Melting of pelitic schists in central Massachusetts

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INTRODUCTION

High grade metamorphic rocks commonly reach temperatures at which they begin to melt. The extent to which they melt depends on a number of variables including the temperature, pressure, bulk composition, and mineral composition of the rock. In most cases, significant melting occurs during metamorphism only when the hydrous minerals of the rock break down and provide water to stabilize the melt (e.g Spear et al., 1999). This "dehydration melting" occurs in pelitic schists between 650°C and 700°C when muscovite breaks down and again at about 800°C to 850°C when biotite breaks down. If the melt leaves the rock, there might be no visual evidence that melting has occurred, although the mineral assemblage, mineral compositions, and textures may record the melting event.

Many authors have proposed partial melting to explain features observed in high grade metamorphic rocks (e.g. Nedelec and Paquet, 1981; Wickham, 1987). Others have studied partial melting in the laboratory, typically using simplified or synthetic starting materials (e.g. Vielzeuf and Holloway, 1988; Peterson and Newton, 1990). The goal of this project was to study melting of the same rocks both in the field and in the laboratory, which we believe has not been done in previous studies. Our plan was to track the melting of pelitic schists in central New England (Tracy, 1978) by: (1) collecting a suite of rocks across several metamorphic grades into zones where melting is believed to have occurred; (2) examining these rocks in the laboratory to identify changes (mineralogical and chemical) that accompany melting; (3) attempting to duplicate the melting processes in the lab by heating at high temperatures and pressures some of the rocks collected in the field; and (4) comparing the changes observed in the samples melted during metamorphism with those observed in our laboratory melting experiments.

METHODS

Samples of Rangeley Formation schists and migmatites were collected from five metamorphic zones (II - VI) in central Massachusetts as defined by Tracy, Robinson, and Thompson (1976). Partial melting is believed to have occurred in Zones IV to VI and perhaps in Zone III (see Figure 1). All project participants cooperated in sample collecting and preparation. In the lab, samples were cut into slabs and many were stained with potassium cobalt nitrate to color the potassium feldspar. Twenty samples were selected, trimmed, broken, and pulverized for whole rock chemical analysis by x-ray fluorescence (at Franklin and Marshall College by Stan Mertzman). Billets were cut from these and other samples and over 50 thin sections were made for petrographic study. Six thin sections were polished, coated with carbon, and studied in great detail with an electron microscope (SEM) fitted with an energy dispersive x-ray spectrometer (EDS). Powders from four of the XRF samples were selected for melting experiments at 6 kb. These were held at temperatures from 650° to 825°C for periods of up to four days. Experimental run products were polished, coated with carbon, and studied with the SEM/EDS.

STUDENT PROJECTS

(1) Whitney Hill of Old Dominion University and Enrique Ureta of the College of William and Mary studied the variation of the major and trace element chemistry of the Rangeley Formation across the five metamorphic zones. Sample variability proved to be a challenge in this study. They found almost as much chemical variation in the samples from one metamorphic zone as they did across the five metamorphic zones.

(2) Roger Gomez of the University of Texas at El Paso and Sean Menton of Whitman College studied samples from Zones II, III, and IV with a petrographic microscope and SEM/EDS in an attempt to characterize the changes from zone to zone. They found that their samples had experienced significant rehydration, possibly due to the release of water from crystallizing melts.

(3) Jennifer Lenz of Smith College and Naila Moreira of Amherst College studied samples from Zones IV, V, and VI with a petrographic microscope and SEM/EDS in an attempt to characterize the changes from zone to zone.

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They, too, found evidence of rehydration and of unusual pressures recorded in the mineral assemblage thermobarometers of their samples.

(4) Jacqueline Sigmon of Eastern Washington University and Tracy Zayac of Georgia Southern University partially melted pulverized samples of Zone II Rangeley Formation rocks at 6 kb in a piston cylinder press. They were able to produce considerable melt. They found that sample preparation can affect the results of short term experiments.

(5) Bethany Bradley of Pomona College and Emily Levin of Amherst College partially melted different pulverized samples of Zone II Rangeley Formation rocks at 6 kb in a piston cylinder press. They found that mineral reactions, particularly involving cordierite and spinel, did not proceed as predicted.

SUMMARY RESULTS

Coarse, textural "melt zones" in the samples have coarse potassium feldspar and garnet, but they do not have the quartz required to be a complete sample of a partial melt (Figure 2). This suggests that melt has been present, to flux the coarse mineral growth, but has moved out of the rock sampled. Whole rock chemical data are very similar across the six metamorphic zones with natural variations in the Rangeley Formation obscuring chemical changes that may occur during melting. Volatile content (LOI) does decrease with increasing grade and the concentrations of some trace elements (Ba, Ni) appear to increase with grade. Geothermobarometry yields consistent increases in calculated temperature with metamorphic zone, reaching 775°C in the Zone VI samples, whereas calculated pressures (4-8 kb) varied erratically. Many samples showed evidence of retrograde metamorphism with, for example, muscovite and quartz overgrowing sillimanite and chemical zoning on the rims of otherwise homogeneous garnet crystals. Heating experiments revealed muscovite dehydration melting (at 680°C and 725°C) and biotite dehydration melting (from 680°C to 825°C) with the growth of garnet, potassium feldspar, and sillimanite. Abundant spinel grew at 775°C and 825°C, orthoamphibole appeared at 825°C, but no cordierite grew to match the cordierite observed in field samples. The proportion of peraluminous granite melts produced in the experiments increased with temperature to comprise over 30% of the sample at 825°C.

ACKNOWLEDGEMENTS

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Figure 1. Feldspar-rich melt layers in the Rangeley Formation from metamorphic Zone V near Monson, MA. The rock has been sheared (Connant Brook Shear Zone) after the melt crystallized. The knife for scale is approximately 9 cm long.

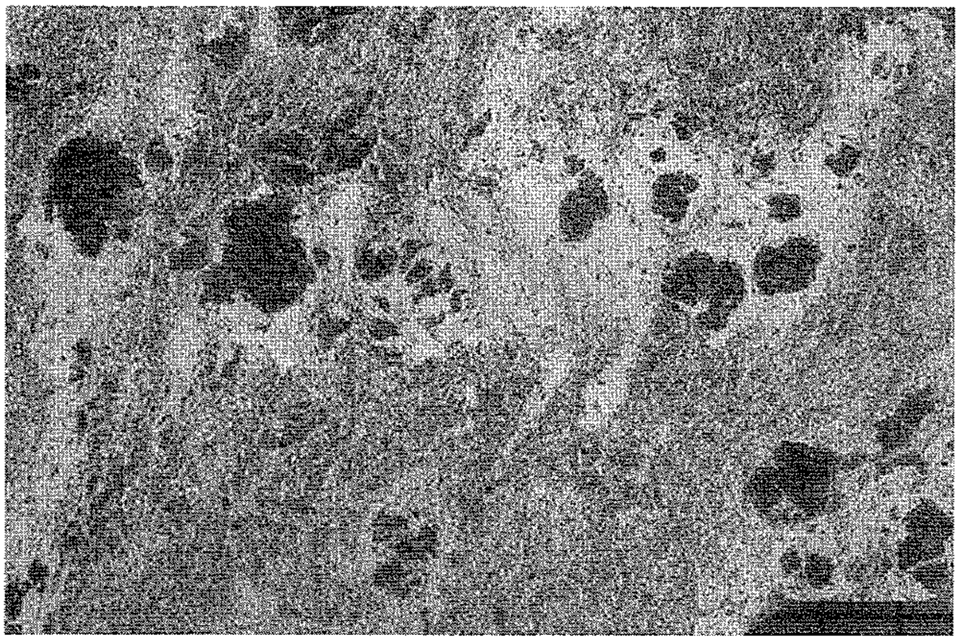

Figure 2. One to two centimeter garnet crystals surrounded by yellow-stained alkali feldspar in a Zone VI sample of Rangeley Formation from Mt. Hitchcock, Massachusetts. Note that most of the crystals around the garnet are the same color indicating that there is little quartz present in these felsic zones. The grid in the lower right corner has a one-half inch spacing.