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Quantifying crustal assimilation in the Kuunnaat complex, south Greenland: implications for rare earth element mineralisation

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The Mesoproterozoic Gardar province in southern Greenland contains a range of alkaline-silicate complexes that were emplaced during multi-stage continental rifting. Evolved portions are compositionally diverse and range from silica-undersaturated nepheline syenites to silica-oversaturated peralkaline granites. The range is attributed to variable crustal assimilation during fractional crystallisation from primitive mantle-derived silica-undersaturated melts [1,2]. The diversity likely impacts the nature of any associated mineralisation; for example, prospective rare earth and high field strength element (REE-HFSE) deposits in the region are mainly associated with silica-undersaturated rocks. However, the controls on the formation of contemporaneous mineralised and barren complexes remain poorly understood.

Here, we integrate petrography and phase equilibria modelling to analyse the development of the barren Kuunnaat complex—a small (~12 km^2) intrusive suite in western Gardar—to further understand the petrogenesis of alkaline-silicate complexes, and associated mineralisation. Kuunnaat presents an ideal case study as it comprises a cogenetic sequence of primitive silica-undersaturated gabbros, augite- and quartz-syenites, and late-stage peralkaline granites, thought to be related by low pressure fractional crystallisation. Some crustal assimilation is implied by isotopic constraints [3].

We model simultaneous assimilation-fractional crystallisation across varying physiochemical conditions, and quantify the fit of modelled liquid evolution paths to whole rock data using principal component analysis. Initial redox states and water content are constrained by the observed gabbroic mineral assemblage, suggesting the primitive melt was relatively reduced (XFe^{3+} of ~0.1) and contained 0.1–0.2 wt% H2O. Our results indicate that 10–15% assimilation of hydrous local gneiss during fractionation at pressures of 1–3 kbar is required to replicate the observed syenitic and granitic compositions; estimates that are similar to other Gardar complexes [1]. Using zircon saturation calculations, we show that crustal assimilation also triggers early zircon crystallisation, consistent with observations of zircon in Kuunnaat syenites. Early zircon would limit the ability of an evolved melt to form more complex Zr-silicates (e.g. eudialyte) typically associated with REE-HFSE deposits, suggesting crustal assimmilation is an important control on mineralisation.

[1] Soderman et al., (2025) *EPSL*, 667:119516.

[2] Beard et al., (2024) *EPSL*, 640:118780.

[3] Upton et al., (2013) *Mineralogical Magazine*, 77/4:523–550.