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Formation of chaotic terrains and associated outflow channels on Mars by burial of ice

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Abstract

Chaotic terrains are common on Mars, whereas analogue terrains on Earth are extremely rare. They are characterized by fractured blocks, tens of kilometers to several meters size, which have been tilted in a chaotic manner. Chaotic terrains on Mars are usually associated with outflow channels, and are widely thought to represent relict areas where subsurface water was released [1,2 and references therein].
Here we present a model for the process behind the formation of chaotic terrains and associated outflow channels on Mars, consistent with their dominant characteristics.

Hypthesis for chaotization and outflow

Several suggestions have been made as to the mechanism of chaotization. In general, water is thought to be released from a sub-surface aquifer.
We suggest that the basic process of chaotization is a simple one, which originally requires water-ice to be present in the subsurface. During the original deposition of the water unit, at ambient surface temperature (-40 ˚C) and pressure (0.007 Bar), the water unit will be well within the ice stability field, and will behave as a rock unit. As the rocky overburden accumulates on top of the geometrically confined water-ice unit, the pressure in the ice unit increases, and will eventually melt if pressures and temperatures at the base reach the solidus. Depending on the overburden composition (basalt or regolith) the lithostatic pressure will increase with between 70 and 110 Bar per km of accumulated overburden. Even at a low crustal thermal gradient (10 K/km) and with the low Martian gravity, this will result in a progressively larger part of the ice unit crossing the phase boundary between ice and water. The ice unit will melt from the base upward, as the overburden accumulates. Eventually the stratigraphic sequence will become unstable, will fracture and collapse. The pressure release as a consequence of fractures propagating through the entire solid overburden (rock and ice) will lead to an explosive event of hydrological fracturing and outflow of water.

Application to Aram Chaos

We tested the above hypothesis by using the geometry and sequence of geological events in Aram Chaos. The ice burial and melt hypothesis, in combination with the Aram Chaos geometry predicts a total volume of water of $0.9\pm0.3x10^5$ km^3. The duration of the outflow event and the amount of water involved were independently calculated from the morphology of the Aram Chaos channel based on the method Kleinhans [3]. The calculated formative time scale is tens of days and the flow volume is in the range predicted by the new model.

References

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