Consequences of a hemispheric dichotomy in crustal structure on the thermal evolution of Mars

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In the absence of direct heat flux measurement, estimates of lithosphere elastic thicknesses provide fundamental constraints on Mars thermal evolution. At the present-day, the lithosphere elastic thickness seems to be very different below the North (~300km) and the South (~160 km). As Mars shows a striking dichotomy in between the Northern hemisphere, lower in elevation, and the higher Southern hemisphere, we wonder if this difference also originates from the dichotomy.

Recent studies have indeed suggested that the North/South dichotomy in elevation could be due to the existence of a buried felsic component in the South. This might also imply an enrichment of the Southern hemisphere in incompatible radioactive elements. Moreover, the Northern lava flows are more consolidated than the fine-particulate materials constituting the Southern surface, suggesting a lower thermal conductivity in the upper Southern crust. We investigate if the observed difference in lithosphere elastic thicknesses could be explained by North/South differences in crustal composition and thermal properties or if it could simply result from a difference in crustal thickness.

First, in order to have a good description of the mantle heat flux and stagnant lid growth in the specific conditions of Mars - convection with internal and basal heating of a fluid with a strongly temperature-dependent viscosity in a spherical shell geometry - we derive scaling laws by running 2D and 3D convection models. Then, we compute Mars thermal evolution and lithosphere growth using our scaling laws in a parameterized convection model with a stagnant lid accounting for two hemispheres with different types of crust.

Implementing our parameterized model in Monte-Carlo simulations, we constrain the North/South crustal properties compatible with observations. Our best fits are obtained for a Southern crust much thicker than the Northern one – respectively between 70 to 97 km and 30 to 60 km – and crustal radioelement enrichment factors ranging from 10.5 to 12.5 for the North and 10.5 to 15.7 for the South. A large North/South difference in thermal structure is found, of ~200 K over ~300 km, and a low present-day surface heat flux in the North of 16 to 20 mW/m^2.