SPATIAL DISTRIBUTION OF PITTED CONES IN UTOPIA PLANITIA FOLLOW BASIN CONTOURS.
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**Introduction:** The northern plains of Mars contain multiple large basins, and we focus within Utopia Planitia. Topography and gravity data of the basin support the hypothesis of an impact structure with erosional degradation and infilling of material (volcanic and sedimentary) [1-10].

Many surface features are unique to or most prevalent in the northern plains of Mars, including the Utopia basin, one of which is the pitted cone. These cone-like features are characterized by a central crater, and resemble terrestrial features such as mud volcanoes (Figure 1a). Many past studies have investigated these features [e.g. 11] but their formation mechanism is still debated. Two primary formation processes which have been proposed are (1) sedimentary or mud volcanism [5,12], and (2) volcanism (i.e. cinder cones) [7-10].

Within the basin, we observe two primary types of pitted cone features. The first is individual pitted cones (Figure 1a). The second is a linear chain-like feature, composed of multiple connected cones (Figure 1b). We investigate the spatial distribution of both types of pitted cones features in UP. Generally, they have been observed in limited regions near the southern rim of UP [13]. The exact spatial distribution of both features was unknown across the entire UP basin.

**Methods:** Mapping was done in ArcGIS 10.8. Basemaps were composed of Context Camera (CTX) images and mosaics (on the Mars Reconnaissance Orbiter [MRO]) [14]. Existing CTX mosaics provide the appropriate spatial resolution and coverage needed. Each pitted cone was mapped as a point feature and each pitted cone chain as a linear feature. Pitted cone chains were mapped in the area spanning 16°-72°N, 72°-160°E (Area 1, see Figure 1c, 1d). Pitted cones were mapped in the area spanning 16°-28°N, 100°-120°E (Area 2, see Figure 1c, 1d).

We apply the ArcMap 10.8 Average Nearest Neighbor tool (NN) to the mapped pitted cone feature populations. This is to measure any clustered or dispersed tendencies; also, it will define any trends in spatial distribution of cones nearing the basin rim.

This tool is applied to three versions of the mapped cone dataset because NN analysis is very dependent on study area. The first version is the original: a rectangle containing all mapped cone features. The second version is the dataset split into 15 4° x 4° squares. Each square containing > 10 individual mapped cones is run through the NN tool. Finally, the third version is the Elysium Mons is labeled with “EM”, and Isidis Planitia is labeled as “IP”. The black asterisk denotes the approximate location of the pitted cones in (1a), labeled with “c”. The white asterisk denotes the approximate location of the pitted cone chains in (1b), labeled with “d”. (d) The extent of Area 1 and mapped features are shown in topographic context (Mars Orbital Laser Altimeter, global dataset). Area 2 is outlined in a black rectangle. Pitted cones are mapped in red, pitted cone chains are mapped in yellow.
dataset split into 60 2° x 2° squares. Each square containing > 10 individual mapped cones is run through the NN tool. NN analysis is very dependent on area. Comparing the three spatial views of the same dataset will display both large- and small-scale trends of pitted cone clustering. The finer spatial grids are used to highlight any small-scale trends which may be lost when viewing the dataset as a whole.

Results: Elevation contours follow the approximate boundary extents of pitted cones and pitted cone chains (Figure 2). The southern boundary contours which approximately outline the mapped cone and chain populations match: -3555 m. Additionally, the northern boundary contours which approximately outline the mapped populations match: -4275 m. The middle contour identified in the pitted cone population has several distinct lobes, particularly in the NW side of the contour, which the cone population appears to follow. This shows a link between pitted cones and the elevation of the present-day UP basin.

![Figure 2: (a) Area 1 extent is shown in topographic context (Mars Orbital Laser Altimeter, global dataset). Mapped pitted cone chains are in yellow. Two elevation contours are shown in black lines: -4275 m and -3555 m. (b) Area 2 extent is shown in topographic context (Mars Orbital Laser Altimeter, global dataset). Mapped pitted cones are in red. Three elevation contours are shown in black lines: -4275 m, -3735 m, and -3555 m.](image)

Generally, cones form ~0-6° from the approximate UP rim. Their density decreases moving toward the center of the basin, and their distribution follows the general circular trend of UP. Chains also appear to follow the basin trend (Figures 1d, 2).

For NN analysis, we find that the three dataset grids (all area, 4° boxes, 2° boxes) display significant clustering of cones. We observed some boxes, especially directly adjacent to the basin rim, that appear to display tighter clustering (smaller NN ratio). This may signify a link between pitted cone clustering and the pre-fill UP basin topography.

Discussion: Mapped populations of pitted cones and pitted cone chains in UP generally parallel the basin rim, which matches observed tectonic features in the region [15]. We also find through NN that the pitted cone features appear to be more strongly clustered moving toward the southern rim of UP. These initial results suggest that the original structure or topography (and basin fill depth) played a key role in the eruptions. Lava eruptions associated with other multi-ring basins do not follow this pattern, so a mud-flow origin might be favored.

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