EPSC Abstracts
Vol. 7 EPSC2012-818 2012
European Planetary Science Congress 2012

Initial Models of Vesta's Crust and Mantle

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Abstract

Dawn has measured the gravity and topography of Vesta with high spatial resolution and accuracy. These data provide information about the interior structure of Vesta, indicating a substantial iron core and a fairly low-density bulk silicate fraction relative to HED meteorites. Three layer models (core, mantle, crust) that match the observed gravity indicate the presence of density and crustal thickness variations that are correlated to geologic structures and composition.

1. Introduction

Dawn's year-long stay at Vesta has resulted in comprehensive mapping of the shape, topography, geology, mineralogy, elemental abundances, and gravity field using its three instruments and high-precision spacecraft navigation. Tracking data from the Low Altitude Mapping Orbit (LAMO) has allowed a high-accuracy gravity field to be derived [1, 2, 3]. Multi-angle imaging in the Survey and High Altitude Mapping Orbits (HAMO-1 and -2) has provided adequate stereo coverage to develop a shape model accurate to ~10 m at 100 m horizontal spatial resolution. Accurate mass determination combined with the shape yields a more precise value of bulk density. The shape and gravity of Vesta have been used to infer the interior density structure and investigate the nature of the crust, informing models for Vesta's formation and evolution. The J_2 gravitational moment indicates a central mass concentration within Vesta, which has been modeled as an iron core (density of ~7400 kg/m^3) of radius ~110 km [4] using a mass balance approach. A bulk silicate density of ~3100 kg/m^3 is implied by this model. This is at odds with the estimated range of bulk density of 3320-3630 kg/m^3 derived from analyses of HED meteorites [5], and likely reflects porosity in the Vestan crust and upper mantle.

2. Gravity and Topography

Figure 1 shows a shape model of Vesta, derived by stereophotogrammetry methods using data from the Survey orbit at ~2700 km altitude, and the first HAMO orbit at ~680 km altitude. The spatial resolution of this model is ~100 m/pixel and heights are accurate to <10 m over most of the body. Above 40°N the illumination conditions did not permit retrieval of heights; however, a more accurate, digital terrain model with coverage to high northern latitudes is expected after successful collection of image data from HAMO-2 in July 2012. The shape of Vesta is dominated by the large Rheasilvia impact basin in the southern hemisphere, and the high topography (Vestalia Terra and Matronalia Rupes) surrounding the Rheasilvia basin and associated with its ejecta. Also apparent are many other large impact basins [6], as well as a marked difference in the dynamic range of the topography between the northern and southern hemisphere, likely due to Rheasilvia.

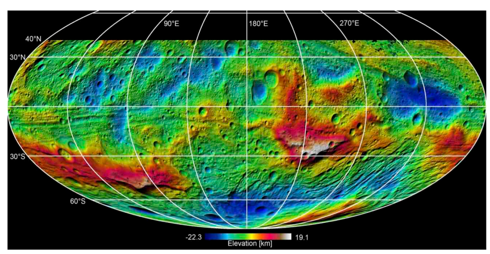

Figure 1: Topographic model of Vesta derived from HAMO-1 data stereo image data shon relative to a best-fit ellipsoid of dimensions 285x229 km [7].

The gravity field of Vesta [2] is highly correlated to Vesta's topography. Removing the gravity due to topography to derive the Bouguer gravity field results in small but significant anomalies that may be interpreted in terms of crustal thickness and/or density variations. Bouguer anomalies over the Rheasiliva basin (Figs 2 and 3) show a clear correlation of positive Bouguer gravity with the high terrain along the western crater rim (Vestalia Terra), and the central peak. The higher density implied for the central peak is in agreement with the presence of diogenitic material identified in VIR data [8]. The low over the eastern rim of Rheasilvia and the slightly smaller underlying Veneneia basin indicates lower crustal density and possibly thinner crust there.

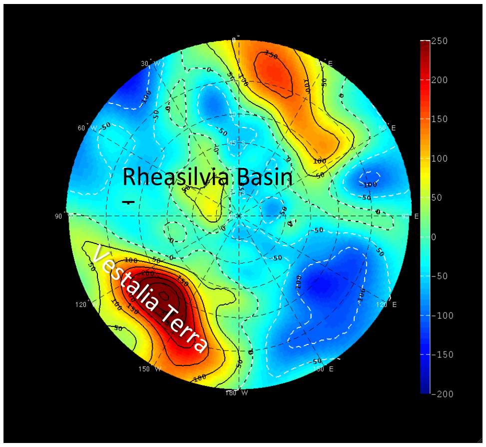

Figure 2: Bouguer gravity for a three layer model using crustal density of 2870 kg/m^3 and mantle density of 3300 kg/m^3.

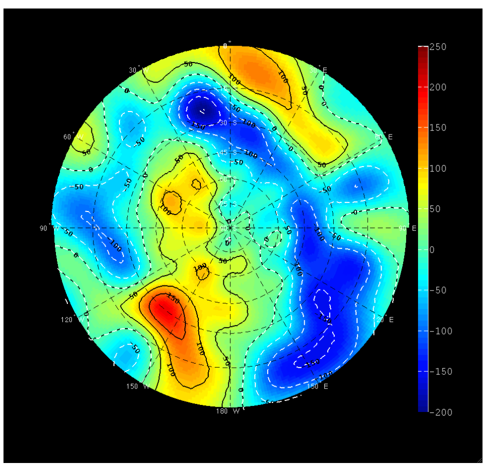

Figure 3: Bouguer gravity for a three layer model using crustal and mantle density of 3100 kg/m^3.

The high Bouguer gravity in Vestalia Terra appears to reflect crust and mantle of density higher than the average bulk silicate density of 3100 kg/m^3. Figure 3 illustrates that this anomaly persists strongly when the crust and mantle density are equal to the bulk silicate value. The central peak in the basin also appears to be denser than the surrounding crust of the basin, consistent with an origin in uplifted mantle. The Bouguer gravity of the basin overall is minimized for a low crustal density (higher crust/mantle density contrast) as shown in Figure 2, and as expected for highly shattered, porous ejecta. The origin of Vestalia Terra is under investigation.

Acknowledgements

The authors thank the Dawn spacecraft, instrument and operations teams for successful mission operations. This work was, in part, carried out at the Jet Propulsion Laboratory, California Institute of Technology, under contract with the National Aeronautics and Space Administration.

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