EXPLORING CONTROLS ON THE FLUVIAL BREACHING OF DEGRADED IMPACT CRATERS.

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Introduction: Many lakes on early Mars were hosted in degraded impact craters. Past work has suggested that landscape erosion and crater degradation were very active prior to the valley network (VN)-forming era on Mars [e.g., 2-4]. Rim relief reduction during degradation may have primed craters for subsequent inlet incision during the VN-forming era [5]. However, not all old, rimless craters on Mars are breached, so extensive rim degradation could not have been the only control on VN inlet formation. In this study, we ask: **Why were some, but not all, degraded craters breached during the VN-forming era?**

Here, we focus on testing whether there are any measurable distinctions between VN-breached and non-breached degraded Noachian craters.

Hypotheses: All else being equal, we hypothesize that inlet formation was promoted on; (i) longer and steeper slopes and; (ii) smoother terrains (as greater roughness, e.g., due to other craters and basins, may have obstructed flow).

Approach: We plan to evaluate the topography and hydrology around approx. 60 degraded craters, 30 with and 30 without VN inlets. VN-breached degraded craters were selected from a previous catalog of martian paleolakes [5, 6]. Non-breached craters, in the ancient southern highlands within 100 km of a VN and other paleolakes, were selected from a large catalog of martian craters [7]. We only analyzed degraded, complex craters (diameters from 12 to 100 km), between 40°N and 40°S.

The data collection approach is illustrated in Figure 1. The diameter of the crater was determined by mapping a circle to the crater [8]. Within circular buffer distances of 2 to 5 crater radii from the center, drainage density within each buffer was calculated using the global VN map from [9], modified from [10]. We used products derived from Mars Orbiter Laser Altimeter (MOLA) elevation data to measure slope and roughness. A clip of the spherical harmonic model (SHM) of Mars' topography up to degree 20 (~500 km on Mars) [11] was extracted at each circular buffer distance and used to calculate the regional slope. A "sector" 60° either side of the upslope orientation was mapped for each buffer distance. Median differential slope (MDS) maps [12] were clipped to each sector buffer area, and the median value of MDS serves as the regional roughness metric. Roughness was assessed at 0.6, 2.4, and 9.2 km baseline length scales [12].

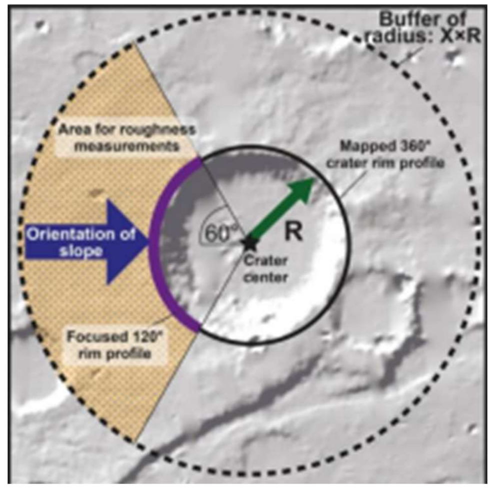

Figure 1: Schematic of measurements described in the text. R: Radius. X: number of radii that defines the buffer (2 ≤ X ≤ 5). Not to scale. Background is MOLA hillshade.

Preliminary Results: Preliminary measurements of regional slope and roughness for 30 non-breached craters and 13 breached craters have been recorded and are summarized below. Reported values for the means for each subpopulation are from the largest buffer size (5R), which appears representative of trends observed at all buffer sizes, unless otherwise stated.

Slope & Roughness: The mean regional slope magnitude for non-breached craters (3.42×10^{-3}) is slightly higher than breached craters (2.95×10^{-3}), contrary to our hypothesis. However, this difference is small and the data distribution is similar for both subsets (Figure 2). The same is true for regional slope orientation, which is primarily in the South to North orientation for both subsets of degraded craters. Likewise, we found little difference in the mean values or overall data distribution for MDS, our proxy for regional roughness, at all 3 scales of baseline length [12] (Figure 2).

Valley Network Drainage Density: At the 5R buffer distance, the mean VN drainage density for non-breached craters (1.99×10^{-2} km/km^2) is slightly lower than that for breached craters (2.54×10^{-2} km/km^2) (Figure 3). The overall distribution of drainage density is similar for both subsets at the 5R buffer distance. **However, closer to the crater at the 4R and 3R buffer distances**, **the mean drainage density for non-breached craters decreases** (while drainage density remains nearly the same for breached craters). At the smallest buffer distance of 2R, the mean drainage density for breached craters (2.38×10^{-2}) is more than 2.5 times the mean value for non-breached craters (9.38×10^{-3}) (Figure 3).

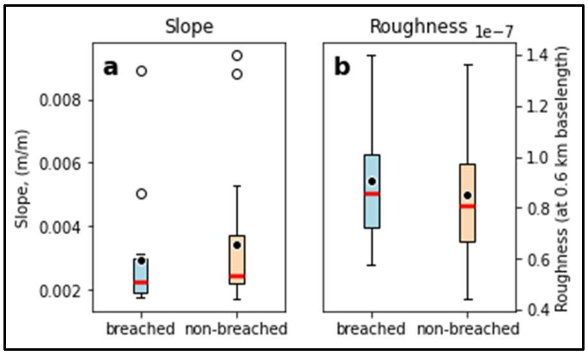

Figure 2: Box and whisker diagram of values for regional slope magnitude (*a*), and roughness (*b*). Roughness, or median differential slope, is at the 0.6 km baseline length. *Both subplots show data for all breached craters (left, blue), and non-breached craters (right, orange), with the interquartile range (IQR; extent of the colored boxes), the range of the data within 1.5 x IQR (black vertical 'whiskers'), median (horizontal red lines), mean (black solid circles) and outliers beyond 1.5 x IQR (white open circles).*

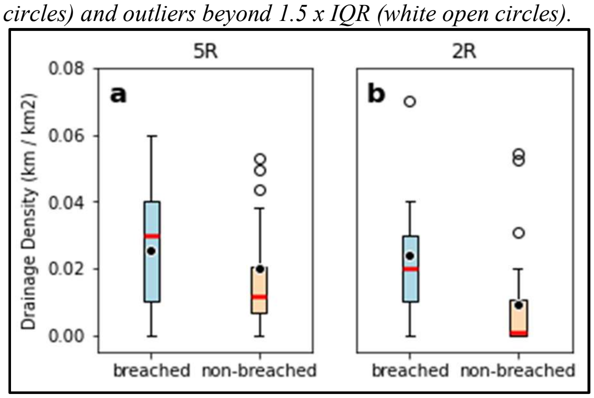

Figure 3: Box and whisker diagram of values for VN drainage density for the 5R circular buffer (*a*) and for the smaller 2R circular buffer (*b*), around each crater. *See the caption of Figure 2 for box plot details.*

Discussion & Future Work: Our data shows that regional topographic factors (both slope and roughness) do not appear to be the major factors in determining whether a crater becomes breached or not. One possible explanation for this is that slope was consistently steep across early Mars' surface [13] such that it was not an important distinguishing factor for inlet breach formation. It is also possible that a not insignificant fraction of inlet incision was driven by fluvial processes not directly coupled to surface topography, for example, groundwater or subglacial processes [e.g., 14-16].

Another possibility is that whether basins were breached by VNs or not may instead be related to their geography, and whether regional climatic conditions promoted precipitation and/or collection of water upstream of the crater [e.g., 17]. This possibility may be consistent with the observed differences between the VN drainage densities close to the crater between breached and non-breached craters. However, we also note that this trend might be expected because the breached craters have a VN inlet, and thus necessarily have a VN within 2R. We intend to test this by excluding valleys within the upslope sector area from the drainage density calculation. If this finding still holds, it may support the suggestion that climate conditions were responsible for controlling VN-breaching of impact craters. Given that the drainage density at 5R is not significantly different between breached and non-breached craters, and that distances between the 2R to 5R radii are mostly < 100 km, this would suggest that climate variability due to local conditions, such as orographic precipitation [18] was likely important.

Finally, we raise the possibility that other topographic factors controlling the routing of valleys close to the crater may be important, such as: (1) whether the basin is topographically perched or inset relative to its surroundings, (2) whether equivalent amounts of potential contributing drainage area were available, or (3) whether highly variable rim topography enabled easier pathways for water to enter the crater from surrounding terrain. Future work will test these alternatives.

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