PLANETARY SCIENCE INSTITUTE

NEWSLETTER

WINTER 2009 Vol. 10, No. 4

Est. 1972 www.psi.edu

From Iceland to Vesta *by Thomas H. Prettyman*

Active volcanism under the surface creates steam at the Nesjavellir power plant near Reykjavik. The geothermal power plant provides hot water and electricity to Iceland's major population center. *(Photo credit: Tom Prettyman and Gil Esquerdo)*

The NASA Dawn Mission spacecraft was launched in September 2007 to conduct the first ever double rendezvous. Its destinations are the two largest objects in the asteroid belt, Vesta and Ceres, which orbit the Sun between Mars and Jupiter. Dawn will be arriving at Vesta in May 2011 and will acquire science data for about a year. The spacecraft will then depart for Ceres, arriving in February 2015. PSI has three scientists on the Dawn Science Team: William Feldman, Mark Sykes, and me.

In August 2009, the Dawn Science Team gathered in Iceland, at 66° north latitude, for their biannual meeting. In addition to technical discussions, the team spent two days on geology field trips to locations within driving distance of Reykjavik, guided by geologists from the University of Iceland and Reykjavik University. The meeting was hosted by the Massachusetts Institute of Technology. Endeavors with the complexity of the Dawn mission require a close-knit, multidisciplinary team. For those of us who are not geologists, the field trips were an opportunity to learn more about volcanism and field geology and to make connections between Iceland and what we might see when the Dawn spacecraft arrives at Vesta.

Like Vesta, Iceland's surface was shaped by basaltic magmatism and achieved its present form quickly, within 20 million years. Due to heating by short-lived radioisotopes injected into the solar nebula by a nearby supernova, Vesta formed hot and, like the Moon, may have had a magma ocean. As Vesta cooled, the small body differentiated, forming a crust, mantle, and core. Molten silicate rock from the mantle erupted through the crust onto the surface, forming features that might be very similar to those seen on Earth. Volcanism on Vesta ceased

(Continued on Page 2)

The longest mountain range on Earth — the Mid-Atlantic Ridge — is an underwater mountain range on the floor of the Atlantic Ocean, extending from Iceland to Antarctica. Almost completely underwater, the Mid-Atlantic Ridge rises above sea level in Iceland as seen here on the Reykjanes peninsula. *(Photo credit: Tom Prettyman)*

Inside this issue:

From Iceland to Vesta (*continued from front page)*

nearly 4.5 billion years ago, once gravitational forcing by Jupiter brought accretion of the main asteroid belt to an end. In contrast, Iceland is located in one of Earth's most active regions and volcanoes have been an important part of Icelandic life since the first settlers arrived in 871 AD.

Intrepid diver Michael Prettyman dons a dry suit in preparation for snorkeling in the near freezing pool of this water-filled crevasse near Pingvellir. Icy water fills deep crevasses in the graben (valley between faults), created when the N. American plate moved away from the European plate. ***(Photo credit: Tom Prettyman)***

Unlike Vesta, which is thought to be bone dry, water has shaped Iceland. Iceland rises from the northernmost portion of the Mid-Atlantic Ridge, where the North American and European plates meet. In fact, Iceland is the only place where the Mid-Atlantic Ridge can be seen above the surface of the ocean. The island is covered with landforms resulting from the interaction of molten rock and ice, including tuyas (mesa-like volcanoes that formed under an ice sheet), rootless cones, and valleys carved by the deluge produced when volcanoes erupted under ice. Glaciation and erosion have also played a role, for example, in creating spectacular fjords in northwestern Iceland (upper right). Some of Iceland's volcanoes erupted in air resulting in volcanic shields and pahoehoe flow fields, including some very long intact lava tubes (at right), similar to those found in Hawaii and my home state of New Mexico.

Deluge of meltwater! The water flowing through the famous Gullfoss waterfall originates from melting of massive glaciers in the interior of Iceland. ***(Photo credit: Tom Prettyman)***

Erosion from moving glaciers created myriad water features in Iceland. A stepped waterfall gently forms intricate patterns in this fjord in northwestern Iceland. ***(Photo credit: Sandra Lapham)***

As we marveled at the different landforms produced by volcanoes, we also became aware of the geochemical diversity associated with volcanism. Magmas reaching the surface can undergo significant chemical alteration as they travel from their source deep within the Earth; however, our guides took us to an outcrop of oceanite, an olivine-rich, basaltic rock that underwent minimal alteration on its way to the surface and is representative of the composition of Earth's mantle. While gazing at the green olivine

Volcanic eruptions have created spectacular intact lava tube systems in Iceland. Spelunkers begin a hike through this intact lava tube, over a quarter of a mile long. ***(Photo credit: Sandra Lapham)***

crystals within the oceanite, I realized similar rocks might be exposed within a giant impact basin located at the south pole of Vesta. The impact, which nearly shattered the small planet, carved deep into the interior of Vesta, affording Dawn's scientific payload a close look at Vesta's mantle.

Iceland is a geothermal cauldron, and silicate minerals are rapidly undergoing chemical alteration by hydrothermal processes. Aqueous alteration products, such as clays, are abundant at numerous hot springs and several active geysers (pictured on page 5). Both Vesta and Ceres formed far enough away from the Sun that water must have played a role in their formation and thermal evolution. Ceres contains up to 20% water and has undergone aqueous differentiation at low temperature, forming minerals

(Continued on page 5)

PSI Scientists in *Geoscientist*

by Chris Holmberg

In the November issue of *Geoscientist* (and the September 17 online edition), reporter Sarah Day reviewed a successful event in the UK that highlighted two PSI scientists. The event consisted of two Geological Society-sponsored sessions at the British Science Festival, one of Europe's largest science festivals. It takes place each September in a different location in the UK and features the latest in science, technology, and engineering.

Matt Balme chaired a session at the British Science Festival. ***(Image credit: Geoscientst)***

The article, "Space and Time: *If you can't paint it, you don't understand it*," covers this year's festival, which was held at the University of Surrey, Guilford. PSI Research Scientist Matt Balme chaired and organized "The Great Mars Field Trip" session and PSI Senior Scientist William K. Hartmann was the keynote speaker.

It is Hartmann's motto about painting that became the subtitle (above) of the article. He explained that his passion for painting and the detailed observations he uses to create his space artworks inform his planetary science observations. Hartmann says creative thinking and careful observations are vital tools in science, helping scientists see connections and draw analogies between ostensibly dissimilar things.

"In terms of geology," said Matt Balme, "it's very hard to start from the ground up and imagine all sorts of new geological processes. Really we've only got the Earth to go by, as an analogue for Mars." The talks arranged by Balme for the Mars Fieldtrip session covered various aspects of Mars research from Earth analogs to planning spacecraft missions, as well as Hartmann's talk on astronomical art and science.

Bill Hartmann giving his keynote address at the science festival. ***(Image credit: Geoscientist)***

Regarding the importance of creative thinking in science, Hartmann observes, "Our education system encourages a career in science if your brain works in a certain focused, problem-solving way, which is essential in science. But I suspect there are additional ways of thinking, picturing things and seeing connections. As Einstein himself recognized, some of those talents are useful in forming new ideas. They are also useful in putting ideas in larger contexts and presenting them to the public." □

2009 DPS Meeting in Puerto Rico

PSI scientists attended the Division of Planetary Sciences' annual October meeting, which was held this year in San Juan, Puerto Rico. Seated around the dinner table at Stingray Restaurant, clockwise from left: Nader Haghighipour, Bill Hartmann, Paul Abell, Donald Davis, Dave O'Brien. Gary Hansen (formerly with PSI), Nalin Samarisinha, Jian-Yang Li, Jeff Morgenthaler, Lijie Han with her daughter Arwen, and Nader's wife, Ada Demleitner. *(Image credit: Dan Durda and Bill Hartmann)*

PSI on Nova Program in 2010

In September PSI Senior Education Specialist Larry Lebofsky (left) was interviewed on camera at our main Tucson office for a PBS Nova program. The show will center on the controversy surrounding Pluto and is scheduled to air in March 2010. Also for this program, PSI Director Mark Sykes was taped in Boston engaged in a debate with Neil DeGrasse Tyson, Director of Hayden Planetarium, Owen Gingerich, astronomer emeritus Smithsonian, and Brian Marsden, Harvard-Smithsonian Center for Astrophysics.

Check your local listings.

New Addition to PSI: Deborah Domingue Lorin

From pulsars to planets, Deborah's professional journey has taken a few unique twists and turns. As an undergraduate working on a bachelor's in physics, she was fortunate enough to earn an internship with Dr. Joanna Rankin at the University of Vermont observing pulsars and working on a catalogue of their properties. One observing trip to Arecibo's world famous radio telescope in Puerto Rico and she was hooked on the skies.

After earning her Bachelor's of Science in physics, Deborah began looking into graduate school, but she couldn't decide if she should be "practical" and earn a degree in geophysics, or follow her heart and earn a degree in astronomy. While exploring her options she discovered planetary science. She earned her doctoral degree in geology and planetary science at the University of Pittsburgh under Dr. Bruce Hapke, the guru of photometric theory.

She graduated in 1990 and began her career with a post-doctoral position at the Lunar and Planetary Institute in Houston where she eventually joined the senior staff. Her research included the study of such diverse objects as asteroids, the Moon, and icy satellites. She was involved in UV observations that led to the discoveries of sulfur dioxide on Ganymede and Callisto, and the detection of ozone on Ganymede. She worked with Dr. Faith Vilas (now MMT Observatory Director and also affiliated with PSI) on a project that showed evidence for hydrated minerals near the lunar poles.

In 1997 she left Texas for Maryland where she joined the staff at the Applied Physics Laboratory of Johns Hopkins University. There she took a position of science planning coordinator for the Near Earth Asteroid Rendezvous (NEAR) mission. In 2001 she joined the MESSENGER mission, where she was later appointed deputy project scientist until her move to PSI in 2009. She has continued her research in the photometric properties of planetary surfaces, the idiosyncrasies of photometric models and modeling endeavors, and has even written an overview of Mercury's atmosphere.

And what has she done in her spare time? Well during her undergraduate days she earned her black belt in Tae Kwon Do, a sport she has just recently returned to with her two young sons, ages eight and six. While living in Houston, where she met her husband Aaron, she learned to downhill ski and to scuba dive. Deborah and Aaron have enjoyed introducing their sons to skiing, but the scuba diving will have to wait until they are older; "much older" she says with a smile. Today Deborah and her husband spend their free time at various sporting events cheering their sons onward and upward.

Deborah joined PSI this past summer as a Senior Scientist, and works offsite in Bel Air, MD. She is a very welcome addition to PSI! □

ONR Visits PSI

Photo credit: Chris Holmberg

This fall, Office of Naval Research Team Leader Renee Luna introduced ONR's new Contract/Grant Administrator Janine "Jay Jay" Hales to our staff at PSI headquarters. From left: Bruce Barnett, Kelly Yoder, Janine "JayJay" Hales (ONR), Mark Sykes, and Renee Luna (ONR).

Photo credit: Chris Holmberg

PSI Senior Scientists Bill Hartmann and Bill Feldman seen sporting their twin "when I was your age, pluto was a planet" t-shirts.

On October 24, PSI Research Assistant Andrea Philippoff married Kevin Jones just outside the Shenandoah National Park in Virginia. Mr. and Mrs. Jones have made their new home in Great Falls.

Best wishes, Andrea and Kevin!

On September 26, PSI Senior Scientist Mary Bourke delivered a beautiful, 8 lb. 8 oz. baby girl. She named her Caoimhe Breda Gemma in honor of her Irish heritage. (Caoimhe is pronounced kwee-va.)

Congratulations, Mary, and welcome, Caoimhe!

Photo credit: Chris Holmberg

From Iceland to Vesta (*Continued from page 2)*

At left, clay minerals formed by a hydrothermal system. ***(Photo credit: Sandra Lapham)***

One of Iceland's geysers (Strokkur, at right) erupts, to the delight of onlookers. ***(Photo credit: Sandra Lapham)***

similar to those found in Iceland. When Dawn arrives at Ceres in 2015, the surface will likely reveal evidence for complex aqueous processing within the interior of Ceres from materials brought to the surface by gas-driven volcanism.

Will Vesta's south polar basin reveal the composition of Vesta's mantle? Does Ceres harbor a subterranean ocean in which life may have arisen? Stay tuned as NASA's Dawn mission continues its journey in space and time. ▫

Director's Note

Recently at the Women in Astronomy (WIA) conference in the DC area, I gave an invited lecture on PSI's policies and practices. The speaker ahead of me presented statistics showing that women in astronomy still have lower pay than men in comparable positions and that success in a variety of categories still has its challenges, which is surprising after so many decades of positive changes. There was discussion of whether unconscious prejudices (or overt in some cases) could be at work.

Then it was my turn to talk.

About 33% of our PhDs are women. This increases to 44% if scientists who received their PhDs more than 20 years ago are excluded, i.e., when the profession was more skewed towards men. PSI has a culture of openness and mutual support, whether in our internal workshops to strategize future proposals to NASA or through our in-house reviews of proposals being submitted.

Everyone at PSI is supported through "soft money," which is a challenging environment requiring one to be both productive *and* able to write competitive grant proposals to cover salaries. When I was a research astronomer at UA, as part of the process for being promoted to full astronomer I needed to solicit letters of reference from prominent scientists in Germany, the UK, and US to speak to the quality of my work and my status in the profession, even though I had been successfully supporting myself on grants for 17 years. Why must one's status in our profession be based on others' subjective perception? At PSI, a person transitions automatically from Research Scientist to Senior Scientist ten years after their PhD. Basically, if someone is still around on soft money after a decade, no further evaluation is needed.

On the salary side, we have guidelines for scientists in different positions, but the decision on salary level is left to each individual scientist. If there is any encouragement on the part of the Institution, it is to generally counter the tendency of people in our field to underpay themselves! The result of our policy is that the range of salaries between men and women at PSI is basically the same, as a function of years since PhD, but a large cluster of women in the 8-15 years post-PhD have an average salary that is higher than their male counterparts. This just tells me whom I need to be applying the encouragement to!

The retention of scientists was a large topic of concern at WIA. This includes the lack of mobility as a consequence of family dynamics. PSI addresses this issue by allowing scientists to work beyond Tucson; we now have scientists working in 16 states and Europe. While the public perception is that these issues primarily affect women, among PSI off-site scientists, proximity to family has impacted seven men and five women. Spousal relocation has likewise impacted three men and five women. Interesting.

Other issues impacting retention include medical problems, children, and funding variations. When work hours drop below the level established by institutions for benefits eligibility, it can have a profound effect (particularly when medical insurance benefits are threatened). Our solution is to first recognize that for some people it is desirable to work less than 40 hours a week, so our benefits eligibility kicks in at half that rate. More importantly, when situations arise causing a scientist to dip below that line, we look at individual circumstances to see how we can preserve benefits while maintaining corporate policy from a broader perspective. At WIA, it was clear that other institutions could benefit by backing away from rigid, automatic responses to short-term situations and instead have the flexibility to look at cases on an individual basis.

All in all, I think we can take some pride in PSI as an institution whose culture, environment, and policies have been created and maintained by its scientists and administration together. It's not perfect, and we are continually learning and evolving, but it is a good place to be.

Mark V. Sykes
December 2009

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