EPSC Abstracts
Vol. 12, EPSC2018-873, 2018
European Planetary Science Congress 2018

Morphometric Study of Longitudinal Striations on Long Run-out Mass Movements and Ejecta Blankets on Mars: Assessment of a common formation mechanism

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1. Introduction

Distinct longitudinal grooves and ridges ("striations") are an enigmatic and unexplained feature of long run-out landslides on Earth [1, 2] and Mars [3, 4, 5, 6]. They form in different materials and in a wide variety of geological settings, for example in rock avalanches [1, 3, 7], landslides deposited on a glacial substrate [1] and volcanic debris flows [2]. Similar features can also be observed on the ejecta blankets of Martian SLE (single-layered ejecta) craters and DLE (double-layered ejecta) craters [8, 9, 10,11]. Several formation mechanisms have been proposed [5, 6, 7, 8, 9, 10, 11], but it remains a central question whether the striations on different types of deposits form by a common mechanism. We conducted a morphometric analysis on topographic profiles of well-preserved Martian landslides and ejecta blankets of DLE and SLE craters to evaluate the possibility of a common formation process.

2. Methods

Topographic tracks were extracted from DEMs generated from high-resolution CTX (5 m/px) and HiRISE (0.5 m/px) stereo data. Decomposition of the signal with a Fourier analysis shows a power law dependency of power spectral density $S(k)$ on wavenumber k for all profiles, as it can be expected for the self-affine properties of topography in general [12]. The data was fitted using a Maximum Likelihood method in the form

$$S(k) = \alpha k^{-\beta} + \gamma \tag{1}$$

where γ is noise, α is a scaling factor and β the power law exponent. The power law dependence inherently means that the topography of longitudinal striations is scale-invariant and self-affine, e.g. there is no "characteristic width" that can be used to quantify those structures. Instead, the power law exponent β and scaling factor α can be interpreted as surface roughness, since a higher slope of the power law means greater importance of longer wavelengths and a higher scaling factor means a greater absolute height of asperities.

Table 1: List of Datasets used for evaluation.

Deposit	Type	Location	DEM res. $[m/px]$
Capri1	Landslide	8.6°S 44.5°W	5.1
Capri2	Landslide	7.6°S 44.2°W	5.1
Coprates	Landslide	11.8°S 67.8°W	5.1
OphirW	Landslide	11.1°S 68.3°W	5.1
OphirE	Landslide	11.1°S 67.9°W	5.1
Melas	Landslide	8.9°S 71.8°W	6.1
Blunck	Landslide	27.5°S 37.0°W	4.7
Steinheim	DLE crater	54.5°N 169.3°W	4.8
Bacolor	DLE crater	33.0°N 118.5°E	5.5
SL5	SLE crater	34.2°N 109.5°E	0.65
SL7	SLE crater	23.6°N 122.3°E	0.6

3. Results and discussion

We compared the power law exponents and scaling factors of topographic tracks perpendicular to striations ("across") and parallel to flow direction in longitudinal direction ("along"). Additionally we used the values of profiles from the surrounding terrain as reference values, e.g. we assume that those profiles are representative for substrate properties. A preliminary summary of results revealed the following relationships: A) The overall range of values for the power law exponent for all deposits is between β = 1.5 and β = 3.5, but covers a specific, smaller range of values for each deposit (Fig. 1). The power law exponents are in the same range regardless of orientation. Furthermore the topography of the terrain surrounding each individual deposit has similar statistical properties as the tracks across deposits. This implies that the roughness of striations is possibly inherited from the substrate. B) For landslides, the scaling factors are lower in longitudinal direction than in perpendicular profiles, e.g. the relief is more subdued along striations. This implies horizontal stretching of the topography in flow direction. More interestingly, for ejecta deposits, the scaling factors in longitudinal direction are higher than in perpendicular direction. It can be concluded that the Fourier analysis is a suitable method for the quantification and comparison of striations. The results show some common relationships, but also reveal important differences regarding the scaling of ridges. Furthermore the results suggest that the formation process might be influenced by substrate properties. This is indicative for formation by a flow process.

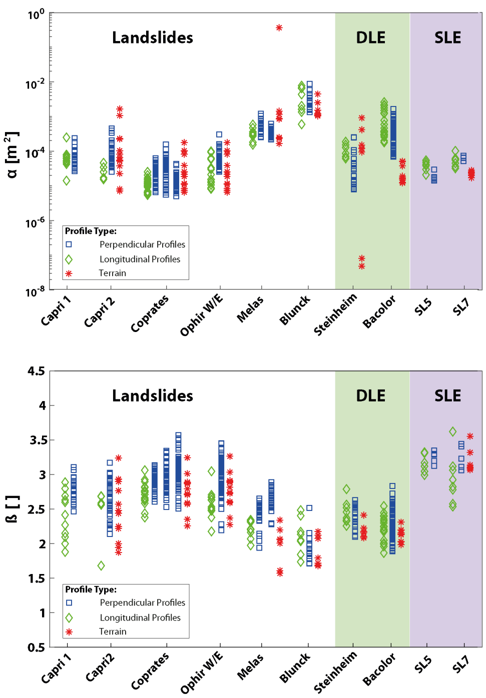

Figure 1: Results for the power law parameters. The different types of topographic profiles are grouped for each dataset (see bottom axis). Top: Results for the scaling factor α, that is a measure for the amplitude of ridges. Bottom: Results for the spectral exponent β, that can be interpreted as surface roughness.

Acknowledgements

This work was funded by a stipend of the LGFG of the Albert-Ludwigs Universität Freiburg.

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