COMPARATIVE MORPHOMETRIC ANALYSIS OF POLYGONAL TERRAIN AT POTENTIAL MARS PHOENIX LANDING SITES.

T. W. Haltigin[1], W.H. Pollard[1], G.R. Osinksi[2], and P. Dutilleul[3], [1]Department of Geography, McGill University, 805 Sherbrooke St. W., Montreal, QC, CANADA, H3A 2K6 (timothy.haltigin@mail.mcgill.ca, pollard@geog.mcgill.ca), [2]Departments of Earth Sciences / Physics & Astronomy, University of Western Ontario, 1151 Richmond St., London, ON, CANADA, N6A 5B7 (gosinski@uwo.ca), [3]Department of Plant Science, McGill University, Room R2-019, Raymond Building, 21111 Lakeshore Road, Ste. Anne de Bellevue, QC, CANADA, H9X 3V9.

Introduction: Launched in August 2007, the Phoenix lander is scheduled to touch down in the northern plains of Mars on May 25, 2008. Amongst others, key mission objectives include studying the history of Martian water and physically examining ice and regolith samples delivered to the vehicle by a robotic digging arm (RA).

The scientific goals thus required a landing site believed to contain ice-rich deposits found beneath a relatively thin cover of dry regolith so as to maximize the potential for the RA to access samples containing water ice [1]. As such, it was necessary to select a region based partially on geomorphic evidence suggestive of abundant quantities of ground ice.

In terrestrial polar environments, perhaps the most obvious indicator of shallow subsurface ice is a landscape feature referred to as *polygonal terrain* - a network of interconnected trough-like depressions on the ground surface that form within ice-cemented soils in regions of continuous permafrost [2]. Based on various lines of reasoning [3-5], it is thought that morphologically similar landforms on Mars may also be indicative of ice-rich ground. As a result, it was decided that Phoenix would aim to land at a site containing such terrain [1].

While, certainly, inspection of available HiRISE imagery has revealed that these features are widespread throughout the potential landing region (Fig. 1), the morphologies observed at individual sites are quite diverse. The overarching goal of this work is to provide a detailed comparison of the polygons' geometric characteristics at numerous locations throughout the landing region, which in turn may yield insight about the physical processes acting at various locations and may reflect variation in near-surface ground-ice content.

Polygon Formation and Development: It is believed that Martian polygonal terrain is formed in a similar fashion as its terrestrial counterpart, through a process termed 'thermal contraction cracking' [3]. Decreases in surface and subsurface temperatures in the winter lead to the development of tensile stress within the ground. If and when the accumulated stress exceeds the ground's tensile strength, a series of vertical cracks open and extend laterally along planes of weakness in order to relieve the stress [6]. Eventually, the cracks interconnect to form enclosed geometric shapes that may continue to subdivide if stress buildup over subsequent years is sufficient to induce further cracking. Thermal expansion processes resulting from seasonal warming lead to redistribution of surface materials, forming the depressions along the crack as well as shoulder-like ridges of material bounding the troughs [7]. Over time, the troughs continue to widen and the ridges become increasingly pronounced [8].

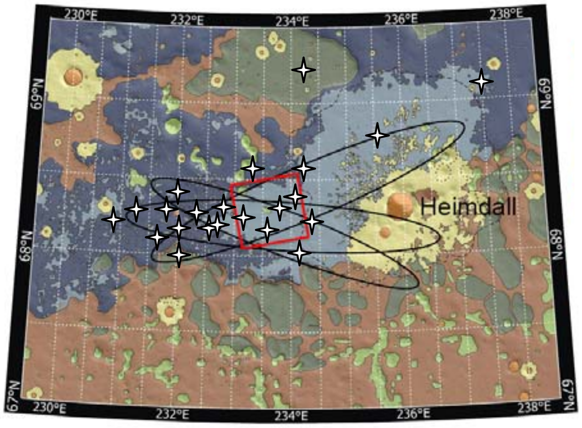


Fig. 1: *Locations of HiRISE images containing polygonal terrain in the vicinity of the Phoenix landing ellipses. (Geomorphic basemap and ellipse definition credit: K.D. Seelos; image available at http://www.nasa.gov/images/content/183675main_ra3-ellipse-label-hires.jpg)*

Given the dependence of terrestrial polygon morphology on local climate [2], surface age [8], and surface material [9], an examination of certain geomorphic characteristics of polygons at a given site can provide information as to the mechanisms responsible for a landscape's appearance. However, it is almost impossible to quantify the effect of climate [10] and absolute ages of the surfaces are difficult to ascertain. Our specific objectives are thus to: (i) describe the morphological variability of polygonal terrain sites at potential Phoenix landing sites, and; (ii) determine whether a relationship exists between surface material (geomorphic unit) and polygon geometrical variability. These results may be used to generate preliminary interpretations of processes that have acted over time at these sites.

HiRISE Imagery: All available images located within the potential Phoenix landing ellipses were downloaded from the online HiRISE gallery (http://hirise.lpl.arizona.edu/). Each image was visually inspected for polygonal terrain, and was then mapped upon thematic base layer of geomorphic units displayed throughout the region (Fig. 1).

Several additional images outside the landing ellipses were also examined; their locations within distinct geomorphic units prove useful for comparative purposes when examining the influence of ground material on polygonal geometry.

In addition to a qualitative examination of polygon morphology, a statistical test (spatial point pattern analysis) was used to assess the spatial distribution of trough intersection nodes. This analysis simulataneously yields quantitative output describing polygon sizes (cumulative frequency of nearest-neighbout distances between nodes) and overall network geometry (random, regular, or clustered) [11].

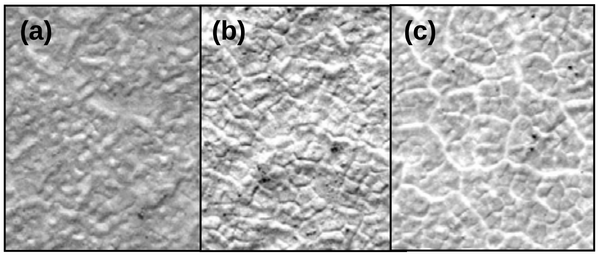
Processed, projected images were imported into a Geographic Information System (GIS; ArcGIS 9.2) and were placed within an arbitrary coordinate system (units = meters) and scaled accordingly. Trough intersection nodes were manually digitzed, and the coordinates were exported for subsequent analysis.

Summary of Findings: Great variation is evident in the observed morphologies (Fig. 2), which show a gradation among: (a) polygons displaying primarily curved troughs and virtually homogeneous trough widths; (b) polygons with both straight and curved troughs and slight variations in trough widths, and; (c) polygons with primarily straight troughs and extremely heterogeneous trough widths. Similarly, the observed spatial point patterns revealed a gradation in median nearest-neighbour distances and observed network regularity.

Upon further inspection, there appears to be a moderate correlation between observed geometry and the geomorphic unit within which the polygons were formed. Specifically, both images located within the "Blocks/Mesas" unit displayed 'Type C' morphologies and were statistically "regular".

However, polygons found within the two lowland units ("Dark" and "Bright") are somewhat more difficult to interpret, as variation in both qualitative morphology and spatial point patterns have been observed. Such differences may be due to site-scale variation, as certain sites within the regionally-defined units have great variation in albedo which in turn may be indicative of substrate heterogeneity.

With respect to formational processes, the observed variations in trough widths may reflect differences in the timing of polygon formation. For example, large polygons with wide troughs enclosing smaller polygons with narrower troughs (e.g. Fig. 2c) are indicative of a well-developed polygonal system that has evolved sequentially. Specifically, the wider 'primary' troughs must have formed first and widened over time, with subsequent 'secondary' and 'tertiary' (increasingly narrow troughs) forming later and subdividing the primary troughs [7].



PSP_002170_2485 PSP_001946_2485 PSP_001418_2495

Fig. 2: *Examples of variable polygon morphology observed at potential Phoenix landing sites.*

Two possibilities remain, then, for polygons with uniform trough widths: either all troughs formed simultaneously and developed at the same rate, or the primary troughs became inactive after a period of time while the secondary and tertiary troughs developed later but became inactive when they reached the same maximum size as the pre-existing primary troughs. It is our assertion that the former is more plausible.

The role of substrate properties in determining polygon geometry must be examined further. Because contraction cracks develop at weakness points in the ground, it is plausible that a more homogeneous substrate would have more evenly distributed weaknesses and thus would appear to have a more 'regular' spatial distribution. Soil samples and surface images from the Phoenix lander can potentially be used to support this notion.

References: [1] Arvidson R.E. et al. (2007), *7th Int. Conf. Mars, Abstract 3204*. [2] Mackay J.R. (1999), *PPP, 10, 39-63*. [3] Mellon M.T. (1997), *JGR, 102(E11), 25,617-25,628*. [4] Seibert N.M. and Kargel J.S. (2001), *GRL, 28(5), 899-902*. [5] Mangold N. et al. (2004), *JGR, 109(E08001)*. [6] Lachenbruch, A.H. (1962), *Spec. Pap. Geol. Sci. Am., 70, 69pp.* [7] Mackay J.R. (2000), *GPQ, 54(1), 41-68*. [8] Sletten R.S. et al. (2003), *JGR, 108(E4), 8044*. [9] Haltigin T.W. et al. (2007), *LPS XXXVIII, Abstract 1635*. [10] Mackay J.R. (1992), *Can. J. Earth Sci., 29, 236-248*. [11] Diggle O. (2003). *"Statistical analysis of spatial point patterns", 159pp.*