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Oxygen isotope heterogeneities and diffusion profile in composite metamorphic-magmatic garnets from the Pyrenees

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Abstract

Unusually large $\delta^{18}O$ heterogeneities (≥4‰) within single crystals are reported in garnets from dioritic migmatites in the Pyrenees. These heterogeneities, together with contrasting Ca and P zoning, allow the identification of different growth zones. Garnet cores with high $\delta^{18}O$ values (12–14‰) are relatively poor in Ca (7–9 mol% Grs) and rich in P (400–900 ppm P_2O_5). In contrast, garnet rims with lower $\delta^{18}O$ values (7–12 ‰) are richer in Ca (12–14% Grs) and poorer in P (100–200 ppm). These growth zones can be ascribed to a metamorphic event followed by crustal partial melting and contamination by magmas from the mantle. High $\delta^{18}O$ intra-crystalline contrasts result from mineral growth in an open magmatic system involving the interaction of partial melts with distinct $\delta^{18}O$ signatures. At the garnet core-rim interface, compositional profiles in major divalent cations are consistent with the relaxation of an initial sharp step in Ca, Fe, and Mg by Ca ↔ (Fe, Mg) interdiffusion. At the same interface, an O-isotope profile is documented. The analogy of Ca and O isotope profiles suggests that the $\delta^{18}O$ distribution may also result from a diffusion process. In this particular case (temperature, garnet composition, oxygen fugacity), O diffusion appears to be of the same order of magnitude as Ca ↔ (Fe, Mg) interdiffusion. Considering a duration of 10 Ma for the plutono-metamorphic event in the Pyrenees, Ca and O diffusivities in the range 10^{-22} m^2/s (at 850 °C) are retrieved from the measured profiles. Like Ca, O diffusion in garnet at magmatic temperatures (850–900 °C) is both slow enough to preserve large $\delta^{18}O$ heterogeneities and fast enough to generate relaxation profiles.