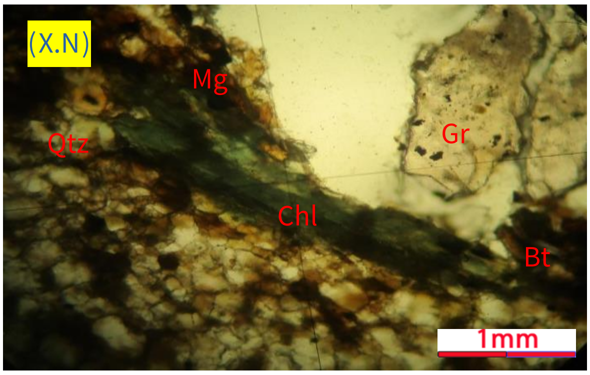


Figure (12) The mixture of chlorite (Chl), biotite(Bt), quartz (Qtz) and magnetite (Mg) occurs at garnet (Gr) margin

Chloritoid has been reported and described in many metamorphic terrains in which this mineral appears in low- and medium-P metapelites impoverished and enriched in Al and high-P metapelites with high contents of Mg. The PT conditions of chloritoid-bearing metapelites range from the sub-greenschist facies to the middle part of the amphibolite facies in the garnet zone. At the greenschist facies, chloritoid is a common mineral associated with chlorite and muscovite in rocks enriched in Fe and with high contents of Al (Turner, 1968). The chloritoid is associated with muscovite, chlorite and quartz in the garnet zone of the epidote amphibolite facies in a deformed and sheared region. However, the chloritoid porphyroblasts do not show evidence of deformation, which could be interpreted as a post tectonic growth. It corresponds to the retrograde step of metapelites with low contents of Al, but somewhat enriched in Fe. The chloritoid mineral occurs as idioblastic sector zoned (hourglass) structure in a matrix of muscovite, chlorite, quartz, ilmenite and graphite as major minerals (Figure 13 a, b). The chloritoid-bearing assemblages indicate the regional metamorphism. The chloritisation (Figure 14) and sericitisation (Figure 15) in the metagreywacke also indicate the retrograde metamorphism_(Barker, 1998).

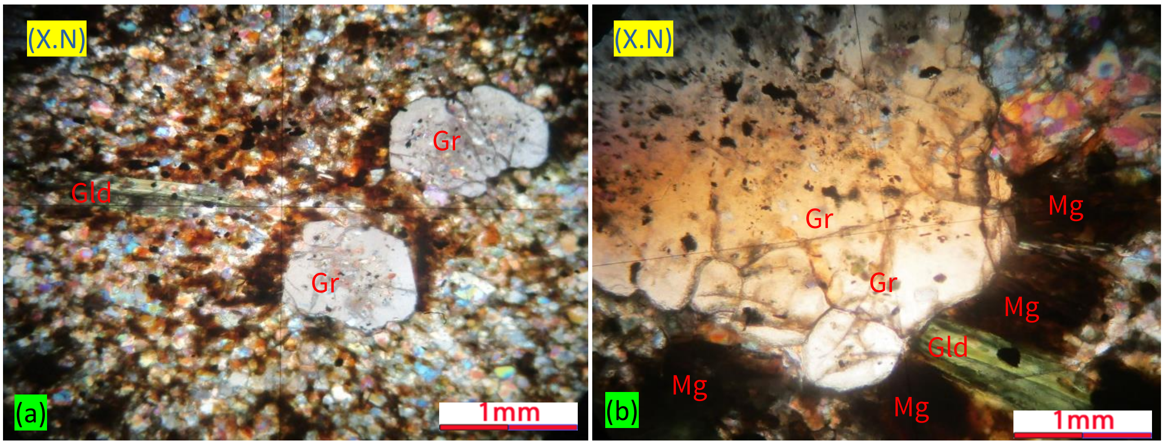
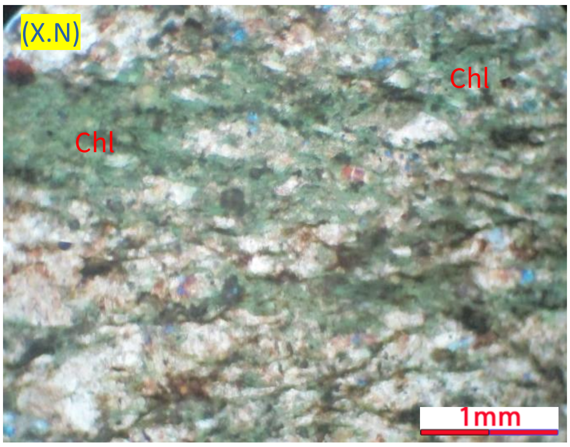


Figure (13 a, b)The chloritoid (Cld) mineral occurs in the Garnet - Mica schist

(Gr = Garnet, Mg = magnetite)



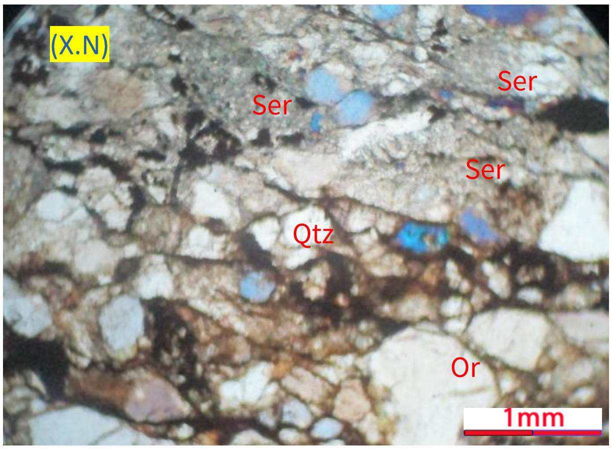


Figure (14) Chloritisation in the metagreywacke

Figure (15) Sericitisation in the metagreywacke (ser = sericite, Qtz = Quartz, Or = Orthoclase)

Protolith

The dominant rock types of the study area are low-grade, regionally metamorphic rocks, such as a variety of Phyllites, Metagreywacke, Quartzite and Schists. Micas plays a character of the important group of minerals in metapelitic rocks. The chief micas in metapelites are muscovite and biotite. Abundance of sericite, muscovite, biotite, pyrophyllite, garnet, graphite, quartz and feldspar in Phyllites, Mica - Schist and Garnet - Mica schists show high aluminous nature, indicating the original pelitic rocks. Moreover, the interbedded nature of Metagreywacke points out quite water environment that is sufficiently deep and relatively free from action of wave. Besides, the present of pyrite in Phyllite suggests a stagnant and reducing environment. Metagreywacke, Phyllite, and Slate in the Chaung Magyi Group of the study area are strongly indicative of turbidite facies, especially general feature of many thick geosynclinals sequence. Besides quartz and mica assemblages in Quartzite and Metagreywacke indacite that original rock is arenitic.

Summary and conclusion

The regionally metamorphosed rocks occurred in the study area have undergone deformation during Charnian orogenic event resulting that have been eroded to expose the metamorphic rocks. The texture of the rocks changes from Slates and Phyllites in the Chlorite zone to Mica - Schists in the Biotite zones, to Garnet -Mica Schists in the Garnet zone. In the study area, the garnet porphyroblast are often rimmed by small amounts of chlorite and quartz, indicating that limited quantities of water were available for the reverse of the reaction given above to proceed during cooling. The chlorite rims on the garnet porphyroblast indicate to the retrograte metamorphism. The development of euhedral garnet porphyroblast with few inclusion probably reflects slow growth. The fractures in garnet porphyroblasts of the Garnet - Mica schist indicate the prekinematic porphyroblasts. The large garnet porphyroblasts contain inclusions of chloritoid, quartz and magnetite. The chloritoid mineral is occurred as idioblastic sector zoned (hourglass) structure in a matrix of muscovite, chlorite, quartz, ilmenite and graphite as major minerals. The chloritoid-bearing assemblages indicate the regional metamorphism. The chloritisation and sericitisation in the metawacke also indicate the retrograde metamorphism. The dominant rock types of the study area are low-grade, regionally metamorphic rocks, such as a variety of Phyllites, Metagreywacke, Quartzite and Schists. Micas play a character of the important group of minerals in metapelitic rocks. The chief micas in metapelites are muscovite and biotite. Abundance of sericite, muscovite, biotite, pyrophyllite, garnet, graphite, quartz and feldspar in Phyllites, Mica -Schist and Garnet - Mica schists show high aluminous nature, indicating the original pelitic rocks.

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