NORTH - SOUTH ASYMMETRY IN DEGRADATION RATERS OF SMALL IMACT CRATERS AT HIGH LATITUDES ON MARS: IMPLICATIONS FOR RECENT CLIMATE CHANGE.
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Introduction: Apparent surface age depends on scale; at smaller scales natural surfaces tend to be younger. All surfaces at high latitudes in both hemispheres of Mars are very young at the small scales, as indicated by general dearth of small impact craters. Except polar layered deposits, dunes, residual ices and rare very steep slopes, all surfaces above 60º latitude are covered with continuous polygonal patterns [e.g., 1-3], regardless of geological settings. The difference in morphology of patterned ground between northern and southern hemispheres is minor despite the strong difference in regional geology. Remote sensing data indicate the presence of large amounts of ground ice in shallow subsurface in these terrains. [e.g. 4 and references therein]. We are carrying out a systematic survey of high-latitude patterned ground on Mars. We focus on population of small impact craters trying to decipher the record of their degradation history. Here we report on an unexpected, strong difference in crater degradation between northern and southern hemispheres.

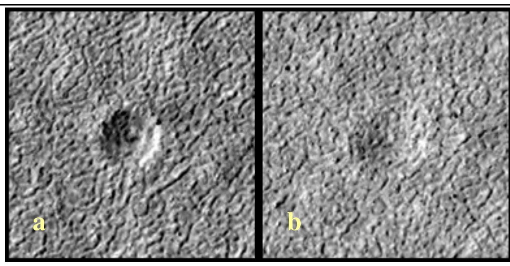

Fig. 1. Typical examples of craterforms in the survey: **(a)** a "sharp" crater **(b)** a smooth depression, presumably a heavily degraded or mantled crater. From HiRISE image PSP_004156_1170, illuminated from upper left, each scene is 50 × 50 m.

Observations: We search full-resolution HiRISE images [5] of patterned ground in 60º - 70º latitude zones in both hemispheres for impact craters. We identify all features that can be considered as small (diameter 5 m < D < 50 m) craters or results of their degradation. Objects smaller than 5 m cannot be recognized as impact features with certainty. For consistency, we use only images taken during the part of martian year where the surface is completely free of the seasonal frost. So far surveyed area totals ~1800 km^2 in the northern hemisphere and ~2200 km^2 in the southern hemisphere. Since HiRISE images are scattered on the surface neither uniformly nor randomly, statistical methods should be applied to results with caution

All craters found so far are at least somewhat degraded in comparison to the fresh (a few years old [6]) same-size craters in ice-rich target: they lack raised rims and ejecta. We distinguish less degraded, "sharp" craters with a sharp slope break between crater walls and surrounding surface (**Fig.1a**), and more degraded craters with smoothed shape (**Fig.1b**) and reduced depth. Degradation sequence of craters is analyzed in [7]. "Sharp" craters can be recognized unambiguously, unlike more degraded craters, whose identification is highly subjective and depends on illumination conditions, the presence of rocks, large-scale topography, image quality, etc.

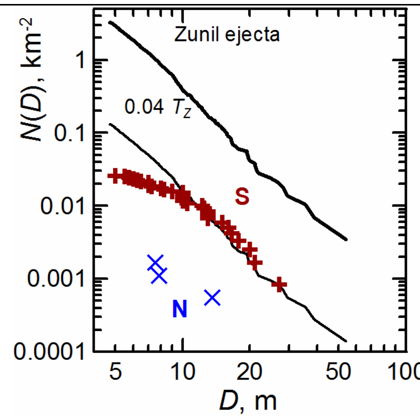

Fig. 2. Size-frequency distributions for "sharp" craters in the S (+) and N (×) polar zones. Thick line shows crater population on Zunil ejecta. Isochrone of 0.04 Zunil ages roughly corresponds to 10 - 40 ka.

Cumulative size-frequency distributions of "sharp" craters in both hemispheres are shown in **Fig.2** along with the distribution for Zunil ejecta that represent production function of small craters on Mars. In the southern hemisphere the size-frequency distribution is rather steep; for larger craters in the studied size range it coincides with production function; inferred crater retention age is within 10 - 40 ka basing on the modern impact rate from [8] corrected in [9]; details of methodology are presented in [10]; uncertainty of the absolute age is very high. In the northern hemisphere we found only 3 "sharp" craters. It is seen that the spatial density (and hence the retention age) of such craters in the northern hemisphere is at least one order of magnitude lower than in the southern hemisphere. Although the absolute age estimates are highly uncertain, the huge difference in the spatial density between hemispheres is very reliable. Non-uniformity and non-randomness of image targeting may contribute a little in the observed effect (the vicinity of Phoenix landing site is a little better represented than other areas in the survey), but this certainly does not define the observed huge difference. The density of heavily degraded craters is also significantly lower in the northern hemisphere, but the uncertainty in identification precludes quantitative comparison.

Discussion. The observed huge difference in the spatial density of the "sharp" small craters begs for explanation. A thicker layer of the *atmosphere* above northern lowlands decelerates projectiles stronger than thinner layer above southern highlands. On the other hand, in the southern polar regions the seasonal frost is thicker and stays longer than in the northern polar regions. The year-average column mass of atmosphere + seasonal frost is greater in the south, hence, the impact rate is greater in the north and cannot account for the observed lack of craters. Thus, the north-south difference is due to much more intensive degradation of the craters in the north.

Since the morphology of patterned ground is quite similar in both hemispheres, it is natural to assume that the observed strong difference in crater degradation rate is related to the *climate difference between north and south polar areas*. At the present epoch the southern summers are significantly warmer and shorter than in the north. The opposite situation occurred ~20 ka ago due to changes of the perihelion season. (**Fig. 3**) The assumption that the crater degradation rates were inverted ~20 ka ago is consistent with the constraints on the "sharp" crater retention age in the south and with rather steep (close to production function) size-frequency distribution.

Deposition and removal of *seasonal frost* may contribute to crater degradation (e.g. due to its weight, spring-time sub-slab gas flows, sudden changes of sub-slab gas pressure, etc.). In the south, the seasonal frost is thicker, and the insolation during its sublimation is higher, hence, all seasonal frost effects are stronger in comparison to the north and *cannot account for* the observed intense degradation in the north.

Dynamic *processes in the patterned ground* do contribute to crater degradation [7]. These processes are ultimately driven by seasonal temperature variations, whose amplitude is significantly higher in the south. The effect of higher temperature amplitude can be overcompensated, if the layer of dry soil above icy soil is significantly thicker in the south. Interpretation of remote sensing data in terms of the dry layer thickness is controversial [e.g., 11, 12], models of ground ice stability do not predict much thicker dry layer in the south (dryer atmosphere is compensated by slightly lower year-average temperature). In summary, there is no reason to expect that the ground-ice-related seasonal processes are much more active in the north than in the south.

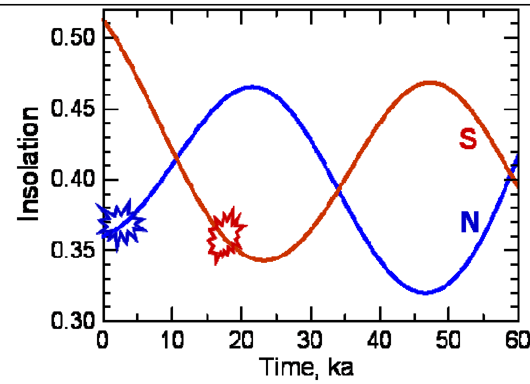

Fig. 3. Evolution of insolation in the polar regions of Mars for in the recent epoch. Marked are hypotetic periods of deposition of icy mantles in the northern and southern polar regions.

As noted in [13], it is possible that martian climate was significantly wetter in a very recent past (~100s years ago) if the perennial solid CO_2 layer was absent, which would be consistent with observations of this layer [14]. Models of atmospheric circulation [15] show that there should be net migration of water from a polar region with warmer summer to the opposite polar region and deposition of water ice. We suggest that *deposition of ice+dust mantles in response to the change of season of perihelion* is responsible for degradation of "sharp" craters. Migration of H_2O from the south to the north have smoothed all "sharp" craters in the north very recently, ~ 1 ka ago, while migration in the opposite direction had effectively done this in the south ~20 ka ago. Redistribution of ice in the ground and further migration of some H_2O to the polar layered deposits occurred concurrently with the mantle deposition. This crater degradation scenario involving mantle deposition is consistent with all our observations.

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