



Cycles of edifice growth and destruction at Tharsis Tholus, Mars

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Tharsis Tholus, approx. 800 km to the ENE of Ascraeus Mons, is unique among Martian volcanoes as it is structurally divided into sectors suggesting a complex volcano-tectonic evolution [1-3]. The objective of this study was 1) to identify cycles of edifice growth and destruction and causes of instability, 2) to estimate the mineralogical composition of rocks and loose deposits, 3) to provide a time frame of volcanic activity, and 4) to characterize eruptive styles at Tharsis Tholus.

The edifice has a planar extension of 155 km (NW-SE) by 125 km (NE-SW) with an elevation up to 9000 m on the west flank. The volcano exhibits a strong relief and can be subdivided into five major sectors: north flank, west flank, east flank, south flank, and the central caldera. The slopes vary from $<1^\circ$ up to 27° . The volcano is partly buried by lava flows, presumably originating from the Tharsis Montes. As a result, the original basement surface is unknown. However, to the east of the volcano, the tips of a large buried impact-crater rim are still preserved. Using the approximate extension of 41×47 km of the impact-crater rim, a rim height of about 500 m results [4], with the basement being at 500 m altitude. The visible edifice volume is approximately 31.1×10^3 km³, however, if a basal horizontal plane at 500 m is assumed, an edifice volume of $>50 \times 10^3$ km³ results.

The structure of the edifice indicates at least four large deformation events. The central and most prominent structure of the volcano is its central caldera. It is bordered by a well-preserved system of concentric normal faults. The maximum subsidence of the caldera floor is 3000 m; the collapse volume is calculated at approx. 2160 km³. The caldera (36.7×38.9 km) has an elliptical shape oriented NW-SE. The flanks of the volcano are characterized by four large scarps oriented radially from the central caldera. The arcuate shapes of the scarps and their orientations suggest voluminous collapses of the western and eastern volcano flanks. On the southern flank, a further caldera structure is displayed by an arcuate scarp and a plateau-like plain. Due to a large impact event, most of the caldera structure is now concealed. Large parts of the volcano are cut by parallel normal faults forming grabens. These grabens post-date the large collapse structures at the volcano's flanks. All graben structures are oriented in the NE-SW direction. Minimum and maximum graben widths are 0.47 km and 4.36 km, respectively.

Multiple areas of volcanic activity at Tharsis Tholus were identified: 1) flank eruptions associated with graben formation, 2) fissure eruptions, and 3) a satellite vent at the foot of the west flank forming a strato-cone. This satellite volcano has a nearly perfect conical shape and rises 1168 m above the surrounding lava plain. The visible volume is about 5.7 km³. There are currently no indications for volcanic activity prior to or after the formation of the central caldera.

First results of crater counting indicate that the oldest parts of the edifice were constructed at around 3.82 Ga (late Noachian). The west flank appears to be ca. 3.73 Ga old whereas the east flank shows an age of ca. 1.08 Ga (Middle Amazonian). A fissure eruption on the south flank produced a lava flow at around 196 Ma (Late Amazonian).

The existence of two main loci of activity, the central caldera and the subordinate southern caldera, indicate a multipart magma storage system. Changes in lava rheology are observed (shield volcano vs. strato-cone), which indicates magma differentiation within the plumbing system of the volcano during phases of activity. The lifetime of the volcano spans more than 3.6 Gyrs starting prior to 3.82 Ga. Hence, the fissure eruption at around 196 Ma may not represent the final volcanic activity at Tharsis Tholus.

Scarps on the western and eastern flanks are interpreted to be structurally related to at least two large sector collapses. Their arcuate shape can be fitted by ellipses suggesting more or less sub-vertical caldera-like collapses, with the major portion of the upper flanks collapsing into the centre of the volcano and minor portions of the lower flanks collapsing laterally forming debris avalanches. Graben formations across the edifice reflect a regional-tectonic deformation superimposed on the local volcano-tectonic pattern of Tharsis Tholus. The least compressive stress of this regional stress field is oriented NW-SE which agrees with the direction of ellipticity of the central caldera and fitted ellipses to the flank scarps. The geometry of the central caldera indicates a shallow magma storage region, probably at the base of the volcano.

References: [1] F. Maciejak et al. 1995. LPS XXVI, 881-882. [2] J. B. Plescia 2001. LPS XXXII, 1090-1091. [3] J. B. Plescia 2003. Icarus, 165, 223-241. [4] D. H. Scott and K. L. Tanaka 1986. US Geol. Survey. Miscellaneous Investigations Map I-1802A.