CLIMATE-RELATED ALTERATION OF CRATERS IN THE NORTHERN PLAINS OF MARS.
M. A. Kreslavsky[1,2] and J. W. Head[1], [1]Dept. Geologcial Sciences, Brown University 1846, Providence, RI, 02912-1846, USA; kreslavsky@brown.edu, [2]Astronomical Institute, Kharkov National University, Kharkov, Ukraine.

Introduction: Impact craters are very helpful for studies of many aspects of surface processes on the Solar system bodies. Here we analyze population of impact craters in the Northern Lowlands of Mars, more specifically, within the typical Vastitas Borealis Formation (VBF) [1]. This is the largest geological unit on Mars. It is thought to have rather uniform age approximately at the Hesperian/Amazonian boundary and accumulation population of relatively large impact craters [2]. These craters were presumably formed in rather similar environment and hence initially had similar morphology. Their formation age is uniformly scattered through the Amazonian. **Fig. 1 A – C** show examples of craters studied. Crater A has rougher ejecta and obviously fresher ejecta morphology, and hence is younger than crater B. We study systematically morphology and morphometry of the whole crater population to infer information about crater alteration and surface modification processes and their rates through the Amazonian.

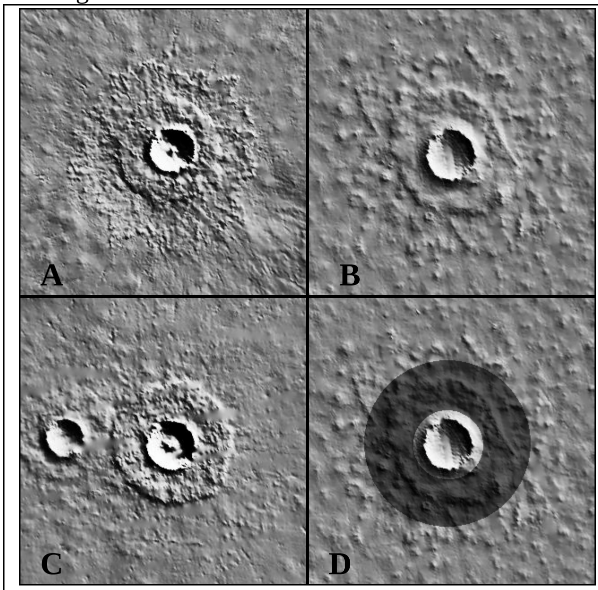

Fig. 1. MOLA-derived simulated shaded topography of craters in the VBF. **A** "Fresh" crater at 73.0ºN 38.3ºE; D = 12.0 km. **B**. "Smoothed" crater at 73.0ºN 22.0ºE; D = 12.9 km. **C**. "second roughest" crater at 69.3ºN 274.0ºE; D = 12.9 km. **D**. Area used for roughness statistics for crater B.

Observations. We considered only craters on the VBF with diameters D from 10 to 25 km. This narrow range of D assured the maximal possible similarity of a pristine ejecta pattern and wall morphology. Almost all these craters have double-layer ejecta. [3] For smaller craters, the ejecta are too poorly sampled with MOLA; for larger craters, the multiple layer ejecta dominate [3]. We excluded craters where large dune fields, ejecta of larger craters, etc. complicate morphology. There is a strong latitudinal trend of subkilometer-scale roughness on Mars caused by climate-related surface alteration [4,5]. In this study we limited ourselves to high latitudes >52°N, that is well within the "smoothed" zone. In total there are 141 craters that match these selection criteria.

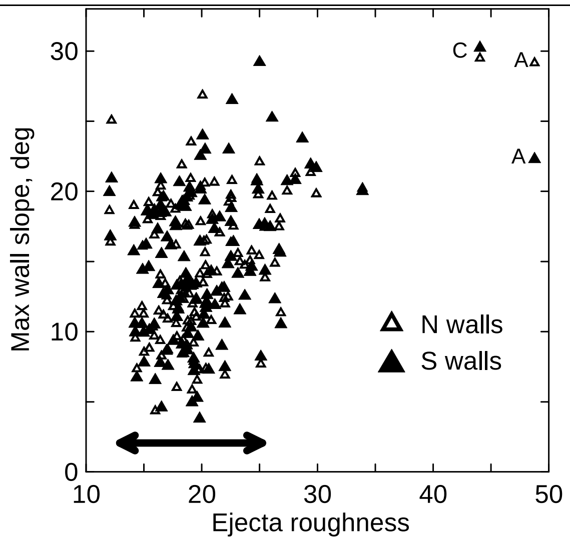

Fig. 2. Scatter diagram of the wall steepness at 0.3 km baseline and ejecta roughness at 0.9 km baseline for 141 craters. Craters A and C are the same as A and C in Fig. 1. Crater B from Fig 1 is close to the center of the cluster. Arrow shows the typical range of VBF roughness.

We use THEMIS VIS and MOC NA images to study morphology of the craters in detail and MOLA data to obtain crater depth, slope steepness and ejecta roughness. As a measure of ejecta roughness, we used the median total surface curvature, which we calculated in the following way. We used gridded topographic data at 128 pixels per degree resolution. In each pixel we calculated two principle curvatures C_1 and C_2 of the surface at 0.9 km baseline and the "total" curvature $C = (C_1^2 + C_1^2)^{1/2}$. For each of the 141 craters, we manually outlined the test ejecta area as a ring loosely inscribing the inner ejecta lobe and excluding the crater rim and floor (**Fig. 1D**). For clearly asymmetric craters we drew a non-circular outline. We preferred this subjective way to mark the test areas, because it allowed us to exclude small craters that overlap the ejecta, as well as to treat overlapping ejecta carefully. Steepness of the northern and southern crater walls at 0.3 km baseline was taken from all individual

MOLA profiles that cross the craters close to their diameters. Some results are presented in **Figs. 2** and **3**.

Synthesis. Below we present a summary of characteristics of several crater modification processes that we infer from the observations.

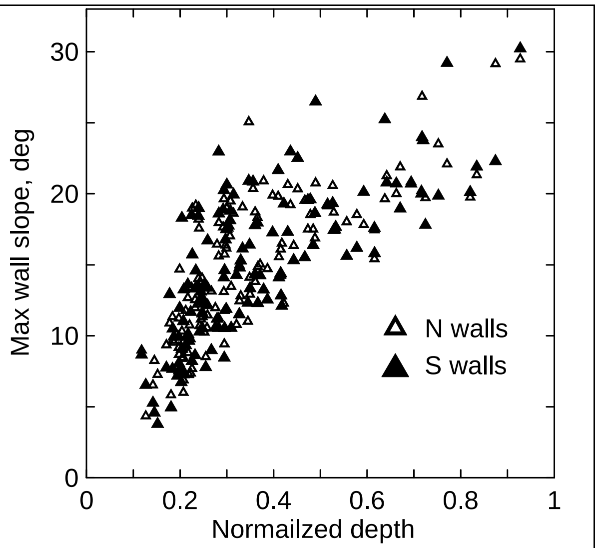

Fig. 3. Scatter diagram of the wall steepness at 0.3 km baseline and the normalized crater depth for 141 craters. The normalized depth is the depth rescaled according to the global depth-diameter trend from [10] and multiplied by an arbitrary constant.

Smoothing (mantling) of ejecta. A few craters (like those in **Fig. 1A,C**) have rough ejecta, while the majority of them (like that in **Fig. 1B)** have smooth ejecta (**Fig. 2**). Thus, smoothing of the ejecta occurs at 10s to 100s Ma time scale, short in comparison to the Amazonian (3.1 Ga according to [7]). High-resolution images show that filling of local lows with mantle material is responsible for smoothing. The roughest ejecta already have well-pronounced mantle in the local lows. This means that the surface smoothing at high latitudes is due to several repeating mantling episodes (ice ages) rather than due to the most recent one.

Several studies have shown that the ejecta volume of the typical craters in Northern plains of Mars is noticeably greater than the cavity volume [e.g. 8]. This has been attributed to deflation of material surrounding the ejecta (an effect similar to pedestal crater formation), which increases the apparent ejecta volume, as well as to crater filling, which decreases the cavity volume. Our morphological observations indicate that emplacement of the mantle material in local lows contributes to the increase of the apparent ejecta volume.

Erosion of crater walls. Craters with rough ejecta (that is the youngest craters) have relatively steep walls (25-30°; see **Fig. 2**). Wall steepness of craters with typical (smoother) ejecta varies in a wide range from ~5° to ~30°. Thus the time scale of wall degradation is longer than the time scale of ejecta smoothing, on the order of 1 Ga.

Almost all craters with relatively steep walls (>~18°) have recent gullies. Erosion of the walls by gully-forming flows [e.g. 9] is one of the mechanisms of wall degradation. In the equatorial region, where gullies are absent, typical crater walls are 30-40° steep, that is steeper than the steepest slopes in the VBF. Gullies are not observed on gentle slopes (<~18°). This is consistent with gullies formed by debris flow rather than water flow [9]. Some other mechanisms are responsible for further degradation of the walls. Generally the amount of crater wall erosion is small, because all craters in the survey have well preserved rims (intense erosion would remove them). This indicates that the climate conditions favorable for gullies formation occurred not frequently in the Amazonian.

Crater filling. Depth / diameter ratio of the VBF craters has been known to be scattered in a very wide range [e.g., 10, 11]. The youngest craters (with rough ejecta) are deep. There is a correlation between wall steepness and relative crater depth (**Fig. 3**). Thus the decrease of crater depth (crater filling) occurs at the same time scale as wall degradation, that is ~1 Ga.

Erosion of the crater walls is not responsible for crater filling: erosion would remove the rims much earlier than make the cavity shallower. We observe migrating sand trapped by craters with steep walls. This is one of the mechanisms that contribute to crater filling. We also observe indication of thick layers of ice-rich material in the craters (concentric crater fill, large-scale polygons etc.). This ice can be deposited from the atmosphere. Alternatively, this ice can be not completely sublimated residue of frozen water flooded the lowlands during Amazonian-age outflow events.

Future work: Study of smaller craters with HRSC stereo images can provide better timing estimates. Comparison of the VBF crater population with craters on other terrains is a clue for understanding of latitudinal, elevational and regional trends.

References: [1] Tanaka K. L. et al. (2003) *JGR 108*, 8043. [2] Tanaka K. L. et al. (2005) *LPS XXXVI*, 2162. [3] Barlow N. G. (2005) *LPS XXXVI*, 1415. [4] Kreslavsky M. A. and Head J. W. (2000) *JGR, 105,* 26695-26712. [5] Kreslavsky M. A. and Head J. W. (2003) *GRL 30,* DOI 10.1029/2003GL017795. [6] Kreslavsky M. A. and Head J. W. (2002) *GRL, 29,* DOI 10.1029/2002GL015392. [7] Hartmann W. K. and Neukum G. (2001) *Space Sci. Rev. 96*, 165-194. [8] Black, B. and S. Stewart (2005) Conf. on the Role of Volatiles and Atmospheres on Martian Impact Craters # 3044. [9] Costard et al. (2002) *Science 295*, 110-113. [10] Garvin, J. et al. (2000) *Icarus 144*, 329 – 352. [11] Boyce, J et al. (2005) *JGR 110*, E03008, DOI 10.1029/2004JE002328