Numerical modelling of the thermo-chemical evolution of the Martian mantle

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Many recent publications have addressed the question of how the crustal dichotomy on Mars could be explained in terms of the thermal and chemical evolution. Most of them agreed, that an early development of a degree-1 convective planform could lead to such a crustal structure. In this thesis, numerical modelling in 2D-cylindrical geometry is used to test several options which possibly could generate a degree-1 convection under a stagnant lid. These options are strongly depth- and temperature-dependent viscosity profiles including viscosity layering, phase transitions and small core settings leading to a perovskite layer around the CMB. Additional to these options, melting, differentiation and self-consistent crust formation were implemented into models of Martian mantle convection for the first time.

The results showed that strongly depth- and temperature-dependent viscosity combined with viscosity layering is a very reliable mechanism to reduce convective degree under a stagnant lid, which is effective over a rather wide range of viscosity parameters. The transition to the next lower degree of convection, going from third degree to degree-1 patterns, was described in full detail. This mechanism strongly depends on the Rayleigh number. Therefore, very small variations of *Ra* over less then one order of magnitude were applied. The final transition to degree-1 convection, however, was in all runs linked to a change to sluggish-lid behaviour. A degree-1 convection under a fully rigid lid could not be obtained.

Against expectations, a smaller core size and the presence of a perovskite layer did not have remarkable positive influence on the reduction of convective degree. The conventional model with a core size of half the planet’s radius (1700 km) generally even produced transitions to degree-1 convection occurring earlier than in small core models with a core size of 1400 km.

The influence of melting and crust formation was found to be of great importance to the thermal evolution of these models. The heat flux transported by melting and eruption significantly reduces mean temperature and surface heat flux. Above plumes, where the crust is thick and the mantle lithosphere gets thinned by thermal erosion, the stagnant lid is weakened and sluggish behaviour sets in. This mechanism could be stopped using an even higher T-dependency of viscosity. This, however, caused numerical problems and therefore the amount of T-dependence was limited to a variation of 10^8 between non-dimensional temperature $T = 0$ and $T = 1$.