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Recent rockfalls on Mars

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Abstract

We study rocks falling from exposed outcrops of bedrock in martian impact craters. Those rockfalls have left trails on the slope over which they have bounced and/or rolled. Craters at ~20°N/S have notably higher frequencies on their equator-facing slopes compared to other slope-orientations. Our interpretation is that thermal stress is playing a more important role than ice-presence in rock breakdown on modern Mars.

1. Introduction

Individual rock falls are one of the currently active surface processes on Mars. Similarly to Earth, clasts detach from upslope outcrops roll/bounce downslope leaving a track on the substratum (Fig. 1B). The presence of these trails shows that these rocks have fallen relatively recently, because aeolian processes are known to infill topographic lows over time (estimations from rover-track erasure rates date these trails at <100 kyr). On Earth, slope instability is usually triggered by phase changes of H_2O [1], but it has also been suggested that solar-induced thermal stress could play a key-role in rock breakdown and triggering of rockfall events [2]. Although liquid water is not stable at the surface of Mars today, water ice can be found as a sub-surface layer from mid- to high-latitudes [3]. Water ice and CO_2 seasonal frost also exist in latitudes down to 30° on shadowed pole-facing slopes [4] and possibly even lower latitudes [5]. Thermal stress linked to insolation is the mechanism proposed to explain fracture orientation pattern in martian boulders observed by MER [6] and other studies suggest that it could cause rock breakdown on airless bodies [7]. Therefore, both phase changes of volatiles and solar-induced thermal stress are plausible mechanisms to cause rock breakdown and trigger rockfalls on modern Mars. The aim of this study is to investigate the mechanism involved in rock breakdown in impact crater walls through the cataloguing of rockfalls in these craters.

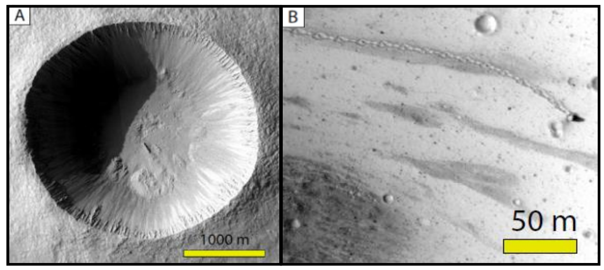

Fig. 1: A: Zumba crater, a morphologically fresh impact crater used in this study. HiRISE image PSP_002118_1510. **B**: Rockfall example displaying a well-preserved trail and 10 m long clast. HiRISE image ESP_037190_1765. Credits NASA/JPL/University of Arizona.

2. Methods

Using HiRISE images at 25-50 cm/pixel, we mapped the tracks left by rocks falling or bouncing from exposed outcrops in 45 impact craters in the equatorial to mid-latitude regions of Mars. Impact craters are widely distributed over the martian surface; thus, one can use them as sample points to test the different factors that may control rockfall. Conveniently, they are circular and therefore allow an assessment of the influence of slope-orientation with respect to the sun. Here, we focus on relatively small (<10 km) and fresh impact craters (Fig. 1A) to reduce the influence of slope-inheritance from other long-term processes. We also calculated surface temperatures of slopes with an angle of 35° facing 4 directions N-S-E-W, in 3 different latitudes using a 1D version of the LMD Mars climate model physics [8] (Fig. 3).

3. Summary and Conclusion

Mid-latitude craters have more numerous rockfalls on equator-facing slopes compared to pole-facing slopes and other orientations. At equatorial latitudes there are more rockfalls on N-S oriented slopes compared to E-W ones (Fig. 2).

In order to verify whether the observed trends are simply a function of asymmetries in slope steepness, we compared our rockfall distribution to slope angle for a sub-sample of craters where we could generate DTM from CTX stereo-pairs. Our results indicate there is no systematic variation in slope angle with orientation that could explain the trends in Fig. 2.

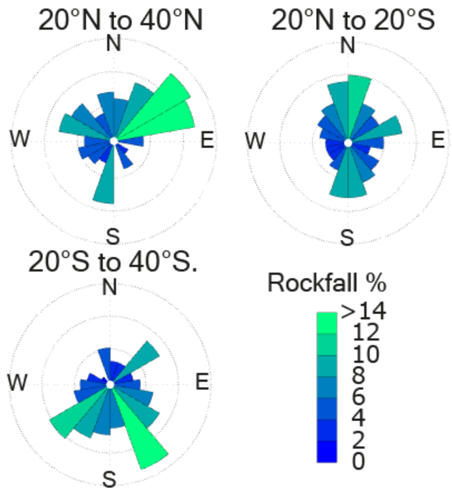

Fig. 2: Standardized distribution of rockfall orientation in fresh impact craters for different latitude ranges (each bin is the mean percentage of rockfalls for a given orientation).

Rockfall events triggered by phase changes should occur where water ice is expected to condense and/or be preserved from previous ice ages (i.e. on pole-facing slopes in the mid to high-latitudes and nowhere at the equator). Therefore, phase changes of H_2O or CO_2 do not seem to play a role in present-day rockfall activity on Mars. Instead, our results show it is likely related to insolation (Fig. 2). Results from the GCM show that at mid-latitude, equator-facing slopes have a higher diurnal range than E-W slopes and pole-facing slopes (Fig. 3), which implies a higher rate of temperature change and potentially higher thermal stress. However, at equatorial latitudes, the model shows that amplitude of temperature is more balanced between different orientations, and E-W slopes have slightly higher diurnal range. This means that simple patterns in insolation are not sufficient to explain the observed rockfall activity trends and other factors not covered by this study (e.g. salt weathering, or combinations of several thermal factors) are likely to influence rock breakdown rate. Moreover, thermal stress mechanisms (thermal shock and thermal fatigue) are still poorly understood and it would require more sophisticated models to take into account combinations of factors.

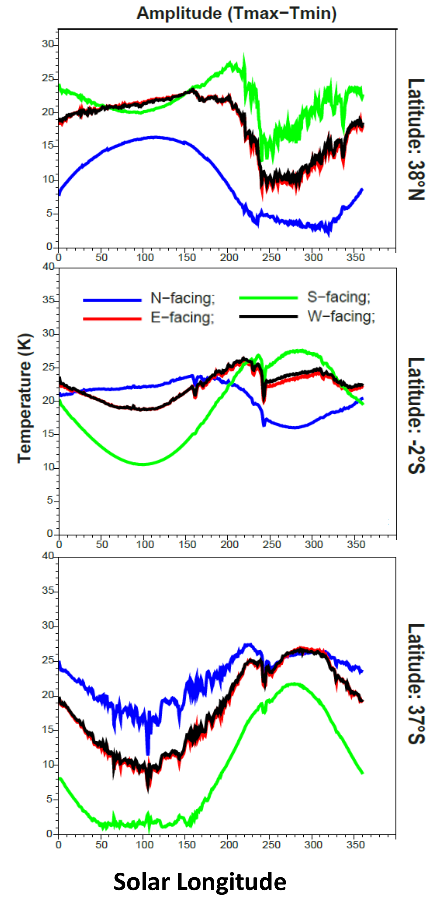

Fig. 3: Surface temperature data calculated using a Global Climate Model [8] for a 35° slope in 4 orientations at different latitudes.

Acknowledgements

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