Distinct styles of subduction and implications for Earth's evolution

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Using a 3-D numerical model of a single, fully dynamic subducting plate, we describe a total of 5 different styles of subduction that can possibly occur. Each distinct style is distinguished by its upper mantle slab morphology resulting from the sinking kinematics. We provide movies to illustrate the different styles and their progressive time-evolution. In each regime, subduction is accommodated by a combination of plate advance and slab rollback, with associated motions of forward plate velocity and trench retreat, respectively. Although only 2 of these styles presently operate on Earth, the possibility exists that other modes may have been the predominant mode of recycling the lithosphere in the past. Subduction dynamics within the upper mantle are responsible for producing the particular type of subduction mode and resultant partitioning of plate motions. In particular, the preferred subduction mode depends upon two essential controlling factors: 1) the buoyancy of the downgoing plate and 2) the strength of plate in resisting bending at the hinge.

Based on these models, we propose that the lithosphere is the primary factor in describing key elements of the plate tectonics system over time, and not the convecting mantle. Thus, secular changes in Earth's tectonic behavior are driven by changes in the nature of the lithosphere. The progression from strong plates in the past to weak plates (present day) has had the most profound influence on controlling transitions between geologic Eons. We propose that during the Archean, very strong plates favored pure trench retreat, which allowed cratons to stabilize as they remained nearly stationary. Throughout the Proterozoic, the mode of subduction switched to one entirely driven by plate advance, which allowed cratons to aggregate into continents. Interestingly, both the pure retreat and pure advance modes result in entirely flat-lying slabs atop the lower mantle, which has implications for geochemical stratification. Finally, the modern-day type of plate tectonics emerged (i.e. the Wilson Cycle) allowing for both plate advance and trench retreat to occur simultaneously.

Thermal structure of Super-Earths and implications for their surface expression

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While in our Solar System plate tectonics is a unique feature, appearing only on Earth, another class of recently discovered extrasolar planets might show a similar behaviour.

As the masses of the Super-Earths range between 1 to 10 Earth masses [1], we also assume increased pressures, leading to higher viscosities at greater depth, and rates of internal heating. Stein *et al*. [2] have shown that such changes in the parameters controlling mantle convection strongly affect the surface expression. Earth-like mobilisation results for convection with a strong pressure-dependent viscosity and stagnant-lid convection for systems that are strongly internally heated (cf. Fig. 1 below).

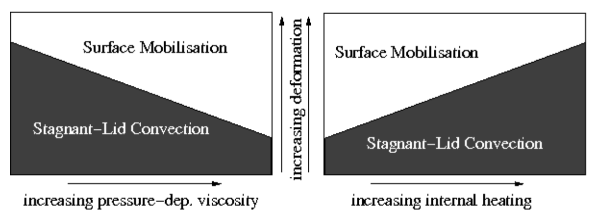

Figure 1: Schematic regime diagramm spanned by suface deformation and the pressure-dependent viscosity / internal heating rate.

Our aim is to investigate the interplay of a high pressure dependence of the viscosity and internal heating rate on the convective flow and analyse the resulting surface conditions. We utilize different model approaches for a benchmark study which consider thermally driven convection of an incompressible fluid with infinite Prandtl number and variable viscosity in a 2D Cartesian geometry (cf. [2] and [3]).

We pay special attention to internal heating by considering convection models with purely internal heating and ones with mixed-mode heating. Our results reveal a great difference between these two modes of heating which has large implications for the thermal history of planets and consequently their surface expression. Purely internally heated systems are characterised by a cooler interior so that it is more difficult to sustain a stagnant lid in these systems.

[1] Valencia *et al*. (2007), *Astrophys. J.* **656**, 545-551.
[2] Stein at al. (2004) *Earth Planet. Sci. Lett.* **142**, 225-255.
[3] Lowman *et al*. (2003), *Geophys. J. Int.* **152**, 455-467