Modeling Vesta's internal structure with Dawn gravity and shape models. Anton I. Ermakov[1], Maria T. Zuber[1], David E. Smith[1,2], Carol A. Raymond[3], Roger R. Fu[1]. [1]Department of Earth, Atmospheric and Planetary Sciences, Massachusetts Institute of Technology, Cambridge, MA 02139, USA (eai@mit.edu); [2]NASA/Goddard Space Flight Center, Greenbelt, MD, 20771, USA; [3] Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA, USA.

Introduction:

Vesta is a differentiated asteroid as confirmed by the Dawn gravity measurements [1,2]. The Rheasilvia and Veneneia impact basins in the southern hemisphere have a substantial effect on the global shape and gravity field of the asteroid. Rheasilvia makes the apparent shape of Vesta more oblate. The basins are surrounded by a belt of thicker crust [3], that can be alternatively interpreted as lower density material [4]. Hydrocode modeling of the formation of the impact basins showed that regions north of the crustal belt are not significantly affected by the impact [5] and, therefore, represent the pre-impact shape of Vesta [3,6]. We use Vesta gravity and topography in connection with the geochemically derived constraints to study Vesta's internal structure, rotational history and compensation state.

Hydrostatic equilibrium:

Vesta was likely near hydrostatic equilibrium immediately after its formation and before the giant impact basins formed [6]. Therefore, it is possible to use the northern terrains of Vesta to determine its preimpact shape and rotation state. We fit a triaxial ellipsoid with 9 degrees of freedom (three axes, three orientation angles and three coordinates of the origin) to the northern terrains unaffected by the late giant impacts [5]. The flattening and orientation of the northern ellipsoid are used to constrain the pre-impact rotation rate and rotation axis orientation. The rotation period that corresponds to the northern ellipsoid flattening is 4.95 hours, which is 7% lower than the present 5.32 hours. The polar axis of the northern ellipsoid is 3.0 ± 0.14 deg off from the current rotation axis [6]. These values are robust with respect to the definition of the region unaffected by the giant impact and constitute evidence for possible reorientation and despinning.

Geochemical constraints:

We compare internal structure models derived from gravity and topography with the results of geochemical modeling [7]. We use the estimated pre-impact rotation rate to compute hydrostatic equilibrium figures of the core and the outer shape for different bulk chondritic compositions. This allows us to eliminate the trade off between the core shape and the mantle shape. The gravity/topography internal structure constraints are consistent with geochemical models for the H-chondrite and mixed 3/4H+1/4CM bulk compositions to 1.7% and 2.4% in crust and mantle mass fractions, respectively. However, the geochemical difference in density can be masked by porosity variations. A bulk porosity of order of 10% results in a density contrast comparable or even higher than pure geochemical density contrast. Such a structure would pose a major challenge in interpretation of gravity anomalies.

Crustal inversion:

Given only gravity and topography data, an absolute mean crustal thickness cannot be computed. However, to study relative crustal thickness variations we can choose densities based on the geochemistry of HEDs [7] to invert for the crust-mantle interface. Using this approach the thinnest crust is observed in the floors of the Rheasilvia and Veneneia basins, which correspond to diogenite-rich region as inferred from the Dawn VIR [8]. Areas of thickest crust are associated with the rims of the impact basins and could be at least partially associated with impact ejecta. We explore the range of possible of crustal, mantle and core densities. The mean crustal thickness as a function of the three densities is shown in Fig. 1.

Compensation state and admittance analysis:

We use the approach of [9] to determine the global compensation state of Vesta. We find that Vesta is likely to be globally uncompensated for all wavelengths. Therefore, we can use gravity/topography admittance to directly constrain the effective density of the crust. We use spectro-spatial localization technique to study lateral effective density variations [10]. A local effective density high is observed at the intersection of the two giants basins – the region of the highest excavation depth due to impacts [5]. Another broad effective density high is located approximately in the antipodal region to the Rheasilvia center. By fitting a line to the effective density as a function of degree we can constrain the rate of density increase with depth. We observe a weak negative correlation between the effective density and the rate of density increase with depth.

References:

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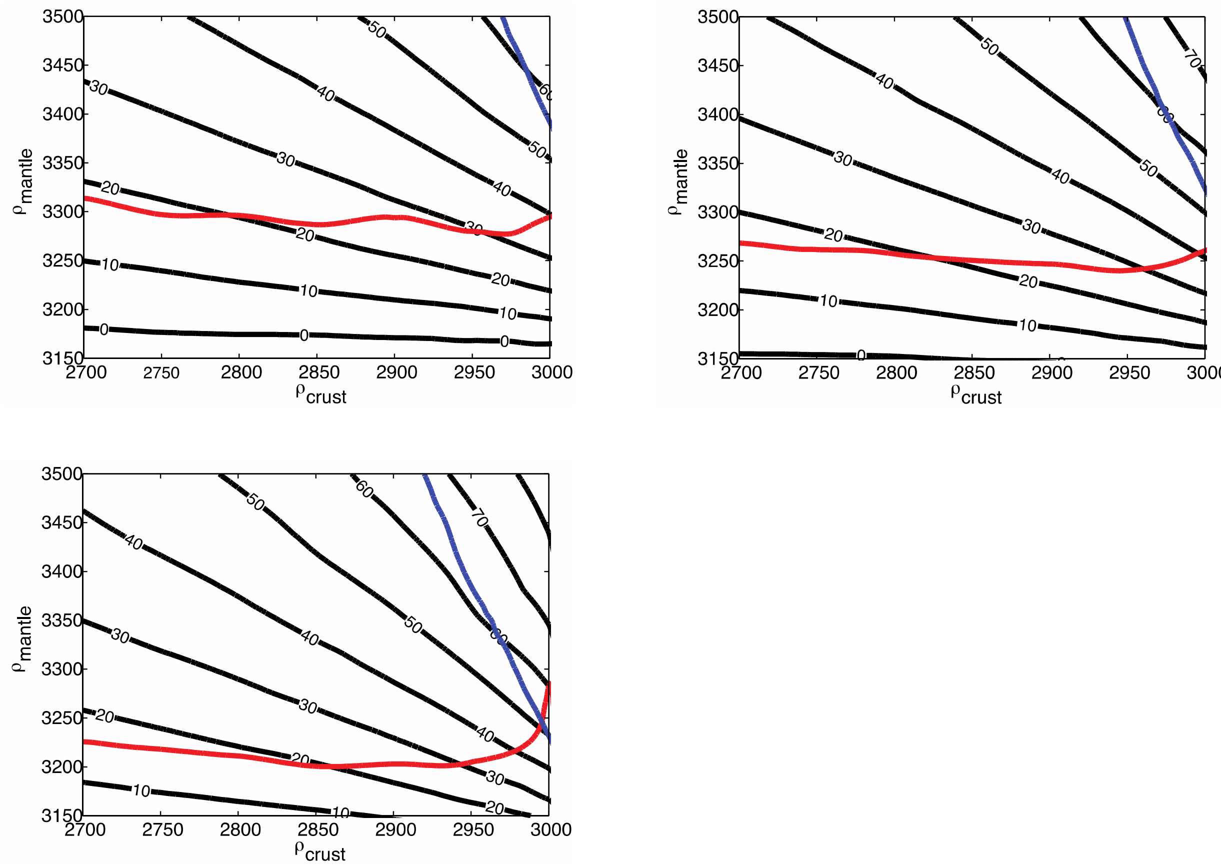

Figure 1. Mean crustal thickness as a function of mantle and crustal densities. Following [1], the mean radius of the core is 110 km. Results are shown assuming core densities of 7800 kg m^{-3} (bottom), 7400 kg m^{-3} (top right), 7100 kg m^{-3} (top left). For the densities below the red line, the minimum crustal thickness is less than zero and therefore those solutions are unphysical. For the densities right of the blue line, the maximum crustal thickness is greater than 100 km.