Early Continental Crust Formation constrained by Open System Models of Silicate Earth Evolution

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Establishing how and at what rate the continental crust has grown is crucial to quantify mass exchange between crust and mantle. It also provides clues to understand the mass flux and storage, or isolation time of recycled crustal material in the mantle. We have developed an open-system model for silicate Earth evolution, incorporating the Sm-Nd and Lu-Hf isotope systematics to study the chemical differentiation in Earth's major silicate reservoirs, but in particular the formation of continental crust during the Archean. Our model comprises four reservoirs: the bulk continental crust (CC), depleted upper mantle (UM), lower mantle (LM) and an isolated reservoir (IR) where recycled crust is stored transiently before being mixed with the LM. The changing abundance of isotope species in each reservoir is quantified using a series of first order linear differential equations that are solved numerically using the fourth order Runge–Kutta method at 1 Myr time steps for 4.56 Gyr (age of the Earth).

The model results show that only continuous and exponential crustal growth reproduces the present-day abundances and isotope ratios in the different terrestrial reservoirs. About 30% of the total present-day CC was formed by the end of the Hadean and about 75% by the end of the Archean. Both the formation and recycling of significant amounts of crust started in the Hadean. Depletion (in incompatible elements) of the UM during the early Archean is mitigated by the input of recycled crust, resulting in a near-primitive composition of the UM. The LM also remained near-primitive during the Archean, but in contrast to the UM, this is caused by the long-term isolation (~1 Gyr) of early-formed crust in the IR and thus limited mass exchange with the LM. Our model-derived composition of the IR is distinct from other mantle reservoirs, and may be related to stable crustal blocks or, alternatively, to recycled crust in the mantle that remains temporarily isolated, perhaps at the core-mantle boundary (c.f. LLSVPs).