A new mechanism for the formation of the Martian dichotomy

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Résumé

The Martian dichotomy is the most conspicuous feature of the surface of the planet. The difference in elevation between the Northern and Southern hemispheres of Mars likely originates from a difference in crustal thickness. Inversion of topography and gravity data constrained by seismic data from the NASA InSight mission suggests that the southern crust is on average thicker by 18 to 28 km than the northern one if one assumes a uniform crustal density of 2900 kg/m3.
Several explanations have been proposed for the origin of this crustal dichotomy, involving external processes, such as a large impact, or internal ones, such as a degree-one mantle convction mode. Here we show that a positive feedback between crustal growth and partial melting in the mantle could have created this dichotomy. Indeed, because the crust is enriched in heat-producing elements (HPE), the lithosphere of a one-plate planet is thinner where the crust is thicker, inducing a lower pressure at the base of the lithosphere. Because of the pressure-dependence of the mantle solidus, partial melting is more important below a thinner lithosphere, causing a larger rate of melt extraction and crustal growth where the crust is thicker.

To model this effect, we use a parametric bi-hemispherical thermal evolution model where a well-mixed convective mantle is topped by two types of lithospheres (North and South) characterized by two potentially different thermal structures. In order to study the growth of a hemispherical perturbation, we impose a small initial difference in lithosphere or crust thickness between the North and South. We then follow the thermal evolution, mantle melting, crustal growth and crustal enrichment in HPE in both hemispheres over 4.5 Gyr.
Our results show that this positive feedback mechanism can indeed create a significant crustal dichotomy. The range of North-South crustal thickness differences that we obtain by varying the different model parameters largely encompasses that predicted by topogravimetric inversions.

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