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Pristine debris flows in a well-preserved impact crater in the Aonia region, Mars

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1. Introduction

Gullies on Mars are known to display a range of different morphologies but typically include an alcove, channel and apron [1]. Several processes have been invoked to explain their genesis ranging from dry granular flows [2], debris flows [3] to fluvial erosion with alluvial deposition [4]. Albeit there is a general consensus that the medium involved is water, more attention is now drawn towards the dominant depositional processes of the gully fan formation. The observed range of fan morphologies asks for several depositional mechanisms and likely vary at different sites due to regional and local differences in climate and colluvial source material. Studies indicate that the common mechanism is fluvial deposition [5] in contrast to debris flow dominated fans which have only been documented at three sites [5,6,7]. These sites formed debris deposits of apparently fine grained dusty mantle material. Here we report on unusual Martian debris flows in an unnamed southern hemisphere crater which is rich in coarse grained colluvial material that forms well preserved debris flows, debris plugs and levees. It also displays numerous fresh looking rock falls. This raises the following questions: Why do so well-developed debris flows occur here and not in other nearby craters? What role does the coarse colluvial material play in debris flow initiation and development? Here we describe the debris flow morphology and we investigate the sieve-deposition [8,9] model as an explanation for the unusual morphology of these debris deposits.

2. Observations

The study site is a ~4.5 km unnamed crater located in the Aonia region (centered at 45.11 S; 274.2 E). The crater is superposed on the ejecta blanket of a much larger 17 km rampart crater. Night- and daytime THEMIS-images point to a surface of either coarse grained material or consolidated sediments (Fig 1). Due to the underlying unconsolidated ejecta the former is favored. Thick debris flow deposits are present at the pole facing inner wall of the crater (Fig. 2a), as well as on the exterior pole facing crater rim. The deposits bare little resemblance to typical Martian gullies and have no clear alcove/channel morphology. Instead the slopes are dominated by debris flows from the alcoves which are incised in highly brecciated material. Numerous distinct, meters high levees are seen (e.g. Fig 2b and d) with crosscutting relationships pointing to multiple debris flow events (Fig 2b). Within debris flow channels, 10 to 15 m, wide debris plugs with rounded termini are clearly visible (Fig 2c). The crater floor display numerous fresh appearing rock falls, with sizes ranging from less than a meter to ~2.5 m. The pole facing deposits display a higher than usual fraction of blocky material, which some deposits seem to be entirely composed of.

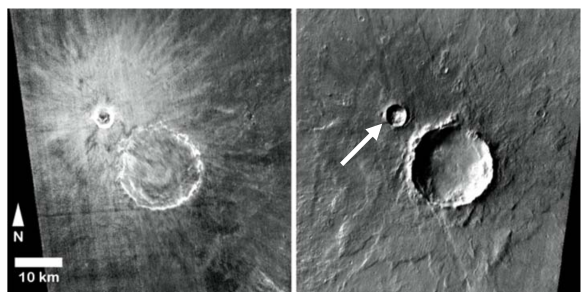

Figure 1: Night time (left) and day-time (right) THEMIS images [11] showing the thermal signature of the surficial material. White arrow shows study site.

3. Discussion

Despite numerous investigations of gullies using HiRISE images only three debris flow sites has been documented so far [5,6,7]. The previously investigated sites show fluvial channels and that the debris flows most likely originated from the ice-dust mantle forming smooth flat debris lobes that lack surface texture, indicative of fine grained composition. What is puzzling is that some of these previously documented gullies apparently incise the bedrock (e.g. [5,7]) but no or very small amounts of coarse material are incorporated in the debris flow deposits. In contrast, our study area displays no clear fluvial channels but instead numerous well developed debris flows with leveed channels, and terminal lobes superposing one another. In addition leveed channels with debris plugs are clearly visible. Although a ice-dust mantle component of these debris flows cannot be excluded a striking difference is the presence of significantly more coarse grained colluvial material from the exposed crater rim. Furthermore the crater displays a spectrum of mass movements ranging from debris flow dominated (pole facing) to fluvial erosion (west facing) and dry debris avalanches (equator facing). This suggests that distinct morphological characteristics are influenced by solar insolation rather than local climate differences. The numerous rock falls in the crater points to an active colluvial forming environment which may play a critical role in the debris flow morphology. Due to the eroded channels in the alcoves and lack of clear linkage between channel and bedrock stratigraphy (aquifer) and lack of tributaries (runoff) we suggest that the most likely source of water is top-down melting of snowpack's [9]. In synergy with previously studied regions these deposits suggests that they may add important insight into the formation mechanisms and hydrological significance of Martian debris flows.

We investigate a model of sieve-deposition for some of the observed debris flow lobe morphologies in the crater. Sieve deposition involves the loss of stream flow capacity by infiltration and results in gravelly, clast-supported, matrix-free, highly permeable, moderately sorted, lobe-shaped deposit [10,11]. Hence the only hydrodynamic requirement for sieve-deposition is a high rate of water loss promoted by permeable bed sediments [12]. The observed deposits have debris lobes at all different elevations and the debris plugs terminate up slope possibly due to a loss of a carrying medium. Both sieve-deposits and debris flows can take place on the same fan. Due to the coarseness of the bed material we suggest that infiltration could play a critical role in water loss from the debris thus bringing the flow to a stop (sieve-deposition) .

Acknowledgements

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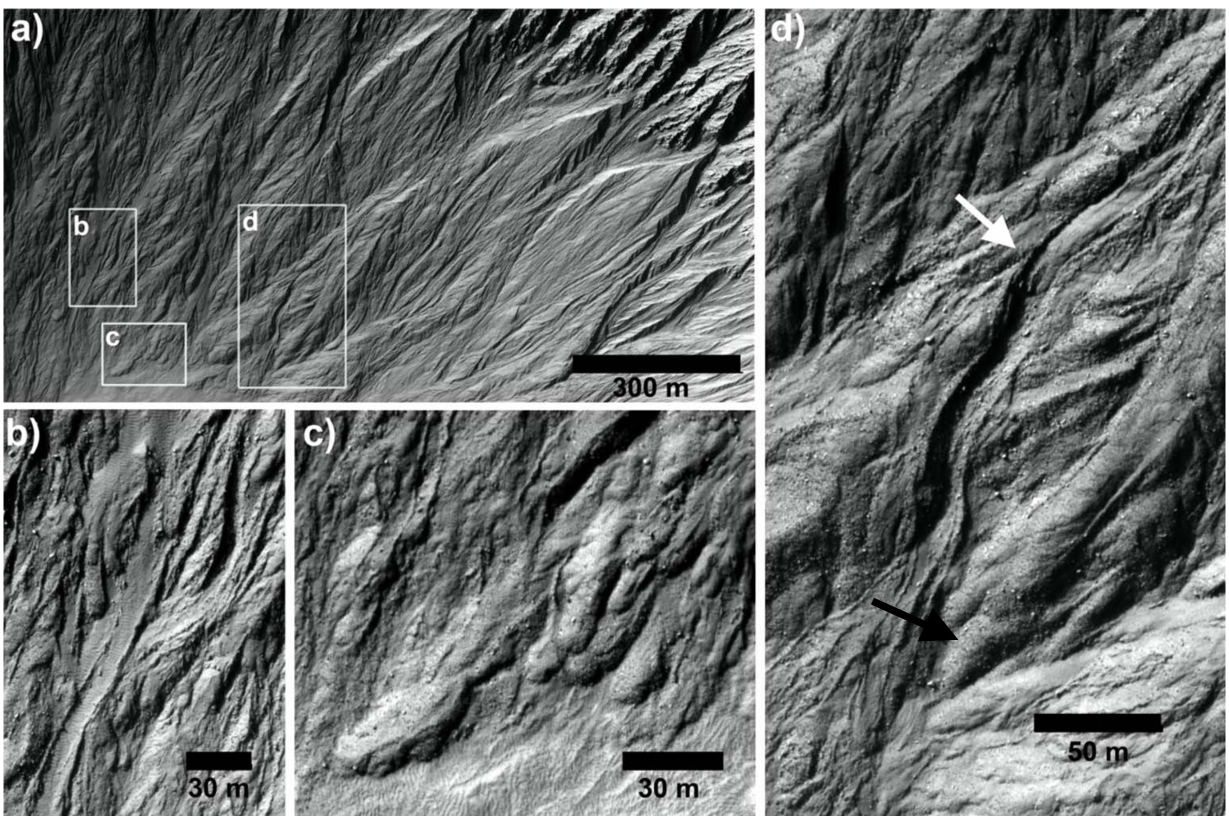

Figure 2 a-f: a) Overview of debris flow deposits. b) distinct levee channel and crosscutting between debris flows. c) Debris lobe termini. d) Large debris plug (white arrow). Note the proximal deposit with apparently blocky termini (black arrow). North is up in all images.