CRATER EVIDENCE DOES NOT SUPPORT THE LATE NOACHIAN ICY HIGHLANDS FOR MARS. B.R. Archer[1,2,3] , B. M. Hynek[1-2] , S. J. Robbins[4], [1]Laboratory for Atmospheric and Space Physics & [2]Dept. of Geological Sciences, University of Colorado-Boulder, Campus Box 600 UCB, Boulder, CO 80303. [3]National Aeronautic and Space Administration Johnson Space Center, Houston, TX 77058 [4]Southwest Research Institute, Boulder, CO 80302. Richard.Archer@lasp.colorado.edu

Introduction: The Faint Young Sun Paradox, which postulates that the Sun insolation was only 70% of today [1], presents a central problem regarding early Mars habitability. Martian climate models [2] have not generally been able Models have not generally been successful creating clement conditions for formation of extensive valley networks [3;4;5] lacustrine and deltaic deposits [6], and the suggestion of a circumpolar martian ocean [7]. Thus, some workers [8; 9] have hypothesized that a cold, arid martian climate resulted in a cold-locked ice sheet hundreds of meters thick above 1 km equilibrium-line altitude (ELA) where net glacial accumulation equals ablation [10; 11] in the Noachian; even suggesting that the fluvial geomorphological features on Mars could have resulted from this scenario [5] A formative prediction of Weiss and Head [9] is that smaller (few km diameter) craters would be better preserved above the Late Noachian Icy Highlands (LNIH) 1 km elevation because they were underneath an extensive cold-based glacier. Conclusions by these workers were based upon a Viking-era crater database that was incomplete and inaccurate [12], based on modern data. Gemperline et al. [13] utilized a modern, global crater database complete down to 1 km diameter [14] and MOLA elevation data [15] in order to investigate evidence for the LNIH in three regions of interest (each covering 90,000 km^2). This initial study did not find statistical evidence for enhanced crater preservation state at and above the proposed 1 KM LNIH ELA. Here, we expanded that original study to encompass the entirety of tropical Mars Noachian highlands in order to provide a comprehensive, agnostic crater preservation study to determine whether statistically significant evidence exists at a planetary scale for an LNIH ice cap [8; 9; 10; 11].

Methods: Noachian geologic units mapped in Tanaka et al. [16] were subdivided into 1 km elevation increments using MOLA data for a Region of Interest (ROI) defined as 20°N to 20°S and 30°W to 180°E and encompassing 10,974,695 km^2; almost the entirety of the proposed Noachian equatorial LNIH ice-cap. Craters from [14] contained within Noachian units were selected based on 1 km increments in ESRI's ArcGIS. All 3-5 km diameter craters in this region were utilized (N = 4360) in order to capture the population of craters most sensitive to erosional processes. This database includes degradation state and morphometric measurements for rim heights, floor depths, and the elevation of the surrounding topography [14]. We considered degradation states of 3 and 4 to represent fresh/pristine craters [14]. If a cold-based ice cap preferentially preserved small craters underneath it, 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 elevation.

Results and Discussion: Fig. 1 shows that fresh crater density of the equatorial Noachian highlands ROI overlaid to the LNIH ice-cap does not reveal preferential preservation of 3-5 km diameter craters at any elevation, contrary to the predictions by [9]. Instead, a consistent stochastic pattern extends across the entire ROI, even across/above the purported 1 km ELA boundary (Fig. 1, blue line).

Figure 2 shows a second line of evidence rejecting the presence of an LNIH ice-cap. Sampling the full 3-5 km crater population for the ROI is, overall, flat, with a fresh/degraded ratio of ~1.5 rather than a stepwise

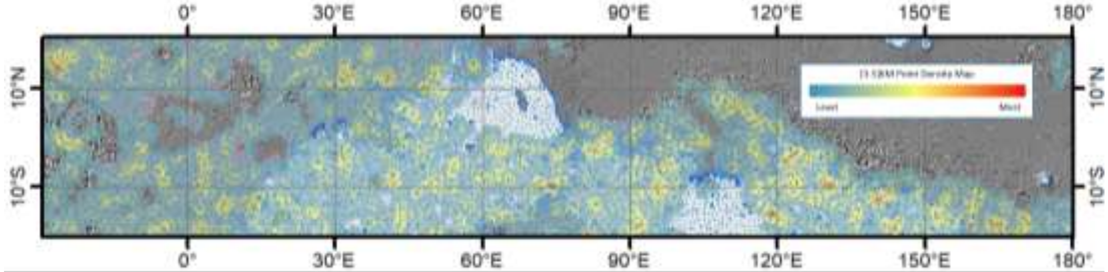

Fig. 1. Point density map of pristine (degradation state 3 or 4 from [17]) across the ROI. The hypothesized ice cap from the LNIH is shown underneath as a white/blue stippled pattern.

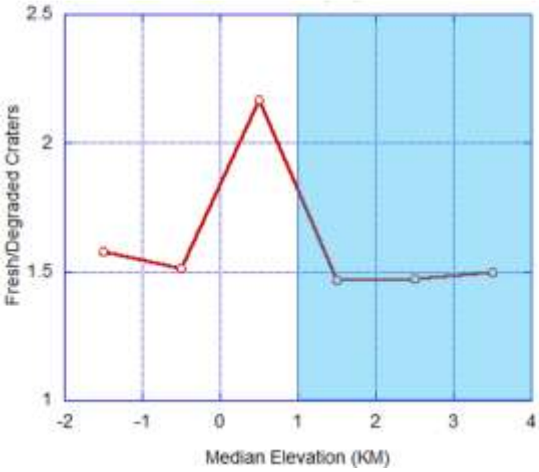

Fig. 2. 3-5 km diameter fresh/degraded craters versus binned MOLA elevation. The hypothesized ice cap from the LNIH is shown as a blue field.

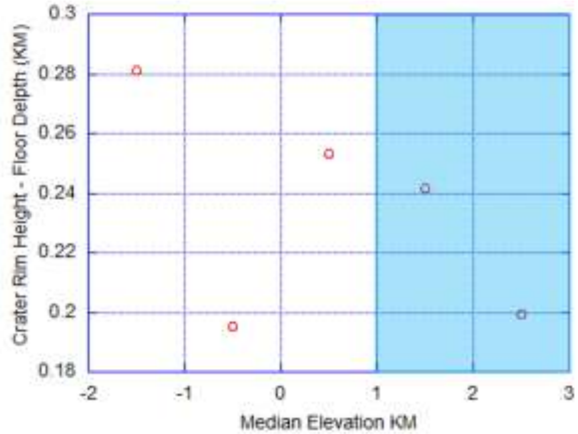

Fig. 3. 3-5 km diameter crater rim height – floor depth versus MOLA elevation. The hypothesized ice cap from the LNIH is shown as a blue field.

function expected for an LNIH. No preferred fresh population dominates above the purported LNIH 1 km equilibrium line proposed by [8] and championed by [9]. In addition, Figure 2 shows a global flat trend with the exception of a positive excursion of fresh craters between 0 km and 1 km elevation, immediately adjacent to and below the supposed LNIH equilibrium line, where weathering should be greatest were the LNIH ice-cap present [8; 9; 10; 11].

We utilized the average rim heights and crater floor depths from [14] to further test crater preservation across elevation in the ROI. If craters under the proposed ice cap were better preserved, then they should have greater relief between the floor and rim than more degraded craters at lower elevation. The overall trend in Figure 3 does not show greater crater relief at higher elevations (under the proposed ice cap; in blue). In fact, the highest crater relief is seen at elevations below the 1 km ELA and enhanced erosion at high elevations is inferred. If a protective ice cap were present in this region in the Noachian, overall rim to floor depth profiles are predicted to be a stepwise function. Instead, the trend indicates mass movement of sedimentary source material from high elevations to lower elevations, consistent with enhanced weathering at higher elevations.

Conclusions: This study countermands the existence of the LNIH via three independent chains of evidence. Our first result (Fig. 1) does not find any expected pattern for preferred preservation at elevations >1 km and crater densities of the 3-5 km diameter fresh crater population are spatially random across the supposed 1 km ELA transition. In our second result (Fig. 2), the trend of fresh/degraded 3-5 km diameter craters is flat with a positive excursion at +0.5 km median elevation, where degraded crater frequency would be greatest if LNIH ice cap existed; opposite of our findings. Finally, Fig. 3 shows that, in contrast to expectations for an LNIH ice-cap, the highest elevations experienced the greatest rate of weathering and served as source regions for lowland deposition. In closing, our findings refute the LNIH hypothesis prediction of enhanced preservation of small craters above the ELA. We propose that sustained temperate habitability was sourced via mantle heating concomitant with the emergence of the Tharsis volcanic system [17]. As the Tharsis Rise migrated toward the crustal dichotomy between 4.0–3.7 Ga [18], vigorous volcanic activity from decompression melting likely occurred concurrent with Noachian valley network formation and protracted habitability [18;19]; thus bypassing the Faint Young Sun paradox climatic constraint.

References:

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