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The composition of Vesta from the Dawn mission

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ABSTRACT

Vesta's surface composition has been of special interest since early, disk-integrated telescopic spectral observations indicated that it is basaltic, differentiated and similar to the HED (howardite–eucrite–diogenite) class of meteorites. The Dawn mission, orbiting Vesta, provided a large and varied set of unique observations on the detailed mineralogy, molecular and elemental composition, and their distributions in association with surface features and geology. The set of articles contained in this special issue is the first treatment of the entire surface composition of Vesta using the complete Dawn Vesta data set and the calibrations from the entire campaign. Most articles treat a region of Vesta within the context of the entire body, but there are several articles that treat global or technical topics. As a whole, these articles provide a current and comprehensive view of Vesta's composition using all the relevant data that is available. Vesta's surface composition is consistent with the upper layer being created by igneous processes, while a more mafic lithology generally associated with a mantle is surprisingly limited. There is evidence of contamination by low velocity infall of several types of objects: dark hydrated/hydroxylated material, and probably Fe/Mg silicates differing from Vesta's. Isolated blocks of differing compositions, seen especially in crater walls, could indicate incomplete melting and mixing during the differentiation process, and retention of some evidence of the original building blocks of the accreted Vesta. This lead article introduces and provides the context for the following articles, presents a summary of the various findings, and integrates them into overall conclusions.

1. Historical knowledge

The global composition of Vesta's surface was known from ground-based telescopic spectral whole-disk observations, before the Dawn spacecraft orbited Vesta in 2012, to be basaltic, rich in the mineral pyroxene, and have mineralogy similar to that of an abundant class of meteorites, the basaltic achondrites (howardites, eucrites, and diogenites – HEDs), suggesting that Vesta was differentiated and could be the source of the HED meteorites (McCord, Adams and Johnson, 1970). Later observations greatly improved the quality of the spectra and confirmed and extended these findings (e.g., McFadden et al., 1977; Feierberg and Drake, 1980; Feierberg et al., 1980; Gaffey, 1997; Binzel et al., 1997; Cochran and Villas, 1998; Reddy et al., 2010). These telescopic observations of the spinning Vesta also showed sub-global compositional variations, which were limited to a differing pyroxene-dominated mineralogy similar to that observed in the HEDs. Based on Vesta being the source of HEDs, laboratory studies of the HEDs were used to infer the evolutionary history of Vesta (e.g., McSween et al., 2011 and references therein). An argument was also developed that a family of other, smaller, objects of similar spectroscopic character are pieces blasted from Vesta (e.g., Binzel and Xu, 1993), suggesting the HED-like composition extends below Vesta's surface. These fragments were seen to extend from Vesta to resonances in the main-belt, revealing the pathway from Vesta to Earth.

2. The Dawn mission context

Dawn (e.g. Russell and Raymond, 2011; Russell et al., 2012) provided the first look at Vesta's surface with spatial resolution sufficient to define detailed surface features, thus providing a dramatic, near-global new dataset for studying Vesta (Fig. 1). As with most first-close-look spacecraft investigations, dramatic improvements in our understanding of Vesta's origin and evolution are now possible. In Fig. 2, Vesta is shown in size context with differentiated, rocky bodies and smaller, fragmented asteroids. Dawn's instrument arsenal is capable of providing much new information about the two most important aspects of a planetary body's surface: (1) surface features, the topographical expressions of surface and

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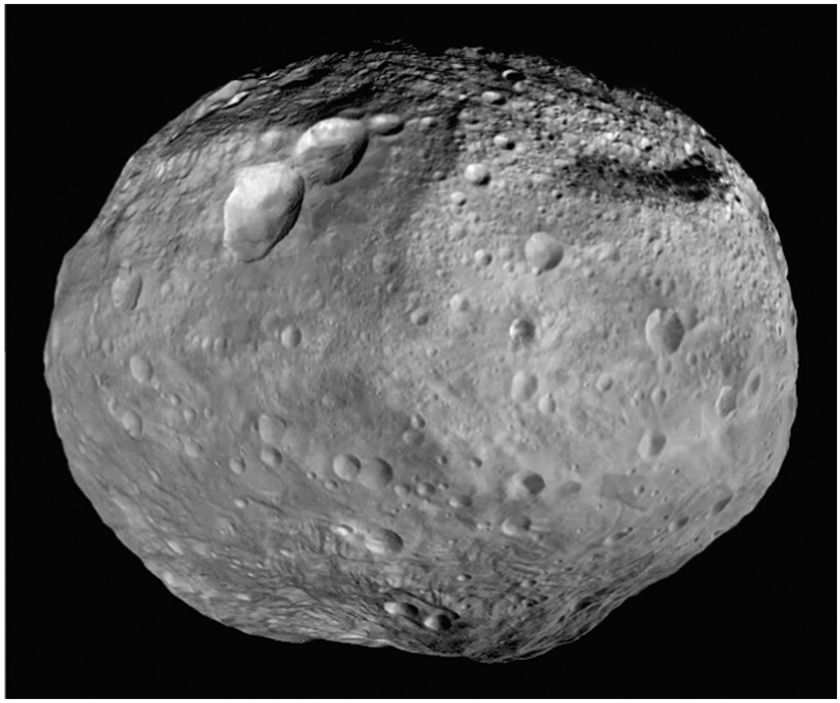

Fig. 1. Overview mosaic of Vesta, made of Framing Camera images taken through the clear filter. This mosaic combines some of the best images taken by the Framing Camera during July 2011 to September 2012. The central mound of the Rheasilvia impact basin can be seen in the bottom right of the image. The large, neighboring craters, Marcia, Calpurnia and Minucia, can be seen in the top left of the image. The Saturnalia Fossae troughs can be seen in the top right of the image. Image credit: NASA/JPL-Caltech/UCLA/MPS/DLR/IDA.

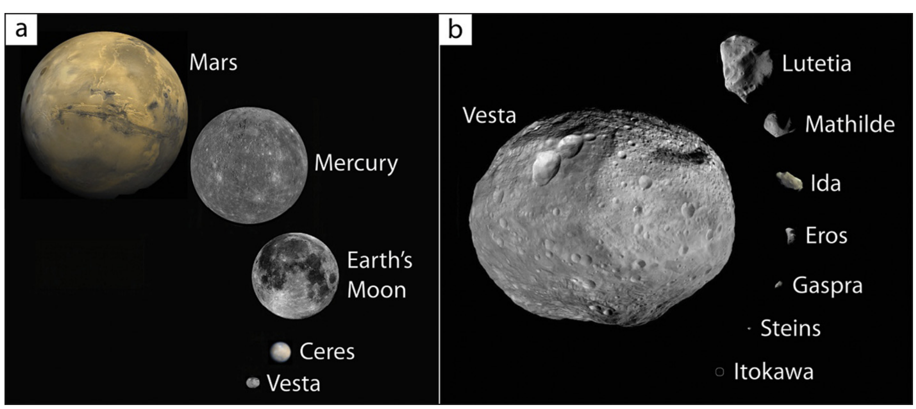

Fig. 2. Vesta's place in the Solar System. (a) The approximate scaled size of Vesta in comparison to larger, differentiated, rocky bodies, and Ceres. Adapted from an image credited to NASA/JPL-Caltech/UCLA. (b) The approximate scaled size of Vesta in comparison to smaller, undifferentiated asteroids. Adapted from an image credited to NASA/JPL-Caltech/JAXA/ESA. Vesta's size and differentiation place it in a intermediate category between the differentiated whole rocky bodies and fragmented objects (e.g. Russell et al., 2013).

interior processes, and (2) composition: mineral, molecular and elemental, resulting from thermochemical processes.

The Framing Camera (FC) (Sierks et al., 2011) provided grayscale and color views of nearly the entire surface, and revealed surface features that include giant impact craters, grooves, ridges, and dark and bright materials (e.g. Jaumann et al., 2012) (Fig. 1). Especially important for this special publication, the FC also enables detailed mapping of some compositional units using the color imagery; although the FC spectral sampling does not allow for detailed analysis of spectral features. For example, FC photometrically corrected reflectance (Fig. 3) and Clementine-type color ratio mosaics (Fig. 4) identify east–west and north–south dichotomies in the surface composition of Vesta, and more diogenitic material is identified in the southern hemisphere (e.g. Reddy et al., 2012a,b). Furthermore, FC color data is critical to interpreting the surface compositions of smaller-scale terrains. For example, these data contribute to the suggestion that 'orange' material in Clementine-type color ratio images is impact melt (Le Corre et al., 2013). In addition, reflectance in the 0.75-μm filter, and ratios using other FC filters, allow for the mapping of dark material, and these data contribute to the interpretation of dark material as exogenic carbonaceous chondrite (e.g. McCord et al., 2012; Reddy et al., 2012b). Framing Camera images are also used to derive global shape models of Vesta (Fig. 5) (Gaskell, 2012; Preusker et al., 2012), which are required to photometrically correct the VIR spectra.

The Gamma Ray and Neutron Detector (GRaND) (Prettyman et al., 2011) mapped elemental composition on a regional to global