**A GLOBAL ANALYSIS OF IMPACT CRATERS ON CERES AND THEIR IMPLICATIONS FOR CRUSTAL STRENGTH.** M. F. Zeilnhofer and N. G. Barlow, Dept. Physics and Astronomy, Northern Arizona University, Flagstaff, AZ 86011-6010 mfz3@nau.edu, Nadine.Barlow@nau.edu

**Introduction:** Pre-Dawn predictions suggested the surface of Ceres would display a minimal number of impact craters due to viscous relaxation based on Ceres' low-density (2162 kg/m$^3$) and its current location in the asteroid belt (2.77 AU) [1]. Contrary to the pre-Dawn proposal, the Framing Camera (FC) onboard the NASA Dawn spacecraft (resolution of 400m/pixel) attained images of a heavily cratered Cerean surface [2-3]. These data suggest a stronger crust than the overall density of Ceres would imply. To further understand these differences, the focus of this investigation will be to determine if there are any regional variations in crustal strength across Ceres which will provide insight into the Dawn observations.

Crater morphologies and morphometries can provide insight into the crustal strength of Ceres because they are influenced by excavation into different target types (rock versus ice). Crater morphologies influenced by crustal strength include central peaks (Pk), central pits (SY for floor pits and SP for summit pits) and lobate flow features while crater morphometries, such as polygonal impact craters (PICs), provide details about structure systems on the surface and in the subsurface which influence the overall shape of the crater [4]. Studies of central peaks and central pits show the peak-to-crater diameter ratio ($D_{pk}/D_c$) increases with a decrease in target strength while the pit-to-crater diameter ($D_p/D_c$) ratio decreases with an increase in gravity and a decrease in volatile content [5]. Studies of the different types lobate flow features (type 1-3) on Ceres suggest impacts into icy material [6] therefore, an increased presence of these features on Ceres would indicate craters are excavating into a weaker target because these features are largely a result of collapse. Lastly, the formation of PICs are a result of impacts into a preexisting weakened target [4] and with a large frequency of PICs seen across the surface of Ceres [7-8] this suggests a presence of structure systems within the surface and subsurface which have weakened the crust over time [4]. The analysis of these crater morphologies and morphometries will provide details on crustal strength difference across Ceres.

**Methodology:** We have created a near-global crater database for Ceres containing 44,594 craters ≥ 1.0 km in diameter [9]. The crater morphologies and PICs were analyzed using the Low Altitude Mapping Orbit (LAMO) data which has a resolution of 35 m/pixel [10]. The PIC, Pk, SY, SP and lobate flow length measurements were measured within the Java Mission-planning and Analysis for Remote Sensing (JMARS) [8] and the PIC angle measurements were measured using ImageJ, an image processing tool.

Craters displaying lobate flow features were recorded in a sperate database for further analysis. There were two additional classes analyzed due to their presence on Ceres: craters which display both type 2 and type 3 lobate flow features and features which were similar to type 2 lobate flows (generic floor deposits) but could not fully be distinguished as type 2 most likely due to resolution.

PICs were also placed into a separate database for a more thorough analysis. The PIC database contains 1,466 craters with four categories: PICs with no relation to visible structures, PICs related to visible structure systems located outside of the crater, PICs with structures located inside of the crater and PICs with structures located inside and outside of the crater [11]. We used a maximum bound of 10 crater radii from the crater's center to identify if a PIC is related to a structure seen on the surface. The PIC database also includes the number of linear rim segments (4-12), the angle between the linear rim segments and the mean angle for the crater, the length of the linear rim segments and the mean length for the crater and the angle of the linear rim segment with relation to the previously mapped structure systems on Ceres [12].

Global and regional crater ages were obtained using the Asteroid Derived Model (ADM) and the Lunar Derived Model (LDM) [2,13]. Ages were obtained for the interior morphologies and PICs to further understand the regional variations observed across the surface as well as any latitudinal differences.

**Observations:** Central peaks are the most abundant crater morphology found within impact craters across the surface of Ceres and the analysis of the median $D_{pk}/D_c$ ratio shows an increase with increasing latitude [Figure 1] at similar onset diameters within each region. Central floor pits have a low frequency across the surface of Ceres and are present in craters at latitudes between 10.55°-74.05°N, while the summit pits are evenly distributed between the two hemispheres. Analysis of the median $D_p/D_c$ for central floor pits also becomes larger near the north pole.

The distribution of the five classifications of lobate flow features show variations with latitude. The type 1 lobate flow features are present in the upper mid-latitudes and the polar regions. The type 2 lobate flow features are present in the mid-latitude regions whereas the generic floor deposits are concentrated in the mid-latitude regions in the southern hemisphere.

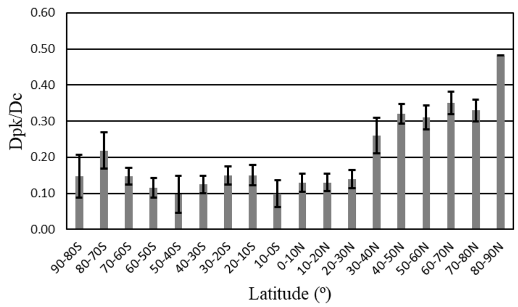


Figure 1: The median $D_{pk}/D_c$ reported for each latitude central peaks were identified in. Standard error bars were calculated.

The type 3-lobate flow features are concentrated in the mid-latitude regions in the southern hemisphere while the combination type 2 and type 3 lobate flows are found in the higher northern latitudes. Type 2 lobate flow features are the most common type found within impact craters across Ceres and the analysis of their drop height-to-runout length ratio are larger in the southern hemisphere than in the northern hemisphere.

The analysis of PICs shows a higher frequency located in the northern hemisphere with PICs not related to the visible structures being the most frequent class compared to the other three classes identified in the study. The PICs not related to visible structures and PICs related to previously mapped structure systems outside of the crater are also found in higher frequencies in the northern hemisphere.

**Ages:** Crater size-frequency distribution plots (SFDs) were derived for craters ≥4.0 km in dimeter producing ages of 1.5±0.02 Ga, using the LDM [Figure 2] and 420±6 Ma, using the ADM. Analysis of the crater ages with latitude show differences between the northern (1200±40-2600±100 Ma (LDM) and 280±10-670±40 Ma (ADM)) and southern hemispheres (700±30-1300±90 Ma (LDM) 160±8-320±20 Ma (ADM)) with the younger ages associated with latitudes at the equatorial region and older ages associated with latitudes near or at the polar regions.

The SFDs derived for the central peaks show older ages for the northern hemisphere (1100±80 Ma (LDM) and 770±70 Ma (ADM)) than for the southern hemisphere (690±70 Ma (LDM) and 490±50 Ma (ADM)). The PICs not related to visible structure systems also show older ages in the northern hemisphere than compared to the southern hemisphere with the oldest ages appearing between 60-90°N.

Analysis of the larger impact craters in the southern hemisphere, Urvara (D = 170.0 km) and Yalode (D = 260.0 km), reveal relatively young ages (Urvara: 19±0.8-170.0±100 Ma (LDM) and 9.8±0.4-42±20 Ma (ADM). Yalode: 46±0.9-200±60 Ma (LDM) and 21±0.4-53±20 Ma (ADM)). The crater diameter range used to derive these ages are between 250.0 m to 7.0

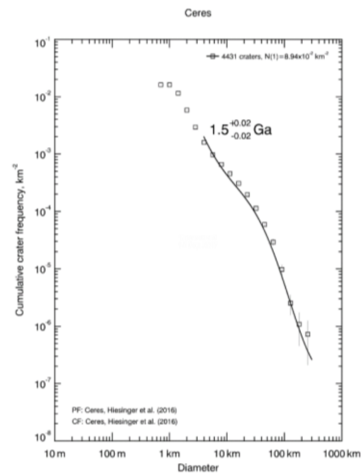


Figure 2: The SFD for craters ≥ 4.0 km in diameter using the LDM for Ceres.

km for Urvara and 350. M to 5.0 km for Yalode.

**Implications:** The observations of the central peak, central pit, lobate flow features and PIC data suggest the northern hemisphere is weaker than the southern hemisphere. These observations suggest a more fractured crust and/or higher volatile content in the northern hemisphere which is consistent with the PIC data which also suggests a weaker target in the north. These data are also consistent with findings from the Gamma Ray and Neutron Detector (GRaND) onboard the Dawn spacecraft which show a higher hydrogen content north of 60º [14]. The age data also implies the northern hemisphere is older than the southern hemisphere which may be a result of the resurfacing of the southern hemisphere by ejecta from Urvara and Yalode. These results suggest a mixed composition of the Cerean crust which are consistent with the previous studies using the Dawn spacecraft data.

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