Goldschmidt 2025 Abstract
https://doi.org/10.7185/gold2025.27645

A time-dependent redox-sensitive modelling approach to constrain the onset of surface material recycling on early Earth

SUKALPA CHATTERJEE[1,2], ARATHY RAVINDRAN[3], QASID AHMAD[4], MARTIN WILLE[5] AND KLAUS MEZGER[2]

[1]University of Cambridge
[2]University of Bern
[3]University of Cologne
[4]Université de Lorraine, CNRS, CRPG
[5]Institute of Geological Sciences, University of Bern

Efficient recycling of surface material through horizontal tectonics is unique to the Earth and has played a critical balancing act in influencing and modifying the geochemical cycles of life-sustaining elements like N, C, S and P on early Earth. This helped in the evolution of the redox state of Earth's mantle and atmosphere [1] and transferred life-essential elements to the continental crust. Weathering of this evolved crust supplied these elements to the ocean and likely was critical for biosphere evolution [2]. Therefore, when and how the onset of surface material recycling manifested on Earth is critical to the understanding of a life-sustaining Earth.

Redox-dependent mobility and isotope fractionation of Mo (expressed as $\delta^{98/95}$Mo) combined with radiogenic isotopes (^{87}Sr/^{86}Sr, εHf, εNd), have the potential to track recycling of surface material and metasomatism of lithospheric mantle [3]. The current study [4] proposes a novel redox-sensitive, multi-component, time-independent elemental and time-dependent isotope mixing model. Using the isotope composition of mantle-derived rocks, this model can efficiently track whether their mantle source metasomatism was driven by the recycling of sediments or mafic oceanic crust, along with determining the prevalent redox condition and timing of recycling. This approach is used to model the genesis of primitive mafic dykes from the Singhbhum Craton (India), which are derived from the lithospheric mantle and have enriched crustal signatures. The multicomponent mixing model affirms that the lithospheric mantle source of the dykes was metasomatized by partial melts that were derived from anoxic sediment and oceanic crust recycled through horizontal tectonics at around 3.44 Ga. This is one of the oldest pieces of evidence for surface material recycling on Earth and coincides with the time of widespread granitoid formation in Singhbhum Craton. Once applied to other cratons, this modelling approach can be critical to understand the timescale of the fundamental process of surface material recycling and continental crust formation on early Earth.

REFERENCES

[1] Trail et al. (2011). *Nature*, **480**, 79-82.

[2] Graber et al. (2017). *Science*, **357**, 1271-1274.

[3] Ahmad et al. (2022). *Geochemical Perspectives Letters*, ***23***, 43-48.

[4] Chatterjee et al. (2025) *Earth and Planetary Science Letters*, **654**, 119227.