EROSION RATES ON MARS: RELEVANCE TO ASTROBIOLOGY.

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Introduction: Surface erosion rates on Mars are known to vary in both time and space. Although there have been numerous estimates of present and past erosion rates at landing sites and other specific locations [e.g., 1 and refs therein], there has not been a systematic effort to quantify the geographic variation in modern erosion rates planet-wide. Here, we propose to use a gridded array of crater counts (i.e., assessments of the size-frequency distribution of impact structures) to investigate the erosion and removal of craters less than 1 km in diameter. The results should clarify and refine expected latitudinal trends in erosion as well as reveal any terrain-specific effects.

Relevance to exploration: The task of quantifying erosion rates is relevant to the study of past habitability of landing sites, for example to assess the potential exposure history and concomitant radiation exposure of surface materials. Modeling of the interaction of galactic cosmic rays (GCRs) with the uppermost several meters of the martian surface suggests that any organic molecules >100 atomic mass units present would be reduced of between 2 and 3 orders of magnitude in concentration over a billion years [2]. At Gale crater, measurements of radiogenic ^{36}Ar, ^{21}Ne, and ^{3}He indicate exposure age dates ranging from about 72 to 84 Ma (± 20 to 30 Ma) [3]. If one could infer the exposure age of surfaces remotely, i.e., through crater size-frequency distribution measurements, this would contribute to the selection of landing sites and sample localities that maximize the potential to sample undegraded organic materials.

Methods: Several researchers have compiled catalogs of martian impact structures, using both manual [e.g., 4, 5, 6] and automated [e.g., 7, 8] methods. These catalogs are largely complete for craters >1 km in diameter. Here we use the Robbins and Hynek [6] crater database that was compiled using THEMIS daytime IR images supplemented with CTX data. In this present study, individual craters counts were preformed on CTX images (pixel scale 5 m [9]) using the CircleCraters plugin for QGIS [10], and the results were analyzed using the Craterstats2 software [11].

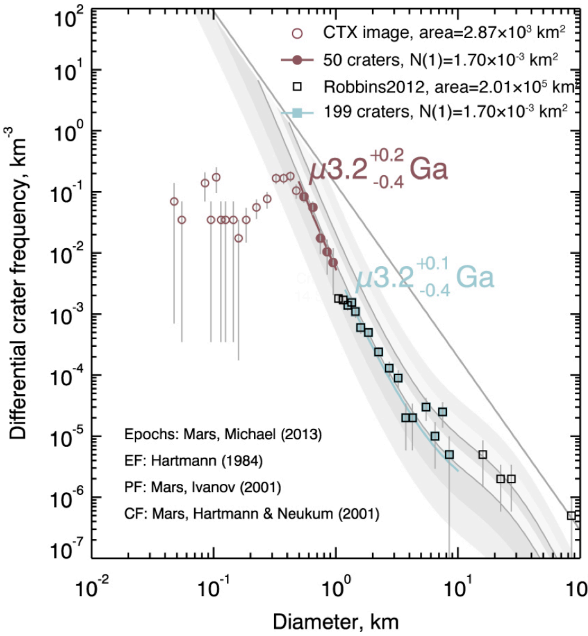

Figure 1. Differential crater size-frequency plot of high latitude sample area between 50–60°N, 110–120°E. Data for craters >1 km in diameter are from [6]; sub-km craters were counted on CTX image F01_036023_2318_XN_51N244W.

Preliminary results: A typical crater count of a high-latitude region is given in **Figure 1.** There is clear agreement between the isochron and model age for large craters (1 to 10 km in diameter) derived from crater crater catalog [6] with the isochron and the model age obtained using craters that are 0.5 to 1.0 km in diameter, a finding that is generally consistent with systematic observations of the >1 km in diameter cratering record in northern plains by [12]. However, sub-kilometer craters fall off of the isochrons in **Fig. 1** and indicate that the number densities of such craters has been reduced to a fraction of their original values. A fall-off in the observed population of small craters on visual images is commonly found when approaching the limits of resolution. Here, however, the detection of a few small impact structures with sharp rim crests and fresh-appearing ejecta indicate that factors such as illumination conditions or high dust opacity are not responsible for the observed population drop. In addition, the lack of an upturn at small crater diameters indicates that a production function has not been re-established, i.e., that the surface has been subjected to continuing resurfacing and erosion. The transition diameter (D_t) between resurfaced and normal crater populations is about 500 m in diameter at this locality.

Discussion: The relative dearth of high-latitude craters on Mars has been pointed out many times previously, starting with Mariner observations and Viking Orbiter images [e.g., 13, 14]. The erasure of small craters at latitudes above about 40°N and S is consistent with the observed shallowing of high-latitude craters as measured using depth to diameter ratios [15-17], latitudinal trends in sub-km roughness measured by laser altimetry [18], and observations of dust-mantled-terrain in specific latitude bands [e.g., 13, 19, 20].

The crater count results in **Fig. 1** raise several obvious follow-up questions. What is the nature of the crater removal mechanism? Is the loss of craters due to burial, erosion, terrain softening, or some combination of these processes? How much resurfacing has occurred, and when did it occur? On the lunar surface, small craters are obliterated due to bombardment by micrometeorites than can be treated on geologic timescales as a continuous, diffusion-like process [e.g., 21]. The thin atmosphere of Mars, however, is sufficient to shield the surface and greatly slow the rate of this process (though impact-genearted regolith is still present [22]). If we consider the most straightforward case of burial, ~35 m of sediment would be necessary to bury a fresh 500 m diameter crater on Mars up to its rim height h (using $h = 0.011D^{1.30}$, the relationship for simple craters derived by [16]). The timescale over which resurfacing (burial, in this simple case) occurs is not constrined by these data. If we assume a slow, steady-state process over the apparent formation age of the surface (~3.2 Ga), this works out to a bit more than 10 m per billion years, or about 1 m per 100 Ma (or 0.01 m/Ma). This is in line with other Amazonian rates compiled in [1], though it would be much higher if resurfacing was concentrated in a smaller epoch.

References: [1] Golombek M.P. et al. (2014) *JGR*. [2] Pavlov A. et al. (2012) *GRL*, *39*. [3] Farley K.A. et al. (2014) *Science*, *343*, 1247166. [4] Mutch T.A. et al. (1976) *The Geology of Mars*, 409 pp. [5] Barlow N.G. (1988) *Icarus*, *75*, 285-305. [6] Robbins S.J. & Hynek B.M. (2012) *JGR*, *117*. [7] Stepinski T.F. et al. (2009) *Icarus*, *203*, 77-87. [8] Salamunićcar G. et al. (2011) *PSS*, *59*, 111-131. [9] Malin M.C. et al. (2007) *JGR*, *112*. [10] Braden S. (2015) *LPSC*, *46*, abstract #1816. [11] Michael G.G. (2013) *Icarus*, *226*, 885-890. [12] Werner S. et al. (2011) *PSS*, *59*, 1143-1165. [13] Soderblom L.A. et al. (1973) *JGR*, *78*, 4117-4122. [14] Chapman C.R. & Jones K.L. (1977) *Ann. Rev. Earth Planet. Sci.*, *5*, 515-540. [15] Stepinski T. & Urbach E. (2009) *LPSC*, *40*, abstract #1117. [16] Robbins S.J. & Hynek B.M. (2012) *JGR*, *117*. [17] Stepinski T. et al. (2012) in *Intelligent Data Analysis for Real-Life Applications,* 146-159. [18] Kreslavsky M. & Head J. (2002) *GRL*, *29*. [19] Mustard J.F. et al. (2001) *Nature*, *412*, 411-414. [20] Head J.W. et al. (2003) *Nature*, *426*, 797-802. [21] Fassett C.I. & Thomson B.J. (2014) *JGR*, *119*, 2255-2271. [22] Hartmann W.K. et al. (2001) *Icarus*, *149*, 37-53.