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Diffusion of Sr and Ba in plagioclase: New experimental data and application to explosive volcanic eruptions

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Constraining the temperature and volatile evolution of magma reservoirs is an important scientific and societal challenge to mitigate future volcanic hazards. Diffusion chronometry represents one valuable tool to track the timescales of magmatic processes and is now routinely applied on erupted volcanic products to infer crystal residence times and mixing-to-eruption timescales. As such, calibrating the diffusion rates of Sr and Ba in plagioclase, probably the most abundant mineral in eruptive products, is critical to place time constraints on different magmatic systems. However, discrepancies between previous studies investigating the diffusion rates of divalent cations in plagioclase persist [1-4]. Here we report diffusion experiments that aim to constrain the diffusivities of Sr and Ba in oligoclase and labradorite at 1 atm pressure, between 900 and 1,200 °C, and as a function of the crystallographic orientation and $a\mathrm{SiO_2}$. The experimental products were analysed by SIMS depth profiling and LA-ICP-MS line scanning. There is no resolvable dependence of Sr and Ba diffusion in plagioclase upon $a\mathrm{SiO_2}$ or crystal orientation. However, Sr and Ba diffusivities are found to vary with plagioclase anorthite content. The diffusion rate of Sr in plagioclase determined in this study is ~1.5-2 orders of magnitude slower than previously determined, whereas Ba diffusion is similar to previous studies. This is likely due to Ba-feldspar stability at the experimental conditions employed by previous studies, whereas Sr-feldspar was absent from their source powder assemblage. By applying the diffusivities determined in this study to plagioclase crystals from the Cerro Galán and Santorini calderas, we find timescales of $\sim 10^5$ years. These Sr- and Ba-in-plagioclase diffusion timescales are remarkably similar to those inferred using Ti-in-quartz diffusion and high-precision zircon dating, and therefore record differentiation and assembly of large magma reservoirs rather than short-lived pre-eruptive processes.

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