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PSI Scientist Shows Evidence of Supervolcano on Mars

by Alan Fischer

A research project led by PSI Research Scientist Joseph R. Michalski has identified what could be a supervolcano on Mars — the first discovery of its kind.

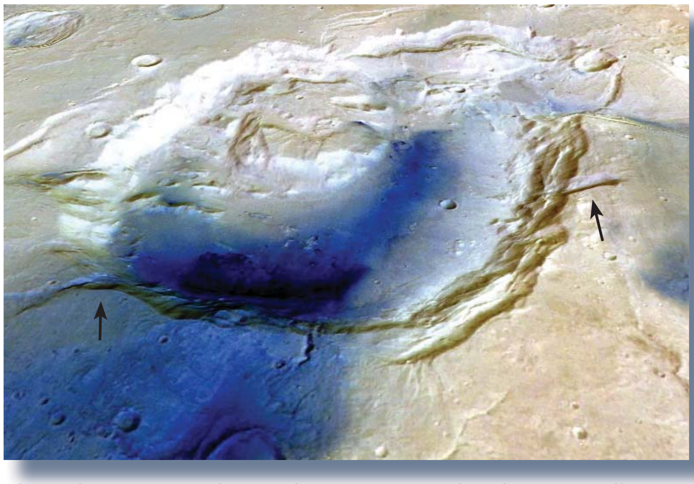
In a paper published in, and featured on the cover of, the Oct. 3 issue of *Nature,* Joe Michalski and co-author Jacob E. Bleacher of NASA Goddard Space Flight Center describe a new type of volcanic construction on Mars that until now has gone unrecognized.

The volcano in question, a vast circular basin on the face of the red planet, previously had been classified as an impact crater. Researchers now suggest the basin is actually the remains of an ancient supervolcano eruption. Their assessment is based on images and topographic data from NASA's Mars Odyssey, Mars Global Surveyor, and Mars Reconnaissance Orbiter spacecraft, as well as the European Space Agency's Mars Express orbiter.

In the *Nature* paper, Joe and his co-author lay out their case that the basin, recently named Eden Patera, is a volcanic caldera. Because a caldera is a depression, it can look like a crater formed by an impact, rather than a volcano.

"On Mars, young volcanoes have a very distinctive appearance that allows us to identify them," Joe said. "The long-standing question has been what would ancient volcanoes on Mars look like? Perhaps they look like this one."

Oct. 3, 2013, cover of Nature featuring PSI Scientist Joe Michalski's research paper about supervolcanoes on Mars. Supervolcano is an informal term to describe an immense eruption that expels more than 1,000 cubic kilometers of rock and ash. *Credit: Nature, Mark Garlick*



This 3-d perspective shows Eden Patera, a 70-km-diameter collapse feature that formed through volcanism on ancient Mars. Note the fractures emanating from the central depression that formed from subsidence and collapse. *HRSC/ESA, University of Berlin*

The researchers also suggest that a large body of magma loaded with dissolved gas (similar to the carbonation in soda) rose through a thin crust to the surface quickly. Like a bottle of soda that has been shaken, this supervolcano would have blown its contents far and wide if the top came off suddenly.

Continued on page 4

Inside this issue:

An Unforgettable Astronomy Day in Limpopo, South Africa *by Henry Throop*

PSI Scientist Henry Throop (top) is surrounded by enthusiastic students at a village school in Limpopo Province, South Africa. Photo: Ephraim Manamela (US Embassy)

PSI Senior Scientist Henry Throop relocated from Washington D.C. to South Africa in 2012. Here is his account of a day spent talking about astronomy at Madikweng Senior Secondary, a village school in very rural Limpopo province, South Africa.

I met these students ("learners") during lunch at Scifest Africa, a large science festival in Grahamstown, South Africa, for K-12 learners. It didn't take long for me to realize that these really were some of the best that I'd met anywhere in South Africa. Smart, focused, engaged, tons of questions...they were really on the ball. And their teachers were encouraging and helping them all the way. We kept in touch and worked out a time for me to visit on September 18.

I talked about New Horizons, the NASA mission to Pluto, and afterwards had 45 minutes of Q & A — awesome! The learners here were fantastic and very knowledgeable. Photo: E. Manamela (US Embassy)

Madikweng is a very rural school, 90 km from the closest major city (Polokwane), and much of that is on dirt roads. I drove up to the school early in the morning—three hours to Polokwane to collect a teacher and then another 90 minutes to Madikweng. The school has no toilets; students use the grass. Some classrooms have electricity; I don't think that any of the buildings have running water. Very few people have computers; most have cell phones and access the Internet that way.

Despite this, the school is truly excellent, with the level of education in math and sciences being very high. The graduation ("matric") rates are phenomenal, and the majority of learners head off to university. I talked with a number of grade-12 students; most had already applied to programs in physics, metallurgy, electrical engineering, actuarial sciences, environmental sciences, etc., at schools like U. Pretoria, U. Cape Town, Stellenbosch, and Wits.

I spent a day with them, giving three long talks (with Q&A longer than the talks!), followed by a night time observing session with two telescopes I'd brought. Usually school is out at 3 p.m., but on this day everyone stayed until 9 p.m.. Madikweng has 250 learners and there were a good number who were able to visit from other schools, such as Dendron Secondary, a much larger school with great science located closer to Polokwane.

Dry ice for "comet-making" wasn't available in Polokwane, so I brought a big box of it from Pretoria. Here I'm actually pouring water, not Sprite... there is a big pile of plastic bottles in the classrooms that the kids fill up from the one water tap outside. Photo: Ephraim Manamela (US Embassy)

I was very touched by the note of one teacher who said: *"Genuinely speaking, I doubt that this school has had an event bigger than yesterday's. The kids were bewildered by your knowledge and brilliance, they say Dr. Throop is genius and loves children. Additionally, there is clear indication in the school that immense interest in astronomy has been aroused. Seemingly, everyone wants to be like Henry!"*

I brought two telescopes: one for the Moon (here), and one for Saturn. That's Venus and Saturn you can see in the sky next to each other, upper left. 250 kids lined up to see the big telescope aimed at Saturn. Saturn's rings were easily visible, and two hours later, just as it set at 9 p.m., everyone had seen it and Titan too! Photo: Henry Throop

Thanks to the learners, teachers, and staff for having me up there, sharing the day with me, and making it unforgettable!

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Special thanks to Gil Esquerdo, Dianne Janis, Emily Joseph, Victoria Klocko, Carol Neese, and Elaine Owens

Please Welcome, Vishnu Reddy

Vishnu Reddy joined PSI this summer as a Research Scientist focusing on surface composition of asteroids, asteroid-meteorite link, and the K-T mass extinction*. His work involves the use of ground-based telescopes and data from spacecraft missions to understand the surface composition of small bodies.

Vishnu's work on the Dawn mission confirmed that the dark material on Vesta came from another asteroid that had a lot of carbon and volatiles in it. The nature of the Baptistina Asteroid Family, proposed source of the K-T impactor, has been a long-standing controversy in the small bodies community. Observational evidence obtained by Vishnu and his collaborators has shown that the family members do not have carbonaceous chondrite composition, weakening the K-T impactor source link.

Astronomy has always been a part of Vishnu's life. Born in an Indian spaceport city on the island of Sriharikota, he grew up dreaming about becoming a space scientist. An avid amateur astronomer since childhood, Vishnu built his first telescope in high school. Vishnu finished his B.S. degree in visual communications and worked in the motion picture industry on documentaries and post-production work on Bollywood films before getting an M.A. in journalism. In India he worked at *The Asian Age*, an international English daily newspaper, for four years as a chief sub-editor.

In 2000, he met Prof. Tom Gehrels from the University of Arizona's Spacewatch program and was inspired to set up a small independent near-Earth object follow-up program in India. In the summer of 2002, Vishnu discovered his first asteroid, 2002 NT, with the help of Tucson amateur astronomer Roy Tucker. This asteroid was subsequently named Bharat (after his homeland) by the International Astronomical Union.

Following the asteroid discoveries, he gave up his job as a journalist in India and moved to the University of North Dakota to get an M.S. in Space Studies and a Ph.D. in Earth Sciences. Before joining PSI, he worked as a research faculty member at the University of North Dakota and on the Dawn Framing Camera team at the Max Planck Institute of Solar System Research in Germany.

In his free time, Vishnu enjoys wildlife photography, painting, gardening, cooking, and astronomy.

We are delighted to welcome Vishnu to PSI!

**Note: Sixty-five million years ago, more than three-fourths of all plant and animal species living on Earth became extinct, the most famous of these being the dinosaurs. This event is known as the K-T mass extinction because it occurred at the boundary between the Cretaceous (K) and Tertiary (T) time periods.*

Lunar Origin: A Crisis at "Downton Abbey"?

by William K. Hartmann

The current leading theory of lunar origin originated at PSI nearly 40 years ago when Don Davis and I combined forces. The biggest mystery of lunar origin during the first Apollo flights was how the Moon could have formed with virtually no iron core.

In that era I had been studying large impacts and got the idea that a big enough body could blow some of Earth's rocky mantle into orbit around Earth, and the Moon could form from the debris. The question was whether big enough impactors could exist. Don was creating some of the first computer models of asteroid and planet growth and he ran his models to examine the size of "second-largest bodies" that could form in Earth's zone. We found that, yes, objects up to the size of Mars could have accumulated as Earth itself was growing toward its present size. There was a fair chance that such a body could hit Earth. The somewhat random nature of the situation explained why most planets do not have Moon-like satellites, large compared to the planet itself. Our "giant impact" model, suggested in a 1974 meeting, thus seemed to explain most of the Moon's features.

About the same time, geochemists discovered that the ratios of oxygen isotopes (for example the ratio of ^{18}O to ^{16}O) was exactly the same in lunar rocks as in the Earth. This was seen as strong support for our idea of lunar material coming out of Earth in a giant impact. Since all other known Solar System materials have different, "alien" O isotope ratios, it seemed the Moon could not have formed anywhere else.

In recent years, geochemists have found that the additional lunar isotope systems (chromium, zinc, titanium, etc.) are the same as Earth's. You might think this would create more support for giant impact. Instead, "giant impact" is now questioned because lunar isotopes are too much like Earth's! The logic: Computer models of the impact suggest that much of the Moon would be formed from the impactor material, and these models assume an "alien" impactor from another part of the Solar System would contain "alien isotope ratios." Thus, the Moon should show traces of the "alien ratios." In short, an "isotope crisis" (in the words of impact expert Jay Melosh) has been declared.

To address the crisis, London's venerable Royal Society (formed in the 1600s by Isaac Newton and his pals) hosted a Lunar Origin conference in September, 2013, to which I was invited. It began with two days of public lectures in London, but the most interesting part was the two follow-up days in one of the great country houses of England. We were all bused about an hour out of London to what we jokingly called "Downton Abbey." Its real name is Chicheley Hall, and yes, it has its own abbey. The Royal Society bought it to host conferees in a single, beautiful site that encouraged relaxed, interpersonal, discussion meetings. It was a great experience (even though I was coming down with mild pneumonia and having trouble breathing. I'm since cured.)

Continued on page 6

Introducing Lucille Le Corre

Lucille Le Corre joined PSI as a Research Scientist primarily working with the Dawn mission data to study surface composition and geology of the asteroid Vesta. For example, her work includes identifying meteorite analogs of surface terrains on Vesta using Dawn Framing Camera multi-band images. Lucille has experience working with other spacecraft mission datasets such as Hayabusa, Mars Express, and Cassini.

Lucille developed a strong interest in astronomy in high school and purchased her first telescope, a used Newtonian telescope from the 70s, to observe the Moon, planets, and a few nebulae. She became more interested after participating in a couple of astronomy summer schools in France, where researchers were presenting their discoveries to the public. She began reading more about it and decided to pursue astronomy and geology courses at Pierre and Marie Curie University in Paris, where she obtained a B.Sc. in Applied Physics and a M.Sc. in Planetary Science.

Working on her Ph.D., Lucille used Cassini VIMS (Visual and Infrared Mapping Spectrometer) data to study the geology of Titan, Saturn's largest moon. Part of this work was to derive the surface composition of Titan, and especially possible crovolcanoes, by comparing VIMS spectra with laboratory spectra of ices including mixtures of H_2O, CO_2, CH_4 and NH_3 ices. She processed and integrated various datasets (visible, infrared, and radar SAR images) from the PDS and created the first comprehensive Geographic Information System (GIS) for Titan. In parallel with her Ph.D. thesis, Lucille enjoyed working at the planetarium in Nantes, France, giving presentations about the Solar System and beyond to the general public and schoolchildren. Upon completion of her Ph.D., Lucille left France to work in the UK at University College London for one year as a post-doctoral fellow, where she studied the geomorphology of Mars using data from the High Resolution Stereo Camera (HRSC) camera onboard ESA's Mars Express and CTX camera on NASA's Mars Reconnaissance Orbiter. She built DEMs from HRSC imagery using in-house software and built regional CTX and HRSC maps.

Before joining PSI, Lucille was employed for two years as a research scientist at the Max Planck Institute for Solar System Research in Germany, working with NASA's Dawn Framing Camera (FC) team. Prior to the arrival of Dawn at Vesta, Lucille worked with the instrument team and scientists to identify and develop the image-processing pipeline for the FC data. Working closely with the USGS Astrogeology Center in Flagstaff, she developed a pipeline that processed returned images from the spacecraft and created image products (such as global maps) for scientific analysis within hours after their arrival on Earth. She was involved in the analysis of these data products in order to derive the mineralogy of specific geologic features. She is currently working on the calibration of the Hayabusa camera and spectrometer datasets archived in the PDS.

Besides planetary science, Lucille enjoys horseback riding, photography, drawing, reading, and playing piano.

PSI extends a very warm welcome to Lucille!

Evidence of Supervolcano on Mars

(continued from front page)

"This highly explosive type of eruption is a game-changer, spewing many times more ash and other material than typical, younger Martian volcanoes," Jacob said. "During these types of eruptions on Earth, the debris may spread so far through the atmosphere and remain so long that it alters the global temperature for years."

After the material is expelled from the eruption, the depression that is left can collapse even further, causing the ground around it to sink. Eruptions like these happened in ages past at what is now Yellowstone National Park in the western United States, Lake Toba in Indonesia, and Lake Taupo in New Zealand.

Volcanoes had not been previously identified in the Arabia Terra region of Mars, where Eden Patera is located. The battered, heavily eroded terrain is known for its impact craters. But as Joe examined this particular basin more closely, he noticed it lacked the typical raised rim of an impact crater. He also could not find a nearby blanket of ejecta, the melted rock that splashes outside the crater when an object hits.

The absence of such key features caused Joe to suspect volcanic activity. He contacted Jacob, a volcano specialist, who identified features at Eden Patera that usually indicate volcanism, such as a series of rock ledges that looked like the "bathtub rings" left after a lava lake slowly drains. In addition, the outside of the basin is ringed by the kinds of faults and valleys that occur when the ground collapses because of activity below the surface. The existence of these and other volcanic features in one place convinced the scientists that Eden Patera should be reclassified.

The team found a few more basins that are candidate volcanoes nearby, suggesting conditions in Arabia Terra might have been favorable for supervolcanoes. It is also possible massive eruptions here could have been responsible for volcanic deposits elsewhere on Mars that have never been linked to a known volcano.

"If just a handful of volcanoes like these were once active, they could have had a major impact on the evolution of Mars," Jacob said.

Visit http://www.psi.edu/news/marssupervolcano.html for images of Eden Patera basin on Mars. *Project funding was provided by the NASA Mars Data Analysis program.*

Director's Note

The Solar System is always busy!

We had great hopes for the "Comet of the Century" ISON to provide a spectacular sky display around Christmas. PSI scientists were tracking it from Kitt Peak National Observatory, other observatories around the world, and even from small telescopes in their back yards. Unfortunately, it disintegrated as it passed close to the Sun around Thanksgiving. Of course nothing really disappears so I am hoping we will see the debris stream in the thermal infrared with the Spitzer space telescope in the near future.

Another comet that is attracting attention is named Siding Spring. In October 2014 it will pass very close to Mars and envelop it in its coma. PSI has one of the two teams that has been contracted to determine if debris associated with that comet could pose a threat to the many scientific satellites that are orbiting the Red Planet.

With all the concern about asteroid hazards (given an uptick with last year's explosion of a very small asteroid over Chelyabinsk, Russia), NASA has turned on the Wide-field Infrared Survey Explorer (WISE) after two years of hibernation in Earth orbit. It will continue the hunt and characterization of near-Earth objects (NEO's) over the next few years until its changing orbit will render it unusable. It was successfully brought back to life and PSI Research Scientist Tommy Grav is a part of the team that is already finding more of these objects. Apart from hazards, it is hoped they might discover a target for a potential future human mission to an NEO.

Closer to home, there was a spectacular fireball that exploded over Tucson late on Dec. 10! It was not quite in the Chelyabinsk category, but the blast rattled homes and illuminated the ground. Visual triangulations and radar detections placed it in the far northwest of the city, and as soon as the Sun rose, PSI had a contingent out hunting for meteorites. Nothing was found and additional data placed the location of any fall further to the west. No luck yet, but hope springs eternal.

As we continue to engage in the exploration of the solar system, these local events remind us that our neighborhood is much larger than can be measured in city blocks. We need to know about where we live!

Mark V. Sykes
December 2013

PSI Staff Awards

PSI Education Specialist and Research Scientist **Sanlyn Buxner** (below) was named one of Tucson's top young community leaders at a "40 Under 40" awards breakfast sponsored by the *Arizona Daily Star* on October 2. She was recognized for her work training scientists and educators who work in space science education and public outreach nationwide. Sanlyn is passionate about promoting STEM education — **S**cience, **T**echnology, **E**ngineering, and **M**athematics — through teacher workshops, youth programs, and public events.

Last fall, PSI Senior Scientist **Robert "Bob" W. Gaskell** was honored by having an asteroid named for him. Asteroid (85015) Gaskell = 2004 BE38 is the official citation as printed in the Minor Planet Circular. It was discovered 2004 Jan. 19 by the Catalina Sky Survey. Bob is known for the development of stereophotoclinometry software tools, which are used to determine the shape and topography of Solar System objects and for spacecraft navigation using landmark tracking.

PSI Research Scientist **Nicholas "Nick" J. Tosca** (below right) was surprised to receive the 2013 Max Hey Medal awarded by the Mineralogical Society of Great Britain and Ireland at the Society Awards in Edinburgh, Scotland.

This award recognizes existing and ongoing research of excellence carried out by young workers within the fields of either mineralogy, crystallography, petrology, or geochemistry. The award of this medal dates back to 1993 and is named in honor of the eminent British mineralogist Dr. Max H. Hey (1904–1984).

PSI Research Scientist Nick Tosca, right, receiving the Max Hey Medal at the Mineralogical Society Awards in Scotland from Adrian Finch, Head of Geography and Geosciences at St. Andrews University.

Bravo to all our Scientists!

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Lunar Origin: Crisis at "Downton Abbey?"

by William K. Hartmann (continued from page 3)

View of the approach to Chicheley Hall, site of Royal Society's lunar origin discussion, northwest of London. *Photo: W. K. Hartmann*

Science reported the meeting with three pages titled "Impact Theory Gets Whacked." However, meeting co-organizer Dave Stevenson (who spoke at PSI's 40th anniversary retreat in 2012), summed up the situation by noting that no better ideas have been suggested for creating a moon with no big iron core. Thus, the giant impact model is still viable. Researchers such as Robin Canup and Sarah Stewart have been experimenting with models that get more equal proportions of the impactor in both the Earth and Moon.

One option I suggested in my talk at Chicheley Hall is that we should reconsider the "crisis-inducing" premise that the impactor came from some other part of the Solar System. Our original 1974 presentation (and our 1975 *Icarus* paper) viewed the impactor as a local 1 A.U. object, a building block of Earth, which would have had the same initial isotopic composition as Earth. The current paradigm favors various kinds of "alien" bodies scattered from other parts of the Solar System, but it is hard to defend. One has to ask why distant bodies with a variety of "alien" isotope ratios did not produce a still-preserved "late veneer" on the Moon with exotic isotope properties?

A related option I suggested is that a particular type of meteorite called "enstatite chondrite" should get more attention. They have the same isotope composition as Earth and the Moon which proves that bodies of the right isotopic composition did exist. There is even some evidence that the enstatite objects originated near Earth's orbit. (They were relatively ignored at Chicheley Hall, however, because of the paradigm about "alien" impactors.)

PSI's Steve Kortenkamp and I explored another idea in which a local impactor was "hung up" for some time in the L4 or L5 Lagrangian points, i.e., gravitationally stable places in Earth's orbit around the Sun. (Alas, our proposal to the NASA Origins Program for more work was turned down in November.)

Other ideas exist. In short, lunar origin is still a challenge, but the "PSI concept" of giant impact still lives.