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Early Earth plume-lid tectonics: A high-resolution 3D numerical modelling approach

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Early Earth had a higher amount of radiogenic elements as well as a higher amount of leftover primordial heat. Both contribute to the increased temperature in the Earth's interior and it is mainly this increased mantle potential temperature T_p that controls the dynamics of the crust and upper mantle and the predominant style of tectonics in the Archean Earth.

We conduct 3D petrological-magmatic-thermomechanical numerical modelling experiments of the crust and upper mantle under Archean conditions using a plume-lid tectonics model setup. For varying crustal compositions and a mantle potential temperature increase $\Delta T_p = 250\,\mathrm{K}$ (compared to present day conditions), a hot lower thermal boundary layer introduces spontaneously developing mantle plumes and after repeated melt removal, depleted mantle lithosphere is formed self-consistently. New crust is produced in the form of both volcanic and plutonic magmatism.

Models show large amounts of subcrustal decompression melting and production of new crust which in turn influences the dynamics. On short-term $(10 - 20\,\mathrm{Myr})$ rising diapirs and sinking basaltic crust lead to crustal overturn and to the formation of the typical Archean dome-and-keel pattern. On long-term a long ($\sim\ 80\,\mathrm{Myr}$) passive 'growth phase' with strong growth of crust and lithosphere is observed. Both crust and lithosphere thickness are regulated by thermochemical instabilities assisted by lower crustal eclogitisation and a subcrustal small-scale convection area. Delamination of lower crust and lithosphere is initiated by linear or cylindrical eclogite drips and occurs as one 'catastrophic' event within a $20\,\mathrm{Myr}$ 'removal phase'.