Geophysical Research Abstracts
Vol. 17, EGU2015-12566, 2015
EGU General Assembly 2015

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

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

We conduct 3D petrological-thermomechanical numerical modelling experiments of the crust and upper mantle under Early Earth conditions using a plume tectonics model setup. For varying crustal structures and an increased mantle potential temperature ΔT_p, a hot lower thermal boundary layer is used to introduce spontaneously developing mantle plumes. The model is able to self-sufficiently form depleted mantle lithosphere after repeated melt removal. New crust can be produced in the form of volcanics and/or plutonics. To simulate differentiation the newly formed crust can have a range in composition from basaltic to granitic depending on its source rock.

For a major increase in the mantle temperature, presumably corresponding to an Archean mantle ($\Delta T_p = 200 - 300\,K$ compared to present day conditions), models show large amounts of subcrustal decompression melting and consequently large amounts of volcanics, which in turn influence the dynamics. Mantle and crust are convecting separately. Dome-shaped felsic plutons can be observed in the crust. Between these domes elongated belts of downwelling basalt and sediments are formed. Both crust and lithosphere thickness are regulated by thermo-chemical instabilities assisted by lower crust eclogitization: linear or cylindrical drips originating at the crust or lithosphere bottom or delamination of lower crust or lithosphere.

Very similar examples of dome and belt structures are still preserved in Archean cratons. One example is the Kaapvaal craton is South Africa where the elongated shape of the Barberton Greenstone Belt, mainly built from mafic rocks and sediments, is surrounded by multiple plutons of both felsic and mafic composition. Another striking example is the Pilbara craton in northwest Australia which shows a very similar distribution of mafic greenstone belts and felsic domes.