Distribution, origin and evolution of hypothesized mud volcanoes, thumbprint terrain and giant polygons in Acidalia, Utopia and Arcadia Planitae: Implications for sedimentary processes in the northern lowlands of Mars.

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Introduction: This study is part of the activities of an ISSI International Team, which intends to produce new geomorphological maps of the northern lowlands of Mars along three long traverses across Acidalia, Utopia, and Arcadia Planitiae [1]. We aim at identifying the evolutionary history and the stratigraphy of sediments and other material and their relation to water and/or ice. This specific study focuses on mounds of different sizes: Large Pitted Mounds (LPM), Thumbprint Terrain (TPT), Small Mounds (SM) as well as km-sized polygons [2,3]. These landforms were formed on the Vastitas Borealis Formation (VBF) Marginal and Interior Units, which are interpreted as outflow channel deposits or sediments of a hypothesized ocean. The VBF units cover large parts of the lowlands [4] and the results from MARSIS data suggest that the porous sedimentary materials of the VBF units have a larger distribution in the subsurface [5]. Skinner et al. [6] interpret flow-like features in the VBF Marginal unit in southern Utopia Planitia as the result of seismically-induced liquefaction of the unconsolidated outflow channel deposits. In contrast, ref [7] concluded that the origin of flow-like lobes and the hypothesized mud volcanoes – hereafter referred to as LPM - is due to overburden pressure on the unconsolidated, fine-grained and water-saturated sediments induced by a later coarser-grained and denser outflow sedimentary activity. The aim of our study is to map the above mentioned features and establish a formational history of the same features along the northern lowlands, based on their detailed morphologic, stratigraphic and distributional characteristics.

- **Methods:** Our study is based on CTX mosaics (6 m/pixel) of three traverses across Acidalia [8], Utopia [9] and Arcadia Planitiae [1] displayed in ArcGIS 10.2.1 software using a grid-mapping approach [1] (Fig. 1). We also used data from HiRISE (0.25 m/px), HRSC (images >10 m/px, HRSC- derived Digital Elevation Models [DEM], grid size 50-200 m), MOLA DEM (~460 m/px), and THEMIS Nighttime IR (~100 m/px). We mapped the same landforms in the three observed areas and performed statistical analysis using point and line-type features in ArcGIS. Using this technique we analyze the relationship and timing of the specific landforms. In summary of our work, we establish a detailed sequence of the sedimentary processes including the LPM, TPT, SM and giant polygons, which were not discussed earlier together.

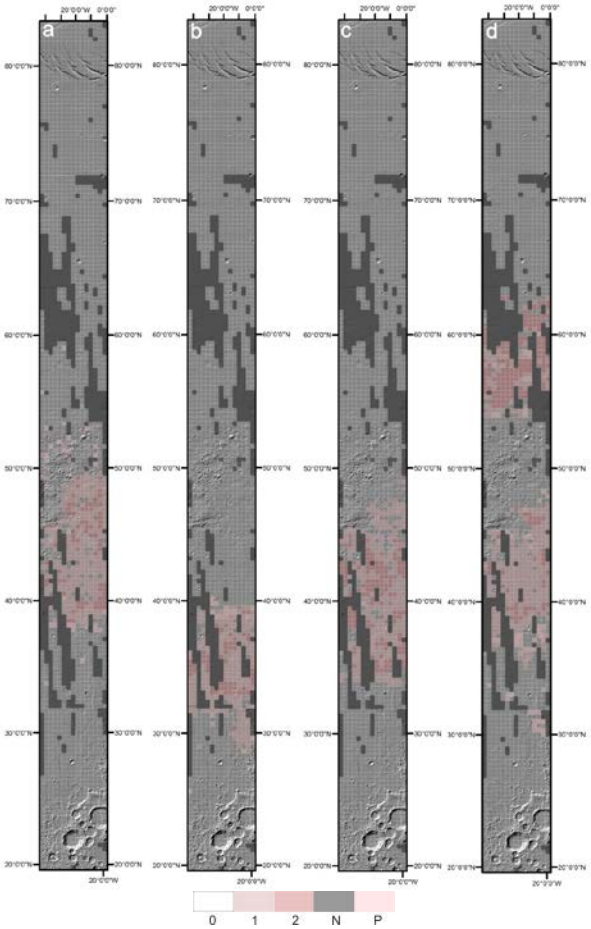

Fig. 1. Grid-mapping results of the Acidalia Planitia. a/Large Pitted Mounds, b/ Thumbprint Terrain, c/ Small mounds, d/ Giant Polygons.

Observations:

Thumbprint Terrain (TPT)

The TPT appears north of about 30°N in the termination zones of the Chryse outflow channels and shows a transition zone with the LPMs at around 36°N in Acidalia Planitia. In Arcadia Planitia the TPT features are concentrated from55°N to 63°N, at higher latitudes than in Acidalia Planitia, although they are located around the same elevation range (-4100 m to -4300 m). We observed these features in Utopia Planitia from 30°N to 40°N.

Large Pitted Mounds (LPM)

North of 39°N, only LPM can be observed in Acidalia Planitia (Fig. 2). PM are typically surrounded by topographic moats. Sometimes more than 75% of a mound can be covered or embayed by „plain filling material" of varying thickness. The LPM are observed in the same area as large-scale polygon troughs associated with circular-shaped small mounds (SM). The LPM either overlie the troughs or are located inside or adjacent to them. In some cases the polygon troughs are filled by dark albedo sediments, and can be almost completely covered. In Arcadia Planitia the LPMs are rare landfroms, they only occur at 38°N and 55°N. In Utopia Planitia, LPM are located from 30°N to 40°N, like the TPT features in this area.

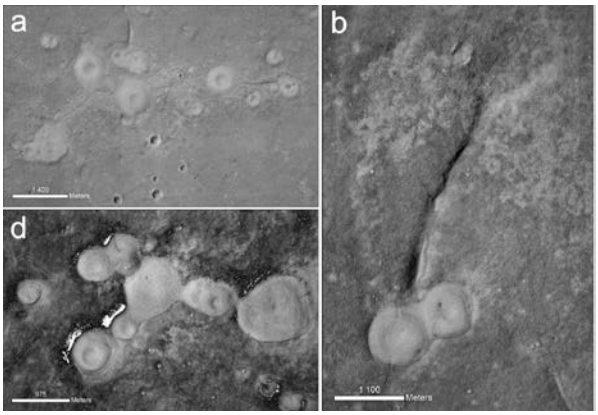

Fig. 2. Large Pitted Mounds (LPM) and Giant Polygon (GP) in Acidalia Planitia. a/ Cluster of LPM b-c/ LPM are located in polygon troughs and surrounded by a moat.

Small Mounds (SM)

The SM in Acidalia Planitia are located from 34°N to 48°N, completely overlapping the area of LPM and partly the TPT. These features are randomly distributed, but commonly arranged in clusters. Their domical shape with the central pit shows morphological resemblance with the LPM. In Arcadia Planitia these landforms are more widely distributed from 30°N to 62°N like in the other areas. They are located not only in assotiation with LPM or TPT but also noutside of their distribution range. In Utopia Planitia, they are located from 34°N to 42°N and more rarely at 50°N, similar to the distribution of the LPM and TPT.

Giant Polygons (GP)

These features characterize the area from 35 N° to 61 N° and completely disappear in the Acidalia Colles region in Acidalia Planitia. In Arcadia Planitia, the GP are located from 70°N to 75°N and possibly from 32°N to 35°N and at 50°N. This observation does not correlate to the distribution of LPM, TPT and SM in this area. In Utopia Planitia the GP are arranged from 36°N to 40°N and from 47°N to 49°N as well as at 60°N. The LPM and TPT are only overlapping with the occurence of the GP at the lower latitudes.

Preliminary Results:

- The grid mapping results show a morphological transition zone of the TPT into the LPM in the Acidalia Planitia. It varies by latitude and may be related to the distance from the circum-Chryse outflow channel and the thickening of sediments towards Acidalia Planitia. This transition along increasing latitudes is not observable in the Arcadia and Utopia Planitiae, although LPM and TPT are both occuring these areas. Thus the initial sedimentary conditions could be different in the study areas.
- We find observational evidence for complete or partial sedimentary burial of LPM as well as polygon troughs by a viscous flow material in Acidalia and Utopia Planitiae. This material shows flow fronts, suggesting an emplacement by viscous flow processes [6,7]. These observations may suggest (multiple) sedimentary processes and similar emplacement mechanism in the Acidalia and Utopia areas.
- We established a new approach of the detailed sequence of the origin of the main four landforms (LPM, TPT, SM and giant polygons) in combining the results of the previous studies [6,7].

References

[1] Ramsdale, J. et al. (2015) 46th LPSC, Abstract # 1339. [2] Frey, H. and Jarosewich, M. (1982) J. Geophys. Res. 87, B12, 9867-9879. [3] Oehler, D.Z. and Allen, C.C. (2010) Icarus 208, 636-657. [4] Tanaka, K.L. et al. (2005) USGS Scientific Investigations Map 2888. [5] Mouginot et al. (2012) Geophysical Research Letters, Vol. 39. L02202. [6] Skinner et al. (2008) XXXIX LPSC, Abstract # 2418. [7] Salvatore, M. R. and Christensen, P. R. (2014) JGR Planets, doi: 10.1002/2014JE004682. [8] Hauber et al. (2015) 46th LPSC, Abstract # 1359. [9] Séjourné et al. (2015) 46th LPSC, Abstract #1328.