**THE IMPACT HISTORY OF VESTA: NEW VIEWS FROM THE DAWN MISSION.** D. P. O'Brien[1], S. Marchi[2], P. Schenk[3], D. W. Mittlefehldt[4], R. Jaumann[5], E. Ammannito[6], D. L. Buczkowski[7], M. C. De Sanctis[6], G. Filacchione[6], R. Gaskell[1], M. Hoffmann[8], S. Joy[9], L. LeCorre[8], J.-Y. Li[10], A. Nathues[8], C. Polanskey[11], F. Preusker[5], M. Rayman[11], C. A. Raymond[11], V. Reddy[8], T. Roatsch[5], C. T. Russell[9], D. Turrini[6], J.-B. Vincent[8] and the Dawn Science Team, [1]Planetary Science Institute, 1700 E. Ft. Lowell, Suite 106, Tucson, AZ 85719 (obrien@psi.edu), [2]NASA Lunar Science Institute, Southwest Research Institute, Boulder, CO, [3]Lunar and Planetary Institute, Houston, TX, [4]NASA Johnson Space Center, Houston, TX, [5]DLR, Institute of Planetary Research, Berlin, Germany, [6]Istituto Nazionale di Astrofisica, Rome, Italy, [7]Johns Hopkins University Applied Physics Lab, Laurel, MD, [8]Max-Planck-Institut für Sonnensystemforschung, Katlenburg-Lindau, Germany, [9]Institute of Geophysics and Planetary Physics, University of California, Los Angeles, CA, [10]University of Maryland, College Park, MD, [11]Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA.

**Introduction:** The Dawn mission has completed its Survey and High-Altitude Mapping Orbit (HAMO) phases at Vesta, resulting in 60-70 meter per pixel imaging, high-resolution image-derived topography, and visual and infrared spectral data covering up to ~50 degrees north latitude (the north pole was in shadow during these mission phases). These data have provided unprecedented views of the south polar impact structure first detected in HST imaging [1], now named Rheasilvia, and in addition hint at the existence of a population of ancient basins. Smaller craters are seen at all stages from fresh to highly-eroded, with some exposing atypically bright or dark material. The morphology of some craters has been strongly influenced by regional slope. Detailed studies of crater morphology are underway. We have begun making crater counts to constrain the relative ages of different regions of the surface, and are working towards developing an absolute cratering chronology for Vesta's surface.

**South Pole Basin Rheasilvia:** Rheasilvia is a broad depression approximately 500 km in diameter. It has a pronounced central peak roughly 100 km across that rises 20-25 km above the relatively flat basin floor (Fig. 1). The basin floor is deformed by a dense network of linear and curvilinear scarps and ridges, which form radial to spiral patterns that often intersect one another. The outer margin of the Rheasilvia basin is not regular, but ranges from a low ridge in some areas to a prominent scarp over 15 km high in other areas. Possible landslide features extend to the basin floor from both the margin and the central peak.

The area surrounding Rheasilvia varies in appearance, from heavily cratered areas which may have received little or no ejecta blanketing, to relatively smooth areas with possible flow features that may represent ejecta from the crater. A pronounced set of troughs circling the equatorial region may be related to the formation of Rheasilvia.

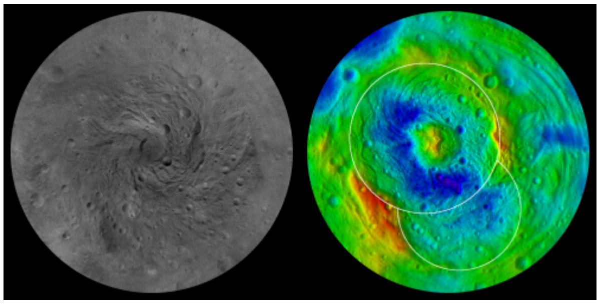

**Figure 1:** *Image mosaic (left) and topography (right) of the south polar region from -90 degree latitude to the equator. Blue represents low regions and red is high; the approximate margins of Rheasilvia and the second south polar basin are shown.*

**Ancient Basins:** Numerous other depressions can be identified in the topography data that may be the remains of large impact basins. All appear to be more eroded than Rheasilvia, suggesting an older age, although detailed crater counts will be necessary to constrain the sequence of their formation. The largest of these is approximately 350-400 km in diameter, and appears to lie partially beneath Rheasilvia (Fig. 1). This basin does not appear to have a central peak, although the region where the central peak would occur corresponds to the rim of Rheasilvia, and thus it may have been destroyed or obscured. None of the other potential basins have central peaks, although most of these basins are heavily eroded.

The number of large basins may provide an important constraint on the impact history of Vesta and the dynamical history of the main belt. Furthermore, basin-forming impacts can potentially reset Ar-Ar ages of rocks on the surface of Vesta, and subsequent large impacts can then eject these rocks to space. These large basins are likely an important part of the story for understanding the Ar-Ar ages recorded in the howardite, eucrite and diogenite (HED) meteorites [2].

**Crater Features and Morphology:** Excluding the large basins, nearly all craters appear to have a simple bowl-shaped morphology, although there are several that could be central peak craters. Many craters show gravitational collapse and slumping from their walls. This may affect the determination of the original transient crater size, which is important for estimating absolute ages of the surface. Topographic profiles of craters are currently being measured, which will establish crater morphology variation on Vesta and determine the critical sizes for transitions between different cratering regimes.

Some craters on Vesta expose atypically bright or dark material, the origin of which is the subject of detailed study. Topography can play a significant role in crater formation and modification processes on Vesta. For example, there are numerous cases of craters formed on slopes where pronounced collapse occurred on upslope sides of the craters with no collapse on downslope sides. In extreme cases, the material from upslope sides may have overrun the downslope rims and flowed out of the craters. Smooth flat regions are seen in the interiors of some craters, which could be due to ponded regolith or impact melt.

**Developing a Cratering Chronology for Vesta:** Radiometric dating of HED meteorites shows that Vesta dates back to the beginning of the Solar System [eg. 3], and its cratered surface potentially provides a record of impacts dating back to that early era. Understanding Vesta's impact record requires a crater chronology curve that relates crater density to surface age (which may be the formation age of the local crust or the time since the last major resurfacing event). One approach to the chronology is to use a lunar chronology curve [eg. 4] scaled to Vesta's current impact rate. Another approach, which we are currently developing, is to base the chronology on models of the primordial depletion and subsequent dynamical evolution of the main belt under the influence of giant planet migration and chaotic diffusion processes [eg. 5-7]. Possible chronology curves are shown in Fig. 2.

The theoretical curve shown in Fig. 2 is preliminary, although for all reasonable ranges of parameters, it lies significantly below the scaled lunar curve prior to 3 Gyr ago. In that range, a given crater density would imply a much older age using the theoretical curve than would be obtained using the scaled lunar curve, which has profound implications for the identification and dating of ancient surfaces on Vesta.

Analysis of Vesta's cratering record may be able to discriminate between these two curves. In particular, the number of ancient basins may provide a constraint on the total number of large impacts that Vesta has experienced over its history. The fact that Vesta's basaltic crust has not been eroded away by collisions also places an upper limit on the early impact rate [8]. Extending the scaled lunar curve back to 4.5 Gyr would imply the formation of hundreds of 100 km scale basins, which may be inconsistent with both of these constraints. The theoretical curve predicts a lower overall cratering intensity, but we must test that such a curve is consistent with the number of large basins and the crater density of the oldest surfaces on Vesta.

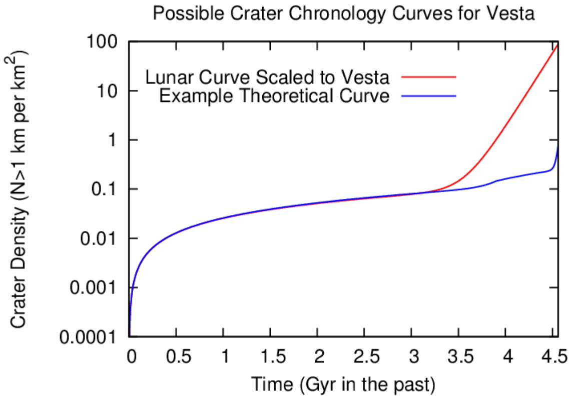

**Figure 2:** *Comparison of possible crater chronology curves for Vesta: A lunar chronology curve scaled to Vesta's current impact rate, and a theoretical curve based on models of main-belt dynamical evolution.*

In addition to the cratering record, we have meteorites from Vesta, the HEDs, that record the ages of major impact events in their Ar-Ar ages. The Ar-Ar ages of eucrites suggest several such events occurred between 3.4 and 4.1 Gyr ago, and that an especially large impact event occurred 4.48 Gyr ago [2]. A primary goal as the Dawn mission proceeds is to tie Vesta's cratering record and the HED meteorite record together in the context of the dynamical and collisional evolution of the asteroid belt, as well as the impact histories of other cratered bodies in the inner Solar System.

**Acknowledgements:** D. P. O'Brien is supported by grant NNX10AR21G from NASA's Dawn at Vesta Participating Scientist Program. The Dawn mission to Vesta and Ceres is managed by JPL, for NASA's Science Mission Directorate, Washington, D.C. UCLA is responsible for overall Dawn mission science.

**References:** [1] P.C. Thomas *et al.* (1997) *Science,* **277**, 1492–1495. [2] D.D. Bogard (2011) *Chemie der Erde* **71,** 207-226. [3] L.E. Nyquist *et al.* (2009) *Geochim. Cosmochim. Acta* **73,** 5115-5136. [4] G. Neukum *et al.* (2001) *Space Sci. Rev.* **96**, 55-86. [5] D.P. O'Brien e*t al.* (2007) *Icarus* **191**, 434-452. [6] A. Morbidelli *et al.* (2010) *AJ* **140**, 1391-1401. [7] D.A. Minton and R. Malhotra (2010) *Icarus* **207**, 744-757. [8] D.R. Davis *et al.* (1985) *Icarus* **63**, 30-53.