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Diffusive fractionation of Ca isotopes in mafic injection zones in granite: Transport, reaction, and cooling timescales at 1-year resolution

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Experimental studies show chemical diffusion in magma induces isotopic fractionation. These studies typically use dry liquids at T ≥ 1200°C; the applicability to natural granites and gabbros is still unclear. Two studies detected diffusive isotopic effects in Mg of a few permil at the borders of mafic injections into granitic magma. We are investigating Ca and K isotopes. At gabbro-granite contacts, Ca and K diffuse in opposite directions. Our first data are from the Pyramid Peak granite (PPG) in the Sierra Nevada near Lake Tahoe, from a mafic dike back-injected by granite dikes with sharp contacts. A Ca isotope transect shows diffusive effects of 1.7‰ that result in higher δ^{44}Ca on the mafic side and lower δ^{44}Ca on the felsic side, and a far-field granite δ^{44}Ca 1.1‰ lower than gabbro. The δ^{44}Ca peak-to-trough distance is 6 mm. Modeling indicates $(D_{Ca}t)^{1/2} \approx 1$ mm on the felsic side and 1.5 mm on the mafic side. Given rapid temperature homogenization, this result suggests D_{Ca} is 2 to 2.5 times larger in mafic magma. The diffusivity of Ca is uncertain because of dependence on both T and H_2O. The likely time to develop the isotopic signal can be estimated from the cooling time of the 10 to 15 meter-thick mafic dike; about 5 years. This timescale implies $D_{Ca} \approx 10^{-10}$ m^2/s in the granite, similar to values measured for dry rhyolite at 1000°C. A Nd isotope profile shows the felsic magma has lower ε_{Nd} by 5 units and suggests $D_{Nd} \approx D_{Ca}$, which is not expected. A second δ^{44}Ca profile from a pillowed mafic injection zone in the Guadalupe Igneous Complex (GIC) in the Sierra foothills, shows smaller isotopic shifts and a peak-to trough distance of 10 mm. The GIC may differ from the PPG in that the initial T was higher, allowing for a longer diffusion time, and the Ca concentration contrast across the boundary is smaller. These diffusion studies can help define the magma mixing and homogenization timescales in granitic intrusives with resolution of years, a much finer scale than can be achieved with radiogenic geochronology.