Kyaukse University Research Journal, 2025, Vol.IV

PETROGENETIC STUDY ON METAPELITIC ROCKS EXPOSED AT SAGAING-KYAUKTA AREA, SAGAING TOWNSHIP, SAGAING REGION

Tin Zaw Oo[1]

Abstract

Sagaing-Kyaukta area belonging to part of Mogok Metamorphic Belt (MMB), that experienced medium-pressure and high temperature metamorphism related to the tectonic evolution of the Sinoburma Ranges and related Sagaing Fault of the Central Myanmar Basin (CMB). Field study is made on April 2020 and 25 representative samples are collected for the petrographic study. For detail petrogenetic analysis 15 thin sections are cut from collected samples. Two lithologically stacked metamorphic units contain hornblende gneiss and garnet gneiss that record thermal conditions of the upper amphibolite (structurally upper unit) and the granulite facies (structuraly lower unit). The paragenesis of Kfs + Grt + Bt represent >600ºC/3.8-5.5Kbar and Grt + Bt + Sil represent up to 720ºC/5.5-7.1 Kbar (Ky-type geotherm). So, the research area falls in upper amphibolite to granulite facies and medium P/high T facies series. Therefore, western part of MMB is imposed by medium pressure and fairly high temperature regional metamorphism.

Keywords: Mogok Metamorphic Belt, metapelitic rock, petrogenesis, granulite facies

Introduction

Geotectonically, the Sagaing area occupies the very central portion of Myanmar and geologically, eastern flank of the Central Cenozoic Belt of Mg Thein (1986) or eastern trough of Myint Thein (1982). It extends all along Myanmar from the East Himalaya Syntaxis to Andaman sea with dextral offset over 50 km or more (GIAC, 1999). Searle *et al.* (2007) demonstrated the Mogok Metamorphic Belt (MMB) that extends along the western margin of Shan-Taninthayi Block, from the Andaman Sea to the eastern Himalaya syntaxis (Figure.3). The Sagaing ridge of the study area is the western continuation of the MMB and terminates along the north-south trending the Sagaing Fault. Location of study area and regional extend of MMB are shown in figure (1) and Three-Dimensional (3D) map in figure (2).

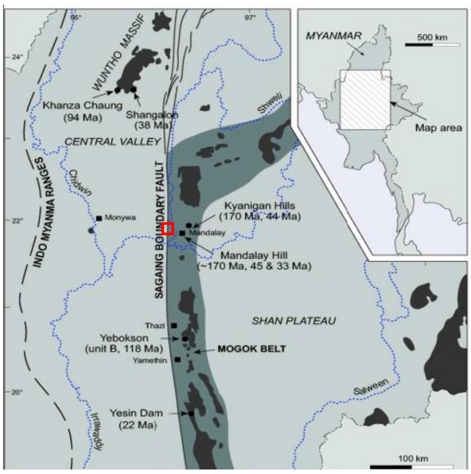


Figure 1 Regional extend of the Mogok Metamorphic Belt (MMB).(Source: M. E. Barley, A. L. Pickard and Khin Zaw *et al.*, 2003).

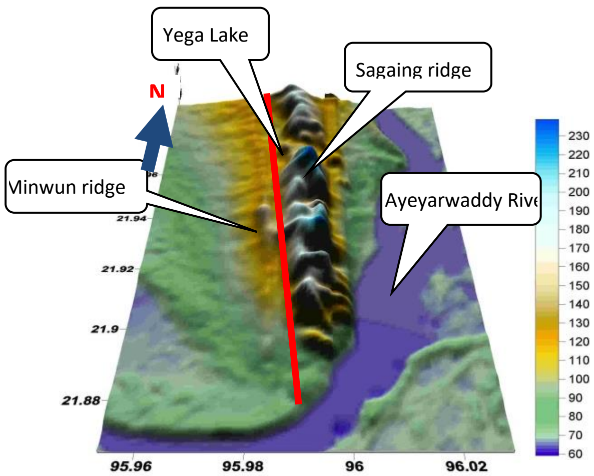


Figure 2 Three dimentional map of the study area.

[1] Professor, Dr.,Department of Geology, Kyaukse University

The metacalcareous rocks and metapelitic rocks are well exposed in Sagaing range. All metamorphic rocks suffer folding, tilting and faulting. The purpose of this research is to constrain the temperature and pressure condition of metamorphism concerned, to describe the sequence and age of protoliths, types of metamorphism, and to decipher the metamorphic history according to metapelitic rock of the research area. To carry out these purposes, the equilibrium mineral assemblages comprised in the rocks as well as textural arrangement of these minerals are studied. Based on the mineral paragenesis of the rocks, the condition of metamorphism and possible reaction isograds have been estimated for metapelitic units in the area. Reactions and petrogenetic grids are also defined in consistent with the petrographic criteria observed, and correlation with other areas.

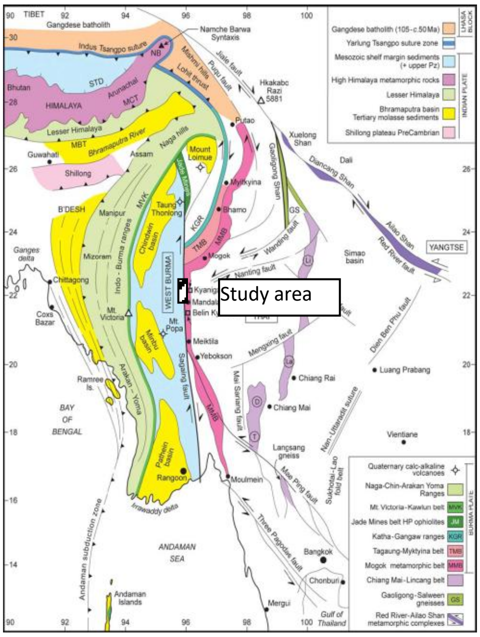


Figure 3 Geological map of SE Asia, Myanmar, and the Andaman Sea region north to southeastern Tibet, showing the major suture zones, faults, and terrain boundaries. (Searle e*t al*., 2007).

General Geology

Sagaing Metamorphics (after Myint Thein, 1982) are exposed in the form of isolated outcrops through the Cenozoic sediments along the western bank of the Ayeyarwaddy River. In the area the major outcrops are located in the whole Sagaing hill, Wachat and KyauktaYega villages. These rocks once again extended north to Mingun-Htonbo area, northern continuation of the rocks of Sagaing ridge.

The Sagaing Metamorphics are grouped into three informal units as Calc-silicate intercalated with Hornblende gneiss unit, Phlogopite-diopside-forsterite marble, and Garnet gneisses and biotite gneisses. Geological map of the study area is shown in figure (4).

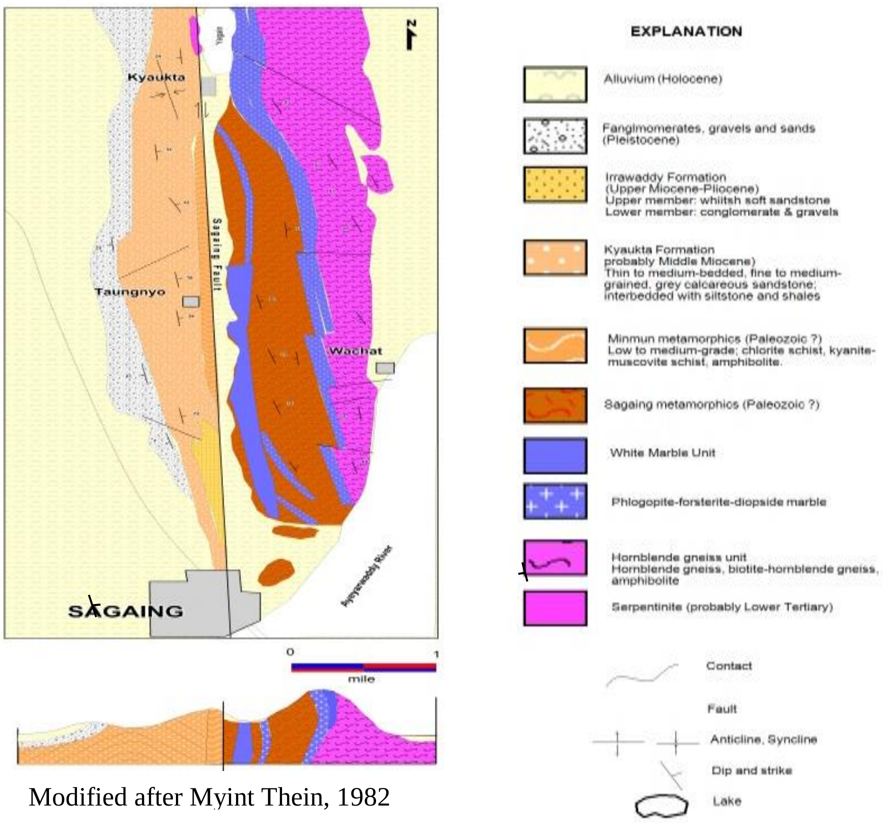
Lithology of Garnet gneiss and biotite gneiss

This unit is mainly composed of the garnet-biotite-gneisses and biotite-gneisses. It is widely distributed along the Sagaing ridge from the Taungbalu Chaung to the east of the Kyaukta village trending the N-S direction. Some localities of the leucogneisses in the field observation show the whitish colour and brecciated nature. They are well cropped out along stream sections and higher parts of the study area. These rocks are thin to medium bedded and light grey on fresh surface and dark grey on weathered surface. These gneisses are medium-coarse grained and occurs as highly jointed form.

These rocks are hard and compact and mainly composed of quartz, feldspar, garnet and biotite. Most of these gneisses show the pitch and swallow structure and organ structure along the foliation plane. Foliation in hand specimen is well marked by platy brown biotite, layers in whitish, quartzo-feldspathic groundmass. The garnet minerals are pink to red and biotites are brown to dark. Garnet porphyroblasts occur in the foliation of garnet biotite gneisses. Large jointing is found in some localities where the bedding is thickened. Foliation is striking in NW-SE with about 30° to 40° east dip.

Some leucogneiss are cropping out along the side of Sagaing ridge at the east of the Sagaing Fault. It is thin to medium bedded nature and whitish in colour. It is mainly composed of feldspar and quartz. In most places, leucogneisses, biotite gneisses and garnet biotite gneisses are interbedded and their foliation are nearly N-S with about 40° to 60° dipping east.

It is found out that the lithologic sequence of protoliths for the Sagaing Metamorphics are well comparable to those of the Ordovician units in both northern and southern Shan State, viz, Naungkangyi and the Wunbye Formations. Therefore, the author has an opinion that the Sagaing Metamorphics are the metamorphic equivalent of the Ordovician (?).



Modified after Myint Thein, 1982

Figure 4 Geological map of the Sagaing-Kyaukta area, Sagaing Township

Petrography

General Statement

About 15 thin sections were cut from various representative rock sample collected from the field to make detail petrographic analysis. Some coarse-grained rocks were established first by visual view, and then studied by point counting method. The Michel Levy's method is used to determine the plagioclase composition. In this study, major rock types are selected to convenience the study of petrography and petrogenesis rather than the major stratigraphc units.

Garnet-Gneiss

In thin section, the gneiss is mainly composed of quartz (45-60%), garnet (2-5%), biotite (20-25%), plagioclase (2-5%), orthoclase (5-10%), and hornblende (3-10%). The texture is generally gneissose, nematoblastic and granoblastic. Garnets are usually unhedral and dark grey to brown color. It is ring by nematoblastic biotite. Biotite is brownish green in color with an average size of 0.4 mm. Biotite occurs as concentrate in thin layers, appear to be slightly deformed and bent around the feldspar and garnet porphyroblasts.

K-feldspar is xenoblast to idioblast in most thin section with the grain size ranging from a 1 mm to 3 mm in diameter. The garnet porphyroblast is warped by the mica flakes, size ranging in 1 mm to 3 mm. Fine-grained quartz occurs as equidimensional xenoblastic crystal of interstitial material. Contact between quartz grains is sutured and display strong undulatory extinction (Figure.5 a-b).

Hornblende-Gneiss and Biotite Gneiss

This rock is composed of quartz (50-60%), orthoclase (5-15%), biotite (15-20%) and. hornblende (5-10%). Biotite is found as lepidoblastic bladed form with distinct basal cleavages. Hornblende occurs as long prismatic with ragged termination. Its color is bluish green to brownish green. Strong paleochroism is also present. Their size varies from 1 mm to 2 mm in diameter (Figure. 5 c-d).

Biotite gneiss is mainly composed of quartz (50-55%), biotite (20-25%), orthoclase (5-15%), plagioclase (2-5%) and hornblende (2-5%). Quartz occurs as anhedral to subhedral and the large grain of quartz are surrounded by flaky biotite mineral. Plagioclase is as both euhedral and anhedral porphyroblast. They are tabular crystal. Polysynthetic twinning is characteristically occurred. Most plagioclase porphyoblasts are aligned by biotite and quartz granulite showing gneissose texture. Orthoclase found as porphyroblast surrounded by biotite and fine-grained recrystallized quartz. The orthoclases are parallel to biotite mineral alignment. They are sometime occurs as twinned. The estimated modal composition of the pelitic rocks are documented in table (1).

Kyaukse University Research Journal, 2025, Vol.IV

Table 1 Estimated modal composition of metapelitic rocks of the research area.

Mineral	Sample Names		
	Hornblende Gneiss (Gn1)%	Garnet Gneiss (Gn2)%	Biotite Gneiss (Gn3)%
Quartz	60	60	50
Plagioclase		2	2
Orthoclase	10	5	15
Biotite	15	20	23
Hornblende	10	8	4
Garnet		2	1
Accessories	5	3	5
Total	100	100	100

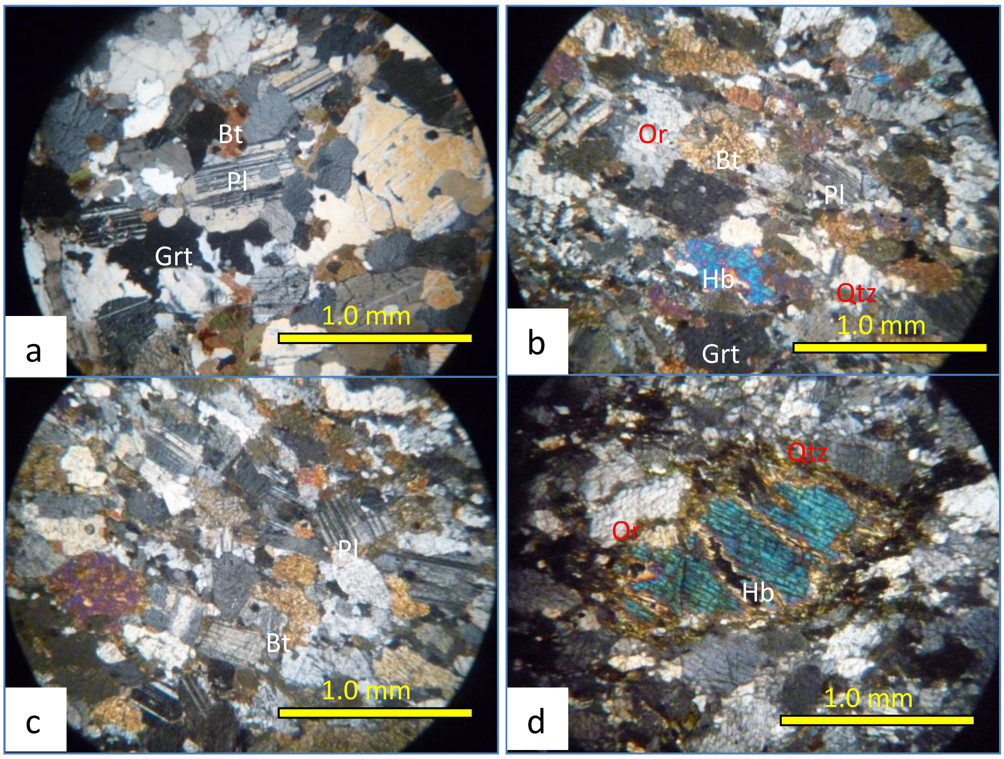


Figure 5 Photomicrograph of garnet gneiss and hornblende gneiss, (a). granoblastic texture of garnet gneiss with unhedral garnet, orthoclase, plagioclase and quartz, (b). lepidoblastic texture with biotite flake in Grt gneiss, (c). anhedral biotite, plagioclase, orthoclase and quartz allied parallel fabric in Bi gneiss and (d). large unhedral hornblende in Hb gneiss.

Mineral Assemblages and Metamorphic Facies

Thin sections cut from various metamorphic rock types, are studied for providing the minerals and their manual relationships. Assemblages of coexisting minerals in the metamorphic rock units provide the principal evidence for the metamorphic condition under which they were formed. These mineral assemblages listed below are from the important and distinct rock units established. Certain mineral assemblages may vary considerably in amount because of diverse lithologies and different bulk compositions. Accessory minerals are not listed in the mineral assemblages of some rocks. The distinctive mineral assemblages of the petrographical images are shown in figure (5). For convenience and to emphasize bulk compositional controls on the assemblages of various rock units, they are divided into (4) typical mineral assemblages.

On the basis of petrographic analysis listed in table (2), the two metamorphic facies have been recognized (Figure. 6), *viz.* amphibolite facies and granulite facies. The prominent mineral assemblages in metacalcareous and metapellite rocks of the study area listed in table (2) are graphically represented by means of AKF diagrams (Figure. 7, 8). The facies classification, nomenclature and defining mineral assemblages used in this works are made following the work of Winter (2010) and Bucher and Grapes (2011). Based on the petrographic analysis the prominent mineral assemblages are as follows;

(1) K-feldspar + quartz + chlorite±talc
(2) hornblende+ muscovite + quartz + garnet + biotite
(3) garnet + sillimanite + biotite + hornblende ±corderite
(4) garnet + sillimanite + biotite + orthopyroxene

The mineral assemblages developed in marbles and calc-silicates of the study area are rather simple but in biotite gneiss and garnet biotite gneiss the assemblages are a little complex. The minerals garnet, sillimanite, and orthopyroxene in pelitic rocks indicated the amphibolite to granulite facies.

Table 2 The prominent mineral assemblages and metamorphic facies in metapelitic rocks of the study area.

Index mineral, (pelitic)	**Mineral assemblages in pelitic rocks**	**Facies**
Garnet	chlorite + muscovite+quartz+ garnet + biotite+hornblende	Lower Amphibolite
Sillimanite	garnet+sillimanite+biotite hornblende ±corderite	Upper Amphibolite
Garnet, Pyroxene	garnet+sillimanite+quartzorthopyroxene +K-feldspar	Granulite

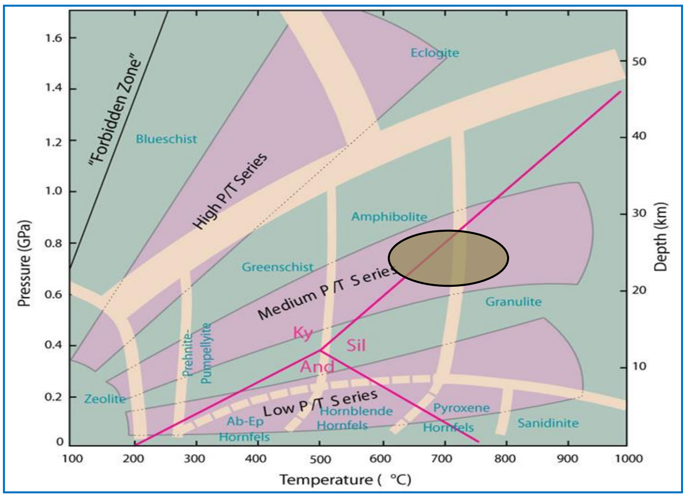


Figure 6 Temperature-pressure diagram showing two major types of metamorphic facies series proposed by Miyashiro (1973, 1994) (in Winter, 2010). The shaded elliptical circle represents the condition of present area.

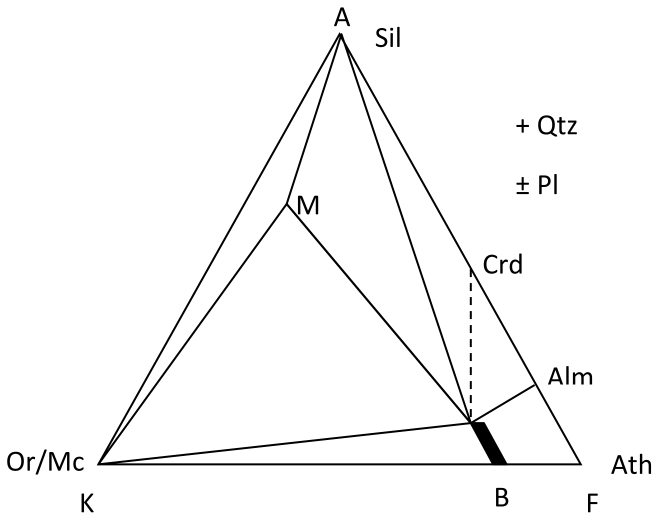


Figure 7 AKF diagram for amphibolite facies mineral assemblages of metapelitic rocks in the study area (source, Hyndman; 1985)

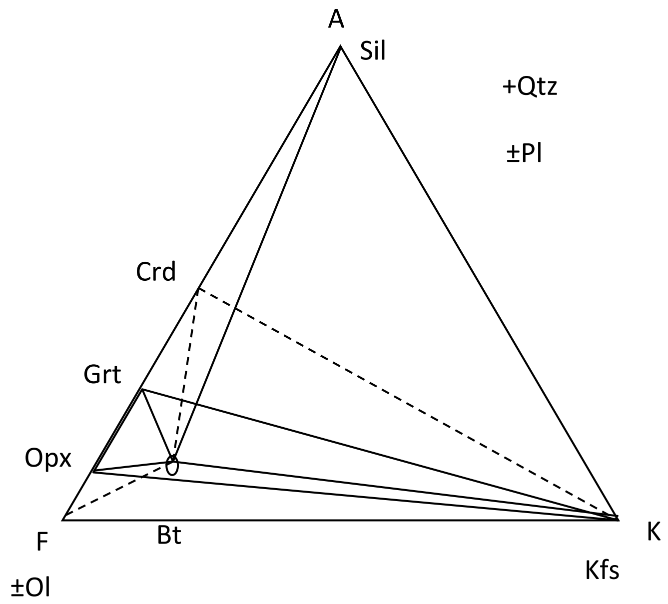


Figure 8 AKF diagram for granulite facies mineral assemblages of metapelitic rocks in the study area (source, Hyndman; 1985)

Age of Metasedimentary Rocks

As previously described, the eastern parts of study area is part of southern continuation of the Mogok Metamorphic Belt and mainly made up of marble, calc-silicate rocks, gneiss which are typically representative of Mogok Series. Thus, on the age basis of lithologic similarities, lateral continuity and regional framework, the age of metamorphic rocks of the research area is thought to be contemporaneous with the Mogok Series and assigned to be Paleozoic age.

Time of Metamorphism

The following points suggest that the age of the metamorphism in this area should tentatively assign to Permian to late Miocene.

(1) Bertrand et al. (1999, 2001) reported diachronous cooling histories for metamorphic rocks from the Oligocene to Middle Miocene on the basis Ar/Ar and K–Ar analyses of biotite and muscovite, and proposed the north-ward passage of the eastern Indian syntaxis with respect to the Indochina region during this time.

(2) Searle et al.(2007) reported U–Th–Pb isotope geochronological data of monazite, zircon, thorite, and xenotime, suggesting two metamorphic events of Paleocene and Late Eocene–Oligocene origin. These authors proposed the possibility that the Mogok metamorphic rocks are equivalent to the unexposed middle or lower crustal rocks of the Lhasa terrain in southern Tibet.

(3) Mitchell et al. (2007) discussed the relationships between the Mogok metamorphic rocks and the calc-alkaline intrusive of Late Jurassic to Early Cretaceous origin, and proposed that Permian and/or Jurassic regional metamorphic event(s) had occurred before the Cretaceous metamorphism.

(4) Searle et al. (2007)reported two sets of chemical compositions of minerals in garnet–biotite gneisses from the Mandalay–Kyanigan and Belin–Kyaukse areas, and estimated their equilibrium pressure/temperature (P/T) conditions to be 0.49 ± 0.17 GPa/680 C and 0.48 ± 0.09 GPa/625 ± 25 C, respectively. These researchers interpreted these two equilibrium conditions as representing metamorphic stages of 45–33 Ma and 29.3 ± 0.3 Ma, respectively.

(5) Yonemura et al. (2013) found a garnet–orthopyroxene gneiss from the Mogok area, and reported its equilibrium condition to be 0.65–0.87 GPa/800- 900 C. These data imply that high-grade metamorphic rocks, from upper amphibolite to granulite facies, occur extensively in the Mogok metamorphic belt.

Discussion and Conclusion

Temperature-pressure conditions of metamorphic rocks in the present area are depicted in figure (9) with their respective facies and zones. P-T conditions to decipher the metamorphic evolution of the rocks have been estimated by three methods: (1) considering the P-T ranges of critical metamorphic assemblages known as metamorphic facies and formation on the minimum conditions for recrystallization of particular minerals, (2) using the empirically and experimentally determined geotherometers such as the garnet- clinpyroxene thermometer of Ghent (1979), and conducted thermodynamic calculations of numerous mineral equilibria relevant to the assemblages observed here.

Metasedimentary rocks of the study area are classified into three distinct zonal patterns based on the appearance and disappearance of index minerals; biotite, garnet and sillimanite/upper sillimanite zones. Reaction isograd and petrogenetic grids are estimated from the equilibrium mineral assemblages of the rocks. Near 400° C, the first biotite appeared in Al-poor metapelites. Biotite formed at the expense of Kfs and Chl. The reaction gives equilibrium conditions of 420° C at about 350 MPa along the Ky-type path in the pure KFASH system. Prograde metamorphism along a Ky-type geotherm produced Bt at about 520° C, the first Grt at 540° C and finally St at 560° C. The three-phase assemblage Grt–Bt–St is characteristic for much of the amphibolite facies. Fe-rich chlorite was replaced by garnet –biotite between 500° C and 520° C. The new assemblage Grt + Bt remains stable to very high grades, and Fe–Mg partitioning between the two minerals is a common of geothermometer. The new diagnostic assemblage is garnet + biotite + sillimanite and marks the beginning of the upper amphibolite facies. This boundary also coincides with the production of the first melt in rocks of suitable composition at H_2O-saturated conditions.

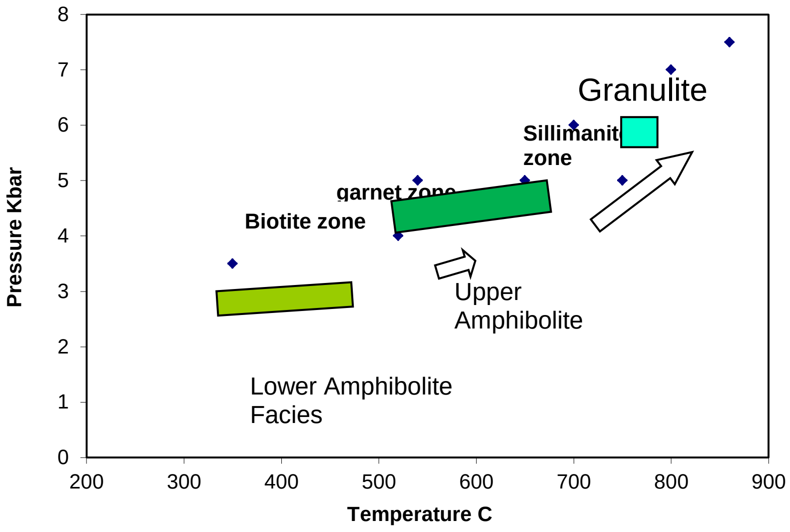


Figure 9 P-T trajectory estimation for each zone of metapelitic rocks and granulite in present area.

Crd–Grt–Kfs–Bt gneisses are transitional between upper amphibolite and granulite facies conditions and the assemblage often indicates equilibration under conditions of reduced P_{H2O}.The representative assemblage in such rocks is Crd-Grt-Sil-Bt. It forms at P–T conditions similar to the Kfs-bearing Crd-gneisses. They are most typically found in terrains that have been metamorphosed at 300–500 MPa and 650–750° C. The pair Opx + Sil is restricted to P>600 MPa at 700° C and toP> 750 MPa at 860° C.

Mineral assemblages, mineral paragenesis, zonal pattern and metamorphic facies series are roughlysimilarto the medium pressure type Barrovian metamorphic style such as biotite, garnet and sillimanite zone. But the study area is relatively higher the Burrow's zone because of the occurrences of garnet, sillimanite minerals that suggest the second sillimanite isograd. Therefore the study area is more similar to Buchan types. Yardley (1989) pointed out that garnet is pressure sensitive and biotite relies on temperature. Biotite is rare or absent in high pressure metamorphic terranes. Also, plagioclase feldspar is entirely absent at very high pressures (Miyashiro, 1961; there in Enami, 1983), and garnet is indicative to medium to high pressure and is absent from metabasites metamorphosed under low pressure conditions, as in most contact aureoles.

Formation of staurolite in biotite zone is controlled by the bulk composition as well as metamorphic conditions. It can be generally stated that the common ferromagnesian minerals contained in peliticrocks are controlled by the Fe/Mg and Al/Si ratio of parent rocks (Spear, 1993; Zaw Win Ko, 2005). Thus the Al and Fe rich bulk rock composition of the pelitic sediments is suitable for the occurrence of staurolite. However, pelitic rocks in present area are mainly rich in biotite, subordinate in albite, and rare in alkali rich minerals so that staurolite cannot be formed in biotite zone of the present area.

Based on the above criteria, metamorphism and metamorphic conditions of the present area are fairly similar to those of the Barrovian metamorphic terranes in Scotland. Again, the rocks are true pelites for epidote group minerals and hornblendes are present but rare.

In addition, the first major deformational episode in the present area produced the predominant foliations and lineation in all rock types accompanied by progressive high P-T metamorphism. The event is characterized by a penetrative flattening foliation and in most gneiss by megascopic scale inclined to recumbent isoclinal folding of the primary layering. In general, the style and intensity of folding vary depending upon the lithology, pre-existing anisotropy and the competency of the rock types. Microscopic post-crystalline strain are common in most gneisses, as evidenced by minor rotation and fracturing of porphyroblaststic garnet, bent micas and strained grains. This post-crystalline strain was followed by a low P high T metamorphism, as evidenced by static overgrowths of cordierite and sillimanite. Both this postcrystalline strain and the postkinematic low-P high T metamorphism are interpreted as related to syn-magmatic metamorphic event and later deformation episode. According to the the paragenesis of Kfs + Grt + Bt represent >600ºC/3.8-5.5Kbar and Grt + Bt + Sil represent up to 720ºC/5.5-7.1Kbar (Ky-type geotherm). So, the research area falls in upper amphibolite to granulite facies and medium P/high T facies series. Therefore, western part of MMB is imposed by medium pressure and fairly high temperature regional metamorphism.

Acknowledgements

I would like to thank to Rector Dr. Lai Lai Wai, Kyaukse University, for her kind permission to summit this research paper.I also greatly indebted to Pro-Rector Dr Seine Nyoe Nyoe Ko for her kind advice. I also deeply acknowledge to Professor Dr. Khaing Khaing Mon, Head of Geology Department in Kyaukse University for her critical reading, valuable advice and discussions throughout this manuscript. Finally, I want to express special thanks to entire colleagues in the geological field for their helpful advice and encouragement in this preparation.

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