Title Development of Clinopyroxene as an Igneous Geospeedometer using NanoSIMS

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Abstract

Geospeedometry, the quantification of timescales from diffusional relaxation of compositional zoning in minerals, is usually implemented using quartz, feldspar, and olivine. Clinopyroxene (cpx), commonly found in both igneous and metamorphic rocks as well as in meteorites, could also be a powerful tool for diffusion-related applications, once the appropriate suite of magmaphile elements with different diffusivities is identified—especially where the initial condition cannot be assumed to be a step function. Here we develop the use of cpx as a geospeedometer in rhyolitic magma by investigating slow diffusing elements via SIMS and NanoSIMS analyses using Yellowstone Plateau rhyolite lavas as a test case. LA-ICPMS analyses identified slow diffusing elements with resolvable abundances in the Yellowstone cpx; Ce and Dy were the best candidates, because experimental studies demonstrate they diffuse 12–88 times slower at a given temperature than elements such as Fe-Mg, which are typically used for diffusion dating in pyroxene. SIMS profiles with ≤ 8 micron resolution across intracrystalline zone boundaries reveal Ce and Dy abundances of ~175 ppm and ~78 ppm respectively, but also motivate analyses with higher spatial resolution in order to quantify concentration gradients for diffusion modeling. Subsequent NanoSIMS profiles at 0.2–1 micron spacing across intracrystalline zone boundaries capture Ce and Dy gradients that can be used to provide rejuventation-eruption timescales from the Yellowstone cpx. SIMS analyses employing energy filtering vs. those collected at full transimission both replicate the cpx Ce and Dy zoning and indicate there are not significant mass interferences for Ce and Dy, confirming that the NanoSIMS results replicate true intracrystalline variation. In addition, NanoSIMS Si, Mg, Fe, Ce, and Dy distribution maps of individual exsolution lamellae from the cpx cores provide information about the cooling history of the cpx.