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What was once an ancient river channel is now a high sandstone ridge—or an "inverted" channel—in the Jurassic Morrison Formation near Green River, in east-central Utah.

Ancient River Channels in Utah, on Mars

In fall 2008, PSI Research Scientist Rebecca M. E. Williams went to Utah to continue a project funded by NASA's Mars Fundamental Research program. The project is "Assessing the preservation of fluvial pathways in the terrestrial geologic record: analogs for the investigation of Martian raised channels." Here is an interview with Dr. Williams conducted by PSI's Chris Holmberg:

What was the objective of your fieldwork?

My objective was to study inverted topography, in this case river channels and valleys. Erosion can lead to inverted topography; for example, if a valley floor is more resistant to wear than the surrounding walls, erosion will strip away the walls leaving the former valley as a high-standing ridge. My interest in inverted valleys on Earth comes from studying similar landforms on Mars. Few scientific studies have been conducted on inverted channels and valleys and how they were formed. In fact, I learned about many of my field sites from guidebooks, rather than scientific articles! The opportunity to test whether models for present-day water flow can be applied to inverted valleys was irresistible.

Why did you choose this location for your fieldwork?

It turns out that Utah has several different types of inverted valleys which enabled me to sample the diversity of these forms in a small geographic area. Tom Chidsey, of the Utah Geological Survey, was instrumental in alerting me to several field locales. Near Green River there are several examples of inverted channels that have been cemented over time by silica and carbonate materials from the Late Jurassic and Early Cretaceous periods. The sediments that filled these channels were buried for millions of years before regional uplift and erosion re-exposed them at the surface. (This area is also famous for dinosaur fossils.) In St. George (southeastern corner of Utah) several Quaternary-aged (1-2 million years old) lava-capped valleys are preserved.

(Continued next page)

An example of an inverted river valley, this oblique aerial view shows the older (two million years old) Black Ridge Mesa — the former valley floor with 'D' on slope (at arrow) — that is at a higher elevation than the younger (one million years old) Airport Mesa in St. George, Utah. (Yes, lava-capped valleys are great building sites for airports and subdivisions!)

Inside this issue:

Ancient River Channels (*continued from front page*)

What are some of the measurements you made?

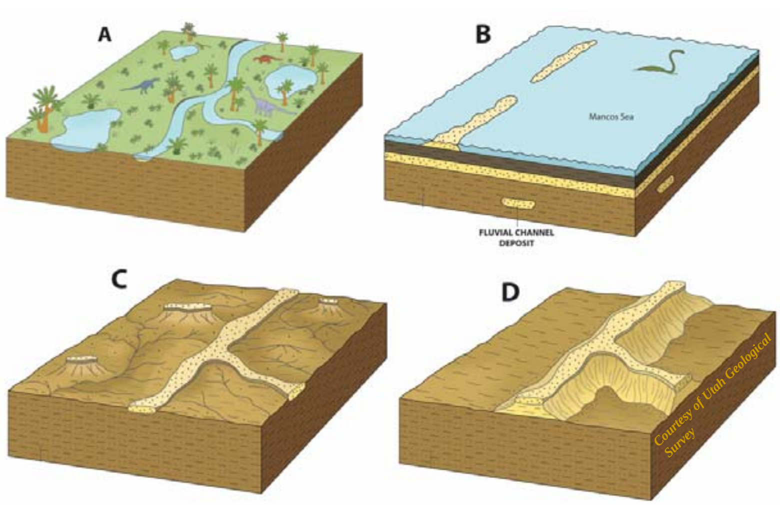
We—our research team included Dr. Jim Zimbelman and Dr. Ross Irwin, both of the Smithsonian Institution—collected topographic data using a global positioning system (GPS). For our topographic survey we obtained elevation measurements as we walked along

Rebecca Williams on cross-beds in the Salt Wash Member of the Morrison Formation (Late Jurassic), near Green River, Utah.

the ridge top. We would also periodically measure the cross-sectional profile (perpendicular to the ridge) to document the three-dimensional shape. We documented the grain size distribution along the way. In addition, we measured the size and orientation of cross-beds, which are related to past flow depth and direction, respectively.

What are some of the observations you made?

When lava flows down a valley, it fills the tributaries and ponds in low-lying regions, so there is considerable variability in the width



These blocks illustrate the development of "inverted" ancient river channels (paleochannels) in the Cedar Mountain Formation, Utah. (A) Sediment was deposited during the Early Cretaceous in river channels (sand and gravel) and flood plains (silt and clay). (B) In the Late Cretaceous, the area was beneath a shallow sea. Ultimately, the Early Cretaceous deposits were buried by about 8,000 feet of sediments and remained buried for more than 75 million years. (C) By late Quaternary time (about 130,000 years ago), uplift and erosion had stripped away the overburden, revealing the paleochannel deposits at the surface once again. (D) Present-day expression of the paleochannels is that of a topographic ridge as high as 130 feet above the surrounding plains (inverted topography).

along the flow path. The cemented inverted channels exhibited a more constant width when the channel fills were preserved. However, erosion is exploiting the underlying weak mudstone and the channel capstone blocks are breaking off, leaving narrow ridges and gaps in the channels. These differences in form are helpful for inferring what material caps the sinuous ridges on Mars.

Did you encounter any difficulties during the fieldwork?

Happily, I can say that my field work went very smoothly. Utah in October has ideal temperatures for fieldwork (often in the 70's) and we had sunny skies throughout. One of our field sites was located on a pheasant ranch and we were grateful to the owners for granting us access. However, it was a first to hear gunfire in the distance from a hunting expedition. We donned orange vests as a protective measure!

What were the highlights of the expedition?

Soaring over the gorgeous Utah landscape in a Cessna 172 four-seater aircraft was definitely a highlight. Our research team sought different vantage points to examine these landforms and provide a basis of comparison for satellite images of the Martian sinuous ridge networks. Changing one's perspective is very instrumental and the flyovers of the field site often illuminated relationships that were not apparent from the ground. We were particularly fortunate that the St. George location was very near Zion National Park and a bird's eye view of the sun-kissed white and rust-colored rock formations was spectacular!

Composite images of terrestrial and Martian river channel features superimposed (at greatly enlarged scale) on images of Earth and Mars, respectively. Left: Oblique aerial photograph of an ancient sinuous river channel preserved in inverted relief in the Early Cretaceous Cedar Mountain Formation, east-central Utah. Features like this in Utah are providing insight into the origin of similar features on Mars. Right: Feature interpreted as a meander loop suggests persistent river activity in the past on Mars. Images obtained by the Mars Orbiter Camera; NASA/JPL/Malin Space Science Systems.

What are the future directions of the research?

The results of our work near Green River have been published in *Geomorphology*. We found that model-derived values for flow depth and discharge matched our field observations for these parameters for the cemented inverted channels. These results suggest that through careful application of flow models to cemented inverted channels, we can reconstruct the amount of water that once flowed through the channels. Now the goal is to visit additional examples of inverted channels to see if the lessons learned at the Utah sites are broadly applicable. □

Robert Reedy Joins PSI

Robert (Bob) Reedy joined PSI as a Senior Scientist in October, 2008 and is an off-site employee in Los Alamos, New Mexico. He is the Deputy Team Leader for the 2001 Mars Odyssey Gamma-Ray Spectrometer (GRS) experiment, which has mapped the distribution of many elements on the surface of Mars since 2002. For over 30 years, with grants from NASA, he has studied cosmic-ray-produced (cosmogenic) nuclides in solar system matter. He is on a large team supported by the National Science Foundation (NSF) to determine the best production rates for cosmogenic nuclides made in situ in the surface of the Earth. He is a Co-investigator on the gamma-ray spectrometer experiment on the Japanese Kaguya (SELENE) lunar orbiter.

Bob was raised in upstate New York and earned his undergraduate degree in chemistry from Colgate University in 1964. In 1969, he received his Ph.D. in chemical physics at Columbia University with a thesis on mechanisms for low-energy nuclear reactions. He did his post-doctoral research at the University of California, San Diego, where he applied his experience in nuclear reactions to the study of cosmogenic nuclides in lunar samples and to modeling the measurements made by the GRS experiments on the Apollo 15 and 16 missions.

He joined the Los Alamos National Laboratory (LANL) in 1972 as a Technical Staff Member in the nuclear chemistry group. In 1986, he moved to one of the space science groups, where he studied energetic particles in space and often did planetary research with William Feldman (now at PSI). He later did some nuclear and space work with Thomas Prettyman (also now at PSI).

While at LANL, he often had research grants from NASA for work other than cosmogenic nuclides. He was appointed by NASA in 1984 to a team to develop advanced gamma-ray spectrometers for space missions and was selected in 1986 for the Mars Observer GRS team. In 1999-2001, he worked on the GRS measurements from the Near Earth Asteroid Rendezvous (NEAR)-Shoemaker mission. In April 2002, he retired from LANL and moved his grants for cosmogenic nuclide research and the Mars Odyssey GRS team to the Institute of Meteoritics at University of New Mexico.

Bob married Maria in New York City in 1969. Their two children, Anne and John, left the nest over a decade ago and now have good careers. And so far Bob and Maria have one grandson.

Bob has always enjoyed running and several decades ago gradually increased his distances to marathons and then 50-mile runs on trails. He has entered and finished three 100-mile runs on trails. He also has competed in race walking, which is useful on his favorite runs in the mountains of northern New Mexico. He also enjoys biking and both cross-country and downhill skiing.

Bob and Maria Reedy

At PSI, Bob is planning to continue his NASA and NSF cosmogenic-nuclide work in collaboration with Tom Prettyman. He will also work on the analysis of the measurements by the GRS experiments on Mars Odyssey and Kaguya.

Welcome to PSI, Bob!

2009 PSI Board of Trustees

PSI's Board of Trustees held their Annual Meeting on February 23, 2009. Front row, l-r: Donald Davis, Mark Sykes, Candace Kohl (Vice Chair), and our newest member, Michael Gibbs. Back row, l-r: William K. Hartmann, Tim Hunter (Board Chair), Benjamin Smith, David Levy, and John Mason (Secretary). Board member Brent Archinal is not pictured.

PSI Off-Site Scientists Get Together at AGU Meeting

PSI off-site scientists enjoyed a night out during the December American Geophysical Union meeting in San Francisco. From left: Leslie Bleamaster (TX), William Feldman (NM), Karly Pitman (CA), Joe Michalski (France), Melissa Lane (Phoenix, AZ) and Jana Bleamaster (Leslie's wife).

Pierazzo on National Geographic Special

by Ed Stiles

PSI Senior Scientist Elisabetta Pierazzo was one of several scientists featured in the National Geographic Channel's new program, "Known Universe." The three-hour program aired on February 15th and February 19th and focused on the biggest, smallest, fastest and most explosive things in the universe.

Elisabetta Pierazzo being interviewed on the rim of Meteor Crater in northern Arizona for the National Geographic Channel program, "Known Universe."

National Geographic interviewed Pierazzo at Arizona's Meteor Crater, the most well-preserved impact crater on the planet. The 3,000-foot diameter, 570-foot-deep crater was formed when a boxcar-sized object crashed in northern Arizona's desert. Pierazzo talked about the energy involved and the consequences of large meteor impacts on Earth.

A larger object that hit Yucatan led to the extinction of dinosaurs. Could a similar-sized object slam into Earth, ending life as we know it? That was one of many questions addressed in the series that combines the latest scientific knowledge with interviews of experts, such as Pierazzo, who can explain complex concepts in ways that are easy for non-scientists to understand.

University of Arizona Regents Professor Jay Melosh, a leading expert on impact cratering, was also featured in the "Known Universe" episode on explosions. While pursuing their individual research programs, Pierazzo and Melosh have collaborated on modeling impact events on the Earth and other planetary surfaces.

"The advantage of modeling real terrestrial impact events, like those that produced structures like Chicxulub (Mexico), Vredefort (South Africa), Ries (Germany), and Meteor Crater (AZ), is that models of their formation can be compared to field data from geologic studies of the craters. This, in turn, helps improve models of impact cratering that can be applied to craters seen on other bodies in the solar system," Pierazzo said.

Pierazzo studies the effects of impacts on the evolution of the environment and climate, and on the origin and evolution of life. ▫

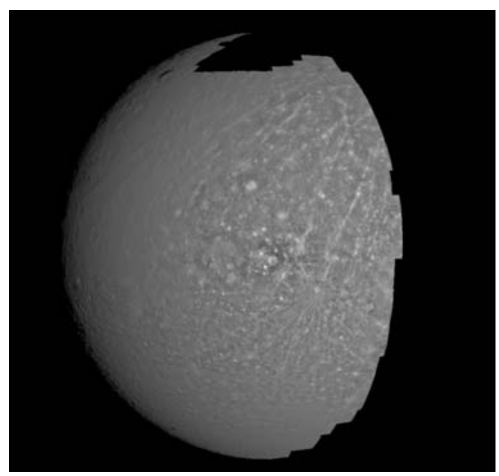
Gaskell dubbed "Captain Cook of Space" in *New York Times* article

PSI Senior Scientist Robert W. Gaskell was the subject of a *New York Times* article entitled "Mapping Celestial Terrains, in All Their 3D Glory," published December 22, 2008.

The article describes how map making has evolved from the days of using 8x10 photographs and straightedges that created less detailed 2D images to the current time with sophisticated computers, digital photography and laser range-finders which create amazing 3D images. These vastly more detailed images help NASA scientists choose landing sites, pinpoint the locations of their spacecraft, and generally visualize the terrain of planets and moons.

There is an art to creating these maps and "nobody does it better than Dr. Gaskell," the article states. "With software he developed over a quarter century of trial and error, he can process hundreds of images in a few hours, slap them atop one another electronically like coats of paint and produce a topographical map so detailed that you often need a pair of 3D glasses to appreciate what he has done. At 63, Dr. Gaskell has become the Captain Cook of space."

Currently he is mapping Mercury, eight moons of Saturn, Earth's Moon (for a contract with NASA) and refining his model of the asteroid Eros. He calls his technique "stereophotoclinometry," "stereophoto" for light coming from different directions, and "clinometry" as in measuring inclines. He needs a minimum of three images of an area, usually from an orbiting spacecraft. The angle of the sun must be different in each of the three images to show different shadows. By comparing shadows his software can calculate slopes and then find the heights.



Mercury in the midst of being mapped by Robert Gaskell. Thousands of maplets representing albedo (intrinsic brightness) and topography are tiled together to produce this image of Mercury under construction. Each 99x99 maplet accurately describes the surface at almost 10,000 points. Almost 35,000 such maplets have been constucted so far, representing more than 300 million surface points, from images gathered by the MESSENGER and Mariner 10 spacecraft.

Gaskell was also profiled in *Astronomy Now Online* (August 22, 2008) in an piece entited, " The interplanetary map-making maverick," which calls his creations "the most accurate topographic maps ever created of other worlds." ▫

Welcome Karly Pitman into the Fold

Karly Pitman joined PSI as an Associate Research Scientist in September 2008 and is an off-site researcher based in Altadena, CA. Karly's areas of interest include planetary surfaces and atmospheres, small bodies (satellites, asteroids, meteorites), astrophysics (interstellar medium, dust), remote sensing, radiative transfer modeling, and laboratory and field spectroscopy at visible to far infrared wavelengths.

Beginning life as an Army brat in Alabama, Karly eventually lived in over 25 different homes in the midwestern and southern U.S. before graduating from high school. As a youngster she enjoyed competing in and winning state Science Olympiads. And later she parlayed her interest in small rocks and the night sky to a double major in astronomy and geology at Vassar College, with thesis work in asteroids and meteoritic microscopy.

After she received a Ph.D. in physics at Louisiana State University, (Geaux Tigers™) in Baton Rouge, she joined Geoff Clayton's interstellar dust research group in 1999. Geoff and another member of this group, Mike Wolff, supported Karly's interest in planetary science and infrared spectroscopy and served as her doctoral advisers on a Mars regolith dissertation.

During graduate school Karly also worked as a Lunar and Planetary Institute Graduate Fellow with Allan Treiman and as a guest researcher at the Mars Space Flight Facility at Arizona State University, hosted by Josh Bandfield. In 2003, Karly happily became a remote researcher at the Space Science Institute in Boulder, CO, funded under Mars research grants. Karly defended her dissertation in August 2005, two days after Hurricane Katrina, in temperatures well over 100^{o}F with no power in her home and only emergency power at two LSU departments. Her stress thresholds are much higher after the experience.

Following graduation, Karly was awarded a position as a postdoctoral research associate with Anne Hofmeister at the Department of Earth & Planetary Sciences at Washington University, St. Louis, MO. This was a joint appointment with the University of Missouri – Columbia, applying laboratory mid- to far-IR Fourier transform spectroscopy and mineral physics to interpret spectral signatures in astrophysical (AGB object) environments. In 2006, Karly became a NASA Postdoctoral Program fellow at the Jet Propulsion Laboratory, California Institute of Technology, working with Bonnie Buratti and members of several Cassini instrument science teams on radiative transfer modeling of Titan's atmosphere to better characterize surface properties as seen by the Cassini Visual and Infrared Mapping Spectrometer. She also performs hyperspectral analysis and mission support for Cassini VIMS data of Titan and the Saturnian icy satellites Rhea, Dione, Tethys, Mimas, and Enceladus. She has several other sidelines of research in the works, including optical constant derivation, and planetary ices.

When not at work, Karly engages in amateur photography, designs and sews her own clothing, supports Women in Science initiatives, and sings 90's alternative rock hits. She would like to say that she engages in these hobbies more regularly, but really, she's rarely not working. Karly is delighted to have the opportunity to work at PSI and is looking forward to working with PSI staff and colleagues.

PSI welcomes Karly into the fold!

Director's Note: *Blazing Trails*

Despite the difficult times in which we live, PSI has continued to flourish. In the past year (which for us ends on January 31), PSI grew more than 20% in both revenue and staff. Under current contracts, PSI will grow another 20% in revenue and we continue to attract good talent. PSI's success is rooted in the quality of its scientists and staff, with whom it is a real pleasure to work.

Do we have a future, though?

Yes, for as long as the US wants to continue to explore the solar system — and there is no indication that that is closing down. PSI supports a number of missions, running instruments on Dawn, MESSENGER, and Mars Odyssey, while providing science team members and participating scientists on these and other missions. We engage in a lot of data analysis, by which NASA missions are successfully completed and from which taxpayers gain benefit from their investment in those missions. We also engage in a substantial amount of the basic research, which creates the knowledge base that allows cost-effective, focused missions to be defined, and provides the framework within which data analysis takes place.

There is one area where our contribution remains untapped: defining the future direction of human activity in space. At present, the US plans to replant flags on the Moon by 2020, without regard to whether lunar activity is sustainable beyond the pure expenditure of money. The lunar missions and research that are underway may provide valuable information about potential resources on the Moon, but US policy is not centered on that question nor the more general question of whether it is possible to sustain and expand human activity in space through the utilization of local resources. That is a challenge!

Researchers, many in Arizona, have laid out the potential of near-Earth asteroids (NEAs) for this purpose. Raytheon Missile Systems, with PSI, proposed an architecture for the Bush administration's Vision for Exploration, that first required an assessment of whether local resources existed and, if so, where they are (NEAs or the Moon), followed by a trade study to determine the relative cost of recovery and utilization. Then, having done our homework, we would decide what human activity would be engaged in where. Current policy puts the cart before the horse. In this context, PSI and other planetary scientists act as the trailblazers. With a new administration in power, perhaps we will have an opportunity to realize that role and put our future human space activity on a solid footing.

Mark V. Sykes
March 2009

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