Petrography and thermobarometry of low-grade metamorphic pelitic schists in central Massachusetts

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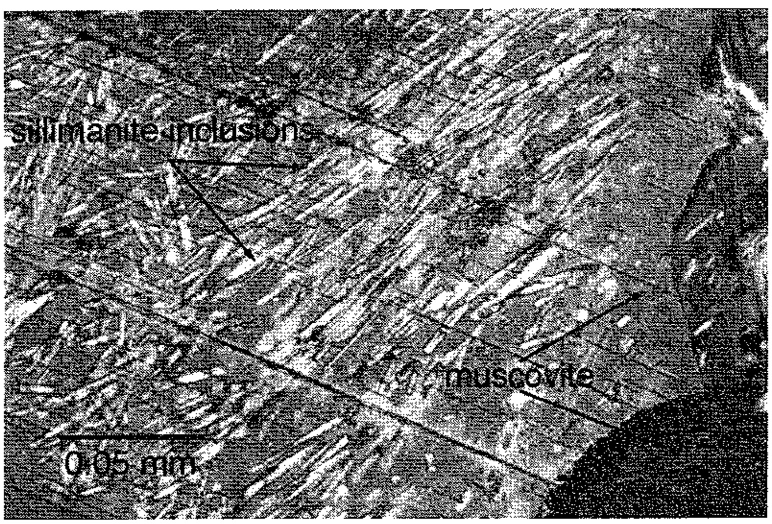
INTRODUCTION

The area of study lies in the Merrimack Synclinorium of north-central Massachusetts. In the Merrimack Synclinorium during the Devonian Acadian orogeny, early high temperature and low pressure metamorphic conditions were achieved, followed by heating to peak conditions, and then retrograde cooling along with compression (Thomson *et al.*, 1992). Samples from three outcrops of the Silurian Rangeley Formation were studied in detail. These outcrops were chosen as examples of metamorphic Zones II and III of Tracy *et al.* (1976). According to Tracy *et al.* (1976), Zone II rocks contain the mineral assemblage quartz+biotite+garnet+staurolite+ sillimanite+muscovite±plagioclase. Zone III rocks are characterized by the assemblage quartz+biotite+garnet+ sillimanite+muscovite+plagioclase. Rocks pass from Zone II to Zone III by losing their staurolite by the discontinuous reaction: staurolite+muscovite+quartz = sillimanite+garnet+biotite+H_2O. No melting is believed to be involved with this change. However, the outcrops contained some granitic pods and dikes. We undertook a detailed petrographic and SEM study of these samples to see if we could determine their metamorphic history and its possible implications for the partial melting of Rangeley Formation rocks at higher metamorphic grades.

METHODS

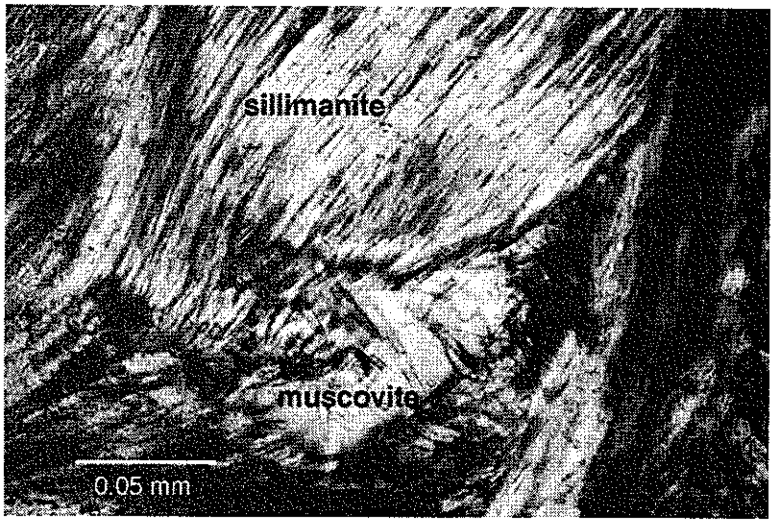
The beginning of the study was spent examining outcrops and collecting samples for experiments and characterization. The localities visited were all in central Massachusetts. After collecting the rock samples, several days were spent at Smith College, Amherst College, and UMASS at Amherst preparing rock chips to be made into thin sections and rock slabs to be stained for K-feldspar. Sample 8C was collected specifically for this study. Sample 6PR was collected by Peter Robinson (UMASS at Amherst). Sample SHL-W was collected by John T. Cheney (Amherst College). Representative samples were prepared into thin sections that were polished for SEM/EDS analysis.

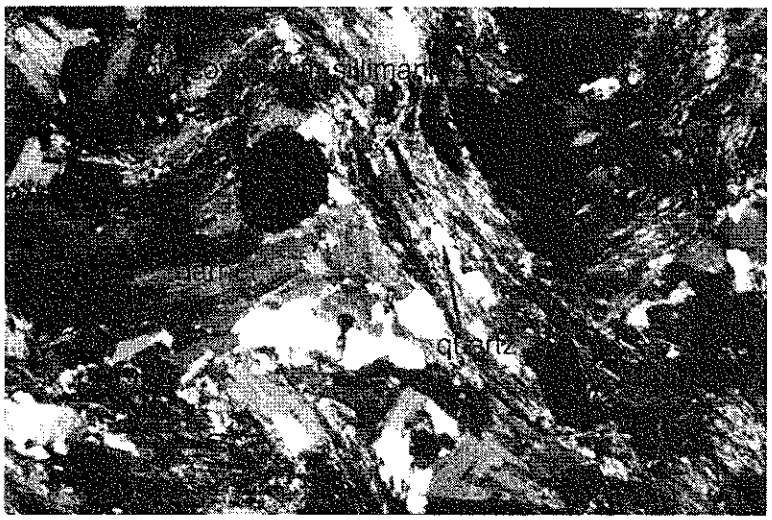
ROCK AND THIN SECTION DESCRIPTIONS



Sample 6PR: Shoemet Lake East, Zone II. Shoemet Lake East samples contain staurolite, the necessary mineral for classification as Zone II. Biotite, garnet, quartz, muscovite, and plagioclase compose the bulk of minerals for SLE. Tourmaline, apatite, and ilmenite are present in small amounts. Muscovite is found in two forms: as pods of small, randomly-oriented crystals and as larger, commonly folded crystals with 0.01 mm wide needle-like sillimanite inclusions. Muscovite with sillimanite inclusions is evidence that this rock was at higher metamorphic grade and that the muscovite grew during a retrograde metamorphic event. Most of the micas have a preferred orientation, perpendicular to regional stress. The outcrop has layers of bull quartz that run the length of the outcrop (approximately 50 ft), a product of metamorphic reactions. These are non-continuous, pinching out at some points, and as wide as 1.5 ft in sections. Also contained in the outcrop is a granitoid layer of plagioclase, quartz, biotite, and muscovite. Field relationships suggest that this is an intrusive dike rather than a locally-derived melt.

Site 7: Shoemet Lake West, Zone III. This sample contains biotite, garnet, sillimanite, muscovite, plagioclase, quartz, and ilmenite. Sillimanite is found in the matrix next to muscovite. There are a few areas where sillimanite is found encased in muscovite and quartz, but not to the degree that it is found in Sample 6PR (SLE). The micas show preferred alignment perpendicular to stress. Plagioclase shows albite twinning in some crystals. The quartz shows undulatory extinction, a product of deformation. In the outcrop, there were large pegmatitic pods containing plagioclase, K-feldspar, quartz, and biotite. It is uncertain whether or not these were intruded into the existing rock or were derived locally or both. Zoned garnet rims containing Fe^{2+} in Shoemet Lake West demonstrate a retrograde history for these rocks, too (Philpotts, 1990).

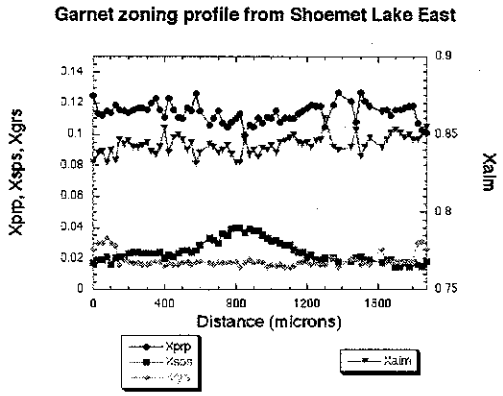


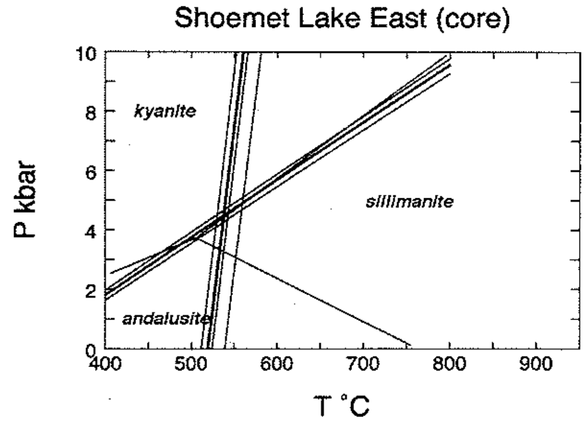


Sample 8C: Athol, MA (Route 2), Zone III. Pods of melt (1-6 cm across) containing quartz, plagioclase, and K-feldspar are found in a matrix containing garnet, biotite, quartz, plagioclase, sillimanite, muscovite, chlorite, and ilmenite. The micas are in a preferred alignment that has been deformed into tight folds visible in outcrop and in thin section. Quartz shows undulatory extinction. The sillimanite is found mixed with muscovite. Some of the plagioclase shows albite twinning. The outcrop exhibited complex folding on a large and small scale. There seem to be two types of solidified melt in the outcrop. There is evidence for an intrusive event that cross-cuts the fabric, thus being more recent than the deformation event. The smaller pods of melt are more integrated with the matrix. This indicates either the melt was derived locally, or that earlier intrusive dikes were severely deformed and dispersed.

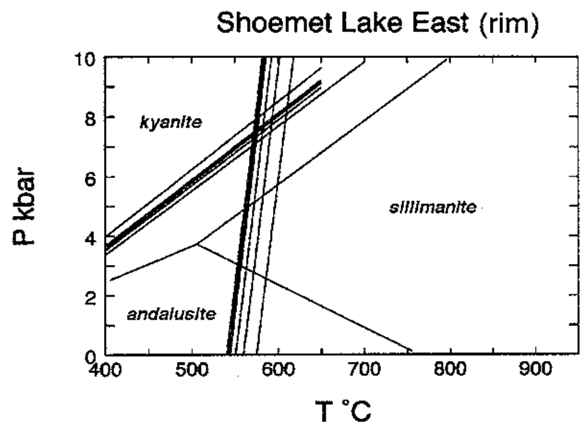
GARNET ZONING AND GEOTHERMOBAROMETRY

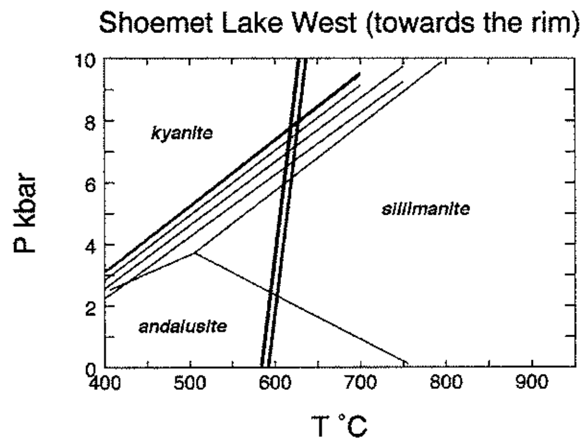
Analyzing garnets for their thermo-barometric geologic history in north-central Massachusetts may be complicated due to the regional metamorphic conditions that took place in the Devonian (prograde and retrograde reactions). Fortunately, garnets have a low diffusion rate enabling the chemically zoned crystals to preserve records of metamorphic conditions (Philpotts, 1990). For SLE, manganese rich cores in zoned garnets (see figure) are a natural occurrence as a consequence of the Rayleigh fractionation model, as the garnet grows during progressive metamorphism in low-grade pelitic metamorphosed rocks (Tracy *et al.*, 1976). Enriched calcium rims (see figure) may show a period of a late retrogradation history in the garnet sample MAK-98-6PR.





Chemical data collected on the minerals of our samples were used to calculate the temperatures and pressures of metamorphism. Geothermometry plots (near vertical lines on the P-T diagrams) were calculated by the garnet-biotite exchange reaction, calibrated by Ferry and Spear (1978) with the Berman (1990) garnet solution model. The geobarometry plots (gently inclined lines on the P-T diagrams) were calculated by the garnet-plagioclase-Al_2SiO_5-quartz exchange reaction, calibrated by Koziol (1989). The geothermobarometry program used was GTB 2.0 from Frank S. Spear (Dept. of Earth and Environmental Sciences, Rensselaer Polytechnic Institute, Troy, NY 12180).





Shoemet Lake West shows a slight increase in temperature (600° to 625°C) compared to SLE (575° to 615°C), but at similar pressures (6.5 - 8 kb). SLW is Zone III (absence of staurolite) compared to Zone II, Shoemet Lake East. Garnet core compositions are consistent with mineral growth initially at lower temperatures and pressures.

CONCLUSIONS

Given the similarity among the bulk compositions of the three sites, it is apparent that the differences in the sites are a result of the grade of metamorphism and possibly from intrusions into the outcrops. If there are intrusions, they might alter the way the outcrop developed, for example through the introduction of fluids enabling the growth of new minerals. Using Robinson's system of metamorphic zone classification, Shoemet Lake West should be reclassified as a Zone III outcrop. In the field, the distance between Shoemet Lake East and Shoemet Lake West is less than half a mile. The boundary between the two zones is somewhere in between. The retrograde metamorphism in Shoemet Lake East is still unexplained. The muscovite needs water to form from the sillimanite, but the source of this water is unknown. It is possible that water was released during the crystallization of hydrous partial melts of these or nearby rocks. The Shoemet Lake West samples exhibit the same evidence for retrograde metamorphism. There were some sillimanite crystals in muscovite and quartz, but it was not as prevalent as it was in Shoemet lake East samples. It is not evident in the SLW geothermobarometry calculations that retrograde metamorphism occurred.

REFERENCES CITED

Philpotts, A.R., 1990, Principles of Igneous and Metamorphic Petrology: New Jersey, Prentice Hall, p. 363-364.

Robinson, P., Ratcliffe, N.M., and Hepburn, J.C., 1993, Tectonic-stratigraphic transect across the New England Caledonides of Massachusetts: *in* Cheney, J.T. and Hepburn, J.C., eds., Field Trip Guidebook for the Northeastern United States: 1993 Boston GSA, vol.1, Geological Society of America, Boulder, CO, p. C1-C47.

Thomson, Jennifer A., Peterson, Virginia L., Berry, Henry N., IV, and Barreiro, Barbara, 1992, Recent studies in the Acadian metamorphic high, south central Massachusetts: *in* Robinson, P. and Brady, J.B., eds., Guidebook for Field Trips in the Connecticut Valley Region of Massachusetts and Adjacent States, University of Massachusetts, Amherst, MA, p. 229-255.

Tracy, R. J., Robinson, P., and Thompson, A. B., 1976, Garnet composition and zoning in the determination of temperature and pressure of metamorphism: Central Massachusetts: American Mineralogist, v. 61, p. 762-775.

Tracy, R. J., 1975, High grade metamorphic reactions and partial melting in pelitic schist, Quabbin reservoir area, Massachusetts. Contribution No. 20, Department of Geology and Geography, University of Massachusetts, Amherst.