

Early evolution and dynamics of Earth from a molten initial stage

Diogo Louro Lourenço and Paul J Tackley

ETH Zürich, Institute of Geophysics, Department of Earth Sciences, Zürich, Switzerland (diogo.lourenco@erdw.ethz.ch)

It is now well established that most of the terrestrial planets underwent a magma ocean stage during their accretion. On Earth, it is probable that at the end of accretion, giant impacts like the hypothesised Moon-forming impact, together with other sources of heat, melted a substantial part of the mantle. The thermal and chemical evolution of the resulting magma ocean most certainly had dramatic consequences on the history of the planet.

Considerable research has been done on magma oceans using simple 1-D models (e.g.: Abe, PEPI 1997; Solomatov, *Treat. Geophys.* 2007; Elkins-Tanton EPSL 2008). However, some aspects of the dynamics may not be adequately addressed in 1-D and require the use of 2-D or 3-D models. Moreover, new developments in mineral physics that indicate that melt can be denser than solid at high pressures (e.g.: de Koker et al., EPSL 2013) can have very important impacts on the classical views of the solidification of magma oceans (Labrosse et al., *Nature* 2007).

The goal of our study is to understand and characterize the influence of melting on the long-term thermo-chemical evolution of rocky planet interiors, starting from an initial molten state (magma ocean). Our approach is to model viscous creep of the solid mantle, while parameterizing processes that involve melt as previously done in 1-D models, including melt-solid separation at all melt fractions, the use of an effective diffusivity to parameterize turbulent mixing, coupling to a parameterized core heat balance and a radiative surface boundary condition. These enhancements have been made to the numerical code StagYY (Tackley, PEPI 2008).

We present results for the evolution of an Earth-like planet from a molten initial state to present day, while testing the effect of uncertainties in parameters such as melt-solid density differences, surface heat loss and efficiency of turbulent mixing. Our results show rapid cooling and crystallization until the rheological transition then much slower crystallization, large-scale overturn well before full solidification, the formation and subduction of an early crust while a partially-molten upper mantle is still present, transitioning to mostly-solid-state long-term mantle convection and plate tectonics or an episodic-lid regime.