RIFTED MOUNDS IN UTOPIA PLANITIA: POSSIBLE ORIGINS AND IMPLICATIONS.

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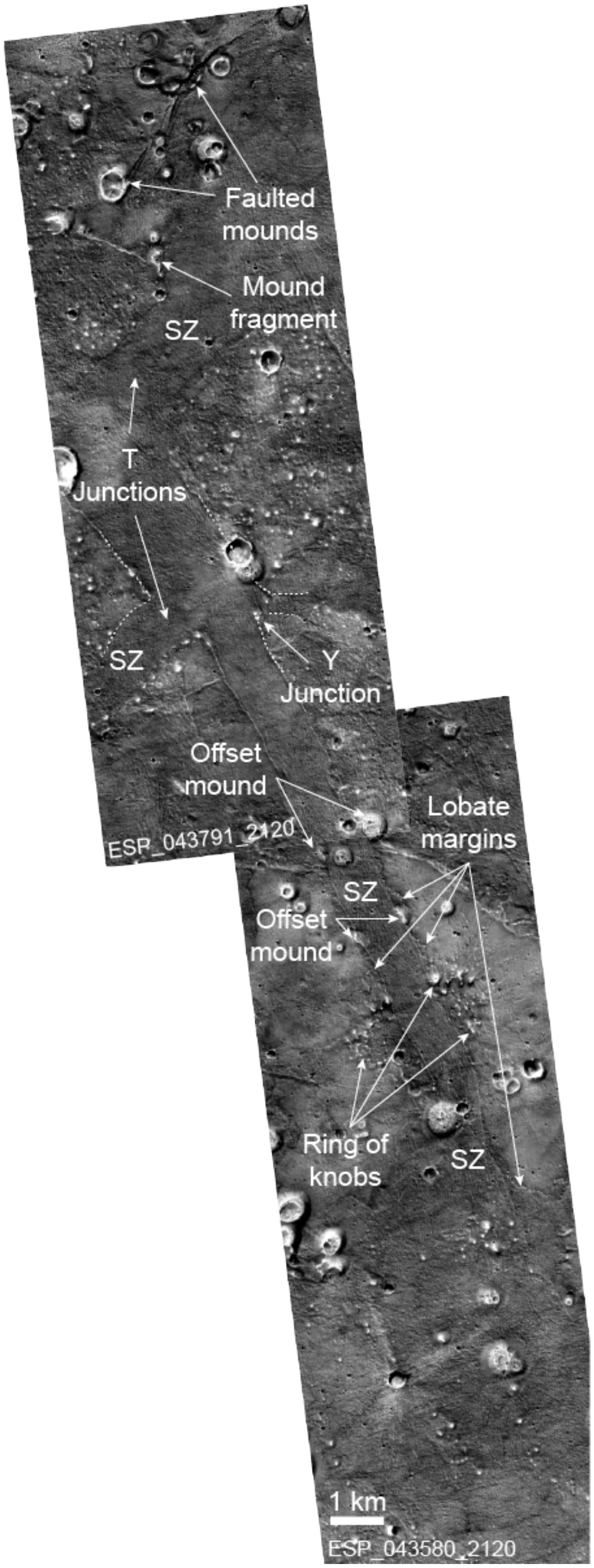

Introduction: A population of mounds in southwest Utopia Planitia exhibits evidence of rifting contemporaneous with their formation (Fig. 1), and in this abstract we evaluate possible causes for this rifting and implications for the formation of the mounds. Mounds such as these are abundant throughout Utopia Planitia and other regions of the northern lowlands. Their origin is contentious and has been variously attributed to diverse processes including mud volcanism [1,2,3], igneous volcanism [4,5] and pingos [6].

Observations: Image data from the High Resolution Imaging Science Experiment (HiRISE) show that mounds are circular in map view, with typical diameters of 50 – 700 m. Three mounds represented in the gridded 128 pixel/degree Mars Orbiter Laser Altimeter (MOLA) digital terrain model (DTM) are 20–30 m tall, but probably not fully resolved. No other DTMs, including HRSC DTMs, of the area are available. One to multiple circular depressions are centered about the midpoint of most mounds. Other mounds have a knob-like morphology with a distinct summit and no depression. The mounds have an albedo that is higher than the surrounding plains, but moderate overall for Mars.

These mounds are located within and around a network of tabular zones that are relatively smoother than the surrounding terrain, which is characterized by the aforementioned mounds, along with smaller knobs and ridges. These smooth zones (SZs) are quasi-linear overall, with boundaries that are marked by broadly sinuous ridges and scarps (Fig. 1). The SZs form a network with T and Y–junctions. In some instances, the terminus of a SZ is not clearly defined–the boundary ridges and scarps become subdued and non-distinct from the local terrain. The MOLA DTM suggests that the SZs are positive relief features, with typically less than 5 meters of relief.

The map-view geometries of the boundary ridges and scarps on opposite sides of the SZs are identical and complementary; that is the boundaries of a SZ would fit together like pieces of a puzzle if the intervening SZ material were removed, like spreading centers or bands on Europa [7]. The surfaces of the SZs exhibit subtle ridges and swales with wavelengths of

Fig. 1 (Left). The smooth zones (SZs) and mounds investigated in this work. Background is a mosaic of two HiRISE observations. Image centers 31.8° N, 95.2° E and 31.5° N, 95.3° E

~50 m. These ridges and swales are oriented subparallel with, or at a low angle to, the boundary ridges and scarps. In some areas, this relatively smooth material superposes the boundary ridges and scarps and has lobate margins distal to the SZ.

The boundary ridges and scarps of the SZs crosscut some mounds. Three mounds in the northern part of the study area are cut in this way, so that a portion of the affected mound lies outside of the SZ, with a complementary portion within the SZ (Fig. 1; landforms labeled faulted mounds). In two instances, crosscut mounds can be matched across a SZ – semicircular mounds on opposite sides of the SZ can be pieced back together along the boundary scarps (Fig. 1; landforms labeled offset mounds). In other instances, fragments of crosscut mounds exist only outside of the SZ, with no complementary fragments observed within or on the other side of the SZ (Fig. 1; landform labeled mound fragment). The SZs also crosscut ridges and other landforms, including an enigmatic ring of small knobs (Fig. 1; landform labeled ring of knobs), which can be matched up along opposing boundary ridges and scarps.

Intact mounds also occur within the SZs and superposing the boundary ridges and scarps. These mounds are circular and exhibit no evidence of crosscutting faults or other deformation.

Interpretations: Here we focus on developing interpretations of the observed SZs and possible clues that they may provide into the origin of the mounds.

Based on the observations that SZs crosscut some mounds, particularly those mounds that are displaced to either side of a SZ, as well as the observation that opposing boundaries of the SZs are complementary, the SZs are interpreted as rifts. This interpretation is consistent with the observation that the SZs form T and Y–junctions, as is characteristic of opening-mode fractures (joints).

The smooth deposits within the SZs are interpreted as mobilized flow-like material based on the observation that this material superposes the boundaries of the SZ in some areas and it has lobate margins (Fig. 1; landforms labeled lobate margins). This material may have welled up from depth below the rift or was emplaced as surface flows that flowed into and filled the rift.

Rift formation through either thin-skinned or thick-skinned deformation is admissible given the currently available observations. A thin-skinned scenario would involve mound formation on the solidified surface of mud or lava flows, so that rifting occurred as solidified plates were rafted above still mobile mud or lava. A thick-skinned scenario would involve mound formation on solid ground, and rifting occurred through brittle faulting to multiple kilometers' depth.

Discussion: We currently favor a thin-skinned scenario for rift formation because the MOLA DTM of the area shows no evidence of the footwall uplift [8] that would accompany normal faulting to multiple kilometers' depth. However given the low resolution of the MOLA DTM, a more conclusive analysis requires a HiRISE DTM – this area has been targeted for stereo HiRISE coverage for this purpose.

If evidence of a thin-skinned scenario for rift formation were found through analysis of the HiRISE DTM, this would afford support to the mud and igneous volcanism interpretations for mound formation, and counter interpretations of the mounds as pingos. Unfrozen/molten mud and lava flows would be incompatible with contemporaneous pingo growth when considering the elevated temperatures associated with unfrozen/molten flows and ground temperatures and timescales required for pingo growth. Observations of terrestrial examples [9] indicate that pingo growth requires frozen ground (permafrost) and that growth over multiple decades would be required to achieve heights of ~30 m, typical of the mounds in the study area. Additionally, we do not observe other associated features commonly attributed to periglacial processes on Mars such as meter-scale patterned ground or scalloped terrain.

Furthermore, the morphologies of the mounds and the surrounding plains also leads us to favor the interpretation that these features formed through mud volcanism. The mounds are morphologically distinct from the rafted phreatovolcanic cones observed in areas such as Athabasca Valles, which are ring-shaped– frequently containing multiple subordinate rings and mounds within–and often surrounded by a shallow moat [10] The plains in the study area also lack common indicators of volcanic flows, such as flow margins, lava channels, tubes, and other markers of consistent flow direction like wakes around obstacles.

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