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Self-consistent formation of continents on early Earth

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In our study we want to understand how Earth evolved with time and examine the initiation of plate tectonics and the possible formation of continents on Earth. Plate tectonics and continents seem to influence the likelihood of a planet to harbour life [1], and both are strongly influenced by the planetary interior (e.g. mantle temperature and rheology) and surface conditions (e.g. stabilizing effect of continents, atmospheric temperature), and may also depend on the biosphere. Earth is the only terrestrial planet (i.e. with a rocky mantle and iron core) in the solar system where long-term plate tectonics evolved. Knowing the factors that have a strong influence on the occurrence of plate tectonics allows for prognoses about plate tectonics on terrestrial exoplanets that have been detected in the past decade, and about the likelihood of these planets to harbour Earth-like life.

For this purpose, planetary interior and surface processes are coupled via ‘particles’ as computational tracers in the 3D code GAIA [2,3]. These particles are dispersed in the mantle and crust of the modelled planet and can track the relevant rock properties (e.g. density or water content) over time. During the thermal evolution of the planet, the particles are advected due to mantle convection and along melt paths towards the surface and help to gain information about the thermo-chemical system.

This way basaltic crust that is subducted into the silicate mantle is traced in our model. It is treated differently than mantle silicates when re-molten, such that granitic (felsic) crust is produced (similar to the evolution of continental crust on early Earth [4]), which is stored in the particle properties. We apply a pseudo-plastic rheology and use small friction coefficients (since an increased reference viscosity is used in our model). We obtain initiation of plate tectonics and self-consistent formation of pre-continents after a few Myr up to several Gyr – depending on the initial conditions and applied rheology. Furthermore, our first results indicate that continents can stabilize plate tectonics, analogous to the results obtained by [5].

The model will be further developed to treat hydration and dehydration of oceanic crust as well as subduction of carbonates to allow for a self-consistent 3D model of early Earth including a direct link between interior and atmosphere via both outgassing [6] and regassing.

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