**GEOGRAPHIC VARIATIONS IN POLYGONAL GROUND ON MARS: POLYGON SIZE AND ITS RELATIONSHIP TO GROUND ICE.**

M. T. Mellon[1], G. Osterman[1,2], and, M. L. Searls[1] [1]Laboratory for Atmospheric and Space Physics, Univ. of Colorado, Boulder, 80309-0392, [2]Colorado School of Mines, Golden 80401.

**Introduction:** Polygonal landforms were first observed on Mars in only a few Viking Orbiter images [*Evans and Rossbacher*, 1980; *Brook*, 1982; *Lucchitta*, 1983] with diameters exhibited of order 100 m. During the past decade, however, polygonally-patterned ground with diameters of 15 m and up have been found to be common in the middle and high latitude regions of Mars [e.g., *Mangold*, 2005]. Mars Orbiter Camera (MOC) images have shown many locations with abundant regular arrays of semi-hexagonal interconnected troughs [e.g., *Malin and Edgett*, 2001; *Seibert and Kargel*, 2001; *Mangold*, 2005]. The High Resolution Imaging Science Experiment (HiRISE) on Mars Reconnaissance Orbiter, with up to 25 cm/pixel resolution, has revealed that polygonal patterns are ubiquitous with diameters less than 5 m to more than 25 m [e.g., *Mellon et al.,* 2008; *Levy et al.*, 2009].

Martian polygonally-pattern ground, as on Earth, is believed to form by thermal contraction of ice-rich permafrost. As such, the distribution and characteristics of polygonal ground serves as a useful indicator of the recent past and present distribution of ice in the martian shallow subsurface, and of the climate conditions under which these features have formed.

In this work we examined HiRISE images from the middle and high latitude regions of Mars for occurrence of polygonal patterns. We measured the physical characteristics of these polygons (with focus on the distribution of diameters) and compared these observations with theoretical predictions of thermal contraction polygon formation on Mars in order to assess the distribution and history of ice-rich permafrost.

**Polygons:** In terrestrial permafrost, polygonally-patterned ground is common throughout the high latitude frozen landscape. These features form when permanently ice-cemented ground undergoes seasonal cooling and thermal-contraction, which results in tensile stresses. When these stresses exceed the strength of the frozen-soil matrix, cracks develop into this permanently frozen portion of the ground, and form a reticulate or honeycomb network, relieving thermal contraction stresses [e.g., *Lachenbruch*, 1962].

Over time cracks become incrementally filled. In regions where a thaw layer and runoff occur above the fractured permafrost, such as in northern Canada and Siberia, liquid water can infiltrate the cracks and freeze to form a subsurface ice wedge [*Black*, 1976]. In arid regions analogous to Mars, such as the Antarctic Dry Valleys, dry surface soil falls into the open crack and forms a subsurface accumulation of fine material often termed a "sand wedge" [*Péwé* 1959; 1974]. These cracks open no more than a few millimeters in any one year. However, repeated cracking and wedge growth in the same locations each year integrates the incremental seasonal strain and develops visible (sometimes pronounced) topographic relief after hundreds or thousands of years. Polygon topography can be quite varied, but is typically demarcated by a perimeter trough and some degree of interior uplift and/or deformation.

**Mars Observations:** In this work HiRISE images were examined over a range of latitudes. Images containing clearly defined polygonal ground were identified and the polygon diameters were measured for several sample areas in each image. Roughly 50-100 polygons were measured per sample area for statistical analysis. In images where superimposed polygons scales were observed, the smallest scale was analyzed in this study. Example study areas and polygonal ground are shown in Figure 1. Polygons were observed in all images poleward of about 35º-40º consistent with earlier studies [*Mangold*, 2005; *Levy et al.,* 2009].

Initial results show that mean polygon diameters decrease by about 2x from nearly 8 m at 40º latitude to less than 4 m at 70º latitude. This observation is in contrast to that reported by *Mangold* [2005] who found an increase in polygon size (~15-30 m) with increasing latitude (~50º-75º). This discrepancy may be the result of lower MOC resolution relative to HiRISE and the inability of MOC to distinguish polygons smaller than about 10 m. Often, a superposition of polygon scales is observed. Smaller polygons regularly subdivide larger forms. The larger forms exhibit wider and deeper perimeter troughs, which are more visible at MOC resolution. One hypothesis is that the larger polygons are a relic of an earlier climate and that smaller (and fresher appearing) polygons are modern. [*Mellon et al.* 2008].

**Numerical Analysis:** Theoretically, polygon size is defined by the ideal spacing between cracks that sufficiently relieves stress such that further cracking and subdivision is not warranted. A large polygon will subdivide into smaller forms if the interior stresses remain high. This process depends on many factors, such as ice-table depth, climate conditions, and latitude, all of which seasonal permafrost temperatures. In addition, ice content plays an important role. It is anticipated that polygons will be smaller at higher latitude because the mean temperatures are lower, hampering viscous relaxation of the ice-soil matrix [*Lachenbruch*, 1962; *Mellon*, 1997]. In addition, a shallower ice table at higher latitude will allow seasonal surface temperatures to more efficiently penetrate the ice-rich portion of the subsurface. Larger temperature oscillations in shallow ice-cemented ground will increase the stresses and facilitate subdivision and formation of smaller polygons. Finally, thermophysical properties of the surface (thermal inertia and albedo) will strongly influence the seasonal temperatures. All of these factors are examined to determine the effective polygon diameter utilizing a finite element model of thermal contraction stress and strain in martian permafrost [*Mellon et al.,* 2008].

This model treats the ice cemented permafrost as a Maxwellian viscoelastic solid [*Lachenbruch*, 1962; *Mellon*, 1997]. Cooling and thermal contraction in the absence of strain results in an instantaneous elastic stress. This stress is gradually relieved by non-Newtonian viscous relaxation of the ice or ice-soil matrix. Fractures further relieve thermal contraction stress through elastic strain. As temperatures change through diurnal and seasonal cycles, cyclic compressive and tensile stresses are generated.

From these calculations the seasonal peak stress in the center of a polygon of given size is examined. If this stress exceeds the tensile strength, the polygon size is deemed too large and subdivision would occur. When peak stress equals strength a characteristics size is determined. Parameters noted above (ice depth, latitude, etc.) are varied and compared with observations. Results of these analyses will be presented.

**References:** [1] Black, R F, *Quaternary Res., 6*, 3-26 (1976). [2] Brook, G A, Reports of the Planetary Geology Program, *NASA Res. Memo TM 85127*, 265-267 (1982). [3] Evans, N, and L A Rossbacher, Reports of the Planetary Geology Program, *NASA Tech. Memo. TM 82385,* 376-378 (1980). [4] Lachenbruch, A H, *Geol. Soc. Am. Spec. Paper*, *70*, 69 pp (1962). [5] Levy, J, et al., *J. Geophys. Res., 114*, E01007 (2009). [6] Lucchitta, B K, in *Permafrost: Fourth Inter. Conf. Proc*, Natl. Acad. Press, Washington (1983). [7] Mangold, N, *Icarus, 174*, 336-359 (2005). [8] Malin, M C, and K S Edgett, *J. Geophys. Res. 106* (E6), 23429–23571 (2001). [9] Mellon, M T, *J. Geophys. Res., 102*, 25,617-25,628 (1997). [10] Mellon, M T, et al., *J. Geophys. Res., 113,* E00A23 (2008). [11] Péwé, T L, *Amer. J. Sci., 257,* 545-552 (1959). [12] Péwé, T L, in *Polar Deserts and Modern Man*, Editors, T L Smiley and J H Zumberge, Univ. of Arizona Press (1974). [13] Seibert, N M, and J S Kargel, *Geophys. Res. Let., 28,* 899– 902 (2001).

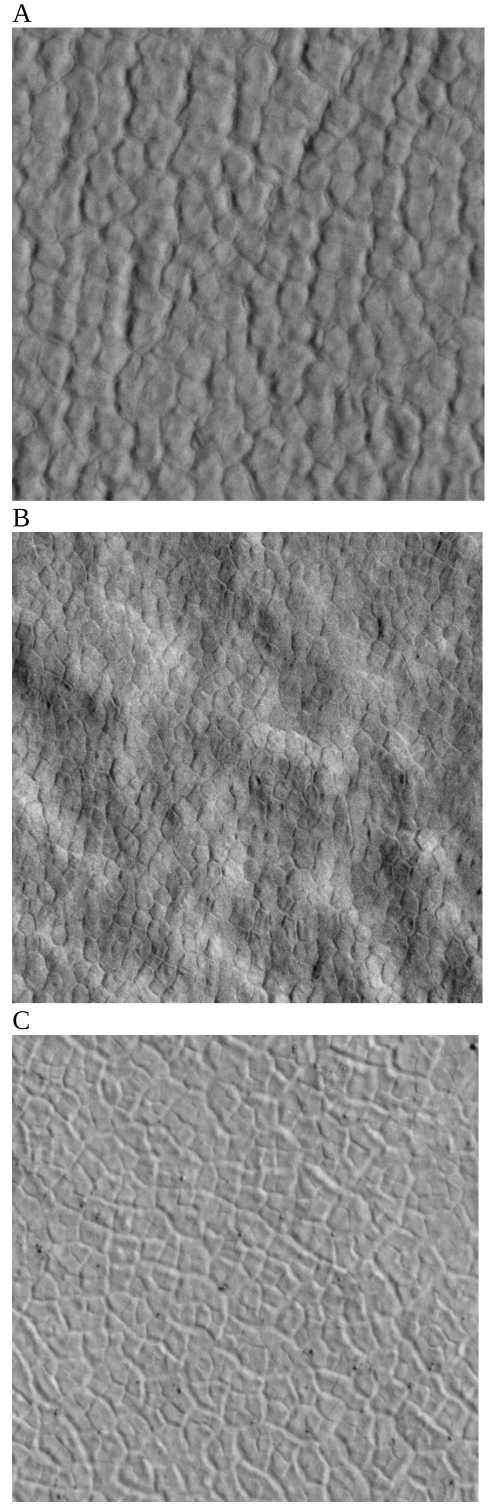


Figure 1. Examples of polygonal ground observed by HiRISE at different northern middle and high latitude locations (A) 43ºN, (B) 54ºN and (C) 71ºN. with mean polygon sizes of 6.9 m, 5.2 m and 4.2 m respectively. Scene widths are ~ 120m. Illumination is from the right to upper right and north is down.