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Constraints from chaotic terrains on the surface temperature of Mars during the Hesperian

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Introduction: The surface temperature of a planet is an indicator of a planet's ability to host life as temperatures well below the freezing point make it difficult for life to develop at or close to the surface. However, it is no easy task to constrain the surface temperatures of a planet in the past. For Mars, different studies yield different results as e.g. [1] argue that surface temperatures on Mars were high enough to allow for liquid water on the surface during the Hesperian evidencent by the observed drainage patterns in the northern Valles Marineris region. On the other hand, [2] have analyzed Argon release in Martian meteorites and conclude that the surface temperatures were well below the freezing point during the Hesperian. One possible explanation for this apparent contradiction are the different time scales considered. While for drainage patterns to develop a time span on the order of ten thousand years is sufficient, the analysis of the meteorites only constraints the long term surface temperatures in the order of one million years and upward.

Here we present another way to constrain the long-term surface temperature of Mars during the Hesperian. Geological analysis of chaotic terrain in Aram Chaos indicates that it might have formed as the result of a buried ice layer which subsequently melted [3]. As the melting process depends on the temperature distribution within the subsurface, it also enables us to constrain the surface temperature which is one boundary condition of the system.

Model: To derive the surface temperature 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 (Figure 1). In this model the thickness of the sediment cover, the thickness of the initial ice layer, the surface heat flux, the thermal conductivity of the sediment and the surface temperature 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.

Results: The results indicate that surface temperatures had to be well below the freezing point for a prolonged period of time as already surface temperatures of more than - 15° C result in an unrealistic amount of melting for Aram Chaos. However, this finding does not exclude short periods of higher temperatures as the temperature wave in such cases does not penetrate deep enough to influence the melting of the ice significantly.

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References: [1] Mangold N. et al. (2007), JGR 113, E08009, [2] Shuster D.L. and Weiss B.P., (2005), Science 309, 594-597, [3] Zegers T. et al. (2009), ESLAB 40th, 2009