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Chaotic terrains and the determination of paleo-surface heat flux on Mars

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Introduction: The surface heat flux is a good indicator of the internal activity of a planet. On Mars direct measurements are so far not possible. Therefore, other techniques to constrain heat fluxes are necessary. Until now, the prime technique has been the analysis of extensional tectonic surface features [1,2]. However, this method only yields heat fluxes in tectonically active regions which exhibit higher fluxes than other areas. Nevertheless, the values of geothermal gradients in the range of 14 to 80 K/km for a period about 3 to 4 Ga ago have been inferred, which correspond to heat fluxes of 28 to 160 mW m^{-2} if a thermal conductivity of 2 $Wm^{-1}K^{-1}$ for the basement is assumed. We use the new model developed by [3] to infer the surface heat flux in Aram Chaos in the Noachian-Hesperian.

Model: To derive the surface heat flux we use the geometry and scenario for Aram Chaos as proposed in [3]: The chaotic terrain is situated in a crater partially filled with an ice layer, covered by an overburden of rock units (sediments). Due to the insulating effect of the sediment, the ice layer will melt under certain conditions. This may eventually (after maybe hundreds of millions of years) lead to the collapse of the overburden, associated with a catastrophic outburst, creating the chaotic terrain. The conditions under which melting takes place in this scenario are calculated in our numerical model. In this model the thickness of the sediment cover, the geothermal gradient and the thermal conductivity of the sediment are varied. Geologic analysis of the crater [3] has yielded a possible thickness of the water layer before the outburst in the range of 700 m to 1500 m. Therefore, we try to identify the parameter combinations which result in a melt layer of equivalent thickness.

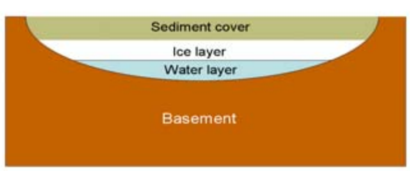

Fig. 1: Model setup (add scale to figure)

Results: The results indicate that surface heat fluxes of at least 20 mWm^{-2} are necessary to explain the observed features. Lower values would require extremely low thermal conductivities or an improbable thickness of the sediment overburden. The most reasonable choices of sediment thickness and thermal conductivity give heat fluxes of 25 to 35 mWm^{-2}. Higher values cannot be ruled out completely but seem unlikely. As the sedimentation rate was probably quite low so that the ice/water layer was probably in a thermal equilibrium with its surroundings all the time, geothermal gradients higher than 35 mWm^{-2} would result in large volumes of melt even with limited sedimentary cover. However, if the overburden increased in thickness rapidly, then even values higher than 35 mWm^{-2} could lead to the observed results.

References:

[1] Grott M. and Hauber E. (2007), LPI *VII*, Abstract # 1353
[2] Hauber E. et.al. (2009) submitted to EPSL
[3] Zegers T. et al. (2009), ESLAB 40th, 2009