An Approach to Relate Major Silicates and Monazite Growth in Metamorphic Rocks: Application to the Upper Granite Gorge (Grand Canyon, USA)

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Introduction

One major goal of structural geologists and metamorphic petrologists is to relate deformation and metamorphic conditions with time. The challenge is not only to find suitable minerals to be dated, but also to associate them with particular geological events or with pressure and temperature conditions. Monazite has proven to be an excellent proxy to date various stages in a tectonic history: it contains very little common lead, it is a highly retentive system, and it can be dated by electron microprobe at very high spatial resolution. In addition, it commonly preserves different growth stages in distinct compositional domains. However, its growth history and relation with major silicate minerals and reactions is usually poorly constrained.

Method

We present here a technique, which aims to relate the growth of monazite with the petrology of major silicate assemblages in metamorphic rocks. Our approach is summarized in Figure 1. From a selected area where the deformation history is well known, we select several samples to obtain PT-conditions as precisely as possible. Within each selected sample, accessory phases such as apatite, monazite, xenotime and zircon are revealed in a full-thin-section WDS compositional map, using Ca, Ce, Y and Zr. After identification of these accessory minerals, 10 to 20 monazite grains are selected for an element mapping of Ca, Th, U, Y, and Si. This is required to characterize the major growth stages of each grain. The image processing of maps for each element is done simultaneously by applying the same level correction in all samples and for each grain within a sample. This allows a direct comparison of each growth stage within a thin section, as also between samples of different metamorphic grade or chemical composition. The

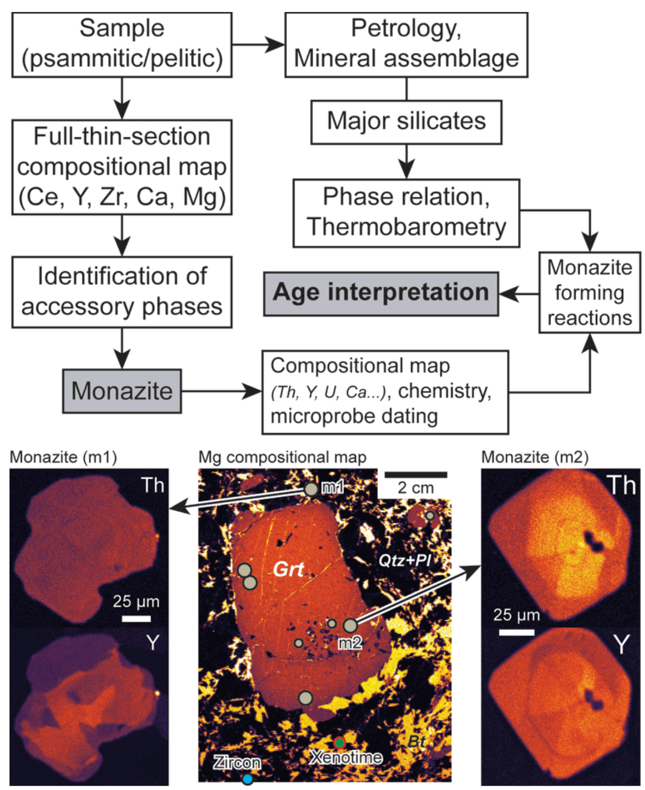

Figure 1: Flowchart of the approach, with example of a full-thin-section (cropped area) and two Y and Th compositional maps in selected monazite.

composition of each monazite domain is then obtained, and microprobe ages using the technique described in Williams and Jercinovic (2006) are obtained. The next step currently being developed is to identify the metamorphic reaction responsible for each monazite growth stage. Thermobarometris tools such as TWQ (Berman, 1991) and THERIAK-DOMINO (de Capitani and Brown, 1987; de Capitani, 1994) are used to decipher the evolution of major silicates. The chemistry of silicates, notably trace elements such as Y in garnet, and the textural/petrological relationships with monazite are used to identify the metamorphic reactions responsible of each monazite growth stage.

Application

The area selected for this study is the Upper Granite Gorge of the Grand Canyon (USA). Paleoproterozoic basement outcrops in this area and is characterized by a segmented, block-type architecture consisting of kilometer-scale blocks of granitic and psammitic/pelitic rocks, separated by shear zone. Previous study by Dumond et al. (2007) reveals constant pressures but variable metamorphic temperatures from block to block. At lest one block preserves a temperature gradient from upper greenschist to granulite facies. Element mapping of hundreds of grains were obtained in several samples of similar mineralogy and chemistry, and revealed a complex growth history within each monazite and also between samples. Although analysis is currently in progress , we have already identified several interesting features, such as the growth of Y-rich rim during garnet resorption or the appearance of a chemically distinct monazite when staurolite appears. The next step will involve the acquisition of precise chemical ages, and the identification of metamorphic reactions responsible for monazite growth.

Conclusions

We aim thus to yield a complete history relating deformation, pressure, temperature and time. Results from this study will also be used to begin development of a monazite database for metamorphic rocks compiling host-rock assemblage and bulk composition with accessory phase assemblage, texture, and composition for comparison with other metamorphic terranes around the world.

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