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The early evolution of Mars' mantle and crust

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The Mars crustal density and thickness have been recently re-evaluated using petrological constraints from remote sensing, in-situ data, and Martian samples (SNC meteorites) [1]. This work indicates that the present-day Martian crust is denser and thicker than previously proposed. As a consequence, the average crustal thickness would be commensurable with the depth of the basalt / eclogite transition, re-opening the question of crustal recycling on Early Mars and more generally throughout all its history. Although a thick crust is easily produced in many numerical models of the thermal evolution of Mars, such models are often discarded for satisfying the condition of early segregation of geochemical reservoirs [2].

We have therefore investigated the conditions under which a thick ancient crust with an eclogitic root could survive through the history of Mars using numerical modelling. The efficiency of delamination processes depends on several physical parameters: the density/compositional profile, the viscous rheology, and the thermal profile. Delamination may occur if the combination of these parameters induces the presence of gravitationally unstable layers and favors a rheological decoupling. Some of these parameters may be well determined as a function of the presumed composition of the Martian mantle. However, other parameters, such as the rheology and viscosity profiles, remain poorly constrained. In order to study the conditions and the time scales for the occurrence of crustal delamination on Mars, we investigated the influence of these parameters for a plausible range of values corresponding to the Martian mantle. For each case we follow the dynamic evolution over geological times of a three-layer system (i.e., crust-mantle with a distinction between low pressure, buoyant basaltic crust and higher pressure, denser eclogitic material). We systematically varied the five governing parameters within plausible ranges: (1) the initial Martian crust thickness, (2) the basalt-eclogite transition depth, (3) the density difference between the mantle and the basaltic crust, (4) the density difference between the eclogitic and the basaltic crust, (5) the viscous rheology. These experiments allow determining the average Martian crustal thickness and its variations at early and late evolutionary stages. The implications of our results on Mars' early and long-term thermo-chemical evolution will be discussed.

[1] Baratoux, D, Monnereau, M., Wieczorek, M.A., Michaut, C., Garcia, R., Samuel, H., Toplis, M.J. A reappraisal of the density and thickness of the Martian crust, AGU, 2013, San Francisco, USA.
[2] Morschhauser, A., Grott, M., Breuer, D. Crustal recycling, mantle dehydration, and the thermal evolution of Mars. Icarus, 212 (2011) 541–558.