EPSC Abstracts
Vol. 10, EPSC2015-760, 2015
European Planetary Science Congress 2015

Sedimentological analyses of Martian gullies: the subsurface as the key to the surface

T. de Haas (1), D. Ventra (1), E. Hauber (2), S.J. Conway (3) and M.G. Kleinhans (1)
(1) Faculty of Geosciences, Utrecht University, The Netherlands (t.dehaas@uu.nl), (2) Institute of Planetary Research, German Aerospace Center, Germany, (3) Department of Physical Sciences, Open University, UK

1. Introduction

Martian gullies are composite landforms that comprise an alcove, channel and depositional fan. They are among the youngest landforms formed by liquid water on Mars, and therefore of critical importance in resolving the planet's most recent hydrologic and climatic history. Water-free sediment flows, debris flows and fluvial flows have all been identified in gullies. These processes require very different amounts of liquid water, and therefore their relative contribution to gully-formation is of key importance for climatic inferences. Many authors inferred that most gullies were formed by fluvial flows because the surface morphology of most gully-fans lacks evidence for debris-flow processes [3,4]. Paired levees, distinct depositional lobes and large boulders all characteristic of debris-flow deposits, are only recognizable on a few fans but are generally not reported [4]. Nevertheless, the morphometric attributes, such as slope-area relations, the steep depositional slopes and channel sinuosity, do suggest a formation by debris flows [1].

On Earth, fans on which primary processes of aggradation have been long inactive are exposed to prolonged weathering and erosion. These secondary processes often dominate fan surfaces due to the long return periods of primary processes, although they generally have a minimal effect on fan aggradation [2]. As such, secondary processes might have modified the surface of Martian gully-fans and hinder identification of primary depositional processes based solely on surface morphology.

Here, we aim to constrain the formative processes of Martian gullies based on outcrop sedimentology (as deposits are generally reworked at their surface but not internally). Secondly, we aim to resolve the apparent discrepancy between genetic interpretations from gully-fan surface and morphometry.

2. Results

This work is based on the analysis of 51 HiRISE images widely distributed over the southern midlatitudes [4]. The resolution of HiRISE images does not allow for fully detailed sedimentological analyses of incised sections; only large boulders (>0.5 m) and layering patterns can be resolved. As such, the presence or absence, and distribution of boulders and large-scale layering within stratigraphic sections are used for process interpretation of gully-fans on Mars.

We show that many gullies dominantly formed by debris flows, based on this sedimentological analysis of outcrops in gully-fans. For gully-catchments which mainly comprise bedrock, the great majority (96%) of outcrop exposures in gully-fans fed contain sedimentological evidence for debris-flow formation. These exposures contain many randomly distributed large boulders suspended in a finer matrix and in some cases lens-shaped and truncated layering (Figure 1). Moreover, mobility analyses show that these boulders cannot have been transported by fluvial flows or rockfalls over typical gully-fan slopes. Similar sedimentological features are rare in gully-fan exposures mainly fed by catchments comprising abundant latitude dependent mantle deposits (LDM; a smooth, often meters-thick deposit consisting mainly of ice and dust), wherein boulders are largely absent. These LDM-fed gullies may have formed by fine-grained debris flows, but this cannot be determined from outcrop sedimentology alone because of the lack of boulders in these systems. The fan surface morphology, in contrast to the subsurface, is dominated by secondary, post-depositional, processes, mainly weathering, wind erosion, and ice-dust mantling (Figure 1). These processes have removed or severely reworked the original, primary, debris-flow morphology over time. This explains the controversy between previously published morphometric analyses implying debris-flow formation and observations of gully-fan surfaces, which are often interpreted as the product of fluvial flows because of the absence of surficial debris-flow morphology. The inferred debris-flow origin for many gullies implies limited and ephemeral liquid water during gully-formation.

3. Conclusions

- Stratigraphic-sedimentological analyses show that the majority of Martian gullies are likely formed by debris flows.
- Large boulders and truncated layering are common diagnostic features for debris flows in vertical sections along incised channels in Martian gully-fans.
- The original gully-fan surface morphology is generally heavily modified and masked by secondary processes, such as weathering, wind erosion and ice-dust mantling.
- The surface morphology is therefore generally not representative for the dominant formative mechanisms of gully-fans.

References

[1] Conway, S. J., Balme, M. R., Murray, J. B., Towner, M. C., Okubo, C. H., Grindrod, P. M., 2011. The indication of Martian gully formation processes by slope-area analysis. Geological Society, London, Special Publications 356 (1), 171-201.

[2] De Haas, T., Ventra, D., Carbonneau, P. E., Kleinhans, M. G., 2014. Debris-flow dominance of alluvial fans masked by runoff reworking and weathering. Geomorphology 217, 165-181.

[3] Dickson, J. L., Head, J. W., 2009. The formation and evolution of youthful gullies on Mars: Gullies as the late-stage phase of Mars most recent ice age. Icarus 204 (1), 63-86.

[4] Reiss, D., Hauber, E., Hiesinger, H., Jaumann, R., Trauthan et al., 2011. Terrestrial gullies and debris-flow tracks on Svalbard as planetary analogs for Mars. Geological Society of America Special Papers 483, 165-175

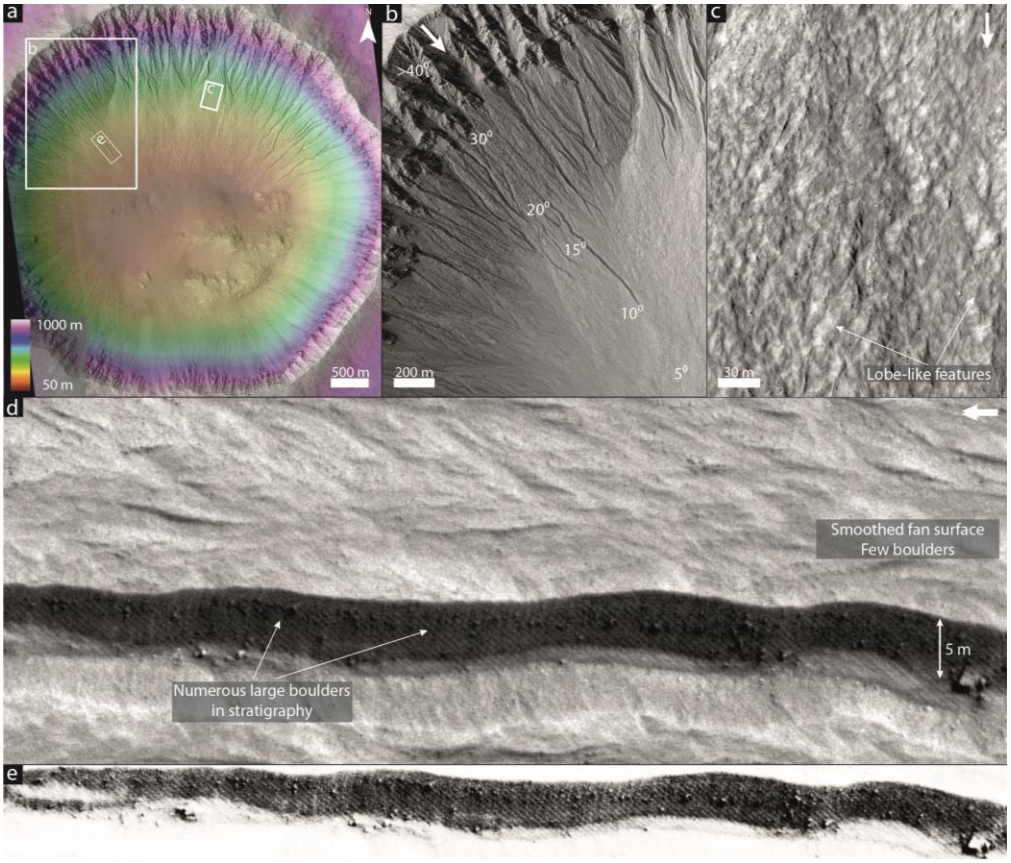

Figure 1: Morphometry, morphology and stratigraphy of gullies in Galap crater. (a) Overview. (b) Detail of northwestern slope showing gradients of catchment and depositional fan. (c) Detail of proximal fan surface. (d,e) Example of stratigraphic section, showing many large boulders dispersed in a finer matrix. This is typical for debris-flow deposits. Note the contrast with the surface deposits where there are far less boulders and no debris-flow morphology. Arrows denote downslope direction. HiRISE image PSP_003939_1420.