The role of gullies in Martian impact crater degradation

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The Role of Gullies in Martian Impact Crater Degradation

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Abstract

We found that craters in the mid-latitudes of Mars possess a marked asymmetry, which is linked with the occurrence of gullies. We also found that a pre-requisite for gully formation is the occurrence of steep slopes. The analysis was performed in three areas with elevation data from the High Resolution Stereo Camera (HRSC) on-board Mars Express.

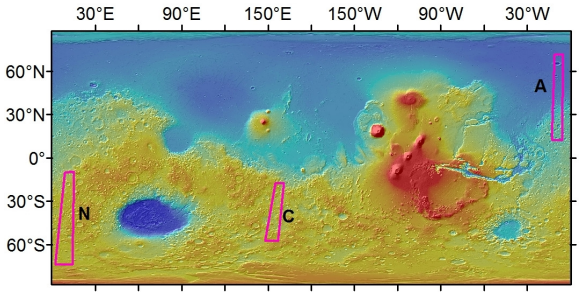

Figure 1: MOLA global map with our study sites marked in pink: N = “Noachis”, C = “Cimmeria” and A = “Acidalia”.

1. Introduction

The mid-latitudes of Mars are a region of transition between the smooth, ‘mantled’ polar terrain and the rough equatorial terrain. The ‘mantle’ deposit, thought to be composed of ice and dust, is discontinuous in this region [1]. This region also has a higher concentration of gullies [2,3], viscous flow features [4], Concentric Crater Fill [5] and lobate depressions. Kreslavsky and Head [6] noted that slopes in this region tend to show a north-south asymmetry. We explore the relationship between this topographic transition and the occurrence of gullies by studying how the shape of impact craters changes with latitude. On average impact craters are symmetrical immediately after formation [7]. Hence, any degradation processes (e.g. gullying) cause a departure from this symmetry.

2. Approach

We studied three different areas (Fig. 1) using HRSC elevation data at 100 m/pix or better. We used the crater catalog of [8] as the basis for our mapping of craters in these regions. We divided each crater into: north-, south-, east- and west-facing segments (Fig. 2). For each segment we extracted all the elevation points and plotted them according to their distance from the centre-point. Using these data we constructed the mean profile (Fig. 2), from which we calculated the maximum slope on the crater wall. We then calculated the difference in slope between the north and south crater walls and the east and west crater walls. These differences were normalized against the average for all four mean profiles (similar to [9]). We mapped all the crater slopes on which gullies occurred and calculated the angular coverage of gullies for each segment (Fig. 2).

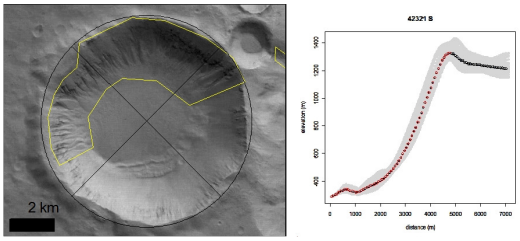

Figure 2: Left, crater showing mapped gullies and segment boundaries. Right, example mean profile (red) with raw data (grey) for south-facing segment.

3. Results & Discussion

In Terra Cimmeria we mapped 590 craters of which 211 have gullies, for Noachis Terra 742 craters of which 9 had gullies and for Acidalia Planitia 491 craters of which 25 have gullies. We found that the slope of crater walls increases towards the equator for all regions (Fig. 3). Gullies occur at latitudes polewards of 30° and only on crater walls with high slopes (Fig. 3). Noachis and Acidalia have fewer steep slopes at these latitudes, which could explain their lack of gullies. Steep slopes formed by other processes also host gullies, e.g. the polar pits in

Noachis. We found no significant relationship between gully coverage and slope, which might be expected if the gullying process itself creates steeper slopes. Fig. 4 shows that craters have steeper equator-facing slopes than pole-facing ones at mid-latidues, as predicted by Parsons & Nimmo [9]. They modelled expected changes in crater shape given the creep of an ice-rich layer exposed to insolation (varying with obliquity) over the last 100 Ma. We found a similar relationship in the west-east direction, which could be attriubuted to diurnal temperature differences, or wind. We found that gullies tend to be found on craters with more marked asymmetry, and hence possibly contribute to it.

6. Conclusions

Gullies need steep slopes on which to form and do not themselves create steeper crater slopes. There is a marked N-S and W-E slope asymmetry at mid-latitudes, in which gullies play a role. Gullies and crater asymmetry seem to be linked to the degradation of the mantle deposit.

References

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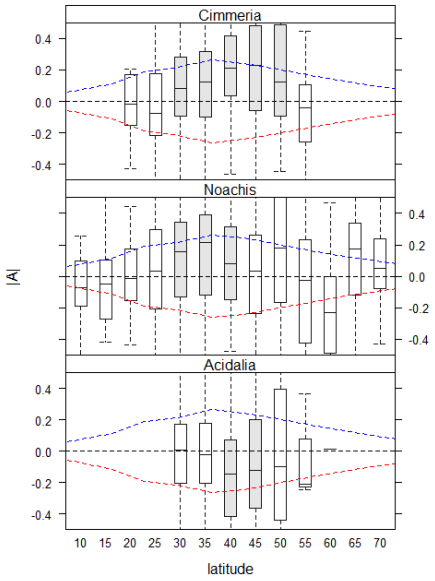

Figure 4: North-south asymmetry for craters in our 3 areas. |A| > 0 means slopes facing north are steeper than those facing south. Blue lines are asymmetry expected by [9] for 150 m ice/dust layer in the southern hemisphere, red is for northern hemisphere.

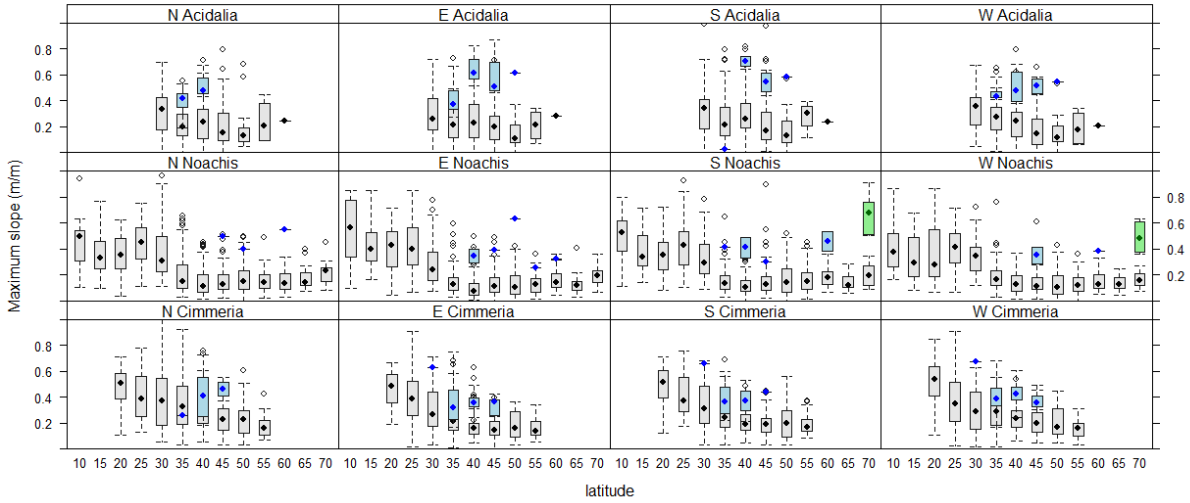

Figure 3: Boxplots of the maximum slopes of the mean profiles for each crater segment (N, S, E, and W) against latitude for all three regions. Grey symbols are crater slopes without gullies, blue are crater slopes with gullies and green are slopes in polar pits with gullies (Noachis only).