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Origins of Central Pits and Domes on Ceres: Dawn Mapping Constraints and Ganymede Comparisons

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Abstract

The bright faculae and central pit/dome of Occator crater Ceres reveal complex geologic processes on that world and confirm that it is volatile rich. Comparison with domes on Ganymede and terrestrial complex craters but most importantly the observed geologic relations indicate that formation likely involves (hydrothermal?) extrusion of bright material onto the pit floor after its formation during impact, followed by subsequent uplift of the dome, fracturing the carbonate deposits.

1. Introduction

Discovery of a central pit and dome associated with the bright facula at Occator crater on Ceres were unexpected, based on comparison with Saturnian icy moons. These bodies have similar surface gravity and it was thought that if Ceres had an ice-rich crust its craters would resemble those on Saturnian moons. Here we explore the nature of central structures of craters on Ceres and what impact models and comparisons with other bodies tell us.

2. Occator Central Complex

Occator is a very well preserved 93 by 89 km across and ~3.75 km deep [1]. The central structure consists of a circular rounded dome ~2 km wide and ~750 m high (Fig. 1) in the center of a shallow depression ~9 km across and ~1 km deep (Figs. 9, 10). The depression is flanked by high-standing irregularly shaped ridges or massifs that form a partial elevated ring around the depression. This morphology strongly resembles many of the central pit/dome complexes associated with large craters on Ganymede and Callisto [e.g., 2].

The central dome is deeply fractured although the central pit walls are not, suggesting that uplift of the dome surface was responsible and did not involve pit deformation. The fracturing of the bright faculae material also suggests that fracturing may have occurred after bright material emplacement.

Numerical 2-D modeling of impact craters are usually hampered by ambiguities along the central axis of the crater model: i.e., the central structure. Therefore they are of limited use in understanding Occator. Field studies of large terrestrial craters and mapping of central pit and dome craters on Ganymede and Callisto are examined in concert with the Dawn mapping results in an effort to move pit and dome formation forward.

Central structures of terrestrial complex craters are noted for their uplift of deep-seated strata [e.g., 3]. Galileo mapping of central domes and pits was very limited and included no well-resolved examples smaller than ~100 km. Those few domes imaged (Doh [Fig. 2], Neith and Melkart especially) are all deeply fractured [e.g., 2] in a manner reminiscent of Occator. What is lacking on Ganymede is evidence of a residual bright deposit in the manner of Occator. Bright materials are seen in fresh dome craters such as Osiris but these cover the entire crater floor or are more patchy is irregularly distributed, suggesting impact-derived surface frost deposits that erode differentially.

The bright deposit at Occator is partially controlled by local elevation and confined topographically. The ribbon-like nature of the fringes of the Occator deposit (Fig. 1) are consistent with hydrothermal-style outflow from discrete sources leading to carbonate-rich surface deposits [4] that accumulated in the pit floor. These are consistent with numerical models that show the deepest and longest lasting residual impact heat within the inner core for the crater almost exactly coincident with the location of the central pit.

3. Figures

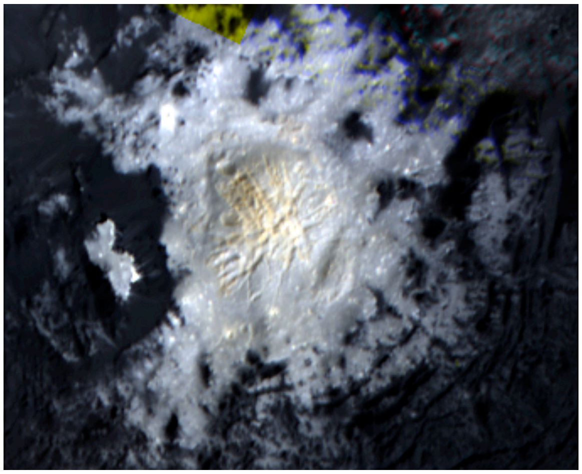

Figure 1: Best color resolution of Occator central structure. Resolution ~35 m/pxl.

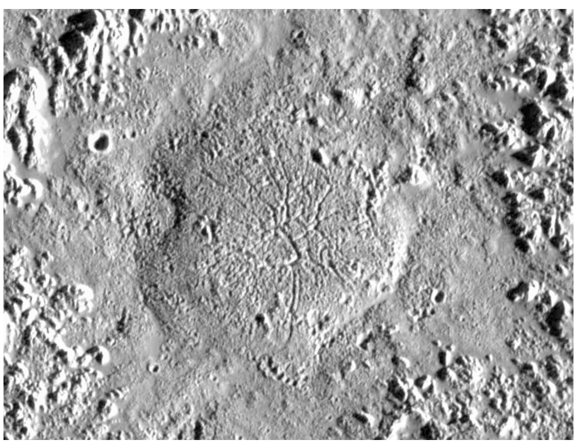

Figure 2: Best Galileo view of fractured central dome: Doh, Callisto. Dome ~25 km across. Res. ~95 m/pxl.

4. Summary and Conclusions

The discovery of complex central structures on Ceres and mapping at high spectral and spatial resolution offers an unexpected opportunity to further constrain these unusual structures. Central pits and domes are confined to ice-rich bodies only. While some central pits are found on Mars, they appear to be distinct and do not possess central domes. While hydrothermal deposition is considered likely in some locations on Mars, we do not observe Occator analogs (perhaps due to the degraded nature of the surface of Mars).

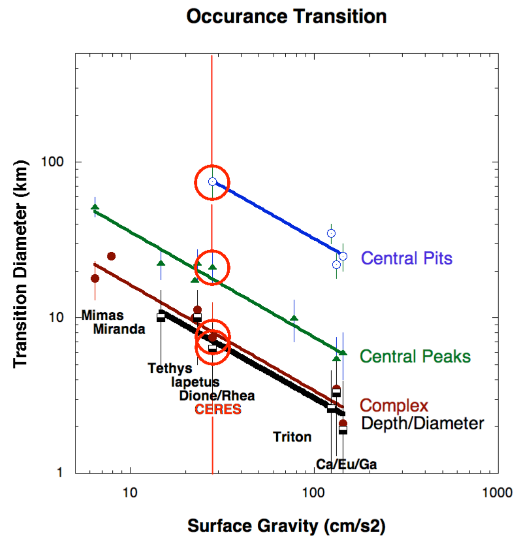

Figure 3: Transition diameters of complex craters on ice-rich bodies. Note lack of transitions to central pits for any of the Saturnian moons, despite nearly identical values for other transitions to Ceres.

The occurrence of central pits on Ceres scales inversely with those on Ganymede, as do other transition diameters such as d/D inflection, central peak formation etc. (Fig. 3), indicative of an outer shell whose rheologic response to impact is controlled by water ice. The lack of such craters in the Saturn system is thus the anomaly and may be related to either the very low temperatures in that system, lower ratios of non-ice materials, or higher impact velocities.

References

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