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Morphology and geology of an interior layered deposit in the western Tithonium Chasma, Mars

Davide Baioni *

Dipartimento di Fisica e Scienze della Terra, Università di Parma, Parco area delle Scienze 157a, 43100 Parma, Italy

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ABSTRACT

This paper describes a morphologic and morphometric survey of a 3.1 km-high, domeshaped upland in western Tithonium Chasma (TC) which coincides with areas containing abundant surface signatures of the sulphate mineral kiersite, as identified by the OMEGA image spectrometer. The morphologic features of the dome were investigated through an integrated analysis of the available Mars Reconnaissance Orbiter High Resolution Imaging Science Experiment (HiRISE), Mars Orbiter Camera, and Context Camera data, while the morphometric characteristics of the structure were measured using a topographic map (25-m contour interval) built from high-resolution stereo camera (HRSC) and Mars Orbiter Laser Altimeter (MOLA) data.

The dome displays surface features that were apparently formed by liquid water probably released from melting ice. These features include karst landforms as well as erosive and depositional landforms. The surface of the dome has few impact craters, which suggests a relatively young age for the dome. Layers in the dome appear laterally continuous and are visibly dipping toward the slopes in some places.

The mineralogical and structural characteristics of the dome suggest that it was emplaced as a diapir, similar to the dome structure located in the eastern part of TC, and to many salt diapirs on Earth.

1. Introduction

The Tithonium Chasma (TC) is the northern trench in the western troughs of the Valles Marineris (VM) structure (Fig. 1A), a rift system that belongs to the Tharsis radial fracture pattern (Carr, 2006). Located next to the Martian equator, the elongated TC extends about 850 km east–west. Both the eastern and western ends of the TC contain deposits displaying dome morphology and consisting of magnesium sulphate, as indicated by Observatoire pour la Minéralogie, l'Eau, les Glaces, et l'Activité (OMEGA) data (Bibring et al., 2006; Popa, 2006; Popa et al., 2007a).

This article focuses on one such dome-shaped upland deposit that rises from the chasma floor in the western part of the TC (Fig. 1B and F). Previous examinations of a similar structure in the eastern TC demonstrated its similarity to terrestrial structures (Baioni and Wezel, 2008), the existence of karst landforms and processes (Baioni et al., 2009), and its probable diapiric origin (Baioni and Wezel, 2010; Popa et al., 2007a). A previous preliminary study (Popa, 2006) also suggested that domes in the western TC had diapiric origins.

This kind of structure, well known as an interior layered deposit (ILD), occurs throughout the chasms of the VM and was first recognised on Mariner 9 images (Lucchitta et al., 1994). In all of these canyons, the layered deposits tend to form light-toned, rounded mounds or flat-topped mesas toward the canyon centres that are separated from the canyon walls by irregular depressions or moats. The albedo and erosive style of the ILDs typically differ markedly from those of the wall rocks (Carr, 2006).

Multiple hypotheses for the origin and mechanism of formation of the ILDs have been proposed (Chapman and Tanaka, 2001; Hauber et al., 2006; Komatsu et al., 1993; Malin and Edgett, 2000; Rossi et al., 2008; Weiz and Parker, 2000). Most authors have suggested that the ILDs are younger than the troughs in which they are presently found, although some have argued that they may be older, exhumed deposits (Catling et al., 2006; Fueten et al., 2008, 2009). The origin of the ILDs remains controversial and unclear.

The goal of this study, following previous work on the dome located in the eastern part of the TC (Baioni and Wezel, 2010), was to determine the nature and possible origin of this elevated structure in the western TC.

To this end, the morphological features of the structure were investigated through an integrated analysis of the available Mars Reconnaissance Orbiter High Resolution Imaging Science Experiment (HiRISE) (McEven et al., 2007), Mars Orbiter Camera, and Context Camera (Malin et al., 2007) data. The morphometric characteristics of the structure were measured using a topographic map (25-m contour interval) built from high-resolution stereo camera (HRSC) and Mars Orbiter Laser Altimeter (MOLA) data.

* Tel./fax: +39 521 905343.
E-mail address: davide.baioni@unipr.it

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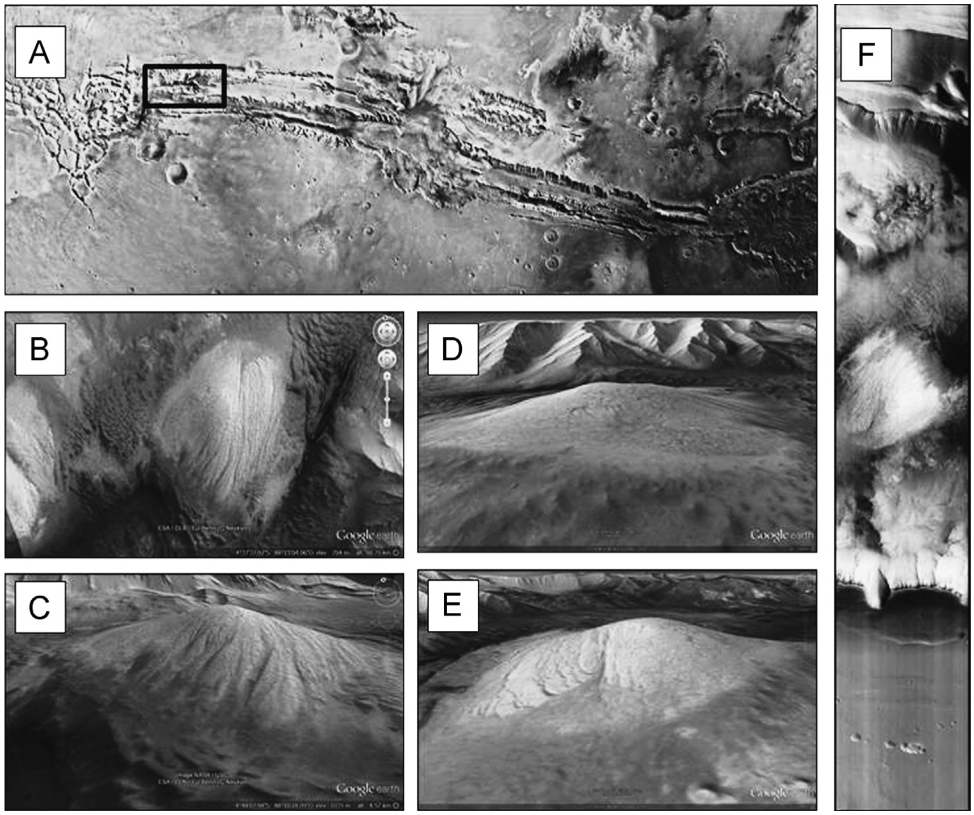

Fig. 1. (A) Location of the study area in the western Tithonium Chasma (TC), in Valles Marineris system, Mars (black box). (B) Image of the WTD, as viewed from above. (C) Image of the WTD as viewed from south. (D) Image of the WTD, as viewed from east. (E) Image of the WTD as viewed from north. (F) portion of western TC where the chasma walls and location of the WTD can be seen. Image CTX P10_005070_1754_XN_04S088W (north toward down). (A)–(E) Images NASA/USGS/ESA/DLR/FU Berlin (G. Neukum) taken from Google Mars (www.google.com/mars).

2. Study area setting

The TC canyon (Fig. 1A) cuts through the surrounding Hesperian Plateau (Scott and Tanaka, 1986) and has a depth of about −2600 m relative to the average Martian MOLA radius datum. Relative to the eastern part, the western TC has a wider opening (130 km) and lower depths. The canyon narrows from west to east and forms another chasma-like depression just before emerging trenches connect it to the Chandor Chasma.

The western part of the TC is a linear trough that may be interpreted as a possible graben in which recent tectonic activity has occurred only on the northern wall. The morphology in other parts of the trough seems to be related primarily to erosional processes and secondarily to tectonics (Peulvast et al., 2001). The chasma walls display numerous finger-shaped side canyons formed by groundwater sapping. Moreover, high angle hillslopes, indicating that the walls consist of consolidated material, can be well observed. The TC floor is mostly rugged. Some regions of the floor are covered with landslide debris or are cracked by movement along faults, suggesting that the topography was produced by subsidence of the floor along the faults.

Spectra from the OMEGA spectrometer provide evidence of sulphate minerals associated with bright ILDs on the floor of the TC. These deposits, which were previously mapped as a geological unit of late Amazonian age and have since been proven to include magnesium sulphate (Bibring et al., 2006), have dome-shaped morphologies (Baioni and Wezel, 2010; Popa, 2006). The deposits are located at both ends of the TC and are elongated parallel to the main tectonic lineation (Popa, 2006). The exposure in the western part of the TC (Fig. 1A) is larger than that in the eastern part.

The western part of the TC starts at 91°W, adjacent to the Noctis Labyrinti, with a wide (maximum 130 km) opening. The southern wall of this part of the TC displays spurs and gullies and some possible faceted spurs, whereas the northern wall displays basal scarps under a much-degraded upper slope with spur-and-gully remnants. The trough floor has impact craters on its surface and sets of lineaments that may represent tectonic fracture systems, and includes wind-related morphologies.

In the central part of the western TC, several sulphate-rich ILDs rise from the chasma floor and display characteristic dome-shaped morphologies (Baioni and Sgavetti, 2013a; Popa et al., 2010). The present analysis focused on the easternmost of these domes (Fig. 1B–F), located close to the southern wall adjacent to the beginning of the central TC (Fig. 1F), hereafter referred to as the Western Tithonium Dome (WTD). The term ‘dome’ is used morphologically to describe the shape of the unit, and does not imply any interpretation or meaning related to the processes that formed the studied relief.

The mineralogical characteristics of the WTD were previously determined by analysis of data from the OMEGA spectrometer, which mapped it as a sulphate deposit (Bibring et al., 2006). Further studies of the characteristic spectral absorptions for the hydrated magnesium sulphate deposits within the TC revealed additional mineralogical details. According to these studies, the WTD and most other domes in the TC seem to display mainly clear signatures of kieserite (monohydrate sulphate of magnesium) (Mangold et al., 2008; Popa, 2006; Popa et al., 2007a, 2007b, 2007c, 2010). More recent analysis of Compact Reconnaissance Imaging Spectrometer for Mars (CRISM) data confirmed the presence of monohydrate sulphate minerals interbedded locally with polyhydrate sulphate-bearing material, and the presence of jarosite in some basements or topographic lows in eroded ILDs (Murchie et al., 2012).