

HFSE enrichment by crustal wall-rock assimilation and metasomatism caused by carbonatite magmas – the Eureka and Palabora case

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Numerous carbonatites show evidence for the interaction between carbonatitic melts and variable crustal country rocks during emplacement. This metasomatic interaction results in the formation of diverse silicate-bearing carbonatites, silicate-rich carbonatites, and carbonate-bearing silicate rocks that have been termed antiskarns. The principle concept for such metasomatic models is based on the low solubilities of Si and Al in carbonatite liquids under crustal conditions. Consequently, abundant silicate minerals such as olivine, clinopyroxene, amphibole and mica may form within and around many carbonatites, at various scales. In some cases, antiskarn formation is accompanied by economic mineralization (e.g., apatite, magnetite and mica in Palabora, South Africa; monazite in Eureka, Namibia). Hence, the origin of abundant silicate minerals and the partially related enrichment of REE (and other HFSE) in carbonatites and associated silicate rocks need to be revisited. At Palabora, calcite-carbonatite (baddeleyite-bearing) forms a metasomatic interaction with the gneissic country rocks on a scale of hundreds of meters. The interaction zone starts with an apatite and magnetite-rich phoscorite (or olivinite in the northern part of the complex) develops into apatite-rich, zircon-bearing clinopyroxenite and finally transforms into glimmerite. In the case of Eureka, metasomatic wall-rock interaction is documented on a decimeter scale: Over a distance of about 30 cm, a dolomite-carbonatite intruding metasedimentary country rocks produces an interaction zone changing from dolomite-carbonatite with baddeleyite to a calcite-carbonatite with coarse monazite to a forsterite-calcite-carbonatite with allanite, followed by olivinite, clinopyroxenite and glimmerite with increasing zircon content (Fig. 1). These systematic changes clearly demonstrate the role of Si and Al as contaminants and the relation of ore mineralogy to wall-rock interaction. The formation of non-carbonate minerals from the carbonatite melt, results in the release of CO₂. As CO₃²⁻ complexes serve as transporting ligands for HFSE-REE in carbonatite melts, the loss of this ligands results in a storage of HFSE-REE in the metasomatites. Thus, the HFSE-REE behaviour during antiskarn formation differs substantially from the process of liquid immiscibility, which enriches HFSE in carbonatitic liquid based on partition coefficients. In conclusion, contamination at emplacement level can be a first order process modifying a carbonatitic liquid supporting enrichments of HFSE.

