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ANCIENT FLUVIAL PROCESSES IN THE EQUATORIAL HIGHLANDS OF MARS

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Martian highland craters typically lack ejecta deposits, have no noticeable rim, and are flat-floored. In addition, crater size-frequency distribution curves show that highland craters have depleted populations <20-km-diameter. A variety of processes have been suggested to explain these observations including deposition of aeolian [e.g., 1] or volcanic [2] materials up to the crater rim crests, thermal creep [3], terrain softening [4], and mass-wasting [5]. However, none of these processes adequately explains both the crater morphology and population distributions.

Deposition of aeolian or volcanic materials up to the crater rim crest could produce a flat-floored, rimless crater at a given diameter; however, smaller diameter craters would become buried, and the larger diameter craters would still have obvious rims. Thermal creep requires a narrow range of climatic conditions not currently present on Mars [3], and which would have been highly dependent upon latitude if present in the past. Terrain softening occurs only at higher martian latitudes and current models [4] do not explain the size range of flat-floored, rimless crater morphology. Mass-wasting suggests that flat-floored, rimless craters should not only occur everywhere on Mars but also on planets such as the Moon or Mercury, and this is not the case. Mass-wasting should also be an ongoing process, but crater populations suggest that the modification process ceased at -3.3 Ga [early Hesperian; 6,7,8].

In order to explain both the martian highland crater morphology and population distributions, we have proposed a fluvial process capable of removing the loose crater rim material [8]. The resulting effect is to decrease the crater diameter, thereby causing the population curves to bend over. The eroded material is redistributed, burying or partially burying smaller diameter craters before complete erosion. This material may also be deposited into local topographic lows, creating the depositional basins observed recently in a variety of highland regions [9]. A fluvial process explains both sets of observations: crater morphology and crater population distribution curves.

As previously reported [10], we have expanded our study to include the entire equatorial highland region of Mars. Based on the published 1:15M geologic maps of Mars, we are limiting our study to two materials: the Noachian cratered plateau unit (Npl₁) and the Noachian dissected plateau unit (Npl_d). Although it is apparent that other Noachian materials in the highlands contain flat-floored, rimless craters, the interpretations of these materials include resurfacing by processes we feel are separable from a global, more extensive process. Using published 1:15M topographic maps of Mars, these materials were binned by elevation.

Preliminary results indicate that the resurfacing process ceased in Npl₁ materials before Npl_d materials. This suggests, perhaps, that ancient valley networks represent the waning stage or a change in the

nature of the process [10]. It also indicates that the resurfacing process occur over a long period of time (i.e., from the middle Noachian to the early Hesperian). This agrees with observations by Arvidson [6] and Gurnis [7] that highland resurfacing occurred through the end of late heavy bombardment.

A preliminary observation is the apparent relation between timing of resurfacing and elevation. Typically at higher elevations the resurfacing process ceased at an earlier time than at lower elevations (Fig. 1). This supports fluvial resurfacing over volcanic or mass-wasting processes, both of which would be independent upon elevation. It also permits some speculation as to the history of the fluvial activity. If the fluvial resurfacing were the result of an endogenic process such as seepage of ground water due to melting, then with time the aquifer should become depleted (Fig. 2a). The result is a gradual lowering of the water table with volatiles migrating to lower elevations. If the fluvial resurfacing were the result of an exogenic process such as rainfall, resurfacing becomes dependent upon the rate of atmospheric degassing. Initially rainfall occurs over the entire surface, but as the atmosphere becomes thinner, cloud condensation, and thus rainfall, occurs at progressively lower elevations (Fig. 2b). In either scenario, the effect is to isolate higher elevations from the resurfacing process with time.

Absolute ages of martian periods determined by Hartmann *et al.* [11] and Neukum and Wise [12] from modelled crater fluxes suggests that resurfacing occurred over a ~400 million year or ~600 million year period, respectively (middle Noachian to early Hesperian). Previously we estimated the amount of material eroded from fluvial resurfacing in the Amenthes and Tyrrhena regions to be between 751,000 to 2,580,000 $\text{km}^3/10^6 \text{ km}^2$ based upon Mars global production crater curves [13] and a modelled production curve [8]. This suggests denudation rates of between 0.001 to 0.006 mm/yr. These rates occur in places such as northern Canada or Siberia on Earth [14], but are typically very low by terrestrial standards. Further study will refine these values and enhance the preliminary observations presented here.

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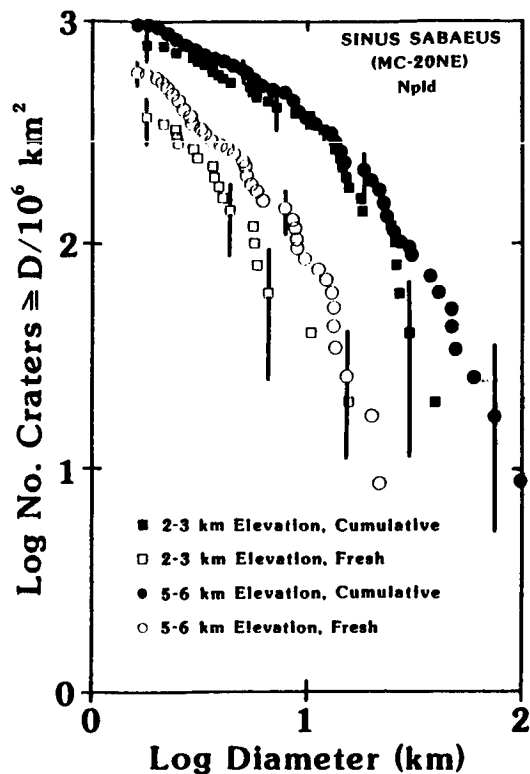


Figure 1 (left). Crater size-frequency distribution curve of Npld materials in Sinus Sabaeus. The curves illustrate relation between timing of resurfacing event and elevation. Fresh crater curves suggest that at lower elevations (2-3 km) the resurfacing ceased earlier ($N[5] = \sim 130$) than at higher elevations (5-6 km; $N[5] = \sim 240$).

Figure 2 (below). (A) Elevation-dependent fluvial resurfacing involving an endogenic process. Progressively later episodes of ground water seepage lower the water table, isolating higher elevations from resurfacing effects. (B) Exogenic process involving rainfall. With atmospheric degassing, cloud condensation occurs at progressively lower elevations.

