EROSION OF THE NOACHIAN HIGHLAND SUBSTRATE ON MARS. R. P. Irwin III and J. C. Cawley, Center for Earth and Planetary Studies, National Air and Space Museum, Smithsonian Institution, PO Box 37012, MRC 315, Washington DC 20013-7012, irwinr@si.edu, cawleyj@si.edu.

Introduction: The Martian highland bedrock has a basaltic composition [1], but widespread resurfacing by Early to Middle Noachian impact basin ejecta [2] and nearly complete burial by subsequent Noachian ejecta [3] imply a mostly brecciated surface. This ejecta is the erosional equivalent of bedrock, in the sense that erosion depends on weathering to smaller particle sizes [3]. Fresh ejecta should be highly permeable [4], requiring either heavy rainfall [5] or advanced chemical weathering of the surface to generate runoff [6]. Cawley and Irwin [6] presented a concept for Noachian surface evolution involving impact ejecta, slow weathering, and infilling of the interstitial space with fines, which would enable runoff with less intense precipitation. We mapped areas where Noachian degraded craters were buried vs. exposed, confirming that deep burial was concentrated on low-relief topographic basin floors, whereas ejecta surfaces evolved as relatively stable pediments. Weathering and erosion smoothed but typically did not completely remove Noachian impact ejecta [3,6].

Here we consider some related issues that may have influenced the development of ancient valley networks. In particular, we consider the relative consistency of fluvial valley morphology among highland pediments, the resistance of Noachian basin fill to later aeolian deflation, and some anomalous variations in valley width that have not been adequately explained. These features suggest that resistant surfaces are widespread but not ubiquitous in Noachian terrain, and that local differences in fluvial valley morphology may reveal a heterogeneous substrate.

Highland Surfaces: Cawley and Irwin [6] described the evolution of escarpments, pediments, and plains as the three main geomorphic surfaces in the Martian highlands. Escarpments originated as fault scarps or impact crater walls, which retreated over time while sustaining gradients of ~5–20°. Most pediments are weathered and smoothed impact ejecta blankets. Plains include various materials that are topographically confined to low-relief basin floors.

Late Noachian to Early Hesperian fluvial valleys that dissect escarpments are typically short, steep, and V-shaped in cross-section, but alluvial deposits at their base tend to be small or not evident. These observations suggest low-magnitude runoff that was transporting finer-grained sediment, rather than intense rainfall that could move gravel clasts and develop alluvial fans.

Valleys that dissect pediments are commonly flat-floored with roughly consistent widths downstream, suggesting that the rate of head-cutting greatly exceeded widening [7,8]. The broad similarity in valley form across the highland intercrater plains suggests that pediments are composed of resistant lithologies (presumably basaltic impact breccia or fractured bedrock), which required further weathering for valley incision and subsequent widening [8].

Local variations in valley morphology can be significant, however, particularly on lower-lying pediments or plains. The causes of this variability are not well understood, and it may reflect differences in the substrate materials rather than hydrologic factors. Some valleys abruptly and repeatedly widen and narrow downstream (e.g., Fig. 1).

Fig. 1. Martian valley that widens and narrows downstream in Terra Cimmeria (11.1–12.9°S, 154.3–159.3°E).
Some fluvial valleys that dissect plains where all Noachian craters are buried or embayed have a morphology that is consistent with valleys on highland pediments, suggesting a similar substrate resistance. These observations could indicate burial of plains by Noachian impact ejecta (e.g., Fig. 2), lithification of Noachian plains-forming sedimentary deposits, or an origin as low-viscosity basaltic lava flows.

Possible Influences on Valley Morphology:
Possible causes for variable valley morphology include: 1) variable substrate resistance, with weaker materials located in reasonable locations for past fluvial or aeolian sedimentary deposition; 2) topographic influences, e.g., deeper dissection of relief would create higher valley sidewalls that may have retreated more rapidly (Fig. 3 may show this relationship); 3) hydrologic factors, such as paleolake overflows or downstream increases in contributing area; or 4) some combination of these factors. It is likely that the controlling factors vary from place to place, requiring local analysis.

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Fig. 2. The ancient Noachian crater A was degraded before it received ejecta from the younger crater B and ejecta exhumed by crater C. Fluvial valleys on the floor of crater A therefore incise resistant ejecta rather than the underlying crater fill. Centered at 4.2°S, 130.2°E.

Fig. 3. Downstream (left, centered at 12.0°S, 9.6°E) and upstream (right, centered at 12.4°S, 13.3°E) reaches of Evros Vallis, showing greater width and sidewall dissection in the downstream reach.