SMALL-SCALE LOBES ON MARS: SOLIFLUCTION, THAW AND CLUES TO GULLY FORMATION.

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Introduction: Small-scale lobes (SSL) on Mars are landforms that show striking morphologic resemblance to terrestrial solifluction lobes [1,2]. Solifluction is the net downslope movement of soil driven by phase changes of near surface water due to freeze-thaw activity [3]. SSL on Mars consists of a clast-banked arcuate front (riser) tens to hundreds of meters wide [1]. Risers are typically decimeters to a few meters (<5m) in height and the tread surface is relatively clast free [1]. SLL often display overlapping of individual lobes. Hitherto SLL's have only been studied in detail in the northern hemisphere on Mars [1,2,4-6] where they have been found to be latitude-dependent landforms [1,2]. In contrast, only a few observations have been made in the southern hemisphere [7,8]. Several authors argue for a freeze-thaw hypothesis for SSL formation on Mars [1,2,4-8]. If correct, the implication is significant since it would require transient H_2O liquids in a frost-susceptible regolith over large areal extents. Thus a better understanding of SLL will allow to identify environments that may possibly have experienced transient liquid water in the shallow subsurface in the recent past.

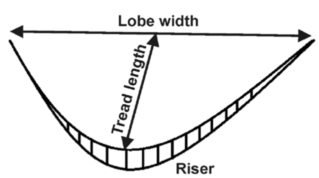

Figure 1. Sketch showing the lobe components. Lobe front points downhill.

This study aims to determine the distribution of SSL in the southern hemisphere and to investigate their relationship to other possible periglacial landforms such as patterned ground, polygonal terrain and gullies. Collectively, these landforms may be linked to phase changes of water at the surface or in the shallow subsurface.

Data and methods: We used images obtained by the High Resolution Imaging Science Experiment (HiRISE), which has a spatial resolution of ~25–50 cm/pixel. We catalogued and investigated all available HiRISE images that were acquired between 2007 and 2013 in the the latitude band 40°S and 80°S on Mars. A total of 2200 HiRISE images have been studied in detail. The Charitum Montes region contains a high abundance of small-scale lobes but HiRISE coverage is limited. Here we used images obtained by the Context Camera (CTX) intrument (6m/pxl) for our mapping. CTX images have been processed in ISIS3 and mapping was performed in ArcMap 10.2. For comparison to terrestrial solifluction lobes we used the airborne High Resolution Stereo Camera (HRSC-AX) [9]. The benefits of using HRSC-AX are its ability to render detailed DTM's and a similar pixel size (20 cm/pixel) as HiRISE.

Observations and results: SLL's are observed on impact crater walls and on topographic highs in Charitum Montes (southern Argyre). SLL's observed in HiRISE (n:30) show a close spatial association with gullies (77%) and polygonal terrain (47%) (Fig 2). Moreover some lobes are superposed by striped patterns (Fig. 3). Stripes were also observed separately from SLL but within the same crater environment (Fig. 4). On Earth stone stripes and sorted stone stripes are landforms that develop in the active layer, a layer that undergoes seasonal and/or diurnal freezing and thawing. SLL's are often, but not always, associated with slopes covered by latitude-dependent mantle (LDM) [10]. Several SLL locations show evidence of dissected mantle (26%). Moraine-like landforms were observed at ten locations (25%).

The SLL identified in the Charitum Montes region cover large areas of the mountain slopes, preferentially on slopes exposed towards NW-N direction (Fig. 5). Although the image resolution of CTX prohibits studies of the small-scale features such as polygonal terrain it allowed for more regional observations. The Charitum Montes SLL occur in areas with significant gully erosion [11].

Discussion and conclusions: Here we show that the distribution of SLL in the southern hemisphere roughly mirrors that in the northern hemisphere distribution. Hence, SLL are hemispherically bimodally-distributed landforms, similar to polygonal terrain [e.g. 6] and gullies [e.g. 12]. However, despite more abundant sloping terrain in the southern hemisphere, fewer SLL are observed, except in the Charitum Montes region. This is in contrast to gully landforms which are more abundant in the southern hemisphere.

Martian gully landforms and their formative processes have received considerable attention in the last decade and there are currently conflicting ideas whether liquid water [e.g. 13] or CO_2–triggered mass wasting [e.g. 14] are the primary agents of erosion. As there are no CO_2 frost triggered hypotheses that can explain the occurance of SSL, a thaw-based hypothesis could explain both landforms. In this scenario gullies and SLL may form a hydrologic continuum where available water content govern the type of landform produced. Solifluction would require ice lense formation (excess ice) to develop. Excess ice were encountered by the Phoenix lander in 2008 [15]. Furthermore, modelling attempts may suggest that ice lenses could be widespread on Mars [16]. However more work is needed to understand the physical environment related to the CO_2 paradigm and the full suite of slope landforms predicted by it. Hence, we suggest that any model to explain gully formation must incorporate the geomorphologic context in which they occur.

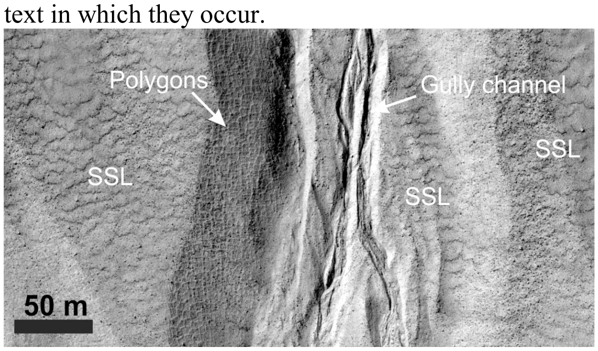

Figure 2. SLL, polygons and gullies in Ruhea crater (43.26°S/173.08°E). Fresh appearing gully channel with polygonal patterns on the gully walls. SLL dominate the scene covering the adjacent walls with overlapping lobes.

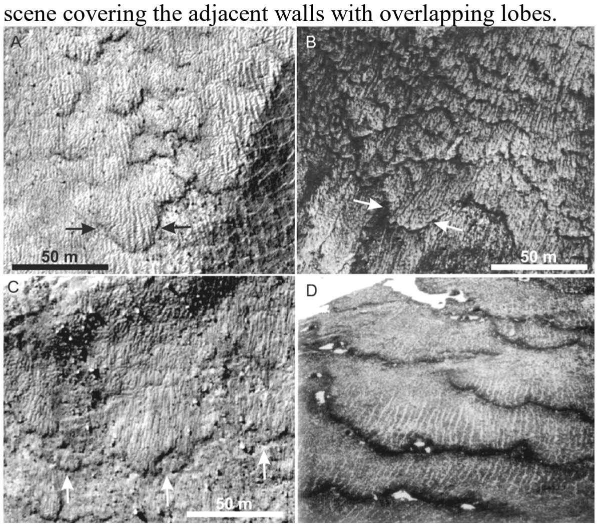

Figure 3. Examples of martan SSL and solifluction lobes on Earth. A) SSL in Ruhea crater, Mars. Overlapping lobes superposed by striped pattern. B) Solifluction lobes superposed by stone stripes, Svalbard. C) SSL in unnamed crater, Mars (45.42°S/25.74°E). Stripes are seen on the lobes. D) Solifluction lobes in New Zealand superposed by sorted stone stripes. Lobe front ~25 cm high (modified from [17])

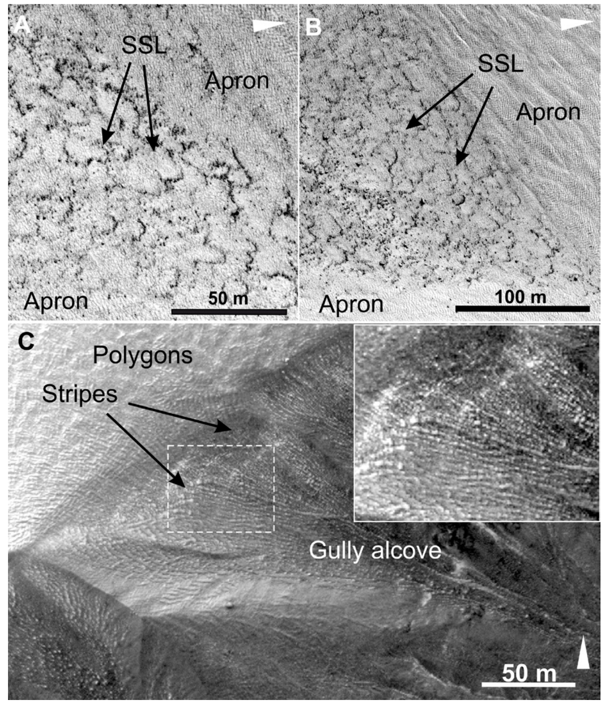

Figure 4. SLL and stripes within Henbury crater in southern Mars. A-B) Slopes between gully aprons displaying clast-banked SLL. Apron superposes SSL. C) Stripes within gully alcove and adjacent polygonal terrain. Stripes seem to follow the steepest gradient and are highlighted by frost. Inset image show a close up of the stripes (white box).

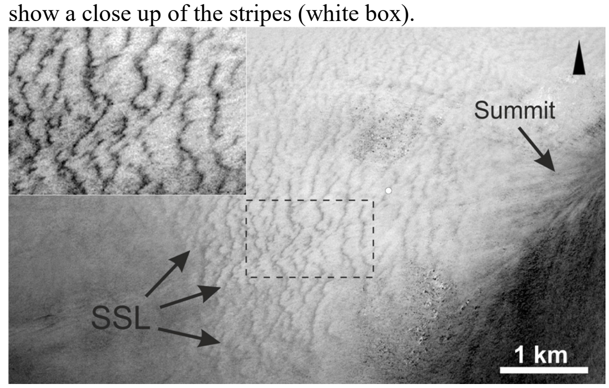

Figure 5. SSL in the Charitum Montes in southern Argyre. Inset image show a close up on SSL (black box).

References: [1] Johnsson et al. (2012) *Icarus 21,* 489–505. [2] Gallagher et al. (2011) *Icarus 211,* 458–471.[3] Matsuoka (2001) Earth-Sci. Rev. 55, 107–134. [3] Gallagher and Balme (2011) *GSL 356,* 87–111. [4] Nyström and Johnsson (2014) *EPSC,* #EPSC2014-480. [5] Balme et al. (2013) *Prog. Phys. Geogr., 37*, 289-324. [6] Mangold (2005) *Icarus 174,* 336-359. [7] Soare et al. (2016). *Icarus 264*, 184-197. [9] Jauman et al. (2007) *Planet. Space Sci.,* 55, 928–952 [10] Mustard et al. (2001) *Nature 412*, 411-414. [11] Raack et al. (2012) *Icarus 219,* 129–141. [12] Harrison et al. (2016) *Icarus 252*, 236–254. [13] Conway et al. (2015) *Icarus 254*, 189–204. [14] Pilorget and Forget (2015) *Nature Geo., 9*. 65–69. [15] Mellon et al (2009). *JGR-Planets 114*, E003417 [16] Sizemore et al. (2015). *Icarus 251,* 191–210. [17] Benedict (1975) *Quat. Res., 6*. 55-76.