EGU22-4850
https://doi.org/10.5194/egusphere-egu22-4850
EGU General Assembly 2022
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Using composite rheology models to explore the interplay between continent formation, surface erosion, and the evolution of plate tectonics on Earth

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The present-day Earth exhibits subduction-driven plate tectonics, which is a surface expression of processes happening in the deep interior. For the early Earth, following the magma ocean solidification stage, a variety of tectonic regimes have been proposed albeit without any consensus: heat-pipe tectonics, plutonic-squishy lid, stagnant lid. Furthermore, the rheological changes required to make the (supposedly gradual) transition to modern style plate tectonics on Earth remain hotly debated. Also, different estimates of mantle potential temperature (Herzberg et al., 2010; Aulbach and Arndt, 2019) for the Archean have been proposed.

Recently, it has been proposed that sediments accumulated at continental margins as a result of surface erosion processes could have acted as a lubricant to stabilise subduction and aid with the initiation of plate tectonics after the emergence of continents around 3 Ga (Sobolev and Brown, 2019). Before that time, the flux of sediments to the ocean was very limited. It was further suggested that subduction zones were already present at that time but were likely initiated only above hot mantle plumes. This tectonic regime of regional plume-induced retreating subduction zones was very different from the modern type of plate tectonics, but nevertheless might have been efficient in production of early continental crust and recycling of water and pre-existing crust into the deep mantle.

In this work, we test this hypothesis of surface-erosion controlled plate tectonics preceded by plume-induced retreating subduction tectonic regime in global convection models by introducing magmatic weakening of lithosphere above hot mantle plumes. We also adapt the effective friction coefficient in brittle deformation regime to mimic the lubricating effect of sediments. Furthermore, these models employ a more realistic upper mantle rheology and are capable of self-consistently generating oceanic and continental crust while considering both intrusive (plutonic) and eruptive (volcanic) magmatism (Jain et al., 2019). We also investigate the influence of lower mantle potential temperatures on crust production and compare our models with geological data.

When compared to models with just diffusion creep, the models with composite rheology (diffusion creep and dislocation creep proxy) result in more efficient mantle cooling, higher

production of continental crust, and higher recycling of basaltic-eclogitic crust through delamination and dripping processes. These models also show higher mobilities (Tackley, 2000), which have been previously shown for diffusion creep models only with low surface yield stress values (Lourenço et al., 2020). Preliminary results from models initialised with lower mantle potential temperatures show an affect on the initial growth of TTG rocks over time. However, no considerable differences in terms of total crust production or mantle cooling are observed.