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Garnet as a useful monitor of growth and ascent rates in felsic igneous systems

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Although garnet is an important accessory phase in felsic igenous rocks, its potential for timescales of magmatic processes such as mineral growth rates or ascent rates through the crust is not fully exploited. The origin of garnet in felsic igneous systems range from crystallization from (mostly) peraluminous melts to entrainment of peritectic or xenocrystic garnets originating from country rocks. We investigated garnets from mid-crustal plutonic rocks from the Ivrea-Zone (N-Italy), which contain metapelitic enclaves and composite metamorphic-magmatic xeno-phenocryst garnet. Using microtomography, high resolution EPMA mapping and detailed chemical transects by LA-ICP-MS we identified garnets with metamorphic cores and multiple igneous overgrowth rims. Using independent temperature and pressure constraints such as Zr saturation temperature from zircon-bearing nanogranitoid inclusions and phase equilibrium constraints the crystallization conditions are constrained to 780 to 820°C and ~3-4 kbars, while the garnet core still records lower crustal conditions. To quantify the duration of magmatic overgrowth, we have numerically modeled Cr, Y, REEs and Hf trace element diffusion, as well as multicomponent major divalent cation diffusion within garnet using available experimental diffusion data and Cr diffusion data retrieved from natural garnets. All modelled diffusants conform to a single temperature-time path, in which the temperatures associated with the first and second magmatic overgrowths persisted for 5.4 and 6.3 kyr respectively (Devoir et al. 2021). Rhyolite-MELTS modeling was used to explore various decompression and cooling paths of ascending rhyodacitic magmas and its effects on the density and viscosity evolution. Using a range of H_2O contents and resulting different viscosities for the ascending felsic magma, garnet grain settling velocities of ca. 1 $m.yr^{-1}$ were calculated using the Navier Stokes equation. To preserve lower crustal garnet core compositions, maximum time scales of melt extraction of ca. 15 kyr are calculcated. Potential implications for magma ascent rates will be discussed.

Devoir, A., Bloch, E., Müntener, O. (2021) Residence time of igneous garnet in Si-rich magmatic systems: Insights from diffusion modeling of major and trace elements. Earth and Planetary Science Letters 560, 116771