Preliminary constraints on the temperature of hydrothermal carbonatite REE mineralisation using O isotope thermometry

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Carbonatites are a major source of REE ore minerals but, despite the strong association between the REE and carbonatite magmas, field and mineralogical evidence strongly indicates that hydrothermal reworking is required to form an ore deposit. The temperature of REE mineralisation, however, remains poorly constrained.

Hydrothermal gangue minerals associated with REE mineralisation commonly include calcite, barite, and strontianite. Oxygen isotope fractionation between calcite, or strontianite, and barite, over the range of temperatures of interest (175–450°C) equates to approximately -1 to -5 ‰. This range in O isotopes is resolvable using SIMS and, as such, represents a new, sensitive, geothermometer. Here, we present the first results of testing this thermometer on the Kangankunde, Okorusu and Khibiny carbonatite complexes.

The majority of data from the study sites are within error of 2–4 ‰ (VSMOW) for barite, and 5–7 ‰ for strontianite and calcite. Taking the maximum and minimum values for these equates to a temperature range of approximately 175–350°C. When screened for the effects of alteration, results from Kangankunde fall into a narrow range of 3–4 ‰ for barite and 6–7 ‰ for strontiantite, equating to 200–240°C. The number of data points from the other two complexes is limited. Results from Okorusu range from near 200°C to less than 100°C, corresponding with fluid inclusion homogenisation temperatures for fluorite minerlaisation. Carbonate and barite from Khibiny, despite texturally appearing in equilibrium, are several per mille different, indicating disequilibrium conditions.

The relatively low temperatures resulting from our study, while preliminary, are supported by recent fluid inclusion studies [1]. In combination, these results suggest that hydrothermal redistribution of REE can be linked to geothermal system conditions rather than simple magmatic ones, potentially requring fluid ingress.

[1] Shu & Liu (2019) *Ore Geol Rev*, 107, 41-57