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^{182}W-^{142}Nd isotope evolution in an open-system model of the Earth: Implication for geodynamic processes in early Earth

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We present a five-reservoir open-system model of Earth evolution incorporating the short-lived ^{182}Hf-^{182}W and ^{146}Sm-^{142}Nd isotope systematics to study accretion and differentiation processes on the early Earth. In the presented model, core formation is complete within 30-60 Myr after solar system formation. The complementary bulk silicate Earth (BSE) differentiates to form a continental crust (CC), an incompatible element depleted upper mantle (UM), an initially primitive but continuously evolving lower mantle (LM), and an isolated reservoir (IR) where the recycled crust is stored for 1 Gyr before mixing into the LM. Late accretion adds bulk Earth-like material to the mantle after core formation, concurrent to progressive silicate differentiation. The model, comprising a series of differential equations computing the changing abundance of isotope species in each reservoir, is solved using a Runge-Kutta fourth order iterative method from the beginning of Earth formation (t = 4.56 Gyr) to the present-day (t = 0 Gyr). The ^{182}W evolution is compatible with models in which core formation is complete by at least 45-60 Myr after solar system formation, which limits the amount of late accreted material to Earth to ~1-0.5% of Earth's mass. Reproducing the observable positive ^{182}W and ^{142}Nd anomalies in the Hadean-Eoarchean mantle require initiation of silicate differentiation by the first 50 Myr that is significant amounts of crust formation in the Hadean. The model results suggest that positive μ^{182}W and μ^{142}Nd reported in the Hadean to early Archean rocks can be reproduced in the UM, which eventually evolves to a present-day composition similar to the terrestrial standards (μ^{182}W or μ^{142}Nd are the ppm deviation in ^{182}W/^{184}W, ^{142}Nd/^{144}Nd from the terrestrial standards). The μ^{182}W or μ^{142}Nd of ~0 in the post-Archean rocks require thorough mixing of the recycled early-formed crust with the mantle reservoirs by the end of Archean. Our study indicates a complex interplay of early geodynamic processes in an energetic Earth producing distinct isotopic signatures in response to early crust-mantle interaction processes.