Mineral Assemblages And Metamorphic Condition Of The Katha Metamorphics Exposed In Katha-Indaw Area, Sagaing Region, Myanmar

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Abstract

The present area is located at the southern part of the Katha-Gangaw Range, Katha-Indaw area, Sagaing Region. Metamorphic rocks of the study area are divided into three informal units: lower most Unit I, middle Unit II and upper most unit III. Unit I is composed of Garnet-biotite schist, garnet-graphite schist, garnet-staurolite schist, garnet quartzite, quartz-mica schist, garnet-hornblende schist, and garnet-barroisite schist. Unit II essentially contains biotite schist, micaceous quartzite, and actinolite schist. Unit III consists of chlorite phyllite, chlorite schist, graphite schist, and serpentinite. Metapelites are divided into chlorite, biotite, garnet, and staurolite zones and metabasites into chlorite, and garnet zones. Chlorite and biotite zones occupy the greenschist facies and garnet and staurolite zones possess the epidote - amphibolite facies. The equilibrium phase diagrams and mineral assemblages of the garnet-barroisite schist reveal the peak condition of pressure ~1.5GPa at temperature ~580C^{o}. On the basis of the P-T condition, the Katha Metamorphics of the study area reached the eclogite facies transition.

Keywords: Katha Metamorphics, Eclogite facies transition, Katha-Indaw area

Introduction

The present focusing area is situated in Katha and Indaw Townships, northern part of the Sagaing Region. It lies between N latitude 24° 05´- 24° 08´ and E longitude 96° 10´ - 96° 20´. The location of the study area is shown in Fig.(1). The study area is chiefly composed of metamorphic rocks, Katha Metamorphics. The dominant rock types are pelitic to psammatic schists and metabasites.

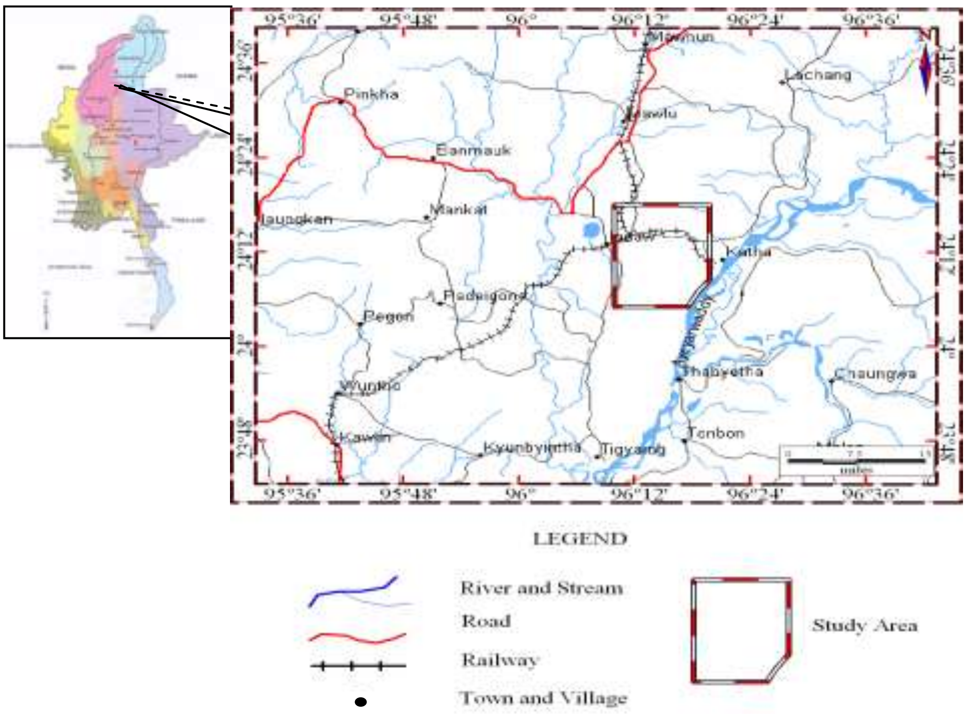

Fig.1 Location map of the study area.

Purposes of Study

This paper is mainly intended: to study the mineralogical and petrological analysis and estimate the metamorphic P-T condition of the rocks.

Materials and Methods

GPS instrument and Brunton compass are used for measuring specific locality, foliation, joints, dip, and strike, etc. The rock samples collected in the field were cut, polished and ground to prepare thin sections. Detailed mineralogical characters, textural features and other petrological features were studied under the petrographic microscope for petrographic analysis. For the calculation of P-T conditions, thecoexisting mineral assemblages are used. Then, the data is correlated to the established thermodynamic data and phase equilibrium.

General Geology

The present study area lies within the northern part of the Central Cenozoic Belt (Central Lowland). The Sagaing Fault passes through the western part of this area. The Katha-Gangaw Range and the Minwun Range are separated by the Meza Valley. Farther west beyond this area is occupied by the Wuntho-Banmauk Uplift (United Nations, 1979b). The southern part of this area is covered by the Tagaung Taung ultrabasics and Mogok metamorphics. Satellite image of the study area and its environs is shown in Fig.(2). The study area is chiefly underlain by the rocks of the Katha Metamorphics. The dominant rock types are pelitic to psammatic schists and metabasites. The Katha Metamorphics are subdivided into three informal units: lower Unit I, middle Unit II and upper Unit III. The order of arrangement of units is concerned with their minerals, mineral assemblages and lithologies. The beds generally dip towards east. The metamorphic grade increases from east to west. The rock sequence (in descending order in age) is given in Table(1). Geological map of the study area is shown in Fig.(3).

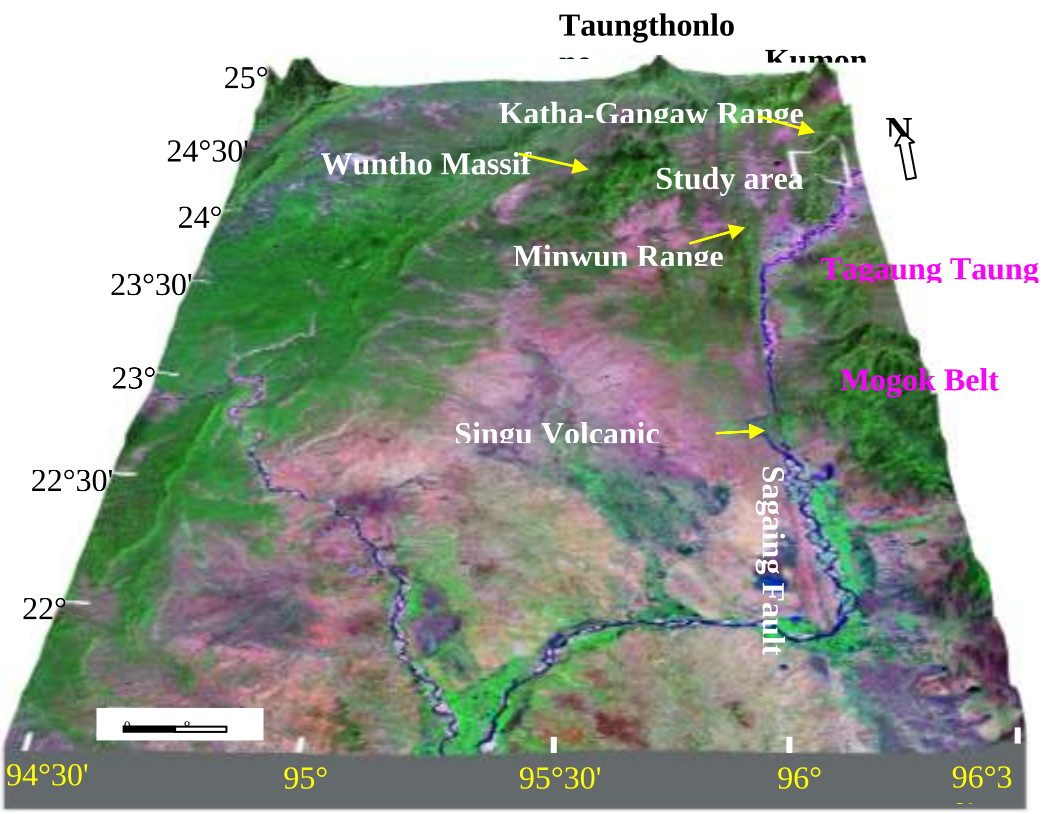

Fig.2 Satellite image of the study area and its environs (Source: Google Earth,

Table 1 Stratigraphic succession of the Katha-Indaw area.

Rock Units		Age
Sedimentary Rocks		
Alluvium		Holocene
	-Unconformity	
Gravel		Pleistocene
	-Unconformity	
Irrawaddy Formation		Miocene to Pliocene
	-Unconformity	
Metamorphic Rocks		
Unit III Chlorite phyllite, chlorite schist, graphite schist, and quartzite.		Late Jurassic – Early Cretaceous
Unit II Biotite schist, micaceous quartzite, and actinolite schist.		
Unit I Garnet-biotite schist, garnet-graphite schist, garnet-staurolite schist, garnet quartzite, quartz-mica schist, garnet-hornblende schist, and garnet-barroisite schist.		

Mineral Assemblages and Metamorphic Facies

In the study area, assemblages of coexisting minerals in the metamorphic rock units provide the positive evidence of the metamorphic condition under which they were formed. Diagnostic mineral assemblages are based to identify the metamorphic facies of metapelites and metabasites. The facies classification, nomenclature and defining mineral assemblages used in this work were mainly based on Turner (1968), Winkler (1979), Hyndman (1985) and Yardley (1988). On the basis of petrographic analysis, (8) representative equilibrium mineral assemblages are defined, (5) in metapelites and (3) in metabasites. The petrographic views of 8 mineral assemblages are shown in figures 4,5,6,7,8,9,10, and 11. The mineral parageneses recognized in the study area may be delineated to be indicative of the greenschist facies to epidote-amphibolite facies in metapelites; and greenschist facies to epidote-amphibolite facies and eclogite facies transition in metabasites. Metamorphic rocks associated with mineral assemblages and metamorphic facies of the study area are listed in Table(2). Common assemblages composed of critical minerals with their respective phase diagram for each facies are graphically represented by means of ACF, AKF and AFM diagrams (Fig.12 & 13).

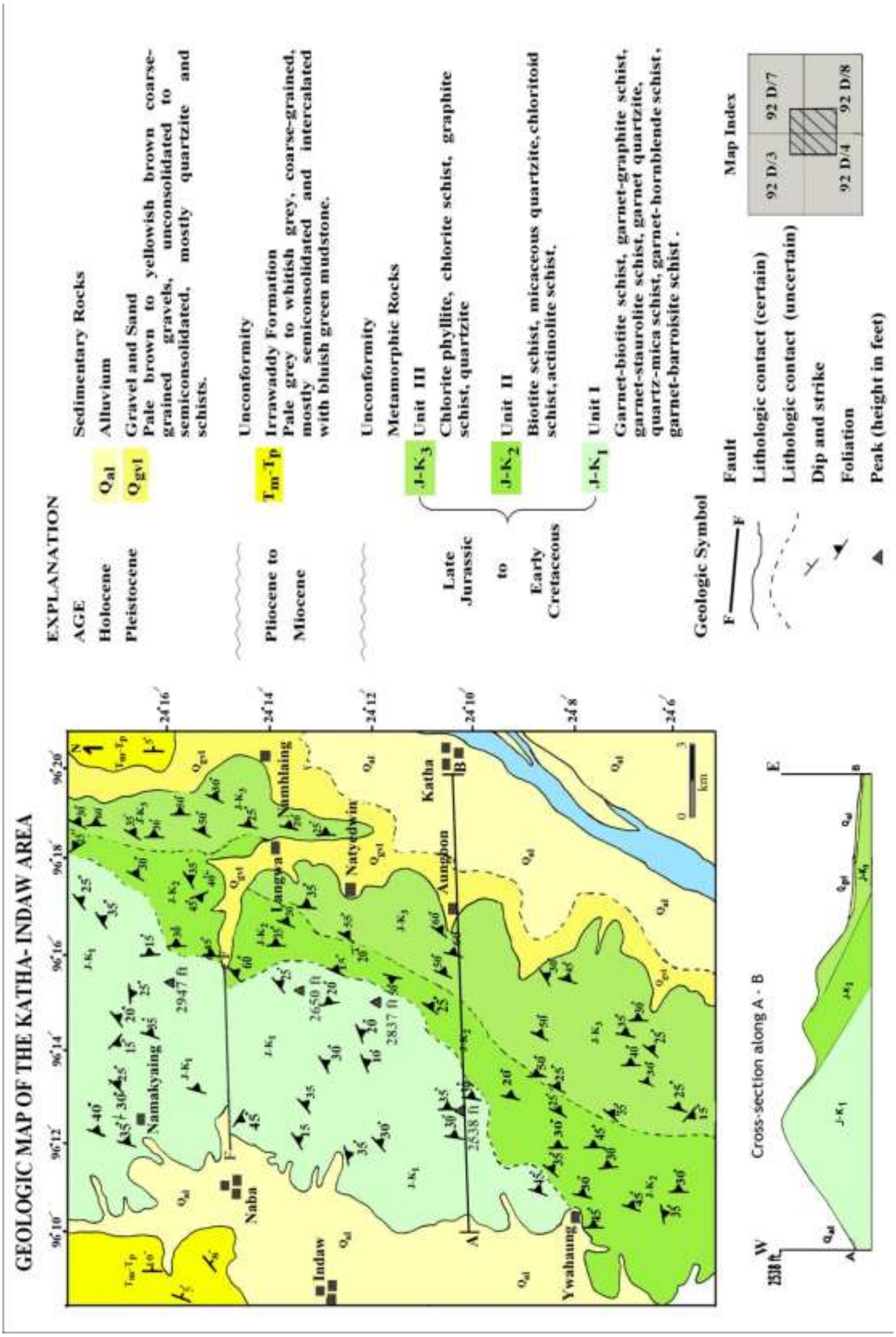

Fig.3 Geological map of the study area. (Geology by Thaire Phyu Win, 2011)

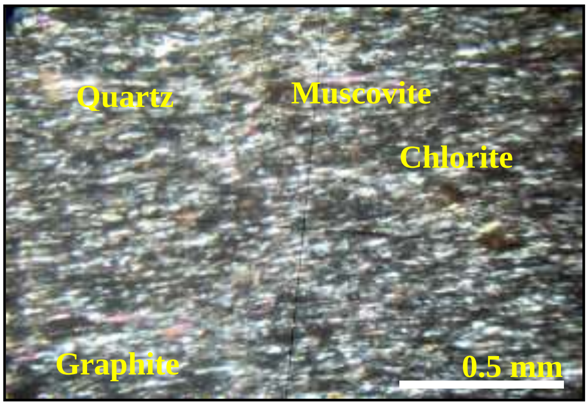

Fig.4 Parallel arrangement of chlorite, muscovite flakes and graphite strings with some lenticular quartz in chlorite phyllite. (XN)

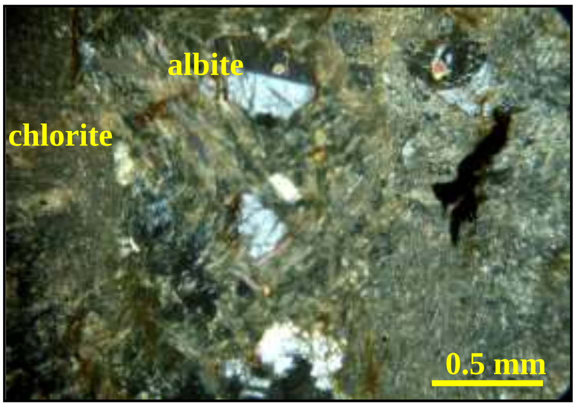

Fig.5 Twinned albite porphyroblasts embedded in chlorite schist. (XN)

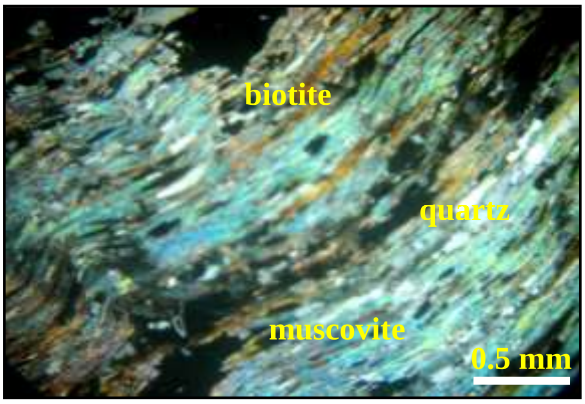

Fig.6 Schistosity, defined by parallel alignment of biotite, muscovite and quartz in biotite schist. (XN)

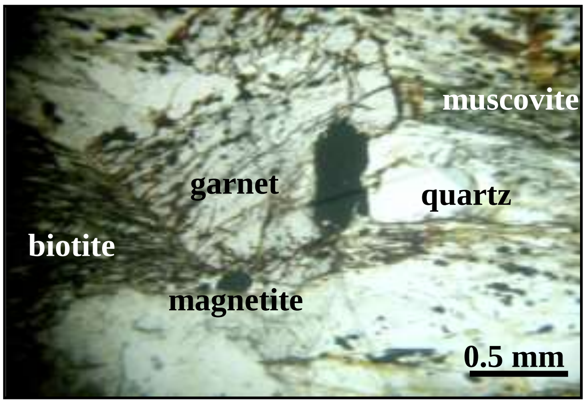

Fig.7 A garnet porphyroblast with a straight inclusion fabric discordant with the external schistosity in garnet-biotite schist. (PPL)

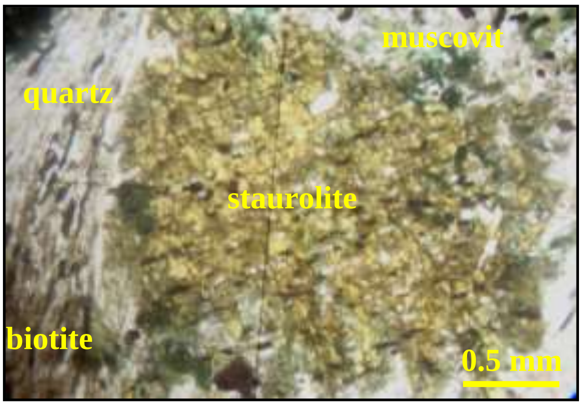

Fig.8 Abundant quartz inclusions in staurolite porphyroblast, showing the characteristic poikiloblastic texture in garnet-staurolite schist. (PPL)

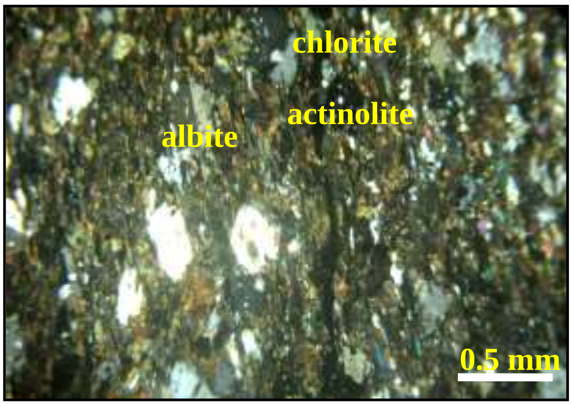

Fig.9 Simple twin developed in an albite porphyroblast in actinolite schist. (XN)

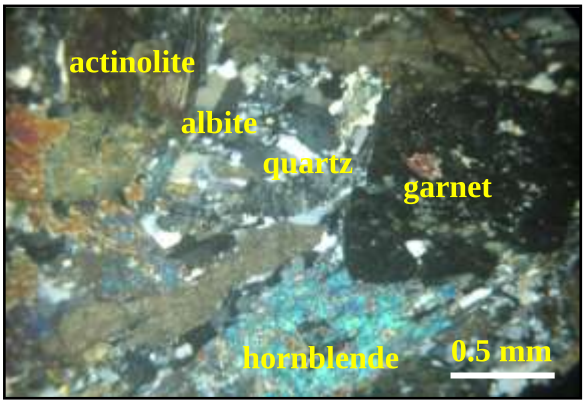

Fig.10 Faint foliation produced by sub-parallel alignment of actinolite, hornblende, and albite in garnet-hornblende schist. (XN)

Fig.11 Photomicrograph showing faint foliation given by coarse-grained barroisite in garnet-barroisite schist. (PPL)

Table 2 Mineral assemblages and metamorphic facies of the study area.

Type of Metamorphism	**Rock Group**	**Representative Rock**	**Mineral Assemblages**	**Metamorphic Facies**
Regional Metamorphism	Metapelite	Chlorite phyllite	**1** Chlorite-muscovite- quartz	Greenschist Facies
		Chlorite schist	**2** Chlorite-muscovite-albite-quartz	
		Biotite schist	**3** Biotite-muscovite-chlorite-quartz	
	Metabasite	Actinolite schist	**6** Actinolite-epidote-albite-chlorite-calcite-quartz	
	Metapelite	Garnet-biotite schist	**4** Garnet-biotite-muscovite-chlorite-quartz	Epidote-Amphibolite Facies
		Garnet-staurolite schist	**5** Garnet-staurolite-biotite-muscovite-quartz	
	Metabasite	Garnet-hornblende schist	**7** Garnet-hornblende-actinolite-plagioclase-epidote	
		Garnet-barroisite schist	Garnet-barroisite-albite-epidote	Eclogite Facies Transition

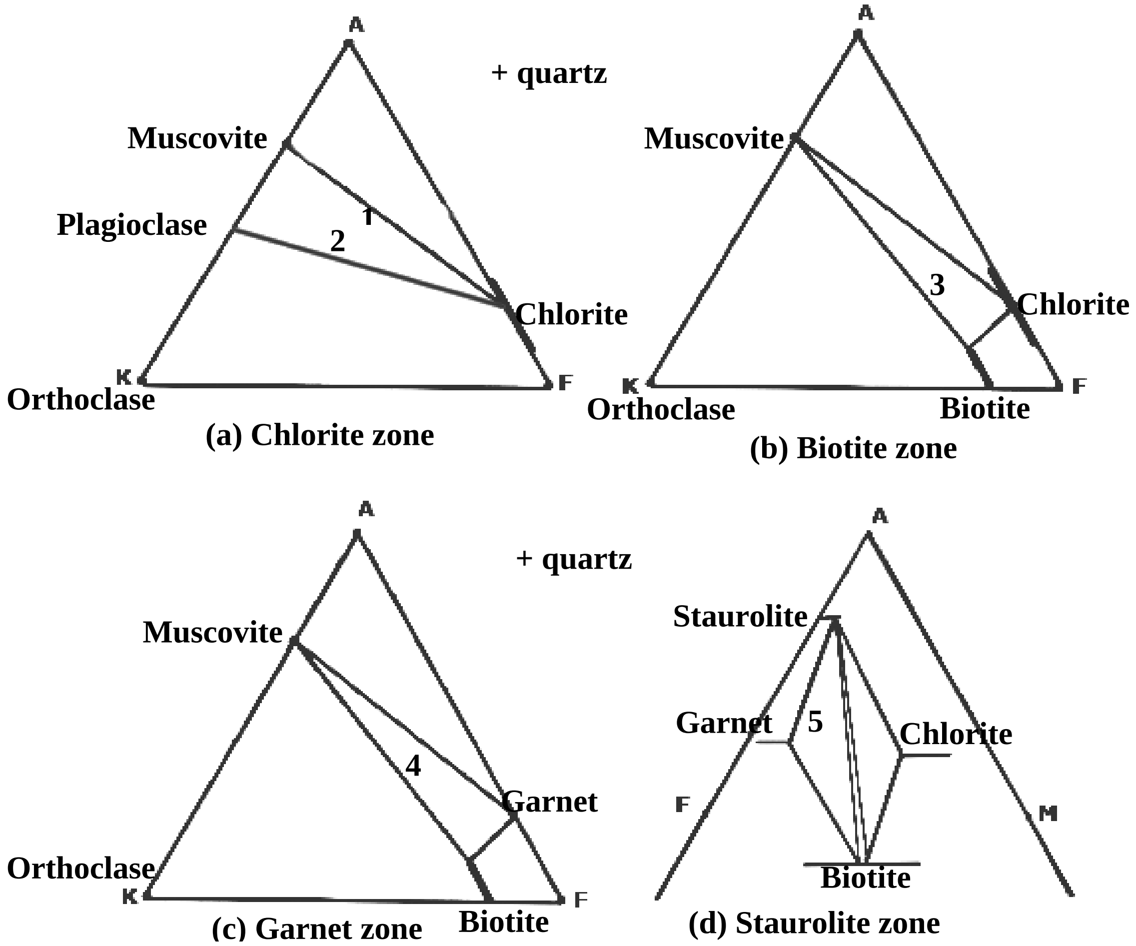

Fig.12 AKF and AFM diagrams for pelitic mineral assemblages developed in (a) chlorite zone (b) biotite zone of greenschist facies and (c) garnet zone and (d) staurolite zone of epidote-amphibolite facies.

Mineral Isograds of Metapelites

In schistose rocks, greenschist facies including chlorite zone, biotite zone and epidote amphibolite facies containing garnet zone and staurolite zone have been delineated. In the chlorite zone, equilibrium is difficult to attain in experiments at these low temperatures so that P-T conditions are not certain but they are believed to be in the 350° to 450°C range (Winter, 2010).

In biotite zone, the biotite isograd reaction that affects pelites is encountered at point 2 in Fig.(14), in which chlorite reacts with K-feldspar to produce biotite-phengite rich muscovite:

3 Chl + 8 Kfs = 5Ann + 3 Ms + 9 Qtz + 4 H_2O

An equilibrium condition for this reaction is 420°C at about 3.5 kb (Bucher and Frey, 1994).

In a garnet zone pelitic rock has the assemblage: garnet-biotite-muscovite-chlorite-quartz. The characteristic garnet of the garnet zone is rich in almandine, and probably grows by continuous reactions (Banno, Sakai and Higshino, 1986 in Raymond, 1995).

Chlorite + Muscovite → Garnet + Biotite + Quartz + H_2O
Chlorite + Epidote → Chlorite + Garnet + Fluid
Chlorite + Quartz → Garnet + H_2O
Chlorite + Quartz + Magnetite → Garnet + H_2O
Chlorite → Garnet + Magnetite + 12 H_2O

In this equation, chlorite decomposes in quartz saturated rocks at about 540°C and almandine garnet and magnetite may appear (Bucher and Frey, 1994). The P-T condition for the garnet-isograd reaction can be observed in Fig.(14).

Staurolite is also found in pelitic rocks by the discontinuous reaction:

Garnet + Muscovite + Chlorite → Staurolite + Biotite + Quartz + H_2O

The first occurrence of staurolite and almandine-garnet marks the transition from the greenschist facies to the amphibolite facies in pelitic rocks. The temperature at the beginning of the amphibolite facies is slightly above 500°C (Bucher and Frey, 1994). Reactions that produce both garnet and stauroltie have been proposed for the production of staurolite in pelitic schists (Spear *et al.*, 1991). In this condition, garnet grows initially in the assemblage garnet + biotite + chlorite + plagioclase + muscovite + quartz along an isobaric heating path at 0.6 GPa from 500°C to 570°C.

Mineral Isograds of Metabasites

In the study area, metamorphism of mafic rocks begins in the greenschist facies, which is correlable with the chlorite and biotite zones of the associated pelitic rocks.

Along the characteristic Ky- and Sil-geotherms, the first occurrence of actinolite+epidote+chlorite+albite+quartz defines the beginning of the greenschist facies. The assemblage is produced by the reactions

5Prh + Chl + 2Qtz → 4 Zo + Act + 6 H_2O

at a temperature of about 280°± 30°C at pressures below 0.6 GPa (Bucher and Frey, 1994). The assemblage is shown by ACF diagram in Fig.13a.

Garnet appears at the transition to the amphibolite facies. The transition to amphibolite facies usually occurs in the upper biotite zone and garnet zone of associated pelitic rocks. Along a Ky-type geotherm, the greenschist-amphibolite facies transition occurs at temperatures of about 500°C (0.5 GPa) (Bucher and Frey, 1994). Garnet zone is defined by garnet-hornblende schist containing the assemblage of garnet + hornblende + albite + actinolite + epidote. The assemblage is shown by ACF diagram in Fig.13b. Progressive mineral changes with their respective reactions and petrographic significance in metabasites of the study area and the approximate location of pelitic zones for comparison are shown in Table(3).

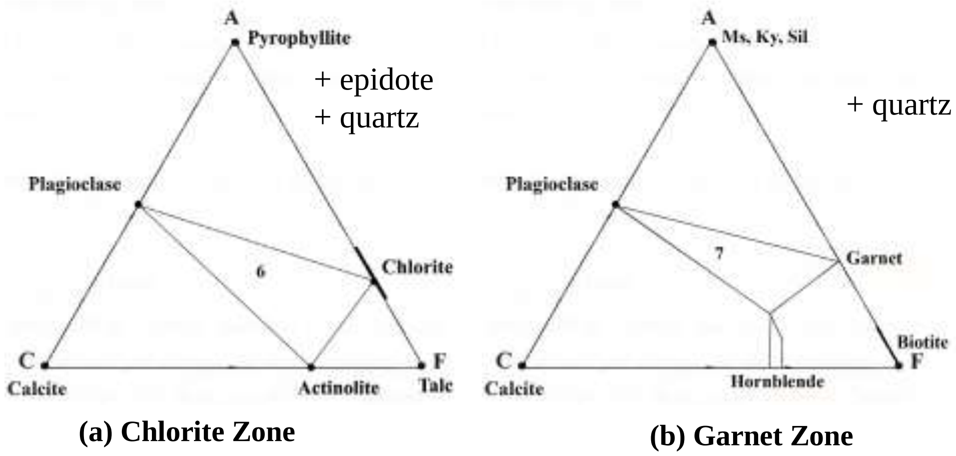

Fig.13 ACF diagram for metabasite mineral assemblages developed (a) chlorite zone and (b) garnet zone.

Table 3 Progressive mineral changes with their respective reactions and petrographic significance in metabasites of the study area. The approximate location of pelitic zones is given for comparison.

Metamorphic Facies	Greenschist Facies	Epidote-Amphibolite Facies	Eclogite Facies Transition
Metamorphic Zoning	Chlorite Zone	Garnet Zone	Garnet Zone
Albite			
Albite-oligoclase			
Epidote			
Actinolite			
Amphibole		blue green hornblende	barroisite
Chlorite			
Calcite			
Garnet			
Representative rock	Actinolite schist	Garnet-hornblende schist	Garnet-barroisite schist
Reaction Stoichiometries	25 Pmp + 2Chl + 29Qtz = 7Act + 43 Zo + 67 H_2O	12 Zo + 15Chl + 18Qtz = 8Grs + 25 Prp + 66 H_2O	6 tr + 48 an + 27 clin = 55 py + 20 gr + $14H_2O$
Petrographic Diagnostic Minerals	Occurrence of abundant actinolite, albite and epidote	Transition from actinolite to blue green hornblende and appearance of garnet.	Transition from hornblende to barroisite
Zone for associated metapelites	Chlorite Zone Biotite Zone	Garnet Zone	Garnet Zone

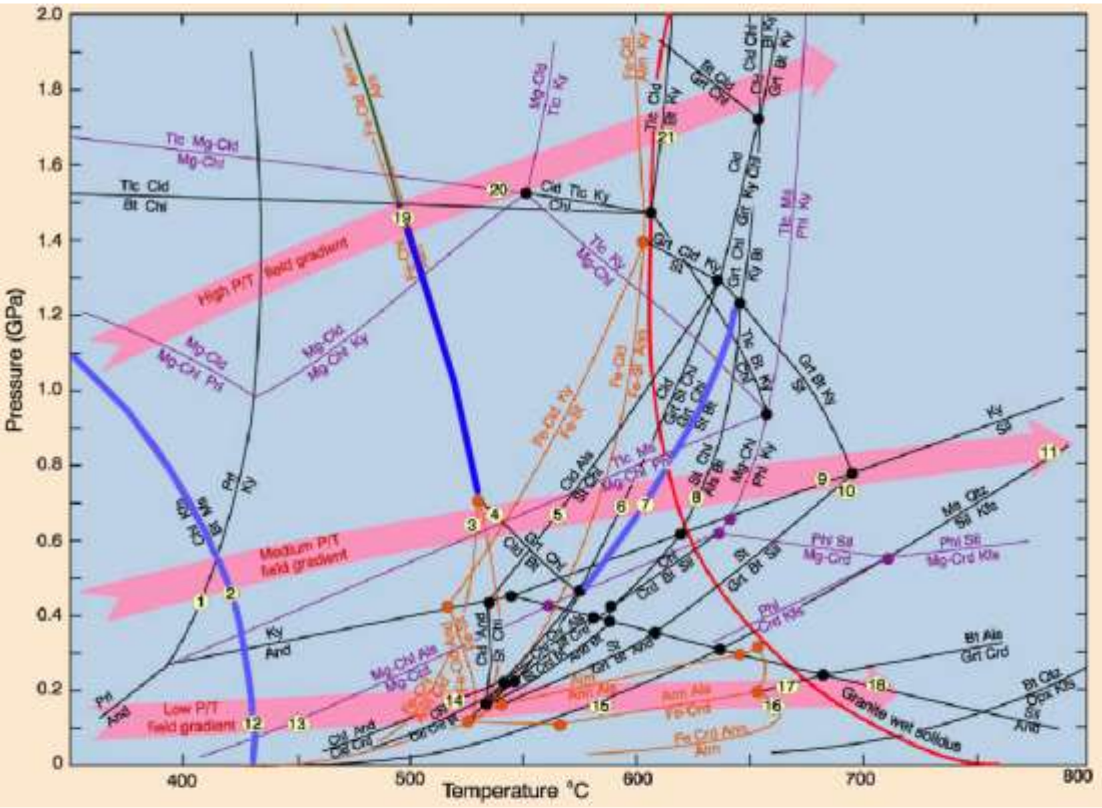

Fig.14 Petrogenetic grid showing the location of selected reaction isograds appropriate for the study area. (Winter, 2010)

Conclusion

Temperature-pressure conditions of metamorphic rocks in present area are depicted with their respective facies and zones. The mineral parageneses may be delineated to be indicative of the greenschist to epidote amphibolite facies in pelitic rocks. It also indicates that greenschist to epidote amphibolite facies and eclogite facies transition in metabasites. In metapelites, the typical greenschist facies mineral assemblage of chlorite + muscovite + quartz occurs in chlorite schist, and that of biotite + muscovite + chlorite + quartz, in biotite schist, and in turn occupies chlorite zone and biotite zone respectively. The P-T condition of these assemblages may be about 420°C and 0.35 GPa. The associated metabasite of actinolite schist contains assemblage of actinolite + epidote + chlorite + albite + quartz which formed at about 400°C and below 0.6 GPa (Bucher and Frey, 1994).

Garnet zone of metapelites mostly occupies the garnet-biotite schist. It has the assemblage of garnet + biotite + muscovite + quartz which is observed at about 550°C (Bucher and Frey, 1994). Garnet + biotite + staurolite + muscovite + quartz assemblage of garnet-staurolite schist occur in staurolite zone. The first occurrence of staurolite and almandine garnet marks the transition from greenschist to epidote-amphibolite facies. This condition occurs at 0.6 GPa from 500°C-570°C.

The prograde metamorphic history of eclogites is commonly inferred from mineral inclusions and compositional zoning in garnet. Discontinuous zonal structure of garnet indicates two-stage growth of the mineral. Although there is little evidence to specify directly the formation stage of the core part of the zoned garnet, the prograde zoning of the core possibly implies that this part was formed during prograde metamorphism, and then reached the eclogite facies stage. Chlorite inclusion with the inner part of the garnet porphyroblast equilibrates at the temperature of 475°C at 1.21GPa. The composition of matrix amphiboles and outer rim of garnet yielded the equilibrium condition of 580ºC at 1.45 GPa. Therefore, in the study area the metamorphism reached the peak P-T condition of 580°C at 1.5 GPa. Therefore, the basic schist of the study area reached the initial stage of eclogite facies stage. P-T diagram for metabasite is shown in Fig.(15).

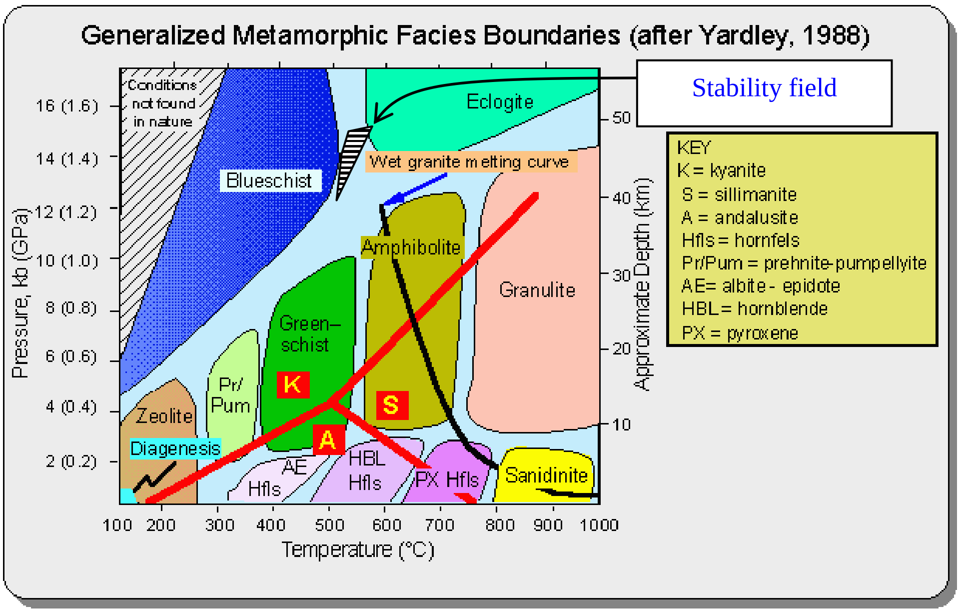

Fig.15 Stability field of garnet-barroisite schist and general metamorphic facies boundaries (in Yardley, 1988). Note that stability field of garnet-barroisite schist (shaded area) falls within the field of eclogite facies transition.

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