CONSTRUCTING A SEMI-AUTOMATED METHOD IN ARCMAP TO MEASURE IMPACT CRATER MORPHOLOGY.

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Introduction: Estimates of Martian erosion rates are derived from assessments of impact crater and associated landform morphology. These assessments can be accomplished through in-situ rover-based studies and from high-resolution satellite imagery [1,2,3,4]. However, the two metrics most commonly used to quantify degradation – changes in crater depth and changes in crater rim height – have been found to yield order-of-magnitude differences in the calculated erosion rates [1,5]. Sweeney et al. [5] calculate a depth dependent erosion rate of 0.02 m/Myr (D = 200 m) and a rim height based rate of 0.008 m/Myr (D = 200 m) from a set of <1 km diameter craters at Elysium Planitia (the landing site for the 2018 InSight mission). Golombek et al. [1] similarly find an order of magnitude slower rim erosion rates versus crater infill rates. This difference indicates that infill of the crater bowl outpaces erosion of the rim and implies that depth-dependent degradation rates could be overestimates of the true erosion rate elsewhere on Mars. A degradation rate based on rim height measurements most likely provides a more accurate estimate of the magnitude of erosive processes [5,6].

Unfortunately, manual measurements of crater depth and rim height are time-consuming. Sweeney et al. [5] determined crater depth for 595 impact craters and rim height for a subset of 208 craters (D < 1 km) using 1 m High Resolution Imaging Science Experiment (HiRISE) digital elevation models (DEMs).

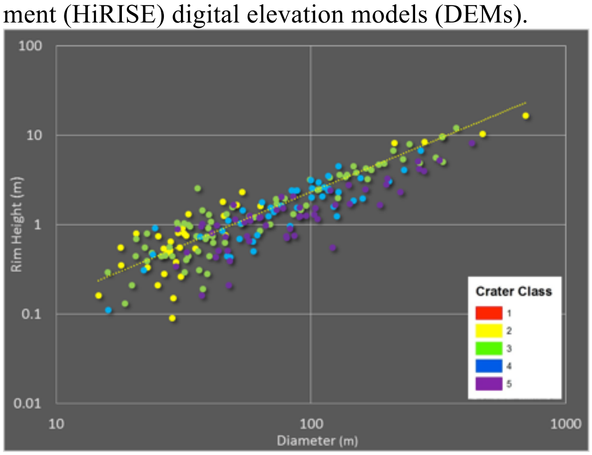

Figure 1: Measurements of REC rim height and diameter (n = 208).

Average depth was calculated across four crater profiles (NS, EW, NESW, NWSE) and average rim height was obtained by measuring rim height at eight locations around the circumference of the crater rim (N, NE, E, SE, S, SW, W, NW). Elevation was measured at the rim peak and at the surrounding plains approximately one crater diameter from the rim. The manual method for measuring rim height is more time-intensive than the depth calculation due to the irregular rim morphology of degraded craters. The manual method does allow for craters with small superimposed craters on the rims, craters impacting steep slopes, or craters bisected by the edge of the DEM to be noted or excluded. However, the time-intensive nature of this method outweighs the benefits of additional user control. The present study, therefore, is an effort to use different tools in ArcMap to develop a faster, semi-automated method of measuring crater morphology, specifically crater rim heights.

Methods: As an alternative method to manually measuring crater morphometry from the DEMs, we utilize a series of ArcMap tools through Model Builder to measure crater depth and rim height. The goal of using Model Builder is to generate a single model that is built on a sequence of ArcMap tools. This model can measure the morphometric characteristics of hundreds of craters simultaneously if the craters have been previously mapped as shapefiles.

To calculate crater depth, we (1) generate a triangular irregular network (TIN) across each crater that represents the elevation of the crater rim. (2) Convert the TIN to an elevation raster. (3) Subtract the DEM from the elevation raster. (4) The difference between the DEM – the elevation of the crater floor – and the elevation raster – the crater rim height – yields mean crater depth.

To calculte rim height, we (1) generate a TIN at a distance of one diameter from the crater rim to represent the elevation of the impacted terrain. (2) Convert the TIN to an elevation raster. (3) Subtract the elevation raster from the DEM to determine the crater rim height above the surrounding terrain. (4) Set all negative elevation values in this resulting rim height raster to null. (5) Clip the raster to a crater rim width of 2 m to determine the mean crater rim height.

A second method is also being developed. In this method, we (1) invert the DEM and use the ArcHydro Fill Sinks tool to flatten positive relief features (fill in the crater rims). (2) Invert the DEM again to restore accurate elevations and fill the craters using the Fill Sinks tool. (3) Subtract the flattened DEM from the original DEM. (4) Calculate mean crater depth. (5)

Calculate mean rim height by clipping the filled DEM to a 2 m rim annulus.

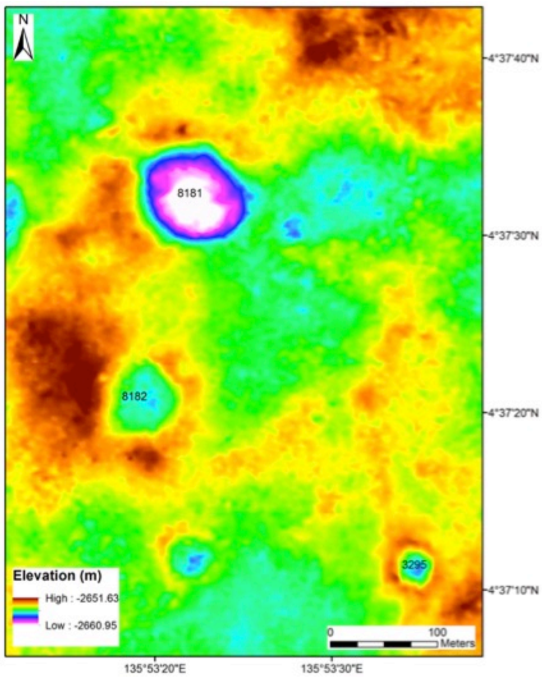

Figure 2a. Digital elevation model (1 m pixel^{-1}) showing the morphology of three degraded craters.

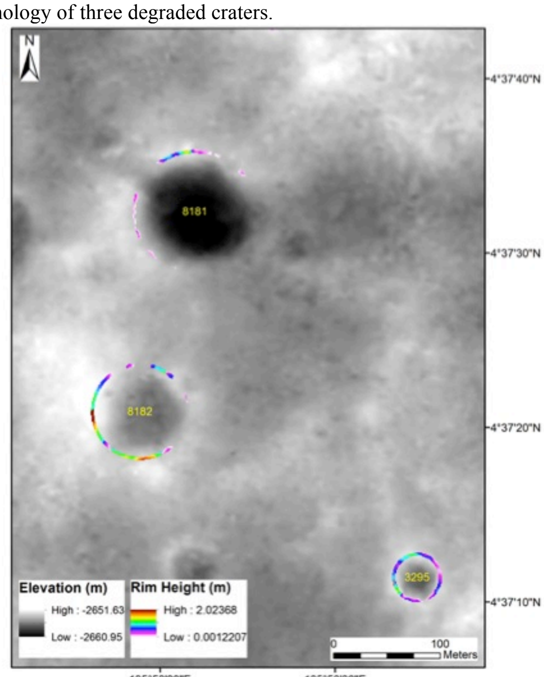

Figure 2b. Rim height raster clipped to a 2 m rim annulus with all negative values removed.

Results and Discussion: The preliminary crater depths and rim heights from the model fall within approximately $\pm$ 1 m of the manually measured parameters for 10- to 100 m-scale craters. The variability between the manual and preliminary model-derived measurements increases for crater diameters > 100 m. The discrepancies between manual and model-derived measurements are greater for crater rim heights than crater depths, possibly due to the irregular morphology of degraded crater rims.

The manually calculated rim heights are systematically greater than the model-derived measurements. The manual model allows for the user to visually identify crater rim peaks, while the model identifies the crater rim as a perfect circle and therefore may not capture the true location of a degraded crater rim. The model may instead be recording the elevation of a portion of the crater bowl or the ejecta as opposed to the true crater rim, resulting in a lower mean rim height. Additionally, the manual rim heights are derived from only 8 measurements, so the small scale variability in crater rim height may be missed. These errors could result in calculated mean rim heights that are not representative of crater. Further adjustments to the model will be made to improve effiency and reduce sources of error.

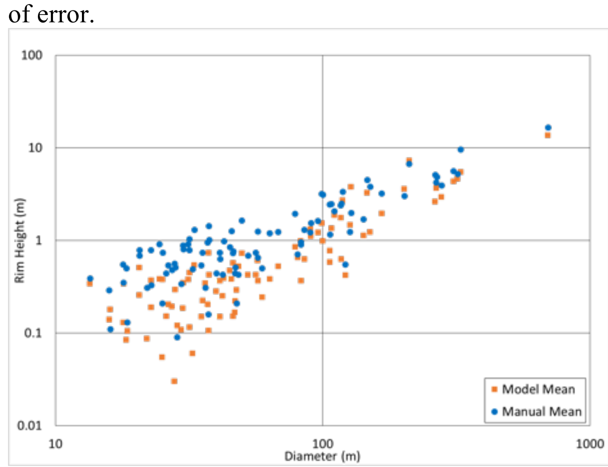

Figure 3. Manually measured crater rim heights compared model-derived crater rim heights (n = 91).

Conclusions: Overall, the semi-automated method achieves an acceptable level of accuracy and requires significantly less time. Using the manual method, Sweeney et al. [5] measured 595 crater depths and 208 crater rim heights in several weeks but a semi-automated model, these measurements can be obtained in minutes. The ability to rapidly assess crater morphometry will allow us to better constrain the magnitude of rim degradation and crater infill in Elysium Planitia, as well as well as other cratered terrains.

References: [1] Golombek, M.P. et al. (2014) *JGR* 119. [2] Golombek, M.P. et al. (2006) *JGR* 111. [3] Warner, N.H. et al. (2010) *JGR* 115. [4] Carr, M.H. (1992) *23rd LPSC*, 205-206. [5] Sweeney, J. et al. (2016) *47th LPSC,* #1576. [6] Golombek, M.P. et al. (2016) *Space Sci. Rev.* DOI 10.1007/s11214-016-0321-9.