

Assessing the Roles of Magmatic and Fluid Processes in the Genesis of REE Deposits in Carbonatites

Andrea Giuliani¹, Max W. Schmidt²

¹Carnegie Institution of Science, Washington, United States, ²ETH Zurich, Zurich, Switzerland

Carbonatites represent the main source of Rare Earth Elements (REE), yet of the >400 carbonatites discovered to date, <10 host active or prospective REE mines. The key factors governing the formation of REE mineralization in carbonatites and related rocks are uncertain, hampering exploration efforts for these critical metals. While there is broad agreement that the ultimate source of REE is the carbonatite melt, current genetic models of REE enrichment in these rocks include multiple steps whose relative importance is poorly constrained. In this presentation, we will critically address the relative roles of magmatic and fluid-related processes in achieving REE enrichment in carbonatites by combining previous and new results (field and textural observations, geochemical and isotopic data) from well-studied carbonatites and REE deposits with experimental constraints and theoretical considerations. We will show that i) formation of mantle sources that are enriched in incompatible elements by either metasomatism or recycling of subducted material is not required. ii) Low melting degrees to generate REE-endowed CO₂-rich silicate melts and their evolution towards alkali-rich phonolitic (syenitic) compositions are essential to achieve high REE contents in immiscible carbonatitic liquids. iii) Carbonatite differentiation does not enhance REE concentrations in residual melts (or 'brine-melts') hence ruling out a prominent role for crystal fractionation. iv) REE-carbonates and REE-phosphates crystallized from C-O-H deuteritic fluids ('carbothermal residua') may accumulate in geochemical traps that locally follow preexisting structures, hence leading to REE mineralization. v) Redistribution of REE in secondary carbonates and phosphates generated by fluid alteration in the waning stages of carbonatite emplacement and/or several million years later is fundamental to substantially upgrade REE tenors. This assessment highlights the dominant role of magmatic and post-magmatic C-O-H fluids in the genesis of REE deposits while stressing the importance of specific magmatic pathways to generate elevated REE contents in carbonatite melts.