Motivation

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 sediments [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 [4,5,6]? 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, findings suggest that pole-facing slopes are systematically steeper than equator-facing slopes [8]. However, it has not yet been established whether a similar process was active in the surface evolution of ancient Mars, where a thicker atmosphere might be expected to disrupt this signal.

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 orthoimages. These include Luba, Roddy, Saheki, Harris, Ostrov, and Holden craters. Using the NASA Ames stereo pipeline [7], 24m-per-pixel DDEM images are extracted and smoothed using a 5-pixel radius filter to reduce noise and small gaps in coverage. For each pixel in the crater wall elevation model (excluding secondary impact craters with a radius larger than 1 km), we calculate a slope, aspect, and angle with respect to the crater’s center. Pixels with slope $>20°$ are excluded from this study (see fig. 3b). Crater walls are further subdivided into alcove and non-alcove sections by visual inspection. 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 reduce noise and small gaps in coverage. For each pixel in the crater wall elevation model over inverted topography, we identify arc segments in a simplified schematic, using a radial position of each point. Although the drainage model does suggest that north-facing ridgelines do appear at elevated frequencies in fan-bearing alcoves, this result was not confirmed by curvature measures. Instead, our statistical analysis shows divergent results, with both drainage and curvature methods reporting significant anisotropy in slope orientation preference, in addition to their preferential incision within alcove sections. Overall, this result diverges from strong anisotropic signals seen in younger craters. For example, $5\mu$m pixels show a strong north-oriented orientation preference, in addition to their preferential incision within alcove sections.

Discussion

Although we find anisotropically distributed characteristics in both Alpine and younger crater wall segments, the spatial scale is higher than the amplitude of the data. Although our analysis is constrained to older crater wall segments, these results suggest that the presence of anisotropic signals may be a common feature in older, more subdued landforms.

Although we find anisotropic aspect frequencies in both Alpine and non-Alpine crater wall segments, neither of these is highly significant at the full scale of both crater wall segments. Although the drainage model data suggest that north-facing orientations do appear at elevated frequencies in fan-bearing alcoves, this result was not confirmed by curvature measures.

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