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Pie-like Mounds on Mars: A Comparative Morphometric Study of Features in Nepenthes/Amenthes and Chryse Planitia

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Previous studies have shown that the Nepenthes/Amenthes region on Mars contains a large number of unusual kilometer-scale landforms—including cones, domes, and mounds—whose origins remain uncertain. Two main hypotheses have been proposed: one suggests these features are the result of subsurface sediment mobilization, potentially forming Martian analogs to terrestrial mud volcanoes, while the other attributes them to explosive volcanic activity involving magma–water interactions. This study aims to shed new light on this debate by analyzing the morphological and morphometric properties of these landforms.

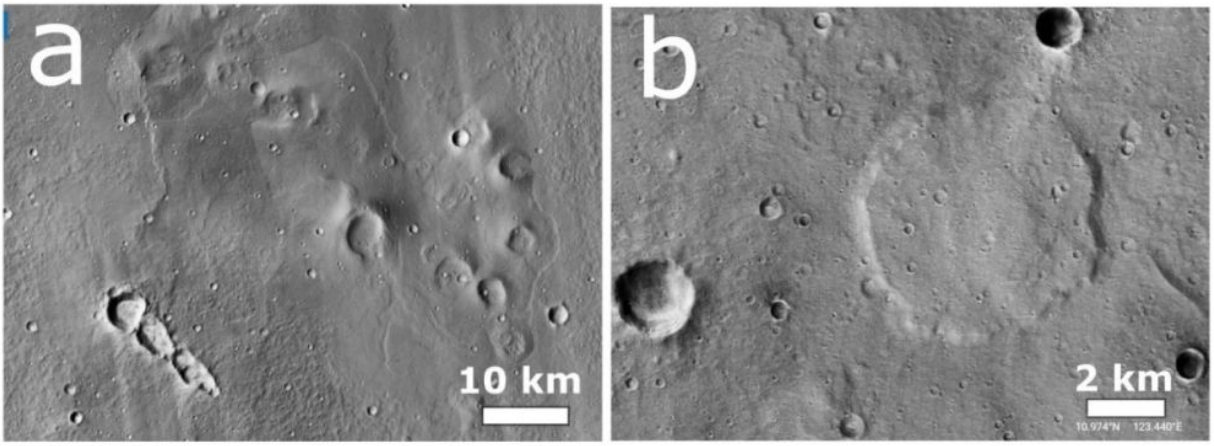

Fig. 1: Examples of cones, and mounds in the Nepenthes/Amenthes. Based on CTX global mosaic.

The Nepenthes/Amenthes region, located at the boundary between the southern highlands and the northern lowlands of Mars, displays significant morphological diversity. The area's geological history includes tectonic deformation, sedimentary processes, and possible volcanic activity (Tanaka et al., 2003; 2005; Skinner and Tanaka, 2007). One interpretation considers the observed conical and mound-like features as sedimentary in origin—specifically, mud volcanoes. This view is supported by similarities to analogous structures in Azerbaijan and by the absence of characteristic volcanic features such as lava flows or well-defined craters (Skinner and Tanaka, 2007). Additional arguments include their isolation from known volcanic centers, lack of dike-related surface expressions, occurrence within a narrow latitudinal and elevation band, and the setting in a compressional tectonic regime between impact-generated structural rings of Utopia basin —conditions favorable for fluid overpressure and sediment mobilization.

Alternatively, another study argues these landforms are volcanic in origin, formed by explosive phreatomagmatic eruptions resulting from interactions between magma and water (Brož and Hauber, 2012). Their morphological resemblance to terrestrial tuff rings and cones, which feature shallow craters surrounded by ring-shaped ejecta deposits, supports this view (Lorenz, 1986).

Similar features have been identified elsewhere on Mars. In the Lederberg Crater, conical structures are interpreted as volcanic due to the surrounding igneous geological context. In contrast, pie-like mounds in Chryse Planitia are considered products of sediment mobilization based on their environmental setting (Komatsu et al., 2016; Brož et al., 2019; 2021). However, a detailed morphological and morphometric comparison between the pie-like mounds of the Nepenthes/Amenthes and Chryse Planitia regions has not yet been conducted (Fig. 2).

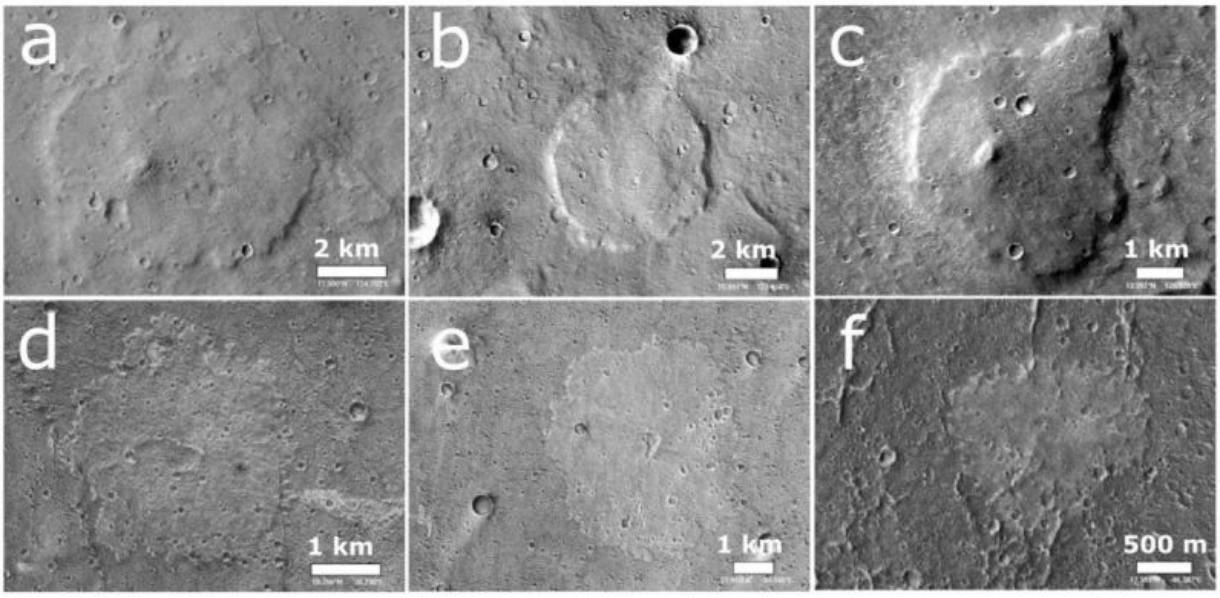

Fig. 2: Examples of mounds in the Nepenthes/Amenthes (a-c) and Chryse Planitia (d-f) regions.

To address this gap, we performed a comparative analysis of these features in both regions. We used the global Context Camera (CTX) mosaic compiled by Dickson et al. (2024), which provides ~5 m/px resolution imagery from the CTX instrument aboard the Mars Reconnaissance Orbiter (MRO; Malin et al., 2007). This dataset enabled us to identify and map kilometer-scale landforms and their associated flow-like structures. For finer-scale analysis, we used selected HiRISE images from the same spacecraft, which offer a resolution of approximately 50 cm/px (McEwen et al., 2007). Elevation data were derived from a blended digital elevation model with 200 m/px resolution, combining data from the Mars Orbiter Laser Altimeter (MOLA), and the High-Resolution Stereo Camera (HRSC; Gwinner et al., 2016).

To quantify the morphological similarity between features in the two study regions, we measured key morphometric parameters, including feature width, circularity, and height. These measurements form the basis for comparing the two populations and contribute to a better understanding of the processes that shaped them.

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