High grade metamorphic assemblages and reactions in pelitic schists of the Merrimack Synclinorium, Central Massachusetts

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INTRODUCTION

Metamorphosed pelites of the Merrimack Synclinorium in central Massachusetts contain mineral assemblages characteristic of metamorphic Zones IV, V, and VI (Robinson & Tracy, 1982). These rocks are comprised of schistose material and quartzofeldspathic material interpreted by Thompson et al. (1992) to have derived from in situ partial melting by the following prograde reactions (Figure 3):

Zone IV to Zone V: **Ms + Qtz = As + Kfs + Melt**
Zone V to Zone VI: **Bt + Sil + Qtz = Grt + Crd + Kfs + Melt**

The rocks in this study were collected from four different outcrops of the Rangeley Formation in central Massachusetts: Templeton (Zone IV), Conant Brook Reservoir (Zone V), Brimfield Road, Wales Quad (pipeline) (Zone VI) and McBride Road, Wales Quad (Zone VI). These rocks contain the following assemblages:

Zone IV: **Ms + Kfs + Bt + Sil + Grt + Qtz ± Ilm, Monazite**
Zone V: **Kfs + Bt + Sil + Grt + Qtz ± Ilm, Monazite**
Zone VI: **Kfs + Bt + Sil + Grt + Crd + Qtz ± Ilm, Monazite**

Textural and compositional evidence suggest significant retrograde metamorphism and back reaction in these rocks, processes that may have resulted from the flushing of water through the rocks during melt crystallization. The existence of the isograd assemblage in the Zone VI rocks examined in this study could be due to such back reaction.

METHODS

Representative samples of the metamorphic zones in question were collected from four different outcrops of the Merrimack Synclinorium. The rocks of this study make up the higher grade rocks of a sequence of six zones of increasing metamorphic grade. The rocks were analyzed petrographically in order to characterize the textural relationships among the minerals. The samples were also analyzed with a Zeiss Digital Scanning Electron Microscope with a LINK Energy Dispersive X-ray Spectrometer at Amherst College to determine minerals zoning patterns and mineral compositions for geothermobarometry.

PETROGRAPHY

The rocks from all three zones contain both a schistose matrix and quartzofeldspathic partial melt material in pods, bands and ribbons. The Zone V rocks occur within the Conant Brook Shear Zone and experienced shear deformation, homogenizing the portions of melt with the neighboring schist and obscuring textural evidence of metamorphic reactions. Textures in the Zone IV and VI rocks, however, appear to be well preserved.

In Zone VI rocks, inclusions of sillimanite, biotite, and quartz in garnet are consistent with the prograde reaction

Bt + Sil + Qtz = Grt + Crd + Kfs + Melt,

the reaction that defines the Zone V - Zone VI assemblage boundary (Figure 1). The presence of bands of garnet between bands of melt and the surrounding schistose matrix further supports this reaction. Also present in Zone VI rocks is evidence of back reaction of the above process, perhaps due to slow cooling or to the flushing of water

Prograde

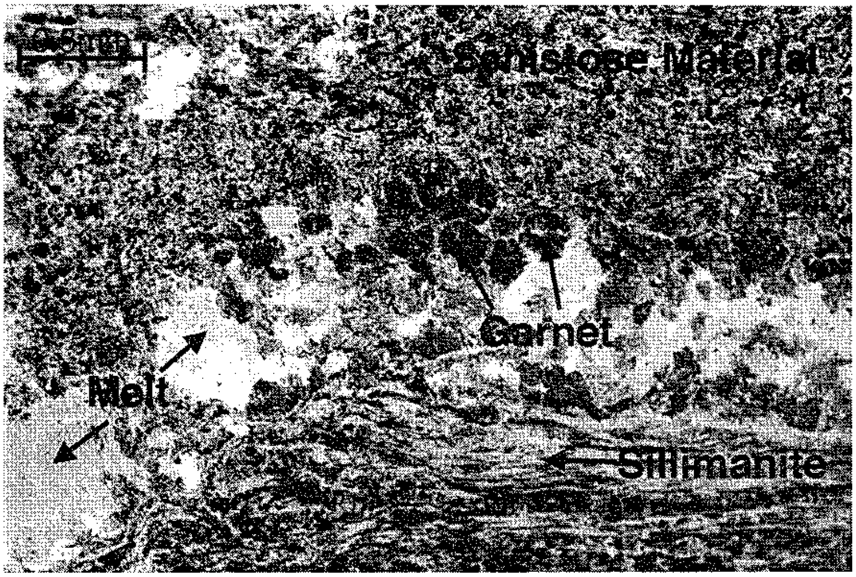

Figure 1. Quartzofeldspathic partial melt concentration in bands and pods. Note the band of garnets between the dark schistose material and the paler band of K-feldspar, evidence of the prograde reaction **Sil + Bt + Qtz = Grt + Crd + Kfs + Melt.** The fibrous region at the bottom of the picture is a band of coarse-grained sillimanite.

Retrograde

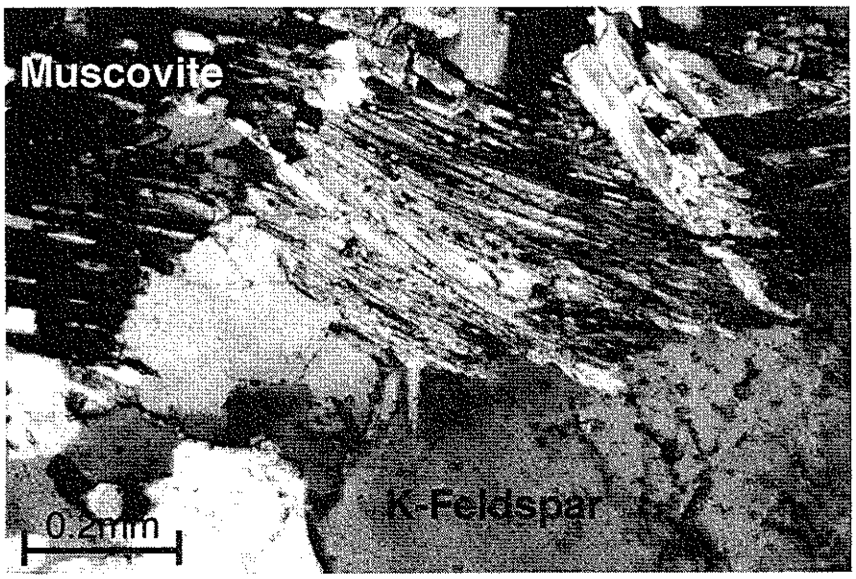

Figure 2. Muscovite pseudomorph after sillimanite, suggesting retrograde metamorphism following higher grade metamorphism, possibly by back reaction of the prograde reaction **Ms + Plag + Qtz = As + Kfs + Melt.** Other evidence for similar retrograde metamorphism includes coarse, cross-cutting muscovite along fold hinges.

through the rocks as the melt crystallized. Coarse grained, cross-cutting biotite and coarse matrix sillimanite both suggest the presence of fluid facilitating back reaction.

Similar processes characterize the rocks from Zone IV; namely, a prograde, melt-producing reaction and later back reaction during melt crystallization. These rocks show dominant retrograde metamorphism in which all the muscovite appears to be late-forming and cross-cuts the rock fabric. Also indicative of this process are muscovite pseudomorphs after sillimanite, suggesting back reaction of the following process (Figure 2):

Ms + Qtz = Sil + Kfs

Because this reaction defines the assemblage boundary between Zone IV and Zone V, these textures suggest that the Zone IV rocks in this study originally equilibrated at higher grade and experienced retrograde metamorphism that overprinted earlier Zone V metamorphism. In addition, complexes of myrmeckite + sillimanite (or muscovite pseudomorphs of sillimanite) + biotite suggest back reaction of the prograde reaction

Bt + Sil + Plag + Qtz = Grt + Kfs + Melt.

This continuous reaction occurs throughout Zone V metamorphism.

CHEMICAL ANALYSIS

Garnets in the rocks were predominantly unzoned, except where adjacent to biotite. This suggests that the garnets either crystallized entirely at one metamorphic grade, or that temperatures and pressures persisted long enough for complete homogenization to occur. Robinson et al. (1986a) suggested that compositional differences in garnet rims adjacent to biotite are due to retrograde ion exchange during cooling.

In one sample from the gas pipeline locality, biotite adjacent to cordierite contained an anomalously low Ti and FeO content. Ion exchange with the cordierite may have caused the abnormal FeO content, but cordierite does not contain Ti. This anomaly has not yet been well explained.

GEOTHERMOBAROMETRY

Pressures and temperatures for these samples were calculated using Kohn and Spear's 1996 program Thermobarometry 2.0, with the Ferry and Spear (1978) with Berman (1988) Garnet biotite-garnet thermometer and the Hodges and Crowley (1985) garnet-plagioclase-aluminosilicate-quartz barometer. Where plagioclase was not readily available in the schistose matrix (Templeton, Zone IV rocks), the barometry was calculated using the Hodges and Crowley (1985) muscovite-biotite-garnet-aluminosilicate-quartz barometer.

Temperatures in all three outcrops fall in the 730° to 770°C range, with temperature steadily increasing from Zone IV to Zone VI. This is consistent with the interpretation that grade increases from Templeton up to Brimfield Road and McBride Road. However, pressures among the outcrops do not provide a consistent picture of increasing pressure with increasing grade. Zone VI experienced 6 to 6.3 kb of pressure; Zone V rocks experienced 4.8 to 5.2 kb of pressure; and Zone IV rocks experienced 6 - 7 kb of pressure. The oddly high pressures calculated for the Templeton (Zone IV) rocks have not been explained and are a subject for further study and analysis.

Lower temperature and pressure analyses were obtained for garnet rims adjacent to biotite, indicating retrograde ion exchange at cooler temperatures.

REFERENCES CITED

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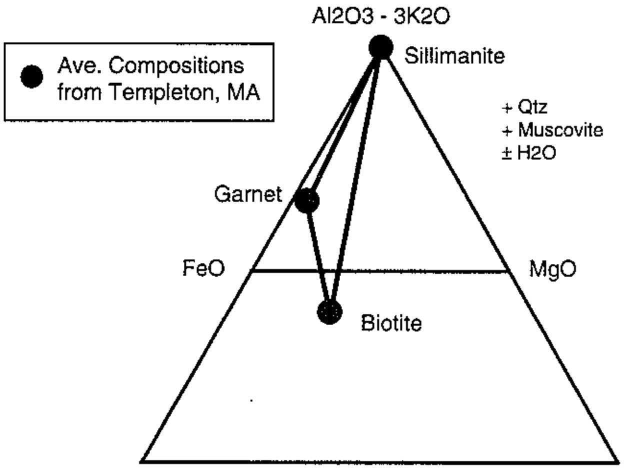
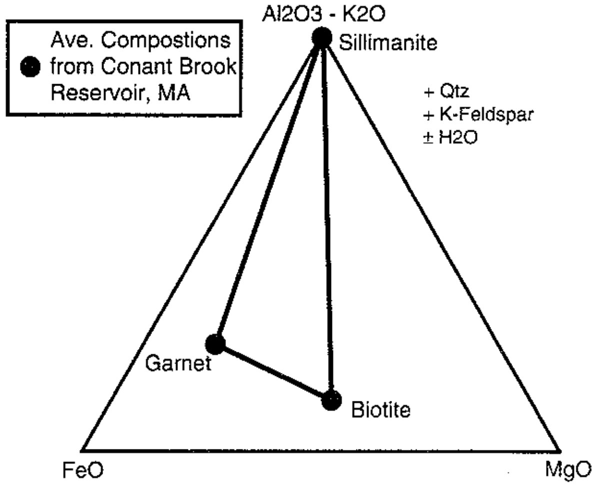
Zone IV Ternary Phase Diagram



Zone V Ternary Phase Diagram



Zone VI Ternary Phase Diagram

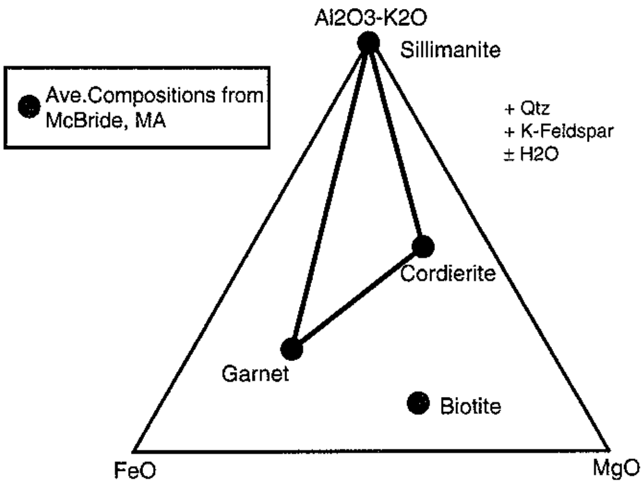


Figure 3. These AFM diagrams show the continuous prograde reaction from Zone IV to Zone V, **Ms + Plag + Qtz = As + Kfs + Melt.** As the grade increases to Zone VI the cordierite is formed in the discontinuous reaction, **Bt + Sill + Qtz = Grt + Crd + Kfs + Melt.** The Zone VI rocks form biotite during retrograde metamorphism as the melt recrystallizes at cooler temperatures. The phase diagramsshow the average mineral compositions at each location determined with the Amherst College SEM/EDS.