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Effect of initial conditions on the evolution of Martian global thermochemical convection

Kar Wai Cheng, Antoine Rozel, Maxim Ballmer, and Paul Tackley
ETH Zürich, Institute of Geophysics, Department of Earth Science, Zürich, Switzerland (karwai.cheng@erdw.ethz.ch)

The Martian crustal dichotomy and Tharsis volcanic province are believed to have an ancient (Carr and Head, EPSL 2010; etc.) and linked origin (Nimmo and Tanaka, Annu. Rev. Earth Planet. Sci. 2005). While numerous efforts have been made to explain these first order features (e.g. Zhong and Zuber, EPSL 2001; Keller and Tackley, Icarus 2009), hybrid models that incorporate both exogenic and endogenic mechanisms (Reese et al., Icarus 2010) are best able to explain observational data like crustal ages. Golabek et al. (Icarus 2011) demonstrated that a giant impact occurring within the first 10 Myr after planetary accretion can lead to a hemispherical magma ocean and thus a hemispherically asymmetrical primordial crust. The sinking of impactor core subsequently causes a thermal anomaly that, together with the primordial crust distribution, serves as the initial state of the long term evolution of mantle convection.

On the other hand, irrespective of giant impacts, Elkins-Tanton et al. (Meteorit. Planet. Sci. 2003) suggested that fractional crystallisation of a Martian magma ocean followed by overturn of the resulting unstable compositional stratification would cause stable mantle compositional stratification, which might delay or suppress thermal convection and influence the distribution of heat producing elements. Ballmer et al. (G3 2017) showed that settling to such a stable configuration could occur within the first 10s of Myr after magma ocean crystallization, comparable to the timescale of the previously mentioned core formation process, and therefore should not be neglected.

We compare the effects of different initial conditions on the long term evolution of Mars' mantle using the thermochemical convection code StagYY (Tackley, PEPI 2008). Three classes of initial conditions are investigated: either a homogeneous pyrolitic mantle, a primordial basal layer with thickness and density consistent with a Martian magma ocean overturn, or a giant impact scenario that involves imposed thermal anomaly and primordial crust distribution. The effect of intrusive magmatism is also studied. Resultant topography, crustal thickness distribution and the presence or absence of a single upwelling are used to compare to present day observations on Mars.