SETTING THE STAGE FOR A MODEL OF THERMOKARST EVOLUTION OF VALLES MARINERIS, MARS.

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Introduction: The formation of the valley system of Valles Marineris (VM) along equatorial Mars is still poorly understood. Models for the geometry of the opening and further evolution of VM can be subdivided into: graben-like opening through normal faults, vertical collapse, and strike-slip (e.g., refs. [1]). Despite its equatorial position, there is some evidence for glacial conditions in VM or in other equatorial positions [2]. Although obvious glacial landforms and moraine deposits in VM are limited, landslides are morphologically similar to those that fall on terrestrial glaciers [3].

A second observation at the basis of the present work is that VM is immersed in a complex network of fractures of different length and characteristics with dominant E-W orientation. Did the very wide (100-200 km) chasmata of VM derive from the enlargement and coalescence of some of such fractures or was the valley enlargement the result of a different process? In order to better understand these processes, we are currently studying the nature of fractures encircling VM, considering the different chasmata of VM themselves as fractures enlarged by headwall retreat. For this preliminary work, a limited amount of fractures was selected. We are extending the analysis to most of the visible and mappable fractures.

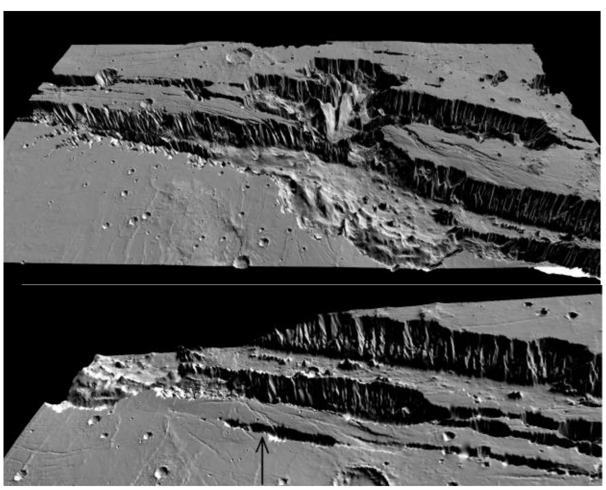

Figure 1. Top: Altimetric 3D MOLA images of Valles Marineris. Bottom: Detail of Capri Chasma; shown with an arrow is the example of a fracture which changes depth and width along its axis. Vertical exaggeration 5x.

Fractures classification

Fractures around VM exhibit certain ranges of width-to depth (Fig. 2). The characteristic and depth-width relationship allow us to classify the fractures in five types. Type 1 are very shallow fractures (<80 m deep) that were not enlarged by erosion and mass wasting, and are tectonically pristine. Type 2 are deeper (up to 300 m) but share the same characteristic with type 1. Type 3 is substantially different as fractures of this class appear to have been enlarged in bowl-shaped collapse pits, perhaps subsequent to tectonic opening (Fig. 2). Type 4 comprises fully opened, flat bottom fractures with pits and mass wasting deposits. Type 5 is the stage of fully-developed chasmata. “Gaps” between these types exist, where fractures are less frequent (Fig. 3).

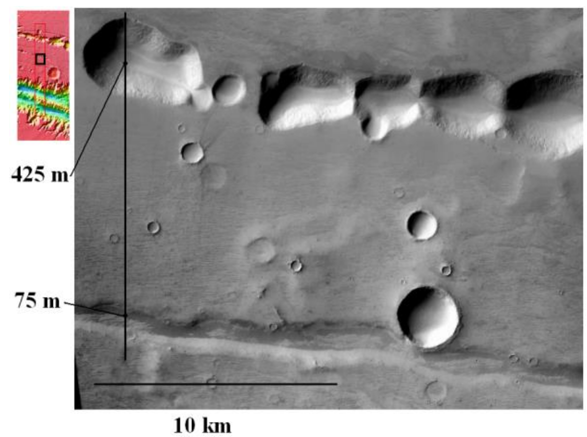

Figure 2. Pits along the deep fractures (“type 3” according to our classification) and “type 1”.

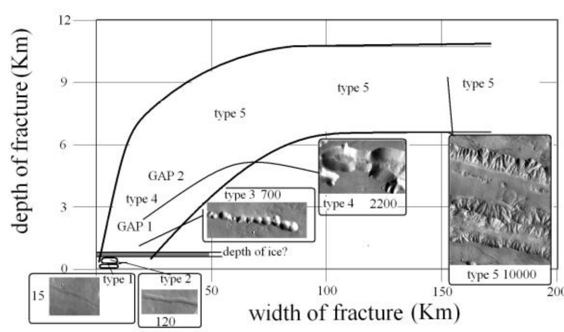

Figure 3. Relationship between fracture width and depth.

Single fractures have failed at some specific points where they formed series of regularly-spaced pits, rather than a single continuous depression (Fig. 4). We suggest that the transition between type 2 and type 3 marks the onset of a new process. In analogy with karst phenomena, the pit formation is indicative of collapse toward the bottom as a consequence of something progressively missing from the bottom itself. In analogy with thermokarst phenomena in Arctic areas, we are exploring the possibility that the "missing" material creating a void could be ice sublimating from a deep layer lying at depths signaled at the transition between fractures of type 2 and type 3. Similar ideas are not completely new (ree refs. in [1]) but to our knowledge have not been been backed by simulations.

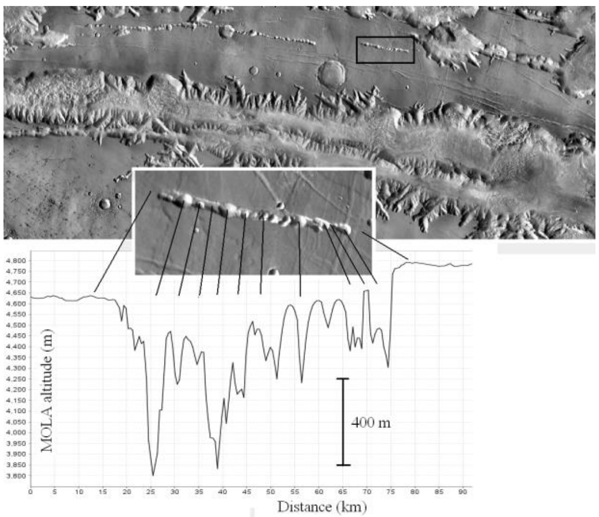

Figure 4. Profile along a fracture line. Note the presence of a series of circular collapse pits.

A simple conceptual model: We are presently investigating the following ideal model for the source of instability of the VM wallslopes. We consider a layer of ice under a certain depth, inactive if unreached by sufficiently deep fractures. During the opening of VM, however, several deep fractures could have exposed the layer, causing the ice to sublimate. We thus assume that the formation of VM and similar chasma occurred in two stages: 1) the opening of the chasmata, and 2) the failure of the chasmata wallslopes via erosion and pit collapse and, in the most severe cases, landsliding. With perhaps the exception of the chaotic terrains in the eastern part of the valley, the evidence for sedimentation of the deepest layers from non-local sources is scarce. We thus envisage a VM filled with loose material deriving from the adjacent wallslopes, implying a maximum distance of material source of the order of 100 km and transport mainly perpendicular to the local valley axis. Because none of the sediments forming the basal chasmata layers appear distorted or teared apart by the valley opening, it can be deduced that most, if not all, of the last deposited sediments occurred after such an opening was complete. In particular, the fact that the landslide deposits appear undistorted while their ages are often very different, indicates that the opening of VM was relatively fast compared to the degradation of its wallslopes due to erosion and landsliding. A normal-fault mechanism ([1]) has some advantages compared to a strike slip geometry [4] for the opening of VM. However, here we shall be mostly concerned with the second stage of VM evolution.

The diffusion coefficients *D* of ice sublimating from a granular medium vary widely depending on grain size, pressure and temperature: values between 10^{-3} cm^2/s < D < 10 cm^2/s can be considered as representative [5]. Thus, imagining a vertical wallslope with a sublimating ice layer at a certain depth (fig. 5) and exposed to external pressure by a vertical fracture opening, the sublimation front after a time T from the time of opening will have traveled inward to a distance $(DT)^{0.5}$; after T=300 Ma this sums up to some tens of km. This figure, notwithstanding the major uncertainties, indicates that a thick and deep ice layer could be at the origin of many puzzling features exhibited by fractures in the VM area. We are currently gathering more extensive data and considering to develop a numerical model for this evolutive scenario.

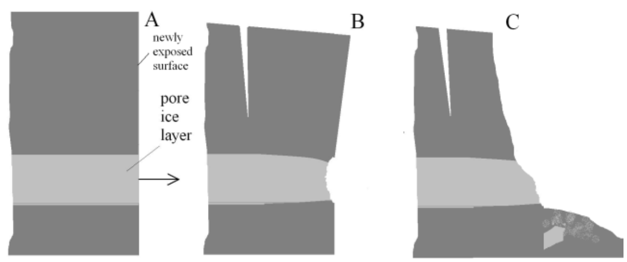

Figure 5. Ideal model of water ice sublimation from an ice layer filling the soil and consequent instability of the wallslopes with formation of collapse pits and, in the most severe cases, large landslides.

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