PACING WIND-INDUCED SALTATION ABRASION ON MARS: USING CRATER COUNTS TO CONSTRAIN AEOLIAN EXHUMATION.

David P. Mayer[1] and Edwin S. Kite.[1] [1]University of Chicago (dpmayer@uchicago.edu).

Introduction: To understand Mars landscape evolution we need estimates of surface erosion rates, and how they vary across the landscape. For example, constraints on wind-induced saltation abrasion can test models of past wind shear stresses [1], as well as models of sedimentary-rock mound formation [2,3]. Erosion rates are also needed as inputs to models of organic matter preservation potential [4]. Measurements of the number and diameter of impact craters are essential inputs for estimating erosion rates. Relatively small, shallow craters are preferentially obliterated as a landscape undergoes erosion [5], so the size-frequency distribution of impact craters in a landscape undergoing steady exhumation will develop a shallow power-law slope [6]. Because crater counts require only orbiter data, they enhance the value of rare direct measurements of exposure age from rovers [4].

Here we present preliminary results from our effort to map impact crater frequency in HiRISE image data for sedimentary rocks across Mars (Figure 1). Fast crater-obliteration has been previously reported for Mars sedimentary rocks, but has not been systematically quantified [e.g. 7,8,13,14].

Data and Methods: We used image data from the HiRISE red channel as the basis for crater mapping. Analysts counted craters on selected areas of map-projected HiRISE images using the CraterTools extension for ArcMap [9].

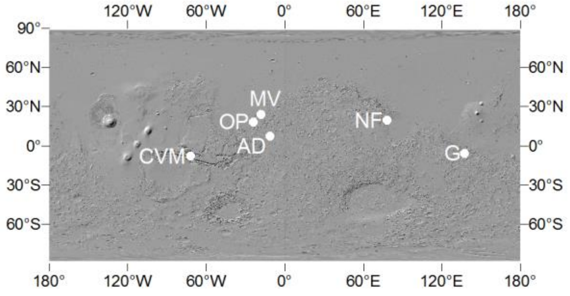

Figure 1. Map showing regions where craters were counted. AD = Aram Dorsum, CVM = Central Valles Marineris, G = Gale Crater, NF = Nili Fossae, MV = Mawrth Vallis, OP = Oxia Planum.

Crater Counting. Analysts (University of Chicago undergraduates) were given 2 hours of classroom training on martian impact crater morphology, with examples primarily drawn from HiRISE image data, followed by ~6 hours of hands-on training mapping impact craters on 2 HiRISE images using ArcMap and CraterTools. Following training, the analysts independently mapped craters in pre-selected areas of ~40 HiRISE images. Portions of the images containing dunes or other landforms of apparently unconsolidated material were masked out.

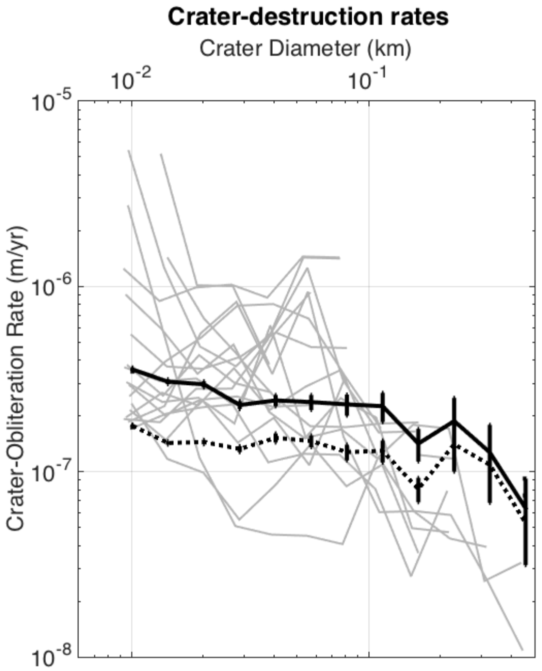

Figure 2: Crater obliteration rates derived from crater counts on HiRISE images. Solid line shows results (and statistical error bars) for craters agreed upon by ≥3 analysts. Dashed line shows results (and statistical error bars) for craters agreed upon by ≥2 analysts; this count includes more false positives. Gray lines show crater obliteration rates for the 18 individual HiRISE images based on craters agreed upon by ≥3 analysts.

Erosion-Rate Estimation. Erosion rates were estimated for areas in HiRISE images in which craters were mapped by ≥3 analysts. For each such image, craters mapped by different analysts were aggregated using a clustering algorithm implemented in Matlab. Overlapping features whose centers were located within 50% of the maximum diameter of one another and whose absolute value of diameter differences were less than 150% were clustered together. Final agreed-upon craters were then defined by the mean center location and diameter of the clustered features. To calculate erosion rates, we used the "1 Ga" flux of craters in Table 1 of Ref. [10]. We then divided our counts (N/km^2) by the fluxes to obtain effective ages of the surface for each size bin. We assumed a resurfacing depth of 10% of the diameter of the crater is sufficient to obliterate the crater (this is ~50% of original crater depth; if the required resurfacing depth is in fact 100% of original crater depth, then our computed rates increase by a factor of 2). With these assumptions, the mean erosion rate for each size bin equals the depth-to-obliteration divided by the size-bin-specific exposure age.

Preliminary Results:

Impact craters were mapped by ≥3 analysts in 18 HiRISE images showing sedimentary rocks (Figure 1). Most of the images were in areas of steep terrain. The false positive crater identification rate appears to be low based on inspection of agreed-upon craters. Therefore, this gives a lower limit on the "true" number of craters within each mapped area – and thus an upper bound on crater-destruction rate. The crater-obliteration rates we obtain are upper limits on the rate of landscape-wide exhumation (i.e. landscape lowering). For example, craters can be removed by diffusive infilling without landscape-lowering, and diffusion fits crater-degradation observations in the flat landscape of the Burns Formation [5]. For an unusually steep sedimentary-rock outcrop, >1 μm/yr average erosion sustained over 200-400 Myr has been reported by [12]. If the erosion rates are interpreted as landscape-lowering rates, then the mean rates are 0.2-0.4 μm/yr (if craters counted by ≥3 analysts are included) or 0.1-0.2 μm/yr (if craters counted by ≥2 analysts are included (Figure 2); this count has a greater frequency of false positives). Individual images showed crater-obliteration rates that clustered in the range 0.1-1 μm/yr, consistent with [6].

Comparison to Other Methods: Most studies involving crater-counts rely on a single experienced analyst to identify craters. The other endmember is crowdsourcing platforms, such as MoonZoo (http://moonzoo.org) and Cosmoquest (http://cosmoquest.org), which invite the general public to count craters on the Moon and Mars. Robbins et al. (2014) compared lunar crater counts from expert analysts to those of non-specialist volunteers using CosmoQuest and found that, on average, non-specialists are able to identify craters as well as expert analysts are [11]. We took an intermediate approach, involving multiple less-experienced analysts with some training, mapping "in triplicate" to minimize false positives.

Summary and Implications: At the conference, we will present a quantitative estimate of the false positive crater identification rate, discuss the implications of our results for aeolian erosion, and relate our results to the organic-matter preservation potential of sites including Oxia Planum, the intended target of ESA's ExoMars 2018 rover.

References: [1] Armstrong et al. (2005) *Icarus*. [2] Day et al. (2015) *LPSC.* [3] Bridges et al. (2012) *Nature.* [4] Farley et al. (2014) *Science.* [5] Golombek et al. (2014) *JGR-Planets*. [6] Smith et al. (2008) *Geophys. Res. Lett.* [7] Sefton-Nash et al. (2014) *Icarus* [8] Malin et al. (2007) *JGR-Planets.* [9] Kneissel T. et al. (2011) *Planetary Space Sci., 59,* 1243-1254. [10] Michael (2013) *Icarus.* [11] Robbins S. J. et al., (2014) *Icarus, 234,* 109–131. [12] Grindrod & Warner (2014) *Geology.* [13] McEwen et al. (2005) *Icarus, 176,* 351-381. [14] Malin et al. (2007) *JGR-Planets.*

Acknowledgments: The authors gratefully acknowledge the summer research assistants who counted craters for this project: Daniel Eaton, Julian Marohnic, William Misener, Emily Thompson, Edward Warden, and Chuan Yin. This work is supported in part by NASA grant NNX15AH98G.