POLYGONAL PATTERNED GROUND AND SORTED ROCKS ON MARS AS SEEN BY HIRISE: THE PHOENIX LANDING SITE, NORTHERN PLAINS, AND BEYOND. M. T. Mellon[1], R. E. Arvidson[2], J. J. Marlow[3], R. J. Phillips[2], E. Asphaug[4], M. L. Searls[1], S. E. Martinez-Alonso[1,5], and the HiRISE Team, [1]Laboratory for Atmospheric and Space Physics, Univ. of Colorado, Boulder, [2]Dept. of Earth and Planetary Sciences, Washington University, St. Louis, [3]Dept. of Earth Science and Engineering, Imperial College London,, [4]Dept. of Earth and Planetary Sciences, Univ. of California, Santa Cruz, [5]Dept. of Geological Sciences, Univ. of Colorado, Boulder.

Introduction: The High Resolution Imaging Science Experiment (HiRISE) has revealed unprecedented detail of periglacial landforms on Mars. In particular, polygonal patterned ground is far more widespread than previously observed. Patterns come in two key forms, polygonal networks of shallow troughs and self-organized surface rocks and boulders. Analyses of these features and their characteristics are valuable towards understanding the distribution, nature, and history of subsurface ice on Mars.

Here we examine the characteristics of polygons and boulder distributions in comparison with terrestrial analogs and numerical models. We emphasize analysis of landforms in the region of the Phoenix landing site (at 68ºN). Additionally, we extend our analysis to the northern plains and the southern highlands in general.

Polygons and Sorted Rocks in Brief: Perhaps the most striking and widespread landforms in terrestrial permafrost are thermal-contraction polygons. Seasonal temperature cycles in permanently-ice-cemented soil produce thermal-contraction stresses, which can result in a honeycomb network of fractures [1,2]. Over time and in arid climates such as on Mars, small open fractures consume loose surface sand and dust, building a subsurface 'sand wedge' and surface troughs [3]. On long time scales continued growth of the sand wedge can force subsurface material into the polygon interior and result in uplift.

Self organization of rocks is also common in terrestrial cold climates, a result of freeze-thaw driven heave [4]. However, in permanently frozen climates, where freeze-thaw is generally absent, rocks may also be driven to the surface by the uplift associated with sand-wedge growth [5] and surface creep [6].

HiRISE Observations: HiRISE on the Mars Reconnaissance Orbiter acquires images with a resolution up to 25 cm/pixel, and a high signal-to-noise that allows for imaging in high-latitude low-light conditions. HiRISE images exhibit an abundance of polygons. Nearly all images obtained poleward of about 60º latitude (and many images between 30-60º latitude) contain small-scale polygonal networks.

Figure 1 shows some examples of polygonal patterns in the region of the Phoenix landing site. Polygons are generally marked by a perimeter trough of order a meter wide and a few decimeters deep. Polygons are largely hexagonal with three-way trough intersections. From polygon to polygon, troughs mostly connect in zigzag patterns, but sometimes join to form what appear to be fragments of larger-scale patterns.

The regularity in size of these polygons is illustrated in the histogram in Figure 2. A mean diameter of about 5 m dominates the Phoenix landing site and similar latitudes in the Northern Plains. Typical terrestrial sand-wedge polygons are larger, 10-35 m [5,7].

Rock sorting is observed in these terrains. Figure 3 shows regularly spaced groupings of rocks and boulders, 'rubble piles', typically 20-35 m apart. At low resolution these rubble piles have been referred to as basketball terrain [8]. Figure 4 shows rocks and boulders collected into the troughs of small-scale polygons.

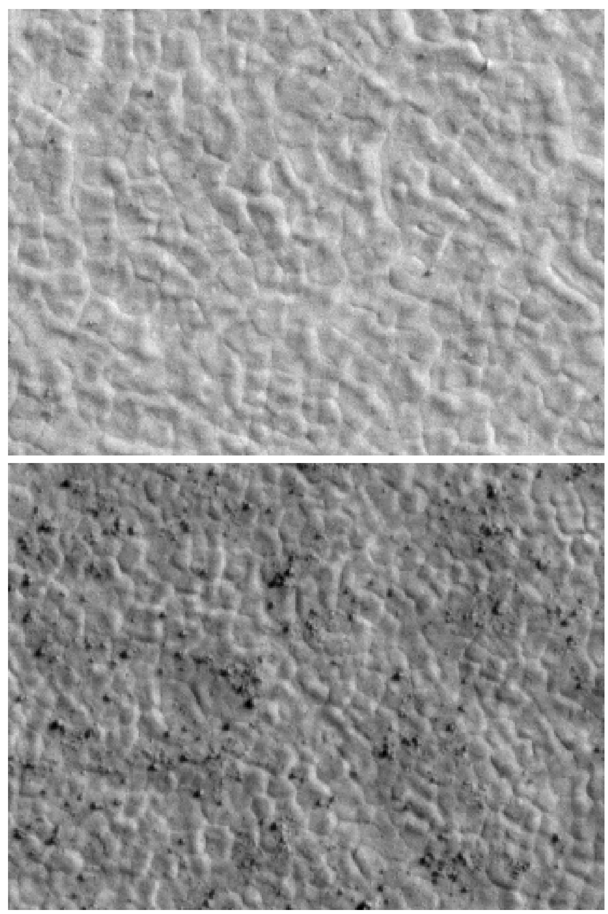

Fig 1. Portions of HiRISE images PSP_002170_2485 (top) and PSP_001959_2485 (bottom) showing abundant small-scale polygons. Scenes are 100 m wide. In all images illumination is from the upper right.

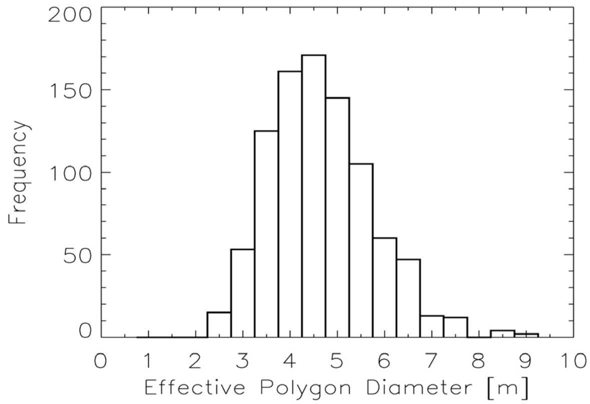

Fig 2. Size distribution of small polygons in the region of the Phoenix landing site. The mean is 4.6m.

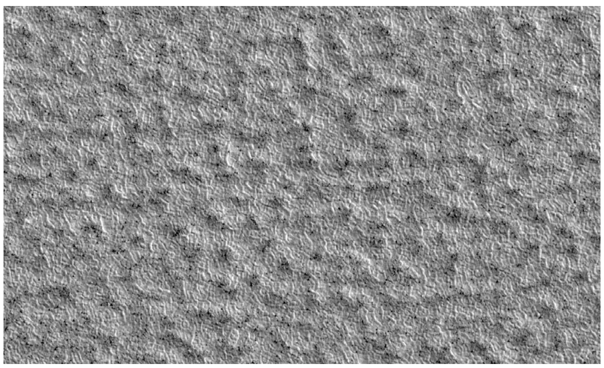

Fig 3. Regularly spaced rubble piles in HiRISE image PSP_002025_2485. Scene width is 500 m.

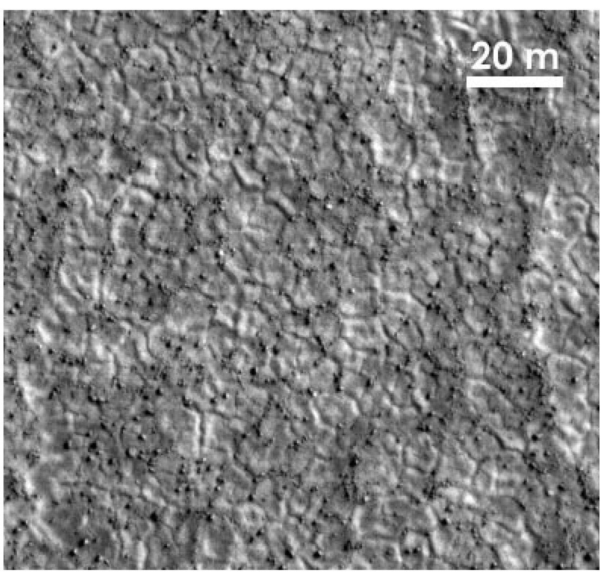

Fig 4. Boulders organized into polygon troughs in HiRISE image PSP_001381_2485.

Polygon Model: To better understand the nature of the observed polygons we modeled the stress that would occur in martian permafrost undergoing seasonal thermal contraction. By varying the depth of the ice-rich permafrost below loose dry soil, the rheology of the subsurface between that of ice-rich soil and pure ice, and the polygon size (in terms of crack spacing) we are able to evaluate if polygons can form this way and , if so, place constraints on conditions on Mars.

Figure 5 shows the peak stress results. Assuming a tensile strength of 2 MPa [9], ~5 m polygons are the preferred size if the ice table is less than ~6 cm below the surface [10]. Larger than 5-m polygons will experience stresses in the center adequate to subdivide the polygon, thus forming of smaller networks.

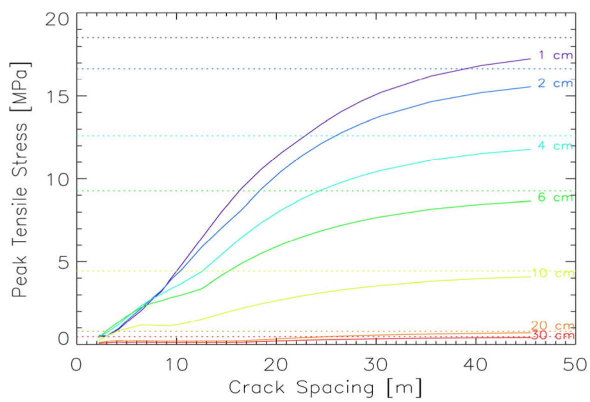

Fig 5. Modeled tensile stress that occurs in the center of a polygon for ice table depths of 1-30 cm, assuming climate conditions at Phoenix landing-site latitudes.

Summary: For latitudes and climate conditions for the Phoenix landing site and Northern Plains, the morphology, size, and location of polygonal ground is consistent with thermal-contraction cracking in ice-rich permafrost. The depth of the ice-rich layer needs to be ~6 cm or less below a layer of loose ice-free soil, else the polygon size will be larger than is observed.

Rock sorting in the thermal-contraction polygon troughs and the 20-35 m spacing of rubble piles suggest that overturning of the regolith by sand-wedge growth is responsible for sorting surface rocks. Freeze-thaw processes are not needed to either to form the observed polygons or to self organize rocks.

References: [1] Leffingwell E. K. (1915) *J. Geol., 23,* 635-654; [2] Lachenbruch A. H. (1962) *Geol. Soc. Am. Spec. Paper 70,* 69p.; [3] Péwé T. L. (1974) in *Polar Deserts and Modern Man*, U. of A. Press; [4] Hallet B. and Prestrud S. (1986) *Nature, 426,* 797-802; [5] Sletten R. S. et al. (2003) *J. Geophys. Res., 108,* 8044; [6] Washburn A. L. (1956) Geol. Soc. Amer. Bull., 67, 823-865; [7] Black (1976) *Quaternary Res., 6,* 3-26; [8] Malin M. C. and Edgett K. S. (2001) *J. Geophys. Res. 106*, 23429–23571; [9] Mellon M. T. (1997) *J. Geophys. Res., 102,* 25,617-25,628;[10] Mellon M. T. et al. (2004) *Icarus, 169,* 324-340.