Geology, Ages, Morphology, and Morphometry of Thumbprint Terrain in Isidis Planitia, Mars.
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Introduction: Large parts of Isidis Planitia are covered with thumbprint terrain consisting of curvilinear ridges of coalesced cones with central depressions or craters [e.g., 1-8]. While thumbprint terrain can be observed in many areas of the northern lowlands [5,9], it is particularly well developed in the Isidis basin. We have mapped thumbprint terrain in western Isidis Planitia using images of the High Resolution Stereo Camera (HRSC) (Fig. 1) augmented by MOLA, MOC, THEMIS, HIRISE and other data. In addition, we have performed extensive morphometric measurements and crater counts in order to constrain the formation of the thumbprint terrain and its timing. Numerous scenarios have been postulated for the formation of thumbprint terrain, and possible terrestrial analogues include for example pingos, moraines, shield volcanoes, pseudocraters, and eskers [e.g., 1-8].

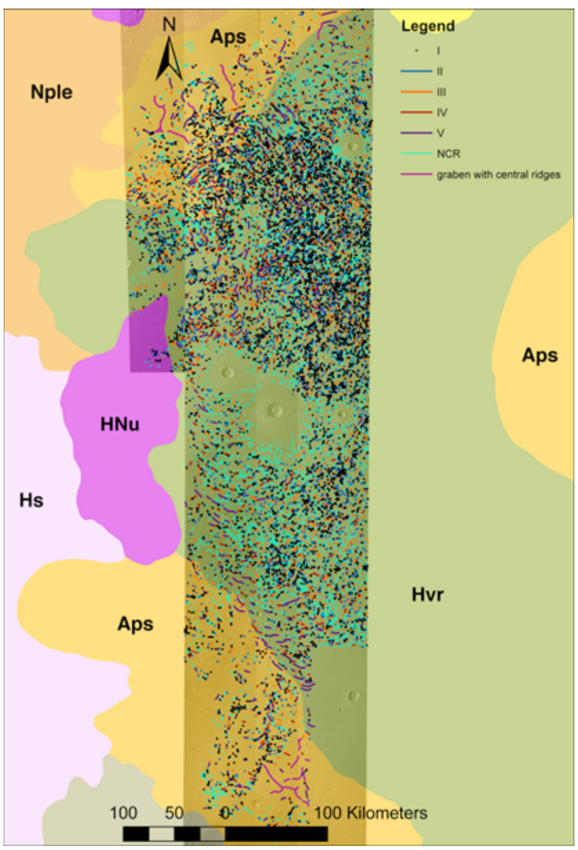

Figure 1: Geologic map of Isidis Planitia [10] with superposed map of thumbprint terrain based on four HRSC orbits [this work].

Methods: We constructed a detailed map of the ridges/cones in order to derive information about their distribution (Fig. 1). Our map is based on HRSC images with a spatial resolution of 12.5 - 25 m/pixel [11]. We classified the thumbprint terrain into six categories, based on the varying lengths of the ridges. Category I includes individual isolated cones, category II consists of 2-3 coalesced cones, category III is characterized by ridges consisting of 4-6 coalesced cones, category IV contains ridges with 7-10 cones, and category V includes ridges with more than 10 coalesced cones. In addition, we identified and mapped ridges without cones, termed "no cone ridges" (NCR) (Fig. 2).

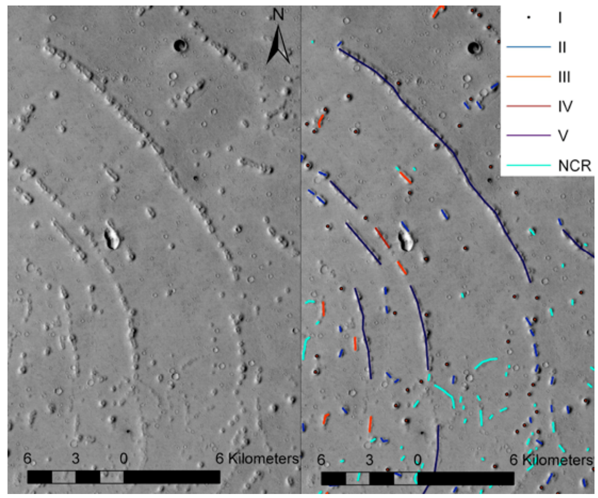

Figure 2: HRSC image with superposed detailed map of ridges and cones on the floor of the Isidis Basin. Numbers I to V and NCR refer to categories described in the text.

For each category, we measured the height of at least 20 ridges/cones per orbit in order to investigate possible correlations between the height and the length of the ridges/cones. For these measurements we used individual MOLA tracks crossing the features of interest. We also measured the basal diameters and the diameters of the central depressions to compare them to terrestrial analogues. To constrain the formation age of the thumbprint terrain, we performed crater counts of the geologic units on which the thumbprint terrain occurs and dated rampart craters that are superposed on the cones/ridges.

Results: Our map indicates spatial variations in the distribution of the thumbprint terrain. For example, the number of ridges and cones of all categories is greater in the northern versus the southern areas of the floor (Fig. 1). In addition, ridges and cones are absent on the ejecta blankets of young rampart craters, which thus postdate the formation of the thumbprint terrain.

On the basis of mapping 8500 ridges/cones and 7000 NCRs, the majority of the investigated features are isolated cones (Cat. I: 43%) and relatively short ridges consisting of 2-3 coalesced cones (Cat. II: 35%). The numbers of ridges with 4-6 (Cat. III: 15%), 7-10 (Cat. IV: 5%), and more than 10 coalesced cones (Cat. V: 3%) are significantly smaller.

We also measured the heights of the ridges within each category. Our measurements revealed that the median height is largest (33 m) for category III. This is similar to the heights of the longer ridges of categories IV (28 m) and V (32 m). The heights of individual cones (13 m) and small ridges with less than 4 cones (21 m) are typically smaller. NCR ridges exhibit median heights of 15 m. These heights are comparable to various terrestrial analogues, including pingos, volcanic cones, pseudocraters, and mud volcanoes.

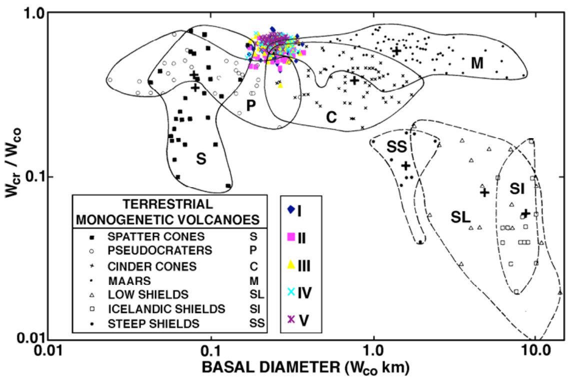

Figure 3: Cone basal diameters vs. crater diameters of terrestrial monogenetic volcanoes (Wood, 1979) and Martian cones on the thumbprint terrain (category I to V).

In order to further constrain the formation process of thumbprint terrain, we plotted the basal diameter of the thumbprint cones against their basal diameter/crater ratio (Fig. 3). Comparing this data to terrestrial monogenetic volcanoes [12], we find the best agreement with cinder cones and pseudocraters and to a lesser extent with maars and spatter cones.

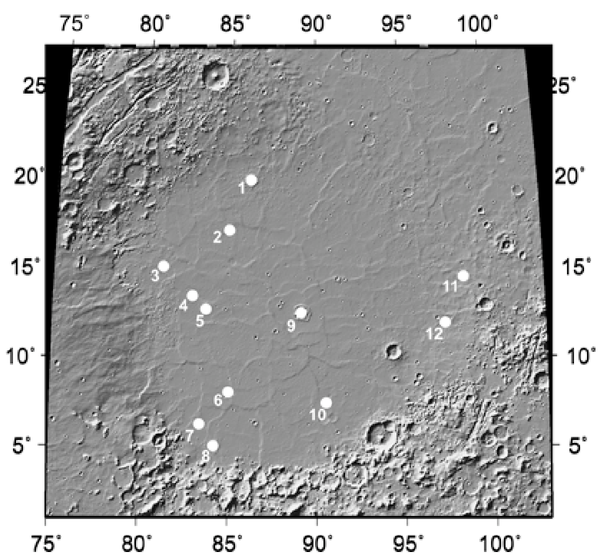

Figure 4: Locations of rampart craters that have been dated in this study. Numbers correspond to numbers in Fig. 5.

To constrain the formation age of the thumbprint terrain, we performed several crater counts for the geologic units and nearby rampart craters that are superposed on the thumbprint terrain (Fig. 4). Based on these crater counts, we propose that thumbprint terrain in western Isidis Planitia could have formed between ~2.5 and ~3.0 Ga. If unit Aps has covered thumbprint terrain that was originally exposed throughout the basin, its formation can be further constrained to ~2.7 to ~3.0 Ga (Fig. 5).

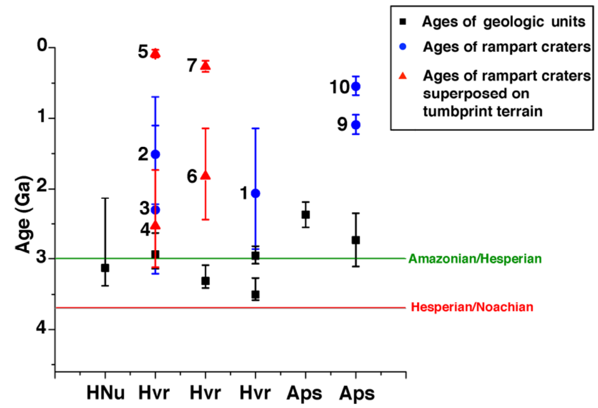

Figure 5: Model ages [this work] of the geologic units defined by [10] for different locations in Isidis Planitia (black squares) compared to those of nearby rampart craters (blue dots) and rampart craters that are superposed on thumbprint terrain (red triangles)

Conclusions: We produced a detailed map of the distribution of ridges on the floor of western Isidis Planitia and measured their lengths, heights, basal diameters, and the diameters of their central depressions. We constrained the age of these ridges by dating the geologic units on which they occur and the superposed rampart craters. We conclude: (1) a greater number of ridges occurs in the northern parts of basin floor; (2) thumbprint ridges are on average less than 35 m high, but there are a few with heights up to more than 70 m; (3) the occurrence of central depressions associated with the ridges/cones in Isidis Planitia is indicative of either collapse (e.g., pingo) or an explosive origin (e.g., volcanic cones); (4) the basal and central depression diameters are most consistent with cinder cones and pseudocraters and to a lesser extent with maars and spatter cones; (5) on the basis of the morphology and morphometry of the ridges and cones, other origins, including various types of moraines, sand ridges, dunes, eskers, drumlins, kames, crevasse fill, beach ridges, berms, table mountains, mud volcanoes, and inverted topography appear less likely; (6) that the formation of thumbprint terrain occurred sometime between ~2.5 and ~3.0 Ga.

References: [1] Grizzaffi and Schultz, (1989), Icarus 77; [2] Hiesinger and Head, (2003) 6. International Conference on Mars; [3] Hiesinger and Head (2004) LPSC 35; [4] Rohkamp et al. (2008) EPSC 3 [5] Tanaka et al. (2005), USGS SIM 2888; [6] Pithawala and Ghent, (2008), LPSC 39; [7] Pithawala and Ghent, (2008), EPSC 3; [8] Bridges et al. (2003), J. Geophy. Res. 108; [9] Pomerantz and Head, (2003) LPSC 34; [10] Greeley and Guest, (1987), USGS I-1802B; [11] Jaumann and Neukum (2007), Planet. Space Sci. 55; [12] Wood (1979) Proc. Lunar Planet. Sci. Conf. 10.