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Impact crater record at the northern patterned ground terrain margin on Mars

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Abstract

This work studies small Martian high latitude impact craters. We focus on the northern polygonal terrain margin, identify and describe crater populations there, associate them with surface texture differences, and show geological evidence of climate changes driven by orbital elements.

1. Introduction

Small impact craters on high latitude polygonal terrains have been shown to exhibit a variety of degradational stages [3]. Those craters are small and rare, almost never have raised rims and are entirely devoid of ejecta fields. This indicates that the surface there is very recent. By doing a systematic search for craters between latitude bands 60°–70° on both hemispheres, it was shown that northern polygonal terrain (NPT) surfaces are much younger than those in the south (SPT) [3]. They attribute this to perihelion season change. Recurring roughly every 50 ka, it affects the polar insolation, which in turn induces net migration of H_2O towards the colder polar region and deposition of water ice there. This has smoothed or obliterated all small craters in NPT within the last few ka – migration to the opposite direction did the same in SPT 10–40 ka ago.

2. Survey

To find and characterize the margins of the NPT region, we conducted a crater and terrain type survey of its margin at eastern Vastitas Borealis region (50–70°N, 0–150°E). Large craters excluded, the surface of this ~1000x4500 km area is generally flat (mean elevation of -4200 m; σ = 320 m). In order to obtain a sample set of uniform quality, we selected only 25 cm/pixel HiRISE images with no seasonal frost. Only images (or their parts) with level surfaces were accepted, avoiding cliffs, steep wall slopes, sharp knobs / mesas and distinctive ejecta fields. So far we have analyzed 38 HiRISE images with a total area of 1596 km^2. Clusters of small craters were considered as single atmospheric meteoroid break-up events with effective crater diameters of $D_{eff} = (\Sigma D_c^3)^{1/3}$ [2].

3. Results

The patterned ground-forming lineaments were found to occur in every image, falling into the following terrain classes: **Type 1**: Smooth large polygons (diameter tens of m), consisting of gentle albedo patterns or wide troughs and intervening hills, creating a hummocky pattern (Fig 1a). **Type 2a**: Small sharp fractures (width <1.5 m, 3–10 m separation), often accompanied by lines of boulders (Fig 1b). **Type 2b**: Pronounced wide sharp fractures (width >1.5 m, 10-500 m separation) which appear to build on Type 2a and often associated ridges (Fig. 1b). The classes are not exclusive; fractures of Types 2a and b often superpose and cut troughs of Type 1. While Type 2b can appear in isolated segments extensively throughout the area, Types 1 and 2a usually exhibit only interconnected patterns. Type 1 smooth polygons are found in abundance throughout the study region, but are often distorted in the north where the fractures are most prominent. Type 2a terrain occurs predominantly north of 57°N and Type 2b north of 64°N.

Crater search revealed further differences between terrains. Types 2a and b have significantly fewer craters than Type 1, consistent with previous observations [3]. To shed more light on this, the distribution and characteristics of 5–50 m craters were closely examined, as they are indicative of near-surface phenomena and recent changes. The youngest subpopulation, namely craters with a sharp slope break between walls and the surrounding surface (Fig. 1a) were specifically considered. They are entirely absent from Type 2a and b terrains, but were, however, observed on solely Type 1 terrains (Fig 1a).

Their size-frequency distribution is shown in Fig. 2 (◆). It should be noted that while the three 40–50 m craters in the plot are "sharp" at their wall breaks, their floors and even walls display slightly stronger modification than those of smaller craters and the surrounding terrain; in one case actually intense fracturing (Fig. 1c). The size-frequency distribution also indicates that they may belong to a different crater population. Thus we additionally plotted the distribution without these craters (◇). The size-frequency distribution of Type 1 terrain sharp craters has a similar shape as the population of sharp craters in the SPT (X), but the crater density is a factor of ~2 higher. The distribution is rather steep (the gentler slope and roll-over at smallest sizes in comparison to the production function is partly caused by seasonal frost). The inferred age is highly uncertain (within 20–100 ka).

4. Interpretation

We find that the occurrence of polygon-forming fractures of Types 2a (small scale) and 2b (strong and pronounced) has a prominent latitudinal trend. All surveyed images north of 60°N exhibit at least one of these types. This is consistent with the extent of current shallow ground ice [1]. We interpret these fractures to be the result of very recent or ongoing permafrost processes within NPT.

We suggest that the set of smooth polygon-forming troughs of Type 1 was formed earlier in a similar process, and that the terrain surrounding the fractured region has previously experienced conditions with shallow ground ice. This is supported by the observations of unique sharp small-scale polygonal fractures on the floors of the 40–50 m craters, suggesting shallow ice exposures within them. The Type 1 troughs are older than the population of sharp craters superposed on them (20–100 ka). It could basically date back to the latest period of higher obliquity (~300 ka). However, the obliteration and smoothing of small craters appears to be much younger than that. We propose that the Type 1 surface has been modified in a similar fashion to what is currently occurring in the NPT, and what occurred at SPT 10–40 ka ago. It is thus suggested that Type 1 terrain is a remnant of one of the latest conditions when the season of Mars' perihelion was similar to what it is now.

Extension of the survey to other longitudes and into the southern hemisphere promises more reliable and detailed results on timing of recent climate-related geological processes.

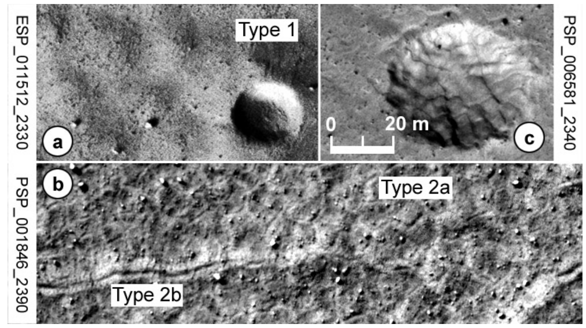

Figure 1: a) Type 1 terrain with superposed sharp crater. b) Type 2a terrain with isolated 2b segments. c) Intensely fractured large crater within Type 1 terrain. Scale applies to all images.

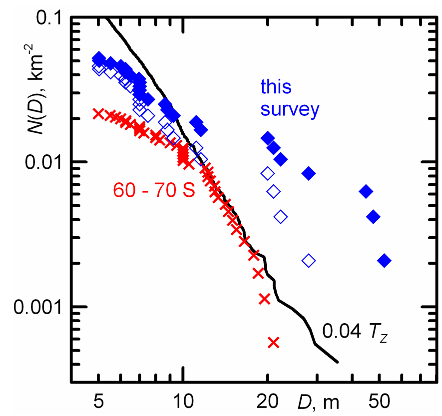

Figure 2: Size-freq. distributions for 'sharp' craters at 60–70°S (X, from [3]) and those from this study (◆). Largest three craters removed (◇, see text). The black line is 0.04 Zunil isochrone, a proxy for production function of small craters roughly corresponding to 10–40 ka age.

References

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