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Hadean crustal composition and evolution inferred from coupled $^{146,147}Sm$-$^{142,143}Nd$ systematics of Paleoarchean Acasta Gneisses

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Reconstructing the evolution and composition of the Hadean crust remains a major challenge because of the scarcity and incomplete preservation of rocks older than 3.8 Ga. Whole-rock $^{146,147}Sm$-$^{142,143}Nd$ (TIMS), major (XRF) and trace element compositions (quadrupole ICP-MS), and U-Pb zircon dates (LA-MC-ICP-MS) from layered gneisses of the Acasta Gneiss Complex (AGC, Northwest Territories, Canada) elucidate their Paleoarchean petrogenesis.

Individual rock samples were cut as slabs along the compositional layering of a gneissic rock package to obtain chemically diverse whole rock samples for analysis. The samples follow variable differentiation trends. The two most mafic samples lie on a broadly tholeiitic AFM trend and have $\mu^{142}Nd \approx 0$, whereas five intermediate to felsic samples define a calc-alkaline trend and are characterized by negative $\mu^{142}Nd$ (-4 to -8.5 ppm). Zircon U-Pb data for the calc-alkaline samples form bands along concordia indicating ancient Pb loss, but with consistent clustering at ca. 3.55 Ga. In contrast to previous studies of the Acasta Gneiss Complex, the samples show correlated $\mu^{142}Nd$-$\varepsilon^{143}Nd_{3.55Ga}$ (R^2=0.9), suggesting that their initial $^{142,143}Nd$ compositions have been preserved.

The observed correlation reflects a mixing relationship that is also observed for various incompatible elements (e.g., Rb, Ba, Th). A possible end-member of this relationship is defined by three felsic samples having an average $\mu^{142}Nd$ value of −8.1 ppm (±2.7 ppm, 2 S.D.) and a corresponding $\varepsilon^{143}Nd_{3.55Ga}$ of −5. Using this information, a two-stage $^{142,143}Nd$ model age of 4.22±0.01 Ga and $(^{147}Sm/^{144}Nd)_{source} \approx 0.14$ are estimated for the Acasta precursor crust. Using the correlation between Lu/Hf and Sm/Nd among global crustal rocks, the AGC protocrust would have had a $^{176}Lu/^{177}Hf$ of 0.016, corresponding to an intermediate composition. When combined with an extraction age of 4.22 Ga, the modeled evolution of the this protocrust matches the $\varepsilon^{176}Hf$ zircon record until 3.6 Ga. The Acasta Gneiss Complex thus appears to record a protracted geological history that started with the formation of a basaltic to andesitic rather than felsic protocrust during the late Hadean. This crust persisted for at least 600 Myr, during which it was episodically re-melted and differentiated into felsic continental crust.