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Thermochemical models of early Earth evolution constrained by isotopic systems

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Rubidium-Strontium (Rb-Sr) and Samarium-Neodymium (Sm-Nd) isotopic systems provide constraints on the crustal growth/recycling and mantle depletion that happened during Earth's evolution. Rb being more incompatible than Sr partitions into the melt with a greater proportion. As partial melting occurs, the mantle residue and the crust become depleted and enriched in Rb (relative to Sr) respectively. For the Sm-Nd system, Nd is more incompatible than Sm and the crust gets enriched in Nd (relative to Sm). By introducing the isotopic evolution of these systems and coupling them with melting processes in numerical models of mantle convection, we compare geodynamical modelling results with geochemical data.

Using the code StagYY[1], these models self-consistently generate oceanic and continental crust while considering both plutonic and volcanic magmatism[2]. They are initialised with realistic parameter values suited for early Earth conditions and incorporate a composite rheology (diffusion creep and dislocation creep proxy) for the upper mantle. The frictional strength of oceanic lithosphere is reduced to test the validity of surface-erosion controlled plate tectonics hypothesis[3]. Pressure-, temperature-, and composition-dependent water solubility maps calculated with Perple_X[4] are also utilised, which control the ingassing and outgassing of water between the mantle and surface[5].

While the presence of liquid water on Earth's surface is necessary for its habitability, it might have also led to the initiation of plate tectonics[6]. The estimates of total amount of water (at the surface and in the deep interior) vary from 5-15 ocean masses (OMs) during the early Earth to 1.2-3.3 OMs for the present-day[7]. As water lowers the melting temperatures of rocks and is also required for the generation of felsic magmas, we vary the initial amount of water in these models to study its exchange between the surface and the mantle.

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