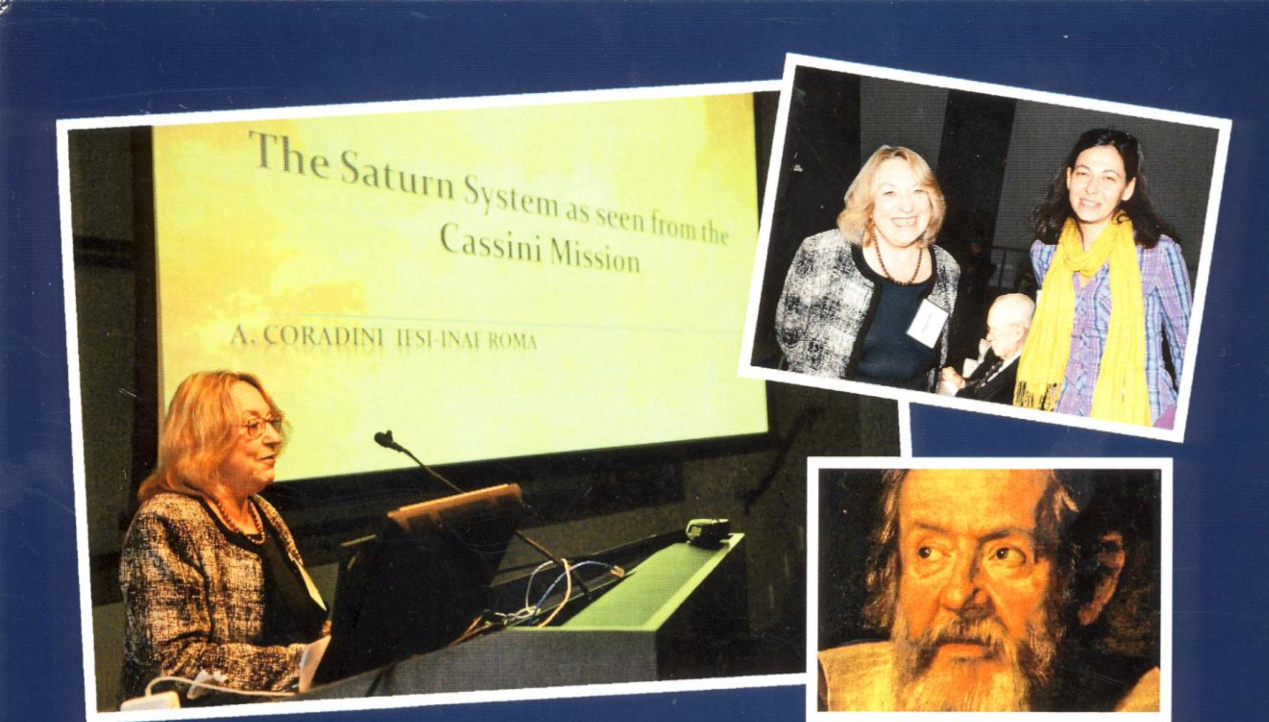
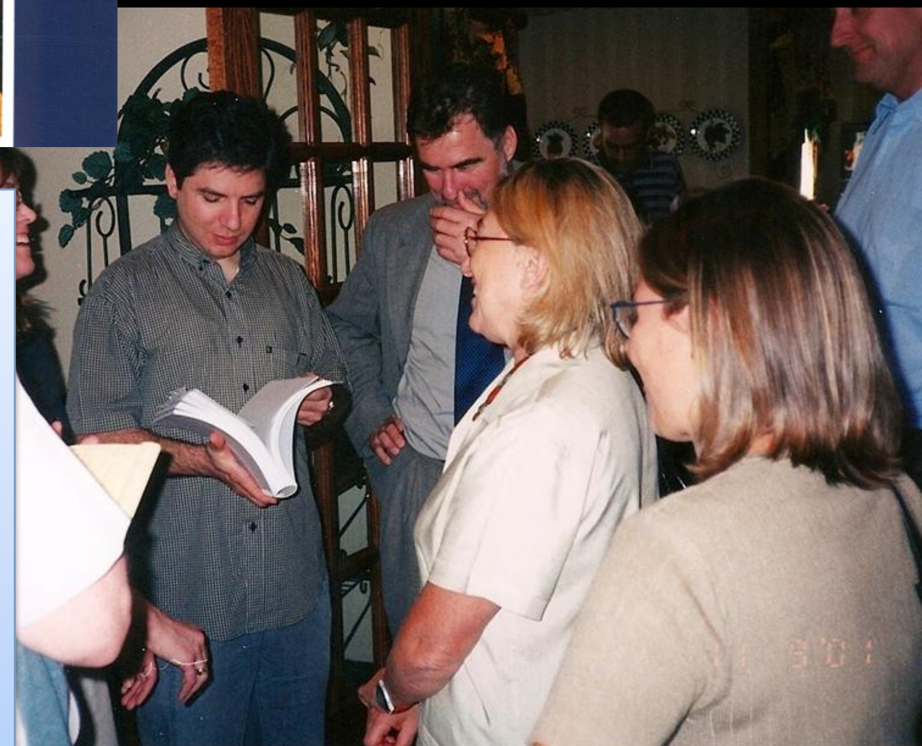
M.C. De Sanctis, E. Ammannito, M.T. Capria, F. Capaccioni, G. Magni, F. Tosi, A. Frigeri, F. Zambon, E. Palomba, S. Fonte , F. Carraro, D. Turrini, L.Giacomini, M. Farina, M. Formisano



Dawn's goal is to characterize the conditions and processes of the solar system's earliest epoch.

First DAWN meeting: Washington, 11 settembre 2001



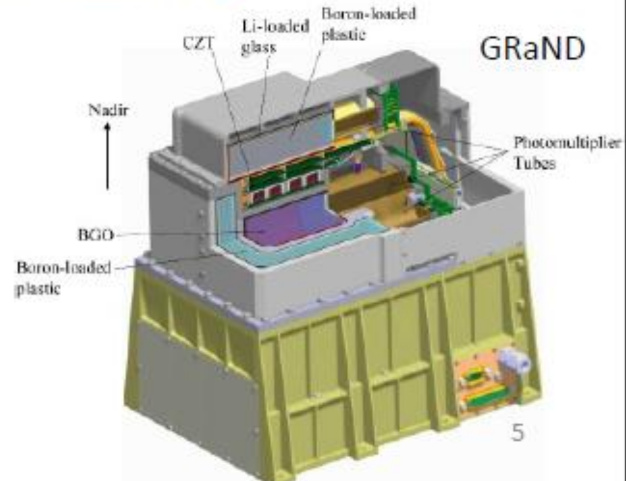
Angioletta was awarded **David Bates Medal**: "In recognition of her important and wide ranging work in planetary sciences and **Solar System formation**, and her leading role in the development of **space infrared instrumentation for planetary exploration**"

Dawn Objectives

- Dawn focuses on two of the first bodies formed in the solar system, the surviving protoplanets, Ceres and Vesta
- These bodies are complementary:
  - Ceres has a very primitive surface, water-bearing minerals, and possibly a very weak atmosphere and frost.
  - Vesta was supposed to be a dry, differentiated body (core, mantle and crust) whose surface has been resurfaced by basaltic lava possibly possessing an early magma ocean like the Moon.
  - **Vesta is the oldest body of the solar system**

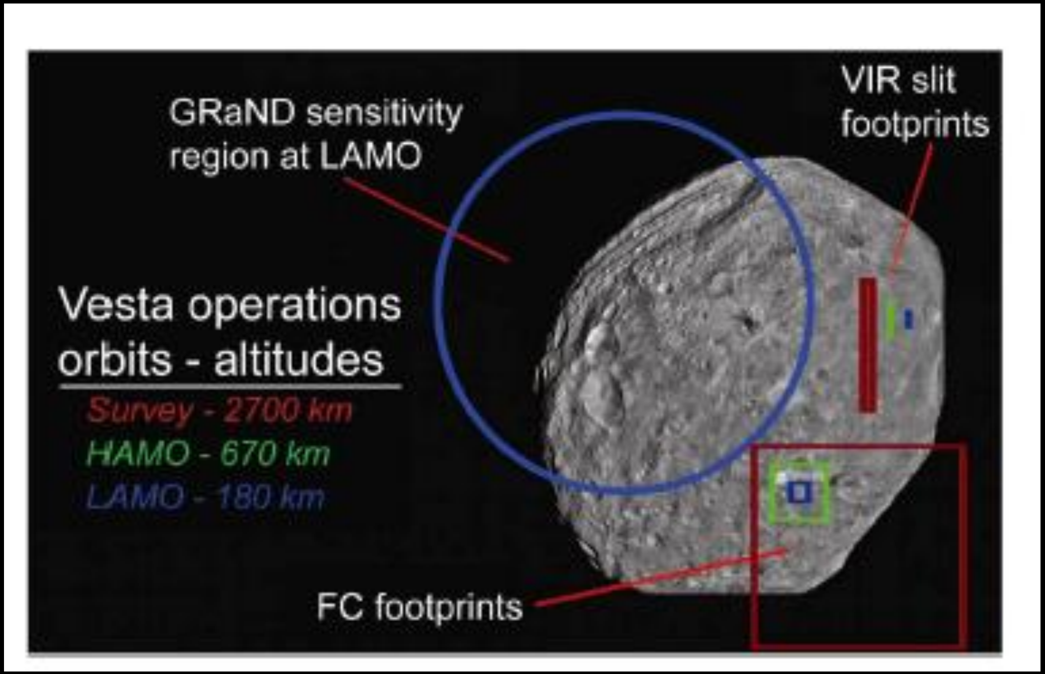
Dawn's Payload

- Two redundant framing cameras (1024 x 1024 pixels, and 7 color filters plus clear) provided by Germany (MPS and DLR)
- A visible and infrared mapping spectrometer (UV to 5 microns) provided by Italy (INAF and ASI)
- A Gamma Ray and Neutron Detector built by LANL and operated by PSI
- A Radio Science Package provides gravity information
- Topographic model derived from off-nadir imaging



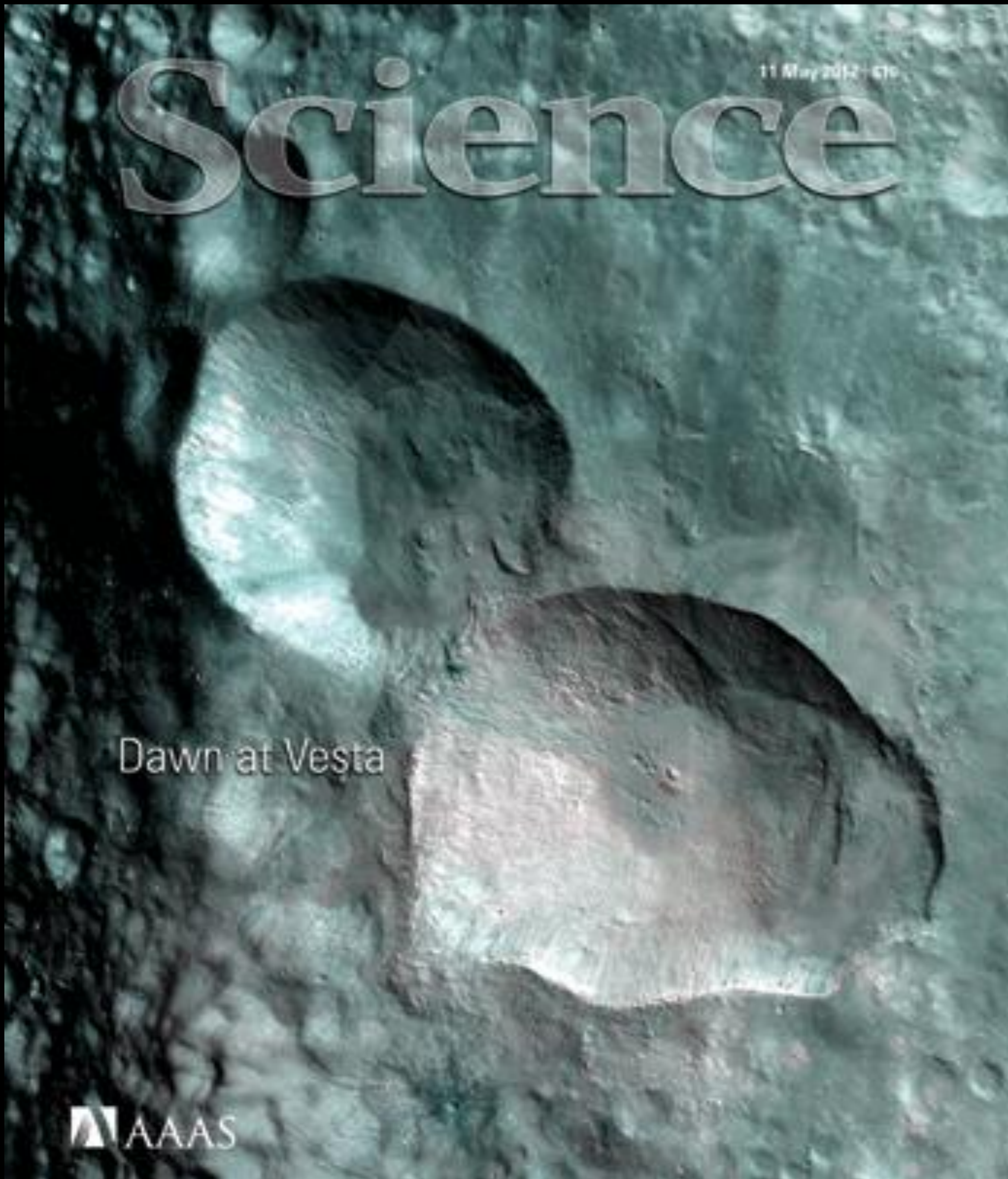
Mission Status

- Dawn acquired Vesta data from June 2011 to August 2012, at different altitudes
- It is now in its way to Ceres, where it will arrive during the summer 2014



Vesta VIR data

- Spectral range 0.25-5.1 micron
- 864 spectral channels
- Spatial resolution from 1.3 km to 70 m
- >20.000.000 spectra



MAIN RESULTS

6 papers in Science, May 11th, 2012

2 papers in Science, October 16th, 2012

1 paper in ApJLett, October 20th, 2012

2 papers in Nature, November 1st, 2012

Dawn at Vesta: Testing the Protoplanetary Paradigm

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The Dawn spacecraft targeted 4 Vesta, believed to be a remnant intact protoplanet from the earliest epoch of solar system formation, based on analyses of howardite-eucrite-diogenite (HED) meteorites that indicate a differentiated parent body. Dawn observations reveal a giant basin at Vesta's south pole, whose excavation was sufficient to produce Vesta-family asteroids (Vestoids) and HED meteorites. The spatially resolved mineralogy of the surface reflects the composition of the HED meteorites, confirming the formation of Vesta's crust by melting of a chondritic parent body. Vesta's mass, volume, and gravitational field are consistent with a core having an average radius of 107 to 113 kilometers, indicating sufficient internal melting to segregate iron. Dawn's results confirm predictions that Vesta differentiated and support its identification as the parent body of the HEDs.

Meteoritic evidence indicates that Vesta probably formed within 2 million years of the first condensation of solids within the nebula of gas and dust that became our solar system (*1*). Short-lived radioactive nuclides, ^{26}Al and ^{60}Fe, were present in these first few million years (*2*), trapping heat inside objects accreting at that time. Bodies that formed very early and incorporated the live radioactive material should have melted and differentiated (*3*), whereas bodies of a slightly younger age may not have. These early-forming objects, both differentiated and undifferentiated, are considered to be protoplanets and constitute the material that coalesced to form the terrestrial planets. Determining whether Vesta was a surviving protoplanet became the objective of Dawn, NASA's ninth Discovery mission, designed to orbit successively the two most massive survivors from the earliest days of the solar system, 4 Vesta and 1 Ceres. On 27 September 2007, Dawn began its 4-year trip to Vesta. After a Mars gravity assist in February 2009, Dawn reached Vesta on 16 July 2011 and slipped into orbit with no critical injection burn.

Vesta is substantially larger than anybody encountered by previous reconnaissance missions within the main asteroid belt (Fig. 1), be an intact original protoplanet that has survived the collisional environment of the asteroid belt since its formation over 4.56 billion years ago. Vesta has been identified as the source of a very common class of meteorites, the howardite-eucrite-diogenites (*5*), which make up ~6% of the meteorites seen to fall on Earth. These meteorites appear to have been liberated from the crust and possibly the mantle of a small differentiated body. Unlike the explorations of the Moon, Mercury, Mars, and Venus, which were undertaken initially without prior knowledge of the target's composition, our exploration of Vesta begins with a rich petrologic and geochemical understanding. Dawn will be providing the geological context for this insight.

Dawn arrived in vestan southern summer, allowing a complete survey of the south polar region. Rheasilvia, a giant impact basin (*6*), dominates this region. Its large central peak is higher than Mauna Kea on Hawaii (with respect to the underlying ocean floor) and rivals the height of Olympus Mons on Mars (Fig. 2). This impact alone could have liberated most of the material that composes the Vestoids, which display orbits and reflectance spectra similar to those of Vesta (*7*, *8*), possibly as recently as 1 billion years ago (*9*). The giant Rheasilvia impact has resulted in a strong dichotomy between the northern and southern hemispheres, reflected in surface albedo and crater densities, but did not erase evidence of an older, underlying large impact basin, possibly providing an earlier additional source of HEDs.

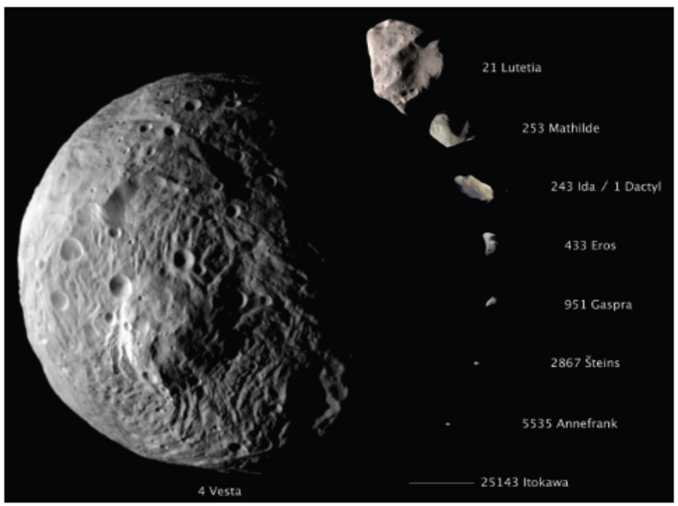

Fig. 1. Collage of Vesta in comparison with other asteroids visited to date for which good images exist. This south polar view of Vesta shows the south pole mountain and the Rheasilvia impact basin surrounding this central peak.

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- Vesta is a small planet
- Dawn observations reveal two giant basins at Vesta's south pole, whose excavation was sufficient to produce Vesta-family asteroids (Vestoids) and HED meteorites.
- VIR mineralogy of the surface reflects the composition of the HED meteorites, confirming the formation of Vesta's crust by melting of a chondritic parent body.
- Vesta's mass, volume, and gravitational field are consistent with an Iron core .
- Dawn's results confirm predictions that Vesta differentiated and support its identification as the parent body of the HEDs.

DAWN NASA UCLA JPL Orbital asi agenzia spaziale italiana DLR INAF MPS

Vesta's Shape and Morphology

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B. W. Denevi,[4] M. C. De Sanctis,[9] W. B. Garry,[5] H. U. Keller,[10] E. Kersten,[1] K. Kr
S. Marchi,[12] K. D. Matz,[1] T. B. McCord,[13] H. Y. McSween,[14] S. C. Mest,[5] D. W. M
S. Mottola,[1] A. Nathues,[7] G. Neukum,[2] D. P. O'Brien,[5] C. M. Pieters,[16] T. H. Pr
C. A. Raymond,[8] T. Roatsch,[1] C. T. Russell,[17] P. Schenk,[18] B. E. Schmidt,[19] F. S
K. Stephan,[1] M. V. Sykes,[5] P. Tricarico,[5] R. Wagner,[1] M. T. Zuber,[20] H. Sierks[7]

Vesta's surface is characterized by abundant impact craters, some with preserved e
large troughs extending around the equatorial region, enigmatic dark material, an
mass wasting, but as yet an absence of volcanic features. Abundant steep slopes i
impact-generated surface regolith is underlain by bedrock. Dawn observations con
impact basin (Rheasilvia) at Vesta's south pole and reveal evidence for an earlier,
large basin (Veneneia). Vesta's geology displays morphological features characteris
and terrestrial planets as well as those of other asteroids, underscoring Vesta's un
transitional solar system body.

Comparative Planetology: Terrestrial Planetary Processes

- While Vesta is much smaller than any terrestrial body, it has features and processes reminiscent of them.
- Some terrain on Vesta resembles that on Mars and that on Mercury.
- Relief of the surface relative to its radius is greater on Vesta.
- Vesta has an older surface in general.
- Can we see past the late heavy
Vesta?

Vesta, Ceres, the Moon, Mercury, and Mars

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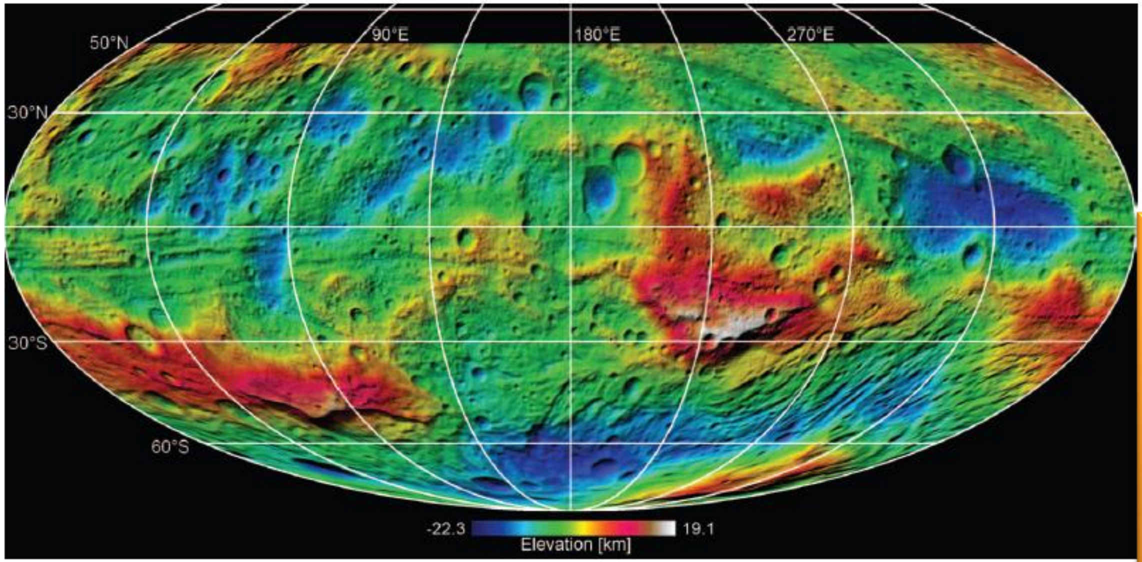
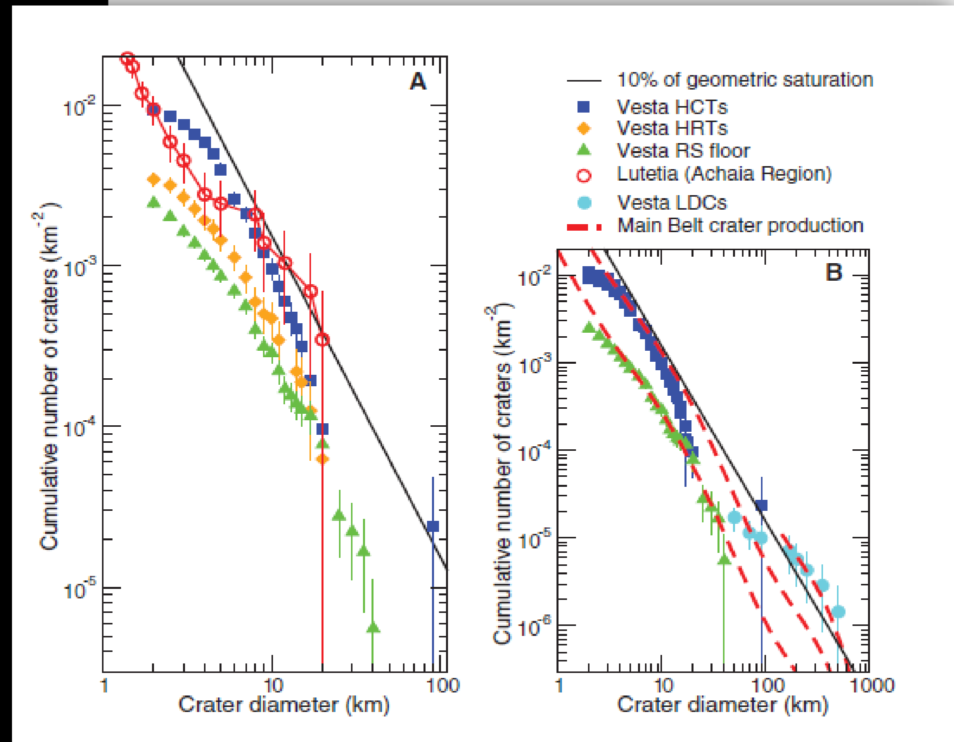


Fig. 1. Global colorized hill-shaded digital terrain model in Mollweide projection (equal area).

Vesta's geology displays morphological features characteristic of the Moon and terrestrial planets as well as those of other asteroids, underscoring Vesta's unique role as a transitional solar system body.

Vesta Collisional History

- Vesta accreted within the first few million years after the formation of the earliest solar system solids.
- Results show that Vesta's cratering record has a strong north-south dichotomy.
- Vesta's northern heavily cratered terrains retain much of their earliest history.
- The southern hemisphere was reset, however, by two major collisions in more recent times.



et al., Space Sci. Rev. 163, 329
., Science 336, 684 (2012).
, Space Sci. Rev. 163, 77 (2011).
itional materials are available as
aterials on Science Online.
l., Icarus 128, 88 (1997).
R. McGetchin, Icarus 18, 612 (1973).
l., Science 277, 1492 (1997).
cience 336, 690 (2012).
ug, Geophys. Res. Lett. 38, L01102
Icarus 120, 158 (1996).
sis, UCLA, Los Angeles, CA (2011).
a thickness is estimated by multiplying
o-diameter ratio with the bin width
ater sizes at which the slope of the
istribution curve is changing because
. S1).
, Icarus 155, 51 (2002).
enberg, C. R. Chapman, M. T. Zuber,
Sci. 37, 1095 (2002).
. C. Thomas, J. Veverka, S. Murchie,
413, 396 (2001).
Sykes, Space Sci. Rev. 163, 41 (2011).
. W. Mittlefehldt, A. W. Beck,
McCoy, Space Sci. Rev. 163, 141 (2011).
Meteorit. Planet. Sci. 32, 813

thank the Dawn team for the
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impact melt, dust levitation and transport, seismic shaking, or slumping of fine material.

Dark material is common on Vesta; it is locally concentrated and mostly associated with impacts (fig. S2). Dark material is either exogenic in origin because of carbon-rich material from low-velocity impactors (18) (i.e., from the impact of a carbonaceous chondrites) or endogenic because of freshly exposed mafic material or impact melt locally mixed into the subsurface and excavated by later impacts. Dark material on Vesta can be divided into four major geomorphologic classes (6): material emanating from the rims or walls of impact craters or running downslope in fans into the crater and on the crater floor because of mass wasting processes; dark material associated with crater ejecta patches or continuous ejecta blankets; material associated with hill flanks and related to impacts on hills; and clusters of dark spots and extended linear dark features. Dark material exposed by impact excavation often shows fine structures indicating a spotty admixture within the regolith. Deposits of dark material are unevenly distributed across Vesta's surface. The major regions with dark material are at about 110°E to 160°E and 10°S to 10°N, 170°E to 225°E and 10°S to

The Violent Collisional History of Asteroid 4 Vesta

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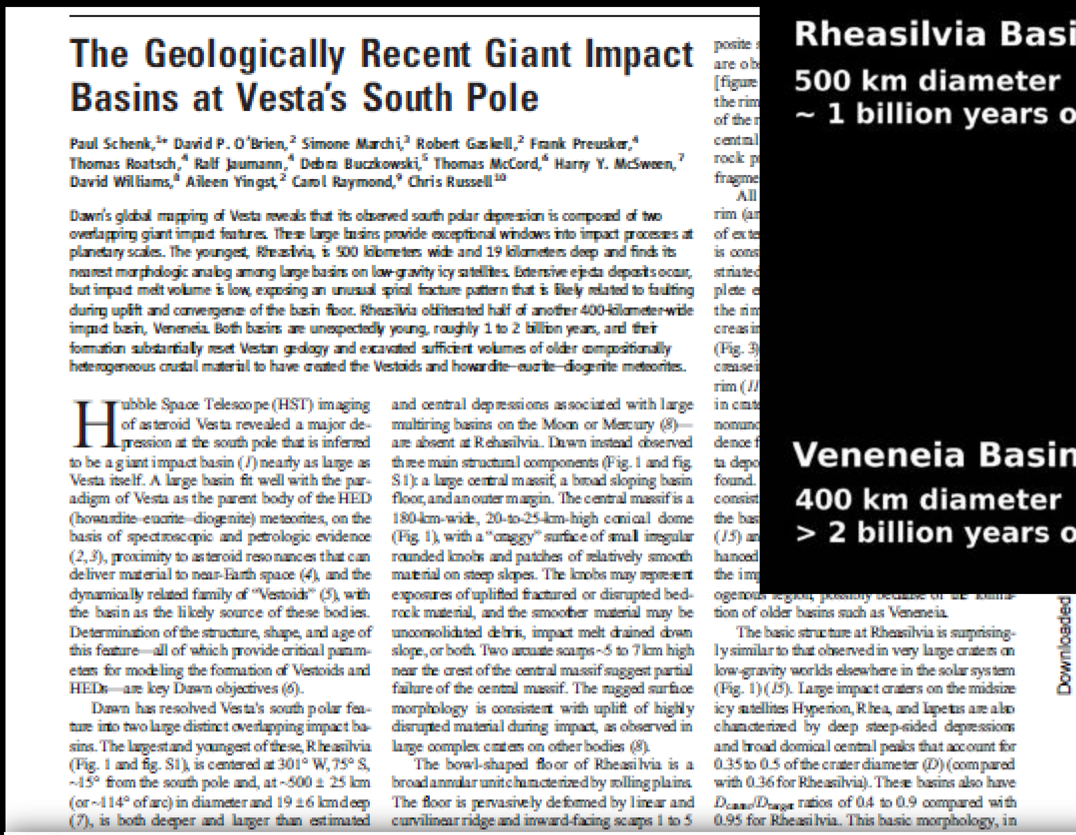
Vesta is a large differentiated rocky body in the main asteroid belt that accreted within the first few million years after the formation of the earliest solar system solids. The Dawn spacecraft extensively imaged Vesta's surface, revealing a collision-dominated history. Results show that Vesta's cratering record has a strong north-south dichotomy. Vesta's northern heavily cratered terrains retain much of their earliest history. The southern hemisphere was reset, however, by two major collisions in more recent times. We estimate that the youngest of these impact structures, about 500 kilometers across, formed about 1 billion years ago, in agreement with estimates of Vesta asteroid family age based on dynamical and collisional constraints, supporting the notion that the Vesta asteroid family was formed during this event.

Asteroid 4 Vesta is the second most massive body in the main asteroid belt, and, according to models (1–5), its early evolution occurred in an environment where collisions with other asteroids were much more frequent than they are today. One notable feature emerging from early observations of the Dawn mission (6) is that the surface of Vesta is dominated at all scales by impact craters. Dawn's framing camera extensively imaged Vesta during its survey phase, at an altitude of ~2700 km. These data have been used to build a global



The Geologically Recent Giant Impact Basins at Vesta's South Pole

Paul Schenk,[1]* David P. O'Brien,[2] Simone Marchi,[3] Robert Gaskell,[2] Frank Preusker,[4] Thomas Roatsch,[4] Ralf Jaumann,[4] Debra Buczkowski,[5] Thomas McCord,[6] Harry Y. McSween,[7] David Williams,[8] Aileen Yingst,[2] Carol Raymond,[9] Chris Russell[10]

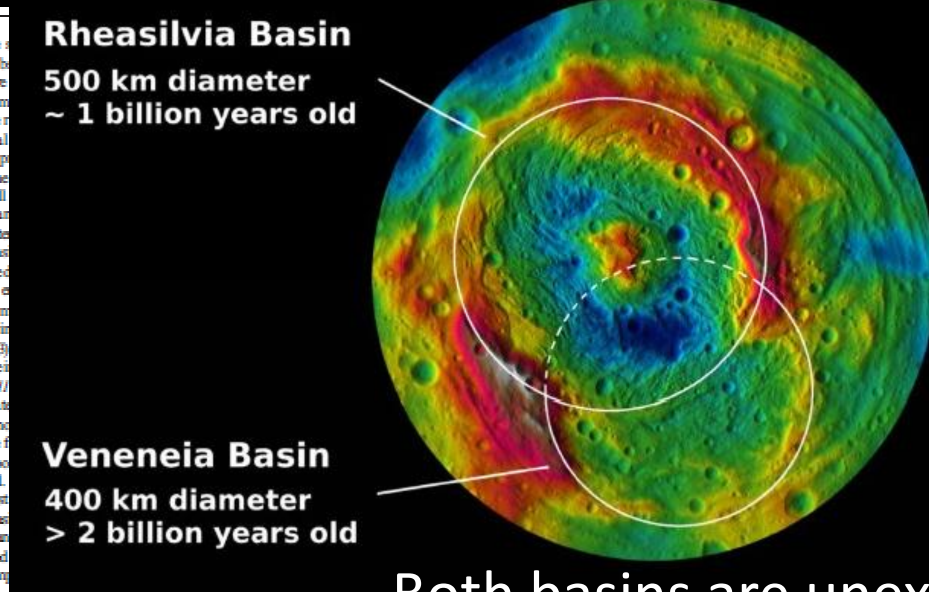
Dawn's global mapping of Vesta reveals that its observed south polar depression is composed of two overlapping giant impact features. These large basins provide exceptional windows into impact processes at planetary scales. The youngest, Rheasilvia, is 500 kilometers wide and 19 kilometers deep and finds its nearest morphologic analog among large basins on low-gravity icy satellites. Extensive ejecta deposits occur, but impact melt volume is low, exposing an unusual spiral fracture pattern that is likely related to faulting during uplift and convergence of the basin floor. Rheasilvia obliterated half of another 400-kilometer-wide impact basin, Veneneia. Both basins are unexpectedly young, roughly 1 to 2 billion years, and their formation substantially reset Vestan geology and excavated sufficient volumes of older compositionally heterogeneous crustal material to have created the Vestoids and howardite–eucrite–diogenite meteorites.

Hubble Space Telescope (HST) imaging of asteroid Vesta revealed a major depression at the south pole that is inferred to be a giant impact basin (1) nearly as large as Vesta itself. A large basin fit well with the paradigm of Vesta as the parent body of the HED (howardite–eucrite–diogenite) meteorites, on the basis of spectroscopic and petrologic evidence (2, 3), proximity to asteroid resonances that can deliver material to near-Earth space (4), and the dynamically related family of "Vestoids" (5), with the basin as the likely source of these bodies. Determination of the structure, shape, and age of this feature—all of which provide critical parameters for modeling the formation of Vestoids and HEDs—are key Dawn objectives (6).

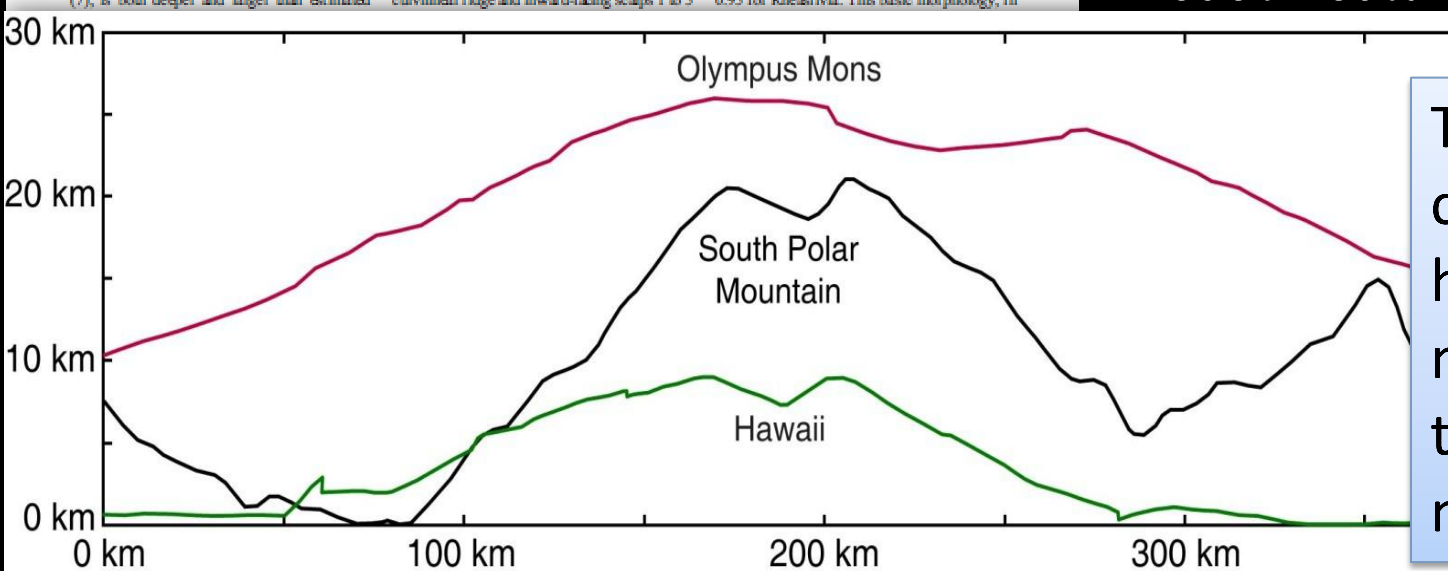
Dawn has resolved Vesta's south polar feature into two large distinct overlapping impact basins. The largest and youngest of these, Rheasilvia (Fig. 1 and fig. S1), is centered at 301° W, 75° S, ~15° from the south pole and, at ~500 ± 25 km (or ~114° of arc) in diameter and 19 ±6 km deep (7), is both deeper and larger than estimated and central depressions associated with large multiring basins on the Moon or Mercury (8)—are absent at Rehasilvia. Dawn instead observed three main structural components (Fig. 1 and fig. S1): a large central massif, a broad sloping basin floor, and an outer margin. The central massif is a 180-km-wide, 20-to-25-km-high conical dome (Fig. 1), with a "craggy" surface of small irregular rounded knobs and patches of relatively smooth material on steep slopes. The knobs may represent exposures of uplifted fractured or disrupted bedrock material, and the smoother material may be unconsolidated debris, impact melt drained down slope, or both. Two arcuate scarps ~5 to 7 km high near the crest of the central massif suggest partial failure of the central massif. The rugged surface morphology is consistent with uplift of highly disrupted material during impact, as observed in large complex craters on other bodies (8).

The bowl-shaped floor of Rheasilvia is a broad annular unit characterized by rolling plains. The floor is pervasively deformed by linear and curvilinear ridge and inward-facing scarps 1 to 5

The basic structure at Rheasilvia is surprisingly similar to that observed in very large craters on low-gravity worlds elsewhere in the solar system (Fig. 1) (15). Large impact craters on the midsize icy satellites Hyperion, Rhea, and Iapetus are also characterized by deep steep-sided depressions and broad domical central peaks that account for 0.35 to 0.5 of the crater diameter (D) (compared with 0.36 for Rheasilvia). These basins also have D_{cano}/D_{target} ratios of 0.4 to 0.9 compared with 0.95 for Rheasilvia. This basic morphology, in



Both basins are unexpectedly young, roughly 1 to 2 billion years, and their formation substantially reset Vestan geology



They excavated older compositionally heterogeneous crustal material that created the Vestoids and HED meteorites

Spectroscopic Characterization of Mineralogy and Its Diversity Across Vesta

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The mineralogy of Vesta, based on data obtained by the Dawn spacecraft's visible and infrared spectrometer, is consistent with howardite-eucrite-diogenite meteorites. There are considerable regional and local variations across the asteroid: Spectrally distinct regions include the south-pola Rheasilvia basin, which displays a higher diogenitic component, and equatorial regions, which show a higher eucritic component. The lithologic distribution indicates a deeper diogenitic crust exposed after excavation by the impact that formed Rheasilvia, and an upper eucritic crust. Evidence for mineralogical stratigraphic layering is observed on crater walls and in ejecta. This broadly consistent with magma-ocean models, but spectral variability highlights local variations, which suggests that the crust can be a complex assemblage cumulates. Overall, Vesta mineralogy indicates a complex m differentiated crust and mantle.

The lithologic distribution indicates a deeper diogenitic crust, exposed after excavation by the impact that formed Rheasilvia, and an upper eucritic crust.

This is broadly consistent with magma-ocean models, but spectral variability highlights local variations, which suggests that the crust can be a complex assemblage of eucritic basalts and pyroxene cumulates.

Telescopic visible and near-infrared spectroscopy shows that the asteroid Vesta has a basaltic surface dominated by the spectral signature of pyroxene. Vesta spectra show many similarities to those of howardite-eucrite-diogenite (HED) meteorites (*1*), leading to the consensus that Vesta is differentiated and is the parent body of the HED achondrites (*2*–*4*). Nu-

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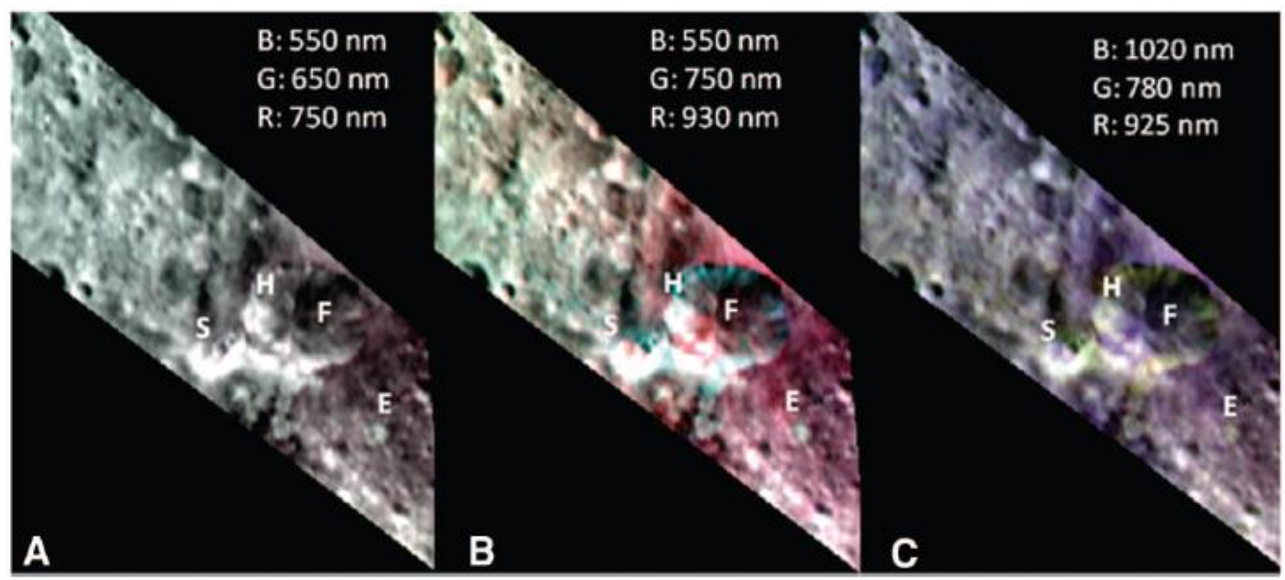
Fig. 1. (To malized at and B indi age. (Top r posite (*red* 0.62 μm, *b* tial resoluti indicates th Average V ±1 SD of t between 2 been remo not yet ful region.

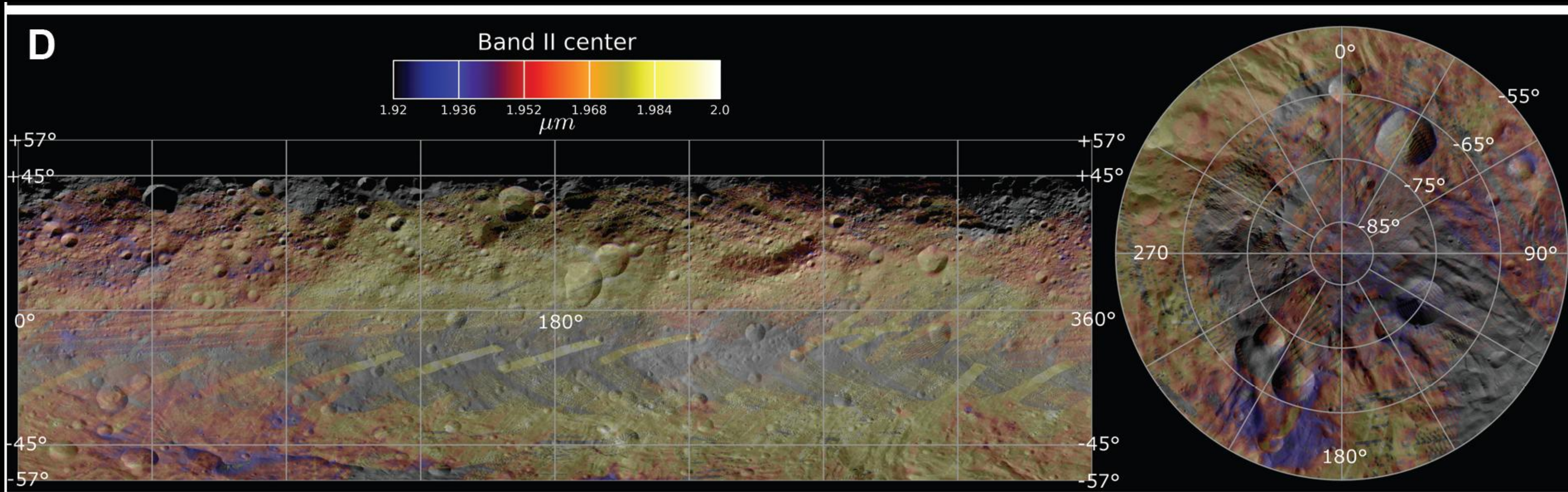
and serial magmatism (*11*–*14*). The spatial dis-



1.9 µm band center distribution

Blue diogenite – Yellow eucrite

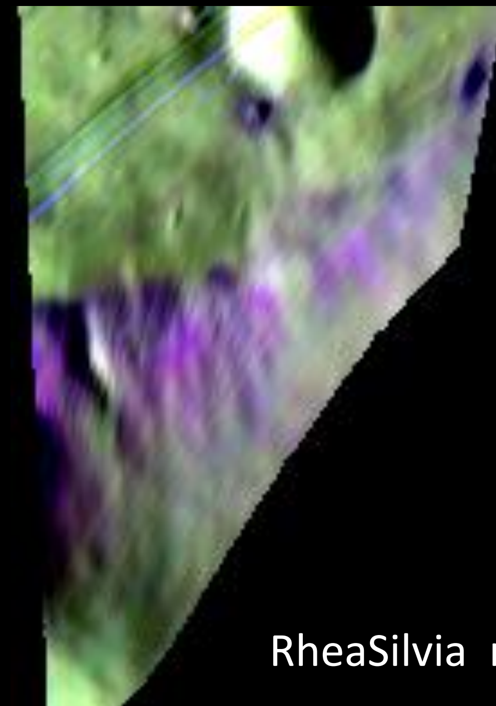
Vesta mineralogy indicates a complex magmatic evolution that led to a differentiated crust and mantle.



De Sanctis et al., Science, 2012

Local stratigraphy

- Clear different material exposed on the slopes
- Lithological differences in the stratigraphy
- The scale of spectral variation indicates that Vesta's crust is compositionally variable at scales from a few hundred meters to tens of km



RheaSilvia rim

Violet: deeper band depths
Green : shallower band depths

The Astrophysical Journal Letters, 758:L36 (5pp), 2012 October 20
doi:10.1088/2041-8205/758/2/L36

DETECTION OF WIDESPREAD HYDRATED MATERIALS ON VESTA BY THE VIR IMAGING SPECTROMETER ON BOARD THE *DAWN* MISSION

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F. Capaccioni[1], M. T. Capria[1], D. W. Mittlefehldt[4], C. M. Pieters[5], J. Sunshine[6], F. Tosi[1], F. Zambon[1],
S. Fonte[1], A. Frigeri[1], G. Magni[1], C. A. Raymond[7], C. T. Russell[8], and D. Turrini[1]
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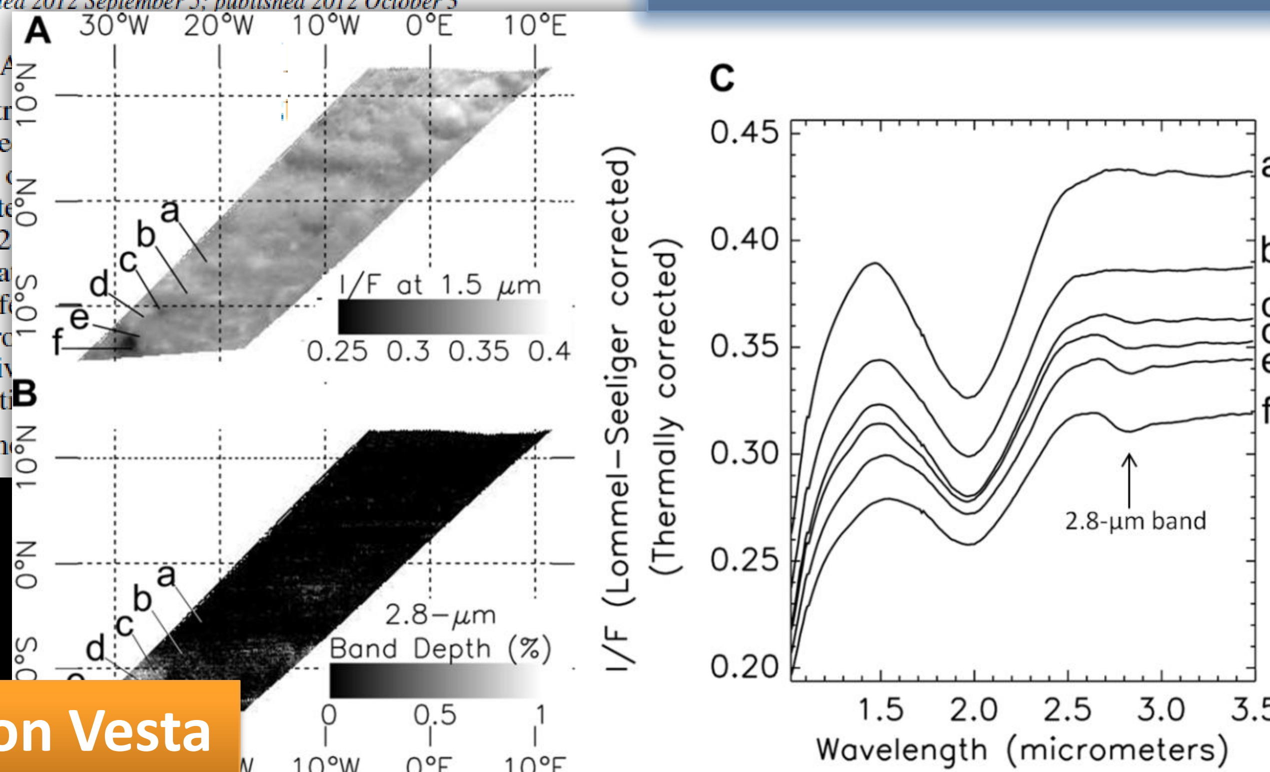
Received 2012 August 17; accepted 2012 September 5; published 2012 October 3

Water plays a key role in the evolution of terrestr
However, the mechanism by which water has be
extensively debated. Here we report the detection o
the asteroid Vesta by the VIR imaging spectromete
is fully differentiated with a basaltic surface. The 2
shows areas enriched and depleted in hydrated ma
unexpected and indicates ancient processes that diff
bodies, like the Moon. The origin of Vestan OH pro
main belt and may offer new scenarios on the deliv
processes that may have played a role in the formati

Key words: minor planets, asteroids: general – min

Vesta is dominated by pyroxenes absorption but also some other bands are recognized in the Vesta spectra

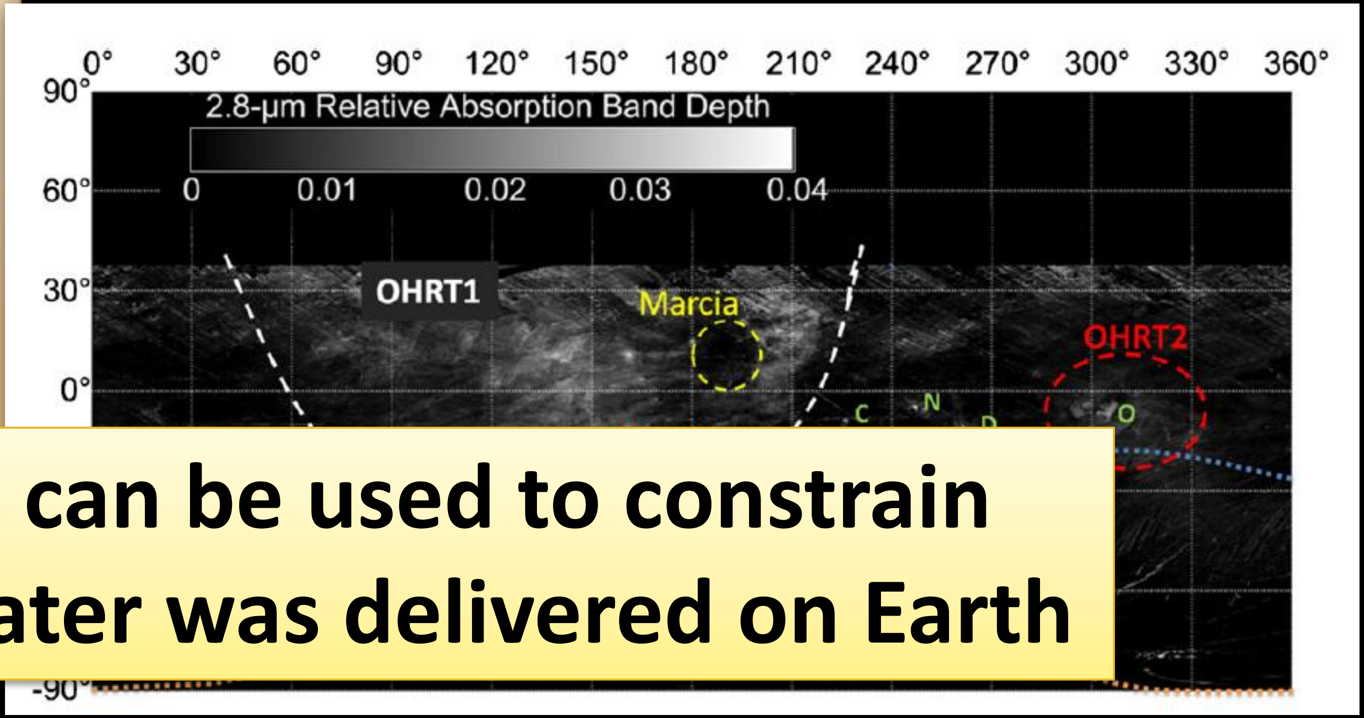


OH band detected by VIR on Vesta

DETECTION OF WIDESPREAD HYDRATED MATERIALS ON VESTA BY THE VIR IMAGING SPECTROMETER ON BOARD THE *DAWN* MISSION

- The Vestan OH distribution reveals that an important primordial process played a role in the terrestrial planets evolution in the early stages of the solar system.
- This process could have also provided a way to transport **organic compounds and water** to main belt asteroids and terrestrial planets.

- The uneven distribution of hydrated mineral phases is unexpected and indicates ancient processes that differ from those responsible for OH on the Moon.
- The origin of most of the OH on Vesta is likely primordial material due to OH-bearing low-velocity impactor



VIR data can be used to constrain when water was delivered on Earth

Pitted Terrain on Vesta and Implications for the Presence of Volatiles

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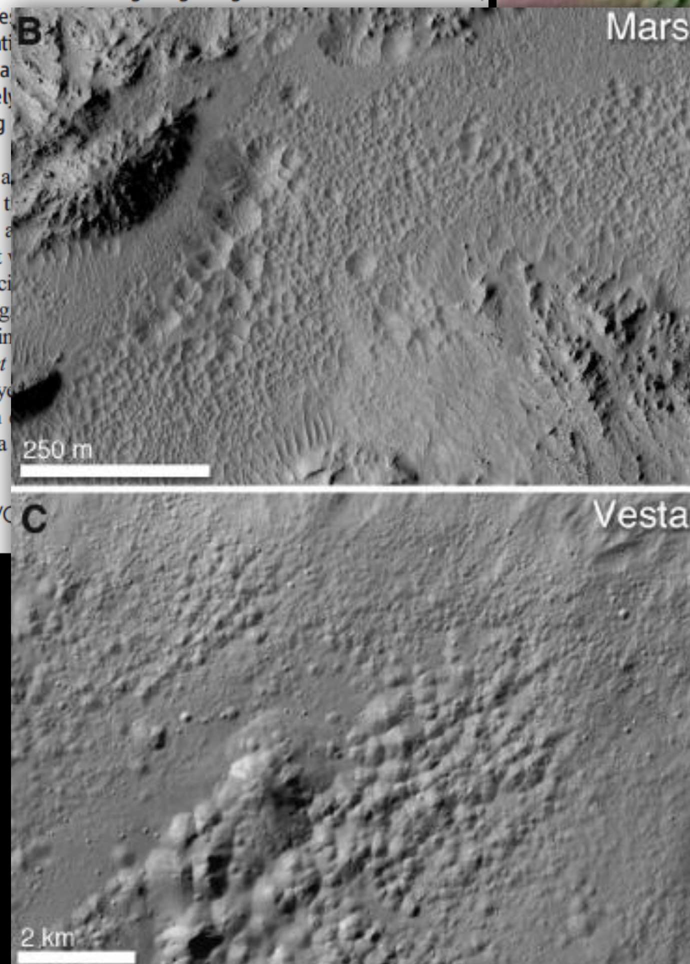
We investigated the origin of unusual pitted terrain on asteroid Vesta, revealed in images from the Dawn spacecraft. Pitted terrain is characterized by irregular rimless depressions found in and around several impact craters, with a distinct morphology not observed on other airless bodies. Similar terrain is associated with numerous martian craters, where pits are thought to form through degassing of volatile-bearing material heated by the impact. Pitted terrain on Ve… manner, which indicates that portions of the surface contain a relati… Exogenic materials, such as water-rich carbonaceous chondrites, ma… suggesting that impactor materials are preserved locally in relatively… that impactor composition has played an important role in shaping…

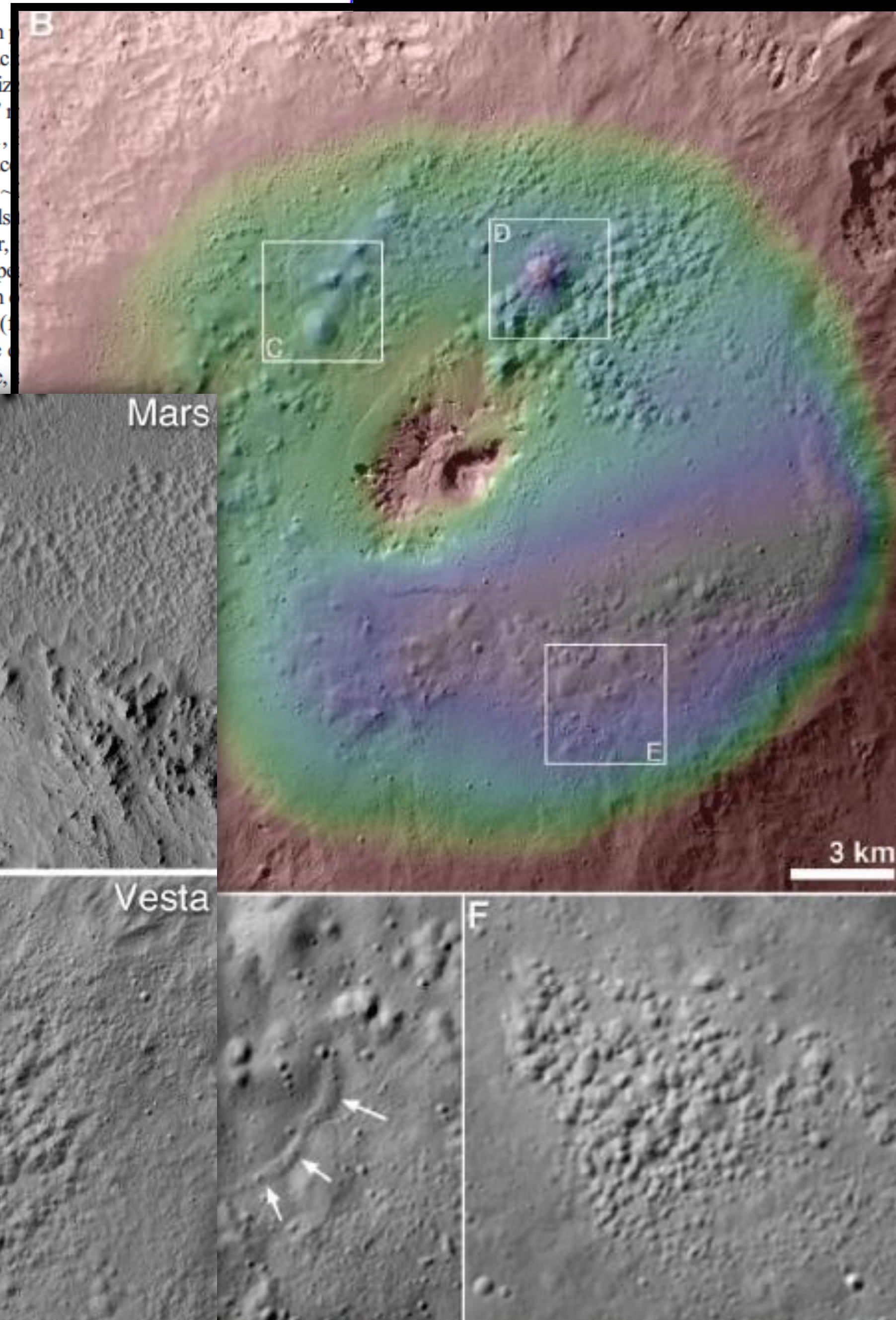
In July 2011, the Dawn spacecraft entered into orbit around Vesta, the second-most massive asteroid in the solar system. After initial Survey and High-Altitude orbits, Dawn spiraled down to its ~210-km Low-Altitude Mapping Orbit (LAMO) (*1*), allowing for acquisition of Framing Camera (FC) images (*2*) at pixel scales of <20 m, as well as high-resolution views of Vesta's geology. LAMO clear-filter images cover >70% of the surface (latitudes above ~55°N were in shadow). In this data set, we identified

terrain with a… we describe t… the presence a…

The most … rain is associ… diameter, Fig… recent large i… of Marchi *et* … ~70 million y… wise smooth … surrounding a…

race, and within … blanket. Pits lac… they range in siz… resolution at 17 … diameter (Fig. 1, … the slump terrac… (largest sizes: ~… where ejecta fills… F). On the floor, … crater walls app… several areas; in … slump deposits (… floor where the … increase in size, …





Other evidences for the presence of volatiles on Vesta

LETTER

doi:10.1038/nature11534

Distinctive space weathering on Vesta from regolith mixing processes

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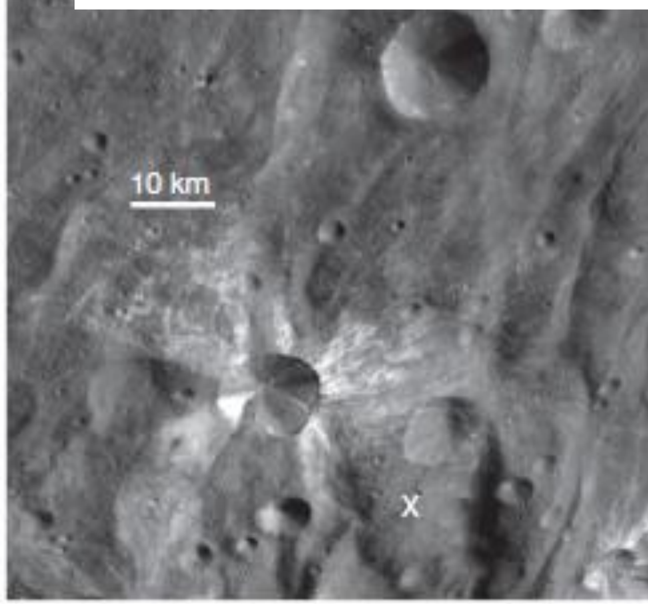
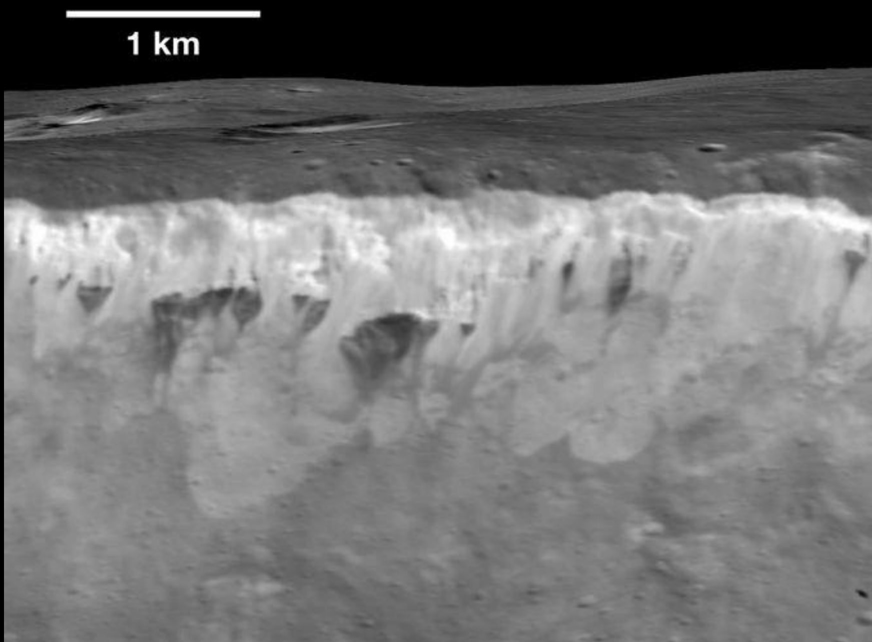


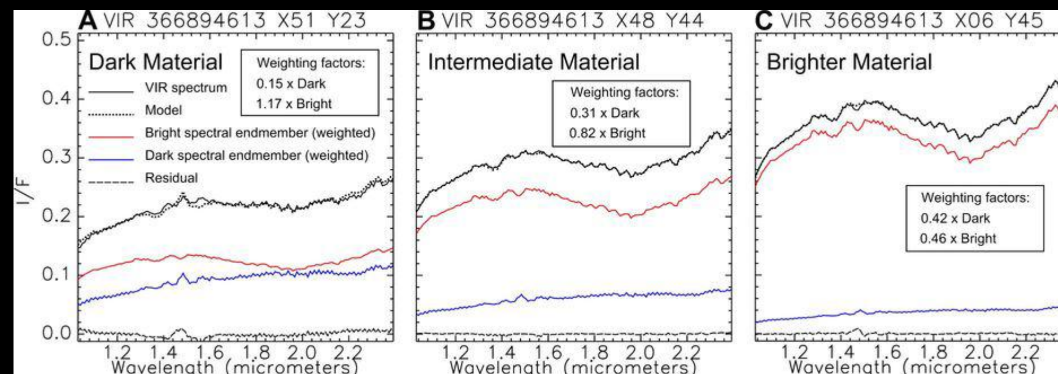
Vesta is the only known airless body in our Solar System that doesn't experience traditional space weathering

"Distinctive space weathering on Vesta from regolith mixing processes" has been scheduled for publication in ***Nature*** **on 01 November 2012**

DAWN UCLA JPL Orbital

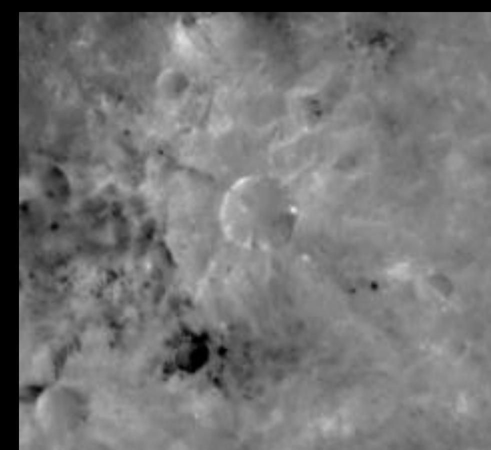


Dark material



"***Dark material on Vesta from the infall of carbonaceous volatile-rich material***" has been scheduled for publication in

Nature **on 01 November 2012**



Dawn at Vesta revealed a unique world that we have only begun to discover

Dawn is on its way to Ceres!