

Trace element partitioning in hyperalkaline magmatic systems: an experimental study

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The partitioning of trace elements between alkaline melts and their dominant mineral phases remains poorly constrained. Feldspathoids in particular have received only limited attention with regards to their trace element uptake, limiting our ability to interpret geochemical trends for alkaline magmatic systems. Here we investigate the influence of the melt-, and crystal-composition on partitioning for feldspathoids, Ca-rich pyroxene, and olivine. We have performed a series of 1 atm gas-mixing experiments using a variety of highly alkaline ($\text{Na}_2\text{O} + \text{K}_2\text{O} = 4.15\text{-}14.97$ wt.%), silica undersaturated ($\text{SiO}_2 = 36.73\text{-}45.96$ wt.%) lava compositions from Nyiragongo, DR Congo ($\text{Mg\#} = 31\text{-}79$). Experimental runs were performed at a variety of temperatures with $f\text{O}_2$ buffered at both QFM (quartz-fayalite-magnetite) and QFM+1 in order to measure the partition coefficients along the entire series of naturally occurring phases (leucite, nepheline, melilite, rhönite ($\text{Ca}_2[\text{Mg,Fe,Ti}]_6[\text{Si,Al}]_6\text{O}_{20}$), clinopyroxene, and olivine). Samples were cooled down from super-liquidus ($1180 - 1500$ °C) to final temperature at a rate of 2-3 °C/h and were left to equilibrate for 2 to 5 days depending on temperature. Glass-crystal pairs in quenched products were analysed by EPMA and LA-ICP-MS in order to constrain partition coefficients for the rare earth elements (REEs), large-ion lithophile elements (LILEs), and high-field-strength elements (HFSEs). Leucite and aluminian melilite are respectively reported to be preferential carriers of LILEs (e.g. $D_{Cs}^{Lc} = 10 - 24$) and Sr ($D_{Sr}^{Mel} = 0.9 - 2.5$). The partitioning behaviour of rhönite is shown to be analogous to clinopyroxene, incorporating significant amounts of transition metals (e.g. $D_{Sc}^{Rh} = 7 - 11$, $D_V^{Rh} = 1.7 - 2.1$), and having a strong preference for heavy over light rare earths ($\frac{D_{La}^{Rh}}{D_{Yb}^{Rh}} \approx 0.25$). Incorporation of trace elements in clinopyroxene (Cpx) is indicated to be primarily crystallographically controlled, positively correlating with the fraction of aegirine in the crystal. REEs are more compatible in these cpx as compared to tholeiitic systems, and a slight enlargement of the M2 site results in more favourable incorporation of light and middle rare earths ($\frac{D_{La}^{Cpx}}{D_{Yb}^{Cpx}} = 0.37 \pm 0.03$ vs 0.15 ± 0.1 ^[1]). The reported partitioning behaviours indicate that whole-rock trends at Nyiragongo cannot solely be explained through fractional crystallization, but also require an effect of crystal accumulation processes.

References:

[1] Bédard, J. H., (2014) *Geochem Geophys.*, 15, 303-336