Chaotic terrains and what they tell us about the geothermal gradients on Mars and Earth

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Introduction

On Earth, direct measurements of geothermal gradient are possible although difficult while they are impossible on Mars. Due to differences in size and therefore in accretional heat as well as in the amount of radioactive heat sources, the thermal gradients for both planets should be vastly different in past and present. This should express itself not only in sheer numbers but also in landforms which depend on the internal temperature distribution. One such feature is the basal melting of ice layers. On Earth this can be observed e.g. in Antarctica in the form of subglacial lakes which start to form due to a combination of pressure- and temperature-induced melting. On Mars, however, things are different. Due to its smaller size, melting of buried ice sheets is rather dependent on temperature than on pressure. But even so, it is difficult to find evidence for basal melting; a fact which is already an indicator for much lower thermal gradients on Mars than on Earth. Nevertheless, [1] propose that the formation of the Aram Chaos chaotic terrain was initiated by exactly this kind of melting process. According to their geological analysis, a melt layer of 750 m to 1500 m formed beneath a sediment cover with a thickness of likely between 1000 m and 1500 m.

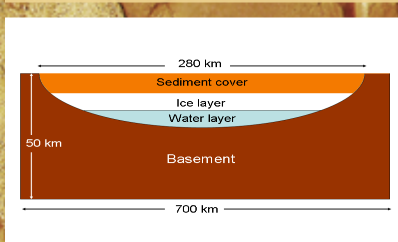

Fig. 1 Schematic view of model set-up

Reference

[1] Zegers T. et al. (2009), ESLAB, Abstract # 1628433

Models

We used a 2D cross-section of the crater to model a steady-state solution of the temperature distribution (Fig. 1). To analyze the effects of different parameters we varied the thickness of the sediment cover and also its thermal conductivity, which this is only poorly constrained. A further parameter was the temperature gradient. To model this last parameter we used a constant amount of radioactive heat sources within the crust and a fixed temperature at the bottom of the model which in combination correspond to a specific temperature gradient. Although this approach may seem simplistic, other factors like the unknown thermal conductivity of the sediment introduce much larger uncertainties. In this preliminary study we aim to show that the concept proposed by [1] is feasible and to give first constraints on the paleo thermal gradient of Mars.

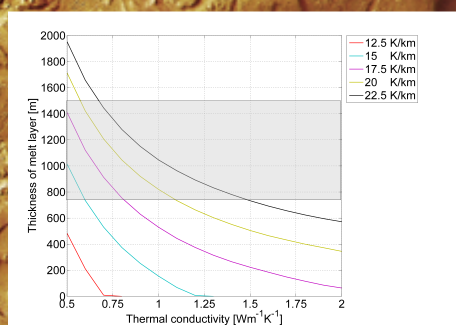

Fig. 2 Melt layer thickness for a sediment cover of 500 m

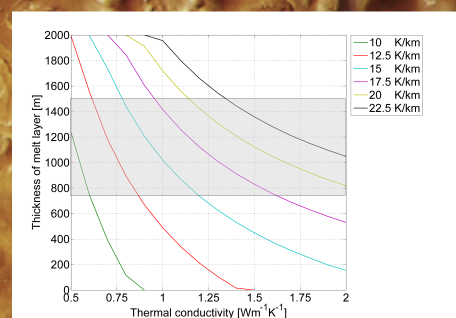

Fig. 3 Melt layer thickness for a sediment cover of 1000 m

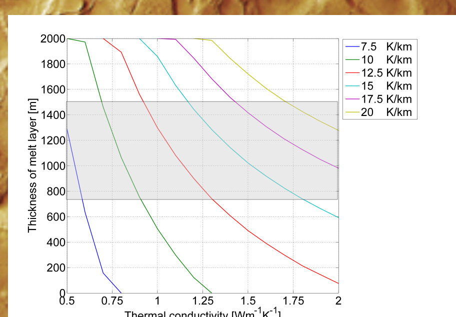

Fig. 4 Melt layer thickness for a sediment cover of 1500 m

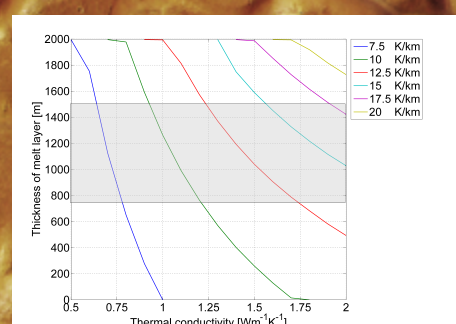

Fig. 5 Melt layer thickness for a sediment cover of 2000 m

Results

Figures 2 to 5 show the results of the calculations. For likely sediment thicknesses of 1000 m and 1500 m, the required thickness of the melt layer (indicated by the grey box) can be reached even for comparatively low thermal gradients and relatively high thermal conductivities. Given these conservative assumptions, the model proposed by [1] for the formation of Aram Chaos is feasible. The fact that this is so far the only observed case for potential basal melting on Mars in past and present shows that geothermal gradients are and were not only much lower than on Earth but that this also has direct implications for many geologic processes.