

EVIDENCE FOR REMNANTS OF LATE HESPERIAN ICE-RICH DEPOSITS IN THE MANGALA VALLES OUTFLOW CHANNEL.

Joseph S. Levy¹, James W. Head¹, David R. Marchant², and Mikhail Kreslavsky¹; ¹ Dept. Geological Sciences, Brown University, Providence RI, 02912, ² Department of Earth Sciences, Boston University, Boston, MA 02215.

Introduction: New high-resolution images from MGS and Odyssey reveal an unusual unit on the floor of the Mangala Valles outflow channel. In contrast to abundant terrain showing scour and hydrodynamic shaping typical of the floors and margins of Mangala Valles and other outflow channels [1], this unit is smooth-surfaced, has arcuate and cusped margins, and has a host of unusual surface features including round pits. We assess several possible origins for this unit and the associated features, and conclude that the most plausible explanation is an ice-rich remnant created by a combination of ponding and ice-cover deflation during the waning stages of the outflow channel flood emplacement.

Description of the Smooth Unit: The smooth unit stretches from the head of Mangala Valles (-18.1 N, 210.6 E) to points at least 400 km north (-11.7 N, 208.8 E), varying in width from up to 10 km to less

measurements and MOLA data indicate a minimum thickness of 10-15 m. At the proximal end of the channel, the unit is composed of two layered sub-units, displaying similar morphology but different spatial extents. In several locations the width of the unit decreases towards the distal end of the channel, developing into a tightly braided system several hundred meters wide.

Description of Surface Features: Both the smooth unit and the surrounding scoured terrain are impact-cratered. Primary impact craters are distinguished by raised rims and generally circular shape. Craters range in diameter from 20-560 m. Impact crater counts between the two surfaces are generally similar, with the scoured terrain appearing slightly older than the superimposed smooth unit.

The most striking features observed on the smooth unit are abundant, shallow, round pits. We measured the diameters of all 404 pits and 2137 craters in THEMIS images V01454004, V0440003, and V04762003. The pits range in diameter from 100-600 m, with a mean of 230 m and standard deviation of 60 m. Large, angular boulders are found at the center of many pits near the proximal end of the channel. Most of the pits with blocks have a marginal raised rim, however, none of the empty pits have raised rims. Pits with blocks tend to be larger than empty pits; however the largest pits are empty [Figure 1 and 3].

The pits are predominantly circular; however, clusters of pits show signs of coalescence, forming elongated rectangular depressions with rounded short sides and long axes sub-parallel with the channel. There is no spatial preference for pitting density.

Several channels < 100 m in width are associated with the smooth deposit at its margin. These meandering channels are all less than 6 km in length [Figure 2]. Similarly, two features resembling small channels trace circuitous paths at the head of the channel [Figure 3].

Discussion and Interpretation: On the basis of these observations, we interpret the smooth unit as an ice-rich residue created by a combination of ponding of flood water and ice-cover deflation during the waning stages of the outflow channel flood event. The presence of the unit in the deepest reaches of the channel supports a ponding hypothesis [2], while the draping of the unit over scoured terrain suggests deflation of an ice cover, as would have formed atop an outflow flood under cold, dry conditions [3]. We interpret the observations to mean that in the early

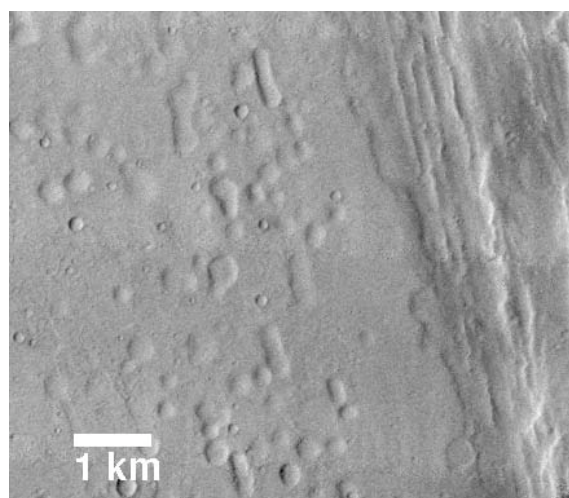


Figure 1. Smooth unit [left] encountering adjacent scoured wall unit [right]. Single and coalesced pits are both visible. From THEMIS image V01454001.

than 400 m. MOLA altimetry demonstrates that the unit is found predominantly in the deepest regions of the channel; however, in several locations the unit drapes the lower walls of the channel. The margins of the unit are undulatory and rounded in some locations, and scalloped in others, forming arcuate serrations. Where the unit abuts the adjacent walls of the channel, or where there is a contact between the smooth unit and the scoured unit upon which it is superimposed, the relatively level and uniform surface of the smooth unit is beveled. Shadow

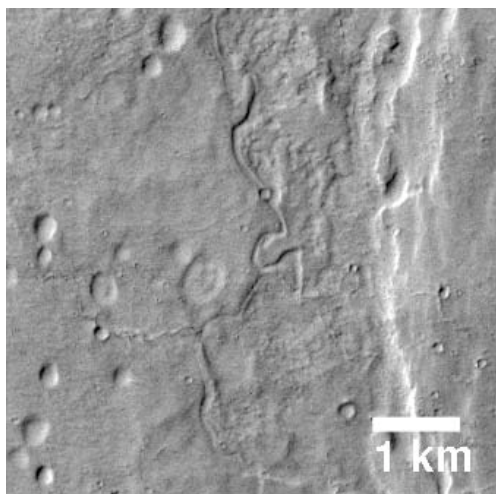


Figure 2. Channel at the margin of the smooth unit [left]. From THEMIS V044000003.

stage, the ponded material and ice-cover froze solid and sublimated, leaving the deposit as a sublimation residue. Locations showing two sub-units of smooth terrain may be areas where an ice-rich cap settled over a debris rich pond, leading to a more heavily degraded ice-rich upper unit, and a less degraded debris-rich lower unit [4]. The lack of elongated craters or streamlines argues against a flowing-ice or glacial ice origin for the unit.

The size-frequency distribution of the pits rules out the possibility that the pits are caused primarily by degradation of impact craters on an ice-rich surface. Rather, the pits in the smooth unit are interpreted as thermokarst-like features, similar to *alases*: terrestrial thermokarst pits [5]. Whereas terrestrial *alases* form through a combination of melt, flow, and evaporative processes, resulting in the lowering of ice-rich terrain, the martian features are interpreted as sublimation pits. Both terrestrial *alases* and martian sublimation pits form when the thermal equilibrium of an ice-rich unit is disrupted, leading to enhanced, localized melting or sublimation [4]. Pits may also be kettles left over from ice-blocks carried downstream by outbreak flood flow [9].

The scalloped or serrated texture of the smooth unit margin is explained as localities where sublimation pits formed near the margin of the unit. Longer embayments may be locations where several sublimation pits coalesced, forming an elongated cavity. Sublimation could be enhanced by scarp formation and marginal wasting.

In areas where the unit thins and adopts a meandering aspect, some sort of esker-like genesis is implied by the braided morphology. Esker-like deposits imply significantly greater ice-cover of the surface than is presently observed, as well as the sub-ice flow of sediment-laden liquid water. These conditions are not inconsistent with those associated with the freezing of debris-rich, ponded flood water.



Figure 3. Pits with large blocks, and channel-like features at the head of Mangala Valles. From THEMIS V04762003.

The presence of pitting even within the thin portions of the deposit suggests that the esker-like formations also contain extant ice, however, the diminutive nature of the deposit suggests that it may be even more debris-rich than the bulk of the smooth unit.

Conclusions: The identification of an ice-rich residue associated with an outflow flood event strongly suggests that this outflow event occurred on a cold and dry Mars, consistent with other observations of the same area of Mangala [10]. Further, the preservation of ice-rich debris beneath a sublimation till suggests that climate conditions have remained cold and dry on Mars for at least the past several billion years, and that flood residue can be maintained for unprecedented periods of time. The formation of extensive sublimation pits strongly suggests that parts of the remaining deposit are currently ice-rich, making this deposit a primary target in exobiological and ancient climate investigations.

References: [1] Malin & Edgett (2001) *JGR*, 106 23,429-23,570. [2] Lucchitta & Ferguson (1983) *JGR*, Supp. 88 A553-A568. [3] Wallace & Sagan (1977) *NASA Tech. Mem.* X-3511, 161. [4] Washburn (1973) *Periglacial Proc and Env.* [5] Soloviev (1973) *Biuletyn Peryglacjalny*, 23, 135-155. (6) Turtle et. al, [2001] *LPSC32* #2044. [7] Hartmann (1977) *Icarus*, 31;2, 260-276. [8] Hartmann & Neukum (2002) *Space Sci. Rev.* 96: 165-194. (9) Benn & Evans (1998) *Glaciers and Glaciation*, 618. [10] Head et al (2004) *GRL*, 31, 40701.