Goldschmidt 2025 Abstract
https://doi.org/10.7185/gold2025.29757

Linking the evolution of short-lived isotopic ratios in mantle to early Earth dynamics: Insights from geodynamic models

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The ^{182}W and ^{142}Nd isotope ratios preserved in Archean and Hadean rocks provide important information about Earth's early differentiation and evolution. The temporal evolution of these isotopic ratios in mantle-derived rocks suggests the long-term mixing of early-formed geochemical reservoirs within the silicate Earth during the Archean and Hadean. However, the decoupling between ^{182}W and ^{142}Nd ratios in various Archean samples implies additional mechanisms, apart from mantle differentiation, influenced the evolution of these isotopic systems.

In this study, we use the global geodynamic model StagYY to track the evolution of the Hf-W and Sm-Nd isotope systems through mantle convection. The model incorporates melting and magmatic crust production, enables the tracking of isotopic ratios in erupted basalt, thus provides a more realistic approach compared to previous mantle mixing studies without melting. Our model setup starts after the solidification of the magma ocean due to the Moon-forming impact. The crystallization of the magma ocean could generate heterogeneities in the lower mantle through element partitioning between melts and perovskite, affecting both density and heat-producing element distributions. Recent studies also suggest that late accretion [1] or the Moon-forming impact [2] could bring dense external material into Earth's lower mantle. Incorporating these variations into our model setup, we show how the evolution of ^{182}W and ^{142}Nd isotopic ratios is linked to mantle mixing, mantle differentiation, and evolving tectonic states.

[1] Korenaga & Marchi (2023), *PNAS 120*(43), e2309181120.
[2] Yuan et al. (2023), *Nature*, *623*(7985), 95-99.