TESTING CRATER DEGRADATION PREDICTIONS UNDER THE LATE NOACHIAN ICY HIGHLANDS MODEL.

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Introduction: The Late Noachian Icy Highlands (LNIH) hypothesis proposes a cold-locked ice sheet hundreds of meters thick above 1 km in elevation during a cold-icy martian climate [1,2,3]. Weiss and Head [4] highlighted key predictions for crater degradation in the Noachian highlands on Mars under the LNIH model: pre-LNIH craters at higher elevations should be better preserved, and melting and retreat of the LNIH would have preferentially removed or infilled small to intermediate sized craters at lower elevations. Weiss and Head argued that these predictions are supported by three lines of observational evidence: 1) a trend of the relatively fresh portion of small N(2) and N(5) fresh craters (i.e. craters ≥2 or ≥5 km diameter) increasing with elevation; 2) the lack of a similar trend for N(16) and N(50) crater populations; 3) the trend of increased degraded crater population with increasing elevation for N(2), N(5) and N(16) crater populations.

These three observations of crater degradation state for Noachian terrains varying with elevation are taken from Craddock and Maxwell [5] who relied on Viking era imagery, elevations, and geologic maps. Since Craddock and Maxwell's study, global measurements of elevation have been drastically improved in accuracy and spatial resolution by the Mars Orbiter Laser Altimeter (MOLA) [6]. In some cases, elevation estimates from Viking data differ by 2 vertical km from more precise MOLA data. Further, Craddock and Maxwell [5] relied on geologic mapping by Scott and Tanaka [7] and Greeley and Guest [8], which also utilized Viking era data. A suite of missions since Viking have provided higher resolution global coverage from many different instruments, allowing for more accurate global geologic mapping of Mars and refinement of Noachian-aged unit boundaries [9]. Further, crater degradation is only analyzed for two units by Craddock and Maxwell, Npl_1 and Npld. Type localities for these two units correspond to remapped Early Noachian and Middle Noachian units, respectively, in Tanaka et al. [9], omitting Late Noachian units crucial to the LNIH model. Finally, more recent, higher resolution data since Viking has facilitated the production of a global database containing ~385,000 craters complete down to 1 km in diameter [10]. Craters ≥3 km in diameter in this database are assigned a preservation state of 1-4, with 1 being highly degraded and 4 being nearly pristine. Values of 3 and 4 are considered 'fresh' in this work [10]. Taken individually, any of these considerations would warrant a reevaluation of the observational evidence in regard to the LNIH model. This updated information since the Viking missions warrants a new analysis of crater degradation.

Methods: Noachian geologic units mapped in Tanaka et al. [9] were subdivided into 1 km elevation increments using MOLA data between ±40° latitude in the eastern hemisphere; covering the main occurrence of the hypothesized LNIH ice sheet [1-4]. In the eastern hemisphere, the majority (93%) of Noachian terrain by area fell between -2 and 3 km (MOLA data). Craters from Robbins and Hynek [10] contained within Noachian units were selected based on 1 km increments in ESRI's ArcGIS. Fresh vs. degraded

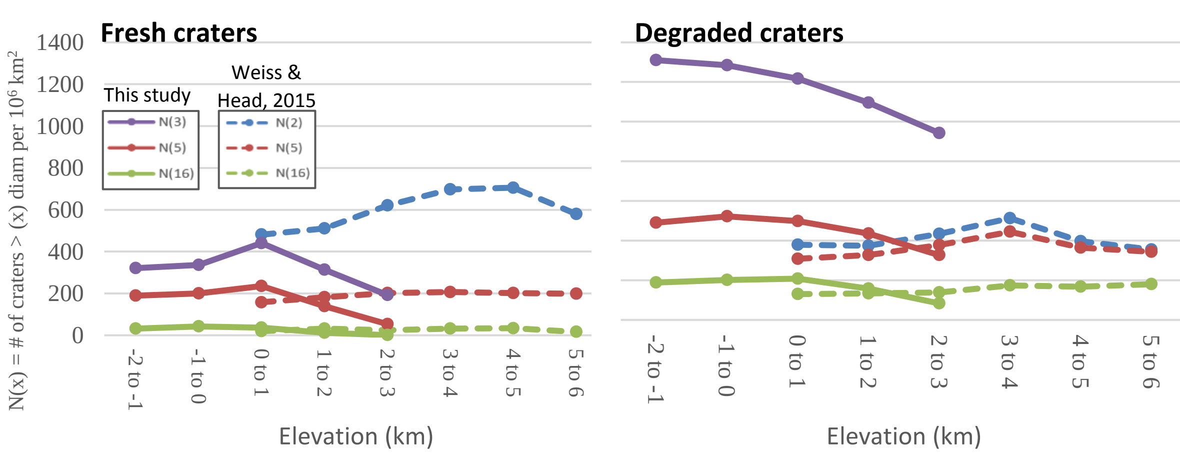

Figure 1: N(x) of fresh and degraded crater counts for Noachian units binned by elevation as reported in Weiss and Head [4] using data from Craddock and Maxwell [5] compared to results from this study using MOLA topography, current geologic mapping, and the global crater database [8,9]. Note that in the new analysis, there is almost no Noachian terrain in this region above 3 km MOLA elevation.

craters in Noachian units were then compared to those reported in Weiss and Head (**Fig. 1**).

The Robbins and Hynek crater database does not contain information on crater preservation state for craters <3 km in diameter, so regional N(3) rather than N(2) values are reported (**Fig. 1**). Nearly complete (97.4%) global mosaics of high resolution Context Imaging Camera (CTX) imagery rendered to 20 m/pixel were used for classification of crater degradation state down to 1 km in diameter. Degradation state for small craters was determined in three study regions of equal area (90,000 km^2) in Noachian terrains at different elevations to test predictions from the LNIH model (**Fig. 2**). From [4], high elevation small craters beneath the ice sheet (Region 3) should appear the freshest and most abundant/area; small craters at the ice margin (Region 2) should be sparse and highly degraded; while off-ice small craters (Region 1) should fall in between these other two populations. Fresh craters were identified as having at least two of the following: well-preserved ejecta, sharper crater rims, and minimal infilling on the crater floor. Spatial resolution from MOLA topography does not allow for measurements of crater rim relief, or depth/diameter ratios for these small impacts.

Results and Discussion: Updated fresh and degraded crater counts for Noachian terrains in the eastern hemisphere of Mars do not exhibit the same trend of increasing fresh, small craters with elevation predicted by the LNIH model. Elevations where small craters were observed to be abundant previously [5] do not coincide with updated elevation for Noachian units (**Fig.1**). Small fresh craters increase in the 0 to 1 km elevation range, contrary to where the LNIH model predicts greater modification.

Our newly-classified crater degradation state for small $\leq$3 km diameter craters shows an inverse trend of the number of fresh craters with increasing elevation (**Fig. 3**). This trend corroborates previous work by Irwin et al. [11] who observed that cumulative size-frequency distributions for small craters ($\leq$ 4 km diam.) at higher elevations (1-4 km) in Noachian units display a Hesperian age, implying complete resurfacing of craters $D < 4$ km following the Noachian. While removal of small craters at higher elevations could be explained from the melting of the LNIH, the predicted increase in degradation at lower elevations below the 1 km ice stability line is not observed (**Fig. 3)**.

Future Work and Conclusions: The three study regions representing different proximities to the LNIH will be expanded to include larger areas. Examining crater preservation states in broader regions will allow LNIH predictions to be more thoroughly tested. However, these preliminary results are contrary to the

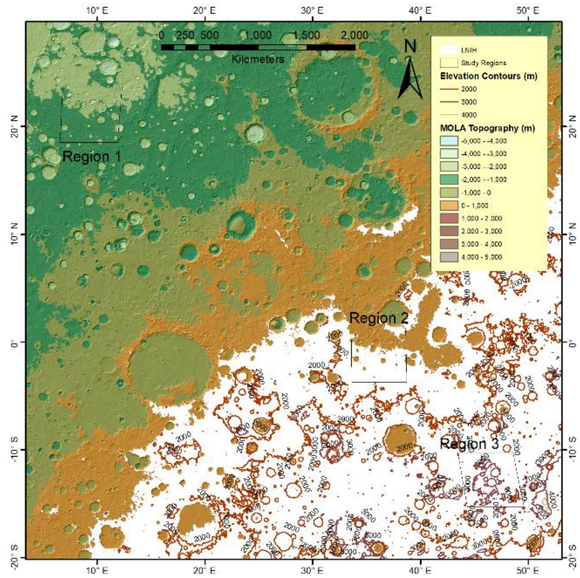

Figure 3: Map showing study regions in proximity to the LNIH.

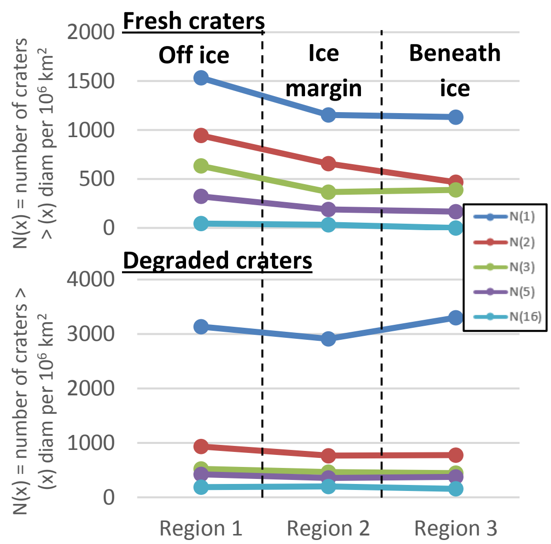

Figure 3: Relative N(x) ages for fresh (**A**) and degraded (**B**) craters in three study regions with average elevation increasing from left to right.

LNIH model predictions of small craters being better preserved at elevations >1 km and craters below 1 km elevation displaying a uniform resurfacing age and enhanced degradation due to erosion and infilling following melting of the ice sheet.

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