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The Crust and Mantle of Vesta's Southern Hemisphere

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Abstract

Vesta's core, mantle and crust define it as a differentiated protoplanet. The vestan crust and upper mantle appear to be extensively shattered, as evidenced by their low density relative to grain densities of HED meteorites. Several areas of mantle uplift and/or relatively unfractured crust are evident and may represent igneous upwellings. Areas of OH enrichment and dark material appear to be less dense.

1. Introduction

Vesta is a geologically complex protoplanet with a differentiated interior. Dawn measured the gravity field of Vesta to degree and order 20 [1] and the topography to < 10 m height accuracy and 100 m spatial resolution [2]. The gravitational moment J_2 indicates a mass concentration at Vesta's center. Using geochemical (meteoritic) constraints on the density of the core (7100-7800 kg/m^3), an estimate of core size (~110 km radius) and silicate bulk density is derived from a mass balance model consistent with J_2. Vesta's bulk density is consistent with macroporosity of order 5-10% in the silicates relative to HED grain densities.

The gravity field of Vesta at degree and order 20, excluding degree 1 and J_2, ranges from -1000 to 2000 mgals, and is highly correlated to the topography [1]. Applying a Bouguer correction results in an anomaly field ranging over hundreds of mgal, roughly 10% of the gravity field. The Bouguer gravity is calculated relative to a three-layer core-mantle-crust model (Fig. 1), using layer dimensions derived from a mass balance model that matches J_2 and that are consistent with geochemical constraints from the HED meteorites. In this model the core is 110 km radius and the crust averages ~19 km in thickness, with the top surface following the shape model and bottom defined by the ellipsoidal mantle layer.

2. Bouguer Gravity

The Bouguer anomaly field shows highs and lows associated with major features of the surface. Considerable variation is seen in the crust/mantle density contrast that minimizes the major Bouguer anomalies in different regions of Vesta. Shown in Figures 2 and 3 are the topography of the southern hemisphere and two Bouguer anomaly maps made with different crust/mantle density contrasts. Significant features of the gravity maps shown in Figure 3 are the large positive anomaly associated with the high topography of Vestalia Terra at the western intersection of the Rheasilvia (RS) and Veneneia basins, a weaker positive over the central mound of the Rheasilvia basin, and negative anomalies associated with the eastern rim of Rheasilvia and most of the Veneneia basin. A second large positive anomaly is seen over the equatorial troughs at the northeastern edge of the RS basin.

The positive Bouguer anomaly over Vestalia Terra (VT) is significantly denser that the average bulk silicate density of Vesta [3], as shown by its persistence in the model at bottom. The gravity data indicate that the RS ejecta are resting on a dense topographic rise that likely is composed of ultramafic mantle material. Its density is consistent with unfractured diogenite. The density of the underlying rise also appears higher than the mantle elsewhere in the southern hemisphere. The high topography at VT pre-dates the Rheasilvia and older Veneneia impacts as these basins carve the edges of VT. Thus, the density structure of Vestalia Terra may be indicative of a more primordial state of the vestan interior. It is difficult to probe the nature of the bedrock beneath the mantling RS ejecta, but several small impact craters indicate at least localized presence of diogenite-enriched howardite material. The origin of VT could be the result of magmatic processes during Vesta's early evolution, or may be explained by variable impact gardening of the vestan crust and mantle.

The regional low associated with the Veneneia basin is also correlated to a concentration of outcrops of dark material that is itself associated with OH enrichment [5,6]. The low density implied by the Bouguer anomalies indicates this area retains more of the lower-density eucritic layer than elsewhere in Vesta, and/or the crust is more porous.

3. Figures

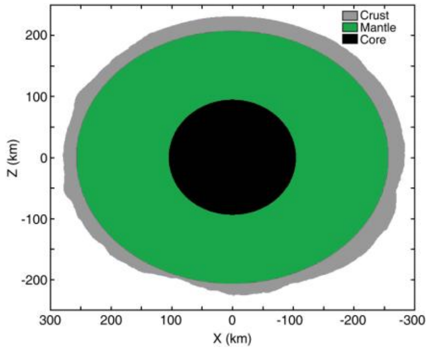

Figure 1. Three-layer model used to calculate Bouguer gravity.

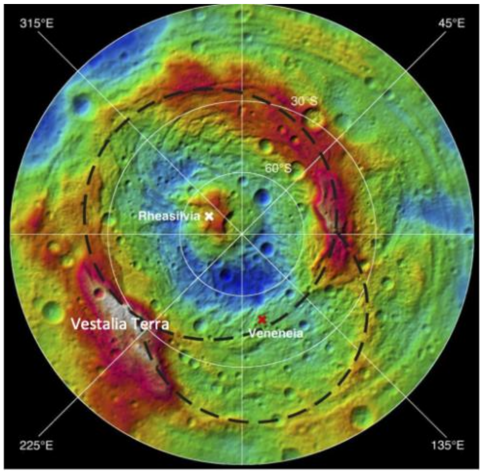

Figure 2. Topography of the southern hemisphere with outlines of the Rheasilvia and underlying Veneneia impact basins**.** Map is relative to a 285x285x229 reference ellipsoid**.**

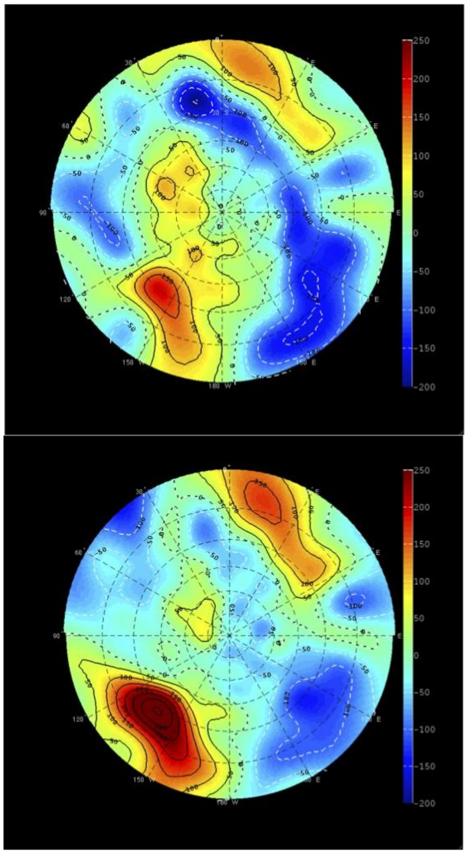

Figure 2: Color contour Bouguer anomaly maps in mgals of the southern hemisphere of Vesta. Top: Bouguer gravity field calculated using crustal density of 2800 kg/m^3 and mantle density of 3300 kg/m^3. Bottom: Bouguer gravity field assuming no crust/mantle density contrast with a density of 3100 kg/m3.

Acknowledgements

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