The Spatio-Temporal Evolution of Gardar Rift Magmatism: Hf isotopic clues to Archean crustal recycling

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The Mesoproterozoic Gardar Province in South Greenland is the product of voluminous alkaline magmatism associated with two stages of continental rifting. Gardar complexes expose medium to highly evolved peralkaline rocks, including two large critical metal deposits (e.g. HREE, Hf, Ta, Nb and Zr at Motzfeldt and Ilímaussaq), a Ti-V deposit (Isortoq) and a cryolite quartz deposit (Ivigtut). To understand further the sources of heavy REE and Hf enrichment, we studied zircon Lu-Hf isotope systematics from Gardar centres emplaced during both Early (Motzfeldt, North Motzfeldt, Kungnat, Ivigtut) and Late (Ilímaussaq, Østfjordsdal, Tugtutoq, Narsarsuk, Nunarsuit, Paatusoq) Gardar rifting and encompassing the full geographical extent of the province from Kungnat in the West to Paatusoq in the East. The magmas intruded variable basement terranes including Archaean crust (Kungnat, Ivigtut) and Ketilidian metasediments (Paatusoq) and granitoids (the others).

Age-corrected Hf data plot below depleted mantle evolution curves and are inconsistent with the melts being sourced from depleted mantle in Gardar times. Early Gardar zircons have significantly lower Hf signatures ($2 > \varepsilon_{Hf(t)} > -6$) than those in Late Gardar magmas ($8 > \varepsilon_{Hf(t)} > 0$), and their Hf values project back to Ketilidian or older mantle extraction ages (> 1.8 Ga). One might interpret such data to indicate that Hf in Early Gardar melts was scavenged from local crust to give rise to the low Hf ratios measured. However, 1) primary Gardar melts are unlikely to have contained negligible Hf, such that an unrealistic proportion of assimilated basement is required and 2) Nd and Sr isotopic data do not support significant crustal assimilation. Instead, we hypothesise that low Hf ratios are consistent with a model whereby subduction of Archaean crust (i.e. low $^{176}Hf/^{177}Hf$) during the Ketilidian orogeny enriched the subcontinental lithospheric mantle with Archaean Hf. Early Gardar decompressional melting preferentially accessed this subducted (Archaean) mantle component and provided magmas with anomalously low Hf ratios. As rifting continued, the Archean component faded and the contemporary asthenospheric Hf signature began to dominate. We infer that the temporal Hf evolution of Gardar melts records 'recycling' of Archaean crust via the mantle in the Mesoproterozoic.