SEARCHING FOR ANISOTROPIC EROSION IN THE FAN-BEARING CRATERS OF EARLY MARS

J. W. Sneed[1*], E. S. Kite[1], D. P. Mayer[1,2]. [1]University of Chicago, Chicago IL (sneedjw@uchicago.edu)
[2]United States Geological Survey Astrogeology Science Center, Flagstaff AZ

Introduction: Despite clear evidence of ancient fluvial sedimentary processes, decades of Mars research provide no conclusive account for the presence of warm conditions that could support liquid water on the planetary surface [1][2]. Many of the processes that would account for the proposed transient liquid water on modern Mars would also produce anisotropic slopes [3]. This motivates a search for the fingerprints of similar processes on more ancient slopes. Did transient periods of snowmelt production on slopes with prolonged exposure to direct sunlight influence the development of late Hesperian or early Amazonian basins [4][5]?

If direct sunlight can act as a control on erosion rates by regulating liquid water availability, then anisotropy in slope orientation might be observed in response. In the case of younger, mid-to-high latitude modern processes, pole-facing slopes are systematically gentler than glaciated equator-facing slopes [6]. However, it has not been established whether a similar process was active in the surface evolution of ancient Mars.

When deeply incised by alluvial fan source regions despite a limited drainage area, circular crater walls provide a natural testing bed, because their modern degraded state may be readily compared to a well-understood initial configuration and because they provide a wide range of exposures at any potential angle. Therefore, we undertake a broad survey of the erosional patterns in such craters in order to look for signs of insolation angle as a major determinant of liquid water availability.

Methods: We examine eight low-latitude crater systems associated with large alluvial fans, as well as either partial or full coverage by 6m-per-pixel CTX stereopairs. These include, e.g., Harris, Ostrov, and Holden craters. Using the NASA Ames stereo pipeline [7], 24m-per-pixel DEM images are extracted and smoothed using a 5-pixel radius gaussian filter to reduce noise and small gaps in coverage. For each pixel,

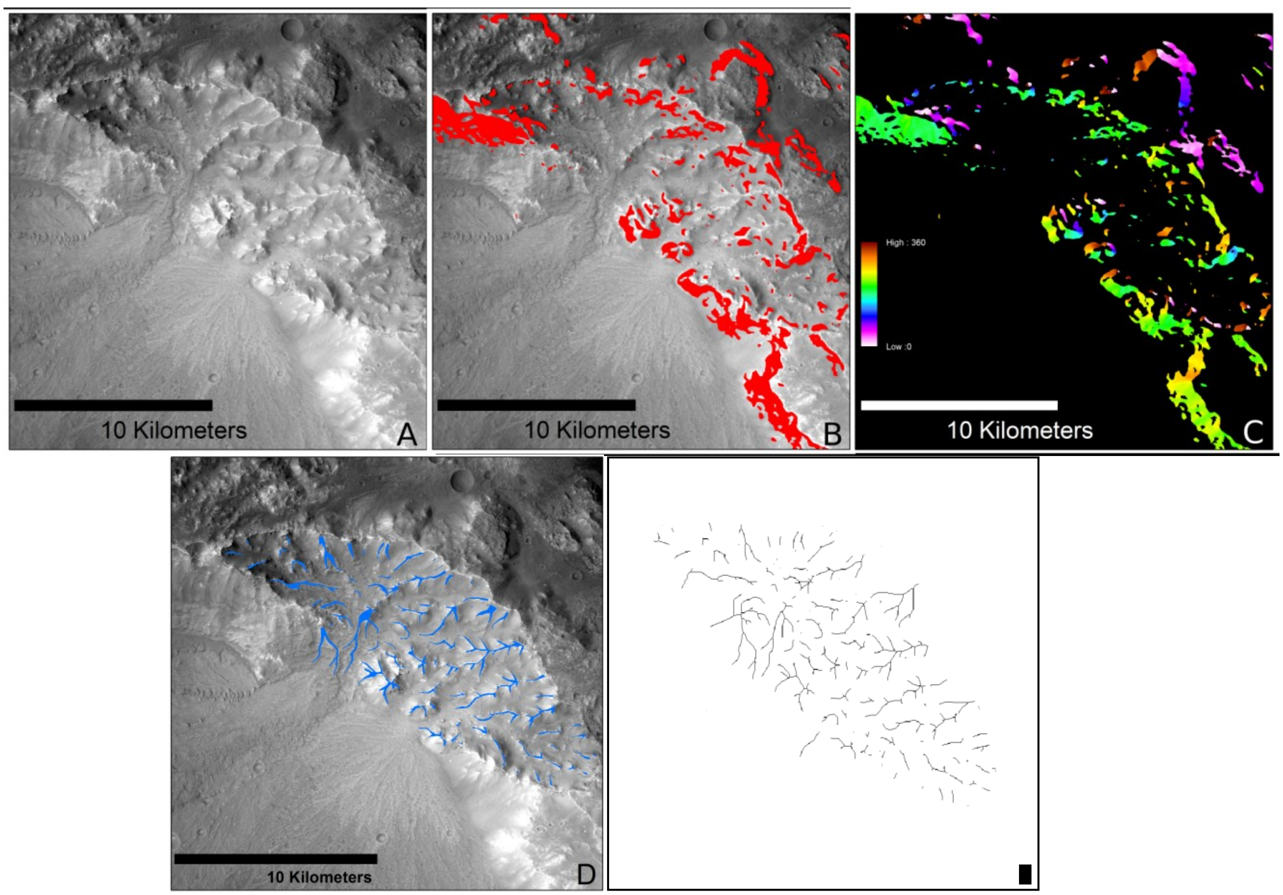

Figure 1: A: CTX orthopairs are selected for analysis. B10_013503_1583_XI_21S292W (Harris Crater) shown here. **B:** Using DTM elevation data, we identify each pixel with slope greater than 20° **C:** Direction of slope and angle from crater center are calculated separately for each point. Aspect (clockwise from north) is shown here. **D:** Using D-Infinity drainage modeling of an inverted elevation map, ridgeline zones are identified. **E:** Ridgeline data are skeletonized prior to statistical analysis.

we calculate a slope, aspect, and angle with respect to the crater's center. Pixels with slope < 20° are excluded from this study.

Each pixel value is binned in ten-degree arcs with respect to their angle from the crater center, effectively creating a weighted average of crater wall aspects according to the radial position of each point. Using a Monte Carlo simulation with 10^3 passes, we sample 10^3 points from each bin per pass.

We will present an analysis of this dataset that includes comparison to equatorial craters with few alluvial fans, as a control set.

Preliminary Results: An early survey of 8 craters shows a clear preponderance of north- and south-facing slopes relative to those facing east and west (Fig. 2). In a sample of 36,000 points drawn evenly from each cardinal direction, differences between the most overrepresented and most underrepresented aspect populations reached a factor of ~1.4. However, this effect exists in fresh (non-fan-bearing) craters as well.

Furthermore, this difference appears to be driven almost entirely by high variance in the aspects measured on the east and west slopes of each crater relative to those in the north and south.

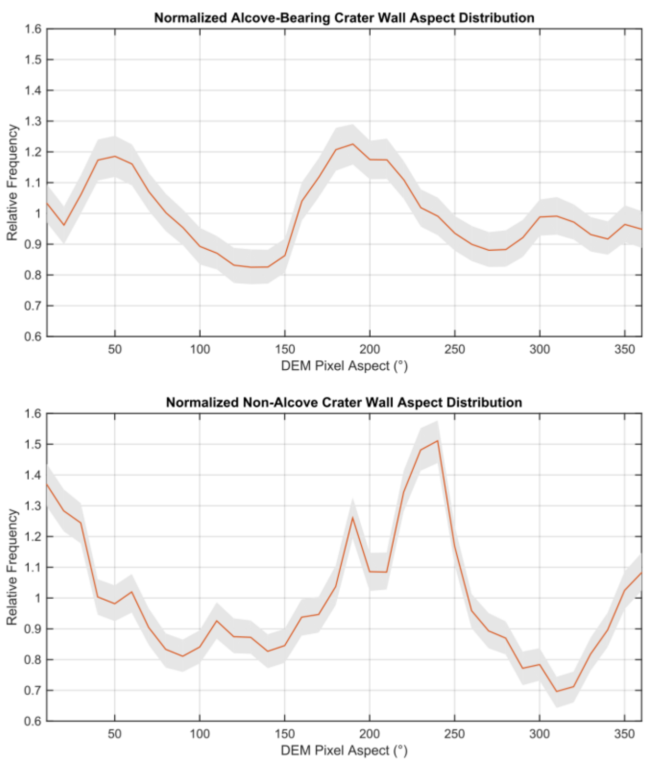

Figure 2: Measured aspect ratios in sampled crater wall sections. 180° = south-facing slopes, 90° = west-facing slopes. Shaded regions show 95% confidence interval in Monte Carlo simulation. **Top:** Alcove walls, **Bottom:** Fresh crater walls (null case). DEM pixel anisotropy shows greater magnitude in fresh craters (NNW orientation) than in fan-bearing alcoves.

Interpretation: Although we find anisotropic aspect frequencies in both alcove and non-alcove crater wall segments, neither of these is higher in amplitude than the null case of fresh crater walls.

Notably, this result diverges from strong anisotropic signals seen in younger features. For example, <5 Ma gullies show a strong north/south orientation preference, in addition to their preferential incision within (themselves anisotropically oriented) water ice mantles [6].

In order to expand the scope of this investigation, we are further examining ridgeline systems within crater wall alcoves; ridgeline tracing is automated using both raw curvature measures and D-Infinity drainage modeling over inverted elevation maps. We define a ridgeline zone as any pixel with an inverse drainage area of greater than 0.9km^2. After both curvature and ridgeline data are skeletonized, and the orientation of ridge segments relative to the crater center can be measured in each case.

It would be unexpected if neither snow accumulation, snow runoff production, nor solifluction-driven mass flows showed sensitivity to cardinal direction. Therefore, isotropic aspect frequencies in crater wall alcoves- consistent with our initial results- might suggest substantially different crater wall erosion regimes in the late Hesperian or early Amazonian than those found today. For example, in a much thicker atmosphere, greenhouse warming and turbulent exchange with the atmosphere would reduce the aspect-dependence of snowmelt runoff, and potentially allow for rainfall rather than snowmelt as a source of liquid water for erosion.

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