GEOPHYSICAL CONSTRAINTS ON THE STRUCTURE AND EVOLUTION OF VESTA'S CRUST AND MANTLE. C. A. Raymond[1], R. S. Park[1], A. S. Konopliv[1], S. W. Asmar[1], R. Jaumann[2], H. Y. McSween[3], M. C. De Sanctis[4], E. Ammannito[4], D. L. Buczkowski[5], C. T. Russell[6], D. E. Smith[7], M. J. Toplis[8], and M. T. Zuber[7], [1]Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA, USA (carol.a.raymond@jpl.nasa.gov), [2]DLR, Inst. of Planetary Research, Berlin, Germany, [3]Univ. of Tenn, Knoxville, USA, [4]INAF/IAPS, Roma, Italy, [5]APL, Laurel, MD, USA, [6]UCLA, Los Angeles, CA, USA, [7]MIT, Cambridge, MA, USA, [8]Uni. de Toulouse, France.

Introduction: During its 14-month stay at Vesta, the Dawn mission determined the gravity field of Vesta to degree and order 20, using high-accuracy coherent Doppler tracking of the spacecraft by the Deep Space Network, especially from the ~480 km radius Low-Altitude Mapping Orbit [1]. A residual gravity field, calculated as the difference between the observed gravity field and one calculated under varying assumptions of the internal density structure that minimizes the misfit with the observed field, reveals density variations in the crust and upper mantle of Vesta. These significant gravity anomalies can be interpreted as crustal thickness or density variations, and likely reflect both sources. The residual anomalies are associated with structural features such has the Vestalia Terra highland and the deep Saturnalia Fossae, as well as lithological provinces, such as the extensive dark material deposits at the Veneneia impact basin rim, and the diogenitic central mound of the Rheasilvia impact basin. As such, these anomalies reflect the modification of the vestan crust and mantle by impacts that have extensively fractured and pulverized it while also exposing deep-seated material and mixing it with the original crust; they also reflect the addition of low-density exogenic material to Vesta's surface. However, impacts alone can't account for the all of the density (and/or crustal thickness) variations implied by the Bouguer gravity field. The presence of significant density anomalies in concert with broad compositional and geologic variations is consistent with heterogeneity in the original crust and mantle of Vesta. Features such as southern Vestalia Terra and similar high-density features appear to be primordial, and suggest intracrustal plutons consistent with evidence from the trace element geochemistry of HED meteorites, and genetic models that include multiple magma chambers.

Gravity Anomalies: Residual gravity anomalies from [3] are shown in Fig. 1a and b. The anomalies range from a low of -194 mGal to a high of 244 mGal. In the northern hemisphere (Fig 1a), negative anomalies are associated with the deep Saturnalia Fossae (troughs) and Feralia Planitia. Positive anomalies occur across a broad swath of the northern latitudes, without clear geologic relationships. In the southern hemisphere (Fig 1b), strong positive anomalies are associated with southern Vestalia Terra, the western portion of the Rheasilvia basin, including the central mound, and the eastern equatorial troughs (Divalia Fossae). Strong negative anomalies follow the Rheasilvia rims except for Vestalia Terra, and cover most of the eastern Veneneia basin. The positive anomalies of the two hemispheres are connected by the broad swath of higher gravity that runs roughly along 0 degrees.

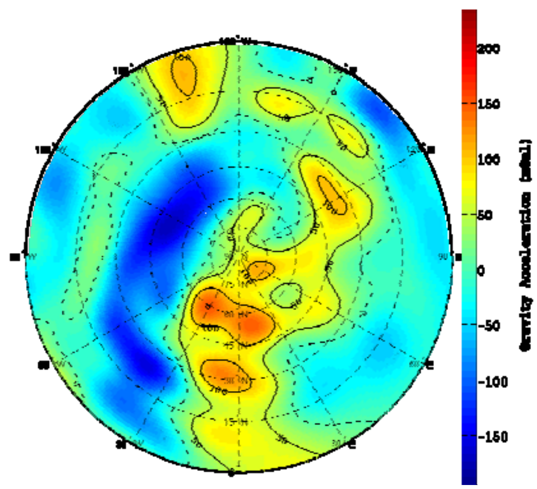

Fig 1a. Residual gravity anomalies of the northern hemisphere of Vesta from [3], shown in the Claudia coordinate system.

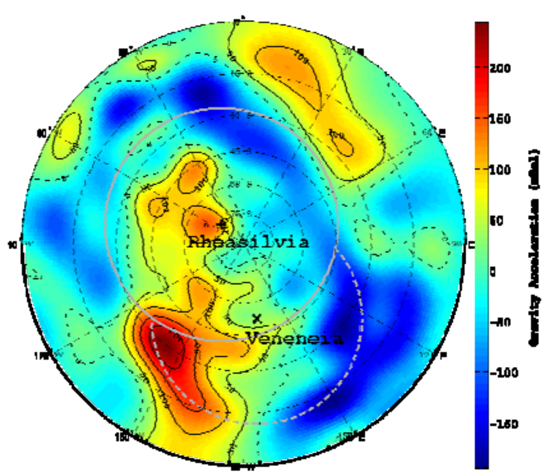

Fig 1b. Residual gravity anomalies of the southern hemisphere of Vesta from [3], shown in the Claudia coordinate system.

Density Variations: Variations in crustal porosity are clearly contributing to the gravity signature, most evident in the negative anomalies at the eastern rim of the Rheasilvia basin, and in the region of overlap between the Rheasilvia and Veneneia basins. In these regions the density is below 2800 kg/m^3 [3]. The strongest positive anomaly in the south is clearly associated with stronger, resistant crust in the southern Vestalia Terra highland, whereas the strong positive anomaly over the eastern troughs has little topographic expression. As shown in [3], the density of these regions is ~3200 kg/m^3, consistent with unfractured diogenite. The admittance for these regions shows a distinct spectrum consistent with high-density intrusions. The positive anomaly over the central mound is consistent with its origin as an uplifted lower crustal/mantle block; however, the entire western Rheasilvia basin appears to be more positive (denser) than average. In the northern hemisphere, the deep troughs of the Saturnalia Fossae have a negative residual gravity signature indicating less dense, more porous crust. The positive anomalies there are without clear topographic or geologic expression.

Compositional Variations: Clues to the sources of the gravity (density) anomalies can be found in their association with compositional variations. Diogenite, representing the vestan lower crust and possibly upper mantle, is found within the Rheasilvia basin, predominantly in the region of overlap between Rheasilvia and the Veneneia basin (Fig 2). Although the low density implicated for this region by the residual gravity field seems to contradict such a finding, it can be explained as a result of deep excavation of the crust and mantle by these two major impacts, which effectively mixed the deeper-seated diogenite material with the surface material. The higher density diogenite within the near surface materials is offset by the extensive fracturing in this location. Southern Vestailia Terra and the central mound show some evidence of diogenite enrichment. In the northern hemisphere, the positive gravity anomalies corresponds broadly to a longitudinally-narrow region of diogenite enrichment that connects to the diogenite concentration within Rheasilvia. Most notably, the area in which olivine has been detected lies at the edge of the region of strong positive anomalies and diogenite enrichment.

Implications for Vesta's evolution: The pattern of residual gravity anomalies and the density variations they imply, together with their associations with diogenite and ancient crust in Vestalia Terra, point to an origin as plutons within the deep crust and possibly upper mantle of Vesta. Vestan crustal genesis and evolution by serial magmatism has been proposed to explain evidence for multiple magma chambers on the HED parent body (Vesta) as shown by varying trace element patterns among diogenites (e.g. [6,7]). Density variations revealed by Dawn's geophysical data favor petrogenetic models that include serial magmatism such as those recently elucidated by [8,9].

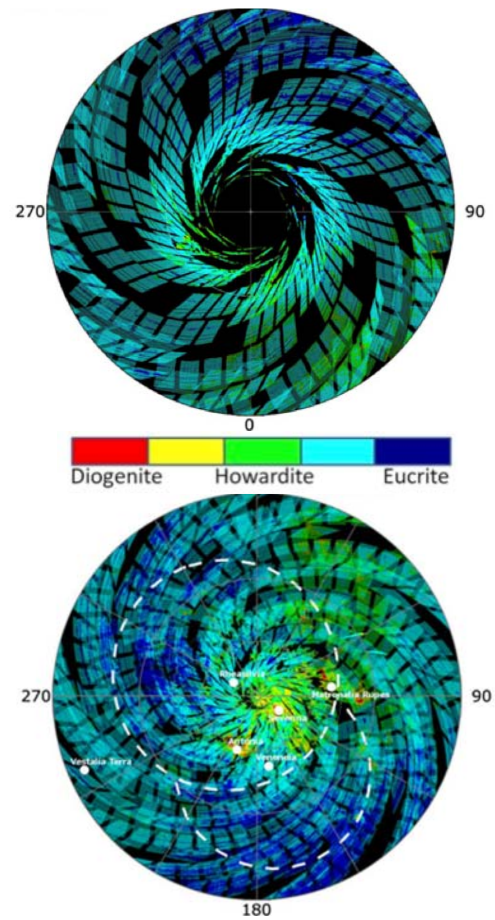

Fig 2. Mapping of the distribution of howardite, eucrite and diogensite across the surface of Vesta as measured by the VIR spectrometer [4]. Top: Northern hemisphere; Bottom: Southern hemisphere.

References: [1] Konopliv A. S. et al. (2013) *Icarus.*, in press. [2] Preusker F. et al. (2012) *LPS XLIII.* [3] Park R. S. et al. (2013) *Icarus*, in press. [4] Ammannito E. et al. (2013) *MAPS*, 12192. [5] Ammannito E. et al. (2013) *Nature*, 122. [6] McSween H. Y. et al. (2011) *Space Sci. Rev*., 163, doi: 10.1007/s11214-010-9537-z... [7] Barrat J. A. et al. (2008) *MAPS* 43, 1759-1775. [8] Mandler, B.E and L.T. Elkins-Tanton (2013), *MAPS*, in press. [9] Wilson L. and Keil K. (2012) *Chemie der Erde* 72, 289-321.