ASSESSING THE TIMING OF HYDROLOGIC ACTIVITY ON MARS USING A PROBABILISTIC CRATERING MODEL.
M.C. Palucis[1*], J.T. Jasper, B. Garczynski[1], and W.E. Dietrich[2], [1]Department of Earth Sciences, Dartmouth College, Hanover, NH, [2]Department of Earth and Planetary Science, University of California - Berkeley, Berkeley, CA, [*]marisa.c.palucis@dartmouth.edu

Introduction: With the increase in high-resolution imagery of Martian surfaces provided by the High-Resolution Imaging Science Experiment (HiRISE) [1] and the Context Camera (CTX) [2], smaller scale features such as alluvial fans and deltas (< ~1,000 km^2) (e.g., [3]-[6]) are being discovered and dated, which has major implications for understanding the hydrologic and climatic history of Mars. However, these depositional features are subject to erosion and infilling, processes which will change the crater population, often preferentially removing craters from the small-diameter end of the distribution [7]-[10]. Here, we propose a simple model to quantify the effects of sample area size and crater obliteration (i.e. craters erased from the surface due to geomorphic processes) on age estimates of depositional features derived from crater counting.

Methodology: In both our "non-eroding" and "eroding" models, large parent surfaces (area=200,000 km^2, which is 10x larger than the largest subsampled surfaces) were generated with crater populations ranging between 16 m and 64 km as defined by the Hartmann isochrons for Mars from 0.5 Ga (Late Amazonian) to 3.7 Ga (Late Hesperian) [2004 iteration, 11]. The center coordinates of each crater were determined using a random number generator, with the only constraints being that the craters must not extend past the parent area and that all of the craters for a given age, as defined by Hartmann [11], be present (i.e. craters cannot obliterate one another). This model does not try to reproduce any true physical processes, like fragmentation mechanics to generate secondaries, rather it assumes that the isochrons as defined by Hartmann [11] are the theoretical size-frequency distributions for well-preserved surfaces of a known age. These "ideal" cratered surfaces were then randomly subsampled over smaller and smaller areas (10,000 km^2 down to 10 km^2), where the number of subsamples ranged from 100 to 1000. Crater populations for subsampled areas were fit to Hartmann's 0.1 to 4.0 Ga isochrons by normalized RMSE (at 0.1 Ga intervals), giving a sample age. Calculated subsample ages agreed within 0.2 Ga with those calculated by CraterStats II software (Chronology system: Mars, Hartmann 2004 iteration; Chronology function: Mars, Hartmann [11]; Production function: Mars, Hartmann [11]; cumulative fit; root-2 binning), a standard tool used for determining surface ages from cratering data [9]. A histogram of ages can then be produced for a given subsample size.

For the "eroding" cases, the obliteration model of Smith et al. [5] was used. Obliteration is defined as the removal of a crater by both erosion of the crater rim, and deposition of colluvium and wind-blown material within the crater. The model assumes a steady production of craters over time with a constant rate of obliteration (% per year), where the loss function is a function of β, which is the sum of the local erosion and deposition rate. For estimated obliteration rates on Mars (1-1000 nm a^{-1}; [8,10,12]), the crater frequency distributions (i.e. number of craters/area versus crater diameter) are most affected for crater diameters <1 km. The same subsampling and dating procedure was used as described above. Figure 1 shows an example distribution of surface ages assigned to 100 km^2 subsamples from a 2 Ga parent surface with an area of 20,000 km^2 and β = 10 nm a^{-1}. We note that zero obliteration was represented as $\beta = 10^{-5}$ nm a^{-1}.

The model was also used to determine ages and β values likely to produce observed crater counts of actual Martian surfaces. We generated parent surfaces over a range of ages (0.1 to 4 Ga) and β values (10^{-5} to 400 nm a^{-1}) and subsampled each of them 1,000 times using a sub-area equal to the area of the surface of interest. Crater counts generated by subsampling the parent surfaces were then compared to the actual count. Modeled crater counts in which the density of craters in all bins matched the actual crater count within 25% were accepted as possible age/β combinations for the observed surface.

Selected Results: A key question addressed by this model is "how accurately can we date surfaces with small areas?" Previous work suggests that areas ~1,000 to 10,000 km^2 are sufficient, but surfaces with moderate to high rates of erosion were not accounted for and the true surface ages were not known [13]. In Figure 2, we show actual crater counts of the Peace Vallis (PV) fan and the Pancake delta [6] in Gale Crater (using diameters greater than 0.25 km), as well as histograms for the number of modeled crater counts for surfaces of ages and β values that closely matched the real data. If β ~ 10 nm a^{-1}, the PV fan is likely young, as proposed by [15], but if β > 100 nm a^{-1}, an age of 1 to 3 Ga is indistinguishable. Also, while the PV fan is likely younger than the Pancake delta, as proposed in [6], there is still a reasonable probability that the two features share an age of about 2 to 3.5 Ga. Current work is focused on extending this model to refine age estimates for other alluvial deposits, which has implications for the timing of surface water on Mars.

References: [1] McEwen et al. (2007) [2] Malin et al. (2007) [3] Anderson and Bell (2010) [4] Grant and Wilson (2011) [5] Morgan et al. (2014) [6] Palucis et al. (2016) [7] Hartman (1971) [8] Kite and Mayer (2017) [9] Michael and Neukum (2010) [10] Smith et al. (2008) [11] Hartmann (2005) [12] Farley et al. (2013) [13] Warner et al. (2015) [14] Le Deit et al. (2013) [15] Grant et al. (2014)

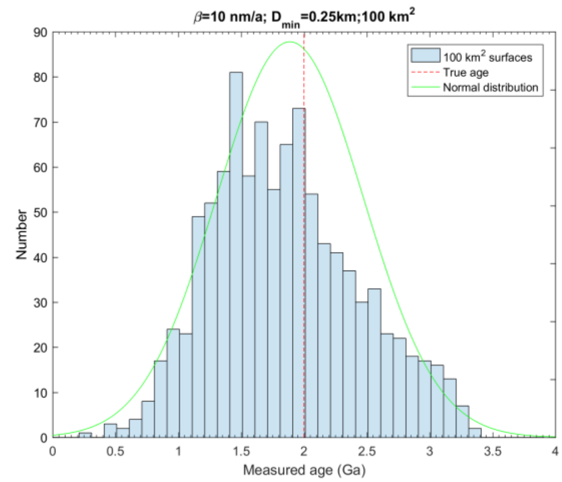

Figure 1.

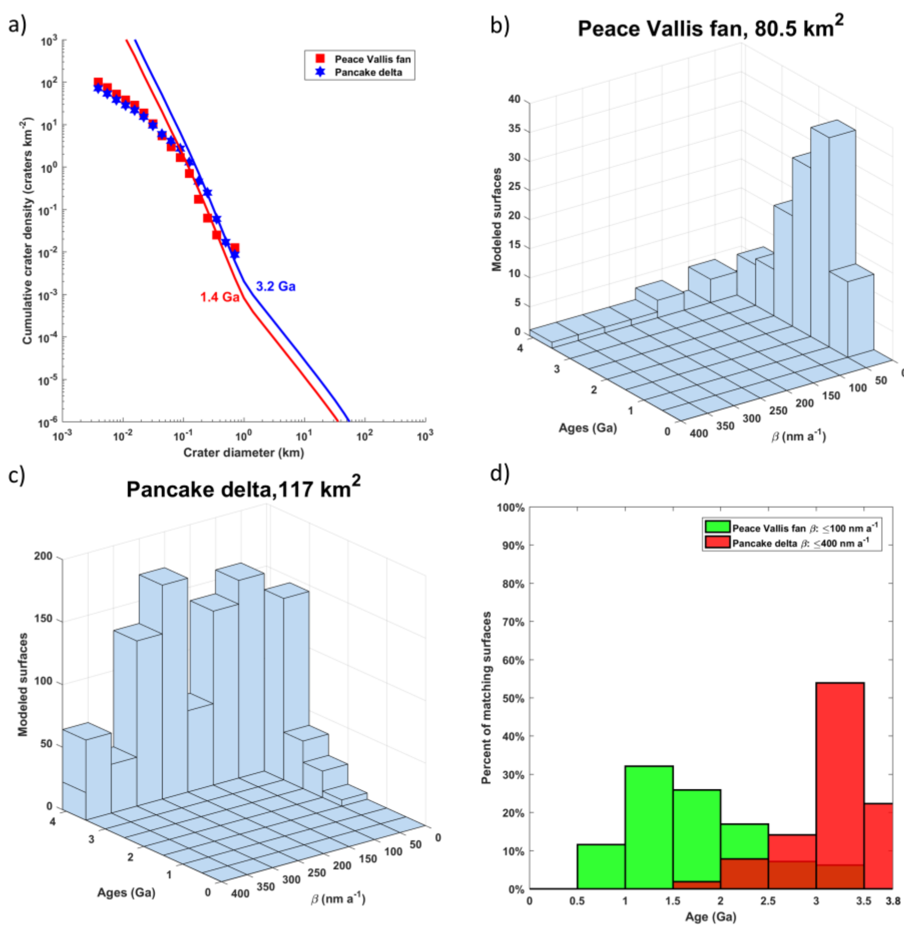

Figure 2.