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Possible Subsurface Sediment Mobilization and Release of Volatiles in Southern Chryse Planitia, Mars

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Abstract

Here we present the results of our mapping of a large field of cones and pie-like features in the Chryse Planitia area on Mars, which have been previously described as mud volcanoes [1]. Our aim was to determine the full extent of this field and perform a comprehensive morphological, morphometrical, and spatial analysis of the landforms. We mapped a total of 1313 objects and distinguished five different morphological classes. The spatial distribution of the features is clustered and anticorrelated to the highlands, favoring a sedimentary origin.

1. Introduction

Ever since the presence of methane in the Martian atmosphere was first reported [2,3], mud volcanism was hypothesized to be a possible release mechanism [4], and various mud volcano fields have been tentatively identified [1]. It is difficult, however, to define diagnostic morphological properties of mud volcanism in remote sensing data, and some of the reported mud volcanoes have alternatively been interpreted as igneous volcanoes [5,6]. In this study, we test the hypothesis by Komatsu and colleagues [1] that small cone- or pie-shaped landforms in Chryse Planitia are mud volcanoes (as the use of the term "mud volcanism" has far-reaching implications [7-8], we prefer to follow a conservative approach and use the more generic term "subsurface sediment mobilization" [9]).

Our study area (8°N to 31°N/315°E to 330°E) is located near the southern boundary of Chryse Planitia at the terminations of the large outflow channels such as Ares, Simud, and Tiu Valles. Ancient highlands are eroded into streamlined "islands", and the former floor of the channels has been resurfaced and forms a relatively flat plain formed by flood deposits and possibly volcanics that slopes very gently towards north (<0.25°). These inter-island plains were mapped as Late Hesperian units HCc_3 and HCc_4 and Early Amazonian unit ABVm [10].

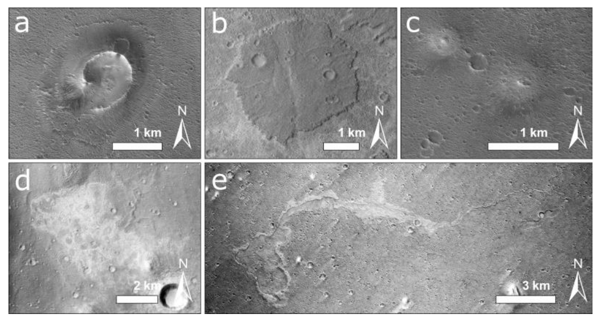

Figure 1: Five types of landforms that may be the surface manifestations of subsurface sediment mobilization. A) type 1, cones; (image: HiRISE); B) type 2, pies (image: CTX); C) type 3, domes (CTX); D) type 4, irregular pies (CTX). (e) type 5, [channelized] flow-likefeatures (CTX). Types 1-3 were already described by [1].

2. Data and methods

Several datasets were used for our morphological interpretations in the Chryse Planitia area: CTX (~5-6 m/pixel, [11]), HiRISE (~0.3 m/pixel, [12]), THEMIS daytime infrared (~100 m/pixel, [13]), and HRSC anaglyph images and Digital Elevation Models (~12.5 m/pixel [14]). Mapping was performed in a GIS (Geo-graphic Information System) environment and units and objects were demarkated as polygons, polylines and shape points. We mapped highlands, craters, ejecta blankets, possibly extrusive features, fractures, and wrinkle ridges. Spatial investigations of mapped objects include nearest neighbor analysis, rectangle analysis, circularity calculations and orientation analysis.

3. Results

Three types of landforms possibly indicative of extrusive processes in the study area were previously described [1]: type 1 (steep-sided cones; Fig. 1a), type 2 (nearly flat, or pie-like, structures; Fig. 1b), and type 3 (nearly circular, dome-shaped features; Fig. 1c). We introduce two additional types: Type 4 (Fig. 1d), is characterized by a sheet-like appearance with irregular plan shape and lobate margins. Objects of this type are nearly flat (almost no topographical expression) and typically larger than 1 km in diameter, similar to type 2 features. Their surfaces are distinctively different from surrounding material, as they seem to exist of two different morphologies: light, smooth material, and dark, fractured material. In several areas these features can be observed in association with the other types suggesting that there may be a genetic link. Type 5 displays a flow-like appearance which is commonly associated with channels (Fig. 1e). The spatial distribution of the possibly extrusive features appears to be anticorrelated to the highlands (Fig. 2), in other words they only occur on the level plains between the erosional remnants of the ancient highland material. Nearest neighbour analysis shows a less than 1% likelihood that the spatial distribution could be random, i.e. the features are clustered. The different types appear in NEE-SWW oriented bands.

The minimum bounding geometry tool of ArcMap gives the length of the longer side of an enveloping rectangle around the polygons, and is here used as a proxy for the orientation of the extrusive features. We obtain a preferred E-W orientation, ranging from 65° to 115° (clockwise from North), with a mean orientation of 88°. Fractures appear mainly in patterns that are oriented parallel to the flow direction in the outflow channels, and their distribution is also anticorrelated to the highlands. The most densely populated fracture areas are observed in the northern (i.e. distal with respect to the outflow channel terminations) parts of the study area, without a clear correlation to the location of the conical features. Further up-stream (proximal), the fractures display more transverse orientations.

4. Conclusions

The spatial distribution of the mapped features, which are excusively located in the sedimentary plains between the erosional remnants of the ancient highlands (see Figure 2), suggests a formation mechanism that is linked to a relatively shallow source beneath or within the sediments. Igneous volcanoes fed from deep sources (e.g., distributed in monogenetic volcanic fields), on the other and, would be expected to be distributed on both the plains and the highlands. Our observations hence support previous conclusions [1] that an igneous origin is less likely than a sedimentary volcanic origin. Such conclusion is further supported by evidences of flow-like features caused by the movement of low viscous material, possibly a mixture of water with sediments.

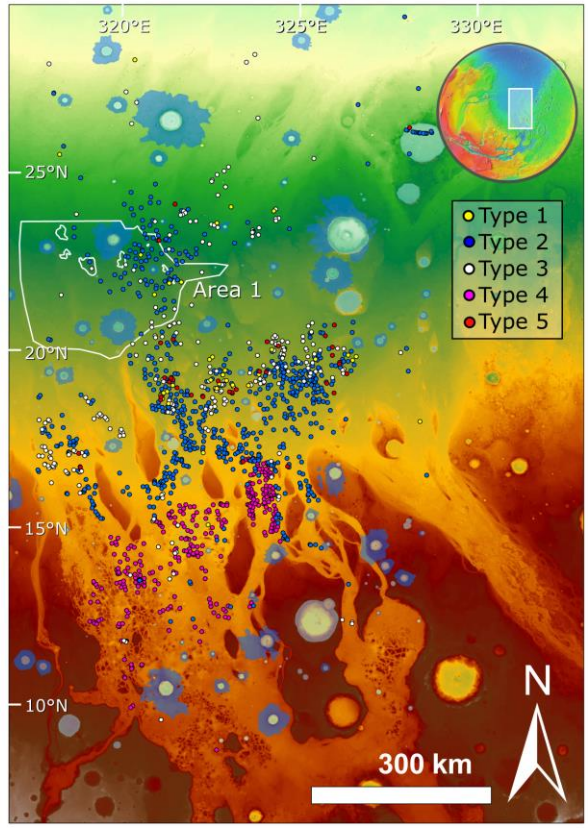

Figure 2: Overview of the mapped landforms on a HRSC DEM basemap. Yellow symbols: type 1 (cones), blue: type 2 (pie-like features); white: type 3 (domes); purple: type 4 (irregular sheet-like features); red: type 5 (large flows). The blue polygons around the impact craters mark the position of rampart ejecta.

5. References

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