EPSC Abstracts
Vol. 10, EPSC2015-400, 2015
European Planetary Science Congress 2015

Impact Craters on Ceres: Evidence for Water-Ice Mantle?

P. Schenk (1), S. Marchi (2), D. O'Brien (3), K. Otto (4), R. Jaumann (4), D. Williams (5), C. Raymond (6), and C.T. Russell (7) and the Dawn Science Team. (1) Lunar and Planetary Institute, Houston, TX, USA, (2) Southwest Res. Institute, Boulder CO, (3) Planet. Sci. Inst., Tuscon, AZ, (4) DLR, Berlin, Germany, (5) Ariz. State Univ., Tempe, AZ, (6) Jet Propulsion Lab, Pasadena, CA, (7) Univ. Calif. Los Angeles, CA (schenk@lpi.usra.edu)

Abstract

Impact craters on Ceres as revealed by the Dawn spacecraft are to first order similar in shape and morphology to those observed on Saturn's midsize icy satellites, consistent with a bulk icy composition for Ceres' outer layers. Rayed craters have been identified and cataloged. Large impact basins have a range of morphologies, some of which are indicative of post-impact modification. Subtle differences in morphology might be related to non-ice material within the crust, pending improved resolution. Additional details are expected to reveal the nature of Ceres interior as higher-resolution imaging and topography become available.

1. Introduction

Dawn's first reconnaissance of the dwarf planet 1 Ceres is now underway. This major body is likely to be ice-rich [e.g., 1,2], given its low density, and may have an icy mantle 50-100 km thick [1,2]. Dawn will investigate the internal composition and mass distribution within Ceres.

Impact crater morphologies are very sensitive to both surface gravity and to composition, as demonstrated by the major differences in morphology on icy and rocky bodies [e.g., 3]. Both rocky Vesta and the ice-rich satellites of Saturn (e.g., Dione and Tethys) have surface gravity very similar to Ceres, facilitating direct comparison of impact craters. If Ceres' outer layers are dominated by ice, then impact craters should resemble those of Saturn's moon rather than Vesta. Here we present initial findings based on initial Dawn mapping of Ceres as a test of whether Ceres has an ice mantle.

1.1 Crater Morphologies on Ceres

Approach and first orbital mapping reveals that Ceres is heavily cratered, exhibiting a wide range of preservations states and morphologies. Bright and dark ray craters up to ~100 km across are evident, which can be used to estimate the current flux of impactors. Whether the bright material is ice-rich has not yet been determined.

A test of ice composition is complex crater formation. Complex craters, in the form of central peaks, dominate on Ceres down to crater diameters of <25 km (Fig. 1). This transition is much lower than the >60 km diameter observed on Vesta [4], but almost as small as on Dione and Tethys (pending higher resolution imaging). To first order, this favors an ice-rich composition for the outer 10's of kilometers of Ceres interior. The degree to which non-ice material can mix into the mantle and still result in similar morphologies is not yet known.

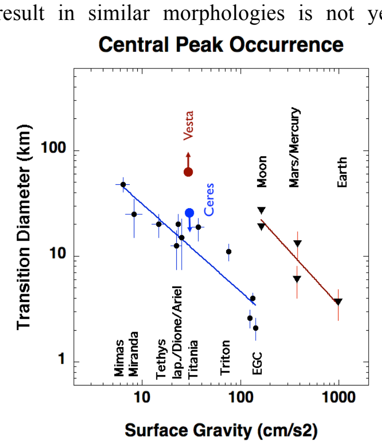

Figure 1: Preliminary simple-complex transition diameter estimate for Ceres. Icy satellite data are from White and Schenk, pers. comm).

At least 3 basins >200 km in diameter have been identified from 4-km/pxl approach imaging. The interior morphology of these structures is not yet clear but there do appear to be subtle differences between these basins and their icy satellite counterparts. A sufficiently large impact into a thinner ice shell will also excavate into the rocky core, potentially producing anomalous landforms [5]. This hypothesis can be tested with resolved imaging and topography.

The largest of these basins, ~275 km across, has a low rim scarp and shallow but uneven topography, Several large floor mounds also occur near the rim. These are several km high and of uncertain origin. Another basin ~150-km across also exhibits similar morphology, suggesting that modification processes on Ceres have characteristics distinct from icy bodies.

Another large (~250-km-wide) basin near the South Pole exhibits a set of arcuate linear troughs extending north from the rim. While the curvature of the lineations is consistent with lateral ejecta and secondary deposition on a rotating body, their origin remains uncertain pending resolved imaging. Impact ejecta, melt distribution, boulder formation, rim angularity and ice excavation are all key features awaiting low-altitude mapping. Ejecta deposits, melt features and secondaries have all been mapped on Saturn's icy moons [6], and are expected on Ceres.

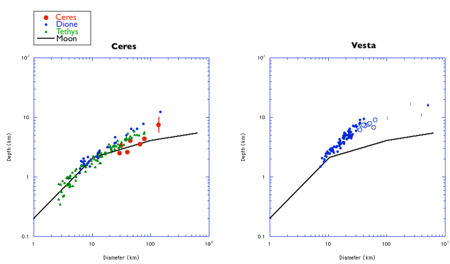

Figure 2: Preliminary crater depth measurements (left) on Ceres, from Dawn approach imaging (blue and green points are crater depths for Dione and Tethys). Fresh crater depths are shallower than on Vesta (right), as expected.

A key prediction for Ceres is that the high surface temperatures will result in flattening of impact crater topography due to 'relaxation' of topography [7,8]. Initial measurements of the most pristine craters suggest depths comparable to unmodified craters on Dione and Tethys (Fig. 2), suggesting that at least some crater have not relaxed. These craters are important for determining the magnitude of relaxation elsewhere on Ceres.

2. Summary and Conclusions

Approach and high-altitude Dawn mapping imaging of Ceres show crater morphologies that initially resemble those of the ice-rich satellites of Saturn, all of which have surface gravity similar to Ceres. Depths and transition diameters are thus far consistent with significant water ice in the outer layers of Ceres. Complicating factors include lower impact velocities on Ceres (~5 km/s), the possibility of extensive mixing of non-ice material within an outer icy layer, and layering within the outer shell. Large impact into a thin ice shell over a silicate core could also produce impact morphologies distinct from icy satellites. Detailed imaging expected later in the mapping phase of the Dawn mission should reveal key features that may provide evidence of these effects.

Acknowledgements

We thank NASA and the Dawn project for supporting this work.

References

[1] McCord, T., J. Castillo-Rogez, A. Rivkin: Ceres: Its origin, evolution and structure and Dawns potential contribution, Space Sci. Rev. 163, 63-76, 2011.

[2] Castillo- Rogez, J.: Ceres: Neither a porous nor salty ball, Icarus, 215, 599-602, 2011.

[3] Schenk, P., Schenk, P., Chapman, C., Zahnle, K., Moore, J., Ages and Interiors, The cratering record of the Galilean Satellites, in *Jupiter*, (F. Bagenal, T. Dowling and W. McKinnon, eds.), Cambridge Press, pp. 427-456, 2004.

[4] Schenk, P., and 10 others: Impact crater morphologies on Vesta in Solar System Context, Lunar Planet. Sci. Conf. 44, abstr. 2039, 2013.

[5] Bowling, T., B. Johnson, D. Blair, and J. Melosh: Large impact basins on Ceres: Probing beneath the icy mantle, AGU Fall Meeting, abstr. P51E-03, 2014.

[6] Hoogenboom, Schenk, P., and Johnson, K.: Contribution of secondary craters on the icy satellites: Results from Ganymede and Rhea, Lunar Planet. Sci. Conf. 46, abstr. 2530, 2015.

[7] Bland, M.: Predicted crater morphologies on Ceres: Probing internal structure and evolution, Icarus, 226, 510-521, 2013.