SMALL VALLEY NETWORKS AND THE PAST AND PRESENT DISTRIBUTION OF SUBSURFACE VOLATILES, AEOLIS QUADRANGLE, MARS;

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The small valley networks of Mars exhibit a variety of planimetric and cross-sectional morphologies. Like valleys on Earth, they may have formed through diverse genetic mechanisms, including floor and wall erosion from down-valley fluid flows, headward valley growth by spring sapping and headwall collapse, and mass-wasting along fractures and faults. It is thus unlikely that the small valleys of Mars all have a single origin. In fact, one scientific outcome of continuing Martian geomorphic investigations may be the development of better observational criteria for separating valleys formed by different mechanisms on both Earth and Mars.

Several common classes of small Martian valleys appear, however, to have one unifying characteristic: the presence of subsurface volatiles, probably water and water ice, during their time of formation. Valley classes such as the sub-parallel slope ravines and the branching, flat-floored trunk valleys (1) are absent on (volatile-poor) Mercury and the Moon. Completed and in-progress geomorphic mapping in the Aeolis Quadrangle agrees with previous work (2) in suggesting a lithospheric, not atmospheric, source for fluids associated with valley development.

The valleys both transect, and are interrupted by, impact features at a variety of scales. It is not yet known whether valley development occurred throughout the Aeolis Quadrangle at closely similar times. Instead, it may be that individual valley networks are of different ages. However, a very widespread period of endogenetic volcanic activity (inter- and intracrater plains volcanism) postdates most slope ravines and the dissected landscapes they produced (3). Additional cratering, during the tail end of the Late Heavy Bombardment, postdates both valley development and plains volcanism. The apparent lack of young Martian valley networks indicates a change in either volatile abundance or the mechanisms for discharging volatiles at or near the surface.

In this respect, a past warmer or denser Martian atmosphere is often invoked as a prerequisite for small valley genesis. If true, this model implies that valley locations contain little or no information about modern subsurface volatile distribution, ca. 3.8 billion years later. However, another valley genesis model (1) does not require a more favorable atmospheric environment. Instead, hydrothermal systems associated with early impact events can explain valley growth through headward extension, down-valley fluid flow, and fracture-related mass wasting. Evidence in favor of this hypothesis includes the small scale global map of the Martian valleys shown in (4). Even at this scale, ca. 200 km wide and larger circular features that lack small valleys are conspicuous. They may represent relatively impermeable impact melt locations associated with old large impacts. Such craters were subsequently partially filled by flow volcanics, and scarred by younger impacts.

This model has different implications for the distribution of subcrustal volatiles through time and at present. If the source for the water and ice that helped mobilize valley development was lithospheric and not atmospheric, then valley location was controlled by: 1) the ancient regional distribution of subsurface volatiles during bombardment, 2) the location of conduits connecting these sources to the surface, as predicted by the structural geology of impact craters, and 3) the relative sizes of impact events: smaller impacts may not excavate beneath a volatile-poor, older impact melt.

Calculations of impact heat energies suggest that hot spring and other hydrothermal activity would be more constrained by volatile availability than by impact energies needed to melt and heat ice and water (1). A major uncertainty, but one susceptible to theoretical modeling, is whether valley development itself caused a significant net transfer of regolith water to the atmosphere. Did volatile abundances become progressively depleted during valley development, or was termination of valley genesis caused instead by a shut-down of release mechanisms? In the latter case, the subsurface abundance of volatiles may still be high.

Assuming a subsurface water origin, the development and location of conduits must exert the dominant control over local valley position. Discharge locations (valley heads) may be strongly affected by regional fracture systems as well as by the fractured and permeable zones surrounding individual impact structures. This is clearly true in quite different, and younger, geologic terrains, such as those in Thaumasia Fossae. There, small valleys are relatively uncratered, and exhibit spatial relationships to visible signs of volcanism and extensional faulting as well as to cratering. Impact events are not the only mechanism capable of melting permafrost, creating conduits, and promoting surface discharge or mass wasting. Thin volcanic flows in Thaumasia partially cover previously dissected surfaces, and have created there a geologic situation at least crudely similar to the more ancient and widespread inter- and intracrater plains volcanics and valleys of the heavily cratered terrains.

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