GEOLOGICAL SCIENCES
UNIVERSITY OF COLORADO BOULDER

Geology News

Geological Sciences Celebrates 20 Years in the Benson Earth Sciences Building

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Editors
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Dan W. Mitchell

2016 - 2017

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Letter from the Chair

Shemin Ge

2016-2017 has given us much to celebrate and more to look forward to. We were very pleased to welcome three new members to our faculty, Sebastian Kopf, Mike Willis, and Boswell Wing (page 6). Seb and Boz mark the successful completion of geobiology hires in the past three years, while Mike fills in a niche in remote sensing geodesy. All have already begun to make excellent contributions to the department in various capacities such that it is hard to believe this is only their first year. We are fortunate that Lon Abbott became a full-time senior instructor and Jen Stempien will increase from 50% to 75% time instructor starting next year. As CU moves towards centralized academic advising with only full time advisors, Lon and Jen shifted their part-time advising duty to instructor. Their experience and knowledge with advising and curriculum will continue to be an invaluable resource for our majors and the department. We are also delighted to anticipate three new faculty to join us in the coming year, Leilani Arthurs, an expert in geoscience education; Carl Simpson, a paleontologist; and Lizzy Trower, a sedimentologist.

You may wonder how we are able to physically accommodate such a robust faculty growth. With creativity, collaboration, and collegiality from current faculty, the Benson Earth Sciences Building continues to amaze us by its capacity that enables the department to expand since we moved into the Building nearly 20 years ago. We welcomed 15 new graduate students in Fall 2016 from a pool of 290 applicants. We celebrated a total of 72 BAs, 6 MSs, and 9 PhDs graduating in winter 2016 and spring 2017. For the second time, we held our departmental spring graduation ceremony on the lawn outside Benson to accommodate a record high attendance. Mary Kraus, Professor and Vice Provost for Undergraduate Education, was our winter 2016 commencement speaker and Dean Miller, Attorney at Davis Graham & Stubbs, spring 2017 speaker. Their experience as alumni and unique career paths are truly inspirational for our students. It was most satisfying for us to see how much our students have accomplished and we are grateful for having had the privilege to work with them.

We continue enjoy strong support from our alumni and friends. Generous and sustained donations have made it possible for us to continue the Bill Bradley new graduate student field trip, provide the extra costs for field courses, offer research experience for undergraduate students through our mentoring program, and support graduate students with fellowships. In spring 2016, we established the Peter Birkeland Scholarship Fund in honor of Pete□s distinguished career in soil geomorphology and his legacy in mentoring students. I am happy to report that the initial goal was achieved in less than one year and we awarded the first fellowship to Emily Fairfax (page 24).

Recognizing that a greater capability in offering graduate student support would further transform the department, we recently established a new Geological Sciences Graduate Fellowship Fund. The faculty and the Advisory Board have pledged 100% participation in contributing to the Fund. This adds to the list of on-going fundraising priorities For the GeoEnergy Initiative and the Bill Braddock in the Field funds.

Approaching the end of my second year as Chair, I increasingly realize that my job would be no fun if I were not in the company of incredibly talented faculty and students; you can read some of their activities in this publication. My job would be impossible if it were not for the dedication and support of Associate Chairs and our staff members. Tom Marchitto served as Associate Chair for Graduate Program for the past three years and will be on sabbatical in 2017-2018. I am grateful for his insightful guidance for our graduate students and the graduate program. I am happy to announce that Alexis Templeton has agreed to and will be the Associate Chair for the Graduate Program next year. Eric Tilton will continue as the Associate Chair for the Undergraduate Program. Eric shepherded us in the past year in revamping our 1000 level courses, which will position the department well in anticipating the implementation of the new Arts and Sciences core curriculum in fall 2018.

In closing, I can't help but brag that CU has again been ranked by the US News and World Report as the world #2 best global university in Geosciences (page 11). We should all be proud of this success. As always, we'll be thrilled to hear from you and please join us to celebrate 20 years of the Benson Earth Sciences Building in September 2017 (page 12-13).

"Thank you for your continued generous support!"

Greetings from the Alumni Advisory Board

Dean Miller

It has been a good year for the Advisory Board and the Department. We welcomed Hal Miller, President of Subsurface Consultants & Associates, LLC in Houston, Texas, to the Board. Hal has been a valuable addition to the Board and we look forward to working with him in the future.

It is hard to believe that the Benson Earth Sciences Building is twenty years old. We are looking forward to the 20th Anniversary celebration in September. As discussed elsewhere in this newsletter, there will be a celebration in the Department on the evening of Friday, September 15, and field trips, a picnic, and a home football game on Saturday, September 16.

Once again, the University of Colorado was recognized by U.S. News and World Report as number two in the world in geosciences, which in large part is due to the Department's success in recruiting both top faculty and graduate students. This is a remarkable achievement, especially considering the competition for top faculty and graduate students. As the Department Chair, Dr. Shemin Ge, discusses in her column, the Department recently established the Geological Sciences Graduate Fellowship Fund to provide additional graduate student support, which is critical to graduate student recruitment since we are competing for the same students with other universities with significantly greater resources.

The Board met once again with Department undergraduates in the Fall and graduate students in the Spring to discuss the state of the Department. I'm happy to report that there are no significant issues to resolve. However, as I mentioned in last year's column, a continuing challenge for students is the high real estate values in Boulder, which is impacting the ability of students to live in Boulder rather than surrounding communities.

The Board held another career night for undergraduate and graduate students earlier this year. The students were very appreciative, especially with the depressed state of both the oil and gas and mining industries. Oil companies did no on-campus recruiting last year. As usual, please let us know if you know of any internships or other opportunities for students.

I had the honor of giving the commencement address at the Department's Spring graduation ceremony. We had an amazing group of both undergraduate and graduate students going through the ceremony. My comments included a summary of my circuitous career path from house painter to geologist to environmental lawyer. I touched on a few themes I thought might be helpful to folks at the beginning or their career, including the value of the critical thinking and writing skills they learned at CU, which will prove valuable regardless of the career path they ultimately follow. I also discussed the current need to advocate for science and fact-based critical thinking, the changing nature of the concept of a career given that most people graduating today will have many different jobs over their lifetime, and the importance of not letting other people define success for you. It was a humbling experience to have this opportunity and I hope the graduates took to heart my comment that you can plan all you want, and then life just happens.

I hope to see many of you at the 20th Anniversary party in September. Even if you can't make it, please stay in touch by letting the Department know your current contact information. And finally, let us know if you would like to come along on the Bradley Field Trip the weekend of August 26-27. It's a lot of fun.

Fall 2016 Advisory Board meeting (L-R); Alan Seeling, Harold Miller, Dean Miller, Andres Aslan, Gus Gustason, Chandler Wilhelm, Penny Patterson, Cheree' Stover, Houston Kempton, Patty Coretta, Joe Zamudio, Karen Kelley, John Roesink, and Shemin Ge

Geological Sciences Advisory Board Members

Andres Aslan
Colorado Mesa University

Sophie Berglund
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Gus Gustason
Enerplus

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Subsurface Consultants & Associates, LLC

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Alan Seeling
Petroleum Geologist

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New Faculty

Sebastian Kopf

Sebastian is a geochemist and geomicrobiologist interested in how microbial life has shaped the Earth's surface chemistry in the past and how it continues to do so today. His research group studies the physiology, ecology and metabolism of microorganisms involved in the production of biological signatures that can be preserved in the environment and in the rock record. His work combines approaches and techniques from stable isotope geochemistry, microbial physiology, genetics, ecology and connects across various departments and institutes on campus. Sebastian joined the Department in the fall of 2016 as Assistant Professor, after finishing a postdoctoral fellowship at Princeton University. Originally from Germany, he finished his undergraduate training at Jacobs University Bremen in Geosciences and Astrophysics, and obtained a M.Sc. in Geochemistry from MIT and a Ph.D. in Geobiology from Caltech.

Sebastian is now in the process of setting up a state-of-the-art Geomicrobial Culturing Facility in the Benson Earth Sciences building with the help of lab manager Jody Donnelly and research assistant Nabil Chaudhry.

Jody joined the Geomicrobial Physiology and Evolution labs (co-directed by Sebastian Kopf and Boswell Wing) in early spring from the National Renewable Energy Laboratory (NREL). She comes to CU with expertise in microbiology, molecular biology, analytical chemistry and microbial ecology, and is excited to apply her experience and unique skill set while learning more about the interface between life and Earth. Nabil Chaudhry is a newly minted alumnus of our undergraduate program who is staying on to delve deeper into the world of geomicrobiology and gain additional research experience before applying to graduate schools in the fall. Additionally, undergraduate honors thesis student Shaelyn Silverman from the Department of Molecular, Cellular and Development Biology (MCDB), and rotation students Elise Cowley and Kelsey Dahlgren from CU's Integrated Quantitative Biology graduate program (IQBiology) were the first to conduct their thesis and rotation research projects, respectively, in the new Geomicrobial Culturing Lab, and helped jump-start its operation.

Sebastian's arrival also added a gas chromatograph isotope ratio mass spectrometer (GC-IRMS) to the analytical inventory of the Organic Geochemistry Laboratory (OG Lab) established by Julio Sepúlveda in the new SEEC building in 2016. This new instrument enables high precision isotopic analysis of individual organic compounds, providing an isotopic window into the formation and history of organic biomarkers. The analytical capabilities of the OG Lab already allow for highly accurate identification, discovery and quantification of organic biomarkers. Together with the new mass spectrometer, the OG Lab will enable exciting new research projects and collaborations. The new instrument was successfully installed at the beginning of 2017 and is now generating some of its first isotopic data.

Sebastian is excited to be joining the vibrant scientific community in the Geological Sciences and at CU, and is looking forward to building his research program over the coming years, establishing new collaborations across campus, and contributing to CU's educational mission at the interface between geology, geochemistry and microbiology.

Michael Willis

Mike did his undergraduate degree in physical geography at Glasgow University in Scotland. While there he spent a very wet and somewhat miserable month camping at an isolated fjord on the western side of Spitsbergen in the High Arctic. He fell in love with the Arctic environment at that time and embarked on a path that would get him back to polar regions. He did his MSc with Ian Whillans at Ohio State University, embarking on several trips to Antarctica. Mike earned his PhD with Terry Wilson at the Byrd Polar Research Center for research on the neotectonics of the Transantarctic Mountains and West Antarctica, a region he spent about two years in total happily traipsing around. Mike then had a year as a Postdoctoral Fellow at the Byrd Polar with Mike Bevis and Terry Wilson before moving on to work, again as a postdoc and then a research associate, at the crustal deformation laboratory of Matt Pritchard and Rowena Lohman at Cornell University, in the very, very lovely Ithaca, New York. He spent an additional few years as a staff research scientist with Cornell, while being based at the University of North Carolina in Chapel Hill, where he got involved in using High Performance Computing (HPC) and computer vision to exploit new satellite imagery becoming available to Federally supported researchers to map the Arctic.

Mike is interested in a wide variety of Earth Science problems from glaciology to mountain dynamics and

earthquake hazards. He attacks them using geodetic and remote sensing tools, mixed with fieldwork whenever possible. The central question of much of his research is what is the dynamic contirubution of land based ice to the global ocean? This has led to studies of most of the glaciers, ice caps and ice sheets around the planet, and Mike has been fortunate enough to work in both Greenland and Antarctica. He is now in the process of building what he calls the 4-D topography laboratory where his post-docs and graduate students will be able to use HPC resources as well as photogrammetry tools such as drones to study, map, model and ultimately understand the ever changing face of our planet. He is starting to look more and more closely at hazards in deglaciating environments and has recently become very involved with cascading hazards caused by landslides into fjords, which cause tsunami. Mike is very glad to have found such an accommodating and welcoming home within the geology department and CIRES.

Boswell Wing

In Boz's own words...

I arrived in the Geological Sciences department last August, after a productive and enriching decade at McGill University. It has been a busy 10 months…

Amy, Isaac (age 9), Luc (age 5), and I packed up our place in Montreal at the end of July, heading across the country filled with enthusiasm for our relocation to Boulder. By all accounts this enthusiasm has only grown. Amy loves her job as the manager for ogallalawater.org, a USDA-sponsored project at CSU looking at sustainable water use and farming in the Ogallala aquifer region. After 3 years in a francophone elementary school, Isaac transitioned smoothly into the third grade in English, making a bunch of new friends and discovering newfound passions for flag football, karate, and running around various parks smacking comp-

mates with foam swords. Luc has turned into a biking fiend, looking forward to pedaling off every AM to spend the day with his pals at the CU childcare center (and looking even more forward to joining his brother in elementary school in the Fall!). As for me, well, each new interaction, opportunity, and conversation reconfirms the rightness of our decision to restart our lives in such a radical way.

I took my PhD at Johns Hopkins as a metamorphic petrologist with field seasons in the Sierras, the Dolomites and the Cuillin. I then spent a few years learning the stable isotope geochemistry ropes at the University of Maryland, before starting a lab at McGill and making the long and slow metamorphosis into a geobiologist with the help of a bunch of students and colleagues. Microbes dominate elemental cycling on modern Earth, implying a long co-evolutionary relationship between the geochemistry of earth surface environments and the activity of their microbial inhabitants. We focus our research on how this relationship falls under the paradox of geobiological uniformitarianism, where interpretations of isotopic and geochemical microbial 'bio-signatures' in the ancient rock record are based on a critical assumption: the microbial metabolisms that produced them have not changed in a long, long time. This assumption is peculiar, especially to anyone who has worried about the rise of antibiotic-resistant 'superbugs' at hospitals worldwide.

We investigate this paradox in a couple of ways. First, we go out in the field and collect large suites of rock samples from well-characterized paleo environments in the deep time record, and see if the isotopic and geochemical patterns that we observe are consistent with bio-signatures from microbial cultures in the laboratory. Second, we take modern microbial populations and subject them to experimental evolution in in the lab, and see if their adaptive changes produce isotopic or geochemical bio-signatures that can inform bio-signatures from the ancient rock record. This work cuts across many disciplines, from molecular biology to geochronology, and is rooted in real-time hypothesis testing, from one outcrop (and one generation) to the next. As a result, it is totally collaborative, highly uncertain, and wicked fun.

I've been fortunate to arrive as the department has gone through a geo-analytical renaissance, and I am excited to work with Katie Snell, Brett Davidheiser-Kroll, Seb Kopf, Julio Sepulveda, and Eve Hinckley (ENVS) to take our isotopic capabilities to the next level. I am also eager to develop a communal culturing facility with Seb, Alexis Templeton and Jeff Cameron (Biochemistry), where geologically relevant microbes will be pushed and pulled to their full physiological and evolutionary potential. After a decade in a science funding system that was stable but self-limiting, I was anxious but excited about the range of funding opportunities available here. I am grateful for the recent news that NASA will be supporting a project looking at whether ribosomes (the protein-making factories in all cells) can be made to evolve in the lab, and that NSF is behind a large, multi-institutional effort to look for isotopic 'ghosts of biospheres past' in really old rocks. This latter project will involve close collaboration with Steve Mojzsis and his CRiO initiative.

In the midst of all this self-referential verbiage, it is easy to

miss that science is really a team enterprise. All the folks on the Geological Sciences staff (Ruth, Marilynn, Kristine, Shana, Paul and Dan) have made sure my start here has been smooth sailing guided, of course, by Shemin Ge's firm hand on the tiller. My biggest thanks and respect are reserved for the brave and brilliant researchers, students and postdocs who have jumped on board, and who I try mightily to keep up with. Jody Donnelly and Nabil Chaudhry came here in the new year, jointly supervised by Seb Kopf and me, and have rapidly made real (and better) a host of our vague culturing plans. Jesse Colangelo-Lillis joined the crew in November after graduating from McGill. He is currently on secondment to Dave Stahl's lab at the University of Washington and he'll be in Boulder fulltime this Fall, supported by a C-DEBI post doc to look at experimental evolutionary adaptation in deep-sea microbes. Sarah Hurley started a post-doc in February after submitting her PhD thesis at Harvard. She is working to unlock the mysteries of cyanobacterial carbon fixation in ancient and modern oceans, and she has made great progress down this path thanks to the fantastic lab of her co-advisor, Jeff Cameron. Ben Johnson will be arriving in October from the University of Victoria, supported by an NSF-EAR post-doc fellowship to work with Peter Molnar and me on the geochemical and tectonic state of ocean ~3.2 billion years ago. New PhD student Jen Reeve will be arriving shortly before Ben (but following a similar path from Victoria), and is planning to use experimental evolution to look at the deep-time historical footprint of cyanobacteria behavior. And last, but not least, there are three super undergrads in the lab - Johanne Albrigtsen, who is triple-majoring (!) in Molecular, Cellular, & Developmental Biology, Biochemistry, and Ecology & Evolutionary Biology but taking her senior thesis in Geological Sciences; Claire Jasper, who is visiting from Boston College and working with Sarah to unravel the intricacies of cyanobacterial lipid production; and Stephanie Plaza-Torres, who is here as a SMART scholar from the University of Puerto Rico and is working with Karen Chin, Brett Davidheiser-Kroll and me to see whether coprolites preserve any isotopic indicators of dinosaur gut microbiota. Whenever I talk science and life with these three, I always feel a little bit sheepish about how I spent my undergraduate days…'nuff said.

Faculty News and Activities

Bob Anderson - **From gophers to glaciers**

Two PhD students have recently graduated from Bob Anderson's research team. Eric Winchell worked on gophers in the Colorado Front Range, while Billy Armstrong worked on glaciers in Alaska.

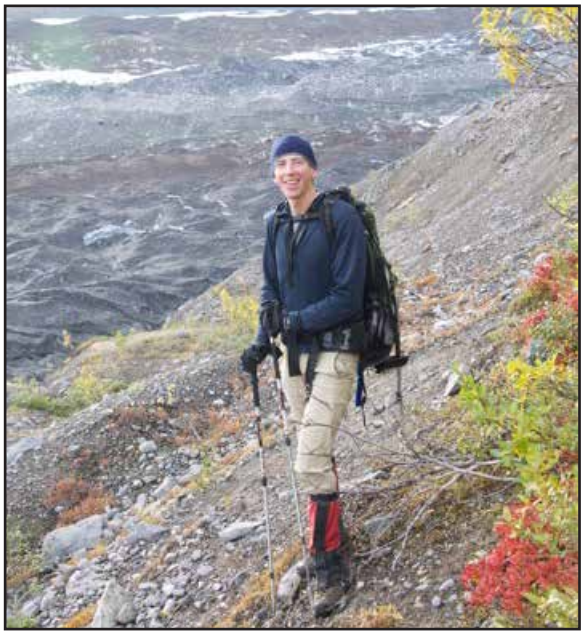
Gophers, it turns out, are very effective at moving soil about. Eric has documented the signatures of gophers in the meadows that dot the forests of Niwot Ridge. Working in two meadows above the Mountain Research Station, he located and measured the sizes of mounds slung to the surface by the digging of these baseball-sized fossorial rodents over three summer seasons. Their digging consistently follows a seasonal pattern. The only signs of digging in the winter are sinuous dirt trails left on the surface when the snow melts. These show how they occupy the snow-soil interface beneath significant snow cover at the upwind edges of the meadows. The snow presumably both keeps the ground surface from getting too cold, and provides protection from predators. In the summer, their subsurface activity expands into the meadow interior and coincides with the maturation of plants whose roots they eat. Eric also documented the signature of gophers in the vertical by first showing that a plane of stones exists at 15-20 cm depth – a "stoneline" -- that reflects the depth to which gophers dig. Stones that they cannot heft to the surface accumulate at the base of their tunnel systems. In addition, he used short-lived radionuclides ^{137}Cs ad ^{210}Pb to test whether the present day rates and depths of digging can explain the stonelines and the fine-grained "biomantle" above it: they can. As the meadows are occupied by gophers and the forests around them are not, the meadows serve as hotspots for the biological churning of our mountainous landscapes.

Eric Winchell amidst his flagged gopher mounds. Each color corresponds to a different week of digging.

Billy studied the sliding of glaciers. His research took him to Alaska's Wrangell-St Elias National Park, where he both instrumented the Kennicott Glacier and used satellite imagery to document glacier speeds across the range. The target was to understand the spatial and seasonal pattern of the sliding of glaciers. As glaciers erode the landscape only by sliding across the bedrock, understanding the pattern of sliding is necessary to understanding how glaciers modify our mountainous landscapes. On the Kennicott Glacier, Billy -- at times with the assistance of a number of other CU geology students -- established GPS monuments on the ice, and documented the levels of side-glacier lakes that constrain the plumbing system in the glacier. Sliding is seasonal, with a major pulse of motion in the early summer that occurs simultaneously with water being fed into the glacier from melt of the surface. Sliding also both displays both a daily cycle, and responds to major outburst floods of side-glacier lakes. But his time as a PhD student also coincided with major advances in the quality and quantity of imagery from space, and the development of algorithms to detect change from one image to another. As the relatively large glaciers of the Wrangell mountains moved significantly

over the several-week intervals between images, Billy was able to document the pattern of ice surface motion over entire alpine glaciers. His work reveals that many of the Wrangell glaciers show seasonal patterns that reflect significant sliding of the lower reaches of glaciers that experience significant melt. The upper parts of glaciers - the accumulations zones - do not slide. This has significant implications for the pattern of erosion of glaciated mountain ranges.

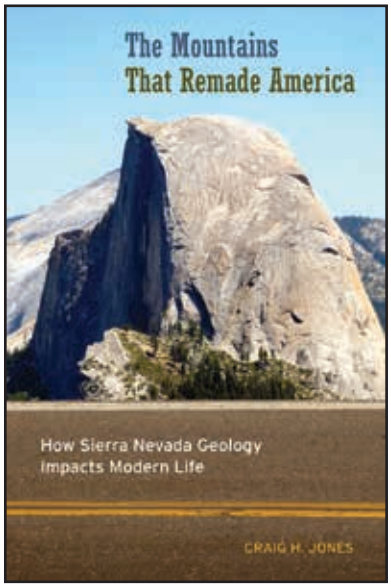
Eric is now off to San Diego where he is hopeful of a postdoc at UC San Diego. Billy, meanwhile, is off to Appalachian State, where his fiancée Sarah Evans (a Shemin Ge PhD graduate) has a tenure track faculty position, and Billy has a teaching post soon to become a fully-fledged faculty position.



Billy Armstrong on the Little Ice Age moraine above the Kennicott Glacier.

Craig Jones

Professor Craig Jones has completed a book, *The Mountains that Remade America: How Sierra Nevada Geology Impacts Modern Life* to be published by the University of California Press in September. Dr. Jones has worked on the tectonics of the Sierra for more than 30 years, and the book attempts to consider questions about the evolution of the range by considering the role geology has played in events like the Gold Rush and the preservation of Yosemite Valley and how those events have reverberated through a broader history. For instance, while the Gold Rush has been examined from nearly every available human perspective, from the means of travel to the literature spawned to the political ramifications of the rush, historians have overlooked a basic truth of the rush: that it was exploiting a globally rare if not unique resource, a triad of economically important gold deposits in one place: placer gold, paleoplacer gold, and lode gold. Each was critical in generating long-lasting results. The placer deposits were the catnip that lured hundreds of thousands to the goldfields of California, an event that so overwhelmed the small and temporary military government that the goldseekers were free to redefine mineral law. The main framework of the 1872 mining law, which is still on the books, rose from the camp meetings of these placer miners. In a similar manner, the paleoplacer deposits rewrote water law as ambitious miners simply redirected streams and rivers to blast away the ancient gravels and run them through their sluice boxes.



Cover image of Prof Craig Jones' new book *The Mountains that Remade America: How Sierra Nevada Geology Impacts Modern Life*

This revised water law, the law of prior appropriation, is the basis for moving huge amounts of water around the west. This was also the economic engine that maintained mine production as placer deposits failed and was the very first example of strip mining in America and the very first to be shut down for damaging a broader ecology. Finally, lode gold demanded industry, and local industry at that, making California something more than a resource-exporting backwater. The modern metropolises of San Francisco and Los Angeles had the time and resources to develop because of that industry and associated capital.

Once a reader can see these connections, returning to discuss the geology that created such a bonanza is more a treat than a chore. In addition to the Gold Rush, the book explores the origins and evolution of the American conservation movement, the motivation for creating national parks, and the means of conveying information about geologic hazards to endangered communities.

Peter Molnar

With curiosity, as a justification for science, under continual threat, Peter Molnar finds pleasant companionship among dinosaurs. Both paleontologists and curious 5-10-year-old kids share a great respect for dinosaurs. So, encouraged by his granddaughters, he aspires to join the big league.

The Great American Biotic Interchange provides the attraction; during this exchange large animals, mostly mammals, crossed from North to South or South to North America in perhaps four waves, beginning when Ice Ages began approximately 2.5 Ma. For example, llamas and alpacas evolved from descendants of North American camelids that are now extinct; armadillos and anteaters went the other way, from South to North America. To change continents, ancestors traveled on foot through the Isthmus of Panama, but few of the survivors, and presumably the ancestors, would do so today. Most prefer open landscapes, such as grassy savannas or arid mountains, to the jungles of snakes, crocodiles, and mosquitoes that thrive in eastern Panama today.

Controversy has surrounded the reasons behind the Great

Eliza Beilinson, Argentine sedimentologist, standing next to a fossil of a relatively small glyptodont in the Museo Municipal de Ciencias Naturales Lorenzo Scaglia in Mar del Plata, Argentina. Glyptodonts are large armadillo-like animals, and some species reach the size of Volkswagens.

American Biotic Interchange. Some have argued that the Isthmus of Panama emerged at 2.5-4 Ma, but recent studies suggest that the Isthmus has been in place since 10-20 Ma. Molnar hypothesizes that waves of immigrating animals crossed through Panama when ice sheets extended as far south as St. Louis, first at 2.5 Ma, then at 1.3 Ma, and couple of times later, and caused Panama to dry out, as it did during the last, less impressive glacial maximum. Molnar has the privilege of working with Argentine geologists/paleontologists Eliza Beilinson, Germán Mariano Gasperini, and Sergio Vizcaíno, as well as North American geochemists Thure Cerling and Matt Kohn, to date the first appearances of large mammals that crossed from North America. They will use cosmogenic nuclides to determine when sediment containing the fossils was deposited, and are processing preliminary samples obtained in October 2016. Argentina reveals the Great American Biotic Interchange in spades. After visiting Argentina, Darwin wrote: "It is impossible to reflect without the deepest astonishment, on the changed state of this continent. Formerly it must have swarmed with great monsters, like the southern parts of Africa, but now we find only the tapir, guanaco, armadillo, capybara; mere pigmies compared to antecedent races." His monsters included both animals from North America and many endemic taxa that did not survive the competition with North American immigrants. Molnar claims that this research is useless, will be of no economic value, and may never receive humongous government funding, but... it is a lot of fun, and kids may well find the results interesting.

Julio Sepúlveda

After a full year of renovations, and the installation and testing of new analytical instrumentation, Julio's new Organic Geochemistry Lab (OG Lab) in the SEEC/SEEL complex is now operational thanks to the dedicated efforts of Dr. Nadia Dildar, manager of the OG Lab. This state-of-the-art shared analytical facility is equipped with instrumentation for the extraction, purification, and chemical and stable isotope characterization of a wide range of organic molecules from environmental samples. Julio's group is excited to share the lab with its close collaborators Profs. S. Kopf and G. Miller, and to expand their collaboration with the groups of their colleagues A. Templeton, K. Snell, P. Molnar, K. Chin, J. Eberle, and J. Andrews.

In June 2016, Julio became an Adjunct Scientist with the Millennium Institute of Oceanography at the University of Concepción, Chile. This affiliation provides new research opportunities to study microbial and biogeochemical processes in the oxygen minimum zone (OMZ) off northern Chile. In February 2017, Julio also participated in the Kiel Off-Shore Mesocosms for Ocean Simulations experiment in the OMZ off Peru organized by GEOMAR-Kiel, Germany. The group will study how microorganisms adapt to multiple environmental stressors by modifying the lipid composition of their cell membranes.

Dr. Aaron "Ari" Meilijson joined the OG Lab as a Research Affiliate in October 2016 after working as a postdoctoral associate at the University of Haifa, Israel. He obtained his PhD., MSc., and BSc. in Geology from the Ben-Gurion University of the Negev, Beer Sheva, Israel. While primarily a sedimentologist and stratigrapher, Ari is now using lipid biomarkers to study the paleoceanographic and biological changes that took place in the Eastern Mediterranean during the Early Eocene and the Messinian Salinity Crisis.

PhD student Lina Pérez-Ángel joined the OG lab in fall 2016 (co-advised by Peter Molnar) after graduating with a BSc. in Geology from the University of Los Andes, Colombia. Lina is studying the climatic and vegetation evolution of the Eastern Cordillera of the Andes since the Pliocene by using a combination of organic and stable isotope proxies. Since her arrival, she has been awarded a seed grant from CIRES, a travel grant from Colombia, and student support from the department. Second year PhD student Garrett Boudinot attended the Stable Isotope Biogeochemistry and Ecology Summer School (IsoCamp) at the University of Utah in summer 2016 with the support of a travel grant. Among many other lab-related activities this summer, Garrett will mentor a RESESS summer intern who will help him generate a high-resolution record of carbon cycle perturbation across the Cenomanian-Turonian boundary before defending his comps in the fall.

The OG Lab (L-R); N. Dildar, M. Gross, A. Meilijson, J. Sepúlveda, G. Boudinot and L. Pérez-Ángel.

Julio was pleased to work with several excellent undergraduate students, Michael "Avi" Gross who graduating with honors, Nina Kentwortz who was awarded an Undergraduate Research Opportunities Program fellowship, and lab assistant Christine Schlarbaum. Raman Umamaheswaran, a Geology senior at the University of Delhi, India visited the OG Lab in summer 2016 as a recipient of the S.N. Bose Scholars Program. He worked on the biomarker analysis of Cretaceous dinosaur coprolites in collaboration with Prof. K. Chin.

Alexis Templeton

Prof. Alexis Templeton is conducting active field research with several PhD students in the Samail Ophiolite in Oman. This ophiolite has the largest and best exposures of mantle rocks, as well as spectacular examples of hyperalkaline seeps where deep seated fluids are released along faults at the crust/mantle boundary. Current PhD students Hannah Miller, Kaitlin Rempfert, and Daniel Nothaft, as well as Research Scientist Eric Ellison, have all traveled to Oman with Alexis in the past few years to collect and analyze the water, minerals and microbiology stored at depth in actively serpentinizing peridotite rocks. This winter, Alexis led a group of nine faculty and students to Oman to sample from deep wells that access hyperalkaline fluids rich in dissolved hydrogen and methane. The fieldwork was designed to capture the water/rock reactions that produce hydrogen at low temperatures, and to explore whether or not microbial life that the Templeton lab has detected within the peridotites is utilizing this hydrogen to reduce dissolved inorganic carbon and thereby produce large fluxes of methane.

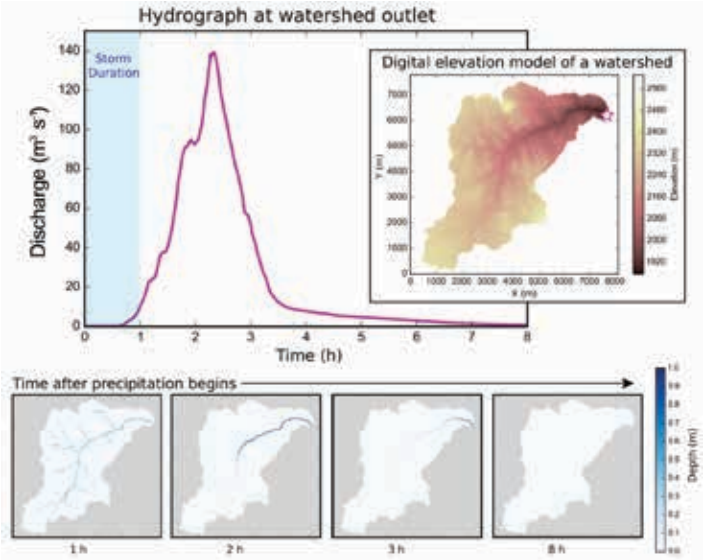
Some aspects of this research are funded by the Department of Energy in order to determine the feasibility of CO2 sequestration in ultramafic rocks, and to assess whether strategies to induce mineral carbonation occur might instead generate methane. Other aspects of this research are funded by the NASA Astrobiology Institute, in order to test how microbial life can be sustained in-situ during low temperature seprentinization. This question is of interest to a diverse range of scientific communities, since hydrating peridotite rocks might be common "habitable environments" on several rocky bodies in our solar system, such as the subsurface of Mars, Jupiter's moon Europa and Saturn's moon Enceladus.

Prof. Alexis Templeton will return to Oman in winter 2018 to work closely with students and faculty from numerous U.S., European and Japanese institutions, in order to conduct microbiological and geochemical sampling during scientific drilling and core recovery of the ophiolite as part of the Oman Drilling Project (https://omandrilling.ac.uk)

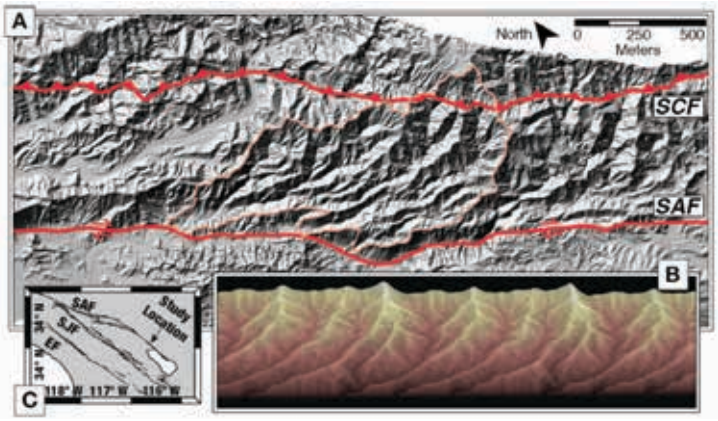
Alexis Templeton, Kaitlin Rempfert, Daniel Nothaft (GEOL department, CU-Boulder) and colleagues from Colorado School of Mines and Montana State University conducing geochemical and microbiological sampling on gas-rich hyperalkaline fluids pumped from 300 meters in peridotite rocks in Oman.

Greg Tucker - Landlab: Lowering the barrier for earth-surface dynamics modeling

The sciences of the earth's surface are evolving rapidly, and new data, discoveries, and ideas continue to fuel the need for new computational models. Numerical models are crucial to the earth-science enterprise because they enable researchers to explore and visualize quantitative hypotheses, and compare hypotheses with data. Yet the task of building, modifying, and maintaining the necessary software behind earth-surface dynamics models can be a daunting one. To sustain progress, it's important that computational software is sufficiently flexible and adaptable so that it promotes, rather than impedes, the discovery process. To help meet this need, Greg Tucker and a team of colleagues at CIRES, Tulane University, and the University of Washington have created a software library that helps scientists rapidly create, explore, modify, and combine two-dimensional numerical models. The Landlab Toolkit (http://landlab.github.io) is a support system for model development that (1) is written in a modern high-level language with a rich set of scientific computing libraries; (2) takes care of common but labor-intensive tasks, such as grid creation and input/output, with a convenient set of functions



Output from a rainfall-runoff model written in Landlab, showing hydrograph produced by a heavy rainstorm. The location is Spring Creek, a tributary of the South Platte River in the Colorado Rockies. (from Hobley et al., Earth Surface Dynamics, 2017).



Example of a Landlab-built landscape evolution model created by CIRES PhD student Harrison Gray to investigate tectonic landforms. (A) terrain along the southern San Andreas Fault, showing ridges and valleys oriented obliquely with the fault trace. (B) Landlab-built model of terrain evolution under tectonic shear demonstrates that "warped" ridges and valleys can result from distributed "off fault" deformation. (C) Location map.

and data structures; (3) packages useful operations and calculations into reusable components; and (4) provides a simple mechanism for a scientific programmer to combine components. Landlab is written in Python, thereby taking advantage of the rapidly growing popularity of Python as an efficient, high-level programming language for scientific computing. Landlab provides a gridding module that allows a researcher to create and configure a grid in just one or a few lines of code. Grids may be structured (e.g., raster or hexagonal) or unstructured (Delaunay/Voronoi). State variables and other distributed data can be attached to a grid, and staggered-grid numerical schemes are easy to implement. Landlab includes a set of process components written by the development team to model a wide variety of processes. These include, for example, incident solar radiation on terrain, evapotranspiration, overland flow, soil creep, stream network erosion, and flexure of the lithosphere. Landlab aims to foster progress in earth-surface dynamics by helping modelers focus on their science rather than the computer code behind it.

Paul Weimer

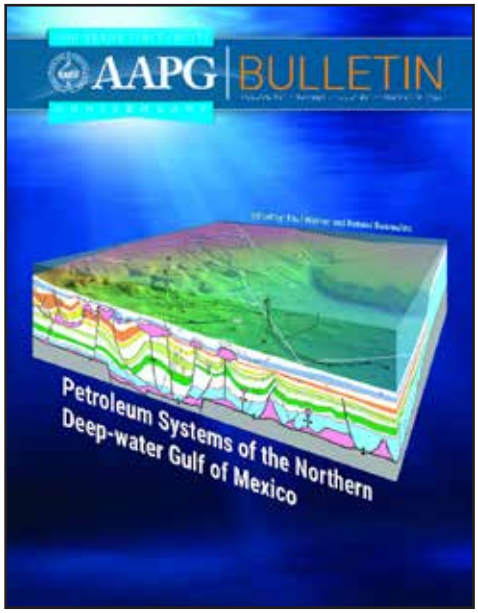
Paul taught three graduate courses this year: Sequence Stratigraphy and Basin Analysis, and Petroleum Systems of Deep-water Settings and Unconventional Resources, which was taught unconventionally. Paul also organized the AAPG-SEG student section talks, which complemented all of the teaching. Highlights included: visiting the offices of four local companies where students were given detailed summaries of their activities in unconventional plays, three talks from the Discovery Thinking sessions at the National AAPG Convention, and three AAPG and SEG Distinguished Lecturers.

In September, he taught a 1.5 day short course for Mexican students at the AAPG International Convention in Cancun. Two weeks later, he chaired and organized a 1.5 day session at the GCAGS Convention (Corpus Christi) on northern deep-water Gulf of Mexico--he gave five papers. In April, the AAPG celebrated its 100th anniversary at the Annual Convention, where Paul's efforts as the final chair of the Anniversary Committee came to fruition. The final committee's products are now ready for distribution, which include 50 GeoLegend interviews, more than 90 talks from the Discovery Thinking series (pdf files, and videos), and the most influential papers (http://100years.aapg.org), and digital field trips. He also has organized seven sessions on global trends in deep-water for the October AAPG International meeting in London.

He supervised seven graduate and two undergraduate students this past year. Their research focuses on the deep-water margins of Peru, Colombia, Falkland Islands, southwest Madagascar (Morondavo Basin), eastern Mediterranean, Myanmar, and the Gulf of Mexico.

This summer, Paul is finishing the final chapters for his book on the Piceance Basin to be published by the RMAG this fall.

In November, Paul will receive the Don R. Boyd Medal for Excellence in Gulf Coast Geology from the GCAGS (AAPG-Gulf Coast Section). The medal is awarded for "having achieved distinguished standing in Gulf Coast Basin research geology, and professional leadership in the GCAGS and in at least one of its member societies."



The July 2017 issue of the AAPG Bulletin is dedicated entirely to Paul's research in the Gulf of Mexico.

The department organized a one-day retreat in January 2017. Bob Anderson, Kristy Tiampo, and Boz Wing spearheaded planning and leading the activity. The retreat was well attended by faculty as well as Mary Kraus, Vice Provost for Undergraduate Education, and Terri Fiez, Vice Chancellor for Research and Innovation. Productive discussions took place on topics ranging from undergraduate curriculum to future of the department, from department social activities to restructuring research interest groups. Picture on next page.

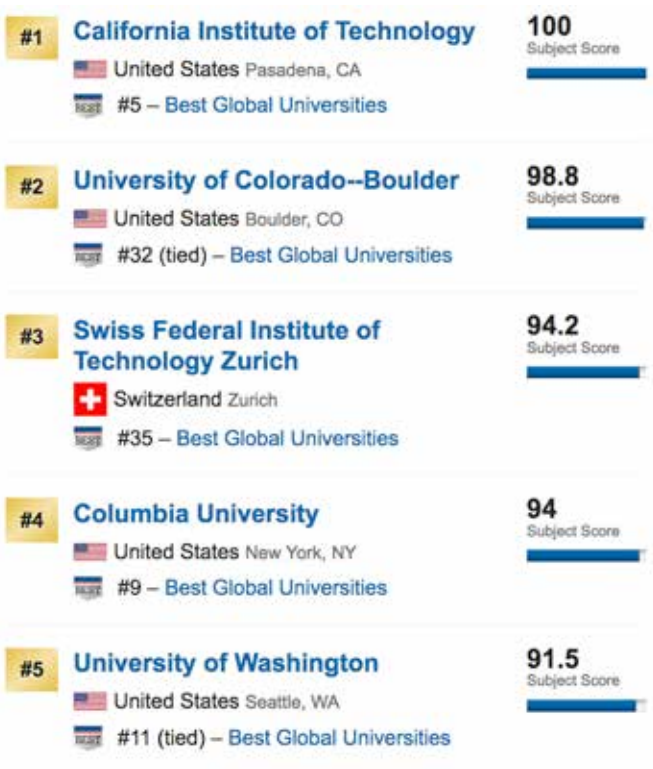
2017 Geology faculty retreat. (L-R) back; Giff Miller, Karl Mueller, Eric Tilton, Brian Hynek, Kristy Tiampo, Julio Sepulvéda, Katy Snell, Jaelyn Eberle, David Budd, Karen Chin, Boswell Wing, Craig Jones, Joe Smyth, Anne Sheehan, Michael Willis, Paul Weimer, Peter Molnar, Bruce Jakosky (L-R) front; Bob Anderson, Tom Marchitto, Lon Abbott, Sebastian Kopf, Jennifer Stempien, Shemin Ge

US News and World Report Ranks CU Geoscience #2 in the World

US News and World Report's 2017 subject rankings list CU's geoscience program at #2 in the world, behind only the California Institute of Technology (https://www.usnews.com/education/best-global-universities/geosciences). The ranking considers the research impact of each school in all geological sub-disciplines, including oceanography, petroleum geology, geology, geochemistry, geophysics, and climatology. All the geoscience research done across campus is factored into CU's ranking, so it encompasses work being done across several departments and institutes. That said, the Department of Geological Sciences is certainly central to the work that US News is honoring.

The magazine ranks geoscience programs on eight criteria: 1) global research reputation; 2) regional research reputation; 3) publications; 4) normalized citation impact; 5) total number of citations; 6) number of publications that are among the 10% most cited; 7) percentage of publications that are among the 10% most cited; 8) international collaboration. Cal Tech, as the highest ranked institution, receives a score of 100 and all other institutions' scores are normalized to that perfect score. CU Boulder received a 98.8 and the #3 school, the Swiss Federal Institute of Technology, received a 94.2. It really is a two-horse race for the top spot in the US News rankings between CU and Cal Tech.
Cal Tech bests CU in four of the eight criteria and CU ranks higher in the other four. Cal Tech has higher global and regional research reputations, but edges CU out slightly in the percentage of publications that are among the 10% most cited, and beats CU handily in international collaboration. But CU comes out on top in the four areas that many people would argue are the most tangible evidence of research excellence: it has a higher normalized citation impact than does Cal Tech, edges them out in total number of publications and is #1 in the world in both total citations and the number of publications among the 10% most cited (Cal Tech is #2 in both those categories).

Any way you measure it, the department's research is getting noticed and having a big impact. Many of you reading this have contributed to that lofty ranking; thank you for your great work and enjoy some well-deserved recognition!



Celebrating 20 years of Benson

September 15th, 2017

The Benson Earth Sciences Building (BESC) was dedicted in October, 1997, which means that we are fast approaching the 20th Anniversary of our home. Geological Sciences is not the same department it was when we moved from Old Geology to our new home. And the building itself has been a major factor in defining the Department's transition. Our ability to hire the very best young faculty, and to recruit top students from around the country has been greatly enhanced by the infrastructure and appearance of BESC. In recognition of the 20 year anniversary, we have scheduled a gala celebration. You are warmly invited. Come help us celebrate two decades of education and research, and a bright future. Please see the invitation on the following page and let us know by September 1. Following are planned activities.

September 15th, 2017, Friday

2:00 - 5:30 pm, labs in Benson open house

5:30 - 8:00 pm, celebration in Benson atrium and auditorium, remarks at 6:30 pm

September 16th, 2017, Saturday

8:00 am - 4:00 pm, Niwot Ridge field trip, Leader **Dr. Bob Anderson**

Limited to 20 participants due to logistics. We will leave Benson Building at 8am and drive to the Mountain Research Station, then up the Niwot Ridge access road, parking at the cable gate. We'll walk at a leisurely pace up to Niwot Ridge. The hike starts at 10,800 ft, reaches TundraLab in the saddle at 11600 ft after 1.3 miles. Weather and fitness permitting, we'll have lunch on the west knoll, 0.4 miles farther. The sweeping vistas include the high country of the range from Pikes Peak to Longs Peak, and the glacially ornamented Indian Peaks sector of the range crest. We will discuss the geologic history of the Front Range, the glacial history of the alpine, and the geomorphology of the ridges above the glacier footprint. We will witness the ongoing research in the long-lived Niwot Longterm Ecological Research (Niwot LTER) site, the Boulder Creek Critical Zone Observatory (BcCZO), and the NOAA gas sampling site. We plan to return to Boulder by roughly 4pm.

8:00 am – 4:00 pm, The Puzzling Presence of the Colorado Rockies, Leader - **Dr. Lon Abbott**

The Colorado Rockies first rose during the Laramide Orogeny, but the mountains we see today are likely much taller than their Laramide predecessors because they ride atop a broad topographic swell that includes the western Great Plains. We'll look at geological evidence supporting this conclusion, as well as clues that might contribute to a resolution regarding when and why that topographic swell formed. We'll travel from the Benson Building to Castle Rock where sediment buried the Laramide Rocky Mountains, then visit Florissant Fossil Beds National Monument to see spectacular fossil trees and discuss the clues the monument's abundant fossil leaves provide for the history of uplift. We'll then visit an Eocene paleocanyon that drained the post-Laramide landscape, and turn for home along the trace of the state's largest Laramide thrust fault, in South Park.

5:00 pm – 8:00 pm, Alumni BBQ

Location will be sent after we receive RSVP's.

September 16th-17th, 2017, Sat-Sun Active Salt Tectonics of Arches and Canyonlands, Utah. Leader - **Dr. Karl Mueller**

Limited to 12 participants. This trip will examine the spectacular geologic structures, erosional history and active salt tectonics of Arches and Canyonlands National Parks. Day 1 will examine extensional faults that accommodate collapse in Arches NP, including hikes to the Delicate Arch Overlook and a traverse through the Fiery Furnace, an amazing maze of sandstone fins and arches. Day 2 will be a trip in modified 4X4 jeeps through the Needles District of Canyonlands where we will see actively dilating grabens and consider recent research at CU on active salt diapirs and extensional faults. Participants can drive to Moab from the Denver area, or fly directly into and out of the Moab airport the day before and after the trip. There may be a cost associated with lodging and meal.

Sunset on the Fiery Furnace, Arches National Park.

Please let us know if you are interested in joining one of the four activities above by August 20th so that we can plan the logistics accordingly. You should contact Shana Mercer by phone 303-492-1328 or email shana.mercer@colorado.edu or drop us a line using the enclosed envelope.

Building Benson Earth Sciences ....

20th Anniversary

BENSON EARTH SCIENCES BUILDING

YOU ARE INVITED TO A RECEPTION HOSTED BY
THE DEPARTMENT OF GEOLOGICAL SCIENCES
CELEBRATING THE 20TH ANNIVERSARY OF
THE BENSON EARTH SCIENCES BUILDING AT
THE UNIVERSITY OF COLORADO BOULDER

FRIDAY, SEPTEMBER 15, 2017
5:30 P.M. - 8:00 P.M.
REMARKS • 6:30 P.M.

2200 COLORADO AVENUE
BOULDER, COLORADO
PARKING AVAILABLE IN LOTS 359 AND 360

SPACE IS LIMITED
RSVP TO www.cu.edu/Benson20
by September 1 at the latest
QUESTIONS? PLEASE CALL
JAZMIN BROOKS AT 303-541-1480

University of Colorado **Boulder**

The new JEOL JXA-8230 electron microprobe: in situ major, minor & trace element analysis in solid material at the (sub-)micron scale

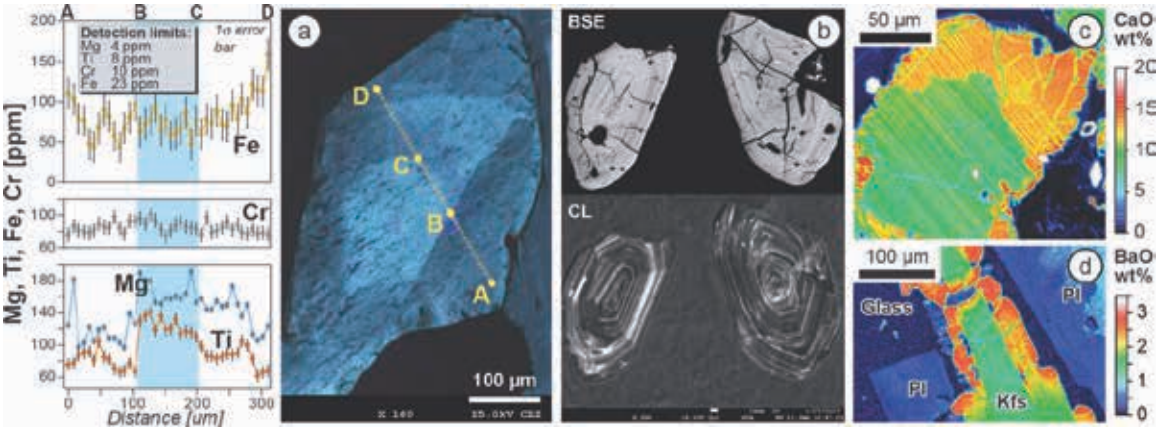
Electron microprobe analysis is a sensitive technique for non-destructive quantification of the chemical composition of in situ micrometer volumes of solid materials (minerals, alloys, ceramics, glass, etc.). The electron microprobe laboratory at CU Boulder was first established in 1988 by Dr. John Drexler and Prof. Chuck Stern, and for almost 30 years, the lab provided researchers from all around Colorado and from different departments (geology, chemistry, physics, engineering, etc.) with precise and accurate chemical analyses. Under the directorship of Prof. Kevin Mahan, a new era for the electron microprobe laboratory began with the hiring of Dr. Julien Allaz to manage the lab in 2012 after Dr. Drexler retired. In 2014, PIs Mahan, Allaz, and Farmer were awarded a 1.24 million dollar grant from the NSF (Major Research Instrumentation program) to replace the aging JEOL JXA-8600 electron microprobe. A new JEOL JXA-8230 microprobe equipped with five wavelength dispersive spectrometers, a state-of-the-art SDD energy dispersive spectrometer, a panchromatic cathodoluminescence detector, and a LaB6 electron gun was installed in March 2016 (Fig. 1), and has been fully operational and open to internal and external users, including industry users, since September. After 28 years of loyal service at CU Boulder, the old instrument was relocated for education and research purposes to the Department of Geology at Auburn University (Alabama), under the directorship of Prof. Willis Hames.

The new JEOL-8230 electron microprobe offers superior-quality analysis, in terms of both precision and accuracy. This new instrument also offers higher spatial resolution and greater analytical capabilities, notably in terms of minor and trace element analysis. A major advantage is the presence of many large-area monochromators, which allow 2 to 3-fold higher count rates, and thus higher sensitivity and lower detection limits. The software capabilities have also improved immensely, and the fully automated instrument offers more accurate and precise results in far less time. Major elements in silicates are analyzed in less than a minute, X-ray element maps can now be quantified (Fig. 2), trace element analysis down to the 1-10 ppm range of the detection limit is reached in just a few minutes, complex minerals with over 25 elements (e.g., REE-bearing minerals) are analyzed in less than 10 minutes, and accurate analysis of beam sensitive materials is easily done without cutting too much of the precision. These updates will certainly foster new collaborations and discoveries for researchers and private customers. For instance, the new instrument now allows for analysis of rare and precious elements (Au, Ag, Te...) in sulfides, trace element analysis in beam sensitive materials, including carbonate, titanium analysis in quartz for thermometry, U-Th-Pb dating of monazite, quick yet accurate and precise homogeneity tests in synthetic materials, etc. The new instrument and lab will be incorporated into a variety of teaching activities including a graduate level course on analytical methods and several undergraduate courses. Activities for the latter will be facilitated by technological enhancements such as a large wall-mounted monitor, a web-cam, and remote access.

This new acquisition would not have been possible without the help of nearly 50 researchers from 10 institutions throughout Colorado and beyond who supported our proposal. The laboratory is extremely thankful to them, and also acknowledge financial support from the University which provided the required 30% cost-share on the instrument, and granted additional funds for laboratory renovation. Additional information can be found on the laboratory website at http://geode.colorado.edu/~jallaz/index.php?page=microprobe.

Julien M. Allaz (julien.allaz@colorado.edu) & Kevin H. Mahan

The new JEOL JXA-8230 Electron Probe Microanalyzer in Benson, room 125A.



Examples of applications: (a) trace element analysis in kyanite with "true color" CL image, (b) backscattered electron and cathodoluminescence images of zircon, (c,d) fully quantified element maps of (c) CaO in pyroxene exsolution and of (d) BaO in plagioclase (Pl), K-felsdpar (Kfs), and glass in rhyolite.

Front Office News

The Geological Sciences department administrative staff play a key role in ensuring the department functions smoothly by helping faculty, researchers, and students interface with the university's many complex policies and procedures.

Marilynn Bender is the department Accounting Tech who diligently enters and tracks the purchases, travel, and sponsored projects. An avid hiker in her off time, Marilynn loves summer hiking in the high country and Rockies. You might spot her power walking through the neighborhoods on the Hill at lunchtime to stay in shape.

Paul Boni has contributed 31 years of service to Geological Sciences. He currently serves as the building proctor and manages the rock shop and x-ray diffraction lab. Paul provides training to students in preparing rocks for geologic studies to those who are willing to get their hands dirty.

Kristine Johnson has shifted her position in the department this year to take on the responsibilities of the Graduate Program Assistant, along with course scheduling. She has a keen interest in people and has made a point to get to know all of our grad students. This helps her manage their requirements for their program. In her off time, Kristine has been training for a half marathon.

Ruth Mansbach continues in the Office Manager and Assistant to the Chair position which includes a variety of duties such as overseeing department budgets and finances, payroll, human resources, and department events. When not at work, Ruth enjoys hiking and biking with her husband. Originally from Philadelphia, she loves the wildflowers and mountains views of her new home in Colorado.

Shana Mercer joined the department in 2016 as the Undergraduate Program Assistant and Transportation Liaison. Her strong organizational skills have been an asset for transportation, because the department has the most field trips of any on campus. Shana is a Colorado native, who ably juggles her time at work with five children under twelve at home, while taking classes as well.

Geological Sciences office staff. (L-R); Kristine Johnson, Shana Mercer, Ruth Mansbach, Marilynn Bender

2017 Department BBQ and student awards at North Boulder Park

Shana Mercer, Marilynn Bender, and Ruth Mansbach discussing important "cupcake" strategies for after the graduation ceremony...

Field Trips

2016 Bill Bradley New Graduate Student Field Trip

(L-R); Boswell Wing, Alan Seeling, Peter Molnar, Joe Zamudio, Dean Miller (L-R) back; Tyler Kane, John Gemperline, Phil Orlandini, Daniel Nothaft, Anne Fetrow, Aaron Hurst, Katherine Pfeiffer, Dan Medina, Arian Sarmiento, Madelaine Atteberry (L-R) mid/front; Lucas Haas, Anna Bergstrom, Rebekah Simon, Laura Stamp, Mylene Jacquemart, Mike Zawaski, Jim Mize, Lina Perez, Ponsit Chongrueanglap photo by Houston Kempton

Field Seminar in Western U.S. Tectonics

The class hit the road this past spring break under the guidance of Prof. Jones with perhaps the most unusual crew ever (in addition to the six undergrads and three graduate students, an instructor from Diné College participated as well as an auditor). A highlight was their first ever visit to the Old Woman Mountains, mainly because of the profusion of blooms that excited everyone, especially our two more senior participants. (A partial photolog of the flowers is at http://www.colorado.edu/GeolSci/courses/GEOL4717/2017_flowers/index.html). Perhaps more memorable though was their visit to the Toroweap Overlook area of the Grand Canyon, where strong winds made standing near the canyon rim nearly impossible, but a retreat behind an overhang turned up a rattlesnake. The evening repast was delayed by more winds, lightning, occasional rain and the need to really strongly anchor all the tents. Despite all that drama (and more than a few soggy participants the following morning) the crew had a successful visit to many key and scenic spots in the southwestern U.S.

Students Maddie Vurgun and Jefferson Yarce examining parts of the Old Woman Shear Zone on the west side of the Old Woman Mtns, CA.

Your generous support helps to fund many of our graduate and undergraduate field trips.
Thank you!

The 10 day field trip for a course on Field Methods in Active Tectonics

was conducted over spring break. This is a popular course among senior level undergrads, this trip introduced 40 students this year to active geologic processes such as earthquakes, landslides and river incision in Zion, Death Valley and Panamint Valley. Costs for this trip run to about $400. per student, taking a $15,000 bite out of the Braddock Field Fund every year.

Students regularly comment on how field courses like this help pull their undergraduate education together into a coherent learning experience. From a teaching perspective, this often marks the transition of undergraduates from geology students to geologists with enough observational and critical thinking skills to thrive in future jobs in industry and/or graduate school after they graduate from CU Boulder. Zion holds evidence of massive recent landslides triggered by earthquakes that blocked the Virgin River, forming a large lake in the upper part of the canyon.

Students appreciate a railing while negotiating the narrow ridge along the Angel's Landing Trail, Zion National Park.

Group shot of this year's herd of undergraduate on top of Angel's Landing in Zion National Park.

Students mapping in Panamint Valley ponder the complexities of active faults and deformed alluvial fans in the Eastern California shear zone. This year's bloom of beavertail cactus flowers was the best in 20 years of teaching field geology in this region.

Students on the hike up Angel's Landing in Zion National Park.

Efforts To Further Undergraduate Experience in Geology

Fostering a Departmental Undergraduate Research Community

During the 2016-2017 academic year, with support from a Chancellor's Grant for Excellence in STEM Education, Lon Abbott and Jennifer Stempien teamed up with seven undergraduate students, five faculty, and two departmental research scientists to launch a collaborative undergraduate research community focused on reconstructing the Cenozoic geologic evolution of the American West. Despite over 150 years of geologic research focused on the region, that evolution remains controversial. Fortunately, a plethora of potential research projects await the efforts of engaged and scientifically curious undergraduate students, the results of which can illuminate aspects of that history and are well suited for an undergraduate Honors Thesis.

The department community collaborates in two main ways. First, everyone participates in a weekly graduate-style reading seminar during which they discuss a published scientific paper or listen to a research presentation that relates to the community's scientific theme. Second, each student embarks on an independent research project that also relates to that theme. Each project's science stands on its own but the projects inform each other and together they contribute different pieces to the assembly of the bigger puzzle that is the West's Cenozoic geologic evolution. The community includes students at various stages in their undergraduate career; the more senior students mentor their younger colleagues, helping them to tackle the challenging task of comprehending primary scientific literature and sharing the excitement of scientific discovery they've experienced while conducting their own research. Together they learn what is known and what isn't about the region's recent geologic history and about the many and varied techniques that are being applied to further scientific understanding of that history. The participating faculty and researchers are experts in different areas of geoscience, which opens up a world of possibilities for participating students to embark on a research project that applies the tool they find most appealing to the specific problem they find most intriguing.

The community is designed to be flexible, with students coming and going as their interests dictate and beginning their research project on the timeframe that best suits their individual circumstances. During the community's first year of existence three of its members graduated, all with Honors, having completed research projects related to its broad theme. First out of the gate was Natalie Tanski, a December 2016 graduate who worked with Greg Tucker and Bob Anderson to develop a computer model that examined the geomorphic response of Arizona's Little Colorado River to damming by a lava flow erupted from a nearby cinder cone. Brett Oliver and Coleman Hiett both graduated in May, 2017. Brett, working with Bob Anderson, used time-lapse photography and image analysis software to document the growth mechanisms and movement of a rock glacier on Colorado's Mount Sopris. Coleman, funded by a grant from Crested Butte's Rocky Mountain Biological Laboratory (RMBL), collected and analyzed six samples from Colorado's youngest granite, the Crystal Pluton near Crested Butte. Under the guidance of Becky Flowers, Jim Metcalf, and Lon Abbott, Coleman did apatite (U-Th)/He thermochronometry analysis of his samples to determine the pluton's exhumation history.

Four more students have embarked on their research projects, all of which will conclude next year. Kelly Curtis is collaborating with Kevin Mahan and Cailey Condit to examine the deformation history recorded in metamorphic rocks caught up in Montana's Big Sky Orogeny. Both Anna Todd and Alejandro Murillo, funded by Undergraduate Research Opportunity (UROP) grants they wrote, are studying clumped isotope thermometry with Katie Snell. Anna is using this technique to study Nevada's paleoclimate and Alejandro is applying it to deduce the paleoelevation of 34-million-year-old Lake Antero in Colorado's South Park. Noah McCorkel is building on Coleman's thermochronometry study, examining the exhumation history of Whiterock Mountain, which rises above the RMBL facility. Noah obtained a Geological Society of America (GSA) undergraduate research grant to fund his research.

Evan Tucker is currently deciding which line of research most excites him and is preparing to share his expertise with new seminar participants Spencer Zeigler and Toby Halamka, who will join the department community during Fall, 2017. Lon received a grant from RMBL that will help fund future research projects in the Crested Butte area and Jennifer, who is studying the efficacy of this community as a vehicle for encouraging persistence in undergraduate STEM education, will present her preliminary findings at the 2017 GSA meeting in Seattle.

Members of the undergraduate research community study one of Alejandro's Lake Antero sample sites in South Park. Lina Perez Angel examines a pit exposure of the Laramide-age Elkhorn Thrust while Katie Snell, Brett Oliver, Alejandro Murillo, Noah McCorkel, Kelly Curtis, and Anna Todd look on.

David Budd Has Flipped!

The last decade has seen an increasing number of teaching innovations and transformations across campus. The goal has been the adoption of a constructivist approach to education, which involves the active engagement of the learner in the development of their knowledge and comprehension. Active learning means encouraging students to analyze challenging questions, work collaboratively with their peers, respond to instructor questions that assess learning, and focus on concepts over facts. This is in contrast to a transmissivist approach in which the instructor is assumed to have "the knowledge" and teaching and learning requires the instructor to pass that knowledge on through a lecture. Both approaches have always been part of a Geoscience education with instructor-dominated lectures complemented by labs, field courses, and seminars utilizing more active, hands-on pedagogies.

Professor David Budd, a fellow in the Center for STEM Learning (Science, Technology, Engineering, Mathematics), is one of the proactive faculty members engaged in classroom transformations. After five years of incrementally implementing active learning in the major-track, junior-level sedimentology and stratigraphy class, David concluded in the spring of 2016 that there were still significant amounts of unfulfilled student learning potential. He decided that a more dramatic intervention was needed and he chose to "flip" the class in spring 2017. In a flipped class, what used to be done in lecture is done by students as homework and what used to be homework is done in class where the instructor can help guide the students. The students have more responsibility and control over their learning, and the instructor has more interaction with the students as they apply concepts and engage in the subject matter.

David first re-focused the course on a reduced number of goals, resulting in a greater balance between content, analytical thinking, problem solving, interpretation and prediction. He then took his 39 existing lectures (30- to 40-minute PowerPoint presentations) and converted them to 30 lectures averaging 19 minutes in length. He recorded each lecture using a simple screen capture program. These were the lectures students had to view before each class. Questions embedded in the videos provided incentive and reward for viewing the videos. On average, 90% of the class viewed each lecture before class.

Nearly 70% of the students at the end of the term stated they preferred the pre-class video lectures to more traditional lecture during class time. Students emphasized that the use of the pre-class lectures meant that they could view and assimilate the material on their own time and pace, take better notes, and re-watch confusing parts. A common theme was that they liked being "introduced to material ahead of class time so it is already in our heads before we get to class."

To complete the "flip", David developed small group activities that were done during one class period, or over multiple class meetings. Each activity was designed to support the concepts developed in the video lectures. For example, after the pre-class lectures on textural and compositional maturity of sandstones, a suite of projects used published data sets to explore textural and mineralogical changes that occurred in sands with progressive transport distance. Other activities, particularly as the semester progressed, emphasized the development of interpretive and predictive skills. For example, students spent most of one week learning how to define facies from various published core and outcrop descriptions, and another week focused on defining and correlating systems tracks within sequence stratigraphic frameworks.

When asked if the activities helped them understand the concepts covered in the pre-class lectures, 58% responded "yes" and 42% chose "sometimes". Only 8% felt they would gain more if the activities were done as homework. Individual students wrote that the activities "solidify concepts" and that they "like having the prof there to guide me… because I learn more about what he is seeing that I am not, and how to think through the problem like a professional." Although not all liked working in groups, an astute student noted that "group work helps me think of things differently" and "do things I would not do on my own", while another emphasized that group work was beneficial in that "other students show me my mistakes."

In order to judge the impact of the flip format, David administered the Student Assessment of Learning Gains survey at the end of the term. The tool assesses students' perceptions of their learning. Relative to responses given by the unflipped 2016 class, the students in the flipped 2017 class reported significantly higher ratings for their understandings of facies, facies analysis and stratigraphy, their ability to describe and analyze sedimentary rocks, develop a logical argument, and connect key class ideas with other knowledge. They also expressed greater enthusiasm for the subject matter, willingness to seek help from classmates, and confidence in their ability to do this subject area.

David is convinced that a flipped classroom is the way to teach our majors and he intends to never return to a more traditional classroom. Like the class itself, he has flipped his appreciation of how students learn, and thus how he should teach.

Students in Sedimentology and Stratigraphy work in small groups on displaying the Permian strata exposed in Last Chance Canyon NM in a chronostratigraphic chart. The activity reinforces the relationships between rock and time-rock units. In the foreground are (L-R); Geology majors Kelly Curtis, Hassan Dasuki, and Kylie Marchiori.

Global Field Studies in Southeastern Australia

Thanks to a generous donation from the Canon family, in July 2016 nine students, accompanied by Lon Abbott, headed to southeastern Australia to participate in a joint undergraduate field class with professors and nine students from Australia's University of Wollongong. While honing their field skills, the students examined world-class geology completely different from anything on offer in the western U.S. The journey began in the Outback's rugged Flinders Ranges, examining one of the world's best Neoproterozoic stratigraphic records, including the Global Boundary Stratotype Section and Point (GSSP). The GSSP is the world standard definition for the beginning of the Ediacaran Period, during which multi-cellular life first evolved on Earth. Students examined the sedimentary clues left behind by various depositional environments and an asteroid impact. They found fossils belonging to the famous Ediacaran fauna, which was first discovered here, and examined stromatolites with Wollongong Head of School Allen Nutman. Nutman made global headlines the following month with a Nature paper detailing his discovery of a Greenland outcrop containing 3.7 billion-year-old stromatolites, the oldest ever found.

While in the Flinders, the CU students and their Australian mates conducted the first of several projects using Wollongong's portable XRF device, documenting the dispersal of copper and other heavy metals around the historic Blinman Mine site. They discovered that wind was the dominant dispersal agent, not streamflow as they had originally hypothesized. Next it was on to Adelaide, where students examined striated glacial pavements. Alfred Wegner used this spectacular record of Permian glaciation on the supercontinent Gondwana to bolster his controversial Continental Drift theory.

While working their way down the South Australian coast, students reconstructed the chronology of Pleistocene sea level fluctuations by studying beach ridges deposited during sea-level highstands, under the guidance of Wollongong Professor Colin Murray-Wallace, author of a 2014 book on Quaternary sea-level change published by Cambridge University Press. The group toured the Naracoorte Caves World Heritage fossil site, a graveyard for giant Pleistocene marsupials. Around Mount Gambier they studied the development of karst topography and of intraplate volcanic activity through examination of Australia's youngest volcanoes. The American and Australian students bonded during the 2500-kilometer road trip, sharing observations about what it's like to be a geology student in each country, their career aspirations, and their tastes in music. As the group glimpsed the famous 12 Apostles sea stacks, everyone sung along to the classic Australian tune 'Great Ocean Road', a song inspired by the spectacular scenery along this coastline, whose geology the group had been studying for days. By the time the bus pulled into Melbourne and the troupe disbanded, the students had made lasting friendships that have since been maintained via regular Facebook contact. In July, 2017 a contingent of Wollongong students will come to Colorado to explore our state's equally special geologic history. Although most of CU's 2016 class participants have since graduated, many are planning to share their enthusiasm for international fieldwork and provide a hearty Colorado welcome to their Australian colleagues at a class barbeque.

Students describing the characteristics of the Permian glacial pavement at Hallett Cove, South Australia.

2016-2017 Undergraduate Mentoring Projects

Mentoree	Mentor	Project
Michael Gross	Julio Sepúlveda	An Investigation of Paleo-wildfires during the Cretaceous-Paleogene (K-Pg) Boundary
Muugii Munkhbold	David Harning	Extracting molecular lipid biomarkers from Holocene Icelandic lake sediment for quantitative paleotemperature reconstructions
Noah McCorkel	Eric Small and Mark Raleigh	Monitoring snowpack density in support of LIDAR-based SWE products
Mazi-Mathias Onyeali	Megan Brown	Denver Basin Combined Disposal Zone Hydraulic Conductivity Estimation via Constant-Head Permeameter Testing
Will Gutterman	Paul Weimer	Summary of deepwater fields, northern deep water Gulf of Mexico
Michael Dulay	Rebekah Simon	Comparative Diagenesis of the Greenhorn and Niobrara Chalks
Josh Straight	Anne Sheehan	Broadband seismometer deployment, NE Colorado

Undergraduate Mentoring Project Reports

Quantitative analysis of the shark teeth in Eocene Arctic Banks Island

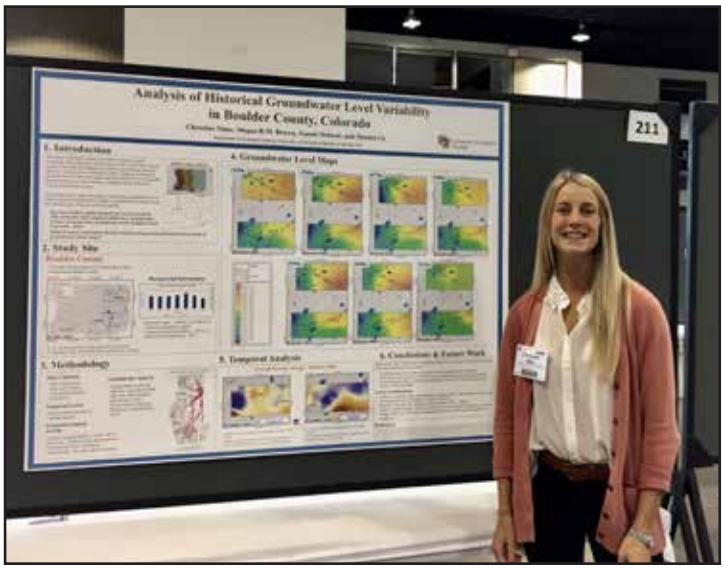
Dina Fieman mentored by Jaelyn Eberle, completed her honors thesis research on early Eocene (ca. 55 - 50 Ma) sand tiger sharks (species Striatolamia macrota) from North American mid- and high-latitude localities. Dina measured the length of several hundred shark teeth as a proxy for determining body size differences between early Eocene S. macrota from Banks Island (BI) in Arctic Canada and the Red Hot Truck Stop (RHTS) locality near Meridian, Mississippi. Both localities were warm, nearshore deltaic environments with an abundance of sand tiger sharks. Given these similar environments, she hypothesized that S. macrota at both localities would be comparable in size. However, she discovered that the mean length of the shark teeth from BI was 13.70 mm, whereas the mean length of the RHTS teeth was only 11.60 mm. In addition, the BI teeth have a higher density of teeth larger than 16 mm, whereas the teeth from the RHTS have a much higher density of teeth smaller than 14 mm. Teeth measured from each locality were also shown to have two relative maxima. This may represent teeth from the upper and lower jaws or capture the teeth of males and females. A plausible explanation for the size difference in teeth between BI and RHTS may be latitudinal differences. According to Bergmann's rule, individuals living in colder temperatures are larger than individuals inhabiting warmer temperatures. Therefore, the body size of individuals increases with latitude. The abundance of S. macrota in both brackish and marine coastal environments across latitudes during the Eocene suggests a wide range of environmental tolerances than is reflected in today's sand tiger shark distribution, which bodes well for their ability to adapt to future environmental change.

Biogenic silica content data used as a metric for the paleoclimate

Over the summer months of 2016, mentoree **Eric Gunderson** assisted mentor David Harning and the staff at INSTAAR in the collection and processing of biogenic silica content data, which was used as a metric for the paleoclimate of the region. This data was obtained from a sediment core from lake Skoravatn, in northwestern Iceland. Processing of this data involved using high precision scales to mix sediment samples with a prescribed amount of potassium bromide, followed by a thorough desiccation and drying process using high temperature ovens. A Fourier-transform infrared micro spectroscopy machine was then used to analyze the samples for biogenic silica content, which allowed for rapid compilation of sample data with multiple trials. From his time working with David and the staff at INSTAAR, Eric has gained a greater insight into the processes and systematic approach required for most scientific investigations. By working closely with colleagues, Eric quickly learned not only the job-specific tasks required for his assignment, but how to work safely and effectively in a lab environment that was simultaneously hosting several programs with diverse needs and expectations. As a student that wished to gain some additional hands-on experience in a large research institution, Eric's time with David and the staff at INSTAAR has been both rewarding and educational.

Analysis of historical groundwater level variability in Boulder County, Colorado

Christine Nims was mentored by Megan Brown and Shemin Ge. Christine conducted a study to assess future changes in groundwater resources through the analysis of historical groundwater level data. Boulder County in Colorado is the study site that encompasses mountainous regions to the west and lowland plains to the east. She examined permitted wells in Boulder County constructed from 1950 to 2016 with data from the Colorado Division of Water Resources including well location, depth, and static water level after well completion. Christine detected overall changes in groundwater levels using geospatial analysis in ArcGIS. To investigate short-term shifts in groundwater levels, the data are evaluated in 10-year increments. Changes in groundwater resources are explored in specific, separate aquifers of the region by analyzing the groundwater level in subsets of wells of similar depths. Analysis of the temporal shifts in groundwater levels from the 1950s to 2016 reveals (1) information on current groundwater levels and (2) the associated changes in groundwater levels with population growth over time. Changes in the groundwater levels in alluvial wells in the plains of Boulder County also indicates the impact of land use conversions and surface water interactions on the hydrogeological system.



Christine Nims with her poster at 2016 GSA. She received an honorable mention for excellent undergraduate poster presentation.

Time lapse helps monitor growth

Bob Anderson and Kelly Kochanski mentored undergraduate **Clea Bertholet** installing and maintaining several time-lapse cameras near the Mountain Research Station Tundra Lab. They used the footage to monitor the growth and movement of surface features, such as ripples and dunes, in the snow. Clea used this work for her honors thesis, which she completed in April. The project was supported by the Patterson Award, which allowed the purchase of new, good quality equipment, which saved many hours in the field and considerably increased the pace of the research.

Graduate Student Research, Publications and Awards...

Emily Fairfax, our inagural Birkeland Fellowship recipient this year, at one of the beaver dams in western Colorado this past summer. This is one of the dams that got Emily interested in how beaver dams function hydrologically in arid climates, particularly during droughts

Emily Fairfax used her 2016 Spetzler Award and was able to purchase the equipment necessary to complete summer 2016 and fall 2016 field work at various beaver dams around the Boulder area and in western Colorado. This award and the associated field work was a critical step in her research progression: with it she was able to move from working entirely with conceptual models based on literature review to creating numerical models based on her own observations in the field. It also got her thinking about the unique hydrologic role beaver dams play in arid climates after seeing several of them in western CO. She presented posters on research stemming from this award at both the GSA and AGU annual meetings this past year.

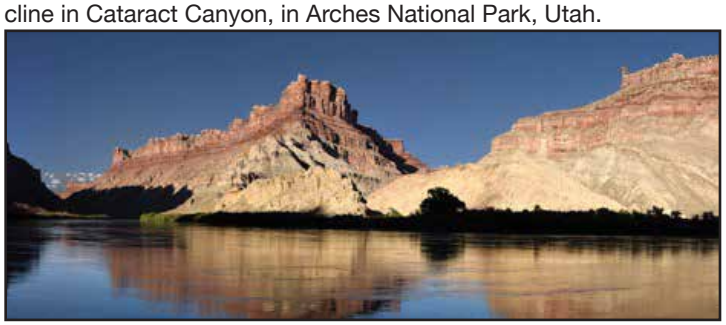
Emily received a travel grant from the department to attend and present her research at the AGU annual meeting this past December in San Francisco, CA. This had a huge positive impact as she was able to meet and discuss her work in person with the handful of other beaver-dam-hydrology researchers out there. She was particularly excited to meet up with several other graduate students studying similar topics who have an interest in coauthoring a "big picture" paper together in the near future as their own individual projects progress.

Last February, geophysics PhD students, **Danny Feucht** and **Jefferson Yarce** participated in the regional qualifications for the Society of Exploration Geophysics Challenge Bowl World Finals. They beat six other teams from Colorado School of Mines and Brigham Young University to win the regional qualification round, and will represent CU in the finals in Houston, TX. This is the second time a team from the department has qualified for the World Finals. For CU's first appearance, in 2015, they achieved second place in a tough competition against the Russian/Indian team. This year, the CU team expects to improve and bring home first place.

Emily Fairfax and **Megan Brown** have got involved with the Teaching as Research program, which is a part of the Graduate Teacher Program. This spring they developed and executed a research project to better understand the "accessibility climate" in our department. They define the accessibility climate as the compilation of experiences, knowledge, and feelings that students, faculty, and TAs have had in the department that pertain to issues in accessibility and disability. They focused their research project on varying levels of physical disability (both temporary and permanent). The last of active data collection ended on May 5th, so expect the results of their study in Fall 2017!

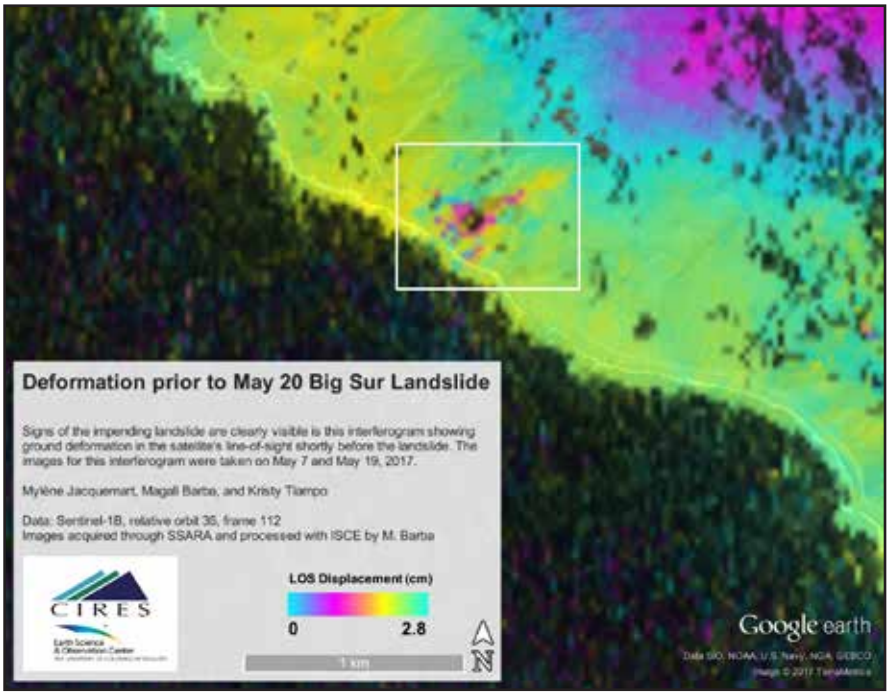
Recent work by PhD student **Katherine Kravitz** working in Professor Karl Mueller's research group has defined how and why Permian evaporite deposits flow into the salt dome at rates of ~ 3mm/yr. Besides recording interesting processes in active tectonics, exposures of halite-rich beds in the Paradox Formation introduce millions of tons of salt into the Colorado River Basin every year. This study has important implications for water quality in parts of the American Southwest that depend on Colorado River water for drinking, irrigation, and other uses.

Active salt diapir (Prommel Dome) forming along the Meander Anticline in Cataract Canyon, in Arches National Park, Utah.



(L-R): Scott Cook (CU Alumni – contest presenter), Jefferson Yarce, and Danny Feucht.

The recent Big Sur landslide, thought to be one of the largest in California history, follows the state's wettest winter in nearly a century. The landslide buried a third of a mile of the famous Highway 1 and added 13 acres to the coastline. Dan Darl, a district director for the California Coastal District was quoted as saying: "A lot of Big Sur is moving; you just don't see it." That's not quite correct. **Myléne Jacquemart**, **Magali Barba** and **Kristy Tiampo** decided to take a closer look using satellite radar interferometry, a remote sensing technique that can be used to measure millimeter-scale deformations on the Earth's surface. They were curious to know if they could see this slope moving before it finally failed on May 20th.



Although such precursory deformations are thought to be common for large landslides, measuring them from space is not always possible due to vegetation and weather influences. Big Sur's scarcely vegetated landscape and clear skies during the image acquisitions, one of which was luckily the day before the slide, resulted in a beautiful deformation image clearly showing the movement of the slope prior to its failure. Hopefully additional images will provide a more complete picture of this slide's history so the processes that govern these catastrophic events can be better understood, in order to potentially predict them in the future.

Sarah Black and the Hynek SPACECATS (Surface Processes And Continuing Evolution of Contemporary Analogous TerraneS) lab had another successful field expedition – this time to Iceland. Brian Hynek and Sarah Black, headed to Iceland in August 2016 along with collaborators from University of Wisconsin – Milwaukee to investigate hydrothermal systems in a geologist's paradise. In addition to a NASA ROSES grant, this work was partially funded by a GSA Graduate Student Grant and an American Philosophical Society Lewis and Clark fund for Exploration and Field Research in Astrobiology which were awarded to Sarah in 2016. The two weeks of Icelandic fieldwork included sample collection at Krafla Volcano in the Northern Volcanic Zone, as well as the Hengill Volcanic Complex and several other areas in the Reykjavik region. Collected data will help shed light on Martian hydrothermal processes and their resulting deposits, and the potential for life to have existed in these systems on early Mars.

Graduate Student Sarah Black and Professor Brian Hynek of team SPACECATS at the Viti crater (Krafla)

Graduate student Sarah Black collecting a fluid sample at Namafjall (Krafla)

Graduate Student First-authored Publications

Evans, S. G. and S. Ge (2017), Contrasting hydrogeologic responses to warming in seasonally frozen ground and permafrost hillslopes, Geophysical Research Letters, 44, doi: 10.1002/2016GL072009.

Glade, R.C., Anderson, R.S., and Tucker, G.E. (2017), Block-controlled hillslope form and persistence of topography in rocky landscapes, Geology, 45, p. 311-314, doi:10.1130/G38665.1.

Harning, D., Geirsdóttir, Á., Miller, G.H., and Anderson, L. (2016), Episodic expansion of Drangajokull, Vestfiroir, Iceland, over the last 3 ka culminating in its maximum dimension during the Little Ice Age. Quaternary Science Reviews, 152, p. 118-131.

Harning, D., Geirsdóttir, Á., Miller, G.H., and Zalzal, K.S. (2016), Early Holocene deglaciation of Drangajokull, Vestfiroir, Iceland. Quaternary Science Reviews, 153, p. 192-198.

Kravitz, K., P. Upton, K. J. Mueller, and S. G. Roy (2017), Topographic controlled forcing of salt flow: Three-dimensional models of an active salt system, Canyonlands, Utah, J. Geophys. Res. B Solid Earth, 122, 1–24, doi:10.1002/2016JB013113.

Lau G. E., Cosmidis J., Grasby S. E., Trivedi C. B., Spear J. R. and Templeton A. S. (2017) Low-temperature formation and stabilization of rare allotropes of cyclooctasulfur (β-S8 and γ-S8) in the presence of organic carbon at a sulfur-rich glacial site in the Canadian High Arctic. Geochim. Cosmochim. Acta 200, 218-231.

Nakai, J. S., A. F. Sheehan, S. L. Bilek (2017), "Seismicity of the Rocky Mountains and Rio Grande Rift from the EarthScope Transportable Array and CREST temporary seismic networks, 2008-2010." Journal of Geophysical Research: Solid Earth, 2173-2192, doi: 10.1002/2016JB013389.

Rempfert K.R., Miller H.M., Bompard N., Nothaft D., Matter J.M., Kelemen P., Fierer N., and Templeton A.S. (2017) Geological and Geochemical Controls on Subsurface Microbial Life in the Samail Ophiolite, Oman. Front. Microbiol. 8:56. doi: 10.3389/fmicb.2017.00056.

Shobe, C.M., Tucker, G.E., and Anderson, R.S. (2016) Hillslope-derived blocks retard river incision, Geophysical Research Letters, v. 43, no. 10, p. 5070-5078. doi:10.1002/2016GL069262.

Shobe, C.M., Hancock, G.S., Eppes, M.C., and Small, E.E. (2017) Field evidence for the influence of weathering on rock erodibility and channel form in bedrock rivers, Earth Surface Processes and Landforms. doi:10.1002/esp.4163.

Schnepf, N. R., Nair M. C., An C., Sugioka H., & Toh H. (2016). Time-frequency characteristics of tsunami magnetic signals from four Pacific Ocean events. Pure & Applied Geophysics, 1-19, doi:10.1002/2016GL069946.

Shellito, P. J., Small, E. E., Colliander, A., Bindlish, R., Cosh, M. H., Berg, A. A., Bosch, D. D., Caldwell, T. G., Goodrich, D. C., McNairn, H., Prueger, J. H., Starks, P. J., van der Velde, R., and Walker, J. P. (2016), SMAP soil moisture drying more rapid than observed in situ following rainfall events, Geophys. Res. Lett., 43, 8068-8075, doi:10.1175/JHM-D-15-0153.1.

Shellito, P. J., Small, E. E., and Cosh, M. H., (2016), Calibration of Noah Soil Hydraulic Property Parameters Using Surface Soil Moisture from SMOS and Basinwide In Situ Observations, Journal of Hydrometeorology, 17, 2275-2292.

Graduate Student Department Awards

John D. Edwards Fellowship	Garrett Boudinot, Victoria Crystal, Anne Fetrow, Lina Perez-Angel
Keith T. Marks Scholarship	Allison Kimbrough, Rebekah Simon
Patterson Geology Scholarship	Aaron Hurst
Peter Birkeland Scholarship	Emily Fairfax
Spetzler Family Fund	Megan Brown, Nadine Reitman, Kaitlin Rempfert, Abigail Thayer, Mike Zawaski
W. Thompson Research Fund	Jenny Nakai, Phil Orlandini, Jefferson Yarce

Graduate Student External Awards

Sarah Crump
- NSF Doctoral Dissertation Research Improvement Grant
- National Geographic Society Early Career Grant
- J. Hoover Mackin Award, Quaternary Geology & Geomorphology Division, GSA

Victoria Crystal
- Top Teaching Assistant award for 2016-2017 from the United Government of Graduate Students of Boulder

Emily Fairfax
- 2017 GSA Graduate Student Research Award

Myléne Jacquemart
- NASA Earth & Space fellowship

Rachel Glade
- GSA John T. and Carol G. McGill Research Award

Kelly Kochanski
- GSA Research Grant

Jenny Nakai
- Ford Foundation Dissertation Fellowship
- CIRES Graduate Student Research Award for 2016-2017

Neesha Schnepf
- NASA Earth & Space Science Fellowship
- CIRES George C. and Joan A. Reid Award
- CIRES Innovative Research Program grant

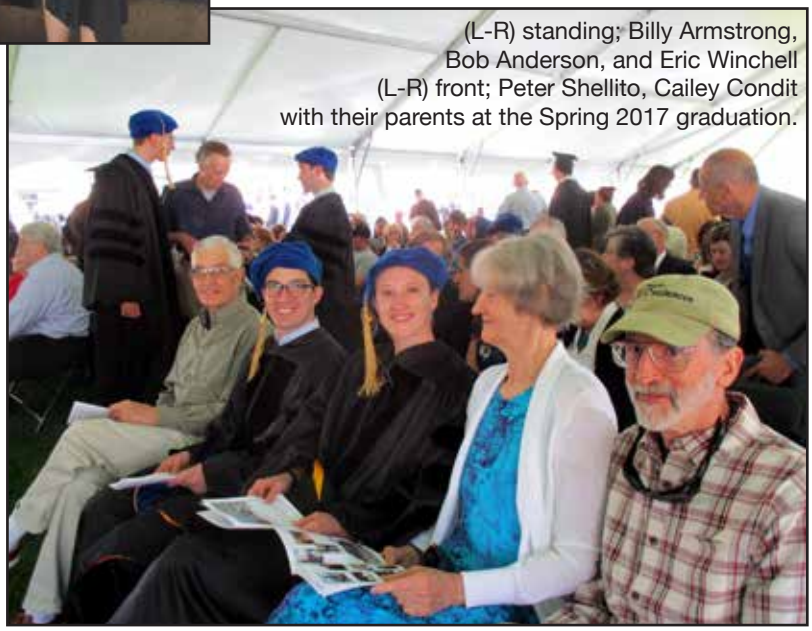
Fall 2016 Graduation

Katie Snell, Sebastian Kopf,
Julio Sepulvéda and Alexis Templeton
enjoying the sun at the Spring 2017 ceremony.

Spring 2017 graduate students
(L-R) front; Peter Shellito, Derek Weller,
William Armstrong, Sarah G. Evans,
Cailey Condit, Karen Alley
(L-R) back; Graham Lau, Hannah Miller,
Rachel Havranek, Eric Winchell

Dean Miller speaks at the Spring 2017
geology graduation ceremony.

(L-R) standing; Billy Armstrong,
Bob Anderson, and Eric Winchell
(L-R) front; Peter Shellito, Cailey Condit
with their parents at the Spring 2017 graduation.



Degrees Awarded (Fall 2016- Spring 2017)

B.A. Geology Majors

Brian Adams
Phillip Maxwell Allen
Robert O'Mara Aronoff
Caleb W Bailey
Michael McCabe Bartholomew
Blythe Rená Befus
Clea Bertholet
Colter D. Birk
Alexander Hudgins Black
Christopher J. Blade
Jonathan Broussard
Julian Michael Caballero IV
Nabil Chaudhry
Caitlin Curran
Brendan Daly
Benjamin Morse DiFilippo
Christopher Donaldson
Conner B. Dunn
Craig Egging
Maxwell James Fanning
Roberta Farrington
Andy Fernandez
Dina Michelle Fieman
Andre Ricardo Fiorito
Ty Aaron Gallaway
John Geiger
Frederick Bear Givhan Jr.
Jamie A Glass
Michael M. Greene
Michael Avi Gross
Will Gutterman
Jack Noah Nicholas Hallowell
Garret Stephen Hammack
Lauren Harding
Philip Mark Hartman
Alexandra Ellen Harwell
Nicholas Riley Heffner
Coleman Hiett
Sarnjev Jayagopal
Stanley Tanner Jones
Ryan Adham Khamis
Tammy Le
Henry Lewis
Nathan James Malefyt
Madison Mamaghani
Misty D. McCumsey
James M. McGahran
Muugii Munkhbold
Selena Kea Neale
Christine Nims
Marie Roxanne Northington
Brett J. Oliver
Mitchell Wright Parsons
Travis J. Payeur
Brett J. Oliver
Anissha Raju
Lauren Roemer
Daniel Schmidt
Michelle Anne Seberg
Meredith Sherock
Dylan Snover
Cody John Spiker
Natalie Tanski
Madeline Vurgun
Janice Wallenburg
Nick Warren
Sean Malcolm Whyte
Wyatt Wicks
Matthew P. Wirfel
Hank Woolley

Undergraduates graduating with honors

	Advisor	**Thesis Title**
Blythe Rená Befus magna cum laude	Giff Miller John Andrews	Hall Basin and the Petermann Glacier, NW Greenland: A late Quaternary Provenance Glacial History
Clea Bertholet cum laude	Bob Anderson	Snow bedform growth as a function of wind speed and snow age
Michael Avi Gross cum laude	Julio Sepulveda	An Investigation of Paleo-Wildfires During the Cretaceous-Paleogene (K-PG) Boundary at El Kef, Tunisia
Coleman Hiett summa cum laude	Lon Abbott	Constraining the Timing of River Incision in the Upper Colorado Drainage Basin Using Apatite (U-Th)/He Thermochronology in the Elk Mountains, Western Colorado
Selena Kea Neale cum laude	Bob Anderson	Pinedale Glaciation at Longs Peak and Glacier Gorge
Brett J. Oliver summa cum laude	Bob Anderson	Utilizing Remote and Numerical Methods to Provide Constraints for the Seasonal Development and Topographic Profiles of Rock Glaciers
Travis J. Payeur summa cum laude	Paul Weimer	Sequence Stratigraphy and Source Rock Evaluation of Jurassic Units, Northeastern Deepwater Gulf of Mexico
Anissha Raju summa cum laude	Kevin Mahan	Characterization of Elastic Tensors of Crustal Rocks with respect to Seismic Anisotropy
Natalie Tanski cum laude	Greg Tucker	Model for Lava Dam Removal Using a Sediment Flux Dependent Stream Power Model
Nick Warren cum laude	Stephen J. Mojzsis	Comparative analysis of stromatolite dome spacing and grazing levels in the Lykins Formation of Colorado and Southern Wyoming

Undergraduate Student Awards

Bruce Curtis Scholarship, Outstanding Senior — Brett Oliver, Anissha Raju
Bruce Curtis Scholarship, Outstanding Geology Leadership — Muugi Munkhbold
K. Johnston Scholarship, Outstanding Geology Senior — Kelly Curtis, Isaac Hinz
K. Johnston Scholarship, Outstanding Geology Major — Toby Halamka
Kolber Award, Outstanding Geology Major — Coleman Hiett
Association of Woman Geoscientists — Anna Todd

M.S. Candidates Graduating with Degrees

	Advisor	Thesis Title
Emily Carbone	Eric Tilton	Estimating surface to root zone soil water flux using unsaturated flow modeling and soil moisture data
Jason J. Fredricks	Paul Weimer	3D seismic interpretation and geologic evolution of an intraslope basin, Talara Basin, Deepwater Peru
Rachel Havranek	Rebecca Flowers	Coupling vertical transect zircon (U-Th)/He and Raman spectroscopy data to constrain Colorado Front Range evolution
Steven Henning	Shemin Ge	Dynamic Response of Watershed Subsurface Systems to Extreme Precipitation Events.
Stephen Heron	Paul Weimer	The origin of the Lower Pliocene deepwater Mari Mound complex, Levant basin, eastern Mediterranean Sea, offshore Israel.
Jonathon Oulton	Stephen Mojzsis	Constraints on the parent body of granitoid clasts in the Adzhi-Bogdo meteorite.

Geology graduates reminiscing before the ceremony.

Peter Shellito, Cailey Condit, William Armstrong, and Sarah Evans enjoying the sun at graduation.

Ph.D. Candidates Graduating with Degrees

	Advisor	Thesis Title
Karen Elizabeth Alley	James White	Studies of Antarctic ice shelf stability: Surface melting, basal melting, and ice flow dynamics
William Armstrong	Robert Anderson	Glacier sliding from space: Multiscale remote sensing, geodesy, and numerical modeling to understand glacier mechanics
Cailey Brown Condit	Kevin Mahan	Fluid enhanced deformation and metamorphism in exhumed lower crust from the Northern Madison Range, Southwestern Montana, USA
Sarah G. Evans	Shemin Ge	The hydrogeology of cold regions in a warming world
Graham Lau	Alexis Templeton	Geochemical and mineralogical analyses of cold spring deposits from Borup Fiord Pass, a sulfur-dominated arctic analog for planetary environments on Mars and Europa
Hannah Marie Miller	Alexis Templeton	Low temperature hydrogen production and habitability of a Hyperalkaline Serpentinite Aquifer in the Samail Ophiolite
Peter Judd Shellito	Eric Tilton	Surface soil moisture dynamics from remote sensing, modeling, and in situ observations
Derek Weller	Charles Stern	Eruption record and aspects of magma genesis and evolution for volcanoes of the Southernmost Andean Southern Volcanic Zone, Chile
Eric William Winchell	Robert Anderson	Understanding the geomorphic imprint of the northern pocket gopher on the subalpine zone of the Colorado Front Range

Alumni/Emeritus News

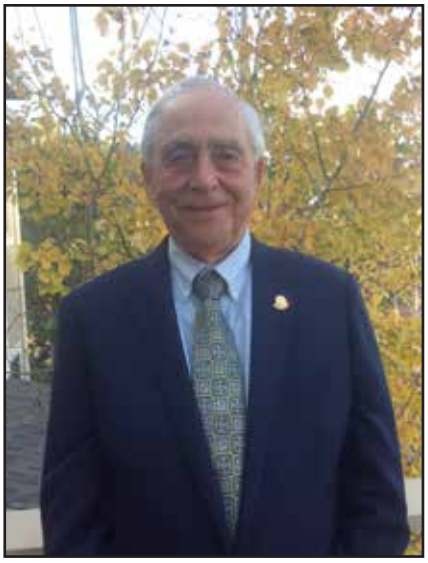
In the Spring of 1970, **John Andrews** organized the first Arctic Workshop, held here in Boulder with a total attendance of perhaps eleven people. An Arctic Workshop, now the International Arctic Workshop, has been held every year since, with attendance between 50 and 150 people, in places as varied as Norway, Iceland, Canada (many times), and numerous US universities. For the past two decades, the Arctic Workshop has alternated between Boulder in even years and somewhere else in odd years. In March of 2017 the 47th Arctic Workshop was hosted by the University at Buffalo, with **Jason Briner** (PhD '03) taking the lead, and with the help of many colleagues there.

During the meeting Jason asked all the attendees who were either directly mentored under John, or were his direct descendants, to gather for a photo-op. Half the attendees felt related and posed with John for the group photo. John Andrews standing in front, CU progeny directly behind from right to left: Darren Larsen, Jason Briner, Giff Miller, Isla Castañeda, Anne Jennings, Sarah Principato, Mike Retelle, and behind them a slew of students and faculty from the long Andrewsian lineage.

Denise (Mruk) Cox (MS '85) of Panama City, FLA was elected President of the AAPG for 2018-2019. She is the fourth CU graduate to be elected to the position, along with **Don Tobin**, **Scott Tinker** (PhD '96), and **Paul Weimer**

Vance Holliday (PhD '82) is the 2018 recipient of the Fryxell Award for Interdisciplinary Research of the Society of American Archaeology. Vance has had a long interest in archaeology and came here to study soils with Pete Birkeland so he could include them in his research in Texas and environs. He is presently at the University of Arizona as a professor of both geosciences and archaeology. At the end of his dissertation he led a Friends of the Pleistocene field trip on his work. Pete and students attended that trip, and still remember when they backed their van into the only tree in Texas! He continues his research in the southwestern USA and Mexico. His previous awards were the Kirk Bryan Award and the George R. "Rip" Rapp Archaeological Geology Career Award, both of the Geological Society of America. When Vance was here we called him "little Vance" as the main researcher in his field was Vance Haynes of the University of Arizona. It looks like there are two "big Vances" now.

Terry J. Mather (MS '67; PhD '70) received the prestigious Norman H. Foster Outstanding Explorer Award from the AAPG in April. The award is given in recognition of distinguished and outstanding achievement in exploration for petroleum and mineral resources, with emphasis on recent significant discovery. Terry has had a forty plus year career beginning with Shell, followed by several independent companies, and finally consultant-explorationist for the last twenty-five plus years. The award is in recognition of Mather's multi-year effort that resulted in the 2010 discovery of commercial oil, condensate, and gas in the State of Idaho, which previously had no production. Mather's discovery opened up a frontier basin, and caused Idaho to create its first ever oil and gas commission.

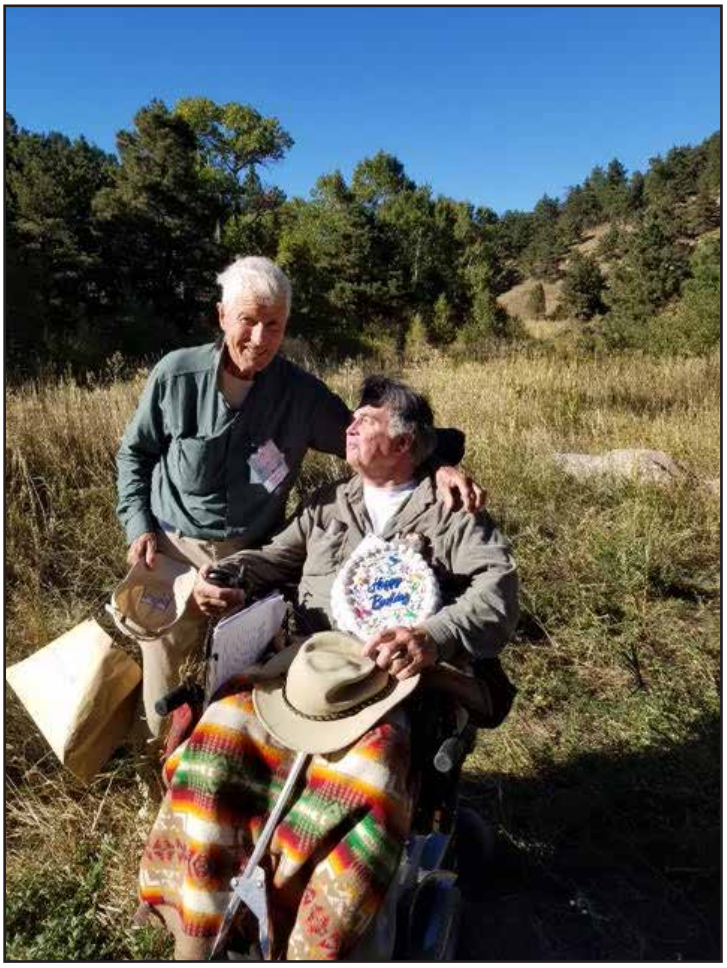


Terry J. Mather

Ronald Weaver (MS '76) is principal investigator and manager of the Snow and Ice Distributed Active Archive Center (DAAC) at CU Boulder's National Snow and Ice Data Center. Serving in this role for 24 of his 37 years at CU Boulder, Weaver is considered an expert in the acquisition, validation, storage, and distribution of data on changing sea ice, snowmelt, and ice loss. Weaver will be awarded the University Medal in recognition of his lasting contributions to climate research and data management.

Melissa Foster (PhD '16), Bob Anderson, Pete Birkeland, and Rachel Glade organized the Kirk Bryan field trip for the GSA Annual meeting in September 2016, along with collaborators from CU and government agencies. The Boulder Creek Critical Zone Observatory, the GSA Quaternary Geology and Geomorphology Division, and the Colorado Scientific Society sponsored the trip. The field trip was a great success, providing a whirlwind tour of CU's work to constrain the Quaternary Geology and surface processes along Colorado's Front Range. Pete led participants through the Quaternary mapping, soils geomorphology, and relative dating that laid the foundation for recent research conducted by CU students. Bob highlighted recent dating techniques and models used to constrain Quaternary landscape evolution. CU alumni Melissa Foster presented her research using cosmogenic radionuclides to date Quaternary strath terraces, while 3rd year Ph.D. student Rachel Glade discussed what her modeling reveals about the evolution of classic hogbacks like the Dakota Ridge. The attendees included many CU alumni from over the decades, generating a lot of great discussion about recent and past work along the Colorado Front Range.

Pete Birkeland reported that at the last stop of the GSA Kirk Bryan field trip, John Pitlick of the Geography Department was going over stream bed load transport during the 2013 flood. It also happened to be his birthday, so former student Bud Burke, who knew John well, gave a short speech on their relationship, then announced his birthday and produced a beautiful birthday cake. John was standing on a lower terrace so Bud handed the cake to Pete for delivery. Alas, as Pete carried the cake down to John, it slipped out of his hands and flew into the air. The field trip participants around John dove through the air, desperately trying to save the cake... but it hit the ground and bounced and was fine! Good thing it was a styrofoam cake! Earlier Pete had pulled the fake cake trick in Shemin Ge's class on her birthday. Her students also dove to save the cake! Pete adds that he will surely miss Ted Walker. He was a stalwart of the Department, and took Pete to Baja, joined him on the Death Valley field trip, led Sue and Pete (and the Pitlicks) on a bike trip down the Danube River, and organized their annual ski trip to Winter Park along with the Bradleys.



Pete Birkeland and Bud Burke after the "cake drop"

In Memoriam

David R. Bedford (PhD '08)
Charles E. Breed (MS '56)
James E. Greer (BA '58)
Donald L. Gustafson (BA '65)
Virgil J. Headrick (BA '59)
Lewis C. Jordan (BA '51)
Erle Kauffman, Professor
Elwin M. Peacock (BA '49)
John Player Jr. (BA '40)
Richard N. Racich (BA '58)
Theodore F. Riedel (BA '60; MS '69)
Richard G. Sherman (BA '60)
Shirley Gibbons Somers (BA '50)
Charles U. Steele (BA '57)
Robert F. Sweeney (BA '70; MS '72)
Roderick W. Tillman (PhD '67)
Ted R. Walker, Emeritus Professor

Donald L. Gustafson, age 78, passed away on May 24, 2017, in Reno, Nevada, at St Mary's Medical Center surrounded by his loving family. He was born on July 8, 1938, in Princeton, Illinois, to Floyd and Marjorie Gustafson. He lived in Walnut, Illinois, until he left for college in 1956. During high school, he enjoyed being class president and the captain of the football team his senior year and was always active in sports. While in high school, he met the love of his life, Marilyn Gallentine. After dating through high school and college, they were married on June 26, 1960, in Walnut. Don graduated from the University of Colorado in Boulder in 1963 with a bach-

elor's degree and in 1965 with a master's degree in geology. While in Colorado their daughter, Dawn, was born.

Don's first job took him and his family to Reno, Nevada, where he worked for the Anaconda Copper Company. While in Reno, their daughter, Kimberley, was born. They moved to Yerington, Nevada, in 1966 for Don to work at the Yerington Copper Mine as a geologist. In 1971, the family moved to Butte, Montana, with Anaconda and Don worked in the underground mines and the Berkeley Pit. Four years later, Don changed jobs and went to work for Homestake Mining Company in Reno, Nevada, and started working in gold. After exploring for gold for seven years, Don was instrumental in the discovery of the McLaughin Gold Mine in Northern Napa County, California. The mine was in production from 1985 to 2004 and produced 3.4 million ounces of gold. He was a long-time member of GSN, ATPG and SME.

In 1985, Don became Vice President and Director of Homestake International. His travels took him to the South Pacific, Asia, South America and North America. In 1990, Don ventured out and formed his own exploration company, Gustafson Minerals International. In 2000, Don went to work for Golden Cycle Gold Corporation as the Vice President of Exploration. He worked in China and Nevada. In 2008, he decided to travel less for work and became a director for Columbus Gold out of Vancouver, Canada. He and Marilyn enjoyed traveling and cruising to many foreign countries and the U.S. He was a member of Montreux Golf Club for many years and enjoyed golfing, sailing, tennis and bridge.

Don was a supportive husband, father, and grandfather who was always there for his family and who instilled his love for travel in his daughters and grandchildren. Don's pride and joy were his grandchildren and he went to all of their sporting and school events while he was able.

Don is preceded in death by his parents, Floyd and Marjorie. He is survived by his wife, Marilyn, daughters, Dawn Welsh (Cary Welsh) from Reno, and Kimberley Gustafson (Nic Capule) from Larkspur, CA, his grandchildren, Connor and Amber Welsh from Reno, his sister, Nancy Hopkins and brother-in-law, Dr. Jim Hopkins from Des Moines, IA, sister-in- law, Charlene Warr from Covina, CA, and several nieces and nephews.

In memory of Donald Gustafson, gifts can be made to the University of Colorado for an endowment to be used towards scholarships for students in the Geology Department. Point of contact is: Jasmin Brooks, University of Colorado, Office of Advancement, 1305 University Avenue, Boulder, CO 80302. or go to https://giving.cu.edu/fund/donald-lee-gustafson-memorial-fund

Published in Reno Gazette-Journal on June 4, 2017

Erle Kauffman (1933 - 2016) did his PhD thesis work in southern Colorado and developed an abiding interest in the Cretaceous of the West which continued after his appointment as curator of paleontology at the U. S. National Museum in 1961.

In 1978 Erle took a sabbatical from the U. S. National Museum and asked if he might take up residence in the Department to do research and writing close to the rocks and fossils that interested him. The department found Erle an office in the basement from which he interacted with the geology faculty and with graduate students. In short order he teamed up with the Rocky Mountain Association of Geologists to produce a guidebook volume on the Cretaceous of Colorado and Utah that achieved wide circulation.

During the same year, paleontologist John Chronic, a long-time member of the Department, accepted an offer from the oil industry. In conversations regarding his departure, John said, "Why don't you hire Erle Kauffman in my place?" The idea had occurred to many in the department and they invited Erle to apply for the vacancy left by John. Erle agreed and submitted a thick CV that reflected his enthusiasm and drive and that documented his impressive achievements.

On reviewing Erle's materials several members of the Department said, "This fellow is clearly a leader and we think he should come in as our Department Chairman." Others thought that on joining the Department Erle should first have a year or two to build up a program in research and teaching before he took on the Chairman's duties. Erle was ready for it all. He came in as Chairman and his research continued unhindered and his teaching, honed at George Washington University and in many seminars across the country, took off on a good footing.

As Department Chairman Erle's substance and enthusiasm quickly impressed the new Dean of Arts and Sciences who joined the University at the same time as Erle. From that point onward the Department, under Erle's leadership, received solid University support. Erle attracted many highly qualified graduate students whose work in paleontology supplemented Erle's own and who have gone on to significant positions in the academic world and elsewhere. Erle led the Department for four years, from 1980 to 1984 during which time it can truly be said that he brought a new dynamic to it.

by Don Eicher

We would like to thank all of our faithful and generous donors. Words can hardly express our gratitude for your continued support and encouragement to the Department of Geological Sciences. We would not be the first-class program that we are without your support.

Our sincerest thanks
from the faculty, staff, and students.

Emeritus Professor **Ted Walker** died peacefully in his sleep at age 96 on March 28, 2017.

Ted discovered geology as an undergraduate at the University of Wisconsin. WWII interrupted his studies, but he applied his geologic background, first with the USGS compiling navigation charts for North Africa and later for the Navy as a photo interpreter. After the war, Ted returned to Wisconsin and completed his PhD (in sedimentary petrology) in 1952, then spent a year as a groundwater geologist with the Illinois Geological Survey. In 1953 he joined the faculty at CU-Boulder as a hydrogeologist, but was soon also teaching geology for engineers, sedimentology, sedimentary petrology, and field geology. Teaching summer field camp in McCoy, Colorado, introduced Ted to the Pennsylvanian strata of central Colorado, and kindled his interests in how those rocks had been deposited and why they were red. A sabbatical in 1961 allowed Ted to study the Quaternary sediments of Baja, Mexico, as a modern analog. That experience lead to the development of one of Ted's mainstay courses – Comparative Sedimentology – plus new student research projects in Baja, numerous field trips, and one of Ted's famous accomplishments – the recipe for a "Baja Bomber" (1 part concentrated lemonade, 2 parts rum).

Through the 1960s and into the mid-1980s, Ted's work increasingly focused on the diagenesis of continental sediment. He was the first to show that hematite in those types of rocks was not a result of extensive weathering of a source regolith, but was due to reprecipitation of iron leached from mafic minerals within the rocks during diagenesis. His studies of modern and ancient continental "red beds" in North Africa, the Middle East, western Europe, and western North America established him as a leading figure in sedimentary diagenesis. Ted presented nearly a hundred papers at symposia, short courses, and conferences, and was an AAPG Distinguished Lecturer. He served as Departmental Chair from 1972 to 1975, and as President of the Society of Sedimentary Geologists (SEPM).

Ted was well regarded by faculty and students for his teaching, intensity and focus. He was a kind and considerate gentleman known for his willingness to drop whatever he was doing to engage with students and faculty colleagues.

Ted went half-time in 1986 and fully retired in 1991. He then put geology completely behind him as skiing and bicycling became his passions. Over a 20-year period, he, bicycled most of Colorado's passes and much of Europe with his wife Barbara, and friends. Ted skied at least 100 days a year for nearly a decade with his last ski outing occurring on his 90th birthday, just 4 months after a bike accident left him with 7 broken ribs and a punctured lung!

Ted often commented that he had lived a rich life and had a fulfilling career. He died with no regrets and at peace with a life well lived. It was a life that touched many students and colleagues who will forever remember him.

Attention Alumni

By completing and mailing in this form, you can help us do a better job of keeping up with you, your whereabouts, and your career or family news. We all enjoy reading about classmates and not-so-close-mates who survived Boulder in whatever era! So send us some news or some recollections—we promise to use them.

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