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Mantle sources for Europe's largest REE belt (Gardar Province, SW Greenland): Insights from Nd-Hf isotopes

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Alkaline-silicate complexes host world-class resources of Rare Earth Elements and High Field Strength Elements (REE + HFSE). Despite their economic importance, we do not have a clear understanding of how the composition of their mantle melt source affects the tonnage of their mineral deposits, or the relative quantity of each metal.

Here we develop this understanding by presenting Nd-Hf isotope measurements —data that directly track the source of the REE+HFSE—for alkaline complexes from the Mesoproterozoic Gardar rift in SW Greenland, Europe's largest REE belt. Early Gardar complexes (1320–1260 Ma) have highly variable $\varepsilon Hf_{(i)}$ (-6.5 to +3), decoupled from their narrow range of positive $\varepsilon Nd_{(i)}$ (+0.5 to +2), whereas late Gardar intrusions (1180–1140 Ma) have a narrow range of $\varepsilon Hf_{(i)}$ (0 to +1) and $\varepsilon Nd_{(i)}$ (-1 to +1). Previous work shows that Gardar intrusions have high Ba/La (10–90) and Zr/Nb ratios (2.5–25), and high F concentrations (0.25–5.5 wt.%), indicating contributions from metasomatised, arc-like mantle [1]. The decoupled Nd-Hf isotope signature is consistent with derivation of early Gardar melts from a subduction mélange including REE-poor, zircon-bearing clastic sediments and oceanic crust. Late Gardar intrusions have higher $\delta^{34}S$ (0.7–3.6 ‰) and Ce/Y (1.4—4.4) compared with early Gardar complexes [1], suggesting stronger source metasomatism, however most have Nd-Hf compositions consistent with a weaker influence of subducted continental materials. An exception is the Ilímaussaq complex—a notably enriched portion of the Gardar Province—which has a wider range of initial isotope compositions ($\varepsilon Nd_{(i)}$ = -2 to 0, $\varepsilon Hf_{(i)}$ = -2 to +5). These signatures are consistent with contributions from subducted pelagic sediments or carbonate metasomatic veins in the lithospheric mantle.

Overall, we interpret the metallogeny of the Gardar rift to be controlled by mantle source composition, which in turn reflects the geodynamic history and the recycling of continental sediments through an ancient subduction zone. Source enrichment is province-wide and changes in character during development of the rift. The formation of world-class REE deposits, such as those within the Ilímaussaq complex, appears to require locally-enriched melt sources (10s km) on the length scale of individual intrusive complexes.

[1] Hutchison et al. (2021), *EPSL 568*.