Distribution and geomorphology of well-preserved pitted mounds in Terra Sirenum, Mars: Implications for possible mud volcanism

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On early Mars (Noachian to Hesperian Periods with approximate absolute age ranging from 4.1 to 3.1 Gyr [1]), groundwater/hydrothermal systems, estimated from the presence of clay minerals on a global scale [e.g., 2], may have occurred, with diverse evidence including a number of putative mud volcanoes being reported in both the northern lowlands [e.g., 3] and relatively old, southern highlands [e.g., 4, 5]. However, the spatial extent of potential mud volcanism on Mars has yet to be fully understood. Moreover, criteria for distinguishing between mud volcanoes and other analogs (e.g., cinder cones, tuff cones, rootless cones, pingos) has yet to be established.
Here we focus on clusters of mounds within an elongated basin floor (~181 km x <~47 km, centered at 203.4°E, 27°S) in the northern Terra Sirenum region (mapped as early to middle Noachian terrain [1]) of the southern highlands, and analyze their spatial distribution, morphological characteristics, and morphometric parameters using high-resolution images recently acquired by NASA's High Resolution Imaging Science Experiment (HiRISE; 25 or 50 cm/pixel spatial scale [7]) and Context (CTX; ~5 to 6 m/pixel [8]) cameras onboard the Mars Reconnaissance Orbiter (MRO), and high-resolution (2 m/post) digital elevation models (DEMs) created from HiRISE stereo pairs.
Mapping of more than 600 mounds, based on a mosaic of CTX images, reveals the alignment of mounds along regional structures, and spatial concentration of ~150/1000 km^2. Using HiRISE images, geomorphological characteristics, such as summit pits, meter-size boulders and dune deposits on their flanks, and smoother surface textures relative to the surrounding terrains, can be commonly observed from most of the mounds. Preliminary morphometric analysis of four mounds, calculated from our DEM, show that they have basal widths ranging from~300 m to 800 m, heights of up to ~40 m, height-to-width ratios of 0.04 to 0.07, and cross-sectional topographic profiles exhibiting convex-upward slopes.
The resultant values are comparable to those of some mud volcanoes on Earth [9], and the slope geometry is highly consistent with the emplacement of yield-strength fluids [10] (e.g., slurries of water and mud or lava flows) rather than deposition of pyroclastic fragments. Though a volcanic origin cannot be ruled out, the combination of their distribution and meter-scale morphology with their morphometry favor a mud volcano origin. If the mud volcano hypothesis is true, their relatively young surfaces suggest that the formation of source reservoirs and conduit openings along regional fissures for erupting mud and water might have occurred during more recent times than Noachian age. This is consistent with other post-Noachian features in the region such as valley networks and collapse depressions which are linked to faults [11]. Additional high-resolution spectral data coverage obtained by the MRO spacecraft in the future will improve mineralogical characterization of the mounds and further discussions of possible diagenetic processes and/or hydrothermal alteration.
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