2016 PROFILE

GEOLOGY // GEOPHYSICS
UNIVERSITY of WYOMING

Department Head
Carrick Eggleston

Awards

Alumni

Faculty

Field Work

Growth

History

Outreach

Research

Students

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FROM THE DEPARTMENT HEAD

The spring semester has started, classes and labs are running, and we are well into the graduate admissions process as well as a search for an Economic Geologist. Also ongoing is the UW Strategic Planning process, initiated by the new president Laurie Nichols and the new provost (and professor in our department!) Kate Miller.

The department had visits from Dean Paula Lutz and from the new President Laurie Nichols during the fall. During these visits we promoted the department and its history, and made important points about how teaching and research go hand in hand - a point made concrete by the many textbooks that our faculty have produced over the years. Research today appears in textbooks tomorrow. Many of the faculty also attended college-level "listening sessions" that took place as information gathering for Strategic Planning. The department's own dedicated listening session was attended by most of the faculty and brought forth the basic outlines of both assets and problems for our department.

The basics are clear – we enjoy strong industry and Alumni support, we have a strong research-active faculty, great graduate students, strong degree programs, and we are well-situated to take further advantage of our unique setting in Wyoming and the Rocky Mountains to promote field-based learning in Geoscience. While many of you may not find as many familiar faces among the faculty, there are new faculty making waves in new areas of research that are important not only to the academic advancement of our science but also to industry and to the state.

There are challenges as well. We lost 5 faculty in the last 2 years, and as many of you know, will lose another key faculty member over the summer (Steve Holbrook). Budget cuts have certainly had their impact, as has the climate of uncertainty with regard to university priorities, with new leadership at almost all levels. The financial impacts of downturn with regard to the state budget are flattening out, but the state still faces further (if smaller) deficits in the coming biennium. It remains to be seen whether the legislature will dip into "rainy day" funds to fill the gap (at governor Mead's request), or impose more cuts.

One thing that I can say for certain, however, is that I have been deeply impressed by the support from you, the Alumni. I am new to the department head job, of course, and am still reeling from the circumstances under which I became department head – and I have therefore never previously been fully aware of the importance and magnitude of your year-end giving along with support for the department's field education efforts. The donations came pouring in from all over, in both small and large amounts. I was impressed and touched. With your support, among other things, we are going to be able to provide a top-notch field experience this coming summer. We will be able to support the best TAs, travel more widely, and replace the old, rusty, leaking and "sketchy" field trailer with a newer one (still used, of course!) better customized to our students' needs. Your support goes far beyond this – it allows our department to provide student support that is not being covered by the state (e.g., TA-ships), to subsidize our teaching mission with needed supplies, to support faculty, and generally weather the downturn with fewer wrenching impacts than would otherwise be the case. That said, the situation is not sustainable - we are going to need to find state support for new positions in the longer run – but for what we have been able to do so far I thank you from the bottom of my heart, and on behalf of the department and the faculty, I thank you for your tremendous support.

I want to extend special recognition to **Randi Martinsen,** who will be included in the AAPG's 2nd edition of "The Heritage of the Petroleum Geologist" and will be honored at AAPG's 100th Anniversary celebration in Houston in April. This puts Randi in the company of 101 of the towering figures of the field including Bob Weimer, Bill Fisher, Mike Halbouty, Phil Anschutz, Marlan Downy Dan Busch and Jack Schmidt (the only scientist to walk on the moon, and who spoke to our department during the new-building celebrations some time ago). Randi will also be featured in an upcoming documentary on pioneering women in the oil industry, also to debut at AAPG in April. Congratulations Randi!

If you have any questions, please do not hesitate to contact me at **carrick@uwyo.edu**.

Sincerely,
Carrick Eggleston
Professor and Head
Department of Geology and Geophysics
University of Wyoming

GRADUATE STUDENTS JASON ALEXANDER AND MATT DUNLOP RECEIVE GSA RESEARCH GRANTS

Graduate students **Jason Alexander** (Ph.D.) and **Matt Dunlop** (Ph.D.) were both recently awarded research grants from the Geological Society of America (GSA). This year, GSA received 699 applications and both students gained first tier awards. Jason was fully funded for his proposal and Mat gained a Lipman Research award and was funded in excess of his proposal.

Jason will use the funding to support his field and laboratory work this summer to measure and analyze processes that create sand bars. The work will largely be conducted on the Niobrara River in Nebraska.

Matt will use his funding to continue his innovative and novel work on the platinum isotope characteristics of Pt bearing ore deposits and their implications for ore genesis. He will especially focus of the New Rambler Mine/deposit in the Snowy Range in Wyoming.

Jason is advised by Assistant Professor **Brandon McElroy** and Mat is advised by Associate Professor **Mike Cheadle**. ❒

PROFESSOR CAROL FROST SELECTED AS 2016 GEOCHEMICAL FELLOW

Professor **Carol Frost** was among 10 other scientists to be selected as 2016 Geochemical Fellows by the European Association of Geochemistry (EAG). The Geochemical Fellows will receive their honor at the 2016 Goldschmidt Conference in Yokohama, Japan. ❒

UW COLLEGE OF ARTS & SCIENCES TO HONOR FACULTY AT ANNUAL AWARDS LUNCHEON

The University of Wyoming College of Arts and Sciences will honor 10 faculty members with Extraordinary Merit Awards in teaching, research and advising.

They will be honored during the college's annual awards luncheon Saturday, May 7, at the UW Conference Center, 2229 Grand Ave. Activities begin with a reception at 11 a.m. followed by lunch at noon.

Faculty members to be honored are:
-- Joshua Clapp, Department of Psychology.
-- Rob Colter, Department of Philosophy.
-- Robert Corcoran, Department of Chemistry.
-- **Ellen Currano**, departments of Botany, and Geology and Geophysics.
-- Antoinette DeNapoli, Department of Religious Studies.
-- Conxita Domenech, Department of Modern and Classical Languages.
-- David Messenger, Global and Area Studies.
-- **Cliff Riebe**, Department of Geology and Geophysics.
-- Qian-Quan Sun, Department of Zoology and Physiology.
-- Anna Zajacova, Department of Sociology.

UW RESEARCHER PART OF TEAM THAT DEFINED LINKS WITHIN TWO SUPERCONTINENTS

April 11, 2016 - Above Photo: Kevin Chamberlain, a research professor in the UW Department of Geology & Geophysics, is co-author of a paper that appears online in Nature Geoscience today (April 11). The paper highlights a technique that he helped develop to test pre-Pangea continental reconstructions. Here, Chamberlain poses with a mass spectrometer and holds a piece of a mafic dike, or black rock, which cuts through white, or granitic, rock (also pictured) that represents continental crust. (UW Photo)

A University of Wyoming researcher contributed to a paper that has apparently solved an age-old riddle of how constituent continents were arranged in two Precambrian supercontinents -- then known as Nuna-Columbia and Rodinia. It's a finding that may have future economic implications for mining companies.

Specifically, the article describes a technique **Kevin Chamberlain,** a UW research professor in the Department of Geology and Geophysics, and other researchers used to test reconstructions of ancient continents. The paper argues that the rocks or crust now exposed in southern Siberia were once connected to northern North America for nearly a quarter of the Earth's history. Those two continental blocks now form the cores of the modern continents of Asia and North America.

Chamberlain was co-author of the paper, titled "Long-Lived Connection between Southern Siberia and Northern Laurentia in the Proterozoic," that appeared in today's (April 11) online issue of Nature Geoscience. The monthly multi-disciplinary journal focuses on bringing together top-quality research across the entire spectrum of the Earth sciences, along with relevant work in related areas. The journal's content reflects all the disciplines within the geosciences, encompassing field work, modeling and theoretical studies.

"The article highlights a technique that our project (**www.supercontinent.org**) has been using to test pre-Pangea or ancient continental reconstructions," Chamberlain says. "We have been using the ages, orientations and paleo-magnetic characteristics of short-lived (1 million to 10 million years in duration) igneous, mafic dike swarms as piercing points to determine nearest-neighbor continents in the past." Mafic dikes are dark-colored rocks or minerals that are in a dike formation, which is a sheet of rock that formed in a fracture in a pre-existing rock body. Chamberlain says mafic dikes, like those studied in the paper, can be found in Wyoming. Mafic dikes in the state include the black vein that can be seen in Mount Moran in the Teton Range; the black, horizontal band on the east face of Medicine Bow Peak; and those that crisscross the Granitic Mountains in central Wyoming.

Using labs at UW and UCLA, Chamberlain says his role in the project was to determine the magmatic ages of numerous mafic dikes through uranium-lead radiometric dating. He was one of four geochronology labs on the team and the only one based in the United States.

The linear dikes from these igneous events (large igneous provinces, or LIPs) are relatively narrow, roughly 100 meters or less, but can be 1,000 to 1,500 kilometers in length. They erupt in a radial pattern.
During later rifting, the continents broke into fragments, which later combined into subsequent new continents, such as our modern-day seven continents.

"There may have been four or five cycles of supercontinent formation," Chamberlain says.
Each continental fragment preserves a dike swarm record, he explains. By comparing the temporal records called bar codes (since a plot of dike date vs. time looks like a bar code) of older fragments known as cratons (the cores of modern continents), Chamberlain says he was able to test whether the cratons were close enough to share LIP dike swarms. He adds the research team also can determine when the two cratons joined, as well as when they split apart.

"In this new study, we believe that northern Laurentia (North America) and southern Siberia were joined for nearly 1.2 billion years from 1.9 billion years ago to 700 million years ago," he says. "Geologists are like detectives. It seems like we come to the crime scene after the fact and put together the pieces."

This finding disproves previous constructions of Nuna-Columbia and Rodinia, and establishes new arrangements of the continental blocks within them, he says.

The project determined the ages of nearly 250 mafic dikes worldwide, a number Chamberlain says is large enough to build a database comparison between all of the older continental fragments from roughly 500 million years ago to 2,700 million years ago. The research group also worked on more recent LIPs -- about 400 million to 100 million years ago -- which have importance for oil and gas exploration, and hydrocarbon maturation models.

A consortium of mining companies funded the research project for five years. Their reasoning: That the continental reconstructions for times when major, known metal deposits formed would be useful for prospecting new finds on the conjugate continents, Chamberlain says. These new deposits may be buried under hundreds of meters of younger rock. So, by establishing which continents were next to the known deposits when they formed, the hope is that additional minerals may be found in the future.

"A lot of the major metal deposits in the earth formed in the early part of Earth's history," Chamberlain says.

Chamberlain collaborated on the paper with researchers at Carleton University in Ottawa, Canada; Tomsk State University in Tomsk, Russia; University of Toronto in Toronto, Canada; Lund University in Lund, Sweden; Queens University in Kingston, Canada; Institute of the Earth's Crust, Siberian Branch of the RAS, in Irkutsk, Russia; Diamond and Precious Metal Geology Institute in Yakutsk, Russia; Institute of Geochemistry in Irkutsk, Russia; Geological Survey of Canada in Ottawa; and the Kosygin Institute of Tectonics and Geophysics in Khabarovsk, Russia. ❒

UW HUSBAND-WIFE RESEARCH TEAM TO LEAD PACIFIC OCEAN FLOOR RESEARCH EXPEDITION

When **Michael Cheadle** and **Barbara John** hit the high seas in January for their next research expedition to the floor of the Pacific Ocean, the two University of Wyoming faculty members will take with them a small sailboat built by UW Lab School students.

The tiny vessel, dubbed "The Jackalope," will be launched at sea, with the hope it washes up on some faraway shore and is discovered.

"It's outfitted with a GPS. NOAA (National Oceanic Atmospheric Administration) will track it for the Lab School Students," says Cheadle, a UW associate professor in the Department of Geology & Geophysics. "It's almost five feet long with no motor. It just has an itty bitty sail and keel."

John, a UW professor of geology and geophysics, adds that the small boat also includes writing in nearly 20 languages, including Cantonese, Chinese, English, French, Mandarin, Papa New Guinea, Portuguese and Spanish, so that anybody who finds it can, hopefully, correspond with the Lab School Students. 'It contains a time capsule about UW and Laramie," John says.

The Jackalope is one component of a multipronged community outreach effort related to the voyage of the U.S. Research Vessel Atlantis and two small submarines tasked with exploring and sampling the sea floor at Pito Deep in the Pacific Ocean. The outreach effort includes partnerships with the Teton County Library in Jackson, the Wyoming Geological Association in Casper and the Birch Aquarium in San Diego, CA.

"We intend to do a lot of outreach," Cheadle says. "We have bought extra satellite bandwidth, so we can do two-way, live interactive broadcast from the ship to schools and other organizations."

The husband-wife research team will lead 17 scientists from the United States and Canada on the research expedition. Eight of those will come from UW. Besides Cheadle and John, these include another faculty member, Susan Swapp; Theresa Williams, a middle school teacher at the Lab School; three graduate students; and one undergraduate student. The Atlantis will leave from Easter Island January 13 to work at Pito Deep before returning to Arica in Chile February 24.

"Barbara and I, along with Jeff Gee from Scripps Institute of Oceanography at the University of California-San Diego, are the chief scientists. So, this is very much our cruise," Cheadle says. "Hence, we get to lead the operations, but also have to deal with any problems."

Expedition Objectives:

The science objective of the expedition is three-fold:

- To sample the interior of ocean crust to better understand how it is formed by working in a large chasm called Pito Deep, which is 3.5 kilometers deep (about twice the depth of the Grand Canyon) that provides a cross-section of samples through oceanic crust.

"Sixty percent of the Earth's surface is the sea floor. Because it's below the water, we don't know enough about it," Cheadle says.

- To map the geometry of the magnetic field boundaries in the third dimension (vertically in the cliff face of the chasm). "This has never been done before," John says.
- To explore for undiscovered hydrothermal vents at the bottom of the chasm and the strange life forms that live in these vents. "Hot water is emitted from the top of these vents, and provides habitat for various bacteria, shrimp and small fish," Cheadle says.

"It's possible these bacteria were the first life forms on Earth," John says.

Two submarines, named Sentry and Jason II, will aid in the exploration. The former is autonomous and uses sonar to map the sea floor. The latter is larger and tethered to the ship, and is used for core sampling both rocks and fluids.

From the Pacific to Wyoming:

A lot of what occurs with the submarines will be transmitted back to shore. Williams will broadcast live to UW Lab School students, and to students from other schools around the world, who will be able to ask questions during the interactive presentation. Williams will provide educational outreach to classrooms around Wyoming and elsewhere through live two-way webcasts.

"The teachers I interact with may send questions in advance or request specific experiences for their students, including a tour of the ship; an opportunity to question the scientists on board; the chance to see some of the samples we've collected; or other interactions of interest to them and their students," Williams explains.

Williams, together with videographer Lucas Kavanaugh, will also create weekly videos, keeping track of happenings during the time the group is at sea. The videos, podcasts and blogs will be posted where people can follow the expedition's progress.

Besides building the boat, students in grades K-8 at the lab school, decorate Styrofoam cups and Styrofoam heads that will make a trip to the bottom of the ocean. Each group of students made predictions about what might happen to the Styrofoam while submerged so many kilometers under the sea.

"This also is a great opportunity for me as an educator, since I will work with the scientists while they are conducting their research," Williams says.
"I will have a chance to learn, firsthand, how the samples and data are collected, and experience the daily rhythm of field work on a ship. A deeper understanding of the work will help me share the information with my students in a more meaningful way with engaging stories that I actually experienced."

"UW is pretty landlocked. A lot of kids don't know much about the exploration of the seas," John says. "With this outreach, they can observe and sample different types of science, from geology to robotics. STEM (science, technology, engineering and math) is not boring."

The outreach will include a one-hour streamed program for adults at the Teton County Library; a live-feed program at the monthly meeting at the Wyoming Geological Association; and interactive communication with some courses at Casper College. Cheadle and John also have received an inquiry for a program from the Wyoming State Museum.

To follow the progress of The Jackalope, go to http://educationalpassages.com/active-boat-map/ and select "Jackalope" from the map. For more information about the expedition, go to https://www.pitodeep.org/ ❐

UW RESEARCHER PART OF INDIAN OCEAN EXPEDITION TO DRILL TO THE EARTH'S MANTLE

Professor Chris MacLeod (left), co-chief scientist from Cardiff University in the United Kingdom, and UW Associate Professor Mike Cheadle, a structural geologist, examine the first piece of core recovered during the Indian Ocean expedition. Cheadle is studying samples brought up from the ocean floor to better understand the Earth's development and how and why earthquakes occur on large faults. (Oliver Pluemper Photo)

Michael Cheadle describes drilling on the ocean floor similar to using a wet piece of spaghetti -- holding it on one end while trying to push the other end deep into a cake.

The University of Wyoming associate professor in the Department of Geology and Geophysics is part of a team of research scientists dealing with that degree of difficulty as they attempt what is akin to a journey to the center of the Earth -- drilling through the seafloor crust and into its mantle -- from the Indian Ocean.

Cheadle is one of 26 research scientists, including nine from the United States, aboard the **JOIDES** Resolution, or "JR" for short. The sea-going research vessel drills core samples and collects measurements from boreholes into the ocean floor, giving scientists a glimpse into Earth's development.

Other researchers hail from China, Italy, the United Kingdom, France, Japan, India, Brazil, Germany, the Netherlands, Australia, South Korea, Poland and the Philippines.

"I'm one of the structural geologists who examine the entire core (samples) for features, like faults, to better understand how the Earth's crust deforms as it is made at mid-ocean ridges," Cheadle explains. "We are drilling one of the largest faults in the world and, by better understanding how these faults work, we can better understand how and why earthquakes occur on big faults. And, the beauty of working on a large fault is it has removed the top of the crust, so we have less far to drill to get to the mantle, which is the main target of the expedition."

Drilling and sampling the Earth's mantle has been a major objective for geologists for more than 60 years, he says. The Indian Ocean expedition is at a point called Atlantis Bank, which was once an island, but has now subsided 700 meters below sea level.

Cheadle says the plan is to ultimately drill to a depth of 5 kilometers (3.1 miles). This will involve three drilling legs -- two conducted by the "JR" to get to a depth of 3 kilometers, followed by an expedition using the Chikyu, a Japanese drilling vessel.

"On this leg, we were hoping to get to about 1200-1300 meters (deep), but we are likely to only get to 800-900 meters, because we've had various problems," he says. Those problems have included having a technician, due to an eye infection, helicoptered off the ship. The vessel had to sail to the island of Mauritius, where a Medivac picked up the patient, who Cheadle reports is now fine.

"It's really difficult drilling deep. One always finds unexpected problems, because it's been done so little," he says. "We are currently the fifth-deepest hole drilled in ocean crust."

This marks the second time Cheadle has been part of a research expedition on this particular vessel. In fall 2012, he was part of a 26-member international research team that cruised to a deep scar in the floor of the Pacific Ocean. That mission entailed studying rocks sampled from below the seafloor in an effort to better understand how the Earth's crust is formed.

In this latest expedition, Cheadle is one of a few researchers to get the first up-close look at the core samples.

"I'm one of the three people who get to touch the core first, because I have to decide how the core is cut into two halves," he says. "One half is an archive half, to be looked at and measured, but otherwise to be saved; and the other half is the working half, which we can sample and use to learn more about the rocks, such as their chemistry."

"We look for clues in the rocks for how the fault works, and measure and catalog what we see," Cheadle adds. Cheadle says he will be aboard the "JR" until Jan. 30. During that time, he will conduct a live broadcast from the ship to one of his science classes for teachers in the UW College of Education. ❐

UW PART OF STUDY TO UNCOVER YELLOWSTONE'S SUBSURFACE MYSTERIES

A helicopter carries **SkyTEM** airborne geophysical equipment above Spirit Lake, Wash. The same equipment will be used to map Yellowstone National Park's subsurface starting Nov 7th. (*U.S. Geological Survey Photo*)

Nov 4th 2016. A new study providing an unprecedented regional view of the earth's crust beneath Yellowstone National Park will begin with a helicopter electromagnetic and magnetic (HEM) survey with a SkyTEM system Monday, Nov. 7.

Scientists from the U.S. Geological Survey, University of Wyoming and Aarhus University in Denmark hope to distinguish zones of cold fresh water, hot saline water, steam, clay and unaltered rock from one another to understand Yellowstone's myriad hydrothermal systems. The flights will continue for the next two to four weeks.

Although the park's iconic hydrothermal systems are well mapped at the surface, their subsurface groundwater flow systems are almost completely unknown. The HEM survey, operated by SkyTEM, will provide the first subsurface view of Yellowstone's hydrothermal systems, tracking the geophysical signatures of geysers, hot springs, mud pots, steam vents and hydrothermal explosion craters to depths in excess of 1,000 feet.

A low-flying helicopter, about 200 feet above the ground's surface, will fly along pre-planned flight grids focusing on the Mammoth-Norris corridor, Upper and Lower Geyser Basins, and the northern part of Yellowstone Lake. An electromagnetic system, resembling a giant hula hoop, will be suspended from the helicopter's base. The equipment senses and records tiny voltages that can be related to the ground's electrical conductivity.

These observations, combined with existing geophysical, geochemical, geological and borehole data, will help close a major knowledge gap between the surface hydrothermal systems and the deeper magmatic system. For example, research shows that the hot water spurting from Yellowstone's geysers originates as old precipitation, snow and rain that percolates down into the crust, is heated and, ultimately, returns to the surface. This process takes hundreds if not thousands of years. Little, however, is currently known about the paths taken by the waters.

The data collected from the flight will guide future ground-based geological, hydrological and geophysical studies.

UW's Wyoming Center for Environmental Hydrology and Geophysics (**WyCEHG**) is part of the research team. WyCEHG previously collaborated with Aarhus University, using SkyTEM, to map groundwater aquifers in the Laramie and Snowy ranges of southern Wyoming. ❐

UW SCIENTISTS GAIN SUPER-VOLCANO INSIGHTS FROM WYOMING GRANITE

University of Wyoming researchers **Davin Bagdonas** and **Carol Frost** make observations on Lankin Dome, part of the Wyoming batholith, in central Wyoming's Granite Mountains. (Myron Allen Photo)

Geophysical monitoring of the ground above active supervolcanoes shows that it rises and falls as magma moves beneath the surface of the Earth. Silica-rich magmas --like those in the Yellowstone region and along the western margin of North and South America -- can erupt violently and explosively, throwing vast quantities of ash into the air, followed by slower flows of glassy, viscous magma.

But, what do the subterranean magma chambers look like, and where does the magma originate? Those questions can't be answered directly at modern, active volcanoes.

Instead, a new National Science Foundation (NSF)-funded study by University of Wyoming researchers suggests that scientists can go back into the past to study the solidified magma chambers where erosion has removed the overlying rock, exposing granite underpinnings. The study and its findings are outlined in a paper published in the June issue of American Mineralogist, the journal of the Mineralogical Society of America.

"Every geology student is taught that the present is the key to the past," says Carol Frost, director of the NSF's Division of Earth Sciences, on leave from UW, where she is a professor in the Department of Geology and Geophysics.

"In this study, we used the record from the past to understand what is happening in modern magma chambers."

One such large granite body, the 2.62 billion-year-old Wyoming batholith, extends more than 125 miles across central Wyoming. UW master's degree student Davin Bagdonas traversed the Granite, Shirley and Laramie mountains to examine the body, finding remarkable uniformity, with similar biotite granite throughout. "It was monotonous," says Bagdonas, who worked on the project with Frost. "Only minor variations were observed in granite near the roof and margins of the intrusion."

This homogeneity indicates that the crystallizing magma was generally well-mixed. However, more subtle isotopic variations across the batholith show that the magma formed by melting of multiple rock sources that rose through multiple conduits, and that homogenization was incomplete.

Studies of the products of supervolcanoes and their possible batholithic counterparts at depth are a vibrant, controversial area of research, says Brad Singer, professor in the Department of Geoscience at the University of Wisconsin-Madison. He says the research by Frost and her colleagues offers "a novel perspective gleaned from the ancient Wyoming batholith, suggesting that it is the frozen portion of a vast magma system that could have fed supervolcanoes like those which erupted in northern Chile-southern Bolivia during the last 10 million years.

"The possibility of such a connection, while intriguing, does raise questions. The high silica and potassium contents of the Wyoming granites differ from the bulk magma compositions erupted by these huge Andean supervolcanos. This might mean that the Wyoming batholith records the complete solidification of potentially explosive magma at depth, without the eruption of much high-silica rhyolite," Singer says. "Notwithstanding, this paper will certainly provoke a deeper look into how ancient Archean granites can be used to leverage understanding of the 'volcanic-plutonic connection' at supervolcanoes."

Large bodies composed solely of biotite granite are more common in the Neoarchean eon (2.8 billion-2.5 billion years ago) than in younger terrains. The reason may relate to higher radioactive heat production in the past, which provided the power to drive extensive granite formation, the UW researchers say. ❐

HIGH ABOVE THE CLOUDS: STUDYING ECUADOR'S ACTIVE VOLCANOES BY KEN SIMS

Ecuador is a land of volcanoes. In an area of just 283,651 km2 (similar in size to the State of Nevada) there are 43 volcanoes (28 volcanoes on the mainland with an additional 15 in the Galapagos Islands). Twenty-three of these volcanoes are active and erupted in the past millennia; 8 erupted multiple times in the 21st century and 4 of those volcanoes on the mainland (Cotopaxi, Reventador, Sangay, Tungurahua) erupted this year and another (Cayambe) shows early signs of unrest.

Because of their imminent threat to Ecuador's major population centers (e.g. Quito, Riobamba) and agricultural valleys, forecasting mainland volcanism is critical to Ecuador's state of health. Over the past 10 years, with funding from the National Science Foundation and the National Geographic Society, my research in Ecuador focused on "boots on the ground" geological fieldwork coupled with state of the art geochemical measurements to determine explicitly both the timing of past volcanic eruptions and the timescales of the magmatic processes that culminate in these eruptions. These temporal constraints are critical to better models of volcanic hazard forecasting, both in Ecuador and throughout the world.

Having been at UW for seven years and thus eligible for sabbatical leave, and having worked in the welcoming culture of Ecuador twice before with my family, I applied for and received funding to be a US Fulbright Scholar. During this sabbatical I was hosted as a visiting professor by the Instituto Geofísico de Escuela Politécnica Nacional (IGEPN) in Quito, Ecuador, who by necessity developed a world-class volcano and earthquake monitoring program.

Figure 1: Chimborazo (6,263 meters/ 20,548 feet above sea level) is the farthest point on the Earth's surface from the center of the Earth because of the equatorial bulge. Much of my sabbatical research effort focused on conducting high altitude and technical fieldwork on Chimborazo, as this seemingly sleeping giant is also a potentially dangerous volcano. Past eruptions produced lava flows and massive debris flows that would be devastating with Ecuador's current population distribution. Given its thick summit ice cap, steep flanks and position above the major population centers of Riobamba and Ambato, forecasting Chimborazo's future volcanism is critical to Ecuador's state of health. Importantly, Chimborazo's rapidly shrinking glaciers and increasing outcrop exposure present an unprecedented scientific opportunity to better understand Chimborazo's geology and volcanic history with the overarching goal of improving hazard forecasting. *Photo by Marco Cruz.*

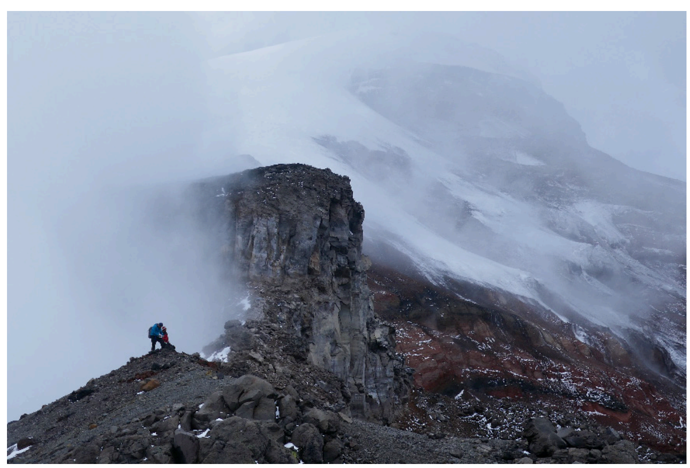


Figure 2: Collecting samples at ~5600 meters/18,500 feet above sea level on the Castillo (Castle) ridge of Chimborazo with scientific colleague and mountain guide Marco Cruz. *Photo by Marco Cruz.*

Figure 3: Collecting samples in the Chalupas Caldera (Ecuador's "super volcano") with UW Geology and Geophysics PhD student **Lisa Kant** who traveled to Ecuador over Christmas break with funding from the UW Center for Global Studies, a Dick and Lynne Cheney study abroad grant, and the John M Hummel Memorial Fund. Because of the caldera's large size and remote location much of the fieldwork travel was conducted on horseback. *Photo by Mark Reagan.*

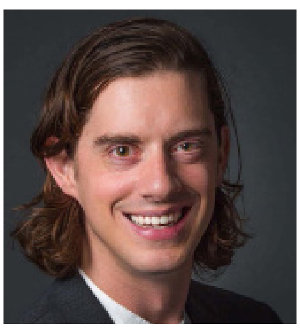
Figure 4: Mountain guide and climbing friend Jamie Vargas on the summit of Cayambe (5790 meters/19,170 feet above sea level) during sunrise. The summits of the high Andean volcanoes Cotopaxi, Antisana, Chimborazo and Sangay rise above the valley clouds. Note that because of snow conditions, rock fall and avalanche safety most Ecuadorian volcanoes are climbed at night. Part of the goal of this climb was to document Cayambe's increased activity, which is not only showing increased seismicity but also higher gas emissions and new crevasses near the summit. *Photo by Ken Sims*

Now at home sitting by a warm fire on a cold Wyoming winter night, it is easy to reflect back on what my sabbatical leave and the US Fulbright award meant to my family and me. As a scientist: I was able to spend six adventurous months conducting field work at high altitudes and in remote pristine locations; I was able to contribute to the education of Ecuadorian students by presenting several seminar talks on volcanism and isotopes, and teaching a short course on Thermodynamics; and, I greatly strengthened my collaborative relationships among my IGEPN colleagues, whose understanding of Ecuadorian volcanism and tectonics is unequalled. As a father and husband, I watched my family: expand their horizons and learn humility as world citizens; learn a new language; visit exotic places (such as the Galapagos, Cloud Forests, or the Andes) that I could only imagine visiting as a kid; thrive in a new cultural setting; and, most importantly, grow yet closer together through our shared experience. What an amazing opportunity my UW sabbatical and the US Fulbright Scholar award afforded us.❐

GRADUATE STUDENT KACY PATRICK RECEIVES GRANT

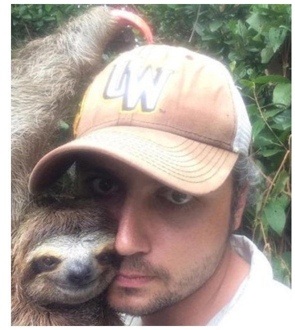
Kacy Patrick is researching PETM floras in the Huerfano Basin of southern Colorado in order to assess paleoclimate and paleoecology associated with rapid warming in geologic time. This study will yield the southern-most quantitative, unbiased census data and climate reconstructions for Paleogene hothouse North America, establishing regional data for paleoecological change with latitude. ❒

GRADUATE STUDENT QUIN MILLER COMPLETES SUMMER '16 GRANT HAT-TRICK



Quin Miller was recently awarded three grants that will support his dissertation research concerning unconventional reservoir rock pore network evolution. Miller's submission to The Clay Minerals Society (CMS) was the highest ranked student research proposal, making him the recipient of the 2016 Robert C. Reynolds, Jr. Research Award. This $2,480 award also includes one year of CMS membership. Additionally, Miller received a $2,000 student research scholarship from the Unconventional Reservoir Special Interest Group of The Society of Petrophysicists and Well Log Analysts. Lastly, Miller was granted the 2016 Spackman Award by The Society for Organic Petrology (TSOP). Miller had the highest rated proposal and will receive $1,000 from TSOP to apply to his research. All three awards will help support Miller's neutron scattering, microscopy, and experimental activities at Oak Ridge National Laboratory, the Center for Advanced Energy Studies, and the University of Wyoming. Quinn is advised by Associate **Professor John Kaszuba**. ❒

GRADUATE STUDENT RYAN HAUPT'S PALEONTOLOGY RESEARCH FEATURED



An extinct giant sloth once used a spacious cave not just as a shelter but also as a massive toilet, leaving droppings on the cave floor whenever nature called. Now, scientists have analyzed the sloth's mummified dung and determined what plants the greyhound-size beast ate most frequently, according to new research.

Chemical analyses of the fossilized poop, known as coprolites, revealed that the ancient sloths primarily chowed down on an orange-flowered perennial shrub known as desert globemallow (Sphaeralcea ambigua), a shrub called Mormon tea (Ephedra) and a drought-tolerant plant known as saltbush (Atriplex), said Ryan Haupt, who is leading the investigation while completing his doctorate in the Department of Geology and Geophysics at the University of Wyoming.

Scientists have known about the coprolites in southern Nevada's Gypsum Cave since the 1930s. The Shasta ground sloth (Nothrotheriops shastensis) lived in the cave at different points, from about 36,000 to 11,000 years ago, Haupt said.

"Radiocarbon dates from the coprolites correlate with periods where the climate was a bit cooler, and since we know that modern tree sloths don't thermoregulate very well, it's possible that these ground sloths were going into the cave to keep warm," Haupt told **Live Science**.

The study, which has not yet been published in a peer-reviewed journal, was presented at the 2016 Society of Vertebrate Paleontology meeting (Oct 27th). ❒

UW TEAM AWARDED FIRST RACHEL CARSON CENTER INTERDISCIPLINARY FELLOWSHIP

Carrick Eggleston, Professor of Geology and Geophysics, and **Sarah Strauss**, Professor of Anthropology, were recently awarded the first Interdisciplinary Fellowship with the Rachel Carson Center for Environment and Society. The **Rachel Carson Center** is a joint institution of the Ludwig Maximilian's University of Munich, the Deutsches Museum (the largest science and technology museum in the world), and the German Ministry of Education and Research. The UW team will be residence for stints in both 2016 and 2017. Fellows from all over the world work on both individual projects and collaboratives at the RCC in Munich.

Photos: (L) Seismic geophysical cable & sensor installations are found strung out all over Munich as the city tests for favorable geothermal drilling sites; geothermal heat is increasingly used for large bldgs or community heating. (Middle) A bioreactor behind a restaurant in south India, using food waste to make biogas. The burner using the biogas from the reactor pictured above. (Right) Women bringing firewood home in the evening; biogas installations impact the demand for firewood and thus also impact forest health. *Photographs copyright Carrick Eggleston and Sarah Strauss.*

The interdisciplinary fellowship brings science perspectives together with social sciences to work on understanding the technical and human dimensions of energy transitions, those already underway globally and those yet to take place. For example, the US has seen little growth in electric power demand for several years, and is shifting away from coal-fired electricity toward more natural gas. The scale of renewable electricity development is also staggering, with the continuous power output equivalent of 7 or 8 nuclear reactors worth of photovoltaics installed globally in 2015 alone – and 2015's wind installations produce even more.

These and other transitions have deep human impacts, as we are feeling in Wyoming today.

Among other projects, Eggleston and Strauss are working with people at the Deutsches Museum as they develop a new exhibit on energy transitions. ❐

Lesley Cunningham Urasky received the 2015 Presidential Award for Excellence in math and science teaching for secondary teachers in Wyoming.

Lesley Urasky has been a science educator for 18 years. This year, she will be teaching 8th grade science, Chemistry, Concurrent Geology, and Biomedical Science at Saratoga Middle and High School. Previously, Lesley taught science for 11 years at Rawlins High School and for seven years at the Science Academy of South Texas. She has also taught at the University of Texas, Brownsville and Western Wyoming Community College.

"For me, teaching science is not just a full time job; it is a passion that spills into every facet of my life. The Presidential Award is validation that the rigor, relevance, and enthusiasm I bring to my classroom can inspire a generation of lifelong learners and problem solvers. It is a great honor to join the cadre of professionals that have achieved this award and a sign that our efforts in STEM education are valued by our nation's leaders."

Involvement in a variety of teacher research experiences has allowed Lesley to bring real-world science into her classroom. Her students have engaged in a variety of activities, from exploring local geology to representing Texas at the First Student Summit on Ocean Issues in Washington, D.C.

She was a PolarTREC teacher to Antarctica and a NOAA Teacher at Sea. Lesley was a recipient of the Wyoming (WY) Geological Association's Earth Science Teacher of the Year and was recognized on Neil DeGrasse Tyson's Cosmos as a "Star Science Teacher of the Week." Lesley has presented from local to national conferences. She is a member of National Science Teacher Association's Awards and Recognition Committee, the WY State contact for the National Earth Science Teachers Association, and is on the WY State Science Standards Review Committee. Lesley earned a B.S. and a M.S. in geology from the University of Wyoming. She is certified to teach 6–12 science. ❐

Michael Cheadle & Barbara John recently attended an 1851 Royal Commission Alumni Association reception at Buckingham Palace in London. Mike was a formally a Great Exhibition of 1851 Fellow, a fellowship which is administered by the Royal Commission. The Association was marking its tenth anniversary by having a reception at Buckingham Palace hosted by their royal highnesses, The Princess Royal & The Duke of Edinburgh. The reception was held inside the Palace and Mike & Bobbie got to see what it's like inside the Palace, entering through the Grand Entrance, and going upstairs to the East Gallery to the reception in the Ballroom.❒

GEOLOGY CLUB WON
"BEST ORIGINAL FLOAT "
AT 2016 HOMECOMING !!

IN REMEMBERANCE

Donald F. Cardinal, 83, passed away peacefully in his home in Casper, Wyoming, on June 27, 2016. Don was born October 28, 1932 in Deadwood, South Dakota, the son of Cecil and Margaret Cardinal. He went to high school in Lovell, WY, where he met the woman he instantly knew he would spend his life with, Alma, and married on June 21, 1953 in their hometown. Don was Sergeant First Class in the U.S. Army and served as a tank commander. He graduated from the University of Wyoming with a Bachelor of Science in Geology with Honors, then went on to receive his Master's degree in Geology from UW. Don and Alma had four children—Linda, Carla, Ralph and Caryn, and after a brief time in Oklahoma City, the Cardinal family settled down in Casper, where Don would call home for the rest of his life. Outside of his beautiful wife and loving family, the love of Don's life was geology, not just as his career, but as his hobby, his passion and the source of his greatest accomplishments. Starting with Mobil Oil Corporation as a Junior Geologist in 1958, Don spent time in Dallas, Oklahoma City and Turkey. He worked with numerous oil companies before becoming a consulting geologist in Casper in 1983, developing young exploration geologists and imparting his knowledge of the industry.

He pursued his life's passion far beyond his daily work, by affiliating with the American Association of Professional Geologists, American Institute of Professional Geologists, Wyoming Chapter, Rocky Mountain Association of Geologists, State of Wyoming Professional Geologists and serving as President of the Wyoming Geological Association. His geological awards include the Frank A. Morgan Award which he won twice, Distinguished Service Award in 1992, WGA Honorary Member, 2000 Exemplary Member Award and in 2015, Don was recognized for his 50-plus years of service to the profession of petroleum geology by receiving the Robert J. Weimer Lifetime Contribution Award. During the ceremony, Don was honored for discovering or participating in numerous discoveries in Wyoming, South Dakota and Colorado. He also contributed to a number of geological publications, including publishing the nomenclature chart of the state of Wyoming. It is rare to meet someone who still finds joy in their work after 50 years, yet Don kept his office open until the very end of his life, going in to work every day—not because he had to, but because it was what he loved; it was who he was.

Don also enjoyed backpacking, fishing, reading and being an active member of Mount Hope Lutheran Church. He engaged his children in meaningful conversation, challenging them to think bigger about the world and be the best version of themselves. He took pleasure in teaching his beloved grandchildren how to play cribbage, and watching those grandchildren have children of their own. He cherished sitting on his back porch and spending time with the friends he loved dearly. He enjoyed dancing with his wife, who after 63 years, he still looked at with such love and admiration. He enjoyed telling stories about his time in the Army and his time overseas. And every Thanksgiving, Christmas and Family Reunion, he gave a toast to tell his family that there was nothing he enjoyed more than seeing them together. He lived life to the fullest and he will be dearly missed by those who had the privilege of sharing it with him. Don is survived by his wife of 63 years, Alma; his daughters, Linda Carter, Carla (Joe) Gennaro, and Caryn Young; his son, Ralph (Kellie) Cardinal; his grandchildren, Jennifer, Meghan, Roxie (Eric), Katie (Matt), Brittany (Cameron), Lauren, Nick, Jon and Sean; his great-grandchildren, Brendan, Aiden, Cashten, Ryleigh, Adeline, Tucker and Isaiah; and his sisters, Irene (Bob) Dehuff and Cleo Stevens; and his special Uncle Floyd, who is like a brother to him. He was preceded in death by his parents, Cecil and Margaret Cardinal, and many favorite uncles.

A funeral service will be held on Thursday, June 30th at 1:00 p.m. at Mount Hope Lutheran Church, 2300 Hickory in Casper, Wyoming and a Committal will follow at Wyoming Veterans Cemetery located at 80 Veterans Road in Evansville, Wyoming. A dessert reception will follow at Mount Hope Lutheran Church. In lieu of flowers, memorials may be made to Central Wyoming Hospice Center, 319 S Wilson St, Casper, Wyoming 82601 or your favorite charity. ❐

Memorial for Paul Heller
(September 16, 1952—July 6, 2016)

With no warning, and far too early, we have lost our friend, mentor, and colleague **Paul Heller**. Paul was part of the New York Jewish diaspora of the 50s and 60s, working his way west via Western Washington University and completing his PhD at Arizona with Bill Dickinson. Having caught the bug for sedimentation and tectonics, he emerged as one of the leaders of the next wave of tectonic sedimentologists, who focused on how new insights on basin mechanics could be used to understand stratal patterns. Some of his earliest work involved deep-marine sedimentation, springing from field work in the Pacific Northwest, and culminating in an important paper proposing the submarine-ramp model for sandy turbidites. Paul also was an early pioneer of the idea of isotopic provenance, i.e. using isotopes as fingerprints of the origin of sediments. But perhaps Paul's most influential early work was that on the interplay of lithospheric flexure and sedimentation – for example, the idea, widely accepted now but controversial at the time, that mountain building in foreland basins might be marked distally not by gravels but rather by fines, if the increasing load creates accommodation faster than it can be filled by sediment. Paul and colleagues synthesized much of this new quantitative approach in a Basin Analysis short course offered through AAPG, and it found another expression through Paul's central and inspirational involvement in the development of experimental stratigraphy. The interplay of tectonic and surface processes remained central to Paul's work, up through his most recent publication, on the dynamic topography of the western interior. But of course basins record more than tectonics, and Paul and his students made major contributions across a wide range of fields and time scales. One of Paul's other recurring themes was avulsion dynamics, and how it controls the stacking of channel deposits. This work led to major conceptual advances in using the stratigraphic record to quantify a process that among other things represents a major but highly intermittent hazard on Earth today and to modeling the downstream evolution of avulsion dynamics; to new ways to apply theoretical and laboratory based scaling to the rock record; and to the discovery of higher levels of organization in channel stacking than anyone had suspected. Paul and his students and co-workers also made important contributions on signal propagation and time scale in alluvial basins; on the tectonic history of the Pacific Northwest, Rocky Mountains, US Atlantic margin, and central China; on the fluvial record of dramatic climate changes during the PETM; and on weathering processes, grain size, and downstream sediment fining.

These are important research contributions that have changed the way we think about sedimentary basins – Paul was an important force in the transition of stratigraphy from its descriptive past to its increasingly analytical present. But Paul's main impact is a human one that cannot be found in his publication record. In a recent reflective moment, Paul mused on his upcoming retirement. He contemplated what composed the totality of a person's life, scoffing at an idea proposed by a colleague who had constructed a 3-ring binder of scientific contributions and manuscripts. He rhetorically asked, "Is that really it? A stack of paper? That's a man's life?" (Adding, of course, a sarcastic comment about whose stack was thicker.) Paul needn't have worried about this in regard to his own life's work. Paul displayed an infectious delight in sedimentary geology, tectonics, and Earth sciences generally, all leavened by his unmistakably loopy, inventive, and blue-tinted sense of humor. Nearly all of Paul's graduate students have a set of eerily similar stories from their graduate career and beyond. The first meeting as a prospective graduate student generally left quite an impression. Paul immediately jumped into the proposed project, growing more and more excited as the discussion continued. He was quick to build momentum, drive, and passion. The student might leave his office with a stack of papers, or perhaps reeling from an impromptu conference call with bigwig experts, or maybe Paul knew of a completely new field area to evaluate (doubling the size of the dissertation). Regardless, the project was well underway by the time the student left, yet no one had signed up for a class or even registered as a student at the university. This unbridled enthusiasm continued throughout the years as projects evolved and developed. One could not help but leave meetings with an eagerness to carry on. He also used students as a sounding board for his own projects and ideas. While this is not unusual for an advisor, what was unusual were the inevitably comedic payouts at the end. For example, on several occasions he wondered if he had the boldness (or if the time was right) to compose a manuscript critically examining the distribution and origin of unconformities within foreland basin strata. He explained that he already had the title picked out though the text was unwritten: "Forebulge Envy in the Rock Record."

Paul was a firm believer that the scientific question should drive the methods. This is evident in the theses and dissertations of his students. His students pursued projects planted in sedimentary geology and tectonics, but fertilized with approaches largely out of Paul's realm of expertise. These ranged from paleobotany, to spatial statistics, to stable isotope geochemistry, to microfossil biostratigraphy amongst others. His own lack of familiarity with a topic was not a limiting factor, what mattered was addressing the question. He seemed unphased and unintimidated by what he didn't know -- an essential part of Paul's charm and ability as an advisor and researcher. It belies a scientific courage combined with humility that allowed him to continually evolve and learn as a scientist. Paired with curiosity, he taught his students by example that science was bigger than one's own insecurity and that the joy of discovery was worth exposing your ignorance. This was incredibly refreshing and enabling for students. Perhaps his approach is best summed up in one of his favorite phrases: "I'd rather be approximately right than precisely wrong."

Paul was a field geologist at heart. Fieldwork with Paul was a real treat, and he became even more exuberant when on an outcrop. Hours could be spent next to conglomerates in Death Valley arguing if they represented debris or fluid flows, or next to cross-beds in the Ferris Formation arguing how to identify bar clinoforms versus large dune stratification, or slowly talking through the identification of Eocene low angle delta front deposits. While these discussions could be seemingly pedantic, in fact they were anything but. This was a smaller version of performing research: the reevaluation of assumptions and critically incorporating the information for yourself and working through the reasoning. Ironically, while lost in these geological arguments about the past he and his students occasionally lost track of the geomorphic and meteorologic activity happening in the present, so that out-running flash floods in Utah was a common activity. Paul's mental astuteness, however, did not necessarily transfer to physical prowess.

He was known to fall and slip several times in a day, and on occasion, he fell from a sitting position as he gesticulated wildly regarding some feature of the Ferron Sandstone. This was an endearing quality to be sure. A person could never quite guess what would occur on a field trip with Paul.

One of the telling aspects of Paul's publication list, of which he was quite proud, is that it includes very few single-author papers. Paul loved to collaborate, and for him that could mean stirring together just about any collection of ideas and people to see what might come out of it. He was fond of bringing together people who either had no experience with a place or approach, or who saw things very differently from him, or from each other, to try and hash things out. And of course, none of this was kept from students, who quickly learned that the research process is never linear, often contentious, and a hell of lot of fun. Scientifically, Paul lived for ideas, and was as generous in sharing his own as he was in enthusing over those of others – the ones he liked, at least. You couldn't be around him for long without feeling smarter, more excited, and perhaps wondering why everyone else didn't have his appreciation for the joy of simply being able to study the Earth for a living. Paul's approach to science, his exuberance, his mixture of harsh criticism and intense support, and his care for his family are all characteristics we will treasure and try to emulate. Although Paul would probably respond ironically that it's mighty Christian of us to say so, we who had the pleasure of working with him will always think of him as the definition of a mensch. ❐

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Photo from the 2016 annual Rocky Mountain Field Trip for new graduate students. Experts from the industry, guests and friends routinely contribute to science discussed on the trip.