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An in-situ chemical and isotopic investigation of carbonatitic apatite and the significance of rare earth element systematics

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Apatite is a minor but ubiquitous mineral in carbonatite and associated alkaline silicate rocks. It is an important mineral not only because of its role as the repository for phosphorus but also due to its affinity for rare earth elements (REEs). Presence of apatite can strongly influence the trace element signature and evolution in all environments, and it is believed to be one of the dominant minerals that control the REE budget for carbonatite [1]. Moreover, it is a liquidus phase that crystallizes throughout carbonatite fractionation. Hence, apatite is favored as a petrogenetic and geochemical indicator for carbonatitic magma evolution (e.g. REE systematics) [2,3].

The Shaxiongdong and Miaoya carbonatite complexes are two important REE deposits located in the South Qinling orogenic belt, central China [4]. Chemical compositions of apatite have been investigated by electron microprobe and laser ablation ICP-MS to identify the carbonatite magma evolution. These are fluorapatite (F= 1.95 – 3.74 wt.%) with low silica abundance, and characterized by variable REE enrichments (2895–24543 ppm). The composition data define a continuous chemical evolution indicated by an increase in REE and Na abundances. They show a good linear correlation, which defines the belovite-type of substitution in the Ca site within apatite (i.e. $2Ca^{2+}=Na^{+}+REE^{3+}$). Three types of chondrite-normalized REE patterns have been distinguished for the apatites: 1) convex-upward shaped pattern with peak at MREE (e.g. Eu or Gd; $La_N/Gd_N < 1$); 2) negative straight linear pattern from Sm to Lu with flat LREE region or slight depletion from Nd to La ($La_N/Nd_N \sim 1$); 3) straight linear trend with a strong enrichment in LREEs ($La_N/Yb_N > 100$, up to 226). REE enrichments show a positive correlation with the pattern indicators (i.e. La_N/Nd_N , La_N/Yb_N). Of note, different REE systematics for apatite have been observed within individual samples or in samples in very close proximity to each other. This suggests that these apatites probably represent cumulates or magma mixing. In-situ Sr isotopic compositions have been obtained by laser ablation MC-ICP-MS for apatite with different REE signatures from the Shaxiongdong carbonatite complex. These apatites display relatively uniform $^{87}Sr/^{86}Sr$ ratios (0.70313–0.70329), which suggest generation from an isotopically homogeneous magma. Hence, they represent cumulates recording different stages of the carbonatite magma evolution.

REE systematics of apatite could serve as a good indicator for carbonatite differentiation processes in the South Qinling carbonatites. Type 1 apatite contains the lowest REE abundances with a convex upward pattern, which crystallizes early in the carbonatite evolution history. Type 3 apatite is enriched in REEs with the highest La_N/Yb_N (>100), which represent crystallization from an evolved carbonatite

melt with high degrees of fractionation. The REE systematics of Type 2 apatite is quite similar to that of Type 3 with the exception of relative LREE depletions, which possibly results from the accumulation or fractionation of minor co-existing LREE minerals (e.g. burbankite, monazite).

References:

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