Inferred Hadean crustal composition and evolution through coupled ^{146,147}Sm-^{142,143}Nd systematics in Paleoarchean Acasta Gneisses

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Reconstructing the composition and evolution of the Hadean crust is hampered by the limited availability and preservation of rocks older than 3.8 Ga. A range of analytical techniques, including whole-rock ^{146,147}Sm-^{142,143}Nd (TIMS), major and trace element compositions (XRF and quadrupole ICP-MS), and U-Pb zircon dating (LA-MC-ICP-MS) were employed to investigate the petrogenesis of Paleoarchean layered gneisses from the Acasta Gneiss Complex (AGC) in the Northwest Territories, Canada, and to identify their corresponding sources.

Rock samples were cut into slabs on the basis of their compositional layering to create diverse whole rock samples for analysis. These samples exhibit varying differentiation patterns. The two most mafic samples follow a tholeiitic AFM trend and have μ^{142}Nd close to zero, whereas five intermediate- to felsic samples track a calc-alkaline trend and have negative μ^{142}Nd values from −4 to −8.5 ppm. Zircon U-Pb data from the calc-alkaline samples form bands along concordia, indicating ancient lead loss, but with major clustering around 3.55 Ga.

In contrast to previous results from the AGC, the samples reveal a strong correlation between μ^{142}Nd and $\varepsilon^{143}Nd_{3.55Ga}$ (R^2=0.9), implying preservation of their initial ^{142,143}Nd compositions. This observed correlation results from mixing, suggesting interaction between an ancient crust and melts derived from a source with significantly more radiogenic Nd isotope composition. One possible end-member of this relationship is represented by three felsic samples having an average μ^{142}Nd value of approximately −8.1 ppm 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 a $^{147}Sm/^{144}Nd_{source}$ value of approximately 0.14 for the Acasta precursor crust are estimated. Considering the correlation between Lu/Hf and Sm/Nd observed in global crustal rocks, a corresponding $^{176}Lu/^{177}Hf_{source}$ value of 0.016 is inferred, indicating that the AGC protocrust likely had an intermediate composition. When combined with an extraction age of 4.22 Ga, the modeled evolution of this protocrust aligns with the $\varepsilon^{176}Hf_i$ zircon record until 3.6 Ga.

The Acasta Gneiss Complex thus preserves a lengthy geological history starting with the formation of a basaltic-to-andesitic protocrust during the late Hadean. This crust persisted for a minimum of 600 million years, during which it underwent intermittent re-melting and differentiation into felsic continental crust.