LANDFORM SCALE CO-EVOLUTION OF POLYGONAL TERRAIN NETWORKS AND SCALLOPED DEPRESSIONS, UTOPIA PLANITIA, MARS.

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Introduction: The development of various landforms in the Utopia Planitia region of Mars's northern plains has been attributed to ongoing adjustments of ice-rich ground to environmental forcing mechanisms [1]. Specifically, thermal contraction crack polygons are believed to represent a rheological response to rapid atmospheric cooling events [2], while scalloped depressions form as a result of surface deflation due to ground ice degradation [3].

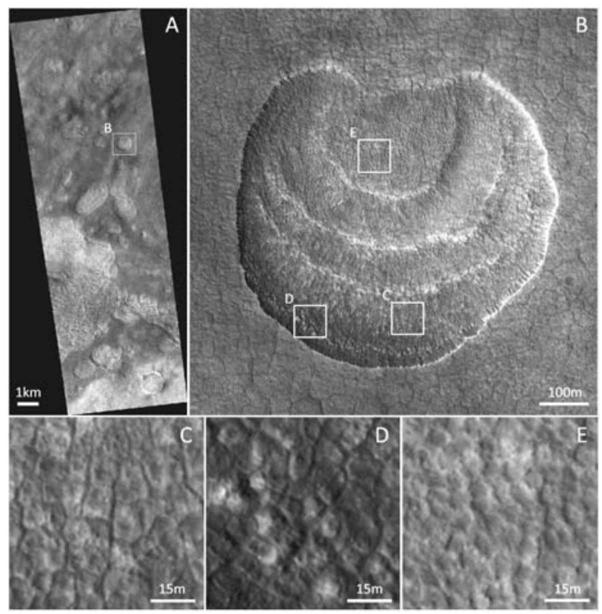
Given that these features are associated with related geomorphic processes and are often spatially coincident, it has been suggested that their evolutionary histories are linked [1, 3]. For example, the dominant morphologies of polygonal networks are strongly associated with their location with respect to an individual scallop [1, 4]. Therefore, it is important to characterize the interactions that occur between these landforms in order to generate a more complete geomorphic reconstruction of the region.

Problem Statement and Objectives: While the concept of co-evolution between scalloped and polygonal terrains has been established statistically at the landscape scale (i.e. hundreds of meters to kilometers) [5], it has yet to be determined if such interactions also occur at the landform scale (i.e. tens to hundreds of meters). Specifically, while polygons tend to decrease in size with increasing landscape degradation [5], it remains to be seen whether any systematic trends in polygon morphology occur within individual depressions in successive states of development.

Previous efforts at relating polygon network geometries with scallop maturity have established some basic spatial relationships. For instance, polygons on scallop floors are typically smaller than those on the surrounding upper plains, but larger than those found right at the base of a scallop scarp headwall [1, 3, 4]. However, the analysis of such trends has been primarily qualitative and descriptive in nature, and thus requires further elucidation.

Accordingly, the overarching aim of our work was to determine if there exists a systematic relationship between the appearance of polygonal terrain networks and the stage of maturity of individual scalloped depressions. By addressing this goal, it is hoped that additional insight can be provided to understand the co-evolutionary trends displayed by these features.

Figure 1: (a) HiRISE image PSP_001938_2265, which contains a variety of scallop and polygon morphologies; (b) Inset of a well-developed scallop containing three categories of polygonal networks as described by [1]; (c) Category UP2: low-centered polygons with upturned edges; (d) Category UP3: high-centered polygons on scarp-parallel ridges; (e) Category UP4: low-centered polygons outlined by single raised rims.



Study Site and Data Preparation: A HiRISE image displaying numerous individual scallops and polygonal networks in various stages of maturity was selected for investigation (Figure 1a). Figure 1b shows an example of a well-developed depression, within which varying characteristic polygonal morphologies exist. As described by [1], three morphological categories of polygons may be present (Figures 1c-e).

Using a Geographic Information System, each scallop on the image was manually digitized and the presence or absence of each of the three categories of polygons was noted. A variety of spatial metrics extracted from the digitized depressions were then compared against polygon network appearances to establish trends in network evolution associated with scallop development.

Morphometric Assessment of Scallop Evolution: The basic conceptual model of scallop initiation and development was proposed by [3], described briefly as follows. Meter-scale topographic variations of ice-rich substrates receive increased insolation on their equator-facing slopes, leading to localized occurrences of ground-ice sublimation and subsequent overburden collapse. As this process is repeated over time, the depression continues to grow both horizontally and vertically, implying that older, more mature scallops are characterized by increases in both planform area and depth.

Polygon Morphologies vs. Scallop Maturity: A total of 96 clearly discernible individual scallops were identified on the image, of which 53, 43, and 44 contained examples of polygon types UP2, UP3, and UP4, respectively. In general, all three categories of polygons show a relationship with scallop area, tending to be present more often in larger than in smaller depressions (Figure 2a). However, for intermediate-sized scallops (~ 10,000-100,000m^2), no obvious trend is evident.

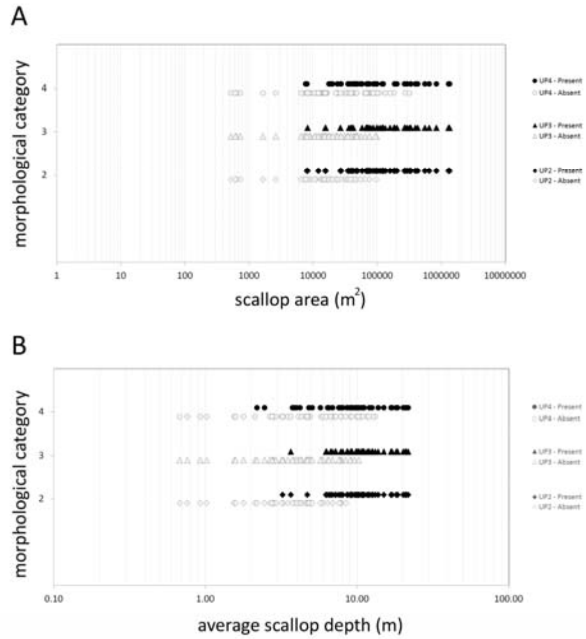
The presence of UP2 and UP3 polygons is slightly better predicted from the average depth of the scallop in which they are found (Figure 2b). Except for a few atypical observations, UP2 and UP3 polygons are almost exclusively found in scallops greater than 6m in depth, and always occur in scallops more than 10m deep. The UP4 polygons, however, can be either present or absent in scallops of virtually any depth.

Implications for Geomorphic Interpretation: Our results provide evidence that the appearance of UP2 and UP3 polygons is heavily dependent upon the relative maturity of the scalloped depressions in which they develop. In general, polygons of these two categories are not found in relatively young scallops while both are almost always found in more mature scallops.

Moreover, the presence of different polygon morphologies is more strongly dependent on scallop depth than on planform area, likely due to ice-table depth in this region. Such a finding supports previous models demonstrating that polygon maturation in this region is linked to vertical subsidence of the surface [3, 5].

Finally, the relationship to both scallop area and depth of UP4 polygons is much less robust, which could indicate that the presence / absence of these features are dictated by a different set of geomorphic processes than the other two categories. Whereas UP2 and UP3 polygons display morphological characteristics common to thermal contraction crack polygons found elsewhere on Mars and in terrestrial polar regions [2, 6], the single raised rims characteristic of UP4 polygons are not typical for thermal contraction crack polygons and thus may imply an alternate process of origin.

Figure 2: Observed presence/absence of polygon morphologies as compared against (a) scallop area, and; (b) average scallop depth.



Summary and Conclusions: This work has provided results of analyses demonstrating that the appearance of various polygonal morphologies is strongly associated with progressive stages of scalloped depression development. These data provide further evidence that polygonal and scalloped terrains in Utopia Planitia behave as a co-evolving system rather than as individual landforms, and thus should be considered as related outcomes of the periglacial processes acting within the region.

References: [1] Ulrich M. et al. (2011) *Geomorph, 134, 197-216.* [2] Levy J. S. et al. (2009) *JGR, 114*, E01007. [3] Lefort A. et al. (2009) *JGR, 114, E04005.* [4] Séjourné A. et al. (2011) *PSS, 59, 412-422*. [5] Haltigin T. W. et al. (2012), *LPSC 43, Abstract 2689.* [6] Mellon, M. T. et al. (2009) *JGR, 114, E00A25.*

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