GEOLOGY OF CERAUNIUS THOLUS, MARS. J. B. Plescia, U. S. Geological Survey, 2255 N. Gemini Drive, Flagstaff, AZ 86001.

The Uranius group of volcanoes in the northeast part of Tharsis includes Uranius Patera, Uranius Tholus, and Ceraunius Tholus; these are among the smaller and older tholi and paterae. Analysis of these constructs is important for understanding the nature and style of early volcanism in Tharsis. Previous studies have considered these volcanoes only in a general manner **(1, 2)**. Here the geology of Ceraunius Tholus is presented; Uranius Patera and Uranius Tholus are described elsewhere **(3)**.

Ceraunius Tholus (Table 1) is an intermediate construct whose most characteristic attributes are the numerous troughs and broader valleys extending down the flank. Between the troughs the flank is characterized by a granular texture; lava flows are not observed. The granular texture is best observed in high-resolution images (Viking 662A) of the eastern flank and is assumed to characterize the remainder of the surface. All impact craters on the flank lack ejecta deposits, suggesting they have either been buried or removed. Circumferential faults or fractures are not observed on the construct. Overall, the surface resembles that of Hecates Tholus **(4)**.

Table 1. Morphometric Parameters

Location	24.2° N 97.1°W
Construct Dimensions	125 x 94 km
Construct Relief [a]	6 km
Flank Slope	6 - 11°
Construct Volume	2.2×10^4 km^3
Caldera Diameter	25 x 22 km
Caldera Depth [b]	0.5 - 2.0 km
Construction Time [c]	200,000 yr.

[a] Relative to surrounding plains.
[b] Depth relative to adjacent flank.
[c] Assumes effusion rate of 0.11 km^3 yr^{-1}.

Three types of troughs are observed: narrow linear troughs; deeper troughs on the north and west flanks; and curvilinear troughs on the south flank; troughs are absent on the west flank. Troughs begin below the caldera rim and are typically set in broader, shallow valleys. They are flat-floored, 300 m to 500 m wide, and spaced ~3 to 4 km. Both pristine and degraded morphologies occur, as noted by **(5)**, suggesting multiple episodes of formation. The morphologic expression of troughs varies downslope between well-defined to vague. High-resolution stereo images (662A) indicate the change in morphology is caused by local changes of slope (i.e., troughs are well-defined on steeper slopes). Troughs terminate at the margins of the construct in fan-shaped deposits.

The linear troughs that characterize most of the flank of Ceraunius Tholus are interpreted to be the result of fluvial processes - a combination of surface runoff and possibly sapping. Such an interpretation is similar to that of **(5)** but contrary to that of **(6)**, who considered them to be the result of volcanic density currents. Volcanic density currents **(6)** are not considered viable as the troughs exhibits morphologic changes associated with subtle slope changes. The large troughs extending down the north and west flank are interpreted to be lava channels.

The summit is characterized by a large, deep caldera and a smaller older caldera remnant to the north; caldera walls are fluted. The caldera floors are typically smooth; a low shield does occur on the eastern side of the main caldera floor. Morphologic relations suggest at least two episodes in which the western margin of the main caldera was breached. Apparently the caldera filled with lava then overtopped and breached the wall and flowed down the flank. Numerous reentrants occur in the flank around the breach, similar to features interpreted as parasitic vents on the flanks of several of the large Tharsis Montes shields **(7)**.

A lack of recognizable lava flows across most of the flank of Ceraunius Tholus and the absence of ejecta associated with the impact craters suggest the flank has been mantled. The presence of troughs suggest the mantling material is easily eroded. As the adjacent plains retain fine-scale morphology, the mantling must be confined to the flanks. Pyroclastic eruptions provide a mechanism to mantle the flanks and afford an easily eroded surface material. The granular texture of the surface is also consistent with a mantling deposit.

Although pyroclastic deposits can explain much of the current flank morphology, other aspects of the geology suggest that effusive eruptions also occurred. The morphology of the west flank (i.e., lava tube), overall morphology of the caldera, and flank slopes suggest that low-viscosity effusive lavas were largely responsible for the construction.

A model for the geologic evolution of Ceraunius Tholus involves the eruption of both effusive lavas and pyroclastics **--** dominantly, effusive eruptions periodically punctuated by explosive eruptions. Effusive lavas are interpreted to be basaltic and as no evidence for silicic chemistries exists, the pyroclastics are considered to be basaltic. A mechanism to produce such pyroclastics **(8)** is interaction of ascending magma with a ground ice / water. Subsurface volatiles are suggested by nearby flow ejecta craters. Although the thickness of the mantle is uncertain, a 50 m thick layer covering the flank amounts to ~500 km^3 of material, approximately the same as the caldera volume. Hence, it is possible that the surface mantle could have been produced simply by a steam explosion in which older lithic material was blown out, enlarging the caldera to its present size.

The source of the water for trough formation is interpreted to be rainfall / snowfall directly associated with the eruptions. Water would have been released by magma degassing in shallow subsurface reservoirs, during effusive eruptions, and during pyroclastic eruptions. A significant fraction of water vapor would be expected to condense upon release and fall back causing erosion. The observation that troughs begin high on the flank (immediately outside the caldera and well above the caldera floor, where little flank volume is available for storage of ground water) suggest that precipitation rather than ground water is the dominant source. Assuming only 1% H_20 by volume, an amount of water equivalent to a layer 23 m thick over the construct would have been produced.

Crater counts were compiled for the flank using two sets of images of different resolution (Table 2). Both sets of counts indicate similar, statistically overlapping frequencies. The crater frequencies are interpreted, based on comparisons with the other volcanoes of the Uranius Group and on thermal issues, to indicate that all three Uranius Group volcanoes were active at about the same time, during the Late Hesperian.

The earliest phases of volcanism in the Tharsis region appear to be characterized by the development of small volcanic constructs having basaltic shield characteristics and minor pyroclastic volcanism. The Uranius Group constructs were active for only short periods of time (individual constructs could be built over periods of only 10^4 - 10^5 years) and may represent areas of higher effusion or higher viscosity eruptions within a broader volcanic province largely characterized by high effusion, fissure-fed, plains-forming eruptions. This style of early constructional volcanism was then followed by the major shield building volcanism in central and northern Tharsis. The change in style may reflect a change in the stress system or source depths. Early volcanism may have been areally extensive because the stress system permitted long regional fractures capable of producing fissure eruptions; younger stresses may not have been conducive to such eruptions. The difference in volume between the smaller constructs in northeast and western Tharsis compared with the Tharsis Montes shields may reflect either a larger, longer lived source region or one of deeper depth allowing for greater pressure to build the taller Tharsis Montes constructs.

Table 2. Flank Crater Count

Diameter	516A22	662A57-60
N (1)	4021±878	4548±1438
N (2)	1340±507	(1000±674)
N (5)	418±281	

where N (d) is the number of craters $\geq$ d / 10^6 km^2.

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