ON THE THERMO-MECHANICAL STRUCTURE OF THE MARTIAN LITHOSPHERE: THE ROLE OF THE CRUST.

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Introduction: An adequate knowledge of thermal and rheological properties of crust and mantle is fundamental for deciphering and understanding the thermal state and interior evolution of a planetary body. Previously, indirect methods have been used to calculate heat flows for Mars. A commonly used indirect method is based on the relation between the thermal state of lithospheric rocks and their mechanical strength, usually related through the effective elastic thickness of the lithosphere or from the depth to the brittle–ductile transition beneath large thrust faults. The so-obtained heat flows are valid for the time when the lithosphere was loaded or faulted, and therefore when deduced from regions deformed in different ages provides information on the thermal evolution of Mars [1].

Thus, heat flow estimates based on lithosphere strength indicators are strongly dependent on the assumed composition, the choice of predominant deformation mechanisms, and other thermal and mechanical parameters. Such an integrated analysis has been performed recently to constrain the thermal history of Mars [1, 2]. However, recent works point to an ancient Martian crust that could contain a substantial amount of felsic rocks [3-7]. This issue motivates us to explore to what extent the composition of the crust could affect the thermal and mechanical structure of the lithosphere of Mars, and hence on the heat flow estimates based on lithosphere strength indicators.

Here we conduct an in-depth study of the thermal structure and rheology of its lithosphere, focusing on the effects of the composition of the crust. To make this, we use suitable parameters (appropriated for, respectively, mafic and felsic materials), in order to evaluate the case of an end-member felsic crust, and its influence on the thermal and mechanical properties of the crust and lithosphere.

Thermal state of the lithosphere: Fig. 1 shows the temperature and heat flow at the Moho as a function of the surface heat flow for selected crustal thicknesses and vice versa. As expected, the temperature at the base of the crust increases with increasing both surface heat flow (Fig. 1a) and crustal thickness (Fig. 1c) (this trend is more pronounced for the first), with higher values associated with a basaltic crust reflecting the predominant effect of the thermal conductivity of the crust against the crustal density; also the amplitude of temperature variations increases with both surface heat flow and crustal thickness.

On the other hand, mantle heat flow values seem to be similar for both cases (slightly lower for a basaltic composition of the crust), being mainly controlled by the surface heat flow (Fig. 1b) and to a lesser extent by the crustal thickness, showing an inverse correlation (Fig. 1d). The mantle heat flow decreases with increasing crustal thickness, and thus with a higher contribution of the crust to the surface heat flow. Under the same conditions, the crustal contribution to the surface heat flow increases with the crustal density, decreasing thereby the mantle heat flow. Consequently, mantle heat flow results for a felsic composition of the crust are slightly higher over the whole range of surface heat flows and crustal thicknesses as a consequence of its lower crustal density.

Thus, the composition of the crust (in terms of crustal density and thermal conductivity) has a strong control on the thermal profiles, resulting in a hotter (colder) geotherm for a basaltic (felsic) crust, whereas variations of the mantle heat flow are mainly dependent on variations of the surface heat flow and crustal thickness.

Mechanical behavior of the lithosphere: Fig. 2 shows strength envelopes for both basaltic and felsic compositions of the crust, in order to analyze in more detail the strength distribution within the lithosphere. One important difference between the results for a basaltic and felsic composition of the crust is the effect of the colder geotherm in the latter (see above) that is naturally incorporated in their strength envelopes, resulting in a mechanically weaker crust in comparison with a basaltic crust as a consequence of its lower crustal density and creep parameters, but in a stronger lithospheric mantle for the same surface heat flow, and therefore in a thicker lithosphere; even may result in a stronger lithosphere as a whole in terms of total strength and effective elastic thickness as a consequence of a higher mantle contribution to the strength of the lithosphere (see Fig. 2).

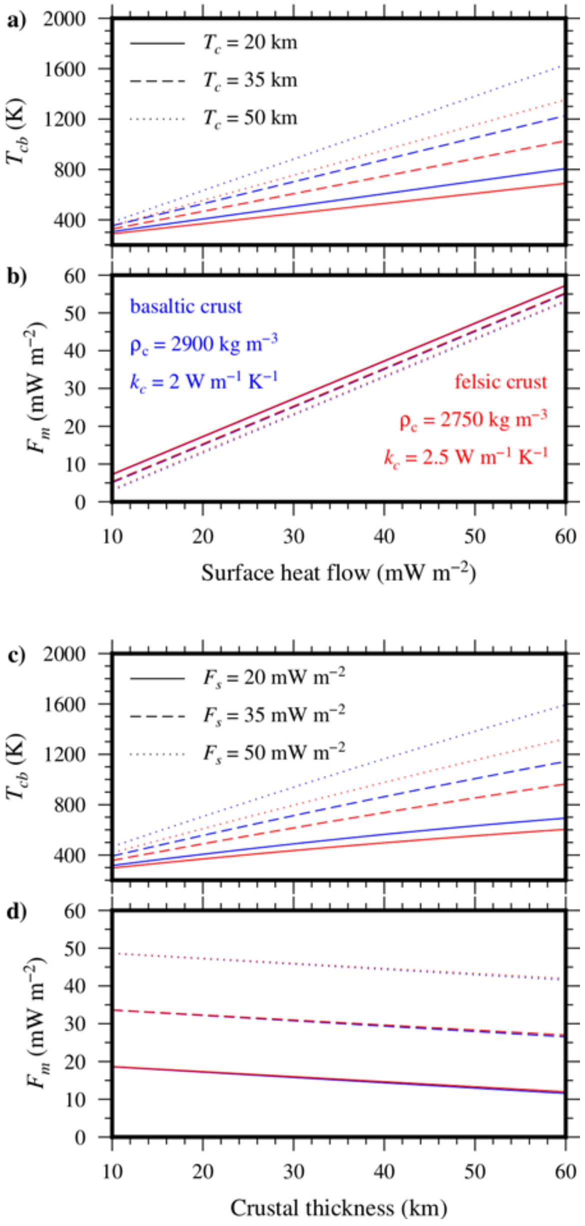

Figure 1. (a) Temperature at the base of the crust, T_{cb}, and (b) mantle heat flow, F_m, as a function of surface heat flow for different crustal thicknesses (T_c = 20, 35 and 50 km). (c) Temperature at the base of the crust and (d) mantle heat flow as a function of crustal thickness for different surface heat flows (F_s = 20, 35 and 50 mW m^{-2}).

Future work: In a forthcoming work we will carefully and systematically explore the effects of composition of the crust on the thermal and mechanical structure of the Martian lithosphere. Also, we will extend our analysis to real case scenarios and discuss the implications of our results for the thermal state and evolution of Mars.

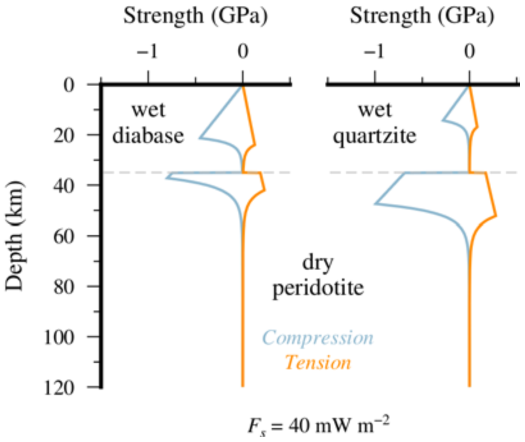

Figure 2. Comparison of strength envelopes for basaltic (left) and felsic (right) compositions of the crust, for a surface heat flow F_s = 40 mW m^{-2}, crustal thickness T_c = 35 km and strain rate $\dot{e}$ =10^{-16} s^{-1}.

Acknowledgments: The work by L.M.P. was supported by a FPU2014 grant from the Ministerio de Educación, Cultura y Deporte of Spain. The work by J.R. was supported by a contract Ramón y Cajal at the Universidad Complutense de Madrid (UCM). This work has received funding from the European Union's Horizon 2020 Programme (H2020-Compet-08-2014) under grant agreement UPWARDS-633127, and from the Spanish Ministry of Economy and Competitiveness Project CGL2014-59363-P (AMARTE).

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