PRELIMINARY INVESTIGATION OF CRATERS ON CERES. 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: Ceres is the largest body in the main asteroid belt with a radius ≈ 470 km, a mass of 9.38x10^{20} kg and a surface gravity of 0.27 m/s^2 [1]. NASA's Dawn spacecraft went into orbit around Ceres on March 2015. The Framing Camera (FC) on board Dawn attained images of the Cerean surface with a resolution of approximately 400 m/pixel. Prior to the Dawn mission the surface of Ceres was thought to have a minimal number of craters [2], but Dawn revealed a heavily cratered surface.

We are conducting an investigation of central peak and central pit craters to provide insight into the surface characteristics of Ceres. Previous studies suggest that the pit-to-crater diameter (D_p/D_c) ratio decreases with an increase in gravity and a decrease in volatile content of the crust. Bodies which are volatile rich will show a higher frequency of central pits (floor pits) than bodies which are volatile poor. Mercury and Mars both show craters which have summit pits which appear to be more common as crustal volatile content decreases [3].

This study investigates craters on Ceres with an emphasis on craters which exhibit central pits and central peaks, as well as determining the depth-diameter ratio of these craters. These preliminary results are for the southern hemisphere of Ceres, excluding the south polar region due to poor resolution.

Methodology: Data were attained from NASA's Dawn spacecraft's Framing Camera (FC) with a resolution of about 400 m/pixel. Using the Java Mission-planning and Analysis for Remote Sensing (JMARS) crater measurement application, we have catalogued craters in the Southern Hemisphere (83.22º S – 0º N 0º – 360º E) on Ceres ≥ 1.0-km diameter. These data were collected with the 3-point crater counting method using the global mosaic of Ceres. The longitude, latitude, and crater diameter were obtained with this method and exported into an Excel spreadsheet.

The minor crater diameter, ejecta and interior morphologies (if present) and crater depths were classified for each crater. Ejecta were classified into non-layered (radial) or standard layered (single, double, or multiple) morphologies [4]. Up to two interior morphologies were classified for each crater. Seven different interior morphologies (bright albedo (BA) and dark albedo (DA) features, wall terraces (WT), and floor deposits (FD)) have been recorded, with central peaks (Pk) and central pits (SP for summit pit and SY for floor pit) being the morphologies of interest for a comparison study with these features on other bodies such as Mercury, Mars, and Ganymede.

We determined the crater depth-diameter ratio for both the mean spheroid and oblate spheroid models obtained from JMARS [5,6]. The oblate spheroid model is generated from the digital elevation model (DEM) radii subtracted from an oblate spheroid since Ceres is non-spherical in nature. This model helps preserve the local topographic differences. The mean spheroid model is generated from the DEM radii which are for elevations above or below a sphere with radius 469,430 m.

Preliminary Results: We have catalogued 18,988 craters in the southern hemisphere of Ceres. Few craters display an obvious ejecta structure, likely due to the low image resolution covering the southern hemisphere. Table 1 shows the number of craters which exhibit a specific interior morphology. We classified 88 craters with central peaks and 2 craters with summit pits. The ratio of the peak diameter to crater diameter as a function of crater diameter is shown in Figure 1.

Interior Morphology	Number of craters
BA	34
DA	34
FD	226
Pk	88
SP	2
SY	0
WT	10

Table 1: Interior morphologies classified for craters in the southern hemisphere on Ceres. Floor deposits are the most prominent and floor pits are the least common features.

The smallest crater diameter containing a central peak was 17.6 km located at 66.78º S 133.37ºE. The smallest crater diameter that contained a summit pit was 30.0 km located at -58.19ºS 206.31ºE. Figure 2 shows that the frequency of craters with central peaks covers a range of crater diameters. Central peaks are most prominent in craters with a mean diameter of 27.3 km. Table 2 compares the central peak and crater data collected for Mercury, Mars, Ganymede and Ceres.

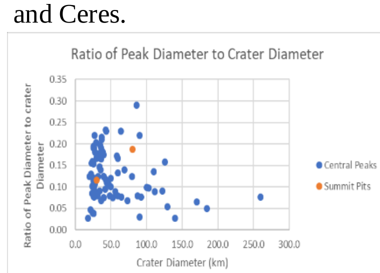

Figure 1: The ratio of peak diameter to crater diameter as a function of crater diameter. No difference is seen for peaks with pits versus non-pitted peaks.

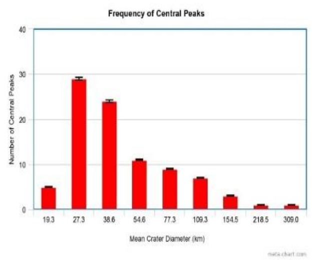

Figure 2: This plot shows the frequency of central peaks in a range of crater diameters. The number of central peak craters increases in the 20-30 km range and decreases as the crater diameter increases. Error bars were calculated using Poisson distribution for error propagation.

The average d/D ratio using the mean sphere model was 0.10 and the oblate sphere model was 0.10. Figure 3 shows the trend for crater depth versus crater diameter in both the models. The freshest (deepest) craters were used in determining the simple-to-complex transition diameter. Fresh complex craters typically have a depth-diameter ratio of about 1/5 [7], which is larger than the average values obtained here. A study shows there is not a definitive simple-to-complex transition diameter for Ceres, but instead has a range of values from 6 km, as a lower bound, to 18-21 km, for an upper bound [8]. Another study suggests this value is ~16 km for an icy Ceres and ~50 km for a rocky Ceres [9]. The simple-to-complex transition diameter based on the central peak data appears to be less than 17 km and based on the depth-diameter data in Fig. 3 the simple-to-complex transition diameter cannot be determined. This places it lower than excepted based on the ~1/g relationship among rocky bodies, but above the ~2 km transition diameter for Ganymede which has an icy crust. Further investigation of craters in the northern hemisphere may give better insight into the crustal properties of this dwarf planet.

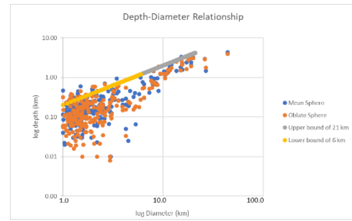

Figure 3: Depth-diameter relationship for both the mean sphere and oblate sphere models. The minimum crater diameter is 1.0 km. The simple-to-complex transition diameter lower bound is 6.0 km and upper bound is 21.0 km. No distinct turnoff is seen.

Conclusion: Our preliminary results find a large number of central peak craters, very few central pit craters, a D_{pk}/D_c close to that of central peak craters on Mercury, and a relatively high simple-to-complex transition diameter. All of these results suggest that the southern hemisphere crust on Ceres has a target strength closer to that of rocky material than ice. This is consistent with the large number of craters observed on Ceres' surface, but contrary to compositional data which suggest significant alteration of surface materials [10] and the proposed removal of large impact basins by viscous relaxation [11]. Extension of this study to craters in the northern hemisphere will expand upon these preliminary results and provide additional insights into the nature of the crust of Ceres

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	Mercury[3]	Mars[3]	Ganymede[3]	Ceres
Number of craters	1764	1682	1080	88
Crater Diameter Range (km)	8.2-251.3	5.0-156.3	7.5-48.6	17.6-260.0
Median Crater Diameter (km)	38.4	10.3	15.2	36.7
Peak Diameter Range (km)	0.8-63.0	0.3-44.5	2.1-23.8	0.5-25.0
Median Peak Diameter Range (km)	5.5	3.4	5.7	5.0
D_{pk}/D_c	0.04-0.60	0.04-0.76	0.11-0.75	0.03-0.29
Median D_{pk}/D_c	0.16	0.32	0.37	0.12

Table 2: Comparison of central peak craters on Mercury, Mars, Ganymede and Ceres. The median D_{pk}/D_C for Ceres us comparable to that of Mercury