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Simulation of Subduction and Crust Formation

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Abstract

The purpose of this study is to understand how Earth's surface might have evolved with time and to examine in a more general way the initiation of plate tectonics and the possible formation of continents on an Earth-like planet. Plate tectonics and continents seem to influence the likelihood of a planet to harbour life, 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), but may also depend on the biosphere.

1. Introduction

Earth is the only terrestrial planet (i.e. with a rocky mantle and iron core) in the solar system where long-term plate tectonics exists. Knowing the factors that have a strong influence on the initiation and maintenance of plate tectonics allows for prognoses about plate tectonics on terrestrial exoplanets and helps to understand why Mars, Mercury and Venus developed in a different way with respect to Earth.

2. Subduction model

In the applied 2D convection model CHIC, we model local subduction of oceanic plates into the upper mantle. We allow material flow at the side and bottom domain boundaries (depending on the convective behaviour). At the right boundary, an oceanic plate is assumed to flow into the investigated domain with a fixed velocity.

Rock alteration (in terms of water content, density, crustal enrichment) is traced over time using particles. Basaltic crust is treated differently than mantle silicates when re-molten to model continental crust formation (to model the first formation of continental crust on early Earth [1]).

In our model we assume that if basaltic material is further differentiated (by remelting of either delaminated crust or subducted crust), partial melting of the basaltic material leads to a decrease in density and conductivity and a felsic mineral-mixture. We assume that the molten material is immediately extracted to the surface.

Re-processing of basaltic material may be needed more than once to produce the stable granitic crust that forms the present-day continents (e.g. [3]). For the sake of simplicity, we assume in this study that basaltic crust has to be differentiated twice until a continental product similar to andesite is obtained.

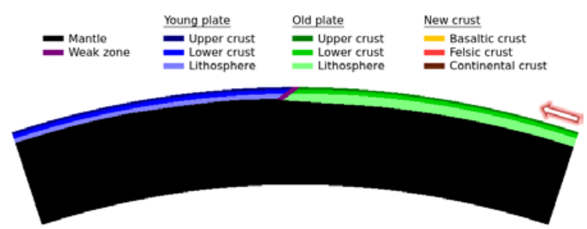

Figure 1: 2D spherical subduction simulation in the upper mantle. Particles trace the material classes for the mantle and weak zone, the initial young and old plate of the subduction setup at an ocean-ocean plate boundary, as well as new formed crust (basaltic, felsic or continental).

3. Particle flow

Particles are predefined randomly over the investigated area and flow during the simulation along the convection stream lines. Particles that flow out of the investigated domain will be reset at the right top boundary, where an old oceanic plate flows into the area. All particles contain information on density, water content, melt depletion, conductivity, and others. In addition, a so-called crustal recycling value is defined (visualized in Fig. 1), where the lowest value stands for a primordial mantle and larger values for basaltic crust or, if newly formed, felsic or continental crust.

4. Evolution of a subduction zone

We show the initiation of subduction for a reference simulation in Fig. 2. The fixed incoming-plate-velocity is 5 cm/yr.

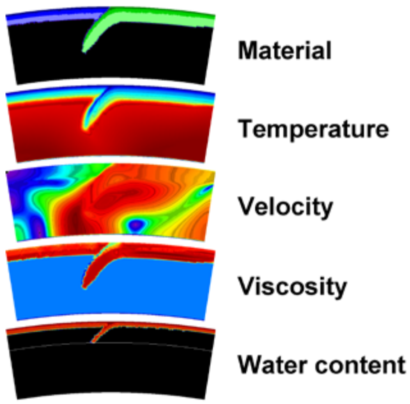

Figure 2: Subduction for a reference case.

Hydrated, subducted crust releases water into the upper mantle when minerals become instable (e.g. by destabilization of serpentinites, [2]). We investigate the release of water in the spherical domain (Fig. 2). In this reference simulation, for simplicity we assume that hydrated minerals become unstable at a pre-defined depth of 200 km (white line in Fig. 2).

Since water reduces the melting temperature of rocks, volcanism close to the subduction zone is expected to appear. We simulate this process in our subduction zone model. We will furthermore compare the different possible evolutions of a subduction zone depending on mechanical parameters (e.g. initial subduction angle), material properties (e.g. initial water content) and rheological properties.

Acknowledgements

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References

[1] Arndt, N.T. and Nisbet, E.G.: Processes on the Young Earth and the Habitats of Early Life, Annu. Rev. Earth Planet. Sci., Vol. 40, pp. 521-549, 2012.

[2] Höning, D., Hansen-Goos, H., Airo, A. and Spohn, T.: Biotic vs. abiotic Earth: A model for mantle hydration and continental coverage. PSS, in press.

[3] Levander, A., Lenardic, A. and Karlstrom, K.: Structure of the continental lithosphere. Cambridge University Press, 2006.