Aegirine-pyroxene as a tracer for REE enrichment in alkaline magma

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Alkaline magmas host several economically important deposits of rare metals, including the REE (Strange Lake, QC; Gardar, Greenland) and the high field strength elements (HFSE) (Nechalacho, NT; Kipawa, QC; Lovozero, Russia). Fractionation of sodic clinopyroxene (and amphibole) is thought to be a major metal enrichment process in these systems, but its impact is not fully understood. A series of internally heated pressure-vessel experiments were performed to constrain the control of pyroxene on REE + HFSE behaviour in alkaline magmas and determine pyroxene-melt element partitioning systematics. Synthetic and natural trachy-andesite to phonolite compositions were run water-saturated at 650–825ºC with fO_2 buffered by *ca.* 1 bar of H_2 (QFM + 1) or by Hm-Mt (QFM +5). Fluorine was added to selected experiments (0.3 to 2.5 wt %) to ascertain its effect on element partitioning. Run products were analysed by EMP for major elements and LA-ICP-MS for trace elements. Mineral and glass compositions bracket the compositions of natural alkaline systems, allowing for direct comparison of our experimental results to nature. Our results indicate that REE partitioning systematics vary strongly with pyroxene composition: diopside-rich pyroxenes ($Aeg_{5–25}$) prefer MREE, medium aegirine pyroxenes ($Aeg_{25–50}$) preferentially incorporate LREE, and high aegirine pyroxenes ($Aeg_{55–95}$) strongly prefer HREE. REE partitioning coefficients range from 0.3 to 40, and are typically between 2 and 6, with minima for high aegirine pyroxenes. Melt composition (e.g. (Na+K)/Al) also impacts partitioning although to a lesser extent, except for the F-content, which shows no impact at all. The composition of fractionating pyroxene has a major impact on the REE pattern of the residual melt, and thus on the ability of a system to develop economic concentrations of REE. Element partitioning systematics suggest that late-crystallising aegirine-rich cumulates would be HREE-rich, in accord with the composition of mineralised intrusions, such as Nechalacho. Partitioning constraints also permit interrogation of pyroxenes from successive cumulate layers of natural systems to reconstruct rare metal enrichment paths in their relict melts. This approach will offer insight into the relative importance of magmatic and hydrothermal processes in the development and formation of peralkaline rare metal deposits.