

Oxygen isotope zoning in garnet from granulite facies rocks, Sør Rondane Mountains, East Antarctica

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Oxygen isotope ratios can be an indicator of fluid-mineral or melt-mineral interactions (e.g., Hoefs, 2004). Among rock forming minerals, garnet has a potential to preserve the oxygen isotope zoning due to the relatively slow diffusivity, in addition to the major and trace element zonings. The diffusion coefficient of oxygen in garnet has been gradually constrained by experimental studies (e.g., Scicchitano et al., 2017), suggesting that the preserved $\delta^{18}\text{O}$ zoning could be used as a speedometry even in high-temperature metamorphic rocks. The goal of this study is to estimate high-temperature duration and constrain the origin of fluid during granulite facies metamorphism.

The studied sample is a garnet-biotite-sillimanite gneiss from Balchenfjella, Sør Rondane Mountains (SRM), East Antarctica. Balchenfjella is located in the eastern part of the SRM, and the crystalline basement exposed is composed of high-grade gneissic rocks accompanied by migmatite, marble and small mafic, ultramafic and granitic intrusive bodies (e.g., Asami et al., 1990; 2007; Ishikawa et al., 2013). In the studied sample, the core/rim boundary of garnet porphyroblasts is marked by a strong decrease in phosphorus (P). The P-rich core with oscillatory zoning is truncated by the P-poor rim. Cl-rich biotite and apatite are exclusively included in the P-poor rim. The core is homogeneous in Fe, Mn, Mg, and Ca ($\text{Alm}_{69}\text{Prp}_{26}\text{Sps}_2\text{Grs}_3$), while Fe and Mn increase and Mg and Ca decrease at the rim ($\text{Alm}_{78}\text{Prp}_{17}\text{Sps}_2\text{Grs}_3$). The pressure-temperature-time conditions of the Cl-rich biotite entrapment is estimated to be $\sim 800^\circ\text{C}$, ~ 0.8 GPa, and ca. 603 Ma, implying Cl-rich fluid or melt infiltration at the garnet core/rim boundary (Higashino et al., 2013).

In situ microscale oxygen isotope analysis of the garnet porphyroblast was performed by secondary ion mass spectroscopy (SIMS). The garnet shows large $\delta^{18}\text{O}$ variations from the P-rich core to the P-poor rim; $\sim 15.4 \pm 0.5\text{‰}$ (2σ) at the core and $\sim 10.7 \pm 0.5\text{‰}$ (2σ) at the rim. The $^{18}\text{O}/^{16}\text{O}$ values gradually decrease from the garnet core towards the rim and become constant at $\sim 400\text{ }\mu\text{m}$ outside of the core/rim boundary defined by P. Gradually decreasing oxygen isotope profile compared to the sharp P-zoning suggests that the former zoning was originally step-like because of an external low $\delta^{18}\text{O}$ fluid infiltration at the core/rim boundary, and modified by a diffusion process after the garnet rim formation. The garnet zoning profile in $^{18}\text{O}/^{16}\text{O}$ is well fitted by the diffusion equation, considering the core/rim boundary as an interface. Using experimentally and theoretically derived oxygen diffusion coefficients in garnet (Freer and Dennis, 1982; Haneda et al., 1984; Zheng and Fu, 1998; Vielzeuf et al., 2005; Scicchitano et al., 2017), residence at 800°C after the garnet rim formation is estimated to be a few Myr. The low $\delta^{18}\text{O}$ values at the garnet rim are expected to be in equilibrium with a fluid derived from igneous or mafic rocks (e.g., Sheppard, 1986; Putliz et al., 2000; Hoefs, 2015). In Balchenfjella, post-kinematic granitic intrusions are dated at ~ 549 Ma, whereas mafic rocks are considered as pre-metamorphic intrusions (Shiraishi et al., 2008; Ishikawa et al., 2013). Therefore, limited previous studies imply that the origin of the fluid is still open to discussion.

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