Metamorphic Condition of Metamorphic Rocks Exposed at Gangaw Range, Tigyaing Township, Sagaing Region

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Abstract

The research area is situated in the northern part of Sagaing Region. It lies between Latitude 23º 45" to 24º 00" N and Longitude 96º 07" to 96º 15" in one inch topographic map of $93A_1$, covering approximately 376.9 km^2. The various metamorphic units, especially low to medium grade schist and quartzite, which are locally juxtaposed with mafic volcanic rocks are the major rock units of the study area. Recent alluvium and Pleistocene gravels can also be found in the eastern part of the area. Generally the features of metamorphic rocks have NNE-SSW trend with easterly dip. Studying of mineralogical and textural features of metamorphic rocks is performed in this research. Metamorphic rocks are primarily derived from the pelitic and psammitic rocks with metabasite of Ngpyawdaw Chaung Formation of late Jurassic to early Cretaceous age. Moreover, these metamorphic rocks are formed by regional metamorphism and less pronounced dynamic metamorphism under the greenschist to amphibolite facies conditions, with the temperature and pressure of 450-500ºC and 7-8 kbar. The metamorphic grade increases from east to west. Time of metamorphism can be tentatively regarded as Cretaceous to early Eocene.

Introduction

The study area, Gangaw Range, is situated in the northern part of Sagaing Region and lies in the southward structural continuation of high pressure metamorphic belt of Jade Mine area (Fig. 1). Various units of metamorphic rock, essentially low to medium grade, schist and quartzite, mainly underlie the whole area. These units are locally juxtaposed with mafic volcanic rocks. Geological map of the study area is shown in fig (2). Based on the observations of mineral assemblages; the metamorphic rocks of the study area were formed under the greenschist to amphibolite facies conditions. A high pressure metamorphism under eclogite facies condition is proved by small eclogite body (SW of Kumon Range, Mogaung District), which are buried to a great depth and later emplaced in metapelitic rocks (Aung Win 2008).

In the study area, southernmost part of Katha- Gangaw Range, the rock units composed are mainly of metamorphics (both pelitic and basic origin), minor igneous rocks and some sedimentary rock. Metamorphic conditions of the metamorphic units are interpreted on the basic of lithology, mineral assemblages and correlation to other areas.

Types of Metamorphism

Mineralogical and textural evidences of metamorphic rocks indicate that two main types of metamorphism could be recognized in the study area: isochemical regional metamorphism and less pronounced dynamic metamorphism characterized by the facts given below:

(1) The occurrence of textural evidences of foliations, mineral lineation, development of schistosity and rotation of large porphyroblast and crenulation cleavage.

(2) Presence of recrystallization textures and neomineralization products such as garnet porphyroblasts, actinolite, epidote and hornblende.

(3) Dynamic metamorphism is evidenced by the presence of strongly preferred orientation of mica, distorted mica flakes, ragged terminated hornblende, curved twin lamellae of plagioclase and intensely fractured grains in schist.

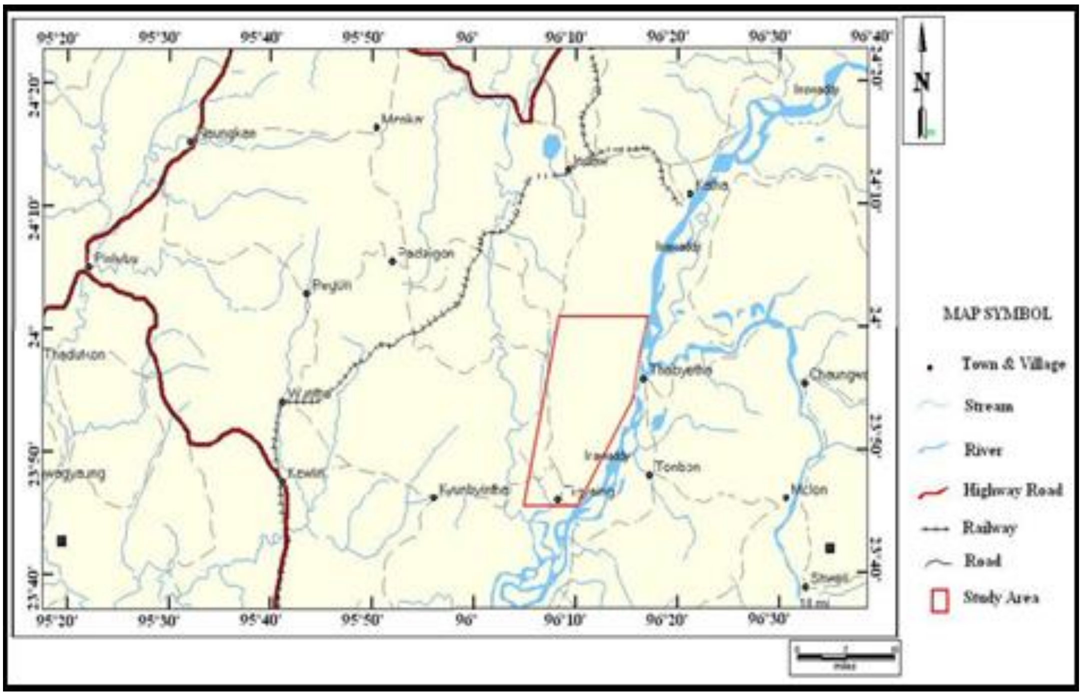

Fig 1: Location map of the study area

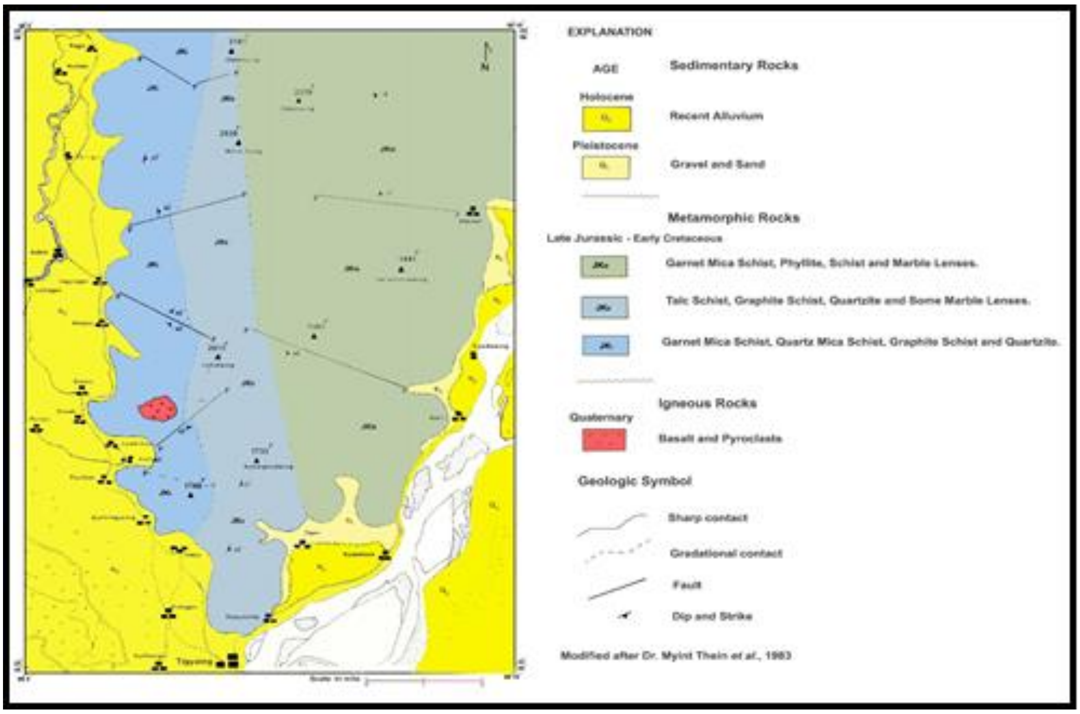

Fig 2: Geological map of the study area

Mineral assemblages, Metamorphic Facies, Grade and Zones

In the present area, the greenschist facies is characterized by the occurrence of chlorite + muscovite + albite + quartz assemblage of quartz mica schist for pelitic sequence (Fig. 3). The occurrence of mineral assemblage garnet + muscovite + biotite in garnet mica schist indicates the upper greenschist facies rock of peilitic origin (Fig. 4).

In metabasic rocks, epidote + chlorite + garnet + quartz is equivalent to upper greenschist facies (Fig. 5). Greenschist- amphibolite facies transition is well documented by the mineral assemblage hornblende + oligoclase + epidote + quartz + magnetite in mica schist (Fig. 6). Depending on the mineral paragenesis, metapelitic rocks are divided into chlorite, garnet, biotite and staurolite zones. Metabasic rocks are divided into chlorite and garnet zones in order of increasing metamorphic grade.

Protolith

In the present study area, the metamorphic rocks may probably be metamorphosed from two major types of protolith: pelitic and basic those are indicated by lithologic characters, textural evidences, index minerals and mineral assemblage in each rock type. Metapilitic and metabasic rocks can occur as juxatapose one another in the field. In general, quartz mica schist, garnet mica schist and quartzite belong to pelitic group. Actinolite schist and amphibolite fall in basic group.

Characteristic minerals of greenschist facies include abundant K- minerals, muscovite in garnet mica schist and quartz mica schist indicating the original pelitic sedimentary rocks. Greenschist of pelitic origin must have abundance quartz and phengite, which has less amount of albite epidote and almost entirely lack of actinolite.

The presence of ferromagnesium minerals, amphiboles, epidote, plagioclase and chlorite that are major constituents in actinolite schist and amphibolite suggests that the parent materials as basic igneous rocks.

Garnet bearing quartzite derived from quartzose sandstone or quartzite. Garnet mica schist may come from Fe, Al rich shale and marl. The abundance constituents of garnet in both quartzite and garnet mica schist indicate rich in Fe, Mn and Al component in parent rock. Graphite schist may come from organic rich layers of sediments. The component of graphite in graphite schist is generated during the metamorphism of black shale.

Schist and quartzite which occur as sequential interlayer in the field suggest that the original rock sequence may probably be alternation of pelitic and quarzose sandstone. Closely associated nature of pelitic and basic rock types in the field suggest that the emplacement of basalt layers and later deposition of pelitic sediment over them.

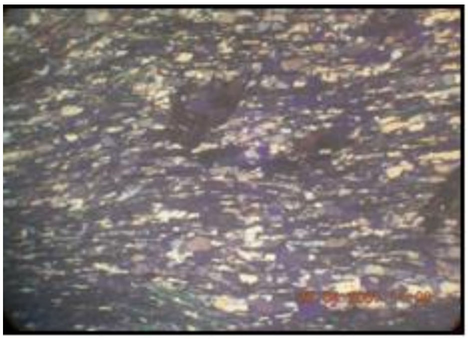

Fig 3: Segregation and parallism of chlorite and muscovite appear as long laths alternating with layers rich in albite and quartz show nematoblastic schistose texture in chlorite schist (Between XN).

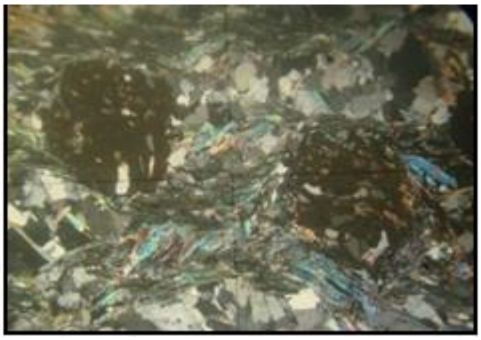

Fig 4: The foliation tend to warp around the garnet porphyroblast in garnet graphite schist due to deformation after they grew (Between XN).

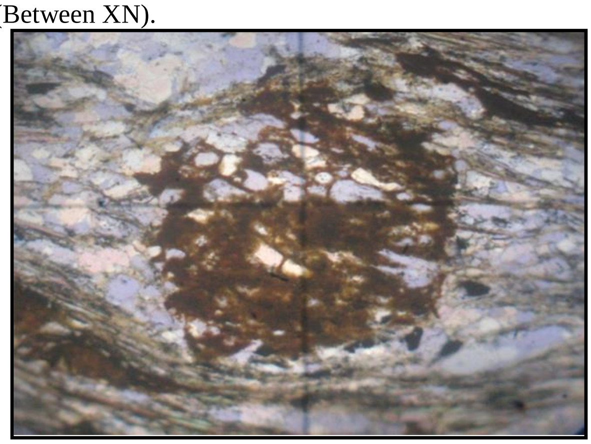

Fig 5: Photomicrograph showing the dominant schistocity of muscovite and graphite. The foliation tends to warp around the garnet porphyroblast due to deformation after they grew (Between XN).

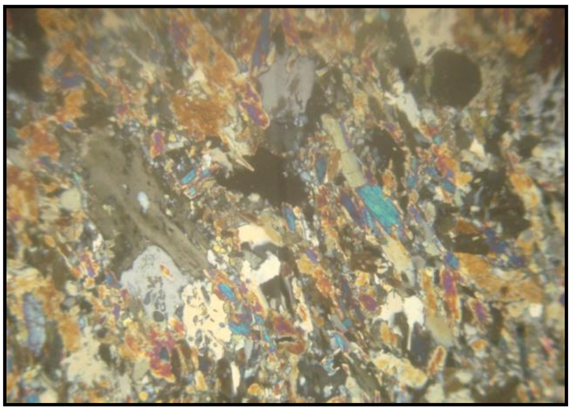

Fig 6: Photomicrograph showing hornblende crystals found as prism with ragged termination and plagioclase (Between XN).

Due to the lack of precise radiochronology and no radiometric ages available for any of the rocks exposed at the Gangaw Range, the present study area, the original age of these rock is not fixed, but correlation with other established area and similar rock unit from surrounding area. Myint Thein et. al., (1983) described that the metamorphic rocks of Gangaw Tange have been derived from rock sequence similar to that of Ngapyawdaw

Chaung Formation and they assigned the age of these rocks as Triassic? At Tagaung Taung area, this sequence has been considered to be Late Jurassic to early Cretaceous in age (Aung Kyaw Thin, 2006). So the age of original rock of metamorphic rocks exposed at the study area may be Triassic and younger.

Time of Metamorphism

Radiometric dating for the metamorphic rocks of the study area has not yet been done, so there is no precise time of metamorphism for these rocks. But GIAC project is carried out radiometric dating for some parts of the Katha and Kumon Range where metamorphose rocks crop out especially in Jade Mine area. Therefore, the time of metamorphism of the present study area can be ascertained to correlate with the surrounding area and other established area depending on the regional framework, lateral continuity and lithologic similarity.

1. In Nagaland blueschist belt, northwestern part of the present study area, block of blueschist, amphibolite and fragments of jades associated with some ultra-mafic. This Nagaland ophilite belt consists of lower to middle Cretaceous radiolarian cherts and volcanic (Bhattacharjee, 1991 in Maruyama et. al., 1996).
2. Jade Mine area northern continuation of the present work, glaucophane schist associated with ultra-basic roks is overlain by the Tertiary clastic sediments (Chhiber 1934, Soe Win, 1968):
3. Mitchell (1998) pointed out that metamorphic rocks in Katha- Gangaw Range may be Pre- Triassic rocks equivalent to the lower part of the Mergui Nappe or Chaungmagyi Turbidites to the east.
4. The metamorphosed rocks associated with ophiolite suite including radiolarian chert in Tagaung Taung Area derived from Ngapyawdaw Chaung Formation assign the age of Lower Jurassic to Early Cretaceous (Aung Kyaw Thin, 2006).
5. Radiometric dating of metamorphic rocks, using Ar37/Ar40 methods for muscovite and biotite in Katha and Kumon Taung that indicate the time of metamorphism took place in 37 to 32 Ma (GIAC 1999).
6. United Nation Team (1978) mentioned that Kumon Range, northern continuation of the study area, is the shoulder of Hukaung basin which is composed of Tertiary sediments. There is no Tertiary sediment in the study area and Kumon Range. So, the relation between the metamorphic rocks of the present study area and Tertiary sediment is not clear. But, the time of metamorphism of these metamorphic rocks is not later than Tertiary.

On the basic of above mentioned points, the time of metamorphism in the study area should tentatively be assigned to middle Tertiary in age.

Reaction Isograds and Petrogenetic Grids

Mineralogical changes and facies characterization for the metamorphic rocks of the study area have been evaluated on the basic of following criteria that are pointed out by Yardley (1989) and Bucher and Frey (1994).

(1) Based on composition of feldspar: Albite occurs at low temperatures but replaced by plagioclase at higher temperature. There is also a tendency for higher anorthite content with increase in temperature. At very high pressure, plagioclase is entirely absent.

(2) Presence or absence of garnet: Garnet mineral is an indicator of medium to high pressure and is absent in lower pressure metabasites as in most contact aeroloes.
(3) Depending on the composition of amphibole: Actinolite is an indicator of low temperature. Medium to high temperature facies are characterized by hornblende and staurolite.

For the pelitic rocks and metamafic rocks, successively reaction isograds are based on the mineral assemblages comprised in these rocks. Due to the poorly accessible of chemical data for the construction of petrogenetic grids, it is not feasible to unravel a distinct P-T trajectory for the rocks of study area. By considering the mineral assemblages observed in each zones of peletic and metamafic rocks, the pressure-temperature condition for formation of these zones could be estimated. The continuous and discontinuous reactions result changes in zonal patterns that permit the approximate pressure- temperature regime of formation of these zones. These metamorphic conditions could be deduced by comparison with the conditions of areas where recognizable information on metamorphism are well documented. Metamorphic conditions for these selected reactions more or less agree with those stated in literatures, as in Turner (1968), Winkler(1979), Mayson (1984), Hyndman (1985), Best (1986), Yardely (1989), Bucher and Frey (1994), Barker (1998), Winter (2001), Raymond (2003).

Regional metamorphism in present area has produced a diversity of mineral assemblages representing crystallization under different conditions of temperature and pressure. A distinctive feature of the pelitic assemblages in this belt is that almandine garnet appears at lower grade than biotite. This implies significantly high pressure for Barrovian metamorphism because stability field of biotite becomes restricted to higher temperature with increased pressure, whereas that of garnet probably expends at high pressure.

In clay rich sediments, formation of chlorite and muscovite (probably phengite) reactions are not definitely known in the present area. As diagenesis of shale merges into low-grade metamorphism, sedimentary assemblages of clay minerals, quartz and feldspar detritus give rise to metamorphic assemblages in which the principle phases are quartz, white mica, chlorite and albite. Micas at this early stage may be phengitic muscovite. Nothing can be inferred from the first appearance of quartz- mica- chlorite assemblages in low grade metamorphism.

Depending on the composition of parent rocks, possible reactions of formation of chlorite and muscovite are documented in literatures but this mineral assemblage is sable below the temperature of 250º C and it is marked by the lower limit of greenschist facies of the present area.

The original clay minerals, such as smectite, are replaced by illite and chlorite. Carbonaceous matter undergoes a series of reaction which ultimately destroyed the organic compounds. Finally, the organic carbon compounds are replaced by graphite. Primary graphite is a common accessory or even a minor component in metapelites and metapsammite rocks, thus low oxygen fugacity is assumed. However, the presence of graphite may indicated by the few amounts present of iron oxide in the rocks.

With increasing the temperature and pressure, the chlorite zone mineral assemblages become unstable and give the reaction to form the garnet zone mineral assemblages. The garnet- in isograd is usually easy to trace in the field because garnet appears in a wide range of rock composition. Frequently, it forms conspicuous porphyroblasts and has almandine rich component in typical of garnet zone distinguished from spessartine garnert which may develop at low- grade in Mn-rich sediments, but is very fine- grained.

Almandine- rich garnet in pelitic rocks first appears in higher temperature part of low-grade metamorphism. The characteristic garnet of the garnet zone is rich in almandine and probably grows by continuous reactions:

Chlorite + Chloritoid + 2Quartz $\longrightarrow$ 2Garnet + 5H_2O --------- (1)

At about 510ºC almandine garnet is formed by chlorite-chloitoid decomposition. The two new diagnostic assemblages are chlorite- almandine and almandine-chloritoid.

3Chlorite $\longrightarrow$ 3Garnet + 2Magnetite + 12H_2O (+QMF) --------- (2)

In reaction (2) chlorite decomposes in quartz saturated rocks at about 540ºC under production of almandine-garnet and magnetite (Bucher and Frey, 1994).

Chlorite + Muscovite $\longrightarrow$ Garnet +Biotite+ Quartz + H_2O --------(3)

The significance of above reaction shows the coexistence of garnet, biotite and chlorite in the garnet zone. The formation of biotite in prograde metamorphism of the present study is controlled by the P-T conditions, especially temperature, rather than bulk rock composition. Other reactions produce the garnet are:

Chlorite1 + Epidote $\longrightarrow$ $Chlorite_2$ +Garnet + Fluid --------- (4)

In which the composition of chlorite become more Mg.

Chlorite + Quartz $\longrightarrow$ Garnet + H_2O --------- (5)

(Banno, Sakai and Higashino, 1986: in Raymone, 2003)

Chlorite + Quartz + Magnetite $\longrightarrow$ Garnet + H_2O --------- (6)

Chlorite- quartz is wide spread mineral combination occurring in almost all pelitic schist of the present area. The stability of Fe chlorite + quartz (Morgan, 1969) and Mg-cholorite + quartz (Fawcett and Yoder, 1966; in Morgan, 1969) has been studied that under the low oxygen fugacity, the maximum stability of Fe chlorite at 2Kbar is 540ºC. Similarly, Fawcett and Yoder found that at 2Kbar, the maximum stability of Mg- chlorite + quartz is slightly less than 565ºC. An increase of pressure to 5Kbar increased the stability field of Mg-chlorite + quartz to 625ºC.

The garnet zone is also often marked by a change in plagioclase composition in pelitic rock. At lower grade the only plagioclase is albite, and Ca may be present in the accessory epidote or other phases. Within the garnet zone oligoclase appears and has rather pure albite coexisting with oligoclase (An_{20} to An_{25}) as separate phases (Crawdord, 166: in Yardley, 1989). So, the lower part of garner zone is approximately equivalent to the epidote amphibolite facies.

The first appearance of biotite in pelitic rocks is thought to be due to reactions between low grade muscovite (commonly phengitic muscovite) and chlorites. In the present area, the formation of biotite is defined by the following reactions.

3Chlorite + White $Mica_1$ $\longrightarrow$ Biotite+ White $Mica_2$ --------- (7)

Micas are very important group of minerals in metapelitic rocks. In the study area mica schists are typical metapelitic rocks and principal micas are muscovite and sericite.

3Chlorite + 8Kfeldspar $\longrightarrow$ 5Biotite+ 3Muscovite+9Quartz+4H_2O --------- (8)

1Muscovite+3Chlorite + 3Quartz ⟶ 4Garnet+1Biotite+ 12H_2O --------- (9)

1Muscovite+ 1Biotite+ 3Quartz ⟶ 1Garnet+2Kfeldspar + 2H_2O ---------(10)

In reaction (8), sedimentary assemblage Kfeldspar + chlorite is replaced by biotite + muscovite. The product biotite is Fe-rich and appears at about 400ºC. Reaction (9) limits the presence of chlorite in rocks containing excess muscovite. The assemblage is replaced by garnet + biotite at a temperature of about 520ºC. Biotite is removed from rock containing much muscovite by reaction (10) at about 590ºC (Bucher and Frey, 1994).

In the present study area, subhedral staurolite minerals are embedded in the matrix of garnet staurolite schist. Winkler (1979) pointed out that the transition between greenschist and amphibolite facies in pelitic rocks is marked by the formation of staurolite and disappearance of Fe-rich chlorite in the presence of muscovite. Bucher and Frey (1994) also suggested that the occurrence of staurolite and almandine garnet marks the metapelitic rocks. The possible reactions for the production of staurolite are:

Garnet + chlorite + muscovite + quartz ⟶ Staurolite + biotite + H_2O --------(11)

Garnet + chlorite + muscovite ⟶ Staurolite + biotite + quartz + H_2O --------(12)

(Sphere et. al., 1991)

The reaction (11) and 12 are compatible with evidence for garnet resorption in most rocks of amphibolite facies and reaction (12) is also apparently resulted in the removal of muscovite from the rock. Metabasite are interlayer with garnet mica schist of garner zone, and the petrogenetic significance obtained by the mineral assemblages coupled with the phase relations observed from the modal system leads to draw a conclusion of metamorphic condition 7-8 Kbar a 550- 600ºC and facies condition is greenschist to epidote – amphibolite facies (Bucher and Frey, 1994).

Conclusion and Discussion

In the present work, the zonal and facies approaches were based on hand specimen and basic petrographic analysis of thin sections and only qualitative idea of the link between mineralogical changes and P-T condition. Estimated zonal pattern in the present area, chlorite zone ⟶ biotite zone ⟶ staurolite zone, pointed out the metamorphic grade in present area increases to westward.

By considering the mineral assemblages observed in each zones of pelitic and metamorphic rocks, the pressure temperature conditions for mineral reactions in the present work agree with many literature.

Mineral assemblages of metapelite and metabasite rocks are classified into three distinct zones base on the appearance and disappearance of minerals; chlorite, garner and biotite. This zonal pattern is the respective of increase in grade and belongs to the greenschist to amphibolite facies. The temperature- pressure range of this facies is very broad. According to mineral assemblages, P-T conditions of greenschist to amphibolite facies are estimated to be temperature between 450ºC and 600ºC and pressure 7 to 8 Kbars.

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