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Decoupled oscillatory and O-isotope zonation in high pressure low temperature garnet: records of heterogeneous fluid transfer processes

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High pressure garnet porpyhroblasts formed in subduction zones serve as a witness to an integrated history of fluid flow, deformation, metamorphic reaction, and exhumation processes. Seemingly ubiquitous within garnet from a heterogeneous suite of eclogite and blueschist units is primary oscillatory elemental zoning—rhythmic, short wavelength (< 10 μm) concentric fluctuations concentrated near the rims of porphyroblasts—which has been documented using a combined major element X-ray mapping and trace element LA-ICP-MS mapping approach. This oscillatory zoning must reflect some fundamental petrogenetic process operating during subduction zone metamorphism. While longer length scale (> 50 μm) oscillations have been interpreted to reflect rock-wide P–T changes during physical cycling through the subduction channel, these short wavelength oscillations have typically been interpreted to reflect changes in the effective grain boundary chemistry induced by fluid fluxing during mineral growth.

Here, we present secondary ion mass spectrometry (SIMS) O-isotope data across the oscillatory zoning in garnet from six subduction settings. A lack of spatial covariance between the elemental and $\delta^{18}O$ records is inconsistent with the interpretation that oscillatory zoning is directly linked to infiltration of chemically and isotopically distinct fluids. However, in most samples, vascillations in $\delta^{18}O$ of < 2 ‰ (over 20–50 μm) in the mantle and rim, coupled with < 1 ‰ net core-to-rim change may point to the predominance of: (a) an internally-controlled grain boundary fluid and relatively stagnant fluid conditions, with grain boundaries that may experience transient opening, heterogeneous and locally-derived fluid fluxing, and then re-sealing, or (b) a rock-buffered oxygen isotope composition during garnet growth between 450 ˚C and 550 ˚C. However, several samples exhibit a systematic 2.5–4 ‰ change in $\delta^{18}O$ across oscillatory major and trance element zoning, accompanied by a 2–3 mol% decrease in andradite content. This change, outside that predicted via closed system crystallization and fractionation, is suggested to reflect the relatively uncommon and sudden transient passage of a reduced external fluid. While this dataset does not reveal the mystery of the oscillatory zoning, it demonstrates spatial and temporal heterogeneity of fluid transfer in subduction zones.