40 years
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Planetary Science Institute

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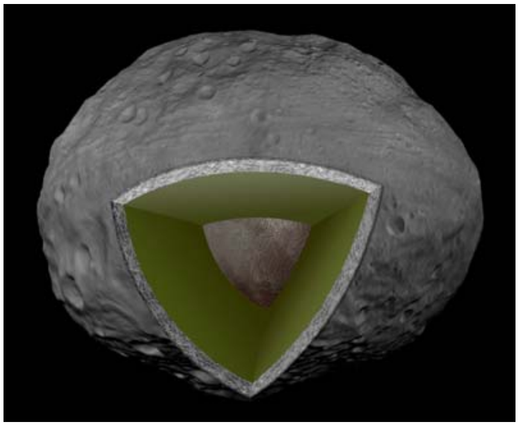
Dawn Reveals Complex Geology of Giant Asteroid Vesta

by Alan Fischer & Chris Holmberg



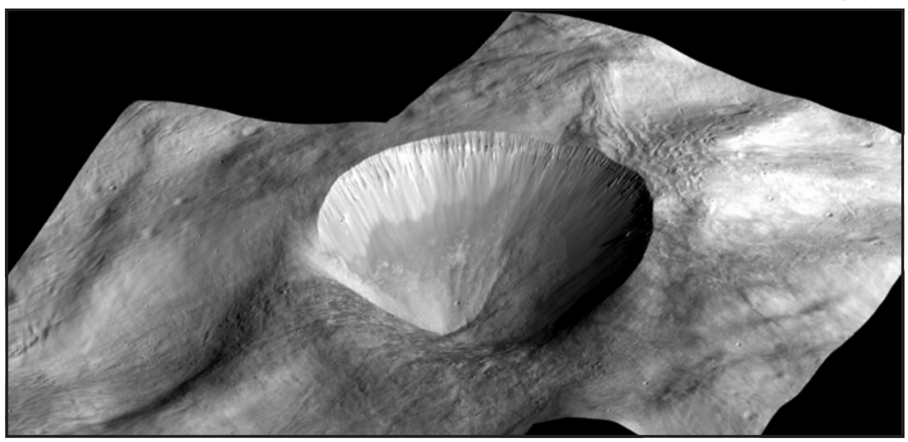
This artist's concept shows the internal structure of the giant asteroid Vesta, based on information from NASA's Dawn mission, and illustrates that it is unique: It has an iron core, a rocky mantle, and a cooled lava crust — more like a rocky planet than an asteroid. The innermost core is depicted in light brown, the mantle in green, and the crust in gray. *(Credit: NASA/JPL-Caltech)*

NASA's Dawn mission — with 13 scientists from PSI — has undertaken the first detailed analysis of the giant asteroid Vesta, providing a view back in time to the beginning of our solar system. Dawn data show that Vesta is the only intact protoplanetary body with an iron core known to have survived from those early days, and the collisions that left large impact basins on its surface are remarkably recent.

"The large impact basins on the Moon are all quite old — over three billion years old," said PSI Research Scientist David O'Brien, a Participating Scientist on the Dawn mission. "The fact that the largest impact on Vesta is so young — a mere one billion years — is surprising!"

O'Brien is a co-author on four of six papers on Dawn discoveries that were published in the May 11 issue of *Science*. Other PSI researchers including Robert Gas-

(Continued on page 2)

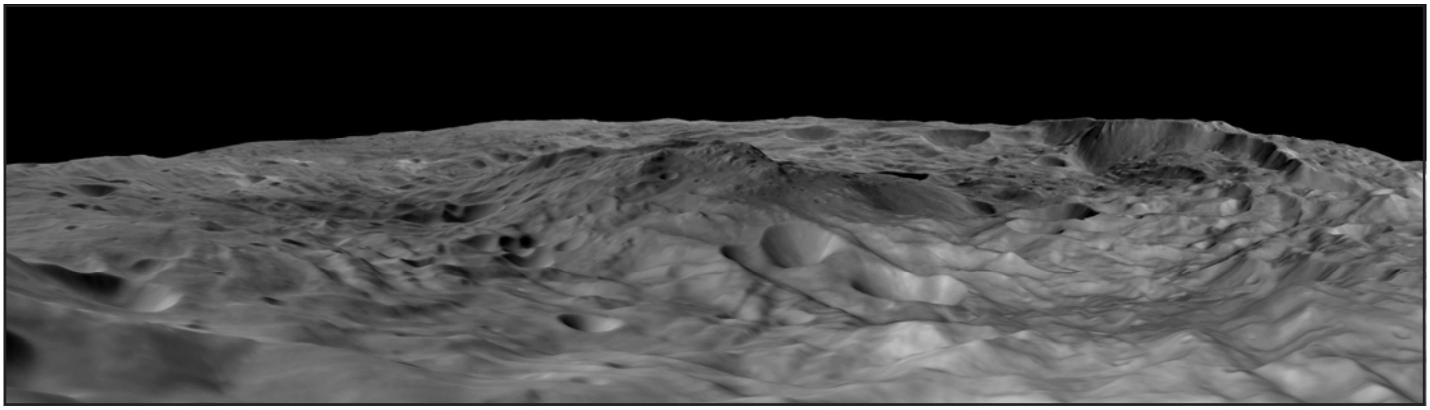


This perspective view, made from data obtained by NASA's Dawn spacecraft, shows a young crater named Antonia in the Rheasilvia basin at Vesta's south pole. PSI Scientist David O'Brien created this image by laying images from the mission's low-altitude mapping orbit (an average of 130 miles, or 210 kilometers, above the surface) atop a digital terrain model. The crater lies on a steep slope, such that the upslope side has completely collapsed, giving a sharp, fresh appearance, while the lower side has avoided collapse or may have been buried by landslide material from the upslope side of the crater. *(Credit: NASA/JPL-Caltech/UCLA/MPS/DLR/IDA/PSI)*

The May 11 cover of **Science** ***featured Dawn at Vesta. PSI scientists contributed to six papers in the issue.*** *(Enhanced-color view of the Snowman craters, generated from Dawn Framing Camera images. Credit: NASA/JPL-Caltech/UCLA/MPS/DLR/IDA/PSI. From Science May 11, 2012, volume 336, issue 6082 cover. Reprinted with permission from AAAS. http://www.sciencemag.org/content/336/6082.toc)*

Inside this issue:

Dawn Reveals Complex Geology of Giant Asteroid Vesta *(continued from front page)*



A view of Vesta from the rim of the south pole basin Rheasilvia looking at the central peak, with the prominent cliff towards the right of the peak. PSI Scientist David O'Brien generated this image by overlaying imaging data from the Dawn spacecraft onto a shape model made by PSI Senior Scientist Robert Gaskell. *(Credit: NASA/JPL-Caltech/UCLA/MPS/DLR/IDA/PSI)*

kell, R. Aileen Yingst, W. Brent Garry, Thomas Prettyman, Mark V. Sykes, Pasquale Tricarico, William Feldman, and Robert Reedy also contributed to the six Dawn Mission science papers.

"Vesta is a window back to the earliest days of the solar system. Understanding the history of impacts in the solar system is important for understanding the evolution of the Moon and planets, including how life evolved on Earth," O'Brien said. "By studying the impact history of Vesta recorded by its impact craters, we can better understand the history of impacts on early Earth." Vesta's largest basin, named Rheasilvia, was determined to be approximately 1 billion years old by counting smaller craters that formed on top of it (see image above and on front page).

Dating Vesta's large impact craters confirms earlier research which suggested that the howardite-eucrite-diogenite (HED) meteorites found on Earth were ejected from Vesta's surface by large impacts within the last billion years. Data from the Dawn mission confirm that link, and are now helping to place those meteorites in a geological context on the surface of Vesta, showing where those rocks came from and the processes that influenced their formation and evolution.

PSI Senior Scientist R. Aileen Yingst developed a geologic map of the entire asteroid using data provided by the Dawn spacecraft. "Dawn data have moved Vesta from being a blurry object a few pixels across in Hubble Space Telescope images to a well-resolved body with complex geology," Yingst said.

"My work has focused on creating the global geologic map for the project. It's important because geologic mapping is a comprehensive approach meant to correlate all the information we obtain from different types of datasets— images, compositions and so on—and to determine geologic units from those datasets."

Data from Dawn's cameras—visible and infrared—helped determine what the rocks are made of on Vesta. "Rocks have a characteristic wavelength signature based on their composition, and this plus their appearance helps us understand how the object was formed. Defining those geologic units is the first step in revealing the underlying geologic processes and placing those processes into a global framework," Yingst said

New global maps and videos of Vesta are available at http://www.nasa.gov/mission_pages/dawn/news/dawn20120510.html

Vesta's surface, which has a diverse range of colors throughout the visible and infrared spectrum, is shaped by material delivered by colliding asteroids, but also by subsurface material ejected from deeper layers by these impacts. These deeper layers, exposed in the walls of the large impact basins like Rheasilvia, suggest that Vesta underwent some kind of melting that separated the denser and lighter materials, resulting in the creation of crust, mantle, and core. This process, known as "differentiation," which occurred about 4.56 billion years ago very close to the birth of the solar system itself, makes Vesta more similar to terrestrial planets and our Moon and less like other asteroids. In fact, through detailed measurements of Vesta's gravity, Dawn has been able to confirm that it is differentiated, having an iron core with a radius of about 68 miles, or 110 kilometers.

"As one of the largest asteroids, Vesta is a type of solar system body that we have not explored before. It is a transitional body between asteroids and full-sized planets. It is similar to many of the small planetesimals that were the building blocks of the planets, and has many features of a small planet itself, having melted and formed a core and crust, and having a diverse range of surface features and compositions," O'Brien said.

Through studying the pattern of minerals that have been exposed in large impact basins on Vesta, Dawn data suggest that the differentiation may have been nearly complete and created a magma ocean early in Vesta's existence. Though there could still be another explanation for the pattern, a magma ocean occurs when a body undergoes almost complete melting and leads to the layered structure characteristic of planets. Other bodies with magma oceans became planets — such as Earth.

Launched in 2007, Dawn began its exploration of the giant asteroid Vesta in mid-2011. The spacecraft's next assignment will be to study the dwarf planet Ceres when it arrives there in 2015. Visit http://www.nasa.gov/dawn and http://dawn.jpl.nasa.gov for more information on the Dawn mission.

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With special thanks to Emily Joseph, Carol Neese, and Elaine Owens

Dave Vaniman, Deputy Principal Investigator on MSL Instrument Team, Joins PSI

Dave Vaniman comes to PSI from Los Alamos National Laboratory (LANL), where he'd been a science staff member since 1979. Before that he was a postdoctoral research associate at SUNY Stony Brook (NY), a graduate student at UC Santa Cruz, and an undergraduate student at Pomona College in Claremont, California. In the time between earning his master's degree and then his doctorate in geology, he spent three years in northern Nigeria, teaching at a secondary school on the Jos Plateau for one year and then working for two years with the Geological Survey of Nigeria in Kaduna. In those last two years he did reconnaissance mapping, covering about 1800 square miles. Education and experience together provided core training in field geology, geochemistry, igneous petrology, and mineralogy.

Although initially rooted in terrestrial petrology, Dave has maintained planetary geology interest and activity since 1976. At that time he was finishing his dissertation on Pan-African metamorphism and plutonism and was offered a chance to work with Apollo 16 drill core samples. The exotic mineral chemistry and incredibly unaltered minerals and glasses in the Apollo samples, despite ages of 3 to 4 billion years, opened up a new world. Dave was quickly convinced that one world is not enough; there is so much interesting and diverse geology, both here and beyond.

From 1976 until the mid-1990s, his interest was focused on the Moon. Devoting himself full time to lunar studies as a postdoctoral researcher with Jim Papike at SUNY Stony Brook led to the use of electron microprobe mineral chemistry to sort out source rocks that have been otherwise destroyed in the formation of lunar rock fragments. Particularly interesting was the discovery of a new, exceptionally low-titanium suite of lunar basalts as small fragments in the Apollo 17 drill core. These small samples extended models of basaltic volcanism beyond the then current much simpler classification that was based on larger samples of previously collected basalts.

This came about at a time when remote sensing was revealing that the range of basaltic compositions in lunar plains included many that were not in the Apollo or Luna sample collections. The Moon possesses complexity that we have not yet tapped, despite continued mapping from orbit and the varied composition of lunar meteorites that can be found on Earth.

During 32 years of work at Los Alamos, Dave continued to pursue a mix of terrestrial and extraterrestrial geology. Terrestrial projects included volcanic and seismic hazards, interactions of clay minerals and zeolites with groundwater and chemical contaminants, and characterization of thick unsaturated zones for isolation of nuclear waste.

In his first two decades working in extraterrestrial geology, Dave focused on the Moon, and discovered and named a new, highly aluminum-rich and silicon-poor silicate mineral, yoshiokaite, that may represent an extreme mineral aberration formed by impact superheating with silicon vaporization from feldspar, which is abundant in the ancient lunar crust.

During this period, at a breakfast meeting between Dave and another LANL scientist, and fellow lunar researcher, Grant Heiken, the discussion turned to aging lunar scientists, forgotten reports, gray (unpublished technical) literature, and scattered lunar data. They rashly decided to solicit NASA funding to corral a team to put together a book summarizing lunar data collected to that point. Years later, after recruiting Bevan French to help with editing, the *Lunar Sourcebook* was produced by the Lunar and Planetary Institute and published by Cambridge University Press. Many people helped, but the memory of that effort still makes Dave cringe whenever someone says "Let's get breakfast . . ."

Mineralogy on the Moon is interesting, but the mineralogy of a wetter body like Mars is significantly more diverse and more complicated, with even more stories to tell. In the 1990s, Dave, along with LANL coworkers David Bish and Steve Chipera, put together an abstract of an instrument concept for X-ray diffraction (XRD) and X-ray fluorescence (XRF) analysis on Mars. Separately, David Blake of NASA Ames came up with a completely different and far more pragmatic design. Dave and his collaborators quickly jumped ship to collaborate with David Blake.

After many proposals and four generations of prototypes, the result is the CheMin XRD/XRF instrument that is now on the Mars Science Laboratory (MSL) rover *Curiosity*, due to land on Mars on August 5, 2012. Dave is the Deputy Principal Investigator (Deputy PI) on the CheMin team.

Dave is also involved with PI Roger Wiens of LANL as a Co-Investigator on *Curiosity's* ChemCam remote chemical analysis and imaging instrument, which uses a laser to generate plasma emission from samples up to about 7 meters from the rover, spectrometers to get chemical information from the plasma, and a telescope to image the samples before and after laser shots. It was the imminent arrival of *Curiosity* on Mars and the growing challenge to be ready for that event that brought Dave from LANL to PSI.

Dave currently lives and works in Simi Valley, CA, 40 miles from JPL where operations for MSL will be conducted. He and his wife Donna retain a home in Santa Fe, NM, where they lived for 32 years and return to a few times each year. This also allows Dave to keep a Guest Scientist position with LANL and maintain better connection with the ChemCam team at LANL.

Dave and Donna have a son, a daughter, and three grandchildren (most recently a granddaughter born in June). In years past, when spare time was a reality, Dave was a potter, exploring clay minerals in many different contexts, from wheel work to slip casting. The MSL mission put all of that on hold several years ago, but it's still there to come back to.

We welcome Dave to PSI and wish him great success with MSL!

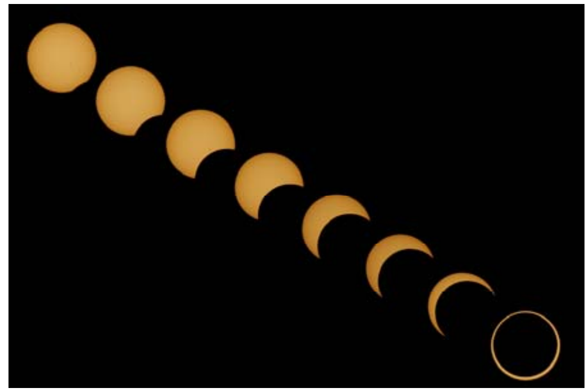
For more information about NASA's Mars Science Lab (MSL) go to http://www.nasa.gov/msl

Dave's newest grandchild Abigail, born June 4, 2012, is cradled by big sister Claire. Lucky grandfather!

Solar Eclipse Views by PSI Scientists Across the Globe

Candy Hansen's daughter, Christy Koharcheck, views the eclipse in Utah, wearing a welder's helmet. Very smart!

PSI Senior Scientist Tom Prettyman caught the annular eclipse on May 20th as it peeked ethereally through the clouds in Tokyo. An annular eclipse of the Sun occurs when the Moon's diameter is too small to block out the whole Sun, thus creating the "ring of fire" effect.



Gil Esquerdo purposely traveled to Zion National Park in Utah to film the eclipse in its entirety. His fascinating composite image shows the eclipse from beginning to end — one hour and nine minutes total.

At left, from PSI Senior Scientist Candy Hansen, in St. George, Utah, the annular solar eclipse as seen through green welding glass.

At right, PSI Senior Scientist Ed Tedesco captured a unique view of the eclipse as the Sun was setting in Los Lunas, NM, looking at El Cerro De Los Lunas (Los Lunas Hills).

Director's Note

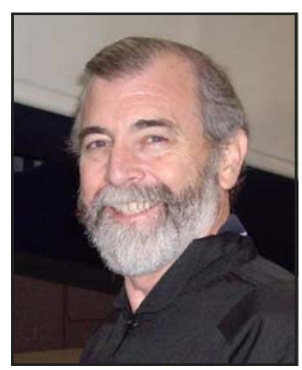
There is never a lack of excitement in our business. The President's fiscal year 2013 budget proposal to Congress cut solar system exploration by 20%, with potentially devastating and long-term consequences.

Mark Sykes (second from left) on Capitol Hill with a group of planetary scientists in May.

Fortunately, in part because of the long, consistent string of spectacular successes of planetary missions, we have friends in Congress on both sides of the political aisle who are supportive of this high profile national enterprise. Many of us in the planetary community have been providing Congress, and the administration, with detailed information on these programs, their costs and the effects of funding them at different levels. Letters from the public and advocacy groups to their representatives in Washington have been extremely helpful.

Looking forward, fiscal uncertainty calls for innovation and initiative. We are looking to build on our NASA successes to see if we can open up new non-governmental funding in our various areas of endeavor in research, education and technology. More on this in a future Note!

In the meantime, we continue to celebrate PSI's 40th anniversary! We had a wonderful annual dinner in April, at which southern Arizona's most well-known and respected interviewer, Bill Buckmaster, talked with PSI founders Don Davis and Bill Hartmann about the history of the Institute and the arc of American solar system exploration. It is posted on the PSI website (www.psi.edu). This was preceded by a live radio interview with Davis and Hartmann on the Buckmaster radio show which was also recorded (at KVOI AM 1030). More events are planned, one in Washington, D.C.



Looking at how much we have accomplished over the years and all the discoveries made, it is hard not to be optimistic about our future!

Mark V. Sykes
June 2012

Planetary Science Institute had a large presence at the 43rd Lunar and Planetary Science Conference (LPSC), March 19-23, 2012 in The Woodlands, Texas. For the conference, 50 PSI scientists contributed to over 150 abstracts.

Two-thirds of the PSI scientists attending the conference gathered at The Grotto restaurant for the annual LPSC group dinner and photograph. Pictured from left, back row: Marc Fries, Henry Throop, Brent Garry, Ross Irwin, Eric Palmer, Dave Vaniman, Jianyang Li, Naoyuki Yamashita, Scott Mest, Gary Hansen (guest). Middle row: Leslie Bleamaster, Sarah Andre, Linda Welzenbach (guest), Frank Chuang, Candy Hansen, Melissa Lane, Mark Sykes, Eldar Noe Dobrea, Deborah Domingue Lorin, Tom Prettyman, Rebecca Williams, Kim Kuhlman, Bill Feldman. Front row: Sanlyn Buxner, Elizabeth Jensen, Alice Baldridge, Kristin Lawrence, Bob Reedy, Catherine Johnson, Manar Al Asad and Jessica Kalynn (students of Catherine Johnson). Photograph by PSI Senior Scientist Henry Throop.

Antarctica Service Medal for Melissa Lane

by Alan Fischer

PSI Senior Scientist Melissa Lane was awarded the Congressional Antarctica Service Medal by the National Science Foundation for her meteorite exploration work at the southern end of the globe.

"It is a huge honor to be a recipient of this medal. Very few people ever have the opportunity to go to Antarctica, let alone stay for two months and contribute to the supply of meteorites recovered by the U.S. Antarctic Program. These meteorites are studied by scientists and many important new scientific discoveries arise because of the U.S. collection," said Lane. "It was poignant that I received this medal on the 100th anniversary of the death of Robert Falcon Scott, on March 29, 1912, who died on the return leg of his quest to reach the South Pole (having been beaten by Norwegian Roald Amundsen's party a few weeks earlier). Though much safer now, Antarctica is still an unforgiving environment, and service to our country under these harsh and hazardous conditions is still recognized by Congress."

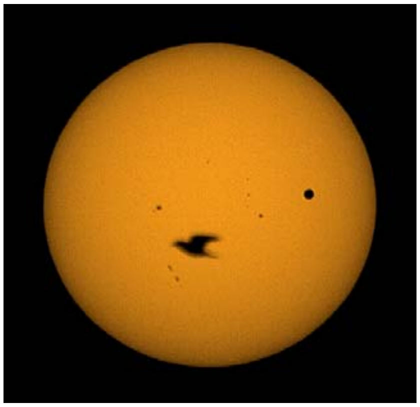
Lane was part of the Antarctic Search for Meteorites (ANSMET) program, which saw 12 people spend eight weeks in Antarctica during the 2010-2011 season, searching for meteorites for the National Science Foundation and NASA. Another PSI Scientist, Leslie Bleamaster, also journeyed to Antarctica with ANSMET a few years earlier.

Lane's four-person reconnaissance team located and recovered 302 meteorites from the Antarctic blue ice. Since the inception of the ANSMET program in 1976, approximately 20,000 meteorites have been recovered. Read the full story of Melissa Lane's adventure in the Spring 2011 PSI Newsletter and about Leslie Bleamaster's in the Spring 2008 issue. (Available on our website: www.psi.edu)

Congratulations, Melissa!

The ribbon of the Antarctica Service Medal (above right) is symbolic: The outer bands of black and dark blue comprise five-twelfths of the ribbon, representing five months of Antarctic darkness; the center portion progresses from medium blue through light blue and pale blue to white, symbolizing seven months of sunlight and the aurora australis (southern lights). The words on the reverse of this medal are a wise command to those who go to the Antarctic — COURAGE SACRIFICE DEVOTION — and are set within a circular border of penguins and marine life.

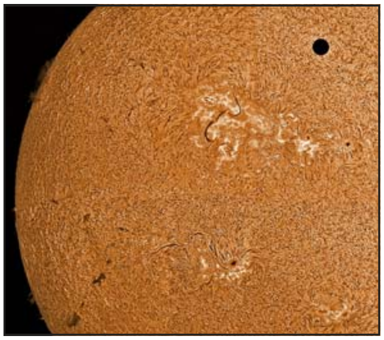
Transit of Venus Views by PSI Scientists



On June 5 and 6, a good portion of the world watched, for over six hours, as Venus passed between the Earth and the Sun. Transits of Venus are rare events, occurring in pairs eight years apart, and then not again for over a century. The previous transit was June 2004 (preceded by transits in 1874 and 1882), and will not occur again until 2117 and 2125.

In the 1700s, astronomers timed the transit from distant corners of the globe and combined their results to determine the first accurate measurement of the distance between the Earth and the Sun. This allowed astronomers to calculate the size of the solar system.

Here are a few of the many spectacular photographs our scientists took of the dark dot of Venus crossing the Sun.



Research Assistant Gil Esquerdo, in Tucson, caught something else in his photo (top) of Venus in transit — a dove, also in transit! The closer view (above), with a different filter, reveals the sunspots in the upper image are active areas of the Sun.

Appearing to hold transiting Venus in his hand, this photo by PSI Senior Scientist Chuck Wood's son, Morgan, in Virginia, was made by holding a card in front of the telescope's eyepiece.

Clouds parted to reveal Venus transiting a ghostly Sun (top), photographed in Washington, D.C. by PSI Senior Scientist Henry Throop. Above, his son Finn Hattenbach, 2½, used the telescope HIS way.

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