FLUVIAL VALLEYS ON MARTIAN VOLCANOES

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Channels and valleys have been known on the Martian volcanoes since their discovery by the Mariner 9 mission. Their analysis has generally centered on interpretation of possible origins by fluvial, lava, or viscous flows (debris, lahar, etc.). As summarized by Baker (1982), fluvial and related degradational processes (sapping) produce landforms strikingly similar to those observed on some Martian volcanoes. However, the possible fluvial dissection of Martian volcanoes has received scant attention in comparison to that afforded outflow, runoff, and fretted channels (Mars Channel Working Group, 1983).

Valley and/or channel forms on Martian volcanoes have not received a systematic investigation, and some confusion has been generated by studies with a local perspective. For example, Milton (1973) interpreted a single high-resolution Mariner 9 picture from the northwest flank of Alba Patera as displaying dendritic fluvial gullies. Carr and others (1977) used Viking imagery of the whole region to demonstrate an origin by lava tube and channel formation. However, in a preliminary mapping study of the Alba channels/valleys, we find that fluvial valleys may also occur with lava channels. The fluvial valleys occur in networks with remarkably high magnitudes for Mars (Table 1). They are well integrated and concentrated on the northern flank of the volcano, in areas where lava flow morphology is subdued. Nearby areas with prominent lava flow fronts and ridges show classic lava channel and tube morphologies.

We have initiated photo interpretive, mapping, and morphometric studies of three Martian volcanoes: Ceraunius Tholus, Hecates Tholus, and Alba Patera. Ceraunius is drained by radial valleys, interpreted as fluvial in origin by Sharp and Malin (1975). Reimers and Komar (1979) summarized evidence that the valleys (or channels) of both Ceraunius and Hecates were not formed by lava erosion, lava tube collapse, or tectonic fracturing. Some lava channels and collapsed tubes exist, but we have found that, as on Alba Patera, these have distributary patterns and discontinuous, irregular surface morphologies. Fluvial valleys, in contrast, are continuous and display tributary development. Some have prominent fan deposits at their mouths, indicating sediment transport and deposition. Fans are especially prominent on the western flank of Hecates, where valleys appear to have reached an advanced state, perhaps by enlargement through sapping.

Preliminary morphometric results (Table 1) indicate that, for these three volcanoes, valley junction angles increase with decreasing slope. Drainage densities are quite variable, apparently reflecting complex interactions in the landscape-forming factors described above.

Five other Martian volcanoes are characterized by prominent valley systems: Uranius Tholus, Uranius Patera, Apollinaris Patera, Hadriaca Patera, and Tyrrhena. Many of these valleys, on preliminary investigation, appear to have formed or were extensively modified by lava erosional activity. Tyrrhena has been interpreted as having a history of pyroclastic activity (Greeley and Spudis, 1981). Its radial system of troughs resembles valleys formed by sapping (Baker, 1982, p. 75-77).

Ages of the Martian volcanoes have recently been reinterpreted in studies in progress by R.G. Strom, N. Barlow, and associates. The new data indicate that Ceraunius Tholus, Uranius Tholus, Apollinaris Patera, Tyrrhena Patera, and Hecates Tholus all date from the period of heavy bombardment. Hadriaca Patera and Uranius Patera date from the terminal heavy bombardment, and Alba Patera is post heavy bombardment. This refined dating provides a time sequence in which to evaluate the degradational forms.

An anomaly has appeared from our initial study: fluvial valleys seem to be present on some Martian volcanoes, but not on others of the same age. The Hawaiian analogy (Gulick and Baker, 1986) may provide some answers here. For example, ash mantling of Hecates (Mouginis-Mark and others, 1982) may have contributed to drainage initiation, as it does on Mauna Kea and Kohala in Hawaii. Volcanic surfaces characterized only by high permeability lava flows may have persisted without fluvial dissection.

Table 1. Morphometry of Valleys/Channels on Martian Volcanoes

Volcano	Average Slope*	Drainage Density (km/km^2)	Magnitude	Junction Angles θ_1	θ_2	$\theta_1+\theta_2$
Ceraunius Tholus	10-12°	0.5-1.1	5+	29	2	28
Hecates Tholus	3-5°	0.6-2.3	10+	25	7	33
Alba Patera	<1°	0.3-1.1	34+	33	7	41

*Reimers and Komar (1979)

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