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Tracing Hadean Crustal Evolution: Sm-Nd and Pb-Isotope Constraints from the Singhbhum Craton and the Acasta Gneiss Complex

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Reconstruction of Earth's earliest crustal evolution is hampered by the absence of a rock record from the Hadean eon. Isotope signatures of extinct radionuclides, such as ^{146}Sm–^{142}Nd, provide a unique means to trace Hadean differentiation processes. Coupled ^{146,147}Sm–^{142,143}Nd isotope systematics of Paleoarchean rocks from the Singhbhum Craton in India and the Acasta Gneiss Complex (AGC) in Canada bear isotopic evidence of their derivation from Hadean sources.

Felsic, mafic, and ultramafic rocks from the Singhbhum Craton exhibit a range of Nd-isotope ratios that are more radiogenic than that of the modern mantle (μ^{142}Nd up to +6), whereas the AGC gneisses are less radiogenic compared to the modern mantle (μ^{142}Nd from −4 to −8.5), providing evidence for distinct Hadean mantle and crustal reservoirs. Both suites exhibit correlated ^{142}Nd and ^{143}Nd signatures, suggesting that they faithfully record the isotope composition of their protoliths. Combined ^{142,143}Nd model ages indicate both source reservoirs were generated at ca. 4.2 Ga and were preserved within the lithosphere for several hundred million years, at least until the formation of the Paleoarchean suites. Using the modelled ^{147}Sm/^{144}Nd of the Hadean crust and a global compilation of igneous rocks, an intermediate composition (∼55% SiO_2) is inferred for the Hadean crust. After transposition of the results into Lu-Hf systematics, this finding also aligns with the Lu-Hf record of the AGC gneisses.

Building on these insights, the Pb-isotope compositions of the same sample suites are investigated with the aim of determining whether they can trace early differentiation events in similar fashion when paired with a Pb-isotope framework for the Bulk Silicate Earth (BSE). Strongly-leached feldspar grains were analyzed by MC-ICP-MS using Tl for mass fractionation correction. First results for the Singhbhum Craton exhibit relatively primitive Pb-isotope ratios with minor deviations from BSE (^{206}Pb/^{204}Pb = 12.5870 (63), ^{207}Pb/^{204}Pb = 14.0528 (70), and ^{208}Pb/^{204}Pb = 32.297 (16)), possibly indicating that U/Pb and Th/Pb fractionation in the Hadean source was either insignificant or has not been preserved.