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Floor-Fractured Craters on Ceres

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Abstract

Several of the impact craters on Ceres have sets of fractures on their floors. These fractures appear similar to those found within a class of lunar craters referred to as “Floor-Fractured Craters” (FFCs). We have cataloged the Ceres FFCs according to the classification scheme designed for the Moon. An analysis of the d/D ratio for Ceres craters shows that, like lunar FFCs, the Ceres FFCs are anomalously shallow. Large (>50 km) Ceres FFCs are most consistent with Class 1 lunar FFCs, while smaller craters on Ceres are more consistent with Type 4 lunar FFCs. This suggests that Ceres FFCs may similarly be due the intrusion of a low-density material below the craters. While on the Moon (and Mars) the intrusive material is hypothesized to be silicate magma, cryomagmatic intrusions are more likely responsible for the formation of the Ceres FFCs. However, new models suggest that at least some of the FFC fractures may have formed due to the solid state flow of a low-viscosity, low-density material into the crater wall.

1. Introduction

Several of the impact craters on Ceres have patterns of fractures on their floors. These fractures are morphologically similar to those found within a class of lunar craters referred to as Floor-Fractured Craters (FFCs). We present a geomorphic and topographic analysis of the cerean FFCs and propose hypotheses for their formation.

1.1 Data

Geologic analysis was performed using Dawn spacecraft [1] Framing Camera (FC) [2] mosaics from late Approach (1.3 km/px), Survey (415 m/px), the High Altitude Mapping Orbit (HAMO - 140 m/px) and the Low Altitude Mapping Orbit (LAMO – 35 m/px) orbits, including clear filter and color images and digital terrain models derived from stereo images.

2. Lunar floor-fractured craters

Lunar FFCs are characterized by anomalously shallow floors cut by radial, concentric, and/or polygonal fractures [3]. These FCCs have been classified into crater classes 1 through 6, based on their morphometric properties [eg. 3, 4, 5]. The depth vs. diameter (d/D) relationship of the FFCs is distinctly shallower than the same association for other lunar craters [eg. 4, 5]. Models for FFC formation have explained their shallow floors by either floor uplift due to magmatic intrusion below the crater [eg. 3, 4, 5] or floor shallowing due to viscous relaxation [e.g. 6]. However, only magmatic uplift models can explain the degree of floor uplift and the asymmetric nature of the uplift present in several of the FFC morphometric classes [5, 7].

3. Cerean floor-fractured craters

We have cataloged the cerean FFCs according to the classification scheme designed for the Moon. Dantu and Occator craters are the type examples for a Class 1 Ceres FFC, having both radial and concentric fractures at the crater center, and concentric fractures near the crater wall. In the magmatic model presented by [5] these craters represent fully mature magmatic intrusions, with initial doming of the crater center due to laccolith formation resulting in the crater center fractures, while continuing outward uplift of the remaining crater floor results in concentric fracturing adjacent to the crater wall. Other large (>50 km) cerean FFCs which have only linear or radial fractures at the center of the crater (e.g. Azacca, Ezinu and Gaue) are also classified as Class 1 FFCs, but likely represent a less mature magmatic intrusion, with doming of the crater floor but no tabular uplift.

Smaller craters on Ceres are more consistent with Type 4 lunar FFCs, having less-pronounced floor fractures and v-shaped moats separating the wall scarp from the crater interior. Lunar Class 4 FFCs all have the v-shaped moat, but have three sub-classes defined by the interior morphology [5]. Lociyo crater is an example of a Class 4b FFC, having a distinct ridge on the interior side of its v-shaped moat and subtle fracturing. Meanwhile, Ikapati crater is a potential Class 4a FFC, with both radial and concentric fractures, and a possible moat. Other small cerean craters more closely resemble Class 4c FFCs, with a moat and a hummocky interior, but no obvious fracturing.

An analysis of the d/D ratio shows that, like lunar FFCs, the cerean FFCs are anomalously shallow. We also observe the d/D trend for the Class 1 FFCs is shallower than that for the Class 4 FFCs. This is consistent with the magmatic intrusion models, which suggest that the increased fracturing of Class 1 FFCs is due to increased uplift.

4. Summary and Conclusions

It has been suggested that the cerean FFCs may be a product of the intrusion of a cryomagmatic material below the craters uplifting their floors [9]. A cryovolcanic extrusive edifice has been identified on Ceres [10], and so the hypothesis of cryomagmatic intrusions is credible. Other features, mapped as large domes [9], have been proposed to be possible degraded cryovolcanic edifices [9, 10].

However, there is a second hypothesis for the formation of the large domes. Preliminary models show that an impact into the edge of a layer of low viscosity/low density (LV-LD) material within the heterogeneous crust of Ceres can result in surface deformation due to solid-state flow of the layer [11]. In the models, this surface deformation is expressed as doming into the crater wall [11], but the location of this modeled doming is also consistent with the location of some of the fracturing that we observe in some FFCs, such as Dantu and Occator. This opens the possibility that some of the FFC fractures may have formed due to solid-state flow instead of cryovolcanism.

None of the impact craters that host large domes have fractured floors, although in some locations there are large domes near FFCs (Fig. 4). This anti-correlation suggests that there may be a difference in crustal properties between the locations where the FFCs and the volcanic features form. It is possible that the large domes form where solid state flow has occurred, while the FFCs form where there was cryovolcanism. However, it is also possible that differences in a putative subsurface LV-LD layer could account for changes in the observed surface deformation. Further modeling will need to be performed to determine which process is more consistent with the observed features and what we know of the Ceres surface and interior.

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