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Modelling the Hafnium–Neodymium Evolution of Eoarchaean crust

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The processes of partial melting and the segregation and migration of melt underpin the differentiation of the lithosphere. The Sm–Nd and Lu–Hf isotopic systems, which are sensitive to these processes, behave similarly during mantle–crust differentiation, leading to isotopically coupled primary (basaltic) and continental (tonalite–trondhjemite–granodiorite, TTG) crustal compositions that define a linear terrestrial fractionation array in eNd versus eHf space. However, Eoarchaean basalts and TTGs from West Greenland do not sit on this trend, and are isotopically decoupled, which may reflect their extraction from a mantle with a non-chondritic composition.

We explore the effects of source composition versus fractionation on the production and evolution of Eoarchaean crust in West Greenland. We use a combination of phase equilibria and trace element modelling to characterize the Hf–Nd evolution of a chain of melting from mantle through basalt to TTG. Approximately 20% decompression melting of mantle with a superchondritic Sm/Nd but chondritic Lu/Hf composition at a mantle potential temperature appropriate to the early Archaean produces basaltic melts with an isotopic composition similar to those measured in tholeiitic basalts from Isua. In turn, 5 to 30% melting of hydrated basalt produces felsic melts with Hf–Nd isotopic compositions similar to those measured in TTGs from the Itsaq Gneiss Complex. Thus, we chart a chain of melting from an isotopically decoupled Hf–Nd mantle composition to isotopically decoupled mafic and felsic crust.

Primitive mantle contamination by 5% recycled continental crust (TTG) requires a higher degree of mantle melting (30%) to produce basaltic melt with a Hf–Nd composition similar to the Isua basalts. A mantle composition with greater than 5% crustal contamination is more enriched than the Isua basalts, placing an upper limit on the amount of crustal contaminant. A non-chondritic mantle source composition in the early Archaean likely imposed a first order control on the subsequent production of crust with decoupled Hf–Nd compositions.

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