

Early results of the Dawn mission were published as collected papers in issues of *Science* and *Nature*, as listed below:

Science vol. **336**, no. 6082, 11 May 2012; six papers on the geology, lithologic diversity, mineralogy and cratering history of Vesta.

Science vol. **338**, no. 6104, 12 October 2012; two papers on the composition of the Vestan surface and the geology of an unusual terrain.

Nature vol. **491**, no. 7422, 01 November 2012; two papers on an unusual lithology on Vesta and on alteration of the surface characteristics by space weathering.

The GRaND element maps shown in figure 2 are from

Prettyman, T.H., Mittlefehldt, D.W., Yamashita, N., Lawrence, D.J., Beck, A.W., Feldman, W.C., McCoy, T.J., McSween, H.Y., Toplis, M.J., Titus, T.N., Tricarico, P., Reedy, R.C., Hendricks, J.S., Forni, O., Le Corre, L., Li, J.-Y., Mizzon, H., Reddy, V., Raymond, C.A., Russell, C.T., 2012. Elemental Mapping by Dawn Reveals Exogenic H in Vesta's Regolith. *Science* **338**, 242-246.

Yamashita, N., Prettyman, T.H., Mittlefehldt, D.W., Toplis, M.J., McCoy, T.J., Beck, A.W., Reedy, R.C., Feldman, W.C., Lawrence, D.J., Peplowski, P.N., Forni, O., Mizzon, H., Raymond, C.A., Russell, C.T., 2013. Distribution of Iron on Vesta. *Meteoritics & Planetary Science*, in press.

Probing Asteroid (4) Vesta, Part 2: Meteorites From Vesta

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In the early 1970s, asteroid (4) Vesta was shown to have a unique reflectance spectra in the visible to infrared wavelength range and to be similar to the laboratory spectra of a clan of igneous meteorites composed of the groups howardites, eucrites, and diogenites (HEDs). With continued astronomical study, the hypothesis that Vesta is the parent asteroid of the HED clan gained widespread support in the scientific community. At the same time, laboratory studies of the HED meteorites resulted in increasingly detailed models for the geologic evolution of their parent asteroid. In anticipation of the arrival of the Dawn spacecraft at Vesta, I began synergistic studies of two types of HED meteorites, diogenites and howardites.

The consensus view is that Vesta differentiated as a global magma ocean that crystallized upon cooling. This model is derived primarily through matching the compositions of basaltic eucrites with chemical models. Diogenites are igneous rocks that were formed by accumulation of minerals from an intrusive magma body. The major minerals of diogenites are magnesium-rich orthopyroxene and olivine. In the consensus view of Vestan geologic evolution, the diogenites formed prior to basaltic eucrites, and thus diogenite compositions should indicate an earlier stage of magma-ocean crystallization. Curiously, the mineralogies (figure 1) and compositions of diogenites do not easily fit into the consensus model. Diogenites show a wide range of trace element

compositions that are difficult to reconcile with an origin in a single, large-scale magma ocean. Studies performed with colleagues from the University of Tennessee, Rice University, and Kilgore College showed that the compositions of diogenites are more consistent with formation in a series of magmas with different trace element contents. The conundrum raised by this result remains to be resolved and continues to be an area of active research.

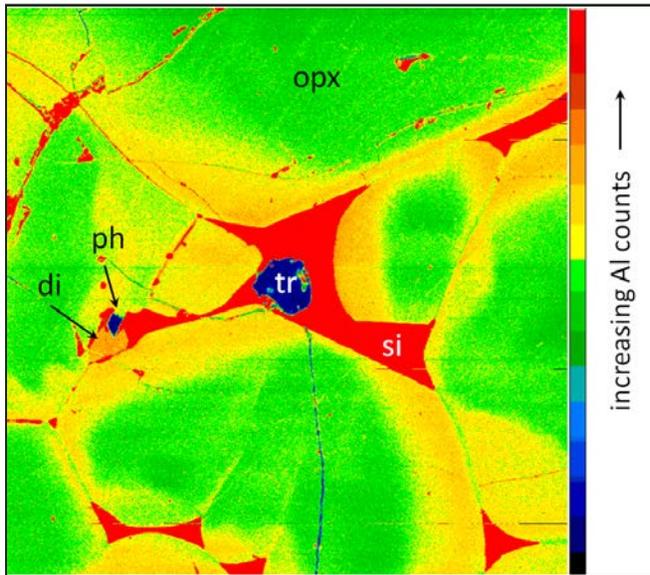


Figure 1.— Aluminum X-ray map of a portion of the diogenite Miller Range 07001. Orthopyroxene (opx) grains have low-Al cores (green) zoned to more Al-rich rims (yellow). Minor phases are the high-Ca pyroxene diopside (di), Ca-phosphate (ph), the iron sulfide troilite (tr), and a silica phase (si) filling the interstices between orthopyroxene grains. The width of the map is 0.5 mm.

Howardites are not igneous rocks. Rather, they are fragmental breccias formed from the debris derived from igneous rocks. All airless bodies in the solar system are covered by fragmental debris engendered by the constant pummeling by meteoroids and asteroids; Vesta is no exception. The fragmental debris layer, or regolith, from Vesta is represented by the howardites. Studies of howardites performed in collaboration with scientists from Franklin and Marshall College; the Max-Planck-Institut für Chemie in Mainz, Germany; and the contractor workforce at JSC should improve understanding of the processes behind the formation and mixing of the Vesta regolith. Through petrologic studies done here, chemical analyses done here and at Franklin and Marshall College, and noble gas analyses done at the Max-Planck-Institut für Chemie, we have identified a subset of howardites that were formed from material from the topmost layer of the regolith that was exposed to the solar wind. We also identified a unique howardite that is composed of roughly equal parts howarditic rock and debris from a carbonaceous chondrite impactor (figure 2). Such rocks inform us of the mixing process acting on Vesta, and understanding their history will help in interpreting data returned by the Dawn spacecraft.

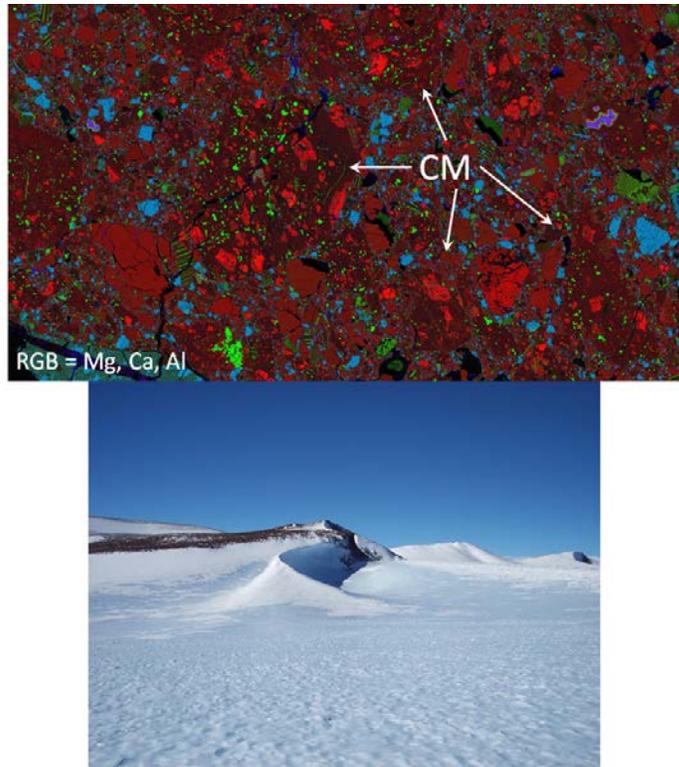


Figure 2.— Upper panel: Elemental X-ray mosaic of howardite Mount Pratt (PRA) 04401 colored using Mg = red, Ca = green, and Al = blue. Roughly 60 percent of the area consists of carbonaceous chondrite clasts (CM), which may be identified by their reddish/brownish-purple matrix. Bright red grains are olivine in CM clasts; the bright green in CM clasts are calcite grains. Light blue grains in the host are HED plagioclase grains. Green-striped grains are HED pyroxenes. The image is 9 mm across. Image acquired and mosaicked by D. K. Ross of Jacobs. Lower panel: Mount Pratt, Antarctica, the find location of PRA 04401. Image by the author, a member of the 2004–2005 Antarctic Search for Meteorites field team that discovered PRA 04401.