THE CAVE OF AN ICE DRAGON: GRAVITATIONAL EVIDENCE OF THE SUBSURFACE STRUCTURE BENEATH AHUNA MONS ON CERES.
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Introduction: The Dawn mission at Ceres identified the 4-km high Ahuna Mons and provided geological evidence for its cryovolcanic origin [1-3]. The growth of the domical mountain involved extrusion of viscous material bearing brine, i.e., a salt-water solution [1]. The presence of this type of water-ice-rich material is supported by modeling of the dome's viscous relaxation [2] and by Dawn's near-infrared observations of Ahuna Mons that identified the brine's solid residue, sodium carbonate [3]. The properties of the subsurface beneath Ahuna Mons are not yet understood. Insights into the nature of Ceres's crust have implications for our understanding of this dwarf planet's differentiation and evolution.

Brines were suggested to originate from a relatively warm region/layer located several tens of km beneath the surface [1]. Here we search for evidence of the possible presence of this region with gravity data. Comparison of gravity [4] to topographic relief revealed large residual isostatic anomalies [5]. Bouguer and isostatic corrections were based on the following properties of Ceres' interior: a crust of ~1379 kg m^{-3} in density and average thickness of ~46 km above a "mantle/core" of ~2442 kg m^{-3} in density [5]. Most of these anomalies are spatially associated with impact craters. This correlation suggests that the geological events associated with the origin of these anomalies are not primarily endogenic. On the other hand, isostatic anomalies show a strong signal of ~60 mGal at Ahuna Mons [5]. This geographic correlation between an isostatic anomaly and a dome is unique on Ceres and suggests that this anomaly may have an endogenic origin. Here we investigate whether the anomaly can be associated with a subsurface structure and linked to the extrusive event producing Ahuna Mons.

Approach: The use of a discrete mass concentration (*mascon*) to describe the gravitational anomaly underneath Ahuna Mons helps us to represent, to a first-order approximation, subsurface models. Possible structures that can produce this large anomaly may be interpreted via three geophysical cases: a region of higher crustal density [e.g., 6], a (cryomagmatic) chamber [e.g., 7, 8], or an uplift of (denser) mantle material [e.g., 9]. To determine the feasibility of this scenario, we developed a technique that helps determine the size, depth and density of the mascon. Gravity anomalies do not provide unambiguous and unique solutions, but the following approach may inform the properties of the subsurface beneath Ahuna Mons.

Method: We computed the Bouguer and isostatic gravity anomalies with the latest Ceres gravity field and topography measured by the Dawn mission [4,10]. By modeling a tri-axial ellipsoid at a certain depth, we determine the properties of this shape that generate gravity anomalies consistent with the isostatic anomalies. The adjusted mascon parameters are the three dimensional axis (a,b,c), the density contrast with the surrounding, the depth beneath the surface, and the geographic position and orientation.

The criterion for the selection of the best solutions relies on the minimization of the difference between mascon gravity and isostatic anomalies (*residuals*). The method adopted in this study has two steps. First, we generate a population of 1 million solutions with a Monte Carlo as an initial guess of the structure. Then a genetic algorithm is used to minimize the sum of the squared residuals providing the best solutions.

Preliminary results: In preliminary runs we find the following: (i) the depth of the ellipsoid and its orientation reach single minima, and the depth is close to the crust-mantle boundary; (ii) the dimensions of the spheroid and its density contrast are strongly correlated and lead to multiple solutions; and (iii) the geographic position is close to that of Ahuna Mons (10°28'S, 316°12'E).

Figure 1 shows the resulting gravity residuals of one of the best solutions. An ellipsoid underneath Ahuna Mons with certain properties is able to reproduce the isostatic anomalies with an accuracy that is lower than the gravity solution uncertainty, which is ~10 mGal over that region of Ceres.

Furthermore, we focused the mascon analyses on constrained conditions. For example, to simulate the region of homogeneous higher crustal density below Ahuna Mons, we simulated the mascon centered in the crust to determine the crustal density increment to fit the residuals. The results of this case show significantly larger residuals compared to the unconstrained case.

Another possible case is the uplift of mantle material that is responsible for the uncompensated crust. In this case we fixed the depth of the mascon at the crust-mantle boundary with a negligible mascon height. This solution is consistent with the unconstrained case.

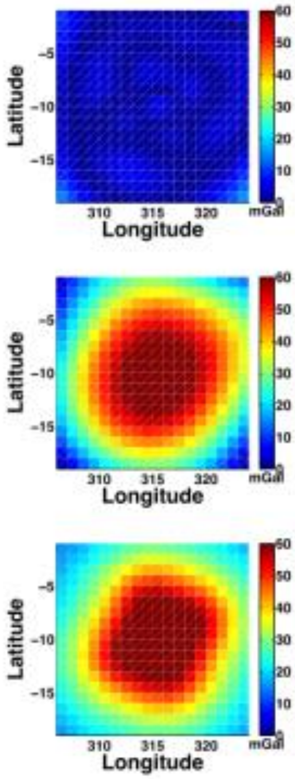

Figure 1. Upper panel: residuals; center panel: isostatic anomalies; bottom panel: reconstructed anomalies. Isostatic anomalies at Ahuna Mons (10°28'S, 316°12'E) are about 60 mGal with an ~10 mGal uncertainty.

Discussion: A density contrast is required by the higher crustal density case and the (cryomagmatic) chamber case and is linked to the current density and porosity of Ceres' subsurface. In order to investigate the physical and mineralogical conditions leading to this density contrast we considered a thermal and compaction evolution model for Ceres [11]. The thermally-activated creep flow of minerals and grain sizes consistent with the current knowledge of Ceres' composition as well as potential effects of the dehydration were considered. We will discuss the conditions for which the density contrast can be due to either, or both, the presence of high density minerals (e.g., magnetite, anhydrous salts) and the decrease in porosity by compaction (e.g., creep, dehydration) and fill. We will also discuss the implications for the case of uplift of mantle material.

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