Geophysical Research Abstracts
Vol. 14, EGU2012-6579, 2012
EGU General Assembly 2012

Mantle Dynamics in Super-Earths: Post-Perovskite Rheology and Self-Regulation of Viscosity

P. Tackley (1), M. Ammann (2), J. P. Brodholt (2), D. P. Dobson (2), and D. Valencia (3)

(1) ETH Zurich, Institute of Geophysics, Earth Sciences, Zurich, Switzerland (ptackley@erdw.ethz.ch), (2) Department of Earth Sciences, University College London, Glower Street, London WC1E6BT, UK, (3) Department of Earth, Atmospheric and Planetary Sciences, Massachusetts Institute of Technology, Cambridge MA 02139, USA

The discovery of extra-solar "super-Earth" planets with sizes up to twice that of Earth has prompted interest in their possible lithosphere and mantle dynamics and evolution. Simple scalings [e.g. van Heck and Tackley, 2011 EPSL] suggest that super-Earths are more likely than an equivalent Earth-sized planet to be undergoing plate tectonics. Generally, viscosity and thermal conductivity increase with pressure while thermal expansivity decreases, resulting in lower convective vigor in the deep mantle, which, if extralopated to the largest super-Earths might, according to conventional thinking, result in no convection in their deep mantles due to the very low effective Rayleigh number. Here we evaluate this. First, as the mantle of a super-Earth is made mostly of post-perovskite we here extend the density functional theory (DFT) calculations of post-perovskite activation enthalpy of to a pressure of 1 TPa. The activation volume for diffusion creep becomes very low at very high pressure, but nevertheless for the largest super-Earths the viscosity along an adiabat may be of order 1e30 Pa s in the deep mantle, which would be too high for convection. Second, we use these DFT-calculated values in numerical simulations of mantle convection and lithosphere dynamics of planets with up to ten Earth masses. The models assume a compressible mantle including depth-dependence of material properties and plastic yielding induced plate-like lithospheric behavior. Results confirm the likelihood of plate tectonics and show a novel self-regulation of deep mantle temperature. The deep mantle is not adiabatic; instead internal heating raises the temperature until the viscosity is low enough to facilitate convective loss of the radiogenic heat, which results in a super-adiabatic temperature profile and a viscosity increase with depth of no more than $\sim$3 orders of magnitude, regardless of the viscosity increase that is calculated for an adiabat. Convection in large super-Earths is characterised by large upwellings (even with zero core heat flow) and small, time-dependent downwellings. In the context of planetary evolution, if, as is likely, a super-Earth was extremely hot/molten after its formation, it is thus likely that even after billions of years its deep interior is still extremely hot and possibly substantially molten with a “super basal magma ocean” – a larger version of the proposal of (Labrosse et al., 2007, Nature), although this depends on presently unknown melt-solid density contrast and solidus.