CHANGING STYLE OF EROSION DURING THE NOACHIAN-HESPERIAN TRANSITION AND A POSSIBLE CLIMATIC OPTIMUM.
A. D. Howard[1] and J. M. Moore[2], [1]Department of Environmental Sciences, P.O. Box 400123, University of Virginia, Charlottesville, VA 22904-4123, alanh@virginia.edu, NASA Ames Research Center, MS 245-3, Moffett Field, CA, 94035-100, jeff.moore@nasa.gov.

Introduction: Based upon Viking images, [1] distinguished between older, 'degraded' valley networks on the Martian highlands and younger, 'pristine' networks restricted to downstream reaches. Recent MOC and THEMIS images confirm this distinction. We provide examples of these fluvial features and discuss their formative processes and environment, concluding that the 'pristine' landforms may have formed during a short climatic optimum.

Noachian Fluvial Features: MOC, THEMIS, and MOLA data support early suggestions (e.g., [2]) that extensive fluvial erosion and deposition occurred throughout the highlands during the Noachian (e.g., [3]). Sediment yields were high, infilling >10 km diameter craters with several hundred meters of sediment and creating alluvial fans at the foot of highland relief (Fig. 1), thus implying active chemical or physical weathering. Erosion of massifs and inner and outer crater wall slopes reached close to divides, and drainage densities locally approached terrestrial values (e.g., [4]). Continuing impact cratering disrupted drainage networks [4]. These fluvial features were highly degraded by impacts, eolian transport, mass wasting [5], and in many areas by extensive airfall mantling by dust, large-impact ejecta, or volcanic ash (e.g., [6]).

'Pristine' Fluvial Features: Relatively undegraded fluvial features are found widely in the equatorial highlands. Sparse, arroyo-like networks incise 20-200 m into onto earlier Noachian fluvial deposits (Figs. 1 and 2). The incised channels seldom extend headward onto crater walls or upland slopes, but they can extend far downstream, rejuvenating the Noachian drainage paths. Although [1] described the channels as 'pristine', MOC NA images show that they were modified by cratering, mass wasting, and eolian deposition, but to a lesser degree than the Noachian network [5]. Alluvial fans and possible deltas may be found on crater floors into which the networks debauch (Fig. 3) [7-9]. Locally, the walls of deep, late Noachian craters feature deep, incised reentrants and fan complexes presumably of equivalent age. These are similar to, but much larger than, the modern gully systems on some mid-latitude crater walls [10]. In most cases (e.g. Fig. 1) a single major episode of incision followed the degradation of the Noachian fluvial network (although local terraces occur [11]). In some locations the incisional history is more complex, with creation of fans and pediments alternating with erosion, but with each fan and pediment system being less extensive than the previous ones (Fig. 4). In such locations the degradation event affecting the Noachian channel network appears to be less intense or absent.

In contrast to Noachian fluvial activity, the runoff incising the 'pristine' channels required larger source areas to collect sufficient discharge to erode. Sediment loads from headwater areas were low, allowing channel incision into earlier fans. Flows were large and long-lasting enough to permit up to 200 m of incision into presumably resistant materials of the Isidis rim massifs (Fig. 2). Deltaic sediments deposited by this upland incision record continuous or recurrent flows of moderate magnitude [8-9]. The 'pristine' fluvial features are the last major fluvial erosion event throughout the highlands, and probably date to latest Noachian and early Hesperian (e.g., [1]).

Climatic environments and history: The contrast in erosional style between the widespread Noachian erosion and the more limited 'pristine' channels indicates different climatic regimes.

Noachian environment. The environment during the Noachian erosion is controversial [3], but the prevailing interpretation is that widespread, although episodic, precipitation (as snow or rain) occurred with associated runoff and groundwater seepage. The abundance of fan-like forms at the base of crater walls and the small number of breached crater rims suggests an arid climate, with ephemeral lakes in the larger craters [3]. Noachian erosion amounts and rates appear to have been much less than terrestrial values, so that precipitation may have been limited to climatic optima produced by volcanic eruptions [12] or large impacts [13].

Noachian-Hesperian transition environment. The environment producing the moderate, but relatively sustained flows forming 'pristine' valleys and associated depositional features is less certain. We entertain several scenarios:

1. A decline in precipitation amounts, frequency, and total duration relative to the Noachian, coupled with airfall mantling, allowed only limited reestablishment of the Noachian network by headward migration of nickpoints, possibly by sapping [1]. The pattern of incision, however, (Fig. 2) indicates amounts of incision varying downstream and correlated with gradient, inconsistent with headward knickpoint erosion.
2. Incision resulting from local discharge of water from beneath a growing permafrost layer, supplied by basal polar melting [14]. However, the headwaters of

some of the incised channels occur at a high elevation relative to close-by terrain that would be more natural discharge locations (Fig. 5), suggesting local sources of water feeding the channels. This also argues against other scenarios involving a prevalence of discharge from regional groundwater flow [15].

3. Basal melting beneath a thick ice cover [16]. This could produce relatively steady discharges, but amounts are uncertain and associated fan and delta deposits suggest subaerial exposure [7-9].

4. Inhibition of fluvial erosion through accumulation of lag gravels or duricrust layers, thus focussing incision into the largest channels and reducing sediment yields [8]. This could account for the relatively localized, alcove-like incision into crater walls [7].

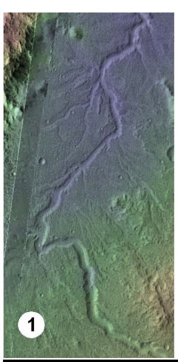
5. A low intensity but relatively continuous precipitation regime. We view this as unlikely.

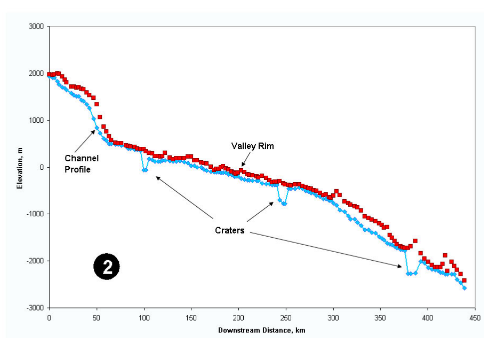
6. Runoff from snowmelt [17]. Quasi-periodic climate change could cause alternating accumulation and melting of precipitated snow. We view this as the most likely candidate because snowmelt would likely occur slowly, accounting for the relatively low drainage density and low sediment yields.

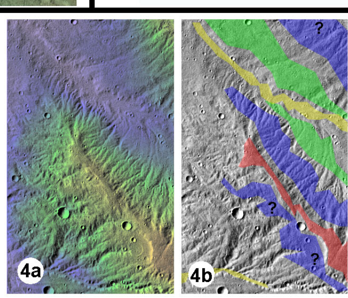
These scenarios are not all mutually exclusive.

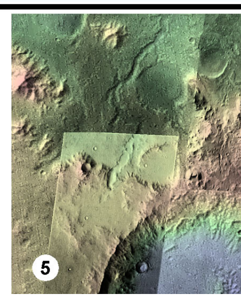
A climatic optimum? The often strong contrast between the 'pristine' and degraded Noachian channels could just be due to a gradual climatic change superimposed upon an episode of mantling associated with early Hesperian volcanism (e.g., [18]). On the other hand, this same period of volcanism could have induced global warming [19] and produced a short-lived optimum for precipitation and runoff. The rapid cutoff of fluvial activity following the development of the 'pristine' fluvial features is consistent with this scenario.

References: [1] Baker, V. R., Partridge, J. B. (1986) *JGR, 91*, 3561-72. [2] Craddock, R. A., Maxwell, T. A. (1990) *JGR, 95*, 14265-78. [3] Craddock, R. A., Howard, A. D. (2002) *JGR, 107*, 10.1029/2001JE001505. [4] Irwin, R. P., III, Howard, A. D. (2002) *JGR, 107*, 10.1029/2001JE001818. [5] Carr, M. H., Malin, M. C. (2000) *Icarus, 146*, 366-86. [6] Malin, M. C., Edgett, K. S. (2000) *Science, 290*, 1927-37. [7] Moore, J. M., Howard, A. D. (2004) *LPSC XXXV, Abstract*. [8] Moore, J. M. *et al.* (2003) *GRL, 30*, 2292,. [9] Malin, M. C., Edgett, K. S. (2003) *Science, 302*, 1931-4. [10] Malin, M. C., Edgett, K. S. (2000) *Science, 288*, 2330-5. [11] Crumpler, L. S., Tanaka, K. L. (2003) *JGR, 108*, 8080. [12] Phillips, P. J. *et al.* (2001) *Science, 291*, 2587-91. [13] Segura, T. L. *et al.* (2002) *Science, 298*, 1977-80. [14] Clifford, S. M., Parker, T. J. (2001) *Icarus, 154*, 40-79. [15] Malin, M. C., Carr, M. H. (1999) *Nature, 397*, 589-91. [16] Carr, M. H., Head, J. W. I. (2003) *GRL, 30*, 2245. [17] Clow, G. D. (1987) *Icarus, 72*, 95-127. [18] Hiesinger, H., Head, J. W. I. (2004) *JGR, 109*, E01004. [19] Squyres, S.W., Kasting, J.F. (1994) *Science, 265*, 744-749.









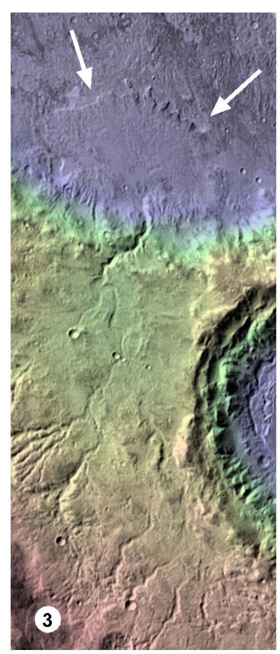


Figure 1. 'Pristine' channel incised into Noachian bajadas/pediments on the Isidis highlands. Image width 27 km., THEMIS IR I02356003 (4.3°S, 93.2°E). Elevation cueing from MOLA data. **Figure 2.** Topographic profile (blue) along incised 'pristine' valley. Red squares are unentrenched surfaces adjacent to valley. **Figure 3.** Dissected landscape in Margaritifer Sinus region at 25.1°S, 357°E. **3b** is interpreted dissected geomorphic surfaces (sequence is red, blue, green, and yellow being the lowest, undissected valley bottom). THEMIS IR image I01686001. Width 32 km. **Figure 4.** 'Pristine' valley network draining into crater basin with probable deltaic deposit (arrows) (28.4°S, 83.1°E). Width 32 km. THEMIS IR I01683003. **Figure 5.** 'Pristine' valley heading in upland flat adjacent to a crater whose floor is 1.4 km lower. Channel head on THEMIS IR I01171001 (32 km wide). (4.3°S, 93.2°E).