Constraining the timing and character of crustal melting in the Adirondack Mountains using multi-scale compositional mapping and in-situ monazite geochronology

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ABSTRACT

Migmatites are common in the hinterland of orogenic belts. The timing and mechanism (in situ vs. external, P-T conditions, reactions, etc.) of melting are important for understanding crustal rheology, tectonic history, and orogenic processes. The Adirondack Highlands has been used as an analog for mid/deep crustal continental collisional tectonism. Migmatites are abundant, and previous workers have interpreted melting during several different events, but questions remain about the timing, tectonic setting, and even the number of melting events. We use multiscale compositional mapping combined with in situ geochronology and geochemistry of monazite to constrain the nature, timing, and character of melting reaction(s) in one locality from the eastern Adirondack Highlands. Three gray migmatitic gneisses, studied here, come from close proximity and are very similar in microscopic and macroscopic (outcrop) appearance. Each of the rocks is interpreted to have undergone biotite dehydration melting (i.e., Bt + Pl + Als + Qz = Grt + Kfs + melt). Full-section compositional maps show the location of reactants and products of the melting reaction, especially prograde and retrograde biotite, peritectic K-feldspar, and leucosome, in addition to all monazite and zircon in context. In addition, the maps provide constraints on kinematics during melting and a context for interpretation of accessory phase composition and geochronology. More so than zircon, monazite serves as a monitor of melting and melt loss. The growth of garnet during melting leaves monazite depleted in Y and HREEs while melt loss from the system leaves monazite depleted in U. Results show that in all three localities, partial melting occurred during at ca. 1160–1150 Ma (Shawinigan orogeny), but the samples show high variability in the location and degree of removal of the melt phase, from near complete to segregated into layers to dispersed. All three localities experienced a second high-T event at ca. 1050 Ma, but only the third (non-segregated) sample experienced further melting. Thus, in addition to bulk composition, the fertility for melting is an important function of the previous history and the degree of mobility of earlier melt and fluids. Monazite is also a sensitive monitor of retrogression; garnet breakdown leads to increased Y and HREE in monazite. Results here suggest that all three samples remained at depth between the two melting events but were rapidly exhumed after the second event.

Keywords: Monazite petrochronology, migmatite, polymetamorphism, Adirondack Highlands

INTRODUCTION

Metamorphic terranes with evidence for high or even ultrahigh-temperature metamorphism have been increasingly recognized in orogenic belts around the world (Korhonen et al. 2014; Kelsey and Hand 2015). Many of these regions involve significant partial melting, which in turn, has important implications for changing rheology, strain localization, petrogenesis of derived igneous rocks, and for interpretations of tectonic history and tectonic processes in general. To constrain the conditions of metamorphism as well as the composition of melts, the degree of partial melting, and the degree to which melt has been lost from the system, it is particularly important to characterize the conditions of melting and the dominant melting reaction(s). Fortunately, new geothermometers, thermodynamic databases, and phase equilibria modeling techniques are increasingly able to accommodate high temperatures and partial melting allowing many new insights into the tectonics of migmatitic rocks (White and Powell 2002; White et al. 2007; Dumond et al. 2015; Koblinger and Pattison 2017). One common question, critical for interpreting the tectonic setting of high-T metamorphism, concerns the timing of melting. Timing constraints typically come from isotopic dating of high-T minerals such as zircon or monazite. Especially in multiply deformed and/or multiply metamorphosed regions, geochronologic analysis requires in situ dating after careful textural analysis to identify domains that represent particular melting/crystallization events.

The Adirondack Mountains of New York are a classic example of a high-grade, polydeformational terrane that has been used as an analog for middle to deep crustal collisional and extensional tectonics (Mezger 1992; Selleck et al. 2005; Rivers 2008). Numerous studies have been conducted to...