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Dawn's Exploration of Vesta and Ceres

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Abstract

Dawn has revealed Vesta and Ceres to be unique, diverse fossils from the earliest epoch of our solar system. Vesta appears to be a surviving archetype of a differentiated, volatile-poor protoplanet, while Ceres is rich in volatiles. Ceres, the only dwarf planet in the inner solar system, bears affinity to outer solar system bodies.

1. Introduction

The Dawn mission launched in 2007 on a history-making ion-propelled journey to visit the two most massive bodies in the main asteroid belt and learn about the conditions and processes that shaped the early solar system. Dawn entered orbit around Vesta in July 2011 and explored the protoplanet for 14 months using its framing camera (FC), visible-infrared spectrometer (0.4-5µm; VIR), gamma-ray and neutron detector (GRaND) and by mapping the topography and gravity. Dawn recently completed its comprehensive mapping of Ceres and has since completed an extended mission. The main results and implications of the investigations of these two bodies, shown in Figure 1, are described below.

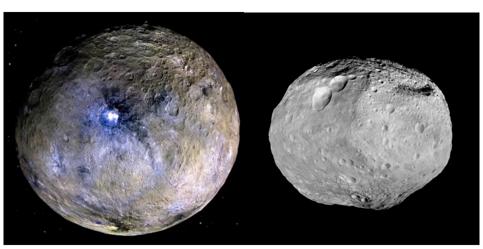

Figure 1: Left: A false color rendering of Ceres (~940-km avg diameter), draped on topography; Right: A gray-scale mosaic of Vesta (~530-km avg diameter) draped on topography.

2. Dawn at Vesta

Prior to Dawn's arrival, much had been inferred about Vesta's evolution from study of the HED meteorites, for which Vesta was the presumed parent. Dawn confirmed the Vesta-HED connection via surface lithologic mapping using VIR spectra [1, 2] and elemental chemistry from GRaND [3, 4], that showed most of the vestan surface is composed of howardite-like material with localized enrichments of eucrite and diogenite (Figure 2). A 110-km iron core was inferred from gravity and shape data, consistent with HED predictions [5]. While Vesta was found to be differentiated, as predicted by the HED paradigm, it appears to have experienced a complex magmatic history that resulted in lithologic diversity [e.g., 6]. Unexpectedly, broad, dark regions shown to be hydrogen-rich by GRaND [3] that also exhibit an OH absorption feature at 2.8 µm in VIR spectra [7], are interpreted to result from a few % of exogenic CM carbonaceous chondrite mixed into the regolith [8, 9]. Dawn also found pitted terrains [10] in young craters interpreted to be the result of outgassing of volatile-rich material, and gullies [11] thought to result from transient flow of water, both associated with impact processes. The discovery of hydrated material on Vesta's surface implies that delivery of volatiles to the inner solar system by primitive asteroids was an important process.

3. Dawn at Ceres

Prior to Dawn's arrival, Ceres was already known to be a dark, wet dwarf planet with evidence for altered minerals and water vapor emissions, from decades of ground- and space-based observations, and was thought to be at least partially differentiated. Dawn arrived at Ceres in March 2015 and found a heavily-cratered very dark surface that was punctuated by isolated, extremely bright areas [12]. This contradicted pre-Dawn model predictions of an ice-rich, viscously-relaxed smooth surface. Ceres is shown to have a mechanically strong crust and is gravitationally relaxed at long wavelengths, implying that the strong crust overlies a weaker interior [13, 14]. Compositionally, Ceres' surface is dominated by dark material, ammoniated Mg-phyllosilicates, and carbonates [15-17]. The ubiquitous presence of ammoniated material (Figure 3) suggests formation in a colder environment, possibly in the outer solar system, while the overall mineralogy indicates Ceres' interior experienced pervasive alteration. Water ice has been observed in fresh craters at high latitudes, and elemental measurements indicate a shallow ice table [18]. These observations, along with Ceres gravity field [19] confirm that Ceres at least partially differentiated, providing evidence for an ancient subsurface ocean that may persist to the present. Local morphology such as crater floor deposits, isolated mountains and the enigmatic bright areas indicate active processes on Ceres that likely involve brine-driven cryovolcanism [20].

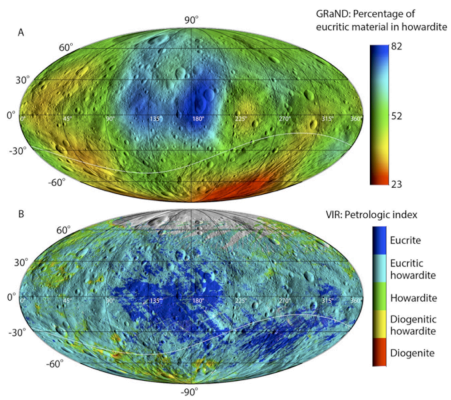

Figure 2. The distribution of Howardite, Eucrite and Diogenite on Vesta, as mapped by GRaND (top) and VIR (bottom).

4. Summary and Conclusions

Vesta is the parent body of the HEDs. It formed early from volatile-poor material with live Al^{26} and underwent a complex magmatic and geologic evolution. Ceres likely formed contemporaneously from volatile-rich material, partially differentiated, and underwent extensive aqueous alteration that moderated internal temperature. Ceres appears to have geologic activity at present. Radial mixing in the protoplanetary disk is evidenced in the history of these two sibling protoplanets.

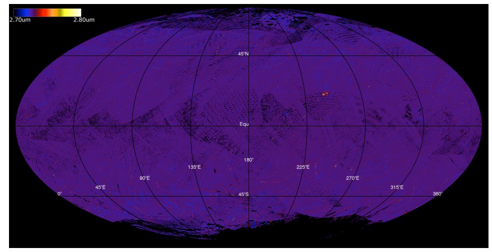

Figure 3. The band center map of Ceres in range 2.7-2.8 microns shows the nearly ubiquitous presence of ammoniated phyllosilicates across the surface [17].

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References

[1] De Sanctis M. C. *et al.* (2012), *MAPS, 48*. [2] Ammannito E. *et al.* (2013), *MAPS, 48*. [3] Prettyman T. H. *et al*. (2012), *Science*, *338*. [4] De Sanctis M. C. *et al.* (2012), *ApJ, 758*. [5] Raymond, C. A. *et al.* (2017), *Planetesimals*. Russell, C. T. *et al.* (2012), *Science*, *336*. [7] Prettyman T. H. *et al.* (2013), *MAPS, 48*. [8] McCord T. B. *et al.* (2012), *Nature, 291*. [9] Reddy V. e*t al.* (2012), *Icarus, 221*. [10] Denevi B. W. *et al*. (2012), *Science*, *338*. [11] Scully J.E.C. *et al.* (2015), *EPSL, 411*. [12] Russell C. T. *et al*. (2016), *Science*, *353*. [13] Bland M. T. *et al*. (2016), *Nat Geo*, *9*. [14] Fu, R. R. *et al.* (2017), *EPSL, in press.* [15] De Sanctis, M.C. e*t al.* (2015), *Nature*, *528*. [16] De Sanctis, M.C. e*t al.* (2015), *Nature*, *536*. [17] Ammannito *et al*. (2016), *Science*, *353*. [18] Prettyman T. H. *et al*. (2016), *Science*, *doi:10.1126/science.aah6765*. [19] Park R. S. *et al*. (2016), *Nature, 537*. [20] Ruesch, O. *et al.* (2016), *Nature, 353.*