MORPHOMETRIC EVIDENCE OF CO-EVOLVING POLYGONAL AND SCALLOPED TERRAINS IN SOUTHWESTERN UTOPIA PLANITIA, MARS. T. W. Haltigin[1,2], W. H. Pollard[2], P. Dutilleul[3], and G. R. Osinski[4], [1]Space Science & Technology, Canadian Space Agency, 6767 Rte. de l'Aeroport, St. Hubert, QC, Canada, J3Y 8Y9 (timothy.haltigin@asc-csa.gc.ca), [2]Department of Geography, McGill University, 805 Sherbrooke St. W., Montreal, QC, Canada, H3A 2K6 (wayne.pollard@mcgill.ca), [3]Department of Plant Science, McGill University, Macdonald Campus, 21111 Lakeshore Rd., Ste-Anne-de-Bellevue, QC, Canada, H9X 3V9 (pierre.dutilleul@mcgill.ca), [4]Departments of Earth Science / Physics & Astronomy, University of Western Ontario, 1151 Richmond St., London, ON, Canada, N6A 5B7 (gosinski@uwo.ca).

Introduction: Utopia Planitia, a topographic basin in the northern plains of Mars, has been interpreted to contain ice-rich landscapes dominated by a variety of landforms similar to those found in terrestrial periglacial environments. Because of their presumed genetic associations with subsurface ice deposits, two such features have been particularly well-documented: scalloped depressions [1,2] and polygonal terrain [3,4].

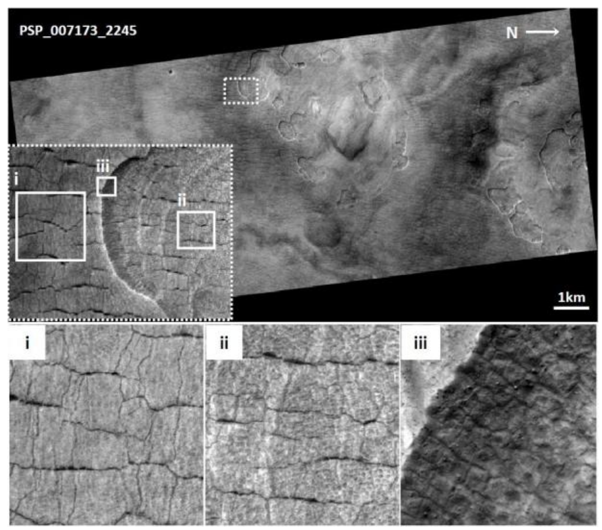
Scalloped depressions are curvilinear erosional features that form due to surface deflation resulting from sublimating ground ice, and can grow in width and depth over time to kilometers across and tens of meters deep [1]. Polygonal terrain is a network of enclosed geometric shapes that forms on the surface as a result of thermal contraction cracking of ice-bonded substrates. Individual polygons progressively subdivide as they evolve, becoming smaller in lateral dimension from tens of meters to meters across [3]. (Figure 1)

Problem Statement and Research Question: Although, individually, each of these landforms has been reasonably well-characterized with respect to its formational processes and basic morphological evolution, relatively limited effort has been directed towards understanding the feedbacks that take place as they mature. Specifically, given that both scallops and polygons are believed to develop as a result of ongoing adjustments of ice-rich ground to local environmental conditions [5], it is reasonable to believe that some level of co-evolution should be evident.

For example, if polygonal network evolution is related to increased subdivision, then smaller polygons can be used as an indicator of advanced stages of network maturity. Moreover, if progressive scallop development is associated with surface subsidence, then a lowered surface elevation should represent a more 'evolved' depression.

In order to illustrate that co-evolution of these landforms is taking place, various morphometric parameters representing average polygon 'size' must be somehow related to surface elevation. Thus, the overarching research question addressed here is "can a statistical geomorphic relationship be shown to exist between polygon network arrangement and ground surface elevation?"

Figure 1: Polygonal network geometrical variation as a function of proximity to an evolving scalloped depression, including: (i) relatively large 'upper plains' polygons; (ii) partially subdivided 'scallop floor' polygons, and; (iii) extremely subdivided small-scale 'scarp face' polygons.



Study Sites and Data Preparation: Three HiRISE images were selected for investigation, representing sites that display qualitative variation in both scallop and polygon maturity (Figure 2a).

Figure 2a(i) contains three-well-developed individual scallops and primarily upper plains polygon morphologies. Figure 2a(ii) shows several individual scallops in various stages of development, with both upper plains and scallop floor polygonal networks present. Finally, Figure 2a(iii) displays a full range of scallop maturity, from small isolated depressions in the south to complex aggregations towards the north, and contains examples of all polygon morphologies.

Each image was imported into a Geographic Information System along with shapefiles of corresponding MOLA elevation tracks. Locations where the transect crossed a polygon trough were manually identified and digitized, with the along-track distances and vertical positions extracted for subsequent analyses.

Polygon Trough Spacing vs. Surface Elevation: Data were aggregated into 300m bins, with each bin centered on a MOLA measurement. Mean nearest-neighbor distances (NND) (i.e. average polygon trough spacings) were calculated, and a correlation analysis was performed examining the relationship between the bin's mean NND and the recorded MOLA elevation.

For each image, very consistent trends emerged. In all cases, trough spacing was found to have a statistically significant positive correlation with elevation, evidenced by an average Pearson correlation coefficient (r) value of 0.53 ($p<0.05$). Such a finding demonstrates quantitatively that polygon troughs become more closely spaced as the surface subsides.

Trough Intersection Density vs. Surface Elevation: Results of the correlation analysis suggest that the average polygon trough spacing decreases as the ground surface lowers. While this finding demonstrates a cross-sectional trend in polygonal subdivision, it is necessary to test whether similar results are evident in planform polygonal geometry.

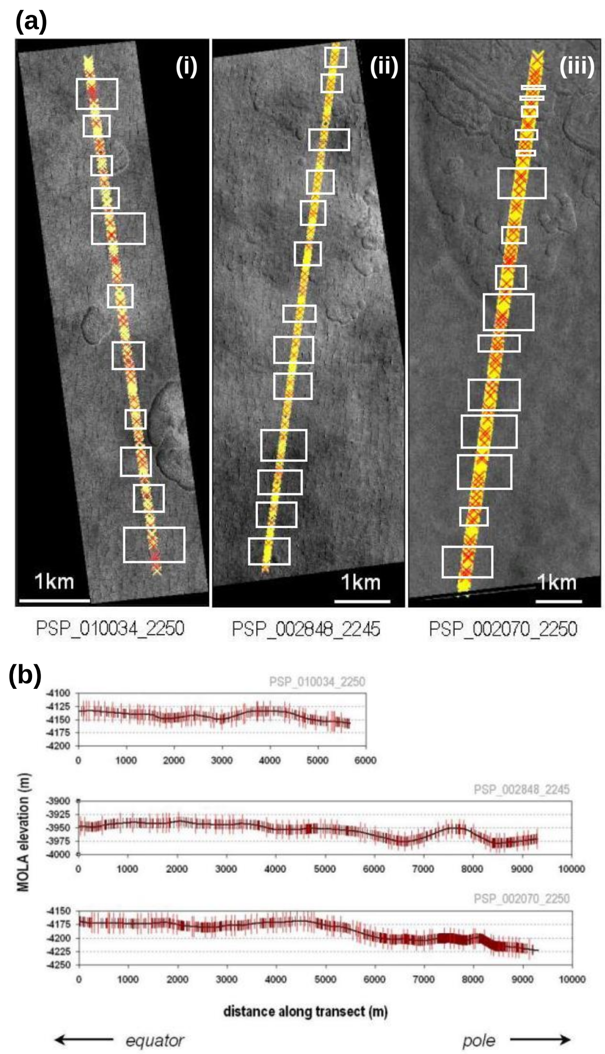
With increasing polygon subdivision comes a greater number of locations where polygon-bounding troughs intersect. Thus, a useful proxy for polygon maturity is the spatial density of trough intersections (number/km^2). Within several sub-regions (outlined rectangular areas in Figure 2a), intersection density was calculated and regressed against the corresponding MOLA observations. In all cases, the coefficient of determination (r^2) values exceeded 0.75, implying that over 75% of the variation observed in intersection density is explained solely by changes in elevation.

Implications for Landscape Interpretations: A previously accepted model [1] has suggested that generalized landscape deflation caused by widespread sublimation brings the surface closer to a more ice-rich layer at depth, thereby increasing the ground's tensile stress and inducing further thermal contraction crack development. The implication of this model is that polygon development post-dates terrain subsidence.

As sublimation-induced subsidence of the land surface occurs, though, a lag deposit of ice-free material is formed, insulating the underlying ice from further removal [6]. Therefore, the model proposed by [1] would require the lag deposits to remain thin enough to allow for further diffusive exchange after subsidence has occurred, thus implying ice contents in the shallow subsurface of perhaps 80-90%.

However, if the substrates near the original surface were, in fact, so ice-rich to begin with, it may be more plausible that advanced polygonal development would have already commenced. As such, it is evident that increased polygonal development must have occurred near the original surface, meaning that polygonal development, instead, pre-dates terrain subsidence.

Figure 2: (a) HiRISE images of landscapes containing (i) limited, (ii) moderate, and (iii) severe modification by scallop development. (b) Cross-sectional plots of polygon trough occurrences along MOLA tracks indicated in (a).



Summary and Conclusions: This work has provided statistical analyses showing that polygonal subdivision in southwestern Utopia Planitia occurs increasingly with advanced stages of scalloped terrain development, thus demonstrating an implicit interconnection between the landscape processes affecting the evolution of these landforms. As a result, it may be necessary to re-examine previously accepted geomorphic reconstructions of this region.

References: [1] Lefort A. et al. (2009) *JGR, 114, E04005.* [2] Séjourné A. et al. (2011) *PSS, 59, 412-422*. [3] Levy J. S. et al. (2009) *JGR, 114,* E01007. [4] Mellon, M. T. et al. (2009) *JGR, 114, E00A25.* [5] Ulrich M. et al. (2011) *Geomorph, 134, 197-216.* [6] Marchant D. R. et al. (2002) *Geo Soc Am Bull, 114.*