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Differentiation of the Martian highlands : insights from a geodynamic inversion based on crustal thickness constraints.

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The Martian crust is mainly made up of mafic rocks. Nevertheless, orbital, in-situ and meteorite observations have revealed the presence of felsic rocks (Payré et al, 2022) in the southern hemisphere where the crust is thicker. These rocks likely formed by differentiation of a mafic protolith. On Earth, this process occurs at plate boundaries and is linked to active plate tectonics. But on Mars, we have no evidence of active or ancient plate tectonics.

On one-plate planets, there exists a positive feedback mechanism on crustal growth: the crust being enriched in heat-producing elements, the lithosphere is thinner where the crust is thicker, which implies a larger melt fraction at depth and therefore a larger crust extraction rate and a larger crustal thickening where the crust is thicker. We proposed that this mechanism could form the Martian dichotomy (Bonnet Gibet et al, 2022). This mechanism implies that thicker crusts are also marked by higher temperatures. Here we investigate whether crustal temperatures in regions of thick crust may be maintained above the basalt solidus temperature during crust construction, which would allow for the formation of partially molten zones and hence differentiated rocks by extraction of these evolved melts. In this scenario, felsic rock formation would be concomitant to crustal construction and dichotomy formation on Mars.

We use a bi-hemispheric parameterized thermal evolution model with crustal extraction. We formulate a Bayesian inverse problem in order to estimate the thermal evolution scenarios that are compatible with constraints derived from the InSight NASA mission as well as topography-gravity surveys. The solution is represented by a probability distribution representing the distribution of the model parameters and evolution scenarios. This distribution, sampled with a Markov chain Monte Carlo algorithm, shows that a non-negligible range of scenarios allows for partial melting at the base of the Southern Highlands during the first giga year of Mars' evolution. On the contrary, partial melting of the base of the northern crust is insignificant. Models that fit InSight constraints and allow for differentiation of a fraction of the Southern crust point to a relatively low reference viscosity (~10^{20} Pa.s).