The Geomorphology of Ceres

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We assess the geology of Ceres at the global scale, to identify geomorphic and structural features, and to determine the geologic processes that have affected it globally. Geomorphic features identified include: impact craters, linear structures, domical features and lobate flows. Kilometer-scale linear structures—grooves, pit crater chains, fractures and troughs—cross much of Ceres, and include both those associated with impact craters and those that do not appear to have any correlation to an impact event. Domical features fall into two broad classes: large domes which are 10s to 100s km in diameter with heights 1-5 km; and small mounds <10 km in diameter exhibiting sub-kilometer relief. A range of lobate flows are observed across the surface of Ceres, and differences in their morphology suggest that multiple emplacement processes might be operative. However, Ceres is dominated by craters, including numerous polygonal craters and several floor-fractured craters (FFCs).

Geomorphic analysis of the Ceres FFC fracture patterns show that they are similar to lunar FFCs. FFCs on the Moon are hypothesized by Jozwiak et al. [2015] to be a product of intrusions of magmatic material below the craters uplifting their floors. We have cataloged the Ceres FFCs according to the classification scheme designed for the Moon. Class 1 Ceres FFCs have both radial and concentric fractures at the crater center, and concentric fractures near the crater wall. In the magmatic model 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) Ceres FFCs which have only linear or radial fractures at the center of the crater 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. The three Class 4 sub-classes all have a v-shaped moat separating the wall scarp from the crater interior, but different interior morphologies: Class 4a, with both radial and concentric fractures; Class 4b, having a distinct ridge on the interior side of its v-shaped moat and subtle fracturing; Class 4c, with a moat and a hummocky interior, but no obvious fracturing. A depth vs. diameter analysis shows that, like lunar FFCs, the Ceres 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.

This three-dimensional characterization of the surface is used to determine if the geomorphology of Ceres

is consistent with models of the dwarf planet predicting an icy crust and/or mantle. The lack of a large inventory of relaxed craters, the presence of ancient surface fractures, and extensive sub-surface fracturing (as demonstrated by the widespread distribution of polygonal craters), suggests that the crust is too strong to be dominated by ice. However, certain geomorphic features suggest that there may be at least some ice in the Ceres crust, and significant ice in its mantle. A latitudinal trend in the global distribution of lobate flows suggests that the differences in morphology might be explained by variations in ice content and temperature at the near-surface. Ahuna Mons and the other large domes appear to be cryovolcanic in nature, and the FFCs are hypothesized to be formed due to cryomagmatic intrusions under their floors. However, none of the impact craters that host large domes have fractured floors. This anti-correlation suggests that there may be a difference in crustal properties between where the FFCs and the volcanic features form.

Keywords: Ceres, geomorphology, floor-fractured craters, cryomagma

