Common patterns of rare-earth-element distribution in garnet

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Summary

The spatial distribution of rare-earth elements (REEs) measured in 11 metamorphic garnets from three localities, combined with previous data from two additional localities, documents patterns that are common to all localities and rock types but that differ for the heavy rare-earth elements (HREEs), middle rare-earth elements (MREEs), and light rare-earth elements (LREEs).

Samples

Understanding of REE uptake and distribution in metamorphic garnets is essential to sound interpretation of petrologic and geochronologic analyses relying on REEs. This work expands upon previous studies of garnets in ultra-high-pressure eclogites from Zermatt-Sass, Switzerland (550-600 °C, 1.5-2.0 GPa; Skora et al., 2006) and from the Western Gneiss Region, Norway (750-800°C, 3.0 GPa; Konrad-Schmolke et al., 2008) by examining garnets in pelitic rocks from the Picuris Mountains, New Mexico (~550 °C, 0.45 GPa; Chernoff & Carlson, 1997) and Passo del Sole, Switzerland (~560 °C, 0.85 GPa; Janots et al., 2009), and in an eclogite block from the Franciscan Complex, California (~600°C, 1.0 GPa, Giaramita & Sorensen, 1994; or ~550-630 °C, 2.2-2.5 GPa, Tsujimori et al, 2006).

Methods

Garnets were located within cylindrical sample cores using high-resolution X-ray computed tomography (HRXCT). With this imagery as a guide, individual garnet crystals were sectioned to expose their morphological centers. Concentrations for HREEs (Lu, Yb, Tm, Er) and MREEs (Ho, Dy, Tb, Gd) were collected by LA-ICPMS. Rim-to-rim line scans, with 20 µm spot size at 5 µm/sec, were obtained for each garnet. LREE (Eu, Sm, Nd) concentrations were acquired by SIMS. Core-to-rim traverses, with 20 µm spot size and less than 20 microns between analyses, were obtained for each garnet.

Results

Peak concentrations for all HREEs are located at the center of each garnet and HREE concentrations decrease progressively outward toward the rim. Each MREE has a local maximum in the center of the garnet, but the primary peak lies partway between the core and the rim, with the primary peak progressively closer to the rim with decreasing atomic number. Outward from the primary peak, a gradual decrease in concentration occurs toward the rim. The LREEs are concentrated in outer portions of the garnet and their primary peaks are rimward of peaks for the MREEs. The SIMS data for garnets from the Picuris Mountains show distinct differences in the locations of the LREE peaks. The Nd peak is closest to the core; the peak for Sm lies farther out from the core; and the peak for Eu lies still farther out. Thus the LREEs show a relationship between atomic number and peak location that is the reverse of what is observed for the MREEs.

Additional complexities arise in garnets from the Picuris Mountains. A previously documented change in the garnet-forming reaction (Crawford, 2008) is represented by a spike in Ca midway between the core and rim (Chernoff & Carlson, 1997). A secondary peak in the HREEs coincides with the location of the Ca spike; rimward of this are secondary peaks in the MREEs which step progressively outward with decreasing atomic number.

Interpretation

Within the resolution of the data, central HREE peaks, progressively more distal MREE peaks, and rimward LREE peaks are common to the garnets examined in Skora et al. (2006), Konrad-Schmolke et al. (2008), and this study. Secondary peaks for HREEs, located rimward of the central peaks, occur in garnets from Zermatt-Sass (Skora et al., 2008) and, to a lesser degree, in garnets from the Western Gneiss Region (Konrad-Schmolke et al., 2006). These peaks are similar to secondary peaks in the Picuris Mountains data, which are attributed to changes in the garnet-forming reaction.

The commonalities of REE distribution seen in garnets from all localities — in both pelitic and mafic rocks, and spanning a range of crustal P-T conditions — appear to illustrate a pattern that may be ubiquitous, or nearly so, in regional metamorphic garnet.

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