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Satellite cones and vents at Tharsis Tholus, Mars

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Abstract

We describe satellite cones and vents at the northern flank of Tharsis Tholus. The cones have an elliptical outline and at their downslope portion, channels may emanate which can be traced for several kilometres. We interpret those cones as scoria cones formed during explosive eruptions. The channels are likely formed by lava flows, indicating syn-eruptive effusive stage(s). A fissure eruption occurred at the base of the NW flank and is located within a graben. An explosive eruptive event is evident because it doubled the width of the graben. The associated fallout was deposited to the north and northwest and is clearly visible in THEMIS infra-red night images. The erupted material is partially dark coloured and is exposed just outside the vent. We conclude this eruption was associated with a regional graben-forming tectonic event where magma was tapped and ascended along deep-reaching faults. Finally, we observed a conical edifice rising about 1160 m above the surrounding plain. This construct may represent a stratocone of alternating effusive and explosive volcanic rocks.

1. Introduction

Tharsis Tholus, a partially buried, steep-sided volcanic edifice [1], is located in the eastern portion of the Tharsis volcanic province, approximately 800 km ENE of Ascraeus Mons. The central portion is dominated by a ~37 × 39 km diameter caldera. The edifice has experienced multiple flank collapse events. These flanks were rebuilt during subsequent growth phases leading to the volcano´s composite, irregularly shaped appearance [1,2]. Although growth and destruction cycles of the volcano were already studied, a detailed description and analysis of the flank morphologies have not yet been undertaken. Here we present the first description of satellite cones and vents on the northern and oldest flank of Tharsis Tholus. We also demonstrate that at least at one location an explosive eruption was triggered by regional-tectonics in the recent volcanic history of Tharsis Tholus.

1.1 Methods

In this study we utilised visible imagery of HRSC (12.5 m/px), CTX (5-6 m/px), and HiRISE (0.5 m/px). Morphometric analyses are based on an HRSC digital terrain model with a cell size of 100 m. All data are stored and managed in a geographic information system.

2. Observation

The northern flank is a remnant of a former Tharsis Tholus proto-shield, which experienced several flank collapses and caldera-forming events [1]. It exhibits normal faults, impact craters, rimmed and rimless depressions, and incised, linear to curvilinear channels trending downslope. The largest impact crater is 1.84 km in diameter and about 70 m deep. Its up-slope rim is levelled whereas the downslope rim is still recognisable. The most peculiar features (apart from fault structures) on this flank are channels. They are partially buried, in parts, by thick aeolian deposits smoothing the channel margins, or are visible in sections of gorges of up to 70 m deep. The positions of deeply incised channel sections are related to high slope inclinations. Some well exposed channels are connected to elliptical to irregular shaped, partially rimmed depressions at their heads (Fig. 1). Fully exposed channels (source to base) are 16 km to 23 km (planar distance) long and rarely branched. Channels are truncated by normal faults, hence, channel formation occurred prior to faulting. Some elliptical depressions display a downslope elongation. Some of them also show rims and/or a downslope opening, resembling a horse-shoe-shaped outline in plan view. Aligned and partially

interconnected pit craters are also observed, particular in the uppermost flank portion.

At the lower base of the flank, a well-exposed 38-km graben is observed. The section cutting the northern flank also exhibits several pit craters – collapse structures associated with the extensional event. Just off the northern flank the graben suddenly widens over a distance of 3 km. Here, at the inner walls solid rock strata alternate with unconsolidated fine-grained layers. To the north and northwest a fine-grained deposit extends up to 10 km from this location. This deposit is clearly visible in THEMIS-IR night images.

Off the western flank a conical construct is observed. The nearly perfectly shaped cone rises up to 1160 m above the surrounding lava plain with a diameter ranging between 5.2 km and 4.6 km and a visible volume of ~5.7 km³. On its northwestern side, the conical construct is attached to a 6.5 km long ridge. Both, ridge and cone, are cut by faults; the former exhibits a graben structure. A close-up of the summit area reveals a breached crater with its southern rim missing. The crater itself is located slightly off-centre of the cone. Several radial ridges are also noted particularly on the upper portion, probably representing lava flow ridges and bluffs. Depressions between ridges are filled by a light-toned, unconsolidated material.

3. Interpretation

At the northern portion of Tharsis Tholus, two types of satellite vents are observed: (1) elliptical, partially rimmed scoria cones with channel outlets and (2) a volcanic fissure located within and associated with a graben formation. Both types are formed by explosive eruptions. Scoria cone formation is also accompanied by the effusion of lava forming deep incised lava channels due to thermal erosion, most prominent at steepest flank inclinations. Fissure and scoria cone-forming volcanic activities are thought to be monogenetic.

Present-day rimless scoria cones were partially buried by successive volcanic activities. The fissure eruption is particularly interesting because of its pristine morphology and the presence of a fallout fan extending from the eruption site. The dark coloured appearance of proximal pyroclastic material suggests a recent eruption at this volcano. The graben system formation is related to the latest phase of regional tectonics within the Tharsis volcanic province. A tentative formation age of about 400 Ma is given by [1]. During this regional extensional phase, deep-seated magma bodies within the upper crust where likely tapped enabling magma ascent along fault planes.

The observed conical construct is rather peculiar. A volcanic origin is likely where alternating successions of loose, unconsolidated pyroclastics and solid lava formed a stratocone. However, a weathering process cannot be ruled out. Erosion could also have formed such a cone.

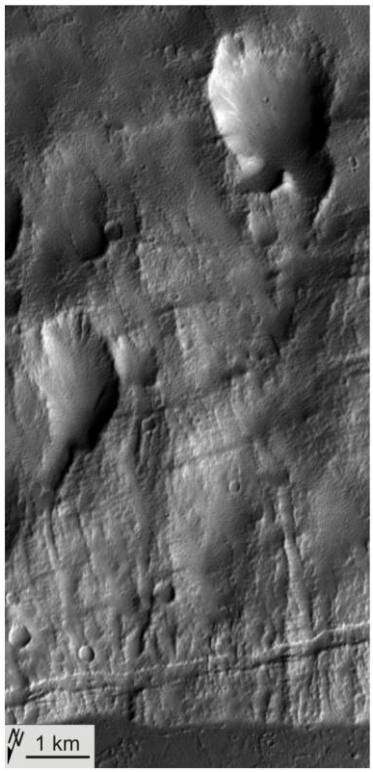

Fig. 1: Satellite cones on the north flank of Tharsis Tholus. Associated channels are cut by normal faults. CTX image P03_002024_1937_XN_13N091W.

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