CONSTRAINING THE ORIGIN OF PITTED CONES IN CHRYSE AND ACIDALIA PLANITIAE, MARS, BASED ON THEIR STATISTICAL DISTRIBUTIONS AND MARGINAL RELATIONSHIPS. J. A. Skinner, Jr., Astrogeology Science Center, U. S. Geological Survey, 2255 North Gemini Drive, Flagstaff, AZ 86001 (jskinner@usgs.gov).

Introduction: Pitted cones are common landforms in the Martian northern plains [1-9]. Though conical features with central craters exist on other Martian terrains, lowland features generally have smaller diameters (800 to 1000 m) and occur in tight, spatial clusters (up to 100/1000 km^2) [1,3-4]. As such, lowland pitted cones implicate a process that is explicitly associated with the geologic and/or topographic setting of the Martian northern plains.

Past investigations have alluded to a variety of potential processes, including magmatic volcanism, periglaciation, groundwater seepage, and mud extrusion [1-8]. The latter process has garnered some recent attention on Mars because it arises from the overpressurization of interstitial fluids within (typically confined) sedimentary sequences [4-6], ingredients that are seemingly abundant in the Martian northern plains [3-5]. Despite this attention, there is still considerable ambiguity surrounding the formation of lowland pitted cones, including (1) similarity of geologic processes in spatially separated regions, (2) the physical character of the materials within which the features arise, (3) the formational influence of the subjacent topography, and (4) the past stability field of subsurface liquids on Mars.Here, I address the hypothesis that spatial distributions of pitted cones in Chryse and Acidalia Planitiae have a measurable variance that can be linked not only to the occurrence of sedimentary sequences but also the underlying topographic framework. These analyses can serve as quantitative points of reference for analysis of populations elsewhere in the Martian northern plains.

Method: Past studies have focused on determining the morphometry of pitted cones using local regions [1,4], which can be qualitatively extrapolated to larger areas. Such extrapolations, however, fail to explicitly address how spatial density varies across a regional setting. I focused on the pitted cone populations in Chryse and Acidalia Planitiae (28 to 60°N, 2 to -62°E) due to their prevalence and interpreted relationship with the Hesperian circum-Chryse outflow channel sediments [3-4,6,8]. After subdividing the study area into 25×25 km cells, a random selection algorithm was used in GIS to identify 25% of the total cells (n=3078), wherein targeted mapping of pitted cones would occur. Features were individually mapped as points in GIS using daytime and nighttime THEMIS IR image mosaics at 1:100K scale. Basemap resolution theoretically allowed identification of pitted cones ≥300 m, though atmospheric haze was a locally limiting factor in some locations. THEMIS VIS images were used to confirm and/or refute the existence of pitted cone populations, as necessary. The mapping task identified 19,316 pitted cones within the region of interest. After reducing the number of pitted cones within each grid to a single point, feature distributions were estimated using an inverse-distance weighted interpolation technique with variable search radius and neighborhood minimums and maximums (**Fig. 1**). Error estimates of the interpolation are within 10% of actual, though predicted values are generally lower than observed, indicating that the resulting density is likely a minimum.

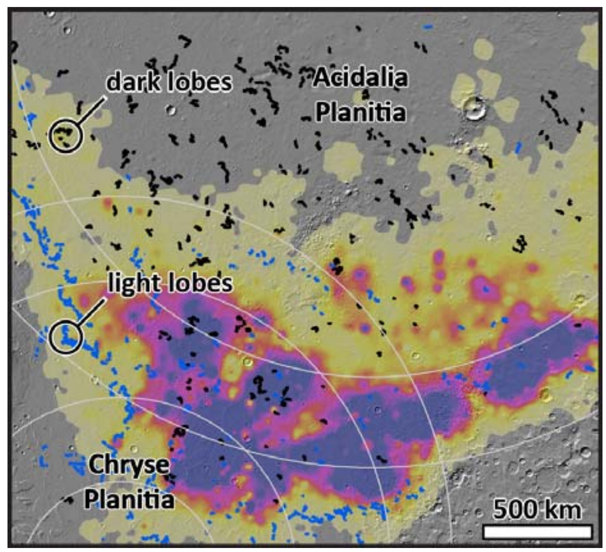

Figure 1. IDW interpolation of >19,000 pitted cones. Blue is high spatial concentration and yellow is low. Highest values are ~400/1000 km^2 and occur in regions where the Chryse and Acidalia impact basins overlap (white lines). Pitted cone populations are bracketed by light and dark flow lobes, suggesting association with near surface processes.

Results: Mapping and interpolation of a statistical subset of pitted cones provides quantitative estimates of their concentration and distribution in Chryse and Acidalia Planitiae. These efforts indicate the region contains >80,000, twice the number predicted by the local analyses of [4]. Spatial concentrations of pitted cones range from a few to ~400/1000 km^2, with a mean value of 13/1000 km^2. These estimates, too, are increased from past studies which suggest an upper limit of ~100/1000 km^2. Pitted cones regionally range in elevation from -3727 to -4914 m (mean of -4256) and nearest neighbor distances range from several hundred meters m to >100 km (1.9 km mean). Estimates indicate pitted cones are located predominantly in the Vastitas interior and exterior units of [3], materials interpreted as reworked sediments of diverse provenance.

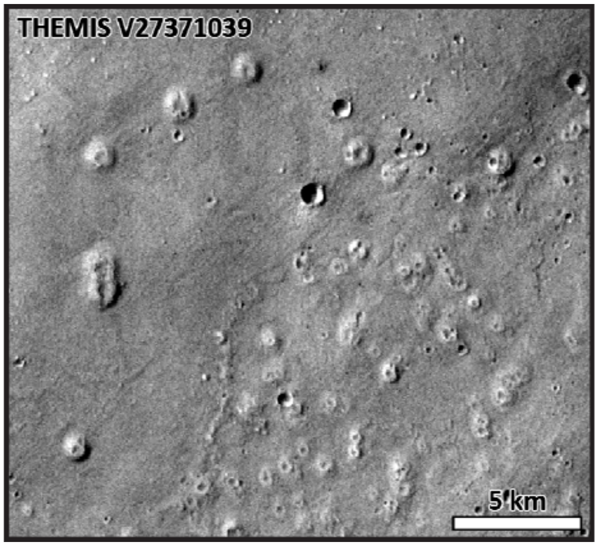

Figure 2. Example of pitted cones in Chryse and Acidalia Planitiae. Note the contrasting density of these features, a spatial characteristics noted by past workers but which is not statistically evident in THEMIS IR images [REF].

Interpretation: The concentration of pitted cones strictly within materials interpreted to be of sedimentary origin confirms that their origin is associated with processes that act upon sediments (rather than materials of strictly volcanic orign). A process of depressurization and de-volitilization (such as mud volcanism [6]) may be the most apt process through which pitted cones originate both within and beyond the study region. However, this study identifies some constraints to the mud volcano hypothesis.

Other than their broad-scope regional occurrence, this study identifies very little evidence to suggest that the pitted cones of Chryse and Acidalia Plantiae are strictly associated with outflow channel activity. For example, concentration at the mouths of Kasei, Ares, Simud/Tiu, or Mawrth Valles that might indicate a clear genetic origin with single outflow events is not discernible. If pitted cones arose specifically from the compaction and dewatering of outflow sediments, it seems reasonable to expect overlapping or truncated populations. Though overlapping populations are locally apparent (**Fig. 2**), regional occurrences show a continuous (albeit variable) swath across all circum-Chryse channel openings. This suggests that either association with a particular channel is evident only for cones <300 m diameter (beyond detection in this study) or that cones are not associated with the outflow process.

Two notable relationships are evident from this work. First, pitted cone concentrations correlate with the overlapping rings of the Chryse and Acidalia impact basins (**Fig. 1**). This suggests that the features formed within materials accumulated in the annular spaces of ancient multi-ring impacts rather than near their centers, as suggested by [4]. Long-lived, basin-related catchments may be a fundamental structural requirement for the origin of pitted cones in Chryse and Acidalia Plantiae and elsewhere [5-6]. However, it is not yet clear whether deeply-seated faults associated with these basins also play a role in their evolution. Second, the concentration of pitted cones are strongly related to the occurrence of light and dark lobes (**Fig. 1**), which clearly discriminate two discrete flow-related geologic processes from opposing directions (light lobes imply flow to the southwest, dark lobes to the northeast [10]). The dark lobes may be vestige digitate terminations of debris flows sourced from circum-Chryse fractures and channels and light lobes may be layers of relatively block-free sediment of airfall origin. Associations with light-toned marginal lobes are also observed in Utopia and Isidis Planitiae [10], regions that are wholly unrelated to catastrophic outflow events. This effectively rules out outflow processes as the primary origin for pitted cones in the Martian northern plains.

Conclusions: The interpolation presented above provides a quantitative estimate of the spatial concentration of pitted cones in Chryse and Acidalia Planitiae. Results indicate that pitted cone concentrations have measurable variance across the region. In addition, there are greater numbers and higher spatial densities of these features than previously thought [1,4]. Similar assessments can be completed for other areas of the northern plains, which may assist with correlating similarity (or difference) in geologic process. Logical next steps include (1) augmenting this study with targeted mapping of pitted cones using higher resolution images, and (2) including measurements of basal diameters to extend the morphometric work of past investigations.

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