Geoid and Terrain Slope of Vesta from Dawn

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Introduction. The data collected by the Dawn spacecraft at Vesta allows the study of its geophysical characteristics. We derive here the shape of the geoid, and then use it estimate the elevation and slope of the terrain.

Methods. The geoid is the reference surface of choice for the determination of the physical height and slope of the terrain of Vesta. It depends upon the gravitational field and rotation of the body. In order to avoid divergences in the calculation of the gravitational field near the surface of Vesta, a 3-layer interior structure model for Vesta's mass distribution has been developed following the results of thermal modeling and mineralogical evidence [1]. The core is assumed to have an average radius of 100 km and a density of 7.0 g/cm^3, the mantle an average density of 3.3 g/cm^3, and the crust an average thickness of 25 km and density of 2.8 g/cm^3. While this solution is not unique, it generates a gravitational field that is exactly equal to the one measured by Dawn [2] (up to degree and order 8), and initial analysis shows that the results presented here are stable for small changes of the interior structure. The gravitational field is then computed by summing over a large number of mass elements, with a scale that is comparable with the resolution of the shape model [3] used (approx. 700 m). The reference value of the geoid's potential is determined iteratively so that its average height is the same of the observed terrain (up to latitude 50°N).

Results. The acceleration at the surface ranges from approximately 0.20 m/s^2 at the equator (0.23 m/s^2 gravitational – 0.03 m/s^2 rotational), to 0.27 m/s^2 at the poles. The elevation and slope maps are an important complement to the framing camera images for the geomorphological analysis of Vesta. An example is provided in Figure 1, displaying the region of highest slope on Vesta. In Figure 2 we have plotted the global maps of the geoid of Vesta, the orthometric altitude of the terrain relative to the geoid, and the slope of the terrain relative to the local plumb line direction. The geoid is relative to a triaxial ellipsoid which is its least-squares fit, and extends only ± 8 km relative to the ellipsoid. The terrain elevation goes from –20 to +16 km relative to the geoid, with the Rheasilvia complex reaching approximately 4.7 km above the geoid, at 293.6°E 78.8°S. The global slope map clearly indicates the absence of large regions of constant slope, and makes it possible to outline many of the morphological features of Vesta. A global slope distribution is plotted in Figure 3, and in particular Figure 4 shows the slope of craters as a function of the diameter.

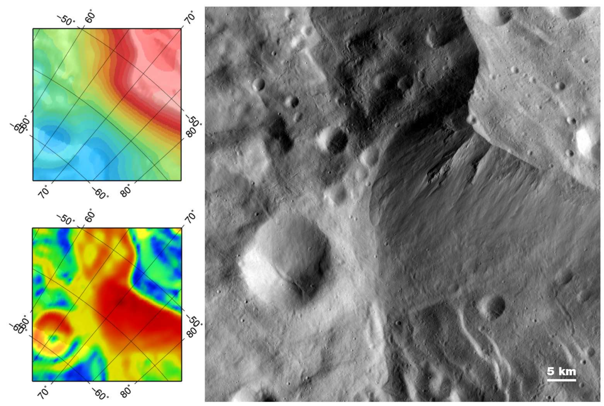

Figure 1: One of the regions with the highest slope on Vesta, on the rim of Rheasilvia: terrain elevation relative to the geoid (top left), terrain slope (bottom left), framing camera image (right, file ID: FC21B0010056_11285101226F1A). The dark red spot in the slope map has a slope of 39°, see Figure 2 for the color scales.

Discussion. Terrain slopes reach 39° at the resolution of the shape model used (700 m), comparable with the typical angle of repose of granular materials in a low-gravity environment [4] such as Vesta's surface. The absence of steeper regions suggest that over the age of the solar system, if an extensive sheet of basaltic magma covered Vesta early in its history, that layer has been heavily fragmented with the result that the physical state of the outermost layer is rubble.

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References. [1] Zuber et al. (2011), SSR 163, 77. [2] Konopliv et al. (2011), SSR 163, 461. [3] Raymond et al. (2011), SSR 163, 487. [4] Kleinhans et al. (2011), JGR 116, E11004.

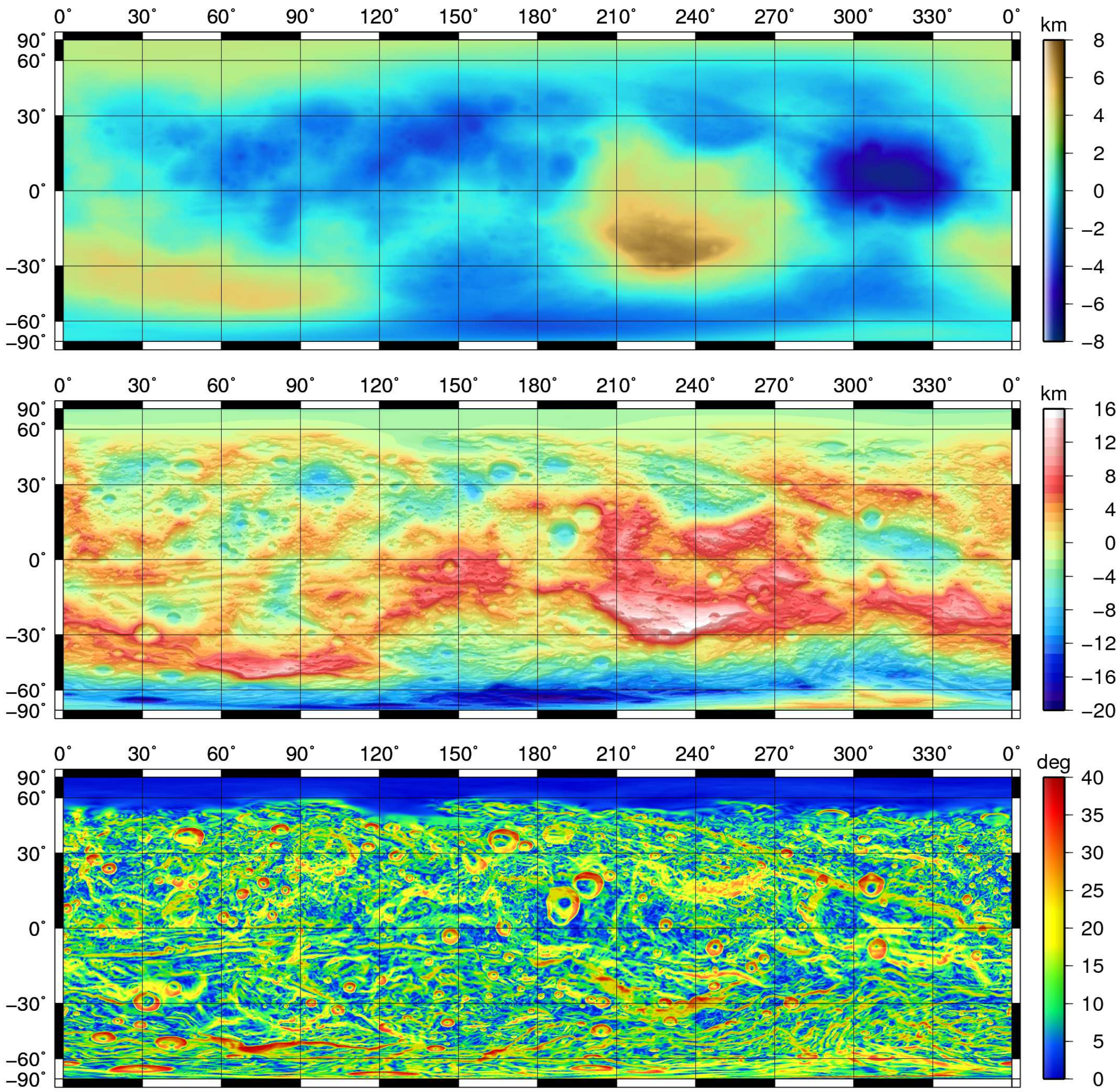

Figure 2: Top: shape of the geoid of Vesta relative to an ellipsoid with axes of 278.2 × 277.1 × 231.0 km. Center: orthometric elevation of Vesta's surface relative to the geoid. Bottom: surface slope relative to the local plumb line direction. All maps are in cylindrical equal-area Lambert projection.

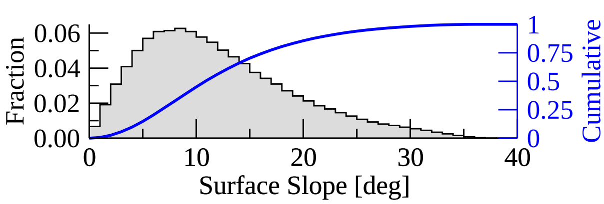

Figure 3: Slope distribution (gray histogram) and cumulative distribution (blue line) for latitudes up to 50°N, at a shape model resolution of 700 m.

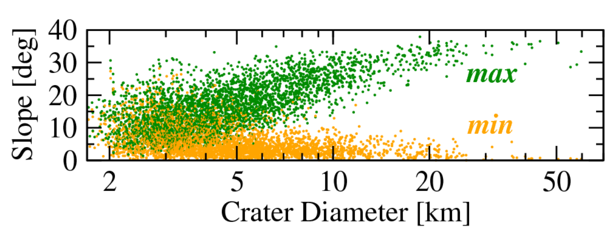

Figure 4: Minimum (orange) and maximum (green) terrain slope in craters, at a shape model resolution of 700 m.