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How wet are gullies on Mars? Insights from high resolution topography

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How wet are gullies on Mars? Insights from high resolution topography.

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Abstract

We have found that debris flows are the main process in forming two gullied crater slopes on Mars. We used 1 m/pix elevation models to derive three topographic indices: slope-area, CAD and DI-25. These indices allow the active slope processes to be identified by comparison to data from Earth analogues. We present data from Meteor Crater together with analogues previsouly presented by Conway et al. [1]. We also compare the signals from the martian gullied slopes with a non-gullied martian example: Zumba crater.
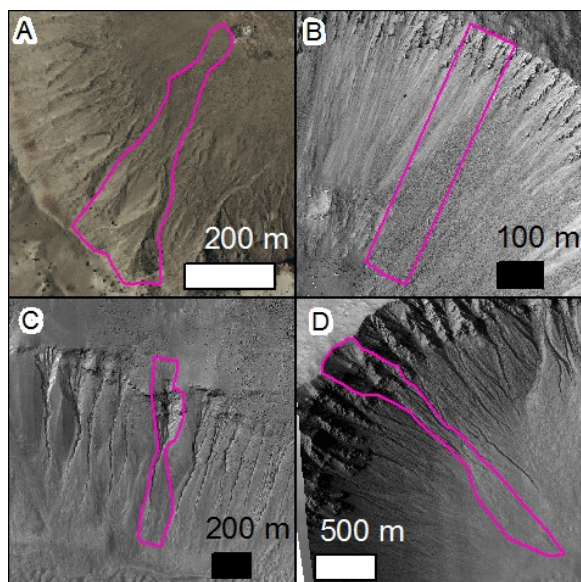
Figure 1: Zones studied (in pink): A, Meteor Crater, image supplied by USGS. B, Zumba crater HiRISE image PSP_002118_1510. C, unnamed crater at 39°S, 160°E, HiRISE image PSP_006261_1410. D, unnamed crater at 38°S, 193°E, HiRISE image PSP_003939_1420.

1. Introduction

Simple interrogation of aerial or satellite images of geomorphic features can often lead to incorrect interpretations of formation process because different processes can lead to the same morphology (*equifinality*). This explains why there has been an on-going debate regarding the processes responsible for gully formation on Mars. Arguments have been put forward for dry mass wasting [2], debris flow [3], or brine/water overland flow [4]. However, each of these processes can be distinguished in terms of the morphometry, i.e. the landscape's 3D form [1]. We use two topographic derivatives, which have already been tested for process-discrimination: Slope-Area [5] and Cumulative Area Distribution ("CAD" [6]). We also present results using the "Downslope Index" (DI, [7]). Our study includes gullies in Meteor crater Arizona and three case studies on Mars (Fig. 1).

2. Approach

We use 1 m/pix digital elevation models (DEMs) to calculate the three topographic derivatives. For Meteor Crater, this was produced from a 25 cm/pix ground-based LiDAR survey collected in May 2008 by the Stennis Space Centre and supplied by the USGS. For Mars, we used publically released DEMs from the HiRISE website, or DEMs produced at the NASA RPIF-3D Facility at University College London. The basis for all of the indexes is the calculation of the upslope contributing area for each pixel in the DEM. This is computed from a flow-routing procedure. Here, we use a "Dinf" model (which allows flow to diverge) for Slope-Area and CAD and "D8" (which does not allow divergent flow) for the DI. All three derivatives are calculated for each pixel within the DEM. Slope-Area is a log-log plot of the local slope and contributing area. CAD is the probability that a given pixel has a contributing area, *A*, greater than or equal to a given contributing

area, A^*. The DI is the distance along the steepest flow path that has to be travelled to drop in elevation by d metres, L_d. We have chosen $d = 25$ m and give DI $= d / L_d$. Fig. 2 shows the expected shape of each plot for each process type.
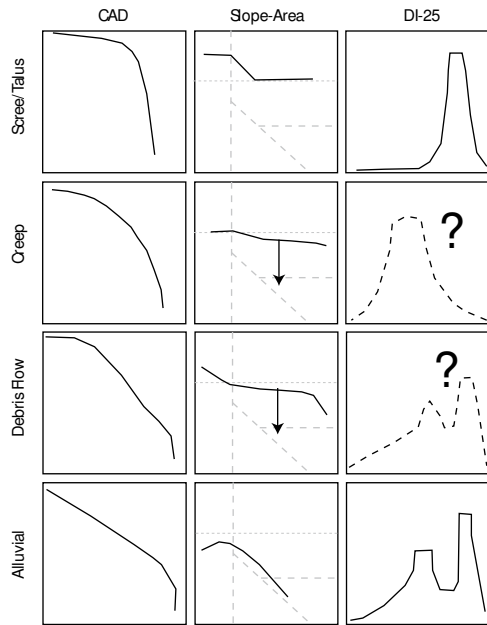

Figure 2: Sketch plots for CAD, Slope-area and DI-25 for each slope process investigated. The arrows show a zone over which the curve could be positioned and '?' indicates relationships not yet explored.

3. Results and Discussion

The results for each of the zones shown in Fig. 1 are presented in Fig. 3. Comparison with Fig. 2 shows that the gullies in Meteor crater are mixed alluvial and debris flow, as previously noted [8]. Zumba crater, in which there are no gullies, shows a talus signal as expected. Crater C, which contains sinuous gullies, has a debris flow signature. The "bump" in the slope-area plot is the result of the rock outcrop mid-slope. Crater D shows a debris flow signal. From our investigations to date the double peak in the DI-25 index seems to be indicative of processes that form channels, i.e. debris flow and alluvial. However, more investigation is needed to explore the exact relationship between DI-25 and slope processes.

4. Conclusions

Different slope processes can be successfully discriminated using slope-area, CAD and DI-25. The gullies on Mars in this study are formed by debris flow, but differences in setting modulate the specific outputs of each of the three indices.
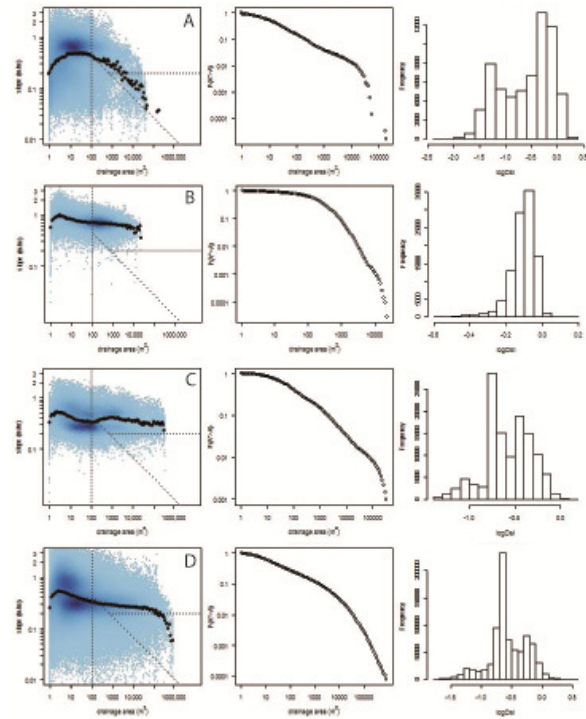

Figure 3: Columns from right to left, slope-area, CAD and DI-25. Rows A-D are the plots for the corresponding zones outlined in Fig. 1.

References

[1] Conway, S.J., et al.: In: Balme, M.R. et al. (Eds.), Martian Geomorphology. The Geological Society of London, (in press). [2] Treiman, A. H.: J. Geophys. Res. 108, 2003. [3] Costard, F., et al.: Science 295, 110-113, 2002. [4] Malin, M.C, and Edgett, K.S.: Science, 288, 2330-2335, 2000. [5] Montgomery D. R. and Foufoula-Georgiou E.: Water Resour. Res., 29, 3925-3934, 1993. [6] Perera H. and Willgoose G.: Water Resour. Res., 34, 1335-1343, 1998. [7] Hjerdt, K. N. et al. : Water Resour. Res., 40, doi:10.1029/2004WR003130, 2004. [8] [1] Kumar P. S. et al. : Icarus, 208, 608-620, 2010.