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CHARACTERISTICS OF VALLEYS ON CERAUNIUS THOLUS AND THEIR FORMATION: PART I.

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Introduction: Gulick and Baker [1] examined the morphology and morphometry of valleys on six Martian volcanoes, including Ceraunius Tholus. They concluded that the formation of Ceraunius' valleys was due to (or initiated by) surface runoff, and that valleys were reactivated (at least partially) and enlarged by groundwater sapping. Gulick and Baker present this evolution from runoff to sapping as a general morphological path for valleys on Martian volcanoes, and argue that it is consistent with evolution of valleys on the flanks of Hawaiian volcanoes. Here, we review Gulick and Baker's work on Ceraunius Tholus using new MOC, THEMIS, and MOLA data.

This work is part of our ongoing effort which aims to place the formation of the valley networks on the Mars' volcanoes in the context of the larger hydrogeological history of the planet. The late formation of the valley networks on Mars' volcanoes (compared to the valleys in the southern highlands) makes it imperative to understand the process(es) responsible for the valley morphology we observe there because this has important implications for global climate history on Mars.

Geological Setting: Ceraunius Tholus (Fig. 1) is a member of the Uranius group of volcanoes, located at the northeast edge of Tharsis. MOLA data shows that it has an average slope of 8° (σ = 3°) on its flanks, which contrasts with pre-MOLA measurements of 10-12° [2]. It is generally believed to be a basaltic shield, although earlier interpretations suggested it was a composite cone. On its summit lies a broad, mostly flat-floored caldera that is breached at its western rim (Figs. 1). Ceraunius Tholus appears to be at least partially mantled by an easily erodible surface layer. This is most readily seen in the smooth region west of the summit caldera and was likely the result of relatively late pyroclastic eruptions (either coeval or after valley formation).

Since Ceraunius Tholus formed roughly coevally with Uranius Patera, Plescia [3] suggested that it is Late Hesperian in age. Direct crater counts of Ceraunius itself using Viking data suggests an earlier age, but are highly uncertain.

Valley Observations: The valley-like features on Ceraunius Tholus were divided into four groups by Gulick and Baker (Fig. 1): (i) relatively small, pristine valleys with steep walls, (ii) small degraded valleys with eroded walls, (iii) linear chains of connected pits and (iv) large, deeply-incised canyons. Here, we discuss the small valleys on Ceraunius Tholus ((i) and (ii)), as well as the "chain of pits" (iii). In the second part of this abstract, we focus on the large valleys found on Ceraunius Tholus' north flank (iv).

Small Valleys: Small valleys incise much of the surface of Ceraunius Tholus, except for a smooth region on the west flank. The small valleys originate below the summit rim and extend down the flanks in a roughly subparallel manner, with few tributaries and small junction angles. The width and depth of the small valleys are hard to ascertain directly because their width often includes only a few MOLA shots. Therefore, an approximate estimate of the range of typical widths is 200-600 m, although the larger channels in this class can be ~1 km wide. The width of a given channel appears to remain fairly constant. The depth of valley incision is also hard to measure directly, but appears to be somewhat more variable than width for a given valley. Depths are typically on the order of tens of meters with the largest of these valleys having depths ~100-150 m. The majority of small valleys on Ceraunius Tholus are smaller than those measured by Williams and Phillips for typical valley networks on Mars [4]. This is a function of both differences in sampling (Williams and Phillips only considered MOLA crossings of valleys in the Carr database, which includes only the largest valleys), as well as geological processes (more small valleys are seen on Ceraunius Tholus than in the highlands).

Gulick and Baker [1] suggest that some valleys on Ceraunius Tholus appear to be especially pristine, which they say implies that they were reactivated by late-stage fluvial activity which they attribute to groundwater sapping. Based on the new data, especially the available THEMIS imagery, this does not appear to be the case. Many of the valleys that look degraded in Viking frames appear to do so because they are smaller and thus harder to resolve than those mapped by Gulick and Baker as pristine. Although there is certainly a range of valley degradation across the volcano, and a few valleys are noticeably discontinuous, the distinction between pristine and degraded valleys is not striking in the new THEMIS images.

In general, however, Gulick and Baker's description of the morphology and morphometry of the small valleys on Ceraunius Tholus remains apt in light of the new data. The radial symmetry of valleys (excepting the western flank), as well as the near-summit valley heads remains strong evidence that surface runoff played a significant role in valley formation, as Gulick and Baker propose. Despite the doubt that new data casts on whether valley reactivation occurred, groundwater sapping (as well as other processes) probably did contribute to the formation of the valley morphology that we observe on Ceraunius Tholus.

Pitted Valleys: Gulick and Baker drew attention to what appeared to be connected chains of pits on the southwest flank of Ceraunius Tholus, extending from near the summit caldera to the base of the volcano (Fig. 1). The chain of pits appears more continuous in THEMIS and MOC images than in the Viking frames (Fig. 2a). The new images indicate that instead of individual pits, the valley is connected and unusually sinuous near the summit. Down flank it transitions into a style quite similar to other (relatively large) valleys, and near the volcano's base, it divides into two channels, the deeper of which truncates the shallower. Both channels have fan-shaped deposits at their base (Fig. 2b). These fans could have been formed by emplacement of lava, debris, or sediment, depending on the mechanism (or mechanisms) that cut the sinuous valley itself, which are also uncertain. Since it erodes the mantled flank west of the summit, and extends almost to the caldera rim, it is probably younger than most of the small valleys we observe on Ceraunius. Further work needs to be done to understand how this unusual late-stage valley formed.

References: [1] Gulick, V.C. and Baker, V.R. (1990) *JGR*, *95*, 14,325-14,244. [2] Reimers, C.E. and Komar, P.D. (1979) *Icarus*, *39*, 88-110. [3] Plescia, J.B. (2000) *Icarus, 143*, 376–396. [4] Williams, R.M.E. and Phillips, R.J., (2001), *JGR, 106*, 23,737-23751.

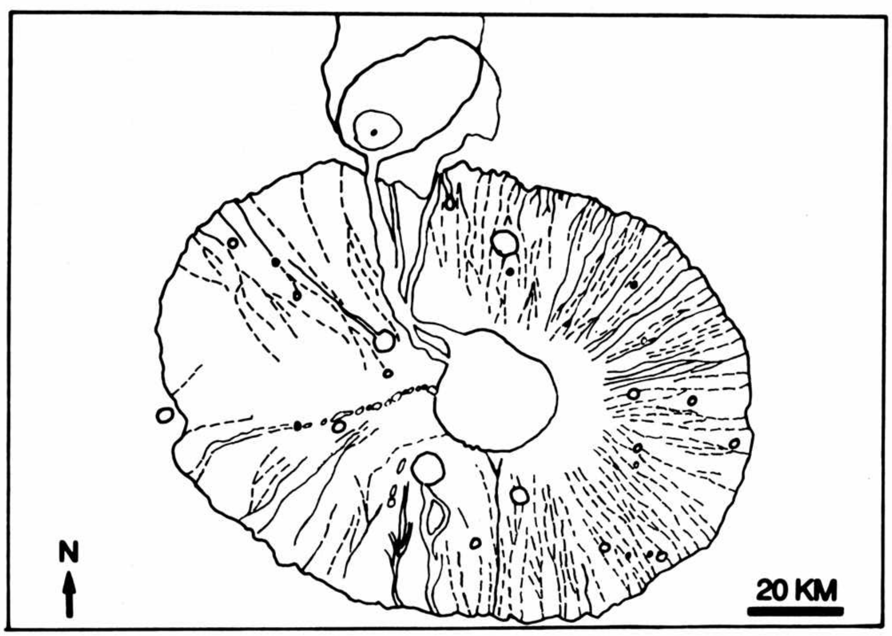
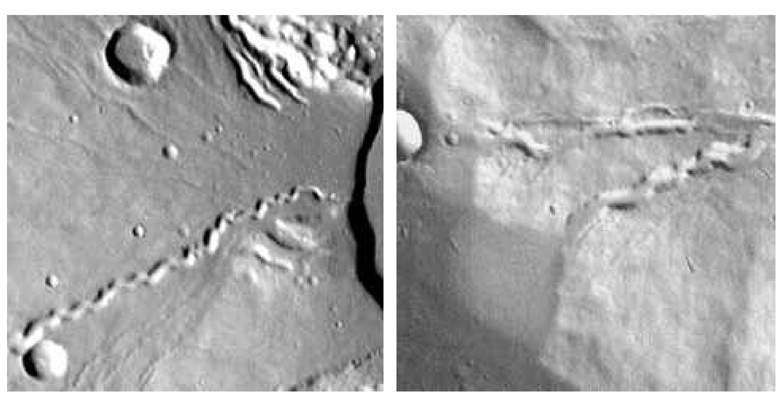


Figure 1: Feature map of Ceraunius Tholus produced by Gulick and Baker [1] (their Figure 5b). The solid lines indicate valleys they consider pristine and the dashed lines indicate valleys they consider degraded. Note that they map the sinuous channel on the southwest flank (shown below in Figure 2) as a chain of pits.



(a) **(b)**

Figure 2: *(a)* A section of THEMIS IR image I2063002 illustrating the unusually sinuous valley on the southwest flank of Ceraunius Tholus. Note the smooth terrain, absence of flows, and evidence of ash-deposits that may infill older valleys on the terrain around this sinuous feature, especially to its north. Also, note the breach in the western crater rim (possibly associated with this ash deposit), and the upper reaches of the large valleys that flow down the north flank of the volcano. *(b)* A section of THEMIS IR image I01364005 that shows the fans at the base two channels that are associated with the valley shown in (a); the bottom valley has a bigger fan and crosscuts the top valley, which must be older.