EPSC Abstracts
Vol. 10, EPSC2015-466, 2015
European Planetary Science Congress 2015

Dawn Framing Camera: Morphology and morphometry of impact craters on Ceres

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Abstract

In the first approach images of Ceres we tried to discern the simple-to-complex transition diameter of impact craters. Limited by spatial resolution we found the smallest complex crater without central peak development to be around 21.4 km in diameter. Hence, the transition diameter is expected to be between 21.4 km and 10.6 km, the predicted transition diameter for an icy target. It appears likely that either Ceres' surface material contains a rocky component or has a laterally inhomogeneous composition ranging from icy to ice-rocky.

1. Introduction

On March 6, 2015 the Dawn spacecraft was captured by Ceres' gravity field. Several optical navigation (OpNav) and rotation characterization (RC) observations were acquired during approach phase by the Framing Camera (FC) [1, 2]. In this preliminary study we used images of RC2 and OpNav7 campaigns taken on February 19, 2015 and April 15, 2015, respectively. We present morphological observations of impact craters and provide first measurements of crater depth to diameter relationships. Then, first inferences about the simple to complex transition diameter and resulting surface property (i.e., icy vs. rocky) are made.

1.1 Data and methods

RC2 and OpNav7 images have been processed at the Max Planck Institute for Solar System Research and were resampled to resolutions of 2 km/px and 1.5 km/px, respectively. Individual images are analyzed using ESRI's GIS environment. Crater diameters and crater shadow casts were measured using the ArcGIS extension *CraterTools* [3], which helped to avoid distortions related to map projections. Crater depths are calculated following the equation:

$$d = L / \tan \theta \quad (1)$$

where d is the crater depth, L is the shadow length, and θ represents the incidence angle. For each crater, the diameter was measured 10 times while the shadow length and incidence angle were determined at five locations. For individual parameters the 2σ confidence interval is provided; the depth value includes error propagation analysis of L and θ.

2. Crater morphology

The surface of Ceres is peppered by impact craters. The largest two basins observed so far have diameters of about 270 km. The largest basin (D~273 km) is centered at 13.1°S/122.7°E and is filled by smooth-textured deposits. A central depression surrounding the central pit is noted. The basin rim resembles a pentagonal shape with the northwestern portion being partially buried and disrupted.

Complex craters feature a flat floor and often show a central peak or pit. The interior of some complex craters appear filled. Crater rims vary in shape from circular/elliptical to rectangular and penta-/hexagonal or in some cases developed a combination of semi-circular and angular (plane view) outline. A preliminary survey revealed that the smallest complex crater showing a central peak has a diameter of about 24.5 km. Due to the limited resolution craters smaller than about 20 km in diameter are difficult to classify as either simple or complex crater. However, based on shadow shape, the 17.5 km crater shown in Fig. 1 may represent a simple crater.

3. Crater morphometry

We applied the shadow cast method [e.g., 4] to estimate the depth of impact craters. In the initial survey we were interested to discern the transitional diameter from simple to complex craters. Figure 1 shows 16 measurements for craters in the size range 17.5–124.8 km.

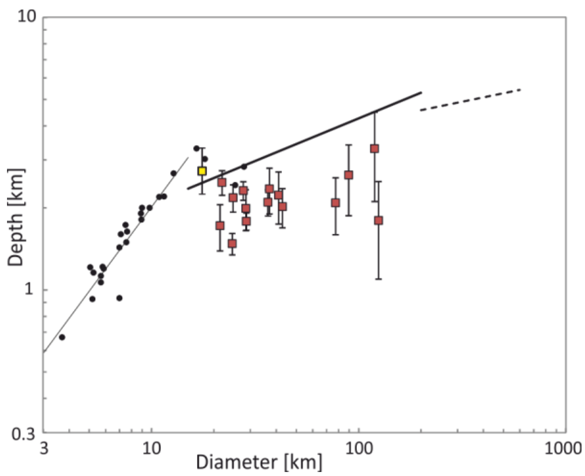

Figure 1: Depth-to-diameter relationship for craters on Ceres (squares). For reference simple and complex lunar craters (black dots) and best-fit lines for simple (thin) and complex (thick) craters, and basins (dashed) are shown [4-6]. Yellow data point may represent a simple crater.

Using the current image data the two smallest flat-floored craters without central peak development are 21.9±0.41 km and 21.4±0.30 km in diameter. In this survey no clear trend within the complex crater population is observed (Fig. 1). The data scatter is likely caused by the craters' different state of degradation resulting in various d/D ratios from 0.01–0.11.

5. Discussion

The determination of the simple to complex transition diameter is particularly important as it provides first estimates of the composition of Ceres' upper crust. The overall density of Ceres is 2077 kgm^{-3} suggesting the presence of 17-27% water by mass [7, 8]. It is commonly thought that Ceres is differentiated into a silicate core and water/ice-rich mantle. However, it is currently unclear whether the water fraction is laterally and vertically homogeneously distributed within the c.100-km-thick mantle and where liquid water (as layer(s) or lens(es)) may occur.

If Ceres's surface is primarily composed of ice, a simple-to-complex transition diameter is predicted at 10.6 km by extrapolation from icy satellites (Fig. 2). The smallest complex crater observed so far is 21.4 km in diameter (Fig. 2) suggesting that the expected transition diameter is somewhere in the range 10.6-21.4 km. Because a number of complex craters without central peak are observed in the size range 21–25 km, it may suggest that the transition diameter is closer to 21 km rather than 10.6 km. If this is the case, then Ceres' surface material cannot be composed of pure water ice and requires a rocky component, or alternatively, lateral inhomogeneity in target rocks (i.e., ice and mingled ice-rock material) is present. At EPSC, we will present an updated survey based on higher resolution data.

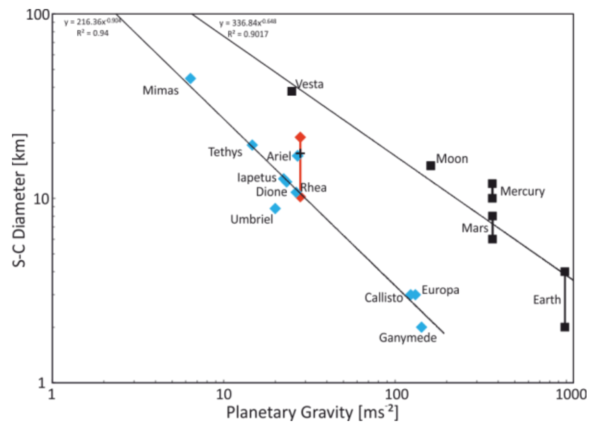

Figure 2: Simple-to-complex transition diameters for various planetary bodies as a function of their surface gravities. Ceres' transition diameter is expected to occur along the red line with the lower point resembling the predicted value and the upper point being the smallest observed complex crater so far. The black cross represents a putative simple crater. Data for planetary bodies taken from e.g. [9–13].

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