Organization of Rocks on Patterned Ground in the Northern Latitudes of Mars.

T. C. Orloff[1], M. A. Kreslavsky[2], and E. Asphaug[3]. [1]torloff@ucsc.edu Department of Earth and Planetary Sciences University of California Santa Cruz 1156 High St. Santa Cruz California 95064

Introduction: The Phoenix Lander recently observed water ice within centimeters of the Martian surface and achieved many of the mission's goals [1][2]. Detailed (25-50cm/pixel) satellite imagery of the landing location show a terrain covered by patterned ground landforms. Here we quantify the migration of rocks on the surfaces of these patterned landforms, by studying the timescale and spatial scale of patterning around recently excavated impact craters.

Background: Patterned ground on Earth is often caused by fluctuations of ice and water in soils. The two general hypotheses for the formation of patterned ground are (1) soil convection due to ice behavior at the freezing front [3], and (2) crack propagation and wedge formation [4]. Sublimation polygons (a type of crack propagation style patterned ground) are a favored mechanism for patterned ground formation in the Phoenix landing site terrains [5][6].

Examples of sublimation polygons have been described in Martian analog field studies in the Dry Valleys, Antarctica [7]. Observations of these polygons have shown that ice cemented soils may contract during a negative temperature shift, forming cracks where the stresses exceed the strength of the soil.

Sand particles may infill the crack and during positive temperature shifts, cause soil expansion. The crack will be unable to seal owing to infilling of dust and sand. Multiple iterations could form meter scale topographical landforms and, over time, broad deformation in the upper meters.

Patterned ground does not only organize the soil of the surface. Rocks are also incorporated into the patterning effect [8], and these are the subject of our study, as tracers of the geomorphic motion. This study looks at the organization of rocks near craters in patterned ground terrain on Mars to determine how patterned ground organizes rocks at the surface over different time scales.

Craters are ideal places to study rock organization in patterned ground because craters create a predictable, observable, cobble-boulder sized rock population the pattern-forming surface may act upon. Crater population statistics also allow us to propose estimates for the timescales under which these forces act and ages for the surface. Future work will make use of the predicted clast radial size distribution with distance from the impact center.

Hypothesis: Rock density is observed to increase with proximity to craters [9]. We assume that the majority of rocks at the surface are created during impact processes and distributed via ejecta or crack propagation through the surface.

As the surface evolves, patterned ground will begin to reform the degrading crater. Buried rocks will be brought to the surface over time (and possibly stranded there); along with rocks already there they partake in the patterning and become organized.

Further degradation – primarily, the breaking down of rocks by meteoritic bombardment or frost erosion -- will eventually remove the rocks at the surface, and exhaust any supply of subsurface rocks, leaving the patterned ground devoid of rocks. Rocks may also be removed due to aeolian erosion, reburial or transport to regional topographic lows. Eventually the crater itself will degrade and disappear.

Data: Our data comes from scanning HiRISE images (initial results plotted in figures are from images PSP_007593_2480 and PSP_007738_2480) in polar latitudes of the northern hemisphere of Mars. We document by hand all visible circular features with radius greater than 20 meters. Polar latitudes are chosen because patterned ground is ubiquitous throughout the region longitudinally and overlie almost all landform features, although we take care to separate the various terrain types in our analyses.

All circular features observed are assumed in this study to be craters. Each crater's diameter is measured and is given two numbers to characterize its appearance.

Rock Organization		Crater Degradation	
No rocks	0	Undegraded	1
No organized rocks	1	Minor degraded	2
Some organized rocks	2	Middle degraded	3
Highly organized rocks	3	Major degraded	4
		Totally degraded	5

Figure 1 shows the results of the statistical analysis of the crater size-frequency distribution (SFD). The plot shows the SFD superposed over Neukum production function (NPF) isochrones. Shown are isochrones for boundaries between geological periods on Mars (according to their original definition by Tanaka [10]), as well as isochrones for 50, 100, and 200 Ma. Error bars for SFD show formal 90% confidence interval.

Figure 2 shows the results of the visual characterization of craters. Data is formatted into # of craters as a function of crater degradation and rock organization.

Preliminary Results: Results of the analyses on Figure 1 and 2 are discussed here.

Crater SFD Results. The first notable observation of the Crater SFD (Figure 1) is the removal of small craters from the population. The smallest observable crater in this region is on the order of 50m in diameter. Smaller impacts are known to occur [11] but are not seen on the surface here. This implies reworking of the surface at short time scales.

The second result is that there appear to be three populations of craters here. The first population, D > 400 m has a crater retention age that is Early Amazonian and is indistinguishable from the NPF for the Vastitas Borealis Formation. The same conclusion was reached by Kostama et al. [12] for craters D > 800m for the global population of such features in the northern lowlands from MOC. There is also a steeper part of the SFD for D ~ 300m. According to the NPF, the confident interval for crater retention age for craters 270 m < D < 400 m is 1.1-1.9 Ga (90% confidence interval). For smaller sizes, the effective crater retention age is progressively younger. For 150 m < D < 270 m, for example, it is about 350 Ma. Based on patterning of all small craters, the upper boundary in time of rock organization is at 4.5 Ma.

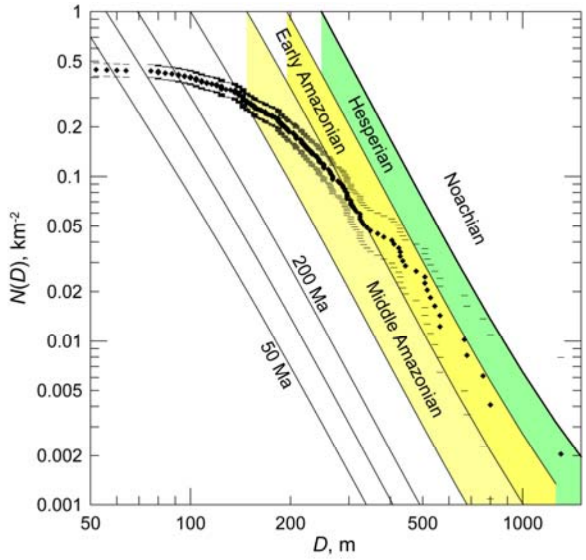

Figure 1 Crater Size-Frequency Distribution for Images PSP_007738_2480 and PSP_007589_2480: Note the three population of craters: D > 400 m, 270 m < D < 400 m, and 150 m < D < 270 m.

Crater Characterization Results. Rock organization in this area is associated to both the formation of nearby craters and the patterned ground mechanism acting upon the surface. Young craters are not patterned, and older craters tend to lose rock organization, hence the bimodal shape of the distribution. Middle-aged craters tend to have rocks that are the most organized.

Our interpretation is that the time scale of rock organization is much faster than the timescale of crater degradation. Rocks go away (through disruption or burial) causing less organization over time among older craters.

Discussion: It appears that the majority of rocks on the surface of the northern lowlands on Mars are related to nearby impact craters. Patterned ground, ubiquitous throughout the northern lowlands, organizes these same rocks into the local polygons that have formed. While the extent to which these rocks partake in the organization is not yet understood, their use as tracer particles indicates that patterned ground formation in the Phoenix landing site terrain has a time scale of order 1 Ma.

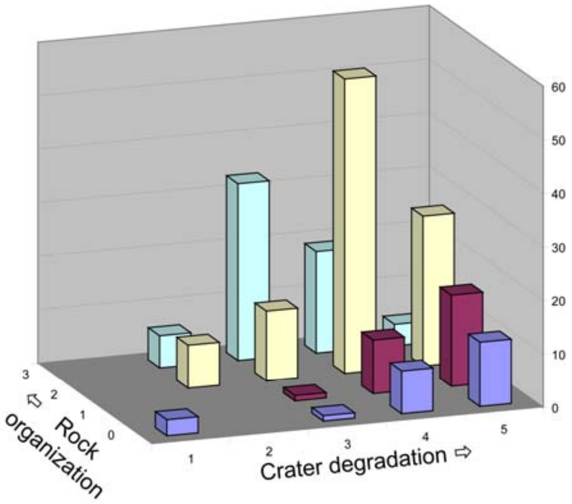

Figure 2 Results of Crater Characterization for Images PSP_007738_2480 and PSP_007589_2480: Number of craters as a function of rock organization and crater degradation.

References: [1] Smith, P. H. et al. (2008) JGR, 113, E00A18. [2] Smith, P. H. et al (2008) Phoenix Mission News Conference, June 20, 2008. [3] Krantz W. B. (1989) Earth-Science Reviews, 29, 117-130. [4] Mellon M. T. (1997) JGR, 102, 25617-25628. [5] Levy J. S. et al. (2008) GRL, 35, L04202. [6] Mellon M. T. (2008) JGR, 113, E00A23. [7] Marchant D. R. and Head III J. W. (2007) Icarus, 192, 187-222. [8] Kessler M. A. et al. (2001) JGR, 106, 13287 – 13306. [9] Golombek M. P. et al. (2008) JGR, 113, E00A09. [10] Tanaka K. and D. Scott (1987) USGS Miscellaneous Investigations Series Map I–1802–C. [11] Hörz F. et al. (1999) Science, 285, 2105 – 2107. [12] Kostama V. M. et al. (2006) GRL, 33, L11201.