Valley Evolution in Margaritifer Sinus, Mars.

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Introduction: The Margaritifer Sinus region of Mars preserves some of the highest valley network densities on the planet [1-4]. Two large northwest draining valley systems, Samara and Parana-Loire Valles, whose associated basins cover an area exceeding 540,000 km^2, dominate regional drainage. These valley systems converge on Margaritifer Basin, a confluence plain shared with the Uzboi-Holden-Ladon-Margaritifer Valles meso-outlflow system (UHLM) that drains northward from Argyre. Detailed geologic and morphometric mapping of the Samara and Parana-Loire valley systems confirms the timing of incisement and permits evaluation of possible mechanisms for valley evolution [2, 5-8].

Geologic History: Geologic mapping and compilation of crater statistics using methods described in [2] and [1], respectively, permit the timing of events responsible for shaping the region to be defined. Mapping identifies the Ladon, Holden, and Noachis degraded multi-ringed impact basins [9, 10] as the oldest features in Margaritifer Sinus. Four resurfacing events that deposited materials interpreted to be of mostly volcanic origin on the basis of wrinkle ridges and occasionally lobate morphology followed formation of these basins. The first three resurfacing events were widespread and ended before evolution of the preserved valleys; the first two occurred during early Noachian heavy bombardment [11] and the second ended at an N5 age of 1400 (number of craters >5 km in diameter per 1,000,000 km^2). By contrast, the third resurfacing event began during the middle Noachian (N5 of 500) and ceased during the late Noachian (N5 of 300) coincident with waning highland volcanism [11]. Formation of Samara and Parana-Loire Valles, the UHLM system, infilling of associated depositional sinks (e.g., Parana Basin at 12.5^{0}W, 22.5^{0}S), and initial collapse of Margaritifer Chaos all occurred from the late Noachian (N5 of 300) into the early Hesperian (N5 of 150). The last, more localized resurfacing event lasted into the early and middle Hesperian (N5 ages 200 to 70) and emplaced materials that embay valleys. Nearly all area surfaces have been subsequently modified to varying degree by eolian activity.

Valley Morphometry: Derivation of linear, areal, and relief morphometric parameters for the Margaritifer Sinus systems permit a number of conclusions to be drawn regarding the evolution of the valleys [2]. For example, terrestrial relationships between the radius of curvature, meander wavelength, and channel width are not well expressed on Mars [12] and indicate the networks are valleys not channels. Further, the Samara and Parana-Loire systems are well integrated and often drained by fourth-order trunk valleys (Strahler classification; [13]) whose tributaries head near basin divides (Fig. 1).

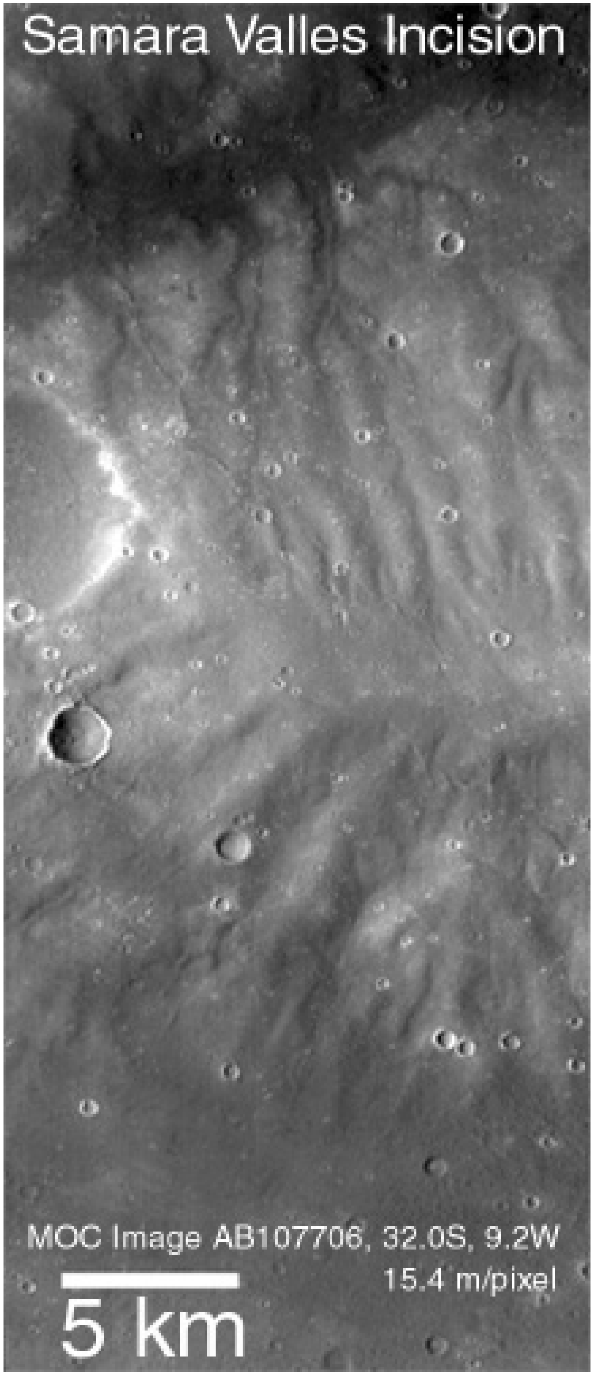

Figure 1. Proximal tributaries to Samara Valles heading along a basin divide.

Preserved drainage densities within both the Samara and Parana-Loire basins are low (0.03-0.11 km/km^2) relative to terrestrial values, but higher than previously reported for Mars [4]. Basin relief ratios and ruggedness numbers for the Martian systems are 0.001-0.13 and 0.005-0.086, respectively, and were calculated using Earth-based radar data [*e.g.*, 14]. Finally, >300 measurements of Martian valley width confirm minimal change in down valley width.

While terrestrial drainage densities derived using 80 m/pixel Landsat data are up to 14 times higher than for Mars, terrestrial densities measured using higher resolution data typically exceed 1 km/km^2 [15]. Hence, measured drainage efficiency on both planets is quite sensitive to the accurate definition of drainage basin area and the resolution of available imagery. Although Martian relief ratios are generally within the range encompassed by terrestrial drainages, they are high when compared with valley densities [12]. Ruggedness numbers are low relative to terrestrial systems, likely due to the influence of the low Martian drainage density values on this parameter.

While not indicative of valley origin by runoff vs. sapping, the Mars morphometric values imply limited runoff from highly permeable substrates possessing high storage capacity. Moreover, a fairly uniform valley width/depth ratio likely characterizes the Martian systems [16]. Together with data on valley width, this implies little down valley change in discharge.

Sediment Volume in Along-Valley Sinks: Partially filled craters are breached by the valleys and form local sinks for transported sediments. The sediment volume in four of these basins (Parana, 12.5^0W, 22.5^0S; Clota, 20.5^0W, 24.5^0S; Oltis (20.5^0W, 23.0^0S); and S2, 18.5^0W, 27.5^0S) was derived for comparison with the volume represented by upstream valleys to establish the minimum amount of sediment that may have been transported from upstream basin surfaces.

The volume of fill within the basins was derived by subtracting the unfilled basin volume from the expected initial volume [2]. Depth of fill was confirmed in Parana Basin using the amount required for near burial of intrabasin craters. Finally, Viking and MOC images indicate nonfluvial fill is <10-20% of the total.

The volume represented by excavation of upstream valleys was estimated using measured valley widths and lengths and assuming both triangular and trapezoidal cross sections [17]. Valley volumes were also derived using a high drainage density value of 0.07 km/km^2. This is in order to compensate for probable destruction of some valleys by resurfacing [1].

In all cases, even the maximum estimated valley volume is only 60% of the volume of fill within associated sinks. Although volume estimates incorporate some uncertainty, they imply surface transport from upstream interfluves contributed sediment to the sinks.

Model for Valley Evolution: A model for valley formation consistent with these results involves mostly localized ground-water discharge enabled by surface-fed recharge. In this model, precipitation (rain or snow) would be largely relegated to subsurface entry by high surface-infiltration capacities. Discharge at exposed relief would be controlled by occurrence of layers/aquitards. Valley evolution would have continued until draw-down of the water table following cessation of precipitation, thereby resulting in a strong sapping overprint.

Martian valley formation by this process may best explain observed morphometry. For example, the basin wide distribution of valleys (Fig. 1), low drainage density and ruggedness numbers, degree of integration, and sediment volume in along-valley sinks may be difficult to accommodate in a hypothesis involving ground-water discharge in the absence of surface recharge. With surface-fed recharge, valley distribution would be controlled mostly by the occurrence of layers/aquitards.

Valley evolution in Margaritifer Sinus was concurrent with gradation in Electris, Northwest of Arabia and Isidis, and in Isidis Basin. In Electris, deposition of a volatile-rich air-fall deposit provided water for valley incisement [18] and supports the hypothesis that widespread precipitation occurred during this epoch.

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