

Potential Sources of Rare Earth Elements (REEs) in Loch Borralan, Northwest Highlands, Scotland: Geochemical and Mineralogical Controls on REE Distribution in Carbonatite

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This study investigates the Loch Borralan carbonatite as a source for rare earth elements (REEs), which are vital for the green transition. The Caledonian Loch Borralan complex is located in the Assynt district, in the NW Scottish Highlands. Analysis of targeted rocks indicates a diverse group of REE-bearing minerals, including bastnaesite, synchysite, ancylite, monazite, apatite, zirconolite, titanite, and REE-rich ilmenite. There are also significant amounts of sulphide minerals such as pyrite, pyrrhotite, and chalcopyrite. This study aims to constrain REE enrichment processes and isolate different magmatic processes that led to the enrichment of REEs in the carbonatite magma from the effect of hydrothermal processes. The $\delta^{13}\text{C}$ (-5.5‰) and $\delta^{18}\text{O}$ (+9.1‰) stable isotopes indicate a mantle origin, whereas $^{40}\text{Ar}/^{36}\text{Ar}$ and $\text{N}_2/^{36}\text{Ar}$ data are compatible with limited crustal assimilation. REE-bearing minerals in the Loch Borralan carbonatite have experienced a sequence of REE mineralisation where early-formed REE-bearing minerals such as REE-titanite and apatite donated their REE contents to more evolved REE-carbonates and phosphates. Although the size of the deposit is unknown, it could have the potential to contribute to securing a sustainable REE mining industry and ensuring supply security of these critical elements; establishing a model for REE enrichment will improve understanding of the origin of this deposit, which could have an impact on future targeting of REE-bearing deposits globally.