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Thermochemical models of early Earth evolution constrained by geochemical data

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Isotopic systems and trace elements are ideal proxies to constrain the production and recycling of crust (both mafic and felsic) over time. Within the Rubidium-Strontium (Rb-Sr) system, Rb-87 decays to Sr-87 and due to the preferential partitioning of Rb into the crust (relative to Sr) during partial melting, $^{87}Sr/^{86}Sr$ ratio of the crust is higher than that of the mantle over time. Trace elements such as Niobium (Nb) and Uranium (U) do not fractionate when mantle melts to form mafic magma (oceanic crust) but they do fractionate when oceanic crust is recycled and undergoes fluid-present melting, i.e., during the production of felsic magmas (continental crust) [Hofmann et al., 1986], thereby resulting in a lower Nb/U of the felsic crust compared to the mantle. In this work, we couple the evolution of the above-mentioned geochemical proxies with the melting processes in global convection models using the code StagYY [Tackley, 2008]. Results from these geodynamic models are then compared with geochemical data obtained from olivine-hosted melt inclusions extracted from komatiites of 3.27 Ga Weltevreden formation (Barberton Greenstone Belt, South Africa).

These models self-consistently generate oceanic and continental crust while considering both plutonic and volcanic magmatism [Jain et al., 2019] and incorporate a composite rheology for the upper mantle. Pressure-, temperature-, and composition-dependent water solubility maps calculated with Perple_X [Connolly, 2009] control the ingassing and outgassing of water between the mantle and surface [Jain et al., 2022]. These models show intense production and recycling of continental crust during the Hadean and the early Archean, which is in agreement with new geochemical data [Vezinet et al., in review] and previous geochemical box models [Rosas & Korenaga, 2018; Guo & Korenaga, 2020]. The thermal evolution is also consistent with cooling history of the Earth inferred from petrological observations [Herzberg et al., 2010].

As the estimates of total amount of water (at the surface and in the deep interior) vary from 5-15 ocean masses (OMs) based on magma ocean solidification models to 1.2-3.3 OMs based on petrological models [Nakagawa et al., 2018], different initial values of water are also tested, which show a strong influence on the amount of felsic melts produced. Ongoing work includes incorporating the effect of water on the density and viscosity of mantle minerals and adapting the lithospheric strength with surface topography.