GLOBAL-SCALE MARTIAN GEOMORPHOLOGICAL STATISTICS REVEAL AN INTEGRATED NOACHIAN HYDROSPHERE

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Introduction:

Geological Evidence for A Warm and Wet Mars
Ample geological evidence exists supporting a "warm and wet" scenario of early Mars; referring to a sustained habitable climate capable of supporting liquid surface water. This evidence includes a continuous spectrum of erosional and depositional water features consistent with sustained intense fluvial activity, including widespread valley networks (VNs)[1-5] emptying into lacustrine and deltaic deposits[6,7] and finally, into a circumpolar northern ocean[8]. This global network of water erosion and depositional features points to an integrated, active and long-lived hydrosphere that existed on early Mars. Statistical evidence may support or refute this hypothesis.

Methods:

Area of Interest (AOI) and Dataset Justification: For this study, I utilized much improved MOLA elevation data, improved geological maps[8], better-quality CTX imagery[2], and crater data from [9]. I expanded crater classification to include 9448 2-3 km diameter craters. As smaller diameter craters are most sensitive to erosion, hoping that increased sensitivity would lead to insights into erosional processes on a global scale. I also incorporated data on valley networks[5] and inverted channels[6] to further explore erosional processes.

I employed an area of interest (AOI) that is constrained to lower latitudes of Mars between 20°N and 20°S and 30°W to 180°E, limiting my study to reflect only Noachian terrain. The area encompasses 11,422,066 km^2 and covers almost the entire proposed Noachian equatorial LNIH ice-cap. I limited my AOI to latitudes between 20°N and 20°S in order to minimize any confounding potential post-Noachian modification, including ice relaxation of crater rims as well as periglacial terrain softening. Utilizing the recent 1:20M-scale global geologic map of Mars the study area was confined to Noachian (>3.7 Ga) terrains, since the LNIH is, by definition, a Noachian phenomenon. Noachian geologic units mapped in [9] were subdivided into 1 km elevation increments using MOLA data. My large AOI extent is designed to capture sufficient numbers of features (craters and VNs) to determine statistically robust relationships.

I examine the distribution and conduct statistical analysis of 14,695 craters between 2 km and 5 km diameter[5,10] and valley networks (VN's) and inverted channels[11,12] within this AOI to determine if the LNIH is either supported or refuted.

Using the ArcMap Toolbox Point Density Tool, crater density maps were generated in order to examine geological and spatial relationships for both fresh (Degradation State = 3,4) and degraded (Degradation State = 1,2) over the entire spatial extent of my AOI. This database includes the degradation state and morphometric measurements for [2-4] km diameter crater rim heights, floor depths, and the elevation of the surrounding topography[5]. We classify degradation states of 3 and 4 to represent fresh craters and degradation states of 1 and 2 to represent degraded craters[5].If a cold-based ice cap preferentially preserved small craters underneath it, as suggested by [13], we expect the following: (1) there should be a higher percentage of pristine craters under the area of the proposed ice cap, and (2) craters in that area should have more relief (higher rims and lower floors) than their counterparts at lower elevations.

Crater Degradation Statistics: As craters are eroded, their rim heights are reduced and floor depths decrease[16]. One might expect that smaller diameter craters should be eroded more quickly than larger ones. We explored the degree of reduced crater rim height together with infilled floors for the [2-5] km diameter craters. Craters <2 km were excluded as these data are not reported. We utilized the Rim Height and Floor Depth columns in the crater database[5] to assess crater relief versus elevation for craters [2-5] km in diameter.

Valley Density Mapping I determined VN density maps and VN and inverted channel statistics as described in I also plotted VN densities against crater preservation states by elevation bin following [14].

Results and Discussion:

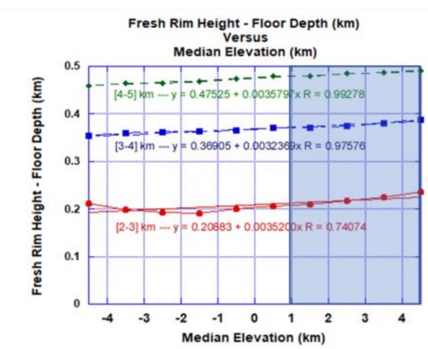

Fig. 1.) Populations of Fresh crater diameters, [4-5] km (green), [3-4] km (blue) and [2-3] km (red) diameter craters against median elevation (km). The location of the LNIH 1 km ELA is shown here as a blue field.

Ratios for crater depth:diameter is ~0.1, however a slight linear negative trend for the three populations how extremely high R values. No departure from a linear trend for Rim Height – Floor Depth (km) is noted across the ELA or under the supposed LNIH icefield.

I propose here that the linear trend may be due to ablation of impactors through a much thicker Noachian atmosphere. This may be modeled in future studies as a function of atmospheric scale height, bolide composition, density, velocity, entry angle and substrate characteristics. In addition, significance of impacting different substrate could be tested using models such as iSale if atmosphere is discounted.

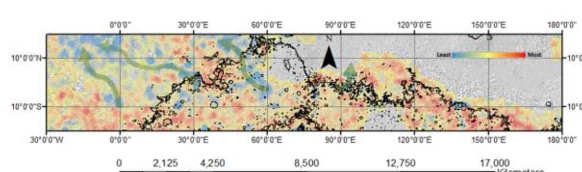

Fig.2.) The ratio of Fresh/Degraded craters for craters that are [2-5] km in diameter is shown for our AOI. The location of the supposed LNIH cold-locked ice cap is represented by the black line. The continuous green lines represent proposed waterflow pathways, northeastward towards the circumpolar ocean.

No preferred preservation of small [2-5] km craters is evident above the proposed 1 km ELA. This is counter to claims by supporters of the LNIH glacially locked, extremely cold martian climate scenario[13;15-17] The preservation trend for [2-5] km diameter craters at elevations ≥ 1 km is negative, inverse to the LNIH hypothesis that craters at high elevations and under the ice cap would have experienced preferential preservation[13]. Areas nearest the Equator in the Southern Highlands appear to be highly degraded, consistent with fluvial erosion at high elevation as well as North-Northeast flow towards a circumpolar ocean.

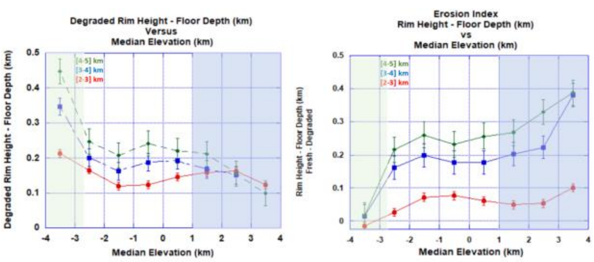

Fig. 3.) Small crater populations for [2-3] km (red), [3-4] km (blue) and [4-5] km (green) are consistent in Degraded Rim Height -Floor Depth (km) overall pattern. The most dramatically degraded small craters occur above the supposed 1 km LNIH ice cap (blue field), the proposed global groundwater table (ultimate water sink) is highlighted in green.

with direct disagreement with the hypothesis of Weiss and Head (2015)[13] that craters would be preferentially protected from degradation under a Noachian ice cap. In contrast, degraded rim height – floor depth (km) is least at highest elevations (Fig. 3. left) indicating great amounts of erosion. The overall pattern of erosion is consistent with adiabatic cooling of a coupled atmosphere experiencing liquid precipitation over geologically relevant timescales (Fig. 3 right).

Examining to what extent degradation state of the smallest craters, [2-3] km diameter, may be related to VN transport of sediments and water from the Southern Highlands to lower elevations reveals a globally continuous system. This is obvious in Figure 4 below, where Highlands >0 km elevation sourced both fluvial water and sediment source to lowland sinks at elevations <0km. Plotting [2-3]km diameter Degraded/Fresh craters versus VN Density one notes that the systems are coupled and inflect at approximately -0.5km elevation.

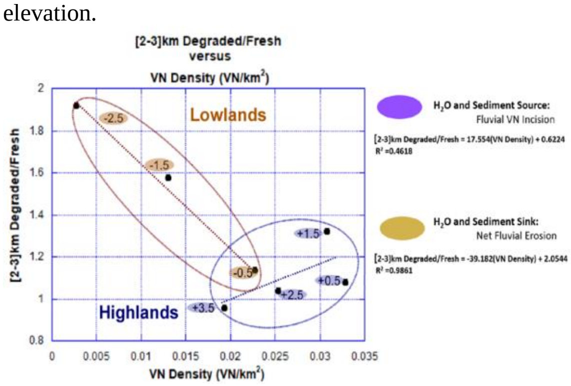

Fig. 4.) Mar's Noachian low-latitude fluvial hydrological system is best described by a linear non-continuous model inflecting just below the geodesic reference elevation (-0.5km) inclusive.

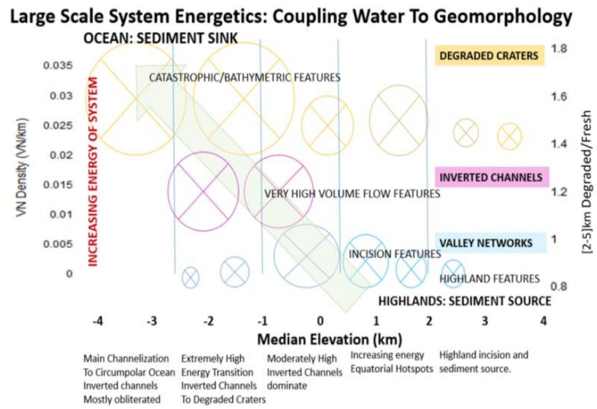

Fig. 5.) A comprehensive, holistic overview of a martian global scale low-latitude hydrological system.

The primary water and sediment source for this AOI appears to be derived mostly from the Southern Highlands, while the water and sediment sink is the lower elevation basins below the 0 km crustal dichotomy and geopotential. It can be inferred that the overall geomorphological evidence reveals greatest erosion is coupled energy via erosion scaled to volume of water and entrained sediment. Comprehensive water and sediment flow indicated in this study is toward the Northwest and the circumpolar ocean[6].

Conclusions:

Globally continuous statistics of VNs together with crater degradation demonstrates that ~3.8 billion of years ago Mars was quite habitable[18,19]; dominated by an integrated clement climate, a likely thick atmosphere and precipitation. No LNIH ice cap[15-17] is supported by these findings. Future 3-dimensional PMGCMs should a be constrained by these target statistics rather than speculation, which is unproductive.

References:

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