LINEAR STRUCTURES ON CERES: MORPHOLOGY, ORIENTATION AND POSSIBLE FORMATION MECHANISMS

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Introduction: NASA's Dawn spacecraft [1] was captured into orbit by the dwarf planet (1) Ceres on March 6, 2015. During the Approach phase capture was preceded and followed by a series of optical navigation and rotation characterization observations by Dawn's Framing Camera (FC) [2], which provided the first images of Ceres' surface. Linear structures on Ceres include grooves, pit crater chains, fractures and troughs. Global geologic mapping of these features establish that they are found all across the Ceres surface [3]. However, differences in orientation and morphology suggests multiple formation mechanisms.

Data: At the time of this writing geologic analysis was performed on Framing Camera (FC) mosaics from late Approach (1.3 km/px), Survey (415 m/px), and the High Altitude Mapping Orbit (HAMO - 140 m/px) orbits, including clear filter and color images and digital terrain models derived from stereo images. Images from the Low Altitude Mapping Orbit (35 m/px) will be used to refine the preliminary analyses.

Regional Linear Structures: A set of regional linear structures (RLS) cross much of the eastern hemisphere of Ceres. Many of the longer RLS are comprised of smaller structures that have linked together, suggestive of en echelon fractures (Fig. 1). Polygonal craters, theorized to form when pervasive subsurface fracturing affects crater formation, are widespread on Ceres [4], and those proximal to the RLS have straight crater rims aligned with the grooves and troughs [5]. This alignment suggests that the RLS are in fact fracture systems, not ejecta scour or secondary craters.

The majority of the RLS are pit crater chains (Fig. 1), a type of linear structure theorized to form when regolith drains into a underlying fault or fracture [6]. This process forms linear assemblages of small depressions, that can merge together to form merged pits and eventually grooves as the feature matures [6]. This maturation of pit crater chains is a probable cause for the occasional groove amd merged pits found among the RLS (Fig. 1). One trough is also identified as belonging to this group of structures.

Although the formation of linear structures on other asteroids have generally been tied to impact events [7], the RLS do not have any obvious relationship to impact craters and may thus represent internally driven tectonics on Ceres [5]. New analyses utilizing LAMO data will help to determine if this is possible.

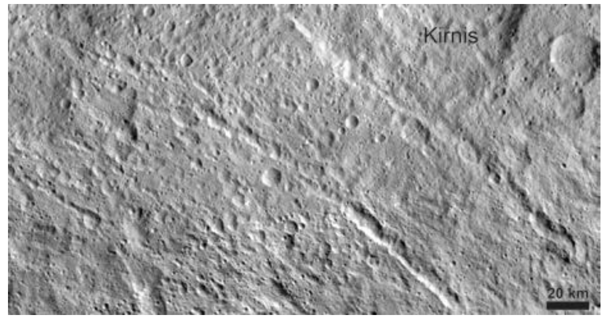

Figure 1. HAMO (140 m/pixel) FC clear filter image of regional linear structures (north is up). Note how the pits do not have rims, suggesting that these are pit crater chains (PCC), not impact crater chains. Upper PCC cuts the south-western rim of Kirnis crater. Lower PPC shows how features evolve from being individual pits into a linear structure of merged pits. Lower structure is comprised of three smaller en echelon structrues that have joined by S-shaped junctions, suggestive of sub-surface fracturing.

Radial Linear Structures: Some of the Ceres structures appear to be radial to the large basins Urvara and Yalode, and most likely formed due to impact processes. Similar radial structures can be found around other Ceres craters [3]. Some of these linear features appear to be secondary craters chains, as they are composed of a series of small impact craters with rims. However, other radial structures have the morphology of fractures or pit crater chains (no crater rims). Interestingly, many of the linear features radial to Urvara and Yalode crosscut the RLS, allowing timing relationships to be determined [3].

Floor-fractured craters: Several of the impact craters on Ceres, including Occator (Fig. 2 top) and Azacca (Fig. 2 middle), have patterns of fractures on their floors. These fractures appear similar to those found within a class of lunar craters referred to as Floor-Fractured Craters (Fig. 2 bottom) [8].

Lunar FFCs are characterized by anomalously shallow floors cut by radial, concentric, and/or polygonal fractures [8]. These FCCs have been classified into crater classes, Types 1 through 6, based on their morphometric properties [eg. 8, 9]. Models for their formation have included both floor uplift due to magmatic intrusion below the crater [eg. 8, 9] or floor shallowing due to viscous relaxation [e.g. 10]. However, the observation that the depth versus diameter relationship of the FFCs is distinctly shallower than the same association for other lunar craters supports the hypotheses that the floor fractures form due to shallow magamatic intrusion under the crater [9].

FFCs have also been identified on Mars [11]. Martian FFCs exhibit morphological characteristics similar to the lunar FFCs, but many of their have been highly dissected. Analyses suggest that the Martian FCCs also formed due to volcanic activity but that the final morphologies were heavily inflenced by interactions with groundwater and/or ice [11].

A preliminary analysis of depth to diameter ratios of Ceres craters based on HAMO data shows a break in slope that implies that the floor fractured craters might be shallower than the other craters [12]. This suggests that the fractures on the floor of Azacca, Occator and other Ceres FFCs may also be due the upwelling of a low-density material below the crater, although more likely an ice-rich slurry as opposed to magma.

We are cataloging the Ceres FFCs according to the classification scheme designed by [8] and utilized by [9] in their d/D analysis of lunar craters. A new analysis of the d/D ratio for Ceres craters based on LAMO data will be performed to determine if, like lunar FFCs, the Ceres FFCs are anamolously shallow.

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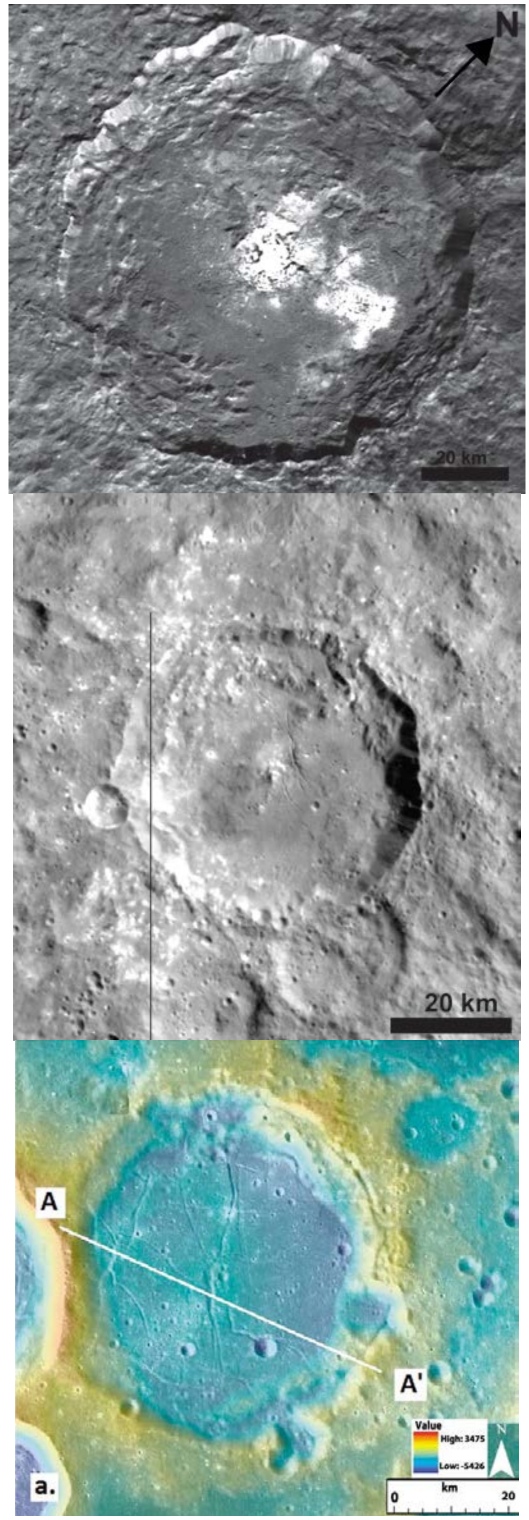

Figure 2. HAMO (140 m/p) FC clear filter image of the 92 km diameter Occator crater (top) and the 50 km Azacca crater (middle). The bright spots in Occator are noticably associated with the floor fractures. Bottom is LOLA topography over a LROC-WAC image (100 m/p) of von Braun crater, a Type 5 lunar FFC [9].