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Phenocryst-Matrix study of Fe isotope fractionation at magmatic conditions

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Iron is the only redox-sensitive major element in magmatic rocks, and the distribution of its stable isotopes can yield important insights into partial melting and fractionation processes. Equilibrium stable isotope fractionation factors, necessary to interpret real-world data, are commonly determined directly between two phases through experiments, or indirectly by spectroscopic investigation of the lattice dynamics of single phases. A third approach is the study of phenocryst and matrix relations in multiply saturated lavas that equilibrated at magmatic conditions. Here, we present new Fe isotope data for phenocrysts and matrix of rhyolitic to intermediate lavas from four well-studied volcanic systems: Thingmuli and Öræfajökull, Iceland, Pantelleria, Italy, and the Bishop Tuff, USA. The lavas host Fa, Cpx, Opx, Bt, aenigmatite, Fsp and FeTi-oxide phenocrysts in a glassy to microcrystalline matrix. For these systems, independent constraints exist on temperatures and pressures of mineral equilibration, oxygen fugacity, and water content. Iron from separated phenocrysts and matrix was chemically purified and analyzed for δ^{56}Fe (phenocrysts relative to matrix) with a Nu Plasma II MC-ICPMS at Aarhus University using pseudo-high resolution and sample-standard bracketing. Temperature-dependent fractionation factors between minerals and matrix ($10^3\ln\alpha^{56}_{\text{min-ma}} \cong \Delta^{56}\text{Fe}_{\text{min-ma}}$; $x10^6/T^2$) calculated from the results span a range of -0.115 to -0.219 for Fa, Cpx, and Opx, -0.126 to -0.140 for Bt and aenigmatite, and 0.402 to 0.743 for Fsp. Across a single volcanic system, fractionation factors increase with $\text{Fe}^{3+}/\text{Fe}_{\text{tot}}$ of the mineral phase. However, differences in fractionation factors between minerals with similar $\text{Fe}^{3+}/\text{Fe}_{\text{tot}}$, *e.g*. Fa, Cpx, and Opx, for the four volcanic systems investigated do not correlate well with the $\text{Fe}^{3+}/\text{Fe}_{\text{tot}}$ ratio of the conjugate matrix, but do show good correlation with magma viscosity estimated from Giordano et al. (2008, EPSL) at magmatic conditions. This correlation highlights the importance of melt polymerization/structure controlling Fe isotope fractionation in silicic systems - here related principally to differences in alkalinity and volatile contents.