EFFECT OF A BURIED FELSIC COMPONENT IN THE SOUTHERN CRUST OF MARS ON LITHOSPHERE GROWTH

Mélanie Thiriet[1], Chloé Michaut[1] and Doris Breuer[2]. [1]Institut de Physique du Globe de Paris, France (thiriet@ipgp.fr, michaut@ipgp.fr). [2]German Aerospace Center (DLR), Berlin; Germany (doris.breuer@dlr.de)

Introduction

Mars surface dichotomy is the most striking feature of the planet. The Northern hemisphere is covered by extensive lava plains and makes up about 42% of the planet. It is lower in altitude than the South. The South is made of highlands with sharper reliefs and appears to be more craterized and older than the North. The origin of this dichotomy remains still debated and various formation mechanisms have been proposed such as a giant impact event, a degree 1 of mantle convection or a mantle overturn [1]. There is, however, a quite good consensus that it is an old feature which probably dates back from the early stages of the planet, i.e. between 4.5 and 3.8 Gy.

A difference in crustal density between the two hemispheres could explain this bimodal distribution of altitudes [2]. In particular, several recent studies have revealed the existence of felsic rocks in the crust of Mars [3,4], some being very similar to the rocks characterizing the terrestrial continental crust [5]. These rocks are all located in the Southern hemisphere and might be evidences of a buried felsic component in the Southern crust [2,5]. A difference in composition in between the Northern and Southern crust would also imply a difference in radioactive element content. In particular, a large buried component of evolved composition of continental type might imply a non-negligible enrichment in radioelements in the South relative to the North. Furthermore, a recent study has suggested that the thermal properties of the surface rocks on Mars depend on their age. Relatively old surfaces in the South are consistent with an explosive volcanism origin with fine-particulate materials, while younger surfaces in the North reflect effusive lava flows with more consolidated materials [6]. Consequently the surface thermal conductivity in the North could be significantly higher than that in the South.

Two distinct crusts in terms of conductivity, density and radioactivity would imply different surface heat flux and lithospheric temperature profiles. Such differences might leave a characteristic signature in the geophysical signals that could be recorded both by the SEIS and HP3 instruments on board of the INSIGHT mission that is supposed to land close to the dichotomy boundary. They would also imply different growth rates for the lithosphere in the North and South. Here we investigate if differences in crustal properties and composition in between the two hemispheres could lead to differences in thickness in between the North and the South and in particular explain the large lithospheric thickness observed below the North polar cap [8] compared to the one in the South [9].

Methods

We adopt a parameterized convection model similar to that implemented by Grott and Breuer [2008] [7]. The rate of lithospheric growth is determined by an energy balance at the lithospheric base and therefore depends on the difference between the heat transferred from the mantle into the lithospheric base and the amount of heat conducted away towards the surface which itself depends on the radioactive heat generation and conductivity in the crust. Heat transport through the lithosphere was determined by solving the steady-state heat conduction equation considering a three layer model with a highly fractured regolith, a crust and a lithospheric mantle. At the beginning of our simulations the crusts are considered to be similar in both hemispheres, characterized by a relatively enriched composition. We start with an initial mantle temperature between 1700 and 1900 K and a steady-state temperature profile in the crust. The formation of the dichotomy is modeled through an instantaneous mixing of the Northern part of the crust into the mantle and the formation of a new crust of higher density and smaller thickness in the North. This new crust is assumed to be more mafic and dense than the crust in the South, we thus use the isostatic Pratt model to calculate its thickness; it is depleted in radioelements and has a higher conductivity than that in the South. The new stagnant lid thickness in the North is set equal to the crustal thickness, to mimic the effect of a large impact. We vary the age of the dichotomy between 4.5 and 3.8 Gy. We do not yet account for melting and crust formation over time. The parameters used are summarized in Table 1.

		Pratt	Airy
Northern crust	Thickness (km)	35	35
	Enrichment factor	5	5
	Conductivity (W m^{-1} K^{-1})	3	3
Southern crust	Thickness (km)	40	60.7
	Enrichment factor	25	5
	Conductivity (W m^{-1} K^{-1})	2.5	3

Table 1 : Parameters used in this study. The enrichment factor is relative to the mantle.

Results

At the beginning of our simulations the evolution of the two lithospheres is similar as the crusts have the same properties. After the dichotomy formation, the growth rate of the Northern stagnant lid largely increases due to the combining effects of the depletion in radiogenic nuclides and the larger conductivity of the new Northern crust. After this episode of fast growth rate in the North, the stagnant lid growth rate is the same in both the North and the South (the thickness trends are parallel on Fig. 1b) with the Northern lithosphere being thicker and more insulating (Fig. 1b). At the end of our simulations, the Northern lithosphere is thicker by several tens of kilometers than the Southern one.

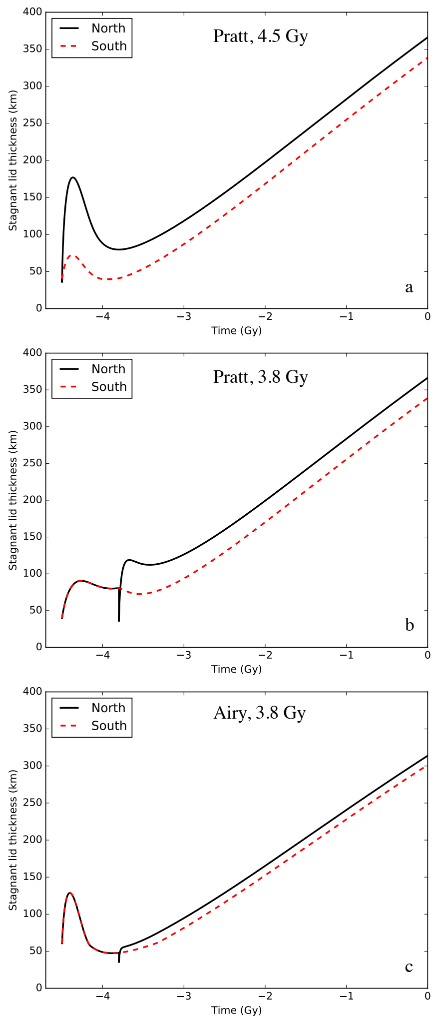

Fig. 1: Stagnant lid thickness evolution (in black for the North, in red for the South) (a) considering a Pratt isostatic compensation and a dichotomy formation at 4.5 Gy, (b) at 3.8 Gy, (c) at 3.8 Gy considering an Airy isostatic model.

The age of the dichotomy has an influence on the earliest stages of the lithosphere evolution only: the earlier the impact, the more important the consecutive peak in the northern lithosphere thickening. The age of the dichotomy does not affect the final difference in thickness between the North and South because of the thickness feedback on the growth rate (Fig. 1a). However, considering melting and crust formation over time might change this result.

Conclusion

Using a parameterized convection model with a Northern crust depleted in radiogenic elements and more conductive than the southern one, we show that a present-day difference in stagnant lid thickness of several tens of kilometers can easily be explained in between the Northern and Southern hemispheres of Mars, using plausible radiogenic heat generation and conductivity values. Compared to a model where the crustal composition is the same in both hemispheres and the difference in elevation results from a large crustal root in the South, i.e. an Airy type of isostatic compensation, the difference in stagnant lid thickness between both hemispheres is larger by a factor of 1.5 to 2.5, whereas the absolute value of the stagnant lid thickness is thicker in both hemispheres by several tens of kilometers (Fig. 1c). This result may partly explain the very large elastic thickness found under the North polar cap [8] compared to the one estimated in the South [9]. A future work will consist in accounting for a more realistic secondary crust formation process by modeling partial melting of the mantle.

References

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