## PRELIMINARY REGIONAL ANALYSIS OF CENTRAL PEAKS ON CERES USING THE NEARGLOBAL CRATER DATABASE AND IMPLICATIONS FOR CRUSTAL STRENGTH. M. F. Zeilnhofer mfz3@nau.edu

Introduction: Dwarf planet Ceres is located at $\sim 2.77$ AU and has a density of $2162 \mathrm{~kg} / \mathrm{m}^{3}$ [1]. Based on Ceres' low-density and its location in the asteroid belt, pre-Dawn predictions suggested the surface of Ceres would display a minimal number of impact craters due to viscous relaxation which would erase these craters over time [2]. The Framing Camera (FC) onboard the NASA Dawn spacecraft (resolution of $400 \mathrm{~m} /$ pixel) attained images of a heavily cratered Cerean surface which posed an interesting question as to the composition of the Cerean crust [1,3]. The Dawn observations suggest a stronger crust than the overall density of Ceres would implies. The presence of clathrates in the crust have also been proposed which may help explain these observations [4-5]. The focus of this investigation will be to determine if there are any regional variations in crustal strength across Ceres by investigating the central peaks within impact craters.

Central peaks ( Pk ) can provide insight into the crustal strength of Ceres because they are influenced by excavation into different target types (rock versus ice). Central peaks on volatile-rich bodies tend to have larger basal diameter with respect to the parent crater diameter than central peaks found on volatile-poor bodies [7-8]. Furthermore, the peak-to-crater diameter ratio ( $\mathrm{D}_{\mathrm{pk}} / \mathrm{D}_{\mathrm{c}}$ ) increases with a decrease in target strength which has been observed for the icy body Ganymede [7]. Therefore, the regional analysis of central peaks (i.e. latitude and longitude, parent crater diameter, basal diameter and $\mathrm{D}_{\mathrm{pk}} / \mathrm{D}_{\mathrm{c}}$ ) will provide details on crustal strength difference across Ceres.

Methodology: Data for this preliminary study were attained from a near-global crater database for Ceres containing 44,594 craters $\geq 1.0 \mathrm{~km}$ in diameter [9].

This dataset contains several interior morphologies, but for the purpose of this study central peaks were chosen due to their higher abundance found in the dataset [9]. Data were collected using the Java Mission-planning and Analysis for Remote Sensing (JMARS) crater measurement application with the Low Altitude Mapping Orbit (LAMO) global mosaic for Ceres (resolution of $35 \mathrm{~m} /$ pixel) [10]. The longitude, latitude, and crater diameter were obtained using the 3-point crater counting routine in JMARS and exported into an Excel spreadsheet. The average basal diameter was reported in the database after taking three measurements across the central peak [Fig. 1]. The $D_{p k} / D_{c}$ was then reported. The crater depths were measured using the two topography models (mean sphere topography model and oblate sphere topography model) found within JMARS [11].

Previously central peaks were investigated on a global scale [12] and by $10^{\circ}$ latitude zones [13]. For the purpose of this study the central peaks were analyzed in $30^{\circ} \times 30^{\circ}$ blocks (starting at $60-90^{\circ} \mathrm{S}$ and 0 $30^{\circ} \mathrm{E}$ ) to look for variations on more regional scales. Craters which displayed a summit pit (a central pit on top of a central peak) were also included in this study Fig. 2]. The central peak portion of the summit pit were measured in the same manner as the central peaks without a pit.
Initial Observations: Central peaks are the most abundant interior morphology observed within the crater database [9]. 264 of 918 complex craters display a central peak while 4 of 918 complex craters display a summit pit. Central peaks are found globally whereas summit pits are evenly distributed between both the northern and southern hemispheres. Similar to the latitudinal analysis of central peaks [13] there appears


Fig. 1: a) A 26.6 km crater centered at $63.20^{\circ} \mathrm{S} 143.60^{\circ} \mathrm{E}$ containing a central peak. Image obtained from the LAMO global mosaic [6]. b) The corresponding topographic profile shows the measurement of the crater diameter $\left(\mathrm{D}_{\mathrm{c}}\right)$ and the central peak diameter $\left(\mathrm{D}_{\mathrm{pk}}\right)$. These measurements were then used to calculate the $\mathrm{D}_{\mathrm{pk}} / \mathrm{D}_{\mathrm{c}}$.


Fig. 2: a) Toharu crater $(\mathrm{D}=86.0 \mathrm{~km})$ centered at $48.32^{\circ} \mathrm{S} 155.95^{\circ} \mathrm{E}$ containing a summit pit. Image obtained from the LAMO global mosaic [6]. b) The corresponding topographic profile shows the measurement of the crater diameter $\left(\mathrm{D}_{\mathrm{c}}\right)$, the central peak diameter $\left(\mathrm{D}_{\mathrm{pk}}\right)$ and the central pit diameter $\left(\mathrm{D}_{\mathrm{p}}\right)$. The $\mathrm{D}_{\mathrm{pk}}$ and $\mathrm{D}_{\mathrm{c}}$ measurements were then used to calculate the $\mathrm{D}_{\mathrm{pk}} / \mathrm{D}_{\mathrm{c}}$.
to be an increase in the median $\mathrm{D}_{\mathrm{pk}} / \mathrm{D}_{\mathrm{c}}$ with increasing latitude at similar depth-diameters (d/D) ratios. The summit pit data did not influence the median $\mathrm{D}_{\mathrm{pk}} / \mathrm{D}_{\mathrm{c}}$ or the general trends observed within their regions due to their small sample size. The median $\mathrm{D}_{\mathrm{pk}} / \mathrm{D}_{\mathrm{c}}$ results along with the similar $\mathrm{d} / \mathrm{D}$ results are further indicating that central peaks in the northern hemisphere are excavating into a weaker and/or more fractured target than craters displaying central peaks in the southern hemisphere. These results suggest that there are regional variations of a weaker and/or more fractured layer at depths $\geq 1.8 \mathrm{~km}$.

The $60-90^{\circ} \mathrm{N}$ block over a majority of the longitudes investigated have larger median $D_{p k} / D_{c}$ with the exceptions of $90-120^{\circ} \mathrm{E}$ and $270-300^{\circ} \mathrm{E}$ [Fig. 3]. The reason there are deviations in the median $\mathrm{D}_{\mathrm{pk}} / \mathrm{D}_{\mathrm{c}}$ value at $270-300^{\circ} \mathrm{E}$ are due to the larger number of craters displaying central peaks between $30-60^{\circ} \mathrm{N}$ ( 8 craters) than at $60-90^{\circ} \mathrm{N}$ ( 3 craters). The $30-60^{\circ} \mathrm{N}$ $90-120^{\circ} \mathrm{E}$ block has only one crater with a central peak present opposed to the $60-90^{\circ} \mathrm{N} 90-120^{\circ}$ E block where there are two craters displaying central peaks. The difference seen between these two $30^{\circ} \times 30^{\circ}$ blocks may be a result of how these data were separated and


Fig. 3: The median $D_{p k} / D_{c}$ calculated for craters in $30^{\circ} \times 30^{\circ}$ blocks across the surface of Ceres. Standard error bars were calculated.
not a representation of a weaker and/or more fractured target within the area.
Conclusions: The preliminary analysis of the median $\mathrm{D}_{\mathrm{pk}} / \mathrm{D}_{\mathrm{c}}$ on a more regional scale does show larger values in in the northern hemisphere which are consistent with past observations [12-13]. These observations suggest a more fractured crust and/or higher volatile content in the northern hemisphere consistent with findings from the Gamma Ray and Neutron Detector (GRaND) onboard the Dawn spacecraft which show a higher hydrogen content north of $60^{\circ}$ [14]. Further investigation with other interior morphologies, such as central floor pits, lobate flows and wall terraces within these regions are needed to understand these observations as well as determining different $30^{\circ} \times 30^{\circ}$ blocks where there are more central peaks and provide additional regional information. Additionally, the investigation of PICs in $30^{\circ} \times 30^{\circ}$ blocks will help identify regions which are more fractured within the crust and how these fractures may be influencing the results in this preliminary study.

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