CHANNELS IN MARTIAN VALLEY NETWORKS: DISCHARGE AND RUNOFF PRODUCTION.

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Introduction: Prior to this study, at least eight interior channels had been identified on the floors of small valleys, by Pieri [1] (Figure 1), Carr [2], Malin and Edgett [3,4], and Irwin and Howard [5]. We have identified ten additional channels. Using a terrestrial empirical relationship between channel width and discharge, scaled to Martian gravity, we have estimated bankfull discharge in 17 of the 18 channels identified to date. The contributing area above the channel exposure was measured for 11 drainage basins, which allowed a bankfull runoff production rate (discharge/m^2) to be estimated. Within the limitations imposed by few observations, scatter in the data, the empirical equation used, and post-flow degradation of the channels, the results can be used to test water supply mechanisms on Mars and to constrain the efficiency of runoff production to first order.

Channels: Features identified herein as channels are elongated, discontinuous, flat-floored interior troughs of nearly constant width that are incised into the otherwise flat floors of stem valleys with few tributaries (e.g., Nirgal) or more extensive highland networks. Where tributaries enter the valley, they also generally incise the valley floor to the level of the channel floor. The elongation with nearly constant width, branching plan form, sinuosity, topographic control, distributed source points, and lack of observed volcanic landforms support interpretation as fluvial channels rather than volcanic rilles, graben, or sites of aeolian deflation. The channels identified here are predominantly located within heavily dissected regions on Mars, i.e., Margaritifer Sinus, Terra Cimmeria, and Terra Sirenum. Most channels are located within major trunk valleys, some of which are part of more extensive networks that dissect cratered surfaces with a dominant regional slope.

Discharge estimates: Discharge was calculated using the established empirical functions relating channel width W and meander wavelength λ (where available) to bankfull discharge Q (m^3/s) on Earth:

$$\lambda = K W \quad (1)$$

$$Q = (W/K_w)^2 \quad (2)$$

$$Q = (\lambda / K_w K_\lambda)^2 \quad (3)$$

where K_λ and K_w are constants with values of 7 14 and 3 5, respectively [6]. For this study, midrange values of K = 10.5, K = 4, and $K K_w$ = 42 are used. Bankfull discharge is assumed to be the dominant control on channel width [6]. To scale the empirical equations to Mars, discharge is reduced to 0.67 times the terrestrial value, which accommodates the reduced gravity g ($Q \alpha (gH)^{0.5}$) [7] and slightly greater depth H ($H \alpha g^{0.2}$) of Martian flows [8].

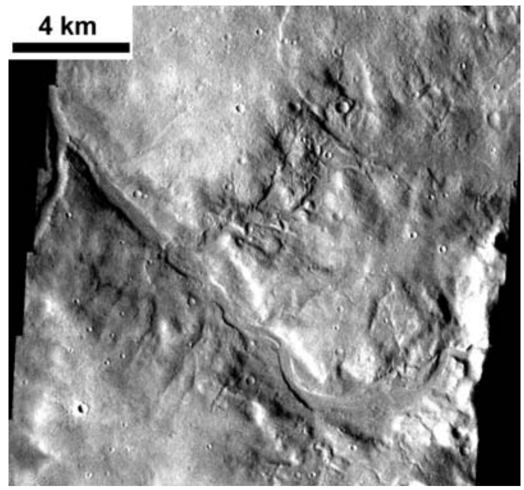

Figure 1. Interior channel in Samara Vallis identified by Pieri [1]. THEMIS image V07878006.

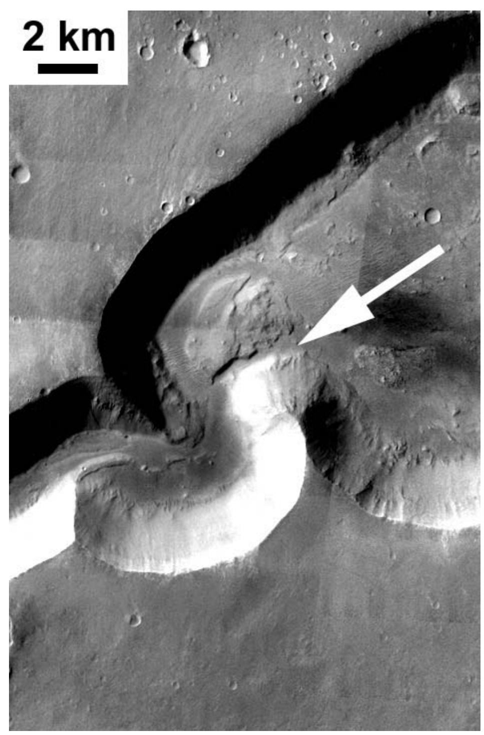

Figure 2. Channel and meander loop cutoff (arrow) in Nirgal Vallis. THEMIS V01837003.

Errors are introduced by the potential for channel widening by post-fluvial degradation, which would tend to enhance discharge estimates above their actual values. To counter the possibility for locally greater widening, we used width measurements at relatively narrow, straight segments of the observed channels. Possible errors on the order of a factor of two are inherent to the empirical functions, due to the natural variability of K_λ and K_w. Errors inherent to the measurements might provide another factor of 2 3 in error. The discharge results are probably accurate only within an order of magnitude.

Runoff production: Runoff includes all river discharge, regardless of whether it moved across portions of the drainage basin in the subsurface. To determine the rate of runoff production, whether by atmospheric or subsurface processes, the contributing area was measured above the channel exposure. For the larger drainage basins, measured areas incorporate some enclosed, degraded impact craters and plains surfaces that may or may not have contributed groundwater. However, errors in area measurements are likely small, because these regions are heavily dissected and have narrow, sharply defined drainage basin divides.

Results: Channel width varies from ~100 to ~1000 m. Channels less than 100 m wide were not observed, consistent with results from Mars Orbiter Camera studies [9]. The lack of preserved channels narrower than 100 m may result from the efficiency of post-fluvial impact gardening [10] and aeolian processes in eradicating small landforms.

Figure 3 shows the relationship between calculated discharge and area for 11 branching valley networks, not including stem valleys with few tributaries. Estimated bankfull discharges are reasonable for terrestrial rivers, ranging from ~600 to ~10,000 m^3/s. Larger valley networks originating at breached basin divides had bankfull discharges of ~10,000 40,000 m^3/s. These larger channels were not used to calculate runoff production as their discharges may reflect drawdown of paleolakes rather than primary production of runoff from drainage basins. Nirgal and Nanedi Valles had comparably high flood discharges. As these two valleys exhibit theater-headed tributaries, their contributing areas were poorly defined, so they were not included in Fig. 3.

Bankfull runoff production rates were, in all but the largest drainage basins, greater than 0.8 cm/day from the basin area. The highest production rates were on the order of several centimeters per day, which likely represent episodic discharges. The discharges reported here are ~2 orders of magnitude higher than production rates that are possible through geothermal heat fluxes, such as melting of ground ice of basal melting of a thick snow pack [11].

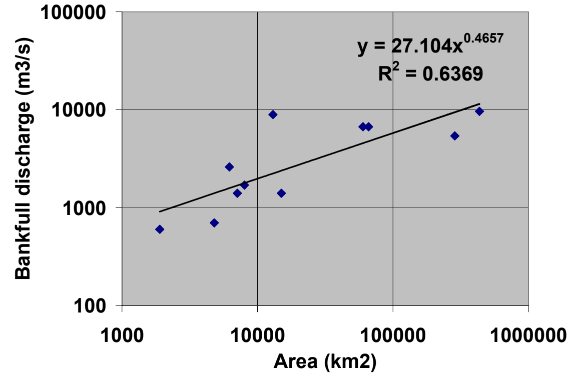

Figure 3. Calculated bankfull discharge and contributing area above the channel head.

Discussion: Peak discharges (Q_{pk}) have a similar relationship with area in both humid and arid regions (Q_{pk} α $A^{0.7}$), and bankfull discharge and area are similarly related. This relationship is due to the comparably small area of the storms that produce the highest discharges in both humid and arid regions [12]. Results for Mars show a similar increase in bankfull discharge with area, but runoff production appears to have been inefficient on Mars per unit area (Q_b α $A^{0.5}$). It should be noted, however, that this empirical relationship is based on few data points and could change somewhat with the introduction of more data. Using all data, R^2 ~ 0.64 for the trendline in Figure 3, although R^2 increases to 0.82 when the result for Durius Vallis is neglected. We are continuing to examine other factors besides area that may influence the basin hydrologic response.

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