Composition of the Rheasilvia basin, a window into Vesta’s interior (McSween et al., 2013)
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In a Sentence: The instruments of the Dawn mission analyzed the Rheasilvia basin for exposed mantle material in the hopes of tying diogenites to the evolution of their parent body, and while diogenite was indeed observed the data does not definitively indicate a formation mechanism.

Main Findings/Methods: The authors use the data from three instruments on the Dawn spacecraft – the Framing Camera (FC) for general geological observations and limited high-resolution spectral measurements, the Visible and Infrared Spectrometer (VIR) for spectral measurements between .25 and 5.1 microm, and the Gamma Ray and Neutron Detector (GRaND), which can also measure compositional variations. One of the main focuses is resolving which of the two formation mechanisms – partial melting of the mantle or fractional crystallization of magma – could have formed the diogenites, both of which are tied to the evolution of Vesta’s mantle.

Figure 4a: A DEM showing Vesta’s southern hemisphere centered on Rheasilvia with 2x vertical exaggeration.
Figure 4b: Clementine color ratios (roughly speaking, green = iron content, blue = high titanium/bright slopes, red = low titanium/high glass content).

The geologic mapping from FC correlates the concentration of diogenite material (found via band depths) with the locations of the lowest topography in the basin. The spectral data from VIR also find widespread occurrence of pyroxene band, confirming the diogenite mapped by the FC. The authors attempted to find different HED spectral areas in and around Rheasilvia, though they had difficulty finding the olivine-rich units they expected when assuming that the mantle was exposed, forcing a reconsideration of the Vestan mantle composition. It is possible that the Vestan upper mantle is composed of more orthopyroxene than olivine, making the olivine signature harder to detect. Furthermore, the authors struggle to match their inferred stratigraphy (that of a thick diogenite unit distributed relatively uniformly) with either crystallization of this unit in a magma ocean or as multiple plutons. The diogenite layer is covered by mass wasting at key locations, making thickness constraints difficult without excessive speculation.

Outstanding Questions: This paper utilized some of the highest-resolution data we have of an asteroid to date, and yet still failed to conclusively answer of the main questions concerning the formation of the body – how good does the data have to be before we can finally get answers?

References for Further Reading:
Vestan lithologies mapped by the visual and infrared spectrometer on Dawn (Ammannito et al., 2013)

Discussion Leader: Alyssa Pascuzzo

**Summary:** The authors present global lithological maps of Vesta based on Dawn spectral data. Their maps confirm that the overall surface is composed of howardite or polymict eucrite, which agrees with both ground and Hubble observations. Detec-
tions of diogenite in topographic lows, excavated by large impacts may suggest and support a magma ocean model for Vesta’s mode of differentiation.

**Important Findings:** Using band center parameters for the two diagnostic pyroxene crystal field splitting absorptions the authors were able to map the distribution of lithologic types based on band center position. They then correlate band center distribution to HED lab spectra to make a global HED distribution map of the surface.

They found that their detections of a howardite dominated surface, which appears mixed with diogenite and eucrite-rich regions, agrees with previous studies from ground and Hubble observations. Thus confirming a fairly thick howardite regolith-megabreccia is present. This occurrence is also consistent with eucrite-rich breccias among other petro-
logical mixtures dominating the HED collection.

Diogenite rich spots are mostly correlated in to-
pographic lows associated with Rheasilvia Basin sug-

gesting that diogenitic material was deeply excavated from the upper mantle/lower crust of Vesta from the large impactor. Diogenite was also detected out-
side of Rheasilvia and could be material related to Rhea-
silvia’s ejecta. This may suggest that the im-

pactor may have been highly inclined on impact re-

sulting in asymmetrical distribution of ejecta.

Basaltic eucrite material is primarily location in the equatorial regions. However, they did not find evidence for olivine-rich regions at equatorial latitude as was hypothesized by Gaffey (1997).

Differentiation of Vesta via a magma ocean sug-

gests Vesta to have a eucritic crust overlying a di-
genite layer (lower crust) with a olivine-rich mantle and metallic core. The observed correlation of di-
genite material in topographic lows, suggesting deep excavation, may support a magma ocean model.

**Outstanding Questions:** Is the asymmetrically distributed diogenitic material, found out side of Rhea-
silvia, in a shape that would be expected for ejecta from an inclined impactor? If not, how else could you get mantle type, diogenitic material distributed outside the basin (e.g. Vesta’s northern hemisphere)?

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**References for Further Readings:**


Curious about Vesta’s shape and morphology? : Jaumann R., et al. 2012. Vesta’s shape and mor-

phology. Science, 336, 687-694

Main Points: The authors use electron and ion microprobe data from olivine, orthopyroxene, and spinel from diogenites to study the metamorphic reequilibration history of trace elements between these minerals. The authors also attempt to reconstruct the petrogenetic relationships between diogenite mineral assemblages to understand the origin of the achondrite QUE 93148.

Fig. 1. Models illustrating the petrogenetic relationships among diogenites, olivine diogenites, and eucrites. A) Serial magmatism model. B) Magma ocean model. C) Mantle and layered intrusions model.

Brief Summary:

- **Formation Hypotheses:** Several models are currently proposed for the origin of diogenites, as illustrated in Fig. 1. The first is the accumulation of orthopyroxene, chromite, and olivine during the crystallization of compositionally distinct basaltic magmas emplaced into the crust of the HED parent body (Fig. 1A). Alternatively, diogenites may have formed via the accumulation of orthopyroxene, chromite, and olivine during the crystallization of a magma ocean during the initial stages of differentiation (Fig. 1B). Finally, the orthopyroxenites may have formed via the crystallization of basaltic magmas within the crust of the HED parent body while the harzburgites formed from the mantle (Fig. 1C).

- **Results and Implications:** Overall the olivines exhibits a range in Mg#. The olivine-orthopyroxene pairs from diogenites experienced varying degrees of subsolidus reequilibration at temperatures between 700 and 1100°C. There are variations in olivine in Ni vs. Co and Ni vs. MnO. Incompatible elements Zr, Yb, and Y systematically increase with Ti for orthopyroxenes. A single process (i.e. a series of layered intrusions or crystallization within a magma ocean) is favored due to the continuous nature of minor and trace element characteristics. A series of layered intrusions is further favored because of the distinct lithologies within polymict diogenites, strong grouping in Ni vs. Co in olivine, and range of incompatible elements.

- **QUE 93148:** Overall, the authors found distinct differences between QUE 93148 and the diogenites, specifically in Ni/Co content in olivine and in the estimated fO2 conditions. They conclude that perhaps the olivine-rich achondrite is more closely related to the main-group pallasites than it is to the HED parent body.

Discussion Questions:

- How can data from the Dawn mission be used to test these origin models?

Further Reading:

*For an invited review of the mineralogy, petrology, chemistry, and petrogenesis of HEDs:*

*For an argument of the magma ocean hypothesis:*