MUD FLOWS IN THE SOUTHWESTERN UTOPIA PLANITIA, MARS. V. Cuřín[1], P. Brož[1,2], E. Hauber[3], Y. Markonis[1], [1]Czech University of Life Sciences Prague, Faculty of Environmental Sciences (curin@fzp.czu.cz), [2]Institute of Geophysics of the Czech Academy of Science, [3]Institute of Planetary Research, German Aerospace Center

Introduction: We present the results of our mapping campaign of a large field of landforms characterized by flow-like morphology in the southwestern part of Utopia Planitia. These have been previously interpreted as mud flows associated with a partly frozen muddy ocean [1,2]. The area of Adamas Labyrinthus lies in the deepest parts of Utopia Planitia which served as depocenters since early in the Martian history [2,3]. Thus, it would be the final destination for any material released during Hesperian catastrophic floods [4]. Consequently, it was proposed that a large body of water might once or repetitively have been present there [1,5]. However, such hypothesis is controversial due to the lack of unambiguous morphological evidence [6]. Our search for evidence yielded more than 300 features with distinct morphology spread across a 500 × 1300 km large area. We find that these features can be grouped into four separate classes with distinct shapes and sizes and a clear evolutionary sequence among them. This suggests that the features were formed by the same basic process of subsurface sediment mobilization and that the material likely originated from the same source.

Methods: Our mapping is based on the global CTX Mosaic (5m/pixel) [7] which served as the base map for delineation of the observed features. The features were marked as point, linear, and polygonal features in a QGIS environment. HiRISE (0.3 m/pixel) and CTX stereo pairs were processed using the MarsSI service [8] to produce digital elevation models (DEM) for some studied landforms. This enabled us to calculate their basic morphometric characteristics, height and volume, but also to reveal the relative stratigraphy among them and their surroundings.

Results: We found and mapped more than 300 features with positive topography characterized by flow-like appearance. We classified them into four groups based on their extent, shape, and morphological properties (e.g., surface roughness). The resulting classes are 'hills' (Fig. 1a), 'ridges' (Fig. 1b), 'plateaus' (Fig. 1c), and 'complexly layered units' (CLUs, Fig. 1d), but we note that landforms commonly show transitional stages, hence share characteristics of multiple classes (such as in Fig. 1b).

Hills are the smallest studied features. They are characterized by circular plan-map appearance. Their surface texture can be either smooth or rough with flow-like structures extending beyond their bases (Fig. 1a). Hills can be solitary features or be associated with fractures, in which case they form hill chains. Ridges are elongated features with rough surface. They vary in width from narrow sub-kilometer stretches to wide and elevated smooth plateau-like features (see Fig. 1b) surrounded by hummocky rims. Plateaus (referred to in [2] as "etched flows") are kilometer-sized features characterized by a smooth central uplifted unit usually surrounded by a rough boundary (Fig. 1c). The smooth unit often contains rimless pits. Plateaus sometimes superpose the polygonal throughs typical for Adamas Labyrinthus. The final type are CLUs represented by extensive and often chaotic combination of overlapping landforms mentioned above (Fig. 1d). Their relative stratigraphy is decipherable only with the use of DEMs.

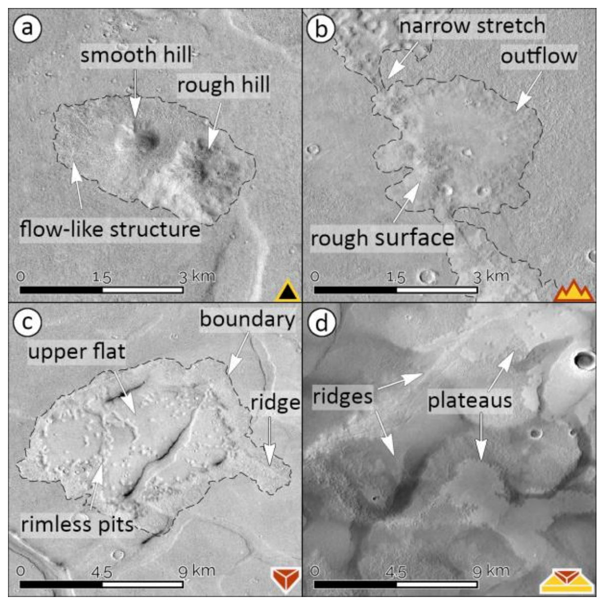

Figure 1. Examples of studied landforms as seen by CTX (a-c) and blended with CTX-derived DEM (d). a) Two hills (CTX image P17_007502_2195, centered at 37.43°N, 104.61°E); b) Ridge with a plateau-like outflow (CTX image F01_036037_2199, centered at 38.09°N, 96.14°E); c) Large plateau consisting of a smooth upper part with rimless pits bordered by lower rough part of rugged hummocky lobes (CTX image P17_007779_2181 and P19_008280_2190 , centered at 39.10°N, 101.00°E); d) Complexly layered unit with two ridges and multiple plateaus (CTX image G03_019264_2169, centered at 36.00°N, 98.81°E).

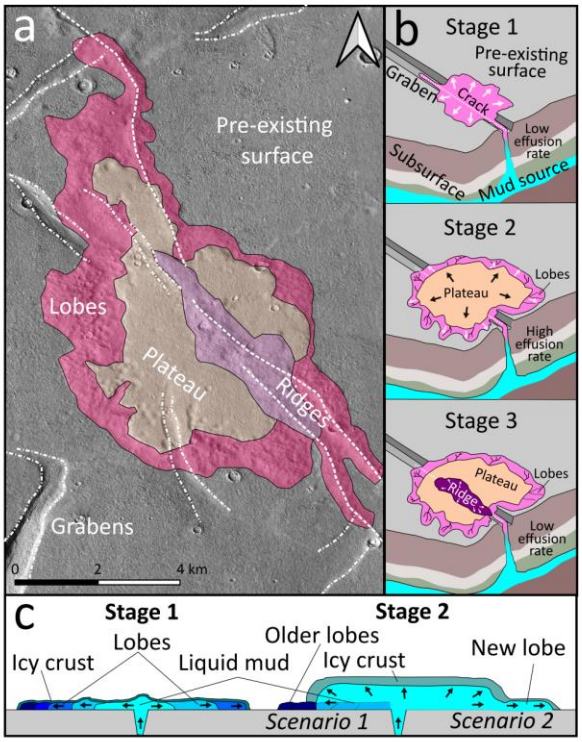

Figure 2. Schematic drawing showing the constructive process by which a plateau with multiple units of different surface roughness is formed. a) Plateau with highlighted central smooth unit, ridges, and lobate edges b) Three stages of development of the depict plateau in a plan-map view with the source area depict in cross-section c) First two stages of development of the depict plateau in a cross-section; CTX image J04_046481_2163_36N260W, centered at 36.96°N, 99.36°E

Discussion: Previously, many flow-like features have been described elsewhere on Mars as lava flows [9,10]. At the first glance this might seem like a plausible scenario even here as the studied features bear many morphological similarities with terrestrial and martian lava flows. However, our survey did not reveal signs of subsidence or explosive excavation associated with studied features, which are commonly accompanying volcanic eruptions [e.g. 9,10]. We also did not find evidence of lava-water interactions (e.g., rootless cones) which would have favorable conditions to occur at this location as the studied features are superposed on terrain enriched in volatiles as documented by polygonal troughs, ghost craters and pedestal craters [2].

Instead, the morphological characteristics of the mapped features, transitions between their categories and the spatial context of the study suggest that the landforms are of sedimentary (mud) volcanic origin. Recently, Brož et al. [11] showed experimentally that low viscosity mud effusively emplaced onto the cold martian surface under the low atmospheric pressure of 7 mbar would behave similar to pahoehoe lava, and resulting landforms might have similar appearance. This is because the evaporative cooling of water would cause the formation of an icy crust on the surface of the mud flow, analogous to a solidified lava crust. This process might explain the observed shapes of the studied features.

Conclusions: We propose that the studied features were formed due to the expulsion of mud from a gradually freezing muddy body (Fig. 2). Because of the climatic conditions on Mars such body would be freezing from the top down, causing an increase in the internal pressure of the still liquid mixture underneath. This would trigger the ascent of the mud towards the surface via cracks in the frozen crust and subsequent effusive eruptions. Once the mud would be exposed to the surface, it would spread by flowing over the surface, while freezing at the same time. This would limit its ability to flow but cause the resulting outflow to have an appearance similar to terrestrial lava flows. This process gave rise to the observed hills, ridges, plateaus and complexly layered units. Emergent landforms degraded over time as the volatile part of the compound sublimed away eventually leading to the characteristic morphology we observe today.

Acknowledgments: This work was supported by Czech Science Foundation (#20-27624Y).

References: [1] Jöns (1985), Lunar Planet. Sci. 16, 414–415; [2] Ivanov et al. (2014), Icarus 228, 121-140; [3] Frey et al. (2002), Geophysical Research Letters 29, no. 10, 22-1-22-4; [4] Carr (1996), Planetary and Space Science 44, 1411-1423; [5] Ivanov et al. (2015), Icarus 248, 383-391; [6] Sholes et al. (2021), Journal of Geophysical Research: Planets 126, no. 5; [7] Dickson et al. (2018), 49th Lunar and Planetary Science Conference 2018, LPI Contrib. No. 2083 ; [8] Quantin-Nataf et al. (2018), Planetary and Space Science 150, 157-170; [9] Hodges & Moore (1994), Atlas of volcanic features on Mars; [10] Hauber et al. (2009), JVGR 185, 69-95; [11] Brož et al. (2020), Nat. Geo. 13, 403-407