SPATIAL VARIATION IN EROSION RATES IN MARS EQUATORIAL REGIONS INFERRED FROM EJECTA RETENTION OF 1–3 KM DIAMETER CRATERS. C. I. Fassett[1], W. A. Watters[2], C. B. Hundal[3], and M. Zanetti[1], [1]NASA Marshall Space Flight Center, Huntsville, AL 35805, [2] Dept. of Astronomy, Whitin Observatory, Wellesley College, Wellesley, MA 02481, [3]Dept. of Earth, Environmental, and Planetary Sciences, Brown University, Providence, RI 02912 (caleb.i.fassett@nasa.gov).

Introduction: The modification of impact craters has long been used to infer the geomorphic forcing on Mars [1], as well as estimate the spatial and temporal variability of this erosion and gradation [e.g., 2]. Here, we studied the population of small primary craters (1-3 km) to understand differences in ejecta retention across equatorial Mars. Specifically, we evaluated whether craters in our study population had observable ejecta deposits (defined on the basis of distinct tone or texture with respect to their surroundings).This is a proxy for the resurfacing rate because only relatively fresh craters retain their ejecta deposits. More broadly, this is part of a larger project we are undertaking [3] to examine crater morphometry and other characteristics from CTX-derived digital terrain models (DTMs), augmented by qualitative observations.

Methods: We identified the set of 1–8 km craters in the Robbins and Hynek [4] crater database overlapping available CTX DTMs we have created as of March 2019. Using local images extracted from a global CTX mosaic [5], all such craters in the 30˚N to 30˚S band (n=31,915) were manually classified on the basis of several characteristics, including whether they are exhumed, have significant interior fill, are probable secondaries, and have distinct ejecta deposits. Through this visual inspection, we also omitted a few percent of craters in the database [4] that we interpreted as non-impact derived (e.g., volcanic pits) or formed from clustered impacts (e.g., due to the breakup of the impactor).

From the resulting crater inventory, we extracted the subset of primary craters in the 1–3 km size range, excluding all probable secondaries and non-impact craters mentioned above. This dataset does include buried and/or exhumed craters, which are relatively common. The total population in the resulting sample is 23,932 craters. Figure 1a shows the spatial frequency of these craters, divided into 10˚×10˚ binned areas.

Results: Across the equatorial band, only 9% of craters of 1-3 km diameter in the study area (~14.6 million km^2) had preserved ejecta (2,193 craters). The frequency of craters that retain ejecta is thus n(1–3) = 0.00015 craters/km^2, accounting for DTM coverage and the observed crater population. This is equivalent to an average ejecta retention age in this size range of 390 Ma in the Neukum chronology. In other words, on average, ejecta of 1–3 km craters are retained only since the Mid-Amazonian/Late Amazonian boundary [6].

Figure 1b shows the spatial variations in frequency of craters with ejecta. In particular, ejecta retention is less common on the older highlands compared to the Hesperian/Amazonian surfaces of the lowlands. The Hesperian transitional unit (*Hto*) [7] of eastern Lunae Planum/Chryse Planitia stands out as an area where craters' ejecta deposits are particularly well-preserved, with ejecta retention for ~1–2.4 Ga; this area includes the landing sites for Viking 1 and Mars Pathfinder. Similarly, the InSight landing site has an ejecta retention period of ~1 Ga. In contrast, Gale, Gusev, and Meridiani all have ejecta retention periods of ~300-340 Ma, closer to Mars equatorial average.

Implications for Erosion/Gradation Rates: Presuming ejecta modification is the dominant factor controlling ejecta retention, we can make an assessment of the relevant erosion and/or gradation rates required to render the deposits unrecognizable. Based on observations of fresh craters, the characteristic relief on ejecta deposits for fresh craters of this size has an amplitude of at least 1% of the diameter (>~10m). The proximal ejecta near to the rim is thicker, but need not be completely removed to render the ejecta deposit indistinct.

Thus, we take ~10 m as the characteristic minimum amount of erosion required to destroy the recognition of 1–3 km craters' ejecta deposits. Combined with the inferred ejecta retention ages, we estimate a global equatorial average erosion/gradation rate to destroy ejecta of 0.03–0.08 m/Myr. Overall, this rate is reasonably consistent, or slightly faster than, what was inferred by Golombek et al. [2] for typical erosion rates in the Late Amazonian. In the highlands, these results are also consistent with the ~0.1 m/Myr erosion rates estimated from small crater statistics in a few locations by Kite and Mayer [8].

The increased retention age for ejecta in Chryse Planitia on unit *Hto* implies erosion occurred at long-term rates ~16-33% of what is typical; in other words, the destruction of ejecta deposits in the vicinity of Viking 1 and Pathfinder landing site demands erosion rates as slow as ~0.005 m/Myr. This rate is still two orders of magnitude faster than erosion estimates (~10^{-5} m/Myr) derived from observations of deflation on their plains surfaces [9]. However, these disparate estimates may be consistent, as the erosion of relief associated with the ejecta of impact craters is likely to be much faster than deflation of a low-relief plains surface. Regardless, these data hint that the erosion rates at the

Pathfinder and Viking 1 sites may be atypical for Mars as a whole.

Discussion and Conclusion: As outlined above, our preferred interpretation is that these spatial variations are predominantly a consequence of differences in long-term modification, rather than differences in the nature of the ejecta deposits at formation. We acknowledge, however, that if fresh crater ejecta differed significantly between different regions that could potentially lead to the observed spatial variability in retention as well. In future work, we will further assess this alternative.

If long-term modification is implicated, the observed variations in erosion or gradation may reflect differences in geomorphic forcing, resistance of ejecta to destruction, or both. A comparatively weak nature for much of the cratered highlands has been suggested from a variety of perspectives before [10, 11], so this may play a significant largest role in explaining the observed differences.

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References: [1] Hartmann, W.K. (1971), *Icarus*, *15*, 410–428. [2] Golombek, M.P. et al. (2014), *JGR-Planets*, *119*, 10.1002/2014JE004658. [3] Watters, W.A. et al. (2020), this meeting. [4] Robbins, S.J. & Hynek, B. (2012), *JGR-Planets*, *117*, 10.1029/2011JE003966. [5] Dickson, J.L. et al. (2018), *LPSC 49*, 2480. [6] Werner, S.C. & Tanaka, K.L. (2011), *Icarus*, *215*, 603–607. [7] Tanaka, K.L. et al. (2014), Geologic Map of Mars, 10.3133/sim3292. [8] Kite, E.S. & Mayer, D.P. (2018), *Icarus*, *286*, 212–222, 10.1016/j.icarus.2016.10.010. [9] Golombek, M.P. & Bridges, N.T. (2000), *JGR*, *105*, 1841–1853. [10] Hartmann, W.K & Barlow, N.G. (2006), *M&PS*, *41*, 1453–1467, 10.1111/j.1945-5100.2006.tb00429.x. [11] Rogers, A.D. (2018), *GRL*, *45*, 1767–1777, 10.1002/2018GL077030. [12] Irwin, R.P. et al. (2013), *JGR*, *118*, 278–291, 10.1002/jgre.20053.

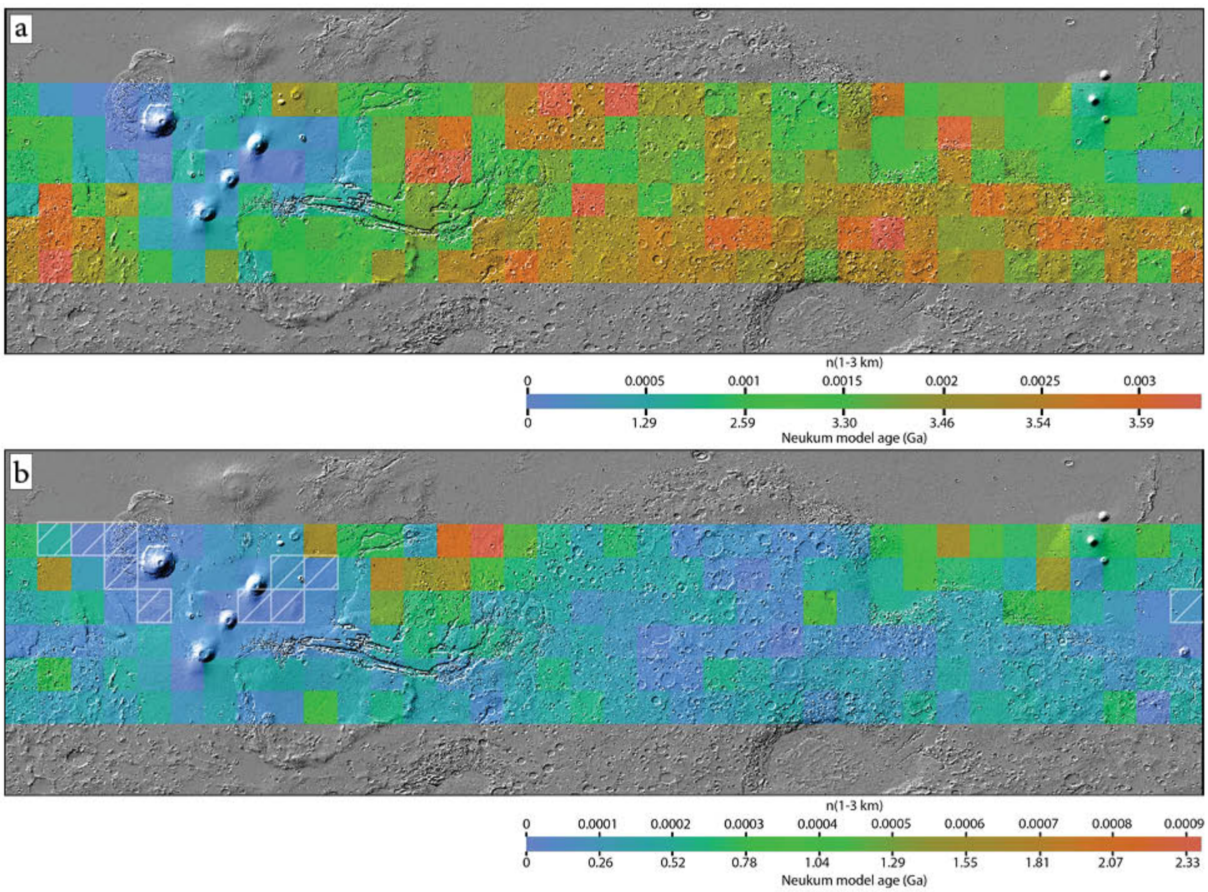

Fig. 1. (a) The frequency of all 1–3 km craters in 10˚ by 10˚ zones, based on [4], limited to craters we interpret as primaries and to our measurement region where there was CTX DTM coverage. Note that, on the oldest surfaces, ~1–3 km craters are imperfectly retained and typically the oldest such craters are only ~Hesperian in age [e.g., 12]. **(b) The frequency of 1–3 km craters with preserved ejecta. Craters with ejecta are less common in the Noachian highlands than northern lowlands, suggesting faster surface modification rates in the highlands than lowlands.** (Hashed out areas in (b) are a poor sample, with <10 craters overall).