HOW DO THE RELATIONSHIPS BETWEEN CRATER LANDFORMS CHANGE OVER TIME ON A GEOLOGICALLY DYNAMIC PLANET?

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Introduction: Quantitative relationships between morphologic characteristics of impact craters (a.k.a. crater morphometry) are well-known for impact craters on most solid bodies in our solar system [1-4]. However, most previous studies have utilized data sets of global crater populations to derive morphometric relationships, including *both* recently-formed and ancient impact craters. Thus our first attempts at deriving morphometric relationships encompass all or many age populations. However, little is known about how impact crater morphometry changes over geologic timespans when craters are exposed to active surficial/atmospheric processes.

In this study, we ask the fundamental question, “How do the relationships between crater landforms change over time on a geologically dynamic planet?” Geologic processes on Earth have largely served to change or altogether remove crater landforms, all but precluding such an assessment. Mars, however, is geologically active planet that has a well-preserved crater population despite the fact that it has been affected by erosion and weathering processes since its earliest epoch. In this study, we have sub-divided the crater population into groups that correspond to the three martian geologic periods (Noachian, Hesperian, Amazonian) and have measured crater dimensions of each age population respectively in an effort to track changes in crater morphometry over time. We expect the data to support the postulate that morphologic features will display systematic changes over time, with central peak height (h_{cp}) decreasing and central peak diameter (D_{cp}) increasing relative to rim-to-rim crater diameter (D).

Methods: A sample population of craters from all major geologic units and spanning all of Mars has been evaluated. The population was constrained to complex craters, specifically those with a single central peak, and a circular rim. Only craters situated on relatively flat topography were selected to eliminate examples where original crater morphometry is variable as a result of target properties rather than post-impact modification. Noticeably elongated crater forms were also excluded from use due to the variability in crater morphometry that may occur in highly oblique impacts [5]. This study examined complex craters ranging between 10-20km in diameter because this diameter range comprises half of the total complex crater population and is outside the transition zones of complex craters to simple craters or to peak ring structures [6]. This process resulted in 865 complex craters selected for examination. Eight topographic profiles were extracted for each impact crater from a 128 pixel/degree spatial resolution Mars Orbiter Laser Altimeter (MOLA) digital elevation model. Profiles were used to measure rim diameter (D_r), central peak diameter (D_{cp}) and central peak height (h_{cp}). Crater rims and central peak boundaries were identified by observing elevation changes in MOLA data and confirming the presence of bedrock in each using THEMIS nighttime TIR data. Rims were defined as the highest elevation immediately beyond the crater floor (excluding collapsed terrace blocks), whereas central peak boundaries corresponded to noticeable slope changes between the high point in the central peak and the crater floor. These boundaries also corresponded to the transition from relatively high thermal inertia material (i.e. “bedrock”) to lower thermal inertia material (interpreted as crater fill).

Each crater was assigned one of three “crater populations” corresponding to Noachian-, Hesperian-, and Amazonian-aged chronostratigraphic units [7]. Thus the “Noachian crater population” represents impact craters that formed since and including the Noachian epoch. Therefore each crater population is cumulative to that particular geologic period. Summary statistics have been generated for each crater which include the mean and standard deviation for the above mentioned parameters as well as maximum and minimum values for central peak height.

Results: The results presented herein are preliminary and include analysis of 102 Noachian, 46 Hesperian and 29 Amazonian terrain craters. Crater diameter has been related to central peak diameter and height with results presented in Figures 1 and 2. For all three populations, central peak diameters increase with increasing crater diameter. Central peak diameters of craters within Amazonian and Noachian terrains are 0.26D and 0.21D respectively. Hesperian terrain craters display larger central peaks, with respect to both both height and diameter, when compared to Amazonian and Noachian terrains, with a much larger deviation in diameter than height.

Discussion: Preliminary results for D and D_{cp} of impact craters on Noachian and Amazonian terrains follow the relationship$D_{cp}=0.23(\pm0.03)D$ established by [6]. The Hesperian crater population, however follows the relationship $D_{cp}=0.39D$. Similarly, central peak heights are relatively consistent between Noachian and Amazonian terrains, $h_{cp}=1*10^{-6}D^{1.93}$, $h_{cp}=2*10^{-5}D^{1.63}$ yet vary significantly with Hesperian terrains, $h_{cp}=3*10^{-5}D^{1.65}$.

Based on the data evaluated thus far there has not been a systematic change to impact crater morphometry with respect to geologic epoch. It is possible that geologic activity hasn't affected morphology in a way that can be detected using crater morphometrics. A more likely scenario is that these preliminary results are limited by too small crater populations. The yet to be examined portion of this crater population will no doubt change the derived morphometric relationships presented here and may support our expectations of a systematic morphometric relationship changes over time.

In conclusion, we have effectively measured roughly 50% of our target crater population and through the completion of the remaining data will provide a comprehensive morphologic dataset of complex craters within a 10-20 kilometer diameter range.

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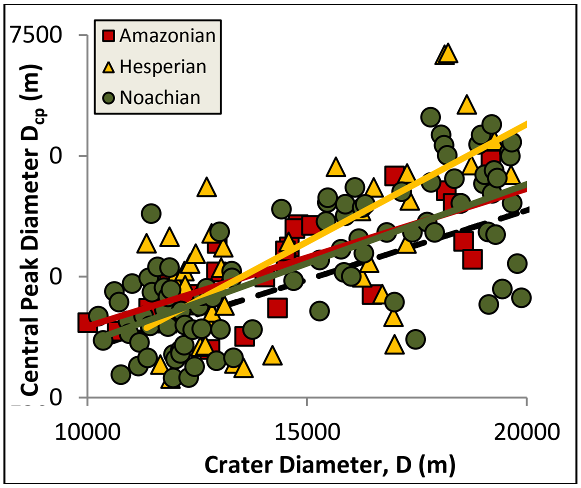

Figure 1: Relationship between crater diameter and central peak diameter Ages represent the age of the terrain for which a measured crater resides not necessarily the age of the individual crater. Best fit line approximations are presented in the appropriate color to represent correspondent age terrains. Black dashed lines represents the average morphometric relationship of $D_{cp}=0.23(\pm0.03)D$ determined for multiple other solar system bodies[6].

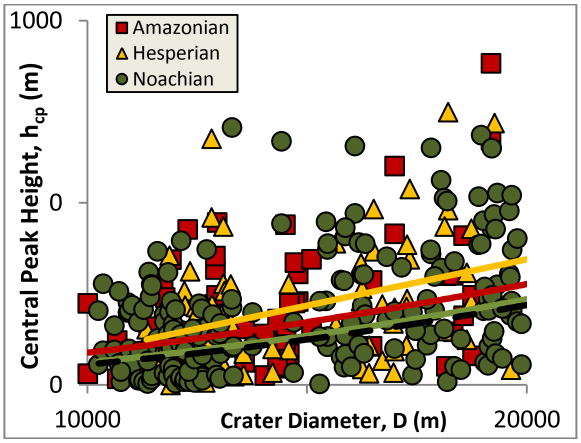

Figure 2 Relationship between crater diameter and central peak height. Ages represent the age of the terrain for which the measured crater resides and best fit lines are color coded respectively. Black dashed lines represents the average relationship $h_{cp}=0.0006D^{1.97}$ determined from multiple other solar system bodies [8].