NOACHIAN GEOMORPHIC SURFACES AND IMPLICATIONS FOR THE PALEOCLIMATE OF MARS.

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Introduction: The original studies of Martian valley networks noted that they incised broad intercrater surfaces with few fresh impact craters and little dissection by tributaries [1,2]. These intercrater geomorphic surfaces formed during the Noachian Period, concurrently with the progressive degradation of Noachian impact craters [3,4]. As such, they represent a long-term geologic record of the Noachian paleoclimate, which may be more valuable for interpretations of habitability than the geologically short-lived epochs of valley network development in the latest Noachian or Hesperian Periods [5,6].

The purpose of this study is to place the extensive intercrater geomorphic surfaces into geologic context and note the constraints that they place on the Noachian paleoclimate and resurfacing processes.

Development of intercrater plains: Recent global geologic mapping found relatively steep, high-standing, heavily cratered areas of Early Noachian age, surrounded by gently sloping Middle Noachian intercrater plains and Late Noachian to Hesperian basin-filling materials in the highlands [7]. The major distinction between the two latter surfaces was that the intercrater plains contain degraded craters, whereas all Noachian craters in the basin-filling plains are either embayed or buried. This finding shows that deep burial was concentrated in basins rather than uniformly distributed across the landscape, which is more consistent with gravity control of burial than with airfall mantling [8].

Another finding of the global map, consistent with earlier results by Hartmann [9], was that nearly all Noachian craters <2–4 km in diameter had been eradicated from the highlands [8]. This result indicates ubiquitous resurfacing to some depth, but not to the extent that is seen on basin floors. In contrast, the surface of Mercury contains many small primary and secondary impact craters from the heavy bombardment epoch (Fig. 1).

Impact crater rims and walls retreated uniformly as escarpments, without changing the circular shape of the crater. This characteristic limits the role of fluvial erosion, which tends to deeply dissect escarpments. Similarly, Noachian tectonic escarpments also retreated without losing their steep slope or sharp breaks in slope at the top and bottom of the escarpment.

Collectively, these observations show that in the Noachian highlands, geomorphic processes were working to eliminate small-scale roughness features in the landscape, including small craters, the ejecta texture of large craters, and small fluvial landforms (Fig. 2). Relief-forming processes at this scale were limited.

Geomorphic processes: The dominant geomorphic processes on Noachian Mars focused erosion on promontories rather than in valleys, and they tended to attack relief by scarp retreat rather than top-down. Deposition was concentrated in basins, however. This pattern is most consistent with transport-limited conditions, where exposed surfaces were preferentially weathered, but debris was removed slowly from low-relief surfaces and transported into basins. The retreat of escarpments may suggest preferential erosion near the base, either due to a weaker substrate or greater availability of water at lower elevations.

Water. Clearly, the greater erosion rates during the Noachian Period require much higher weathering rates [10]. The net transport of debris from higher areas into basins also suggests an important role for a gravity-driven erosion process. Most surfaces did not experience deep fluvial dissection, however.

Wind. Particularly in a thicker atmosphere, wind would redistribute the medium-to-fine-grained products of weathering locally on intercrater plains. This process operates on Amazonian Mars as well, but at a much slower rate [9]. Wind may account for some of the infilling and loss of small craters.

Mass wasting. The role of diffusional processes such as creep was apparently limited in the equatorial highlands, although some rounding of promontories is observed. Obvious periglacial modification is not apparent in orbiter or lander data.

Glaciation. The equatorial highlands were unglaciated during the Noachian Period, as shown by the lack of glacial dissection of escarpments. This observation suggests that the highlands were too warm, too dry, or both to have developed glaciers.

Structural processes. Tectonic modification was limited in the Middle to Late Noachian highlands. Impact crater rims and ejecta represented radially dispersive, concave surfaces with high infiltration capacity, which are not favorable characteristics for fluvial erosion. For this reason, geomorphic surfaces could develop to relatively stable end states without the tectonic or eustatic rejuvenation that is common on Earth.

Paleoclimate: The Martian highlands were apparently more arid during the Noachian Period than around the Noachian/Hesperian transition, as shown by the development of extensive geomorphic surfaces with little fluvial dissection. There was enough water to achieve significant weathering over time, however. Clear evidence for cold-climate processes is lacking in the equatorial band.

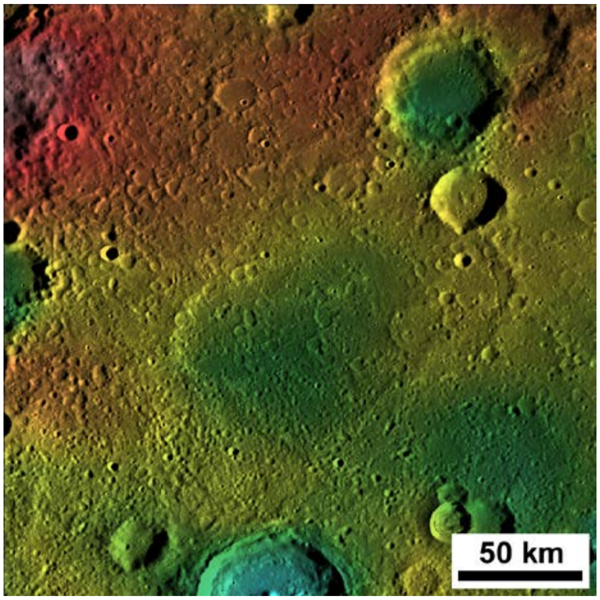

Figure 1. Intercrater plains on Mercury (15–32º N, 20–37º E) with many small primary and secondary craters preserved. Mercury MESSENGER imagery colored with Mercury Laser Altimeter data to show elevation (warmer colors are up).

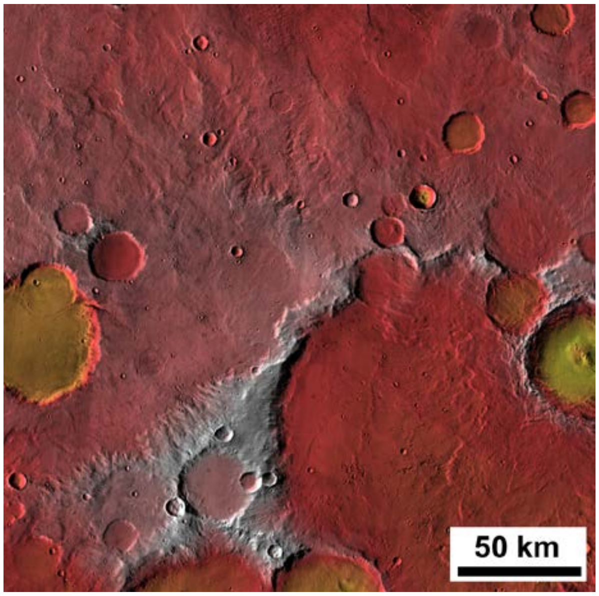

Figure 2. Intercrater plains in Noachis Terra, Mars, at the same scale as Fig. 1, showing the sparse cratering at small diameters and extensive development of intercrater plains. Mars Odyssey Thermal Emission Imaging System mosaic colored with Mars Orbiter Laser Altimeter topography to show elevation (warmer colors are up).

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