

Hydrothermal upgrading as an important tool for the REE mineralization in the Miaoya carbonatite-syenite complex, Central China

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ABSTRACT

Secondary hydrothermal reworking of REEs has been widely documented in carbonatites/alkaline rocks, but its potential role in the REE mineralization associated with these rocks is currently poorly understood. This study conducted a combined textural and in situ chemical investigation on the REE mineralization in the ~430 Ma Miaoya carbonatite-syenite complex, central China. Our study shows that the REE mineralization, dated at ~220 Ma, is characterized by a close association of REE minerals (monazite and/or bastnäsite) with pervasive carbonatization overprinting the carbonatites and syenites. In these carbonatites and syenites, both the apatite and calcite, which are the dominant magmatic REE-bearing minerals, exhibit complicated internal textures that are generally composed of BSE-bright and BSE-dark domains. Under BSE imaging, the former domains are homogeneous and free of pores or mineral inclusions, whereas the latter have a high porosity and inclusions of monazite and/or bastnäsite. In situ chemical analyses show that the BSE-dark domains of the apatite and calcite have light REE concentrations and $(La/Yb)_N$ values much lower than the BSE-bright areas. These features are similar to those observed in metasomatized apatite from mineral-fluid reaction experiments, thus indicating that the BSE-dark domains formed from primary precursors (i.e., represented by the BSE-bright domains) through a fluid-aided, dissolution-reprecipitation process during which the primary light REEs are hydrothermally remobilized. New, in situ Sr-Nd isotopic results of apatite and various REE minerals, in combination with mass balance calculations, strongly suggest that the remobilized REEs are responsible for the subsequent hydrothermal REE mineralization in the Miaoya complex. Investigations of fluid inclusions show that the fluids responsible for the REE mobilization and mineralization are CO₂-rich, with medium temperatures (227–340 °C) and low salinities (1.42–8.82 wt%). Such a feature, in combination with C-O isotopic data, indicates that the causative fluids are likely co-genetic with fluids from coeval orogenic Au-Ag deposits (220–200 Ma) in the same tectonic unit. Our new findings provide strong evidence that the late hydrothermal upgrading of early cumulated REEs under certain conditions could also be an important tool for REE mineralization in carbonatites, particularly for those present in convergent belts where faults (facilitating fluid migration) and hydrothermal fluids are extensively developed.

Keywords: Apatite, calcite, REE mobilization and mineralization, hydrothermal upgrading, Miaoya carbonatite-syenite complex