Shell tectonics - the pre-cursor of mantle convection

T.V. Gerya (1), J.R. Lin (2,1), P.J. Tackley (1), A.D. Yuen (3)

(1) Geophysical Fluid Dynamics Group, Institute of Geophysics, Department of Geosciences, ETH-Zurich, Switzerland (taras.gerya@erdw.ethz.ch)

(1) Institute of Oceanography, National Taiwan University, Taiwan(linj@erdw.ethz.ch)

(3) University of Minnesota Supercomputing Institute and Department of Geology and Geophysics, University of Minnesota, Minneapolis, USA

The early stages of terrestrial planetary accretion and differentiation are largely enigmatic and require extensive realistic numerical modelling efforts especially in 2D and 3D geometries. One of the hypothesised processes is destabilization of the cold undifferentiated core that builds up during "cold" accretion, by a surrounding liquid iron layer that builds up through iron segregation in a magma ocean, or by the accumulation of 'blobs' sinking from local magma ponds. This destabilization breaks the spherical symmetry of the planet and, therefore, can not be addressed properly in existing 1D models of accretion. We have developed a 2D thermomechanical numerical model of primordial core destabilization including self-gravity, visco-elasto-plastic rheology of materials, a free planetary surface and feedback from shear heating. By varying the size of the planet and metal/silicate ratio we tested various cases corresponding to early stages of terrestrial planet growth. Primordial core destabilisation causes rapid planetary scale reshaping that we call "shell tectonics" as the units involved in rearrangements are planetary shells. The gravitational redistribution process lasts for less then 1 Myr (depending on the effective rheology), being fully dominated by shear heating and thermal advection. Internal gravitational redistribution processes result in planetary shape-changing revealing significant transient aspherical deviations from the original perfectly spherical geometry. During this stage the primordial core can become exposed at the planetary surface making possible its reworking during ongoing accretion processes. Most of the enormous amount of heat is produced during this very short time span associated with the core-formation and is then chaotically distributed throughout both the core and the mantle. Gravitational energy dissipation along the localized deformation zones dramatically increases rates of rearrangement and can potentially result in thermal runaway processes and sudden primordial core fragmentation. The magnitude of thermal perturbations can reach several thousand degrees, which cataclysmically raises the effective Rayleigh number for the planetary mantle to a very large number favouring onset of powerful mantle convection and possibly results in the formation of a magma ocean with the molten mantle rocks rising from the deep planetary interior. In future work, such instabilities will be considered in the context of ongoing planetary accretion in 2D or 3D rather than starting from the end state of a 1D accretion model.