

Experimental melting and analysis of the Rangeley Formation Zone II pelitic schists in the Appalachians of south-central Massachusetts

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INTRODUCTION

The Silurian Rangeley Formation of south-central Massachusetts (Fig. 1) is comprised principally of pelitic schists and gneisses that seem to have undergone partial melting during the Acadian orogeny. This partial melting resulted in the formation of cordierite- ± garnet-bearing pegmatites in the granulite facies region (Thomson et al., 1992). Representative samples were collected from various localities with metamorphic grades ranging from Zone II (sillimanite-staurolite zone) to Zone VI (garnet-cordierite-sillimanite-K-feldspar zone) based on pelitic rock assemblages (Tracy et al., 1976; Robinson et al., 1982). Geochemical, mineralogical, and experimental analyses were conducted on the samples in order to examine the behavior of pelitic schists during melting.

MINERALOGY

The sample investigated here is a Zone II pelitic schist from Shoemet Lake, MA, (sample 6PR) previously collected by Professor Peter Robinson. This sample contains the following mineral assemblage: staurolite crystals

1-2.5 mm wide; abundant muscovite crystals; 1-mm-wide biotite flakes with zircon inclusions; quartz grains up to 2 mm wide; subhedral garnet grains .25-2 mm wide; plagioclase crystals up to 2 mm wide; sillimanite as fibrolite pods approximately 2 mm wide, isolated crystals of tourmaline, K-feldspar, and apatite; and trace amounts of opaque minerals.

METHODS

Samples were slabbed, crushed, and powdered for experimental melting under high pressures (approximately 6 kb) and a variety of temperatures (650-825 °C). Sample powders were loaded into a nickel sample holder lined with gold tubing, which was then sealed and prepared for the experiment, following the procedure of Ayers et al. (1992). The complete sample assembly was then loaded into a 3/4-inch piston cylinder pressure vessel (Fig. 2), where the sample was heated and pressurized for an average of four days per experimental run. Six experiments were conducted at temperatures ranging from 650 °C to 825 °C. At the end of each run, the nickel sample holder was removed, bisected, and mounted in epoxy. The hardened sample was polished, carbon-coated, and examined under a scanning electron microscope for compositional analysis of the minerals and any melt that formed.

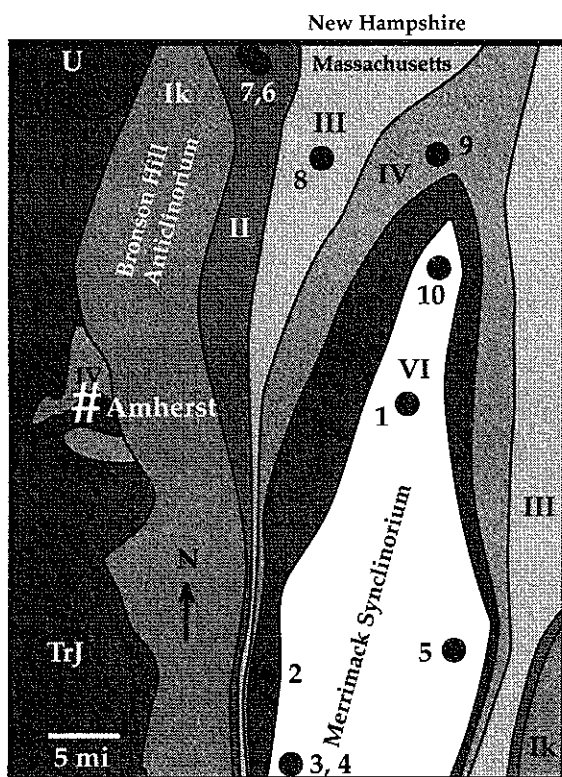


Figure 1. Metamorphic zones of central Massachusetts (modified from Robinson et al., 1982) showing sample locations.

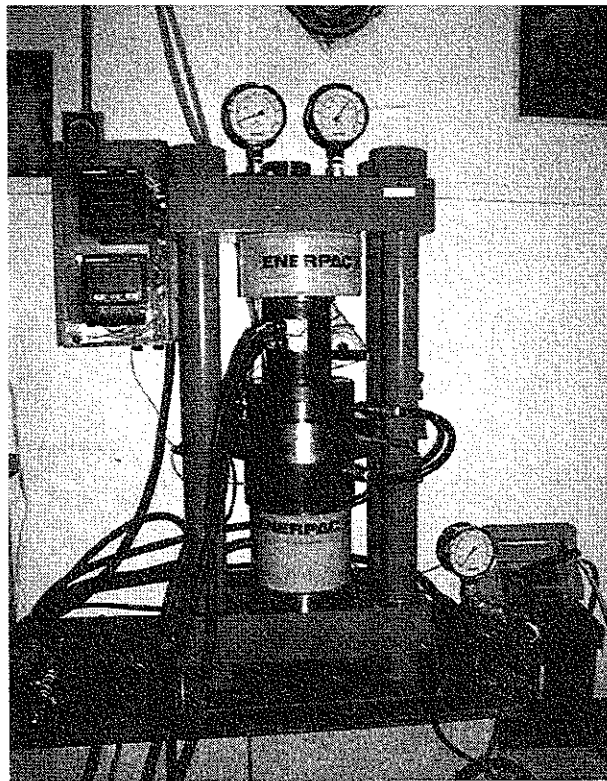


Figure 2. Piston-cylinder press at Smith College.

RESULTS

We determined that the modes of the minerals present in the melted sample changes with increasing temperature. A comparison of the composition of sample 6PR before melting with the composition of the melted 6PR shows that some of the minerals in the melted samples replace minerals that disappear during melting reactions. For example, K-feldspar replaces plagioclase at temperatures greater than 770 °C. In addition, the presence of aluminosilicate + melt and the disappearance of muscovite at temperatures above 725 °C indicate that muscovite breaks down to supply the water to generate the melt. Minerals that are present as a result of melting reactions, such as K-feldspar, spinel, and aluminosilicate + melt, increase in abundance, whereas minerals such as plagioclase, muscovite, and biotite decrease in abundance, as the temperature increases (Fig. 3). In the 825 °C experiment, we found orthoamphibole in conjunction with spinel and melt (Fig. 4). This is the only run in which orthoamphibole was identified. The presence of the orthoamphibole at 825 °C may be the result of the incongruent melting of biotite.

The presence or absence of a given mineral, as well as the percentage of that mineral present, illustrates the reactions that occurred in the samples during the experiments. For example, sample 6PR from Shoemet Lake contains abundant muscovite and biotite.

Muscovite is absent, however, in all of the experimental samples except for the 680 °C sample, which underwent no melting. This absence of muscovite in the melted samples indicates that muscovite has broken down completely, providing water for melting reactions to take place in the sample. Biotite, which was present in all samples as remnant grains, also breaks down, though not always completely. This reaction also releases water into the experimental systems. Thus, aluminosilicate + melt appear in the experimental system at the expense of muscovite and biotite.

In analyzing our melted samples, we found that minerals such as staurolite, garnet, plagioclase, quartz, and biotite are present as large remnant crystals. These may be present because of our failure to pulverize the rock powders finely enough to reduce the size of remnant crystals prior to beginning the experiments. Some of these remnant crystals served as "seeds," onto which other minerals grew as a result of melting reactions; this occurred in all samples except the one at 680 °C, in which no melting reactions took place. Garnet and plagioclase crystals in all melted samples are the "seeds." More magnesium-rich rims of garnet surround the iron-rich remnant garnet grains, and rims of K-feldspar surround the remnant plagioclase crystals.

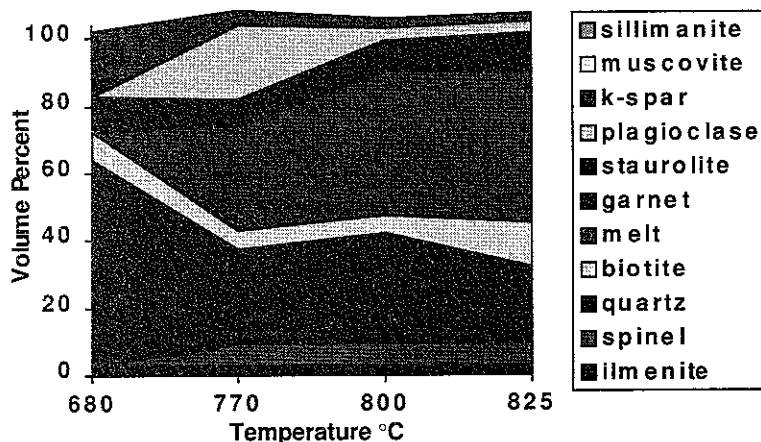


Figure 3. Modal data from experiments at 6 kb. The horizontal axis is not to scale.

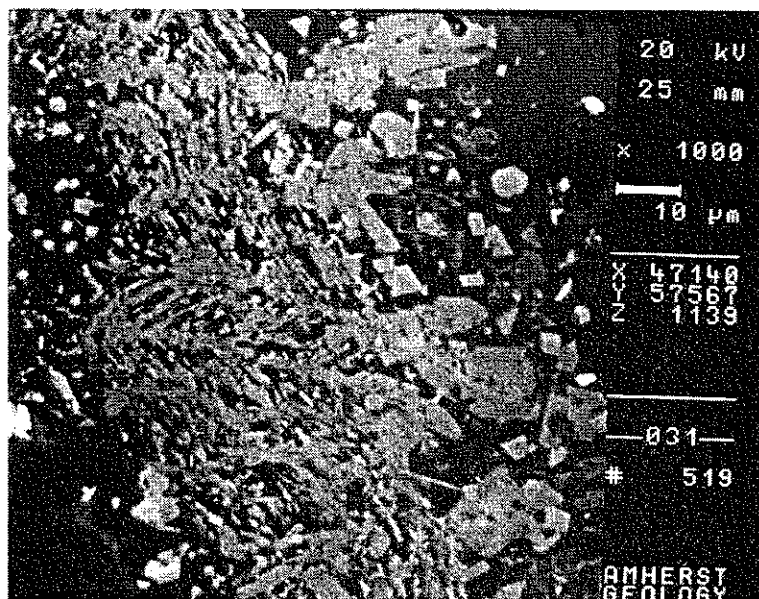


Figure 4. Backscattered electron image of 825°C experiment.

Mineral compositions in the samples vary with increasing temperature. For example, the rims of garnet that grow onto remnant garnet crystals are more magnesium-rich than the remnant crystals themselves. Melt composition becomes less aluminum-rich as aluminosilicate grows and takes up more of the aluminum, and the growth of K-feldspar rims onto remnant plagioclase decreases the amount of potassium in the melt.

DISCUSSION

The experimental results show changes with increasing temperature in our sample that are somewhat analogous to those observed in higher-grade rocks from granulite facies of south-central Massachusetts, which contain segregated, partial-melt patches of quartz-K-feldspar-sillimanite-garnet (Thomson et al., 1992). It seems that in light of the distribution of minerals in the samples and their compositions, each experiment probably achieved local equilibrium, in which muscovite and biotite break down and provide water for melting reactions to occur. These reactions produce aluminosilicate + melt. K-feldspar is present as both isolated crystals and as rims around remnant plagioclase. Garnet grows as rims around remnant garnet crystals. Although staurolite is present in the experiments as remnant crystals, it is likely that, in the natural granulite-facies rocks, staurolite also breaks down to provide water for melting reactions. The results indicate that the rocks of south-central Massachusetts may have undergone in situ dehydration reactions to produce partial melts.

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Experimental melting of a low grade pelitic schist from the Rangeley Formation, Massachusetts

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INTRODUCTION

The objective of this project is to characterize dehydration melting processes within aluminous crustal rocks by experimentally melting a low grade pelitic schist over a range of temperatures at constant pressure. By comparing the muscovite and biotite dehydration reactions observed in the experimental study to those predicted by theoretical models, it is possible to constrain the pressure-temperature paths of metamorphism in anatectic pelites. The chemical reactions predicted by Spear et al. (1998) to occur in rocks of this bulk composition are:

Muscovite + plagioclase + quartz = sillimanite + K-feldspar + melt
(discontinuous in Ca-free system: T ~ 690° C @ 6 kb)

Biotite + sillimanite + quartz = garnet + K-feldspar + melt
(NaKFMASH continuous)

Biotite + sillimanite + quartz = garnet + cordierite + K-feldspar + melt
(NaKFMASH discontinuous: T ~ 780° C @ 6 kb)

Garnet + sillimanite = spinel + cordierite + quartz
(NaKFMASH discontinuous: T ~ 950° C @ 6 kb)

In order to test the validity of these predictions, one sample from an outcrop west of Shoemets Lake (SLW) was experimentally melted and analyzed. The SLW sample is from the Rangeley Formation, a prograde sequence of pelitic schists located within the Merrimack Synclinorium of central Massachusetts. The metamorphism and intense deformation of Silurian sediments in the Merrimack belt results from convergence associated with the closing of Iapetus Ocean during the Acadian orogeny (Thomson et al., 1992).

MATERIALS AND METHODS

Sample SLW was chosen for analysis because it is a mica-rich low grade rock which does not appear to contain in-situ melt. It is a Sillimanite Zone pelitic schist which contains the equilibrium assemblage of garnet, sillimanite, biotite, muscovite, plagioclase, quartz, and ilmenite. Therefore, SLW can be experimentally heated to temperatures which produce the melting associated with the muscovite and biotite dehydration reactions.

Run Number	Temperature (° C)	Pressure (kbar)	Duration
Melt 1	650	6	1 day
Melt 2	650	6	2 days
Melt 3	680	6	4 days
Melt 4	725	6	4 days
Melt 5	770	6	4 days
Melt 6	800	6	4 days
Melt 7	825	6	4 days

Figure 1. Experimental Conditions.

The sample was cut and polished to remove weathered edges, then pulverized with a tungsten carbide shatterbox to homogenize the rock. The resulting powder was then used in the experimental procedure. The experiment was performed using a 3/4 inch, end-loaded piston-cylinder device at constant 6 kb pressure and temperatures ranging from 650° C to 825° C. The powder was sealed in 2mm gold tubing within a nickel sample holder to prevent reaction