REE-rich carbonatites immiscible with phonolitic magma

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Carbonatites, which represent an enigmatic and uncommon type of magmatic rocks dominates by carbonate, are broadly enriched in rare earth elements (REE) relative to the majority of igneous silicate rocks. While more than 500 carbonatites are referenced worldwide [1], only a few contain economic REE concentrations that are widely considered as resulting from late magmatic-hydrothermal or supergene processes. Magmatic pre-enrichment, linked to the igneous processes at the origin of carbonatites, are, however, likely to contribute to the REE fertilisation. Field observations [1] and experimental surveys [2, 3] suggest that a large part of the carbonatite melts can be produced as immiscible liquids with silicate magmas. Experimental constraints reveals that such immiscibility processes can lead to both REE enrichments and depletions in carbonatites [2, 3], making the magmatic processes controlling REE enrichments unclear.

Here we present results of high-pressure and high-temperature experiments, simultaneously addressing crystal fractionation of alkaline magmas and immiscibility between carbonate and silicate melts. The experimental data reveal that the degree of differentiation, controlling the chemical composition of alkaline melts is a key factor ruling the REE concentration of the coexisting immiscible carbonatites. The parameterization of the experimental data together with the compilation of geochemical data from various alkaline provinces show that REE concentrations similar to those of highly REE enriched carbonatites ($\sum$REE > 30000 ppm) can be produced by immiscibility with phono-trachytic melt compositions, while more primitive alkaline magma can only be immiscible with carbonatites that are not significantly enriched in REE.

[1] Woolley *et al.* (2008) *The Canadian Mineralogist* **46**, 741–752. [2] Martin *et al.* (2013) *Journ. of Pet.* **54**, 2301-2338. [3] Veskler *et al.* (1998) *Journ. of Pet.* **39**, 11-12.