UNIVERSITY OF WYOMING
Department of Geology and Geophysics

FALL 2014

PROFILE

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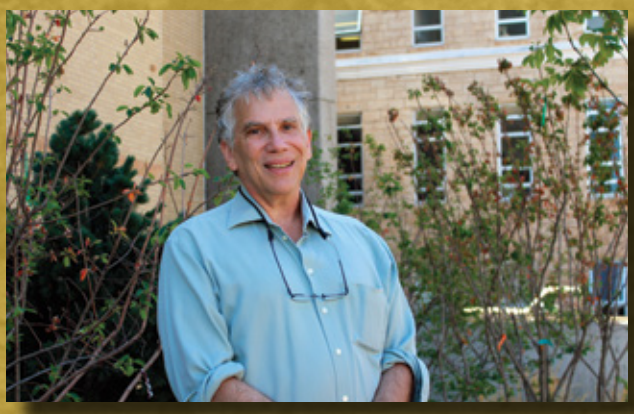
GEOLOGY & GEOPHYSICS



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FROM THE DEPARTMENT HEAD

Welcome to the Fall newsletter. So far, 2014 has been an excellent year for the Department. I am particularly pleased to announce two new text books written by faculty members that came out this year. **Dario Grana**, along with coauthors J. Dvorkin, M. Gutierrez, published *Seismic Reflections of Rock Properties*. **Ron Frost** and **Carol Frost** published *Essentials of Igneous and Metamorphic Petrology*. Both were published by Cambridge University Press. Also, **Jim Myers** has a book out with coauthor Robert Mayes. It is entitled *Quantititave Reasoning in the Context of Energy and Environment* and published by Sense Publishers. In addition, I have just now learned that our newest faculty member, **Ellen Currano**, who has a split appointment with the Department of Botany, just received an NSF Early Career Award. These are highly competive awards to support junior faculty who exemplify the best qualities of integrative teacher-scholars. Congratulations Ellen!

Last spring we had the first meeting of our newly formed Alumni Council. The council, headed by **Mary Kraus** (class of '79), submitted a report that went far beyond alumni relations, but also addressed aspects of our curriculum, provided feedback on graduate student concerns, and made many useful suggestions on improving our connections with the State and the energy industry. They did express concern over the loss of **Randi Martinsen** and **Art Snoke**, both of whom are retiring this academic year. Although we have grown in recent years in the field of petroleum geophysics, it is true that with these retirements our petroleum geology-related offerings are diminished. The council suggested we prioritize the development of an endowment for a Petroleum Geology Chair. While this would be great, and I would think that with our connections within industry such a goal is achievable, this would be no small task. Endowed chairs these days cost around $4 million! While daunting, I am certainly willing to give this a try and will bring this up to the UW Foundation. Meanwhile, I'd be delighted to hear from any of you about ideas of how this might be done. It occurred to me that having a named chair in honor of a former, illustrious faculty member (Knight? Blackstone? Boyd?) might galvanize the community.

Speaking of former illustrious faculty, **Don Boyd** has been named one of four AAPG Distinguished Educators for 2015 as announced in the December issue of the *AAPG Explorer*. Ten of our alumni wrote letters of support describing the impact that Don had on them and their careers. If you have a moment, I encourage you to send Don a note of thanks (boyd@uwyo.edu).

Alumni Council member **Mark Olson** (class of '99) has kindly offered to help organize an alumni event for those of you in the Houston area for sometime this coming Spring. Details, including a date, are yet to be worked out. We will be sending out an email once we know more, but those of you definitely interested might let me know (heller@uwyo.edu) so we can be sure to include you in the invite.

Lastly, thanks again to the many of you who have continued to support the Department through the years. The level of support we receive from our alumni make us the envy of the College. I am particularly touched by your generosity. ❖

UW'S FROST ACCEPTS TWO-YEAR NSF APPOINTMENT

Longtime University of Wyoming geology professor and administrator **Carol Frost** has accepted a two-year appointment with the National Science Foundation to serve as director of its Earth Sciences Division.

"I wish to thank the university for allowing NSF to 'borrow' Carol," says Roger Wakimoto, associate director for NSF's Geoscience Directorate. "She will be a tremendous asset to the earth sciences community in her new capacity."

Frost will serve as NSF's principal spokesperson in the area of earth sciences, directing all Earth Sciences Division activities, including assessing needs and trends in geosciences research and education, allocating resources, implementing overall strategic planning, and setting policy. The senior executive service-level appointment required a personal meeting with and approval by NSF Director France A. Córdova.

"This is an opportunity for me to contribute to the nation's science and education mission at the highest level, and it offers a chance to learn new capabilities and skills," says Frost, who begins her new appointment Dec. 15.

Frost, who will retain her UW faculty position, says she will return periodically during the two-year NSF appointment to maintain her research program at UW.

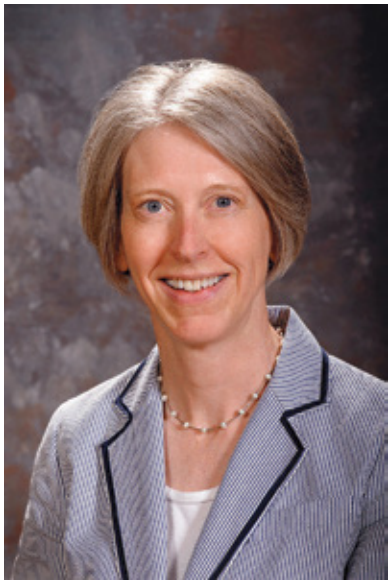
"This is a major appointment and a high honor for Carol," says Bill Gern, UW's vice president for research and economic development. "The good news for the university is that she will return with extremely in-depth knowledge of the inner workings of NSF."

NSF is an independent federal agency that supports fundamental research and education across all fields of science and engineering.

Frost joined UW's Department of Geology and Geophysics in 1983, after receiving her Ph.D. in earth sciences at Cambridge University in the United Kingdom. From 2006-2013, she served as founding director of UW's School of Energy Resources, associate vice president for research and economic development, vice president for special projects in the office of the president, and associate provost.

Among her accomplishments at UW is development of the university's isotope geology laboratory, a world-class facility that has played a key role in a variety of research projects based in Wyoming, the western U.S. and various foreign locations.

Her published research record is extensive, with more than 125 articles in peer-reviewed journals or books—on topics ranging from the origins of the Wind River and Teton ranges to the geochemistry of water co-produced with oil and gas. She served as science editor of the journal Geosphere from 2009-2013 and is co-author of a geology textbook published by Cambridge University Press earlier this year.



Professor Carol Frost will serve a two-year term at the National Science Foundation as director of its Earth Sciences Division.

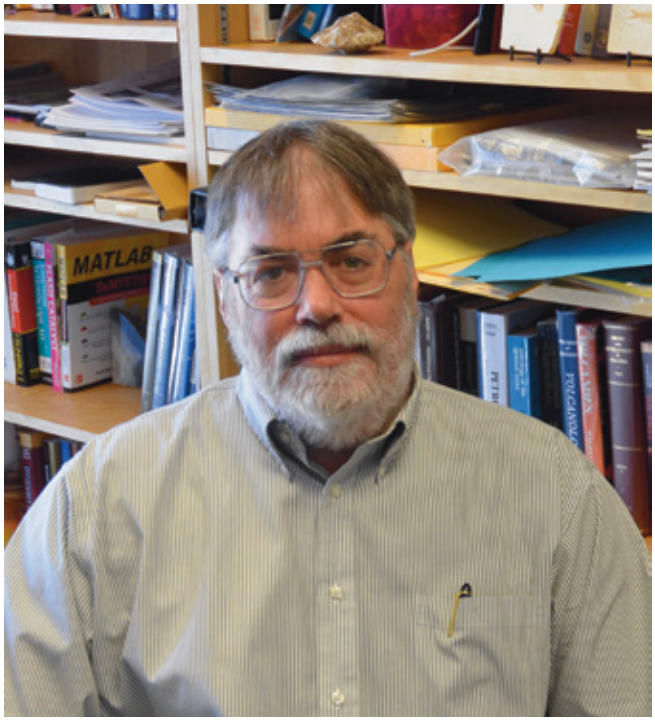
Frost's excellence in the classroom, as a scholar and in service to the state has been recognized with UW's George Duke Humphrey Distinguished Faculty Award; College of Arts and Sciences Extraordinary Merit awards for teaching and research; the Ellbogen Meritorious Classroom Teaching Award; and the Carnegie Foundation/CASE Wyoming Professor the Year Award. ❖

UW PROFESSOR ASSUMES PRESIDENCY OF NATIONAL GEOSCIENCE TEACHERS ASSOCIATION

James Myers, University of Wyoming Department of Geology and Geophysics professor, is serving a one-year term as president of the National Association of Geoscience Teachers (NGTA).

He was elected two years ago as second vice president, served as first vice president last year and takes the reins as president this week at the Geological Society of America national meeting in Vancouver, B.C.

Founded in 1938, the NGTA works to raise the quality of and emphasis on teaching the geosciences at all levels. Members include K-12 teachers and college and university faculty members as well as educators at outlets such as



Professor James Myers will serve a one-year term as president of the National Association of Geoscience Teachers.

museums and science centers. The organization has more than 1,300 members from the U.S. and around the world.

"Our three main goals are to improve geoscience education, to emphasize the relevance and cultural significance of the earth sciences, and to disseminate knowledge to educators and the general public," Myers says.

He says this is accomplished through professional development opportunities, publications, scholarship and awards and sponsored sessions and events, including organizing the technical program in geoscience education at every Geological Society of America annual meeting.

At UW, Myers conducts research involving igneous petrology (the study of the origin of igneous rocks particularly in the volcanic Aleutian arc), geological carbon sequestration and geoscience education. He has conducted professional development programs on the energy and environment for Wyoming K-12 teachers as well as university and college faculty from across the nation.

He says today's students face a job market in which they will likely change jobs many times during their careers.

"Consequently, students need communication, critical thinking and problem solving skills," he says. "A class is more valuable if it provides students with the opportunities to learn these skills."

Myers received a B.S. degree (1973) at the University of Rhode Island, and M.A. (1977) and Ph.D. (1979) degrees at Johns Hopkins University. ❖

UW WINS DOE GRANT FOR FURTHER STUDY OF ROCK SPRINGS UPLIFT

Years of work by University of Wyoming researchers have characterized a geological formation in southwest Wyoming as a potentially secure site for storing carbon dioxide underground.

Now, a new grant from the U.S. Department of Energy will allow an interdisciplinary team of UW scientists to further study how injecting CO_2 into the Rock Springs Uplift would affect underground conditions.

The $1.1 million grant, which takes effect Oct. 1, will help fund a three-year research project to predict changes in the subsurface during and after injection of CO_2. Research has shown that two deep saline aquifers in Sweetwater County's Rock Springs Uplift could store 26 billion tons of CO_2 over 50 years as part of a future carbon capture and storage operation.

"The goal of this research is to improve our understanding of the geomechanical effect of CO_2 injection on two types of reservoir rocks, sandstone and limestone/dolomite," says **John Kaszuba**, associate professor in UW's Department of Geology and Geophysics and the School of Energy Resources (SER). "The ability to predict geomechanical behavior in response to CO_2 injection, if successful, could increase the accuracy of subsurface models that predict the integrity of the storage reservoir."

UW researchers in 2009 began a study of the Rock Springs Uplift, with funding from the Department of Energy and the state of Wyoming, to determine its potential for storing CO_2. UW's Carbon Management Institute, one of SER's centers of excellence, led the effort, which included the drilling of a 14,000-foot test well. The project resulted in a thorough characterization of the Rock Springs Uplift as a potential commercial-level geological CO_2 storage site.

"The new research will build upon the strong foundation of studies that have been completed on the Rock Springs Uplift, such as field work and subsurface characterization of lithology, structure, mechanical stratigraphy, fracture systems and in situ stress," Kaszuba says.

The research also could provide insights for the oil and gas industry, which uses CO_2 injection to enhance the recovery of oil and gas.

The team led by Kaszuba includes scientists from three UW departments: Department of Chemical and Petroleum Engineering Associate Professor Vladimir Alvarado; Department of Geology and Geophysics Senior Lecturer **Erin Campbell-Stone**; Department of Geology and Geophysics Assistant Professor **Dario Grana**; and Department of Civil

and Architectural Engineering Assistant Professor Kam Weng Ng. Grana, also a member of the Department of Chemical and Petroleum Engineering faculty, and Kaszuba hold joint appointments in SER.

The researchers plan to use a variety of tools—including lab experiments on core samples taken from the Rock Springs Uplift, computer modeling and seismic data—to predict the underground impacts of CO_2 injection at the site. That information is important in solidifying the suitability of the Rock Springs Uplift as a site for commercial CO_2 sequestration.

"We know the potential is there for successful large-scale CO_2 storage in the Rock Springs Uplift. The new research should provide insights to assure the feasibility of such a project," Kaszuba says. "This is another important step toward keeping Wyoming at the forefront of carbon capture and storage technology." ❖

ROCKY MOUNTAIN RENDEZVOUS ATTRACTS MORE THAN 460 STUDENTS NATIONWIDE

Like many students from the University of Wyoming and other universities, **Jacob Buettner** was looking for a full-time job or internship in the oil and gas business.

Buettner, currently a master's student majoring in geology at New Mexico State University who received his bachelor's degree in geosciences from UW in 2013, interviewed with Apache and ExxonMobil at the 13th annual Rocky Mountain Rendezvous Geoscience Students and Employers (RMR) job fair Sept. 26-29. The event took place at UW's Conference Center and Hilton Garden Inn.

"I'm looking for a full-time job in exploration of hydrocarbons. However, I am open to an internship to develop my current knowledge," says Buettner, originally from Fort Laramie. "Exploration is looking at different data sets to infer where potential hydrocarbon resources could be in the subsurface. I want to help determine where the hydrocarbons actually lie."

A record 461 students and 29 companies from across the nation participated in the job fair. One of five regional job fairs nationwide, the event was sponsored by the American Association of Petroleum Geologists (AAPG) and the Society of Exploration Geophysicists. The UW Department of Geology and Geophysics and the School of Energy Resources co-hosted the event.

"A lot of recruiters that are here are alumni of the event," says **Randi Martinsen**, a senior UW lecturer in geology and geophysics, and the event's founder and coordinator. "They are very loyal and show support for this event. This is how many of them got their jobs."

Martinsen, president of the AAPG, was impressed with the number of states and schools represented by the students seeking jobs.

"What we're seeing are more students from other states—Kentucky, South Carolina, Tennessee, Indiana, Illinois and California," she says. "They're hungry and want jobs."

Looking for work

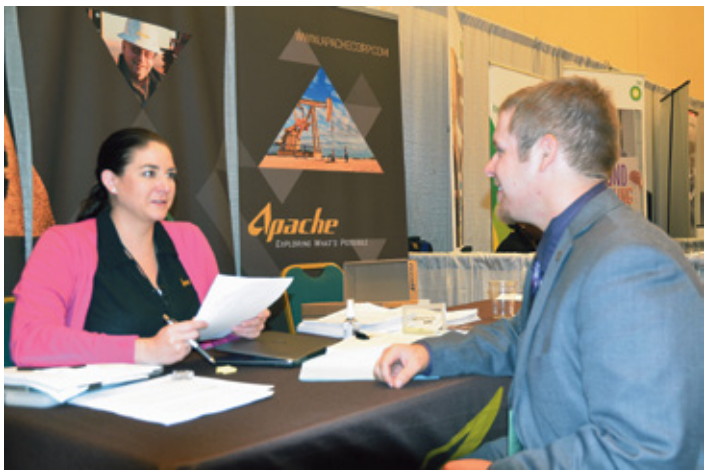
Students with UW ties were hungry, too.

"If I can, I'd like to get on an exploration geology team. Reservoir production would be my second pick," says **John Zupanic**, currently a master's student in geosciences at the University of Montana and a 2013 graduate of UW.

Zupanic, originally from McKinney, Texas, interviewed with Apache and ConocoPhillips. During his interview with ConocoPhillips, Zupanic described it as a "technical interview" in which data were presented to him and he had to create a profile. In addition, he was asked about a time in his life when he faced adversity and how he was able to overcome that.

Karen Aydinian, a UW master's student majoring in structural geology, says she had five interviews at last year's RMR, but did not land an internship. The Houston, Texas, native, who is a fracture specialist, was optimistic she would garner one this year.

"Full-time positions are hard to come by, but I'm looking for an internship," says Aydinian, who interviewed with Apache, Chevron, Encana, ExxonMobil and Noble Energy. "There are not as many people in structural geology as in



John Zupanic, who graduated with a bachelor's degree in geosciences from UW in 2013, is interviewed by Emily Pherson, a human resources generalist with Apache Corp., at the recent Rocky Mountain Rendezvous. (UW Photo)

other geology disciplines. Right now, what I do is significant with all of the hydraulic fracturing occurring in North Dakota, Texas and Pennsylvania."

Aydinian says she has had three previous internships, all secured through the RMR.

Charles Nye is another UW student returning for a second year of interviews at the RMR. The Laramie native expects to receive his master's degree in geology in December before joining a company.

"Even with a master's degree, I may accept an internship rather than a full-time job," he says. "Many companies hire from their intern pool, which makes off-the-bat, full-time positions rare."

Two of the jobs for which he applied require work using interdisciplinary skills. If he lands one of those jobs, Nye hopes to use his background in graphic design and computer science.

"This is a really great event," he says.

Recruiters keep coming back

Recruiters with oil and gas companies say they continue to return to the RMR because of the well-qualified candidates they interview for jobs and internships.

"UW students have traditionally been very strong," says **Genevive Mathers**, an exploration geologist with BP. "Because of the relationship between the school (UW) and industry, and the fact so much money from oil and gas tends to fund the school, UW students have an understanding of oil and gas, and have a pure love for geology."

She adds UW students are refreshing to interview and are not typically polished with answers they think recruiters want to hear. Mathers herself received a master's degree in geology from UW in 2009.

"If I had not come here (for school), I would not be in the oil and gas industry," she says. "I don't know what I would be doing."

Ben Schupack, another BP geologist, served as a company recruiter for the second consecutive year.

"We are looking for highly motivated, self-starting students who have a background in geology and geophysics," Schupack says. "I am looking for someone I would like to work with on a daily basis—someone who can effectively communicate; is motivated; can work together on an interdisciplinary team; and can synthesize data into concise thoughts."

Mark Olson, manager, sedimentology and stratigraphy, geological technology and subsurface technology for Conoco Phillips, says his company is offering three types of internships: exploration, development and technology.

"Why we like UW students is their fundamentals of geology," says Olson, who received his bachelor's degree and master's degree in geology, both from UW. "We can teach them computers and software programs. We can't teach them rocks. That's why we like coming up here. This area has rocks exposed. It's a natural lab students can learn from. You don't learn geology from a book."

Conoco Phillips interviews students from out-of-state universities during the RMR and then spends a couple of days on campus to interview UW students.

The RMR event included a vendor expo; on-site job interviews; receptions; short courses; student poster presentations that included cash prizes; and field trips that included an Anadarko oil rig tour and a walking tour of the Nash Fork formation in the Medicine Bow Mountains.❖

UW RESEARCHER CONTRIBUTES TO LARGE MAMMAL BONE DISCOVERY OF EXTINCT ANIMAL IN ASIA SKULL AND TWO JAWBONES FROM ANCIENT MAMMAL

A University of Wyoming faculty member contributed to the discovery of a long-extinct group of mammals previously thought to have originated in Africa.

Mark Clementz, a UW assistant professor in the Department of Geology and Geophysics, was among scientists who discovered a large land mammal that lived about 48 million years ago in parts of Asia. The discovery led scientists to identify a new branch of mammals closely related to modern horses, rhinos and tapirs.

Clementz contributed to a paper, titled "Anthracobunids from the Middle Eocene of India and Pakistan are Stem Perissodactyls," which appeared in today's issue of Public Library of Science (PLoS) ONE. The open-access, peer-reviewed journal covers primary research from any discipline within science and medicine. Lisa Noelle Cooper, an assistant professor of anatomy and neurobiology at Northeast Ohio Medical University, was the paper's senior writer.

This family of large mammals, called Anthracobudinae, is only known from India and Pakistan, and commonly considered to be ancestors of modern elephants and sea cows. Geographically, this was a puzzling idea because elephants and their relatives were groups that were known to be from Africa, not Asia. These new fossils indicate that anthracobunids are related to the tiny tapirs that are well known from the Pakistani rocks, and that perissodacytls (odd-toed ungulates) probably originated from Asia.

Mark Clementz, a UW assistant professor of geography and geology, was part of a research team that discovered the bones of a large land mammal that lived 48 million years ago in Pakistan and India. (Lisa Cooper Photo)

"While this is a group that is not well known by the public, the new placement of this group is a big deal because it resolves an important biogeographical conundrum: How can a group always thought to be related to African mammals (elephants, sea cows and hyraxes, which look similar to rodents and rabbits) have their earliest fossil record in Asia, well before land bridges between these two continents were in place?" Clementz says. "The answer is that this group isn't part of the African mammals. It is, instead, more closely related to horses and rhinos which, not surprisingly, originated in Asia."

Clementz analyzed the carbon and oxygen isotope composition of tooth enamel from the fossils to determine the diet and habitat preferences of these animals. As with an earlier Journal of Paleontology paper—about the Jaggermeryx, an extinct swamp-dwelling, plant-munching creature with large lips that lived 19 million years ago in Africa—Clementz found tooth enamel values in these mammals were low enough to suggest aquatic habitats.

"Unfortunately, we didn't have enough fossils available to make a sufficient comparison, so these results, while interesting, weren't definitive," he says.

Clementz and Cooper discovered that these animals were large and lumbering, and most likely fed on land. However, they spent a considerable amount of time in or near water, which is similar to modern rhinos and tapirs.

"Increasing evidence suggests the Eocene tropics were much warmer and, possibly wetter than today, which may explain why some mammals were spending more time in the water," Clementz says.

Cooper examined bone density and compactness in the fossils. She found that the limbs and ribs of anthracobunids were denser than most terrestrial mammals and more similar to what is seen in hippos, manatees and early whales—all animals that inhabited shallow water habitats.

"Anthracobunids are just one of many lineages of vertebrates that evolved from terrestrial animals, but then left to live in a shallow water habitat and had thick bones," Cooper says. "These thick bones probably acted like a ballast to counteract body buoyancy. You can see that kind of bone structure in modern hippos, otters, penguins and cormorants." ❖

UW RESEARCHER CONTRIBUTES TO DISCOVERY OF MICK JAGGER-LIKE SWAMP CREATURE

It has super-sized lips like Mick Jagger, but is even older than the ancient rock star of the Rolling Stones.

An extinct swamp-dwelling, plant-munching creature that lived 19 million years ago in Africa has been named after the famous band's lead singer. **Mark Clementz**, a University of Wyoming associate professor in the Department of Geology and Geophysics, was part of the discovery.

Clementz is among seven writers of a paper, titled "Anthracotheres From Wadi Moghra, Early Miocene, Egypt," published in the Sept. 8 issue of the Journal of Paleontology. The journal publishes original articles and notes on the systematics, phylogeny, paleoecology, paleogeography and evolution of fossil organisms.

"As far as my contribution to the paper goes, I analyzed the stable isotopic composition of the teeth of this animal, which we used to interpret its diet and habitat preferences," says Clementz, who is on sabbatical this year in Berlin, Germany.

Researchers from Duke University and Wake Forest University gave the creature the scientific name of Jaggermeryx

Mark Clementz (right), samples a jaw fragment of Jaggermeryx naida, an extinct creature that was discovered to have super-sized lips and was named after Rolling Stones lead singer Mick Jagger. (Ellen Miller Photo)

naida, which means "Jagger's water nymph." The animal's fossilized jaw bones suggest the creature was roughly the size of a small deer, and akin to a cross between a skinny hippopotamus and a long-legged pig.

Gregg Gunnell, a Duke University paleontologist and director of the Division of Fossil Primates at the Duke Lemur Center, says he is a huge Rolling Stones fan, and Jagger's name took precedence over suggestions by other researchers, who wanted to name the new species after Hollywood actress Angelina Jolie.

"'Exile on Main Street' and 'Let it Bleed' were my favorite albums," Gunnell says of the two Rolling Stones classics.

Clementz says the research team looked at the oxygen isotopic composition of the tooth enamel to determine how much time Jaggermeryx was spending in the water. Relative to other medium- and large-sized Jawbone fragment and ruler. The lower jawbone of Jaggermeryx naida has several small holes, roughly where the chin and lower lips would be located. mammals in the same area, modern hippos have much lower oxygen isotope values because their body water more closely reflects that of the surface waters they live in rather than the water in the grasses they consume on land.

"Jaggermeryx also had very low oxygen isotope values when compared to the rest of the fauna of the same age and location, which indicates this animal most likely spent as much time in the water as a modern hippo," Clementz says.

According to a Wake Forest University media release, the creature belonged to a family of extinct hoofed animals called anthracotheres. Jaggermeryx is one of six species of anthracotheres found at a remote site in the Egyptian desert. The Jaggermeryx, compared to other members of the family, is distinguished by a series of tiny holes on either side of its jaw that held the nerves that provided sensation to its chin and lower lip.

"If you look at the dentary, or lower jaw, of Jaggermeryx, you'll see that it has several small holes, or mental foramina, at the anterior end, roughly where the chin and lower lips would be located," Clementz says. "These holes would have allowed nerves to reach the lips. Given the number of holes, it's a good bet this animal probably had large, sensitive lips, which could have helped it feed in muddy water."

The Egyptian site where the fossils—multiple jawbone fragments—were found is predominantly desert today, but geological data suggest the area, millions of years ago, was a lush, tropical delta crisscrossed by rivers and swampland. The creature's fossils were found alongside fossilized catfish, turtles, water birds and crocodile dung.

Preliminary measurements of the relative amounts of different isotopes in the animal's bones suggest that it probably ate plants on land but, when not feeding, spent the rest of its time in the water, Clementz says.

The Jaggermeryx fossils now reside in collections at Duke University, the Cairo Geological Museum and Cairo University.

The research was supported by the National Science Foundation. ❖

NEW FIELD GUIDE OFFERS LOOK AT SOME OF WORLD'S BEST ANCIENT STROMATOLITES

Earth has an astonishingly long geologic time span, but evidence of early life forms on our planet can still be seen today in the form of distinctive bodies of rock called stromatolites.

The Wyoming State Geological Survey (WSGS) at the University of Wyoming has published a new field guide, titled "Self-guided Walking Tour of the Paleoproterozoic Stromatolites in the Medicine Bow Mountains, Wyoming," which provides a guided tour to many of the best outcrops found in the Medicine Bow Mountains, located west of Laramie.

"Our guided tour will take people to some of the best examples of ancient stromatolites in the world, found right here in southeastern Wyoming," says co-author **Don Boyd**, professor emeritus with the UW Department of Geology and Geophysics.

The WSGS website features a stromatolite page (www.wsgs.uwyo.edu/Research/Geology/Stromatolites.aspx) containing the downloadable report, an interactive Google

Earth map of the tour stop locations (with photos) and a video with additional photos of each stromatolite outcrop included in the guide.

The 24-page color guide includes photos, illustrations, maps and GPS coordinates to lead users to stromatolite outcrops dotting the high-alpine landscape. A stromatolite looks like a cross between a cauliflower and a rock. The delicate lamination and internal structure can be seen on the weathered surface of rocks.

"The picturesque patterns were brought into relief by weathering during thousands of years of exposure since the last glacial event," Boyd says.

"We created this walking tour to satisfy the many people who have heard about these unusual life forms found in the rocks, but did not know where to look," says co-author David Lageson, professor of geology at Montana State University.

Based on a comparison with similar features forming today and the work of geologists studying similar Precambrian structures, the co-authors conclude that the 2 billion-year-old Medicine Bow stromatolites were built by communities of bacteria and bacteria-like organisms that dominated a shallow marine environment long before an oxygen-rich atmosphere and the appearance of animals.

"In our interpretation, the distinctive layering of a stromatolite was created by repeated colonization of a sea-floor mound by microbial mats that both trapped sediment and precipitated cement," Boyd says. "The unequal contribution of organic and inorganic processes produced a diversity of stromatolite shapes and sizes."

The primary organism that built the stromatolites is believed to have been cyanobacteria, which are prokaryotic bacteria (domain of life Eubacteria). As photosynthesizers, they played a major role in oxygenating the Earth's oceans and atmosphere.

Boyd and Lageson's field guide describes a wide variety of stromatolites.

"Some are classic microbial growth structures of various shapes and sizes, and are typical of similar forms found in Precambrian and younger rocks in other parts of the world," Lageson says. Others, however, tell a different story. "It depends on the stromatolite being observed."

Included in the field guide are directions to representative outcrops with descriptions of stromatolite features of interest at each location. The geology behind these ancient records of life on Earth is described.

Wyoming's Paleoproterozoic Nash Fork Formation, the major unit in which the stromatolitic beds occur in the Medicine Bow Range, is about 1.2 miles thick and consists of tan stromatolite-bearing dolomite with thick interbeds of pyritic black argillite and phyllite, and some quartzite. Stromatolitic zones are most common in the lower 700 meters of the Nash Fork Formation; they are found in massive dolomite and silicified dolomite intervals. The largest stromatolites (true giants) are found in the "silicified domal digitate stromatolite facies association" in the lower Nash Fork Formation between 100-200 meters and 300-400 meters from the basal thrust fault contact.

Well-known Wyoming geologist S.H. Knight extensively studied the Nash Fork Formation stromatolites, producing research that garnered major international attention. The walking-tour guide includes many of the outcrops illustrated in Knight's research paper published in 1968. Together with most of his contemporaries, Knight believed stromatolites exhibit the original size and shape produced by the organisms that built them.

While Boyd and Lageson agree that this is true for some of the Medicine Bow stromatolites, they describe abundant evidence at outcrops visited in the tour for major alteration of stromatolite shape and dimensions by post-depositional processes, such as soft-sediment deformation (sliding and slumping) and perhaps storm events.

"Our intent with this field guide is for users to ponder the evidence as they visit each stromatolite outcrop," Boyd says. ❖

UW RESEARCH: BACTERIA SHOW PROMISE IN RESTORING AQUIFERS USED IN URANIUM MINING

Wyoming's resurgent uranium industry could get a further boost from University of Wyoming scientists, whose research on post-mining environmental restoration is yielding extremely promising results.

Research in UW laboratories has shown that stimulating growth of native bacteria could be a more effective way to remediate aquifers tapped by in-situ leach uranium mining, the technique used in the vast majority of Wyoming's existing and planned uranium operations. If those findings are confirmed in the field, uranium companies could save significantly in groundwater restoration costs while achieving better results.

"The remediation process simply involves feeding the existing bacteria—no new bacteria are introduced," says **Kevin Chamberlain**, a research professor in UW's Department of Geology and Geophysics. "The result is a better restoration for less cost to the mining company— a win-win situation for the environment, the state and the company."

Wyoming, which once had a thriving uranium mining industry, remains No. 1 in the nation in uranium reserves and is seeing something of a renaissance in mining operations after

decades of industry decline and delay. Cameco's Smith Ranch-Highland mine in Converse County is one of the country's biggest producers, and several other companies have opened or are preparing to start in-situ leach (ISL) operations in the state—which stands to benefit through job creation and tax revenues.

ISL uranium mining involves injecting a groundwater solution (fortified with oxygen and carbon dioxide) into underground ore bodies through cased wells. The solution permeates the porous rock, dissolving the uranium from the ore, and is pumped to the surface through other cased wells. The uranium-rich solution then is transferred to a water treatment facility, where the uranium is removed from the solution by adhering to ion exchange resin beads. The groundwater solution exiting the ion exchange system is then sent back to the injection wells for reuse.

Consequently, there is little surface disturbance in ISL mining, and no tailings or waste rock are generated.

However, not all of the uranium is removed from the water, and the process also liberates other metals such as selenium and vanadium. Federal and state regulations require mining companies to restore aquifers by fixing the suspended metals. Most companies now do that with expensive, repeated reverse-osmosis water sweeps, using large amounts of water containing metal-fixing chemicals, with mixed long-term results.

Bacteria Do the Job

At the Smith Ranch-Highland mine, Cameco, in the early 2000s, experimented with bioremediation: stimulating native bacteria to fix the metals. These bacteria live in the uranium-rich strata and use uranium as an electron acceptor in their natural life cycles. A number of substances, such as safflower, crude whey protein and even molasses, have been used to "feed" the bacteria, but the results were mixed.

In 2011, Chamberlain received a $100,000 grant from the UW School of Energy Resources' (SER) In-Situ Recovery of Uranium Research Program, with a $25,000 match from Cameco, to study restoration of the relatively deep uranium aquifers at the Smith Ranch-Highland site using bioremediation. He says it became clear right away that more laboratory work was needed before initiating a field study.

Chamberlain enlisted the expertise of others on campus, including John Willford, coordinator of the instructional labs for the Department of Molecular Biology in the College of Agriculture and Applied Science; UW researchers John Willford, left, and Kevin Chamberlain stand in a lab in the UW Agriculture Building where scientists have been testing the feeding of naturally occurring bacteria to fix uranium and other metals. Willford, a microbiologist, and Chamberlain, a professor of geology, are part of an interdisciplinary UW team working to help Wyoming's uranium industry. (UW Photo)Pete Stahl, professor of soil ecology and director of the Wyoming Reclamation and Restoration Center; Craig Cook, research scientist in the Department of Ecosystem Science and Management and director of UW's Stable Isotope Facility (SIF); David Williams, professor of botany and renewable resources and faculty director of SIF; and Calvin Strom, research scientist in the Department of Ecosystem Science and Management. Recently, scientists from outside the university—including the Los Alamos, Pacific Northwest and Lawrence Berkeley national laboratories—also have become involved.

Two UW laboratory projects were undertaken to determine the best "food" for the naturally occurring bacteria, and the optimum rate of feeding. The first project, which is complete, showed that the most effective substance to stimulate the bacteria at the Smith Ranch-Highland site is tryptone, a partially degraded milk protein commonly used in laboratories. The second project—which better simulated actual field conditions, tested different feeding rates and developed monitoring criteria—is nearing completion. It was funded by an additional $107,000 SER grant to Willford and Chamberlain, with a Cameco match of $50,000.

In the experiments, introduction of tryptone produced a 60 percent reduction in soluble uranium over 30 days, with higher reductions over the long term. The researchers believe the growth of bacteria will be long-lasting and effective in fixing the remnant uranium and other metals.

"We're not introducing anything but a little food," Chamberlain says. "We're restoring the natural balance by feeding the naturally occurring bacteria that use uranium as part of their life cycle. Essentially, we're just speeding up what's believed to eventually happen anyway to keep the metals from remobilizing. It does a better job, and it's less expensive."

From the Lab to the Field

With the knowledge gained from the lab studies, the UW interdisciplinary team of scientists plans to begin the field trial with tryptone at Smith Ranch-Highland later this month. The study is expected to take 10 months to a year.

"Now, we feel armed," Chamberlain says. "No. 1, we know bioremediation can work. No. 2, we've found a food that works well at this site. No. 3, we know the best rate at which to feed. We're excited to put it all to work in the field."

In addition, Chamberlain is developing isotopic metrics to effectively monitor the bioremediation process at a relatively low cost.

Cameco officials say they look forward to the prospect of using bioremediation, if the final results of the research confirm the laboratory findings.

"Cameco is pleased to be working with the world-class researchers of the University of Wyoming to hone restoration processes for the in situ recovery uranium industry," says Jim

Clay, senior scientist for the company. "The work being done at our Smith Ranch-Highland mine in Converse County is a collaborative effort with these researchers that will benefit both the environment and the mining industry in Wyoming."

Chamberlain says this bioremediation technique has the potential to reduce the cost of aquifer restoration by as much as 90 percent, and may result in reduced regulatory bonding obligations for companies—along with improved results in the ground. While each ISL mining site is different, he and Willford believe the methodology used to develop the plan for the Smith Ranch-Highland site will work for other uranium operations as well.

"The system we developed for this should be applicable everywhere," Willford says. "We're working to find a good, long-term solution for the industry in Wyoming and elsewhere. Being the only research institution in the state, it's appropriate for us to do something to help this industry and the state's environment and economy."

The In-Situ Recovery of Uranium Research Program was established by the Wyoming State Legislature in 2009. Sen. Jim Anderson, R-Glenrock, says the bioremediation research is exactly the type of work that he and other legislators hoped to see.

"In-situ recovery uranium mining is a critically important industry in my district and the state of Wyoming," Anderson says. "It is important for Wyoming to invest in the most current science available to assist in improved production methods while protecting the state's environment. These investments made by the state are critical in allowing the industry to move forward while sustaining Wyoming jobs and the economy." ❖

DEPARTMENT NOTES

In 2015, Emeritus Professor **Don W. Boyd** will be one of four recipients of the *AAPG Grover E. Murray Memorial Distinguished Eductator Award*. The award is given in recognition of distinguished and outstanding contributions to geological education. Contributions leading to consideration for this award will most often involve the teaching and counseling of students at the university level, and contributions to the education of the public, and management of educational programs may also be recognized.

In June, Assistant Professor **Dario Grana** was awarded the *The Eni Award* for "Pioneering innovations in theoretical and practical rock physics for seismic reservoir characterization," as a member of the Rock Physics Research Group with Professors Tapan Mukerji, Gary Mavko and Jack Dvorkin (Stanford University).

The Eni Award was officially established in July 2007 in order to develop innovative ideas for a better use of energy sources, promote environmental research and to valorize new generations of researchers. The award is launched annually and has an established and prestigious network of researchers in the field of energy and the environment. Its target is to monitor and promote the best research and the best scientists in the world in the field of energy, with the ambition to become a sort of Nobel Prize for Energy.

Grana also received the 2014 Petroleum Engineering Junior Faculty Research Initiation Fellowship Award from the Society for Petroleum Engineering (SPE) for his research work with students.

In early June, Professor **Ron Frost** spent two weeks in China where he presented two lectures on granite petrology to the Chinese Academy of Geological Sciences in Beijing.

Also in June, Frost participated in the U Cross Experiment, a program where four scientists and four artists spent two weeks in residence at the U Cross ranch. The idea behind the program was to see whether a scientist paired with an artist could come up with a different way of seeing reality. Ron ended up being paired with Anne Guzzo, a composer from the University of Wyoming music department. Together they are writing an opera on the geologic history of the Powder River Basin. At the end of the two week residence all pairs of participants presented the progress they had made on their respective projects at Saturday University. A film of the first pass on the opera is on record at You Tube (www.youtu.be/sgbAjuwynUg). The first two arias were performed August 7 at the Aquila Summer Concert Series in Greeley. Recordings of these are present on You Tube under www.youtu.be/p2PdJ9Ye6j8 and www.youtu.be/hxXqE3_o6is.

Graduate student **Robert Mahon** (PhD candidate) recently received the *Dick and Lynne Cheney Fellowship for Excellence in Study Abroad* to participate in a multi-institutional experiment in sedimentary process at Utrecht University, The Netherlands. The $4,000 award is given to no more than six UW undergraduate and graduate students each year in support of significant contributions to their field of interest via international research or study. The fellowship is through the U.W. International Programs office.

"This type of multi-institutional experiment is novel in sedimentology and stratigraphy," says Mahon's advisor **Brandon McElroy**. "The ultimate goal is to develop a new model for collaborative experiments to be run concurrently and in parallel in multiple laboratories. This will increase the efficiency with which we will be able to tackle grand challenges in sedimentary and surface process research-accelerating the pace of discovery."

"This is a very valuable opportunity for me to be involved with an international collaborative effort at the forefront of the experimental stratigraphic and surface process communities," says Mahon. "This workshop will undoubtedly have a profound influence on the way I conduct experimental research at UW and in my future career and I am extremely grateful for the support of the International Programs Office through the Cheney Fellowship."

Robert was also recently awarded a $2,000 scholarship from the Society of Independent Professional Earth Scientists

and a $1,000 Gene George Petroleum Geology Scholarship from the Wyoming Geological Association. The $1,000 award was one of the first two ever given for this new scholarship.

Graduate student **Jeremiah Marsicek** (PhD candidate) recently received an Environmental Protection Agency STAR (Science to Achieve Results) fellowship. The one-year $42,000 fellowship includes an option for a second year in the amount of $42,000 for a total award of $84,000. The fellowship will help to support Jeremiah's research project titled, "Abrupt climate change in the northern mid-latitudes at ca. 5ka: pollen-inferred evidence for hemispheric-scale climate change."

The study focuses on temperature change over the thousands of years since the last ice age, particularly the period of time 5000 years ago (5ka). At the time, 3000 BC, changes took place globally from desertification and the rise of the Egyptian civilization in Africa to major forest changes in North America and Europe, but the patterns of climate change have not been well understood.

"By reconstructing temperature changes in the past—in this case, the past 11,700 years—we can place our recent and future warming in a long term context to understand the processes involved in creating the temperature changes," explains Marsicek. "This affords us the opportunity to better understand future abrupt changes and the consequences for ecosystem services, such as water availability."

Marsicek's advisor, **Bryan Shuman**, noted that "the award provides an exciting opportunity to study the tempo of past climate change and the risk that warming can lead to sudden changes that have consequences for society."

On May 12th, the University of Wyoming Board of Trustees formally announced the promotion of Associate Professor **Kenneth Sims** to full Professor and conferred tenure and promotion to Associate Professor to Assistant Professors **Po Chen** and **Clifford Riebe**. Congratulations to all three!

On May 15th, Professor **Kenneth Sims** was chosen as one of the two University of Wyoming (UW) Faculty Senate Speakers for 2014–2015.

The Faculty Senate Speaker Series is an award established by the Faculty Senate. The award carries an honorarium and requires two lectures, one on the UW campus and one at the UW-Casper campus. Nominations are open to all faculty and academic professionals. Sims presented a talk entitled "Volcanoes on the Verge."

Also, on April 24th at the A&S all College Faculty meeting, Sims' outstanding contribution to teaching at both the undergraduate and graduate levels was recognized by the College with an Extraordinary Merit for Teaching award.

Graduate student **Josiane Pafeng Tchuindjang** (PhD canddiate) was recently awarded the *James L. Allen Scholarship* from the Society of Exploration Geophysicists Foundation (SEG). Dr. Allen is a geophysicist, foundation trustee, and alumnus of the University of Wyoming, who got his Ph.D. in Physics in 1974.

The scholarship will help support Josiane's research, which addresses seismic and EM inversions for subsurface characterization, as well as petrophysical inversion for reservoir rock and fluid properties.

Josiane is advised by Professor **Subhashis Mallick**.

In November, Associate Professor Ye Zhang gave an invited talk at the AAPG Geosciences Technology Workshop in Golden, Colo. titled, "Hydrogeochemistry & Gas Chemistry of Uinta Basin: Implication for Genesis & Migration of Unconventional Gas." ❖

ALUMNI NOTES

Alumnus **John Bradford Branney** (B.S., 1977) has just published his fourth novel, Light Hidden by Darkness, which takes place in an alternate world, a place that many people believe exists, but no one has ever visited and returned to tell about it. John Bradford Branney retired from the oil and gas industry in 2011 and then began his second career as an author. Other books by John include Shadows on the Trail, Ghosts of the Heart, and Saving Miguel.

Alumnus **Cary E. Brus** (B.S., 1981) is currently working as a senior Vice President at Nerd Gas Company where he manages oil-gas-uranium-GTL, equipment and technology investments and personnel. He also works as Board Chairman, Director of Jonah Bank in Wyoming. This year, Cary is celebrating his 30th year of marriage to his wife Karen. They have three sons, Christopher, Andrew, and Ben.

After starting out in geology, Cary took a 15 year detour into commercial banking doing energy finance. He returned to the energy business in 2000 with Mick McMurry at Nerd Gas. He went back to banking in 2006 with the inception of Jonah Bank. Cary writes, "Energy business and banking business are, it turns out, complementary businesses. I have been fortunate over 33 years to straddle the unexpected volatility of the energy side and the desired predictability of the banking industry."

Alumna **Sarah (Stacy) Fitz-Gerald** (B.S. 2009) and **Braden Fitzgerald** (M.S. 2008) were married on August 17th, 2013. They both work as geologists for Hess and ExxonMobil respectively.

Alumnus **Mark W. Travis** (B.S., 2006) is currently working as an underground mine geologist for Barrick Gold N.A. and Cortez Underground. After leaving the uranium scene in 2013, he is now working in North-Central Nevada in Carlin type gold deposits. This is the first underground mine I've been exposed to and I thoroughly enjoy the experience," Mark writes. "I spend part of my time underground monitoring drilling progress and the other part of my time core logging the mud rocks that host the disseminated gold deposits."

Mark also recently became the V.P. of the Elko Chapter of the Geological Society of Nevada. ❖

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Participants of the 2014 ConoccoPhillips-sponsored Rocky Mountain Fieldtrip. This year's field trip focused on the crustal architecture of the Bighorn Mountain region of north-central Wyoming. Highlights from the trip included sandstone dikes and natural fracturing near Sheep Mountain, Archean granitoids in the Big Horn Mountains, and 3D seismic data on fault architecture in the region. The trip was lead by faculty members Eric Erslev, Ron Frost, Carol Frost, Art Snoke, and Johanna Moutoux, a UW alumnus, was the ConoccoPhillips representative on the trip.