A NOACHIAN/HESPERIAN HIATUS AND EROSIVE REACTIVATION OF MARTIAN VALLEY NETWORKS. R. P. Irwin III[1,2], T. A. Maxwell[1], A. D. Howard[2], R. A. Craddock[1], and J. M. Moore[3], [1]Center for Earth and Planetary Studies, National Air and Space Museum, Smithsonian Institution, MRC 315, 6th St. and Independence Ave. SW, Washington DC 20013-7012, irwinr@si.edu, maxwellt@si.edu, craddockb@si.edu. [2]Dept. of Environmental Sciences, P.O. Box 400123, University of Virginia, Charlottesville, VA 22904, alanh@virginia.edu. [3]NASA Ames Research Center, MS 245-3 Moffett Field, CA 94035-1000, jeff.moore@nasa.gov.

Introduction: Despite new evidence for persistent flow and sedimentation on early Mars [1–3], it remains unclear whether valley networks were active over long geologic timescales (10^5–10^8 yr), or if flows were persistent only during multiple discrete episodes [4] of moderate (≈10^4 yr) to short (<10 yr) duration [5]. Understanding the long-term stability/variability of valley network hydrology would provide an important control on paleoclimate and groundwater models. Here we describe geologic evidence for a hiatus in highland valley network activity while the fretted terrain formed, followed by a discrete reactivation of persistent (but possibly variable) erosive flows.

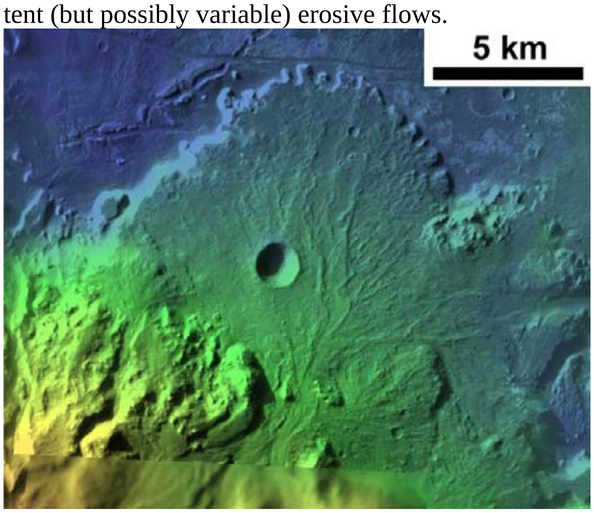

Figure 1. Scarp-bounded fan in Holden crater. A smaller fan segment occurs SE of the fan head.

Putative deltas: High-standing valley-terminal deposits with a peripheral scarp have been found in only ~19 impact craters [1,2,6–13]. We are unable to locate such deposits in many of the craters where Cabrol and Grin [7,9] reported deltas (Malin and Edgett [1] had a similar result). Few of the putative deltas show fan-head trenching, entrenchment of the peripheral scarp, or fan segmentation that would indicate long-term changes in fluvial base level or water/sediment supply (Figure 1). All but one of the 19 putative deltas occur at the ends of V-shaped, pristine, entrenched lower reaches of valley networks (Figure 2). These lower reaches are sharply defined with few or no tributaries and limited sidewall dissection, although somewhat degraded contributing networks are common at higher elevations [14]. Moore and Howard [3] identified large alluvial fans that may be contemporary in degraded craters of the southern equatorial latitudes. All of these deposits likely formed during the last stage of valley network activity, which appears to have declined rapidly.

Gale crater: Gale crater is an important stratigraphic marker between discrete episodes of valley network activity. Gale retains most of the characteristics of a fresh impact crater [15]: a rough ejecta blanket, raised rim, hummocky interior walls, secondary crater chains, and a (partially buried) central peak (Figure 2). This morphology suggests that the crater formed after the period of ubiquitous crater degradation, which ended during the Late Noachian [16]. The Gale ejecta blanket and secondary craters are exposed (possibly exhumed) to the south of the crater but are not observed to the north, where they are buried by the Aeolis Mensae fretted plateau (subdued cratered unit) [13]. The crater contains a ~5-km-thick central layered mound, which may be unrelated to aqueous deposition as it stands 3 km above the crater rim. The end of crater degradation and the superposition/degradation of Aeolis Mensae tightly constrain the time of impact to near the Noachian/Hesperian boundary. After the interior layers were emplaced and eroded largely by wind, some gullies formed on the Gale crater rim and the central mound, but fluvial degradation of the crater is limited. A (possibly contemporary) V-shaped entrance breach was formed in the southern rim of the crater by flows originating near Herschel crater to the south, and two deltas or fans were deposited in the crater floor on either side of the wind-eroded mound [17].

Highland valley entrenchment into fretted terrain: Along the dichotomy boundary in Aeolis Mensae, several hanging fluvial valleys have longitudinal profiles that are graded to levels 1 km or more above the present fretted and knobby terrain basin floors. Steep, narrow lower reaches were later entrenched below that 1 km perched level, depositing alluvial fans on the basin floors [13]. No indication of prolonged, multi-stage development is evident from the fan morphology. In Arabia Terra, several valleys from high-standing regions to the south have incised the dichotomy boundary scarp, with low base levels in the fretted terrain. Fretted terrain development and backwasting left these valleys hanging during a hiatus in valley network activity. The terminal entrenchment appears to be of Early Hesperian age [18].

Exit breaches in impact craters: Many highland craters and other basins have pristine, V-shaped entrance or exit breaches with little tributary development. Prior to entrenchment of the late-stage valleys, these basins were eroded only internally. In a 46-km crater along the Herschel/Gale valley network and at an unnamed crater in Terra Sirenum, we find late-stage entrenchment of an earlier, higher crater outlet, so that a terrace now occurs in the outlet valley. In each case a large source valley network occurs in the highlands south of the breached basin. These breaches suggest a temporary increase in water budget shortly before valley network activity declined permanently.

Channels in valley networks: We have identified channels within 21 valley networks across the Martian highlands, which record significant flows at the end of fluvial activity, with runoff production rates up to centimeters per day [19]. Smaller subsequent flows were not available to reduce the width and increase the sinuosity of the channels, as occurs in terrestrial arroyos. Discharge appears to have declined rapidly in these valley networks.

Discussion: These observations suggest a brief episode of relatively intense fluvial activity after the fretted terrain formed. Longevity of persistent flow in the middle range (≈10^4 yr) seems most likely responsible for the late-stage landforms. Much less time seems inconsistent with deposit volumes [2,3], but greater duration of persistent erosive flows would likely create well developed tributary networks with higher drainage density [14]. Baker and Partridge [14] recognized the late-stage entrenchment of lower reaches of some valley networks, which they attributed to sapping along older degraded valley floors. We view long-term groundwater sources as unlikely because: 1) The Aeolis Mensae fretted terrain and the Gale crater deposits appear to have formed during a hiatus in valley network activity [13], so a recharge mechanism would be required to raise the water table at the end of this hiatus. 2) Valleys attributed to sapping typically have stubby tributaries, are often structurally controlled rather than sinuous, are not often V-shaped in cross section, and might be expected at more than one site along a large crater's circumference. 3) Discharge estimates from channel morphometry indicate runoff production rates up to centimeters per day from the watershed areas, and discharge scales with area as in terrestrial drainage basins. A simpler explanation involves a brief episode of relatively intense runoff, concentrated in higher elevations as in terrestrial deserts, which could fill and overflow previously enclosed basins. Several processes may have induced short-term climate change and reactivated valley networks, including periodic release of volatiles from volcanism, impact cratering, or outflow channel formation. This conclusion of a brief late stage of fluvial activity is consonant with other recent studies [3,12].

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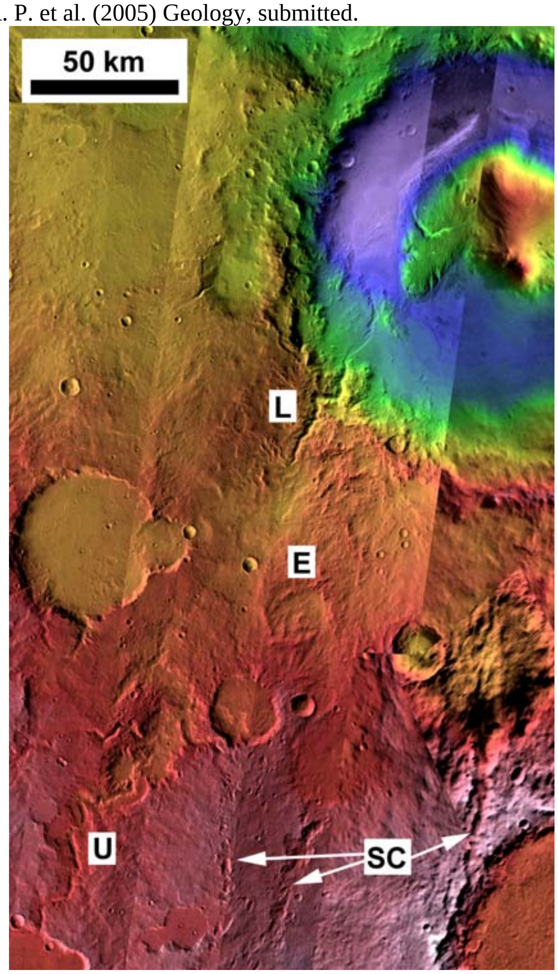

Figure 2. Gale crater with secondary craters (SC), entrenched lower reach (L), middle reach buried by ejecta (E), and upper reach (U) of contributing valley.