WHAT ON

FALL 2020

EARTH

A PUBLICATION OF THE COLLEGE OF MINES & EARTH SCIENCES AT THE UNIVERSITY OF UTAH

STUDENTS ENGAGED IN SUSTAINABILITY RESEARCH

College of MINES & EARTH SCIENCES
THE UNIVERSITY OF UTAH

U of U Mine Rescue Team takes first place: Victor Harrell (trainer), Travis Brammer, Rebecca Ray, Stephen Hall, Jack Peterson, Paige Epsten, and Amy Richins. (See this story on page 6).

Hello friends of the College of Mines and Earth Sciences (CMES). Mother Earth has done her best this year to alert us to the reality that she is still in control. Despite earthquakes, extreme weather events, and of course an ongoing pandemic, our students, staff, and faculty continue to excel in their pursuits of research and academic excellence. Adaptation to our new reality has not been easy, but I can't overstate just how proud I am of my colleagues and our students in the responsible way that they have responded to the ongoing challenges. I'm also very grateful for the leadership of President Watkins, and Senior Vice Presidents Reed and Good, and many others on campus, as they have not only led the University response to COVID-19 in a very safe, transparent, and effective way, but have also contributed in important ways to our state health care response.

Fittingly, this volume of What on Earth (WOE) is dedicated to the topic of sustainability. The term sustainability should not be confused with sustaining the status quo. Sustainability is about change as much as it is about resiliency. Perhaps a better term would be *transiliency* (you heard it here first). As we adapt at the University of Utah to our new circumstances and the many changes in education and student demand, CMES has continued to be laser focused on our academic mission and to carrying out research that contributes to sustainable communities, an understanding of Earth's systems and processes, and our water, energy and raw material sources.

In addition to reading about these areas of research and scholarly activity in this volume of WOE, you'll learn about some of the ongoing research in the college to mitigate the effects of COVID-19. You will also learn about the many accolades and achievements of our students and faculty, as well as some updates from our alumni. We really enjoy hearing from you, so if you have any personal news or status reports, please send them to TJ McMullin for inclusion in the next volume of WOE.

While we are all challenged in different ways, this is a time to be thinking about others. Many families and many of our students are struggling from the health and economic impacts of the pandemic. Please know that your donations over the years have created a sustainable endowment that helps us keep the costs of education low for our students and their families through scholarships, fellowships and paid research opportunities. We are lucky to have alumni and friends like you. Stay safe, stay healthy, and stay in touch. -- *Dean Darryl Butt*

CMES LEADERSHIP

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Cari Johnson	Associate Dean of Research
Marjorie Chan	Associate Dean of External Relations
Travis (TJ) McMullin	Development Director
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Brenda Bowen	Dir., Global Change & Sustainability Center
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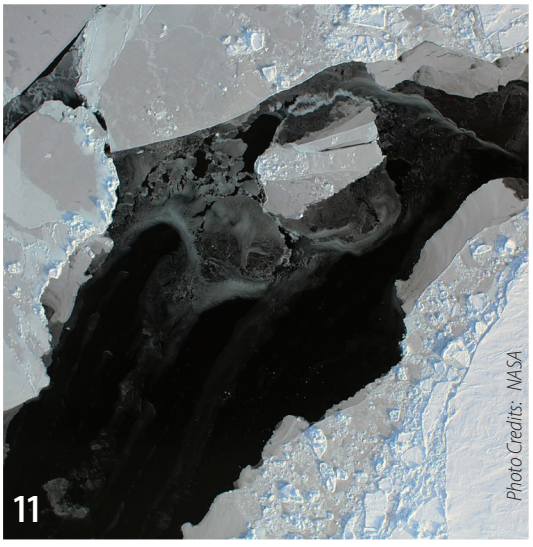
John Horel	Chair, Atmospheric Sciences
Thure Cerling	Chair, Geology & Geophysics
Brenda Bowen	Associate Chair, Geology & Geophysics
Michael Simpson	Chair, Materials Science & Engineering
Taylor Sparks	Associate Chair, Materials Science & Engineering
Michael Free	Chair, Mining Engineering



ON THE COVER: *(From top clockwise) Students Bonnie Erdenekhuyag, Lily Bosworth, Andy Park, Matt Newton, Travis Parsons, and Jeremiah Bernau doing research in the field.*

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Learning To Be A More Sustainable Community

Photo credit: Gannet Hallar, ATMOS 3000

Sustainability is becoming a common word in our vernacular as humans. We strive to live more sustainably in hopes of maintaining the delicate balance of give and take with the earth and its resources. Often, we need to be taught how to recognize this mindfulness and implement it into our daily lives. Sustainability is a cornerstone of the College of Mines and Earth Sciences and as a teaching community, we strive to keep this concept in mind as we learn about earth processes. Below are some examples of how CMES is determined to prioritize teaching these important concepts.

"We are producing CO_2 at an exponential rate, and the longer we wait to start the change the longer it will take to get back to equilibrium whether we help the earth or not." These were the concerns of one CMES student who participated in the survey sent to those enrolled in courses with a focus on sustainability. In **Climate Change (ATMOS 1020)**, taught by Jay Mace, students explore how the uneven distribution of energy ultimately defines a planet's climate and how seemingly innocuous changes to atmospheric composition can interrupt the delicate balances within a climate system, using the past as an analog to study future implications.

Quantitative data is an important component in researching sustainability. Knowing the numbers associated with change helps determine how to move as a society toward more sustainable practices. In Gannet Hallar & Logan Mitchell's spring 2020 course, **Air Pollution (ATMOS 3100)** students quantitatively described the processes that control the chemical composition and evolution of the Earth's atmosphere using recent research and data regarding climate change. One student enrolled in this course said the most interesting thing they learned was, "about how certain types of pollution are actually contributing to the cooling of the planet. While still not being great for humans or the environment [this] showed that the change in climate and air pollution is a lot more complex than I thought".

"It was a good reminder that we need to balance economic development, human well-being and healing our environment."

Marine ecosystems are degrading at an alarming rate. The delicate balances are shifting due to overfishing, pollution, habitat destruction and climate change. These issues are discussed in **Oceans (GEO 3800)**, taught by Brenda Bowen. In this class, students will develop an "oceanic" perspective of earth systems by exploring oceanic processes and the relationships between the ocean and other earth systems. Current events and the newest research are used to explore solutions to the crisis facing the ocean ecosystems. As teams, students must create a plan for an invention that will help solve a problem directly related to the ocean, such as designing a garbage filter that skims the surface of the water. This project allows students to explore creativity, research and sustainability while learning about unique struggles different communities and ecosystems face.

Carbon cycle describes the distribution of carbon as it is recycled through the biosphere, hydrosphere, and atmosphere. **Carbon Cycle (GEO 5680)**, taught by Gabe Bowen, explores the role of the carbon cycle in the context of earth history, climate, surface processes, ecology, energy, human society, and the future of the planet. Students study carbon modeling to determine the level of carbon in our atmosphere and research what the future levels might be. Real world applications like these help scientists determine what direction communities should go to mitigate changes. "It was interesting to take a look at the economic and societal effects of changing the ways that we live. It was a good reminder that we need to balance economic development, human well-being and healing our environment," said a graduate student enrolled in the spring 2020 course.

Living with Quakes (GEO 3030) dives into the world of seismology and volcanology through the lens of not only science but also of affected communities. The course stresses the "importance of having better infrastructure in areas prone to natural disasters. This can save large amounts of money and lives. In addition, it promotes better use of resources to make

LEARNING SUSTAINABILITY (continued)

things more sustainable" said one student about the spring 2020 course taught by Lowell Miyagi.

A new graduate level course in CMES, **Sustainable Resource Development (MGEN 5080)** taught by Pratt Rogers, explores the concepts of sustainable mineral development, permitting, and reclamation of mineral development projects. "Mining is an important activity that affects us personally but also expands to the environment as a whole, which people often neglect. The whole process for permits, exploration, etc., is often tedious, but it is for protection for human health and also the environment," said one student about the most enlightening aspect of this course during the spring 2020 semester.

Why should we care about promoting sustainable practices?

Climate change, natural disasters, and dwindling resources influence our lives in direct and sometimes less apparent ways. If we can learn to live more sustainably as a society, these events can have a more superficial impact and allow communities to rebound more quickly. *-Sarah Hamilton*

Learning Sustainability in Iceland

Geology and Geophysics undergraduate student, Travis Parsons, participated in a 60-hour intensive course at Reykjavik University's Iceland School of Energy in December 2019. The course focused on renewable energy innovation and sustainability. Iceland is unique in that ~90% of their energy consumption is from renewable resources. The course is a combination of classroom teaching and field study. Classroom instruction covered geology of Iceland, engineering of geothermal and hydroelectric power and bio-fuels, energy economics, and sustainability. These classes are paired with trips to a geothermal plant, a hydroelectric plant, and a rapeseed bio-fuel farm and production facility in which students engage with experts in these fields and get first-hand instruction on how these facilities work and how they can be improved.

Photo credit: Travis Parsons

Hotspring in Iceland

In addition to trips to these facilities, they also made several hikes to hot springs and geysers, through the backcountry and black sand coast, and on a glacier, to not only enjoy the natural beauty of Iceland, but to gain a better understanding of how nature can be used responsibly and how to protect it. "I would recommend this experience to anyone interested in geology, engineering, and sustainability, especially as Utah explores geothermal prospects in the state." *- Travis Parsons*

Life-changing Impact of CMES Classes

Students are excited about the long-lasting impact that CMES classes have on their lives. Here's what they are most enlightened about after taking our courses:

Climate Change

- Understanding past climatic events can help predict how the earth will react to the current changes in order for us to create mitigation and adaptation strategies for human societies.
- I was surprised to learn that there are a number of ways to tackle the climate change problem. It gave me hope that there is not a true "one size fits all" solution, and that as a global community, we might be able to find ways of enacting policies that protect our planet and still allow for some sustainable economic growth and development.
- The most interesting concept was the time it takes for carbon to cycle through the system. Our current emissions will have effects long into the future even if we stopped emitting today, which is especially alarming considering the current trajectory we seem to be taking.

Living with Quakes and Volcanoes

- GEO 3030 provided greater context on how the culture of an area as well as the type of natural disaster can contribute to how devastating a major event can be.
- During a Utah earthquake, my roommate and I who took GEO 3030 knew exactly what to do. Within seconds we recognized it was an earthquake and protected ourselves immediately.
- The understanding of earthquakes, how they happen, and preparedness of them happening came in great use when we experienced a 5.7 magnitude earthquake mid semester.
- I learned that Utah is surprisingly geologically active, due to the continent thinning out under our feet, and that the Wasatch fault line is building our mountains at the same time.

Student Research in Sustainability

Making N95 Masks Reusable

Karthikeyan Baskaran is a graduate student from Chennai, India who joined Prof. Carlson's group in spring of 2020 as a Ph.D. candidate in materials science and engineering. They are researching silica xerogels for use in N95 respirators. Making filters from silica would allow for sterilization and reuse because they can be cleaned with powerful disinfectants without damaging the material. Xerogels are highly porous solids that are synthesized from gels. Karthikeyan's role is to understand how to control and tailor the porosity of the xerogel to block viruses as the airstream moves through the filter. The team will be working with Prof. Swomitra Mohanty's group to functionalize the filters with metal nanoparticles that can inactivate viruses. If successful, these metal-fucntionalized silica filters could have larger pores to provide more airflow to the user while still providing effective virus filtration. Karthikeyan is enthusiastic about being a graduate researcher as it allows him to continue to learn while using his skills towards product development. (See this story on page 8).

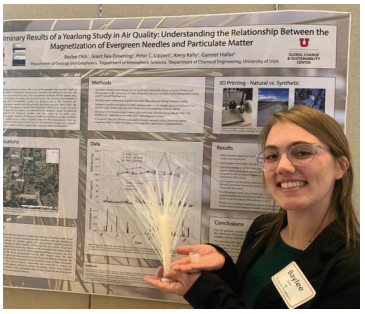
Pretend Beavers

Beginning with a summer internship with Trout Unlimited in 2018, **Lily Bosworth,** a recent graduate in Honors Geological Engineering and Environmental Geoscience, has been conducting research on beaver dam analogues (BDAs) advised by Dr. Paul Brooks. Beavers, once widespread in Utah, are natural stream geological engineers. Historically, their dams slowed streamflow, minimized erosion, recharged groundwater, and provided habitat for both aquatic and terrestrial species. BDAs are a new, affordable, low-tech stream restoration tool that mimics the benefits of natural beaver dams. However, little quantitative data is available on BDAs' impact on stream hydrology. Water is a vital, sensitive resource in Utah and throughout the West, so it's important to understand how BDAs impact water availability and timing. Lily obtained a grant from the Sustainable Campus Initiative Fund and partnered with Trout Unlimited, Wild Utah Project, and a Summit County rancher to install a BDA restoration site and collect before-and-after hydrologic data. Lily completed her research during summer 2020 as a research assistant for Wild Utah Project with Adam Culbertson continuing the research to inform stakeholders on how BDAs can be used to balance stream restoration goals with water availability.

- Lily Bosworth

Pine Needles and Air Quality

The magnetization of evergreen needles might be a low-cost, high-density measurement of harmful particulate pollution in the air we breathe. **Baylee Olds,** an undergraduate student in geology and geophysics, helped test this idea with Professor Peter Lippert and PhD candidate, Grant Rea-Downing. Beginning August 2019, Baylee 3D-printed, deployed, and collected synthetic and natural pine needles from two on-campus locations and measured their magnetic properties in the Utah Paleomagnetic Center. She presented the preliminary findings at the 2020 Global Change and Sustainability Center's Research Symposium. Baylee feels strongly about promoting public education and community awareness. "I am incredibly proud to be a part of this project, especially as it investigates the impact of fossil fuel combustion on air quality and the health of individuals living along the Wasatch Front. I find communicating my research findings to the community to be the most challenging aspect of my research, but this public education, now more than ever, is the most critical part of our work if we are to build a more healthy and sustainable future." - *Baylee Olds*



The Great Salt Lake vs The Greatest Snow on Earth

Chase Hodges-Heilmann, an undergraduate student in atmospheric sciences, researched the effects of the Great Salt Lake on snowpack. As the Great Salt Lake shrinks, the dry lake bed contributes to more windblown dust. When this dust deposits onto snow, the albedo of the surface is decreased, and thus snow melts quicker. Chase, along with his advisors, Dr. Gannet Hallar, Tanner Visnick, and Christopher Rapp, concluded that drying of the Great Salt Lake has serious consequences on the rapid melting of snowpack in the Wasatch mountains and that new sources of dust must be investigated and researched.

Managing Slope Failure in Communities

Shakir Shaharudin, an undergraduate researcher in geology and geophysics, with advisor Dr. Paul Jewell, characterized landslides in the Weber River delta to help identify and locate areas with the highest susceptibility of a landslide based on previous events. A threshold for slope failure can be identified and applied to a reasonable size area, such as a neighborhood. This is helpful in identifying problem areas and addressing how to move forward to ensure these landslides have less impact on communities.

Student Field Experiences

Photo credit: Erich Petersen

Bingham Canyon Mine

On a joint trip with The Association of Environmental & Engineering Geologists (AEG) and American Association of Petroleum Geologists (AAPG), students and faculty toured the Bingham Canyon Mine to learn about the geology of this porphyry copper deposit and the mining/refining process. The Bingham Canyon mine is the largest and deepest open pit mine in the world. It is one of the main sources of copper in the US and is important to the economy of Utah. The scale of the operation is massive. The tires used on the hauling trucks are about 12 feet tall. Students were astounded watching these large trucks ascend the 100-foot terraces lining the outside of the pit.

Moab, UT

On this collaborative trip, University of Utah and Colorado State University AAPG Student Chapters went into the field to learn about erosional features in Arches National Park in Moab, Utah. They learned about how the salt tectonics created the joints in overlying rock units as the salt moved. Then, weathering along those joints formed the magnificent features seen in the park, such as arches and hoodoos. "Through this trip, we were able to get hands-on with a really neat part of our local geology and learn more about salt tectonics, implications of these processes and deposits for petroleum systems, as well as were able to collaborate with like-minded students from another AAPG student chapter," said one student.

Photo credit: Teresa Langenkamp

Andros Island, Bahamas

Photo credit: Cari Johnson

Professors Cari Johnson, Brenda Bowen and Kathleen Ritterbush from the department of geology and geophysics accompanied students on a week-long trip to study modern carbonate processes in the Bahamas. Students and faculty visited limestone outcrops on the island as well as reefs and shoals offshore. Graduate student Hannah Hartley recalled, "One of the neatest things we saw were oolitic shoals, mobile islands composed entirely of tiny round carbonate grains [called] ooids. I've seen oolitic limestones, and I've learned specifically about that location even before the class, but to stand in the middle of the process and see how the waves rolled the ooids around was Incredible." Many students expressed appreciation of observing processes in action. Casey Duncan, also a graduate student, explained how seeing modern environments changed his view of what he sees in rocks. "Exploring the ecosystems and environments that form the carbonate rocks allowed me to gain a greater appreciation for the complexity and interconnectedness within these systems."

Department of Environmental Quality - Air Quality Division

Students enrolled in Professional Development in the Atmospheric Sciences (ATMOS 3000) in Fall 2019, participated in a field trip to the Department of Environmental Quality - Air Quality Division. The students toured a new laboratory facility located in Salt Lake City, where instrumentation is tested before being deployed to monitoring sites across Utah. Students in this class, taught by Gannet Hallar, also had the opportunity to learn about other careers and opportunities including broadcasting, road and fire weather forecsting, data science, and climate science through other field trips around Salt Lake City. These field trips included visiting KTVX-TV ABC Channel 4 UTAH for a tour from broadcast meteorologist, Dan Pope, visiting UDOT Traffic Operations Center for a tour with UDOT Weather Operations Manager/ Meteorologist, Jeff Williams, and touring the National Weather Service. Students received an introduction to the atmospheric sciences profession and related environmental fields which provided an overview of career opportunities in government, industry, and education.

Photo credit: Gannet Hallar

Outstanding Teaching Assistant Award

Levi Gardner received the 2020 CMES Outstanding Teaching Assistant Award. This award honors the teaching and educational service of one graduate student each year in the College of Mines and Earth Sciences and is considered one of the highest College honors. Levi is a metallurgical engineering Ph.D. candidate and has been a teaching assistant for several years, working under Dr. Krista Carlson. Levi was selected for his unwavering commitment to helping students have a meaningful learning experience and because of his talent for teaching and communicating with students. One student commented, "Levi's work in Elements of Mechanics is unparalleled. I've never worked with a TA as attentive, available, and proactive."

Outstanding Undergraduate Research Award

Christopher Rapp is the recipient of the 2020 Outstanding Undergraduate Research Award for the College of Mines and Earth Sciences. Christopher, who is majoring in atmospheric sciences and mathematics, was nominated by Professor Gannet Hallar. Christopher developed a diagram describing the relationships between meteorological variables, size of particles, and various pollutants that make up inversion. "As an undergraduate researcher I have had the opportunity to work with research professors on complex projects, communicate my results at conferences with posters, and have gained a deeper passion for conducting research."

The Oblad Silver Medal of Excellence

Benjamin Bonney received the Oblad Silver Medal of Excellence for Mining Engineering, which recognizes the senior student with the highest academic achievement. Benjamin interns with Virtual Consulting International (VCI) where he acts as an engineering and business analyst supporting the digital transformation of mining. **Tanner Livingston** received the Oblad Silver Medal of Excellence for Metallurgical Engineering. He became fascinated with metallurgy when he first saw the phenomenon of a shape memory alloy wire straightening itself out with just a small amount of heat.

NSF Graduate Fellowshps

Two materials and science engineering students, **Danielle Beatty** and **Ashlea Patterson** were selected for NSF Graduate Fellowships. The National Science Foundation GRF program recognizes and supports outstanding graduate students in NSF-supported science, technology, engineering, and mathematics disciplines who are pursuing research-based masters and doctoral degrees.

DOE - NEUP Graduate Fellowships

Two metallurgical engineering graduate students, **Jarom Chamberlain** and **Matt Newton**, were announced as winners of a 3-year DOE NEUP (Department of Energy Nuclear Energy University Program) graduate fellowships, worth $161,000 each. Only 34 fellowships were awarded across the entire country. DOE NEUP funds nuclear energy research and equipment upgrades at U.S. colleges and universities, and provides student educational support.

Williamson Science Communications Fellowship

This year was the inaugural year of the Chuck and Cathy Williamson Science Communications Fellowship. Founded by Chuck Williamson, a University of Utah Geology alum, the goals of the fellowship are to initiate an outreach geoscience communications program that reaches a diverse audience, provide University of Utah Geology and Geophysics students with science communications experience, and to engage youth in the earth sciences.

During the year, geology graduate students **Riley Finnegan** and **Philip-Peter Maxeiner**, with help and guidance from Laura Meyer, the former College of Mines and Earth Sciences' Outreach Coordinator, partnered with local schools and teachers to provide learning opportunities for young students. Throughout the year Riley and Peter worked most closely with Bryant Middle School, a STEM-focused school for grades seven and eight, which has a partnership with the Salt Lake Center for Science Education.

Shoemaker Ph.D Fellowship Grant

Amy Richins received the 2019 shoemaker Ph.D. Fellowship Grant. This is a prestigious SME award that provides financial support to graduate students pursuing a PhD. Associate with mining.

Undergraduate Research Poster Session

Tristan Lundgren, a Crus Scholar in metallurgy, took 2nd place in the undergraduate student poster competition during February's Society for Mining, Metallurgy and Exploration (SME) meeting in Phoenix, AZ. Tristan's research is identifying efficiency issues related to a critical step of the gold mining process. Tristan is excited about the experience and says, "I learned and networked more than I've ever had the opportunity to do before, and I'm already putting those ideas and connections to use."

Mine Rescue Team Takes Gold!! The University of Utah mine rescue team took first in the overall competition at the 2020 Society of Mining, Metallurgy and Exploration (SME) Annual Conference in late February. The team led in first aid and breathing apparatus categories. The winners were Victor Harrell (trainer), Travis Brammer, Rebecca Ray, Stephen Hall, Jack Peterson, Paige Epsten, and Amy Richins. Read the full story at ***cmes.utah.edu.***

Outstanding Faculty Teaching Award

Dr. Kathleen Ritterbush, assistant professor of geology and geophysics, received the 2020 Outstanding Teaching Award. This student driven award is considered the highest teaching honor in the College of Mines and Earth Sciences. Kathleen is a passionate and dedicated professor. Her lectures are interactive and filled with hand drawn visual aids which help tell elaborate and fascinating stories that connect with students to make the complex concepts relatable and understandable. She is accessible, approachable, and inclusive toward her students. "The most valuable lesson I learned from Dr. Ritterbush is the humanity of science," said one student about Dr. Ritterbush's profound impact.

Career Champions Award

Dr. Peter Lippert, assistant professor of geology and geophysics, received the 2020 Career Champions Award. The Career & Professional Development Center receives nominations for individuals who have made a substantial impact on students' career development at the University of Utah. "Without Professor Lippert's mentorship, I would not be where I am today, dreaming of all the ways that I can make a difference out in the 'real world'. Professor Lippert is an exemplary faculty member who is active in helping students realize their full potential and explore career options they would never have thought of on their own," says the student nominator.

Early Career Teaching Award

The University Teaching Committee has selected **Dr. Peter Lippert** to be a recipient of the Early Career Teaching Award for 2020. The award is given to outstanding young faculty members who have distinguished themselves through the development of new and innovative teaching methods, effectiveness in the curriculum and classroom, as well as commitment to enhancing student learning.

Celebrate U Award

Dr. Jessica Wempen, assistant professor of mining engineering, was honored for a Celebrate U Research Award for "Remote Sensing for Mine and Environmental Monitoring." Dr. Wempen was nominated by Dean Butt and selected as an honoree for her overall research work in 2019.

Émile Argand Medal

Distinguished professor of geology and geophysics and Biology, **Dr. Thure Cerling** was awarded the Émile Argand Medal by the International Union of Geological Sciences. This is the organization's highest honor, and is awarded to honor an active senior geoscientist of high international recognition and outstanding scientific record.

L. Jackson Newell Liberal Arts and Sciences Fellow

Dr. Jeffrey Moore, associate professor of geology and geophysics, was selected as the 2020-21 L. Jackson Newell Liberal Arts and Sciences Fellow, administered through the Honors College at the U.

GSA Distinguished Service Award

Dr. Marjorie Chan, distinguished professor of geology and geophysics, was awarded the 2020 Geological Society of America (GSA) Distinguished Service Award for exceptional service to the Society. Dr. Chan has enjoyed a rich career of GSA involvement including: initiation of the successful On To the Future (OTF) program which encourages diverse students to attend their first GSA meeting; being the 2014 GSA Distinguished International Lecturer; service as GSA councilor (2016-2020) with numerous other leadership and committee positions; and recognition as the 2019 Sloss Awardee for lifetime achievements in Sedimentary Geology.

SME Freeport-McMoRan Career Development Grant

Dr. Jessica Wempen, assistant professor of mining engineering, was recognized for the SME Freeport-McMoRan Career Development Grant. This grant provides tenure-track assistant or associate professors with the financial support needed to better participate in activities such as research, publication and professional service which are necessary to achieve tenure and promotion.

SME Fellow and Distinguished Member

Dr. Michael G. Nelson, professor of mining engineering, was recognized as a Society for Mining, Metallurgy, and Exploration (SME) Fellow and Distinguished Member for 2020. The SME Fellow award is awarded to members of 15 years or more who have made significant and sustained contributions to the minerals industry and to SME.

Dual Degree Program

Dr. John Lin, atmospheric sciences, and Dr. **Fan-Chi Lin**, geology and geophysics, have led the establishment of a dual-degree program with the National Taiwan University to cultivate an international workforce and to boost student competitiveness in the international workplace.

TMS Distinguished Service Award

Dr. Michael Free is the recipient of the 2020 TMS (The Minerals, Metals & Materials Society) Distinguished Service Award. This award recognizes an individual whose service to TMS has "clearly facilitated the Society's capability to serve its members and their supporting organizations."

In the Fight for COVID-19 Solutions

By Vince Horiuchi, College of Engineering

Photo credit: XXXXXXX

University of Utah researchers are dedicated to finding solutions to fight the COVID-19 coronavirus that has plagued most of the world. The University of Utah's Office of the Vice President for Research, in partnership with the Immunology, Inflammation and Infectious Disease (3i) Initiative, has awarded $1.3 million in seed grants to 56 cross-campus research projects that will examine a host of issues arising out of the pandemic. Of those, two are going to projects initiated by College of Mines and Earth Sciences researchers.

Synthesis of easily sterilizable and reusable xerogel filters for N95 respirators (Metallurgical Engineering Assistant Professor Krista Carlson)

Single-use N95 respirator masks are in great demand at hospitals nationwide due to the COVID-19 pandemic, but manufacturers cannot keep up. Krista Carlson, who is also under the U's College of Mines and Earth Sciences, is developing a silica xerogel filter that provides the same efficiency as a N95 filter, but unlike the single-use respirators or current filters for reusable respirators, these xerogel filters can be repeatedly sterilized for reuse. Filters will be made by drying silica-based gels to obtain crack-free xerogel filters that fit into reusable respirators. Data collected from this study will also be used in future proposals to study filtration efficacy of other particulate matter.

Chemical free inactivation of coronavirus via electroactive nanostructured cupric oxide (ENCO) (Metallurgical Engineering/Chemical Engineering Assistant Professor Swomitra Mohanty)

Mohanty and his team have developed a nanostructure from a form of copper (Cu2+) that can deactivate the virus by interacting with the nucleic acids that make up the virus and their outer protein membrane. Copper normally disarms viruses over time, but it is a slow process. This material employs a unique method to immediately deactivate the virus in tiny droplets This material, which is chemical free, could be used in N95 masks to neutralize the virus as it is drawn into the mask or in hospital air filtration systems. It also could be built into a device like a wand or mop that could deactivate the virus on a table surface or floor.

Tracking COVID-19 Infections Through Waste Water

In April 2020, researchers from The University of Utah, Brigham Young University, and Utah State University partnered with the Utah Department of Environmental Quality to find ways of tracking coronavirus levels through waste water, a concept pioneered at The U. Infectious diseases can be traced through waste water that is coming into the treatment plant and could provide an estimate of the number of COVID-19 cases within communities.

Researchers have found traces of the virus in the waste water in 64% of the 171 samples collected at 10 treatment plants throughout Utah. Plants were selected to represent data from different types and sizes of communities across the state. "If we are able to correlate the viral waste load in waste water or sewage to infection rates that are known in various communities across the state, then it could become a tool that our public health partners could use to inform some of their decision making," said Erica Gaddis, the director of the Utah Division of Water Quality and adjunct associate professor in the dept. of geology and geophysics.

The five-week pilot aimed to find outbreaks in the early stages, confirm low infection statistics, and track community infection trends by monitoring concentrations of the virus in the water. The results of the study indicate the virus can be found in water entering the facility but is not present in the water leaving treatment plants. The study

also shows that case counts for COVID-19 testing in communities reinforce estimates through the analyzed waste water. Furthermore, when community infection rates rise, the virus is detected in higher concentrations, giving community leaders correlations to make informed choices on how to manage the pandemic. Tourist communities showed a higher concentration of the virus when compared to similarly sized areas with less tourism; as do urban areas.

Tracing viruses through waste water is an effective way to collect data related to infectious diseases. The results of this study help provide important information about the spread of coronavirus and how individual communities are affected by it. Learn more at https://udwq.shinyapps.io/pilot-ww-virus-db/#dashboard-1 *-Sarah Hamilton*

DISCOVERING A NEW DINOSAUR

Thanks to research by students like Savhannah Carpenter, supported by professor Mark Loewen, a paleontology scholar, a "new" dinosaur will soon be recognized as a species.

Carpenter, a third-year geology major, didn't expect to be part of such a big discovery. When she started at the U, she decided to volunteer with the Natural History Museum of Utah, where she spent a lot of time as a kid. After her volunteer work, she was offered an internship and eventually invited by Loewen to join in his research on ceratopsian dinosaurs, like triceratops.

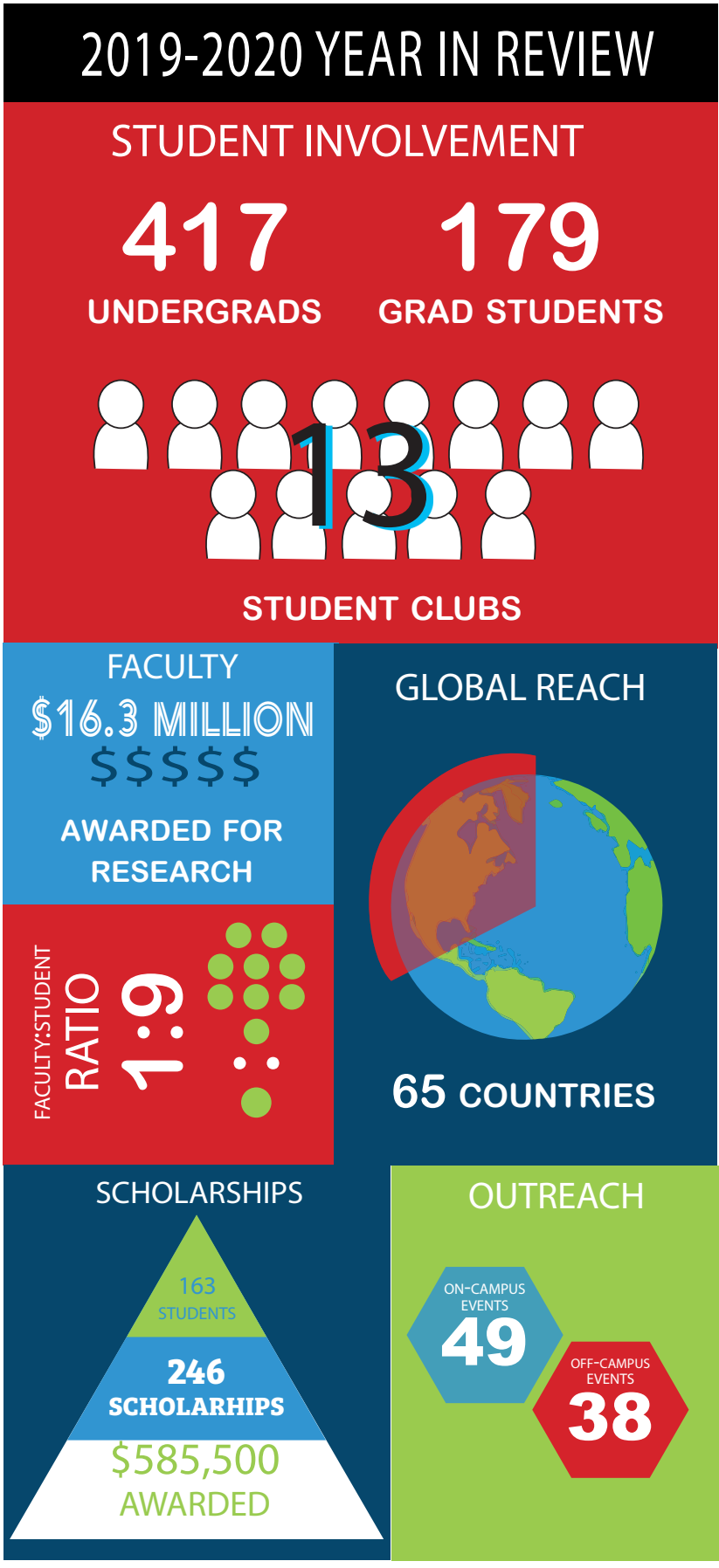
"In my research, I do everything from looking at bones and describing them in papers to traveling to museums in other states and countries to present the research to children and other researchers," Carpenter said.

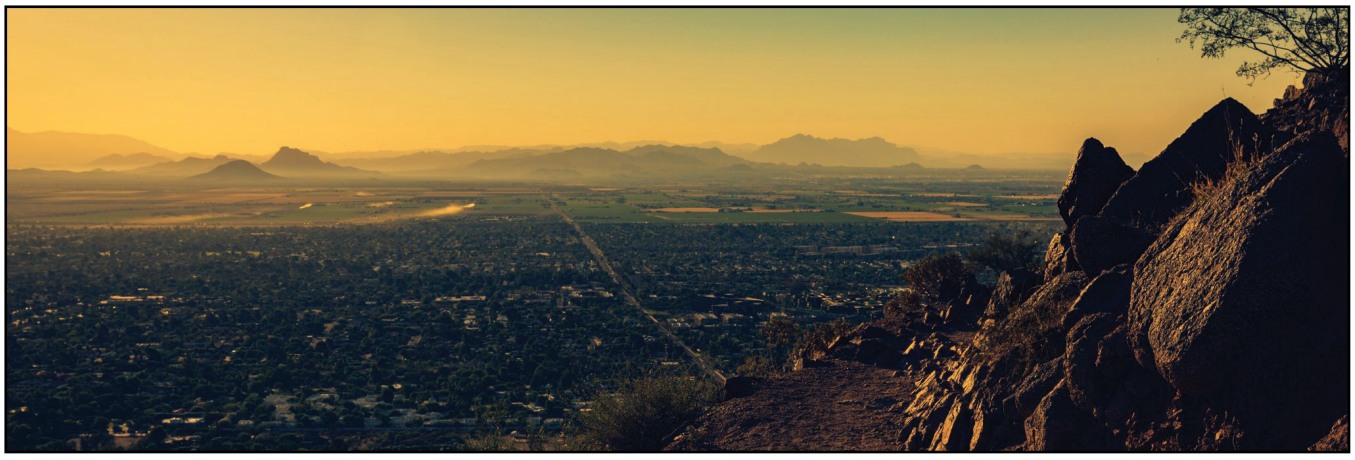
This specific dinosaur was discovered nearly a decade ago, but was sitting in the collections department of the Natural History Museum. Loewen began to study the bones and realized that the dinosaur wasn't like ones he'd seen before. He passed the bones on to Carpenter, who worked for over a year analyzing each piece.

"We plugged all of those physical traits that I found into a coding system called TNT parsimony," Carpenter said. "That system comes up with the simplest family tree based on the traits that you coded for. We used more traits than had ever been used in coding ceratopsian dinosaurs, and it created an entirely new family tree.

The research will culminate in a published paper, which is currently in the peer review process. The paper was presented at the annual Society of Vertebrate Paleontology Conference as a valid new species. It's currently named "UMNH VP 20600," but will be assigned a new name at the end of the peer review process.

"Anyone interested in paleontology, stick it out," Carpenter said. "Put the work in, and good things will come. I started as a volunteer, and all of this happened in just a couple of years. When you like what you do, it's worth it." *-Lassonde Staff*





NASA Satellite Offers Urban Carbon Dioxide Insights

By Paul Gabrielsen, science writer, Marketing & Communications & Alan Buis, NASA Jet Propulsion Laboratory

A new NASA/university study of carbon dioxide emissions for 20 major cities around the world provides the first direct, satellite-based evidence that as a city's population density increases, the carbon dioxide it emits per person declines, with some notable exceptions. The study also demonstrates how satellite measurements of this powerful greenhouse gas can give fast-growing cities new tools to track carbon dioxide emissions and assess the impact of policy changes and infrastructure improvements on their energy efficiency.

Cities account for more than 70% of global carbon dioxide emissions associated with energy production, and rapid, ongoing urbanization is increasing their number and size. But some densely populated cities emit more carbon dioxide per capita than others.

To better understand why, atmospheric scientists Dien Wu and John Lin of the University of Utah in Salt Lake City teamed with colleagues at NASA's Goddard Space Flight Center in Greenbelt, Maryland, Universities Space Research Association (USRA) in Columbia, Maryland and the University of Michigan in Ann Arbor. They calculated per capita carbon dioxide emissions for 20 urban areas on several continents using recently available carbon dioxide estimates from NASA's Orbiting Carbon Observatory-2 (OCO-2) satellite, managed by the agency's Jet Propulsion Laboratory in Pasadena, California. Cities spanning a range of population densities were selected based on the quality and quantity of OCO-2 data available for them. Cities with minimal vegetation were preferred because plants can absorb and emit carbon dioxide, complicating the interpretation of the measurements. Two U.S. cities were included—Las Vegas and Phoenix.

Many scientists and policymakers have assumed the best way to estimate and understand differences in carbon dioxide emissions in major cities is to employ a "bottom-up" approach, compiling an inventory of fossil fuel emissions produced by industrial facilities, farms, road transport and power plants. The bottom-up method was the only feasible approach before remote sensing data sets became available. This approach can provide estimates of emissions by fuel type (coal, oil, natural gas) and sector (power generation, transportation, manufacturing) but can miss some emissions, especially in rapidly developing urban areas.

But for this study, researchers instead employed a "top-down" approach to inventory emissions, using satellite-derived estimates of the amount of carbon dioxide present in the air above an urban area as the satellite flies overhead.

"Other people have used fuel statistics, the number of miles driven by a person or how big people's houses are to calculate per capita emissions," Lin said. "We're looking down from space to actually measure the carbon dioxide concentration over a city."

Published Feb. 20 in the journal Environmental Research Letters, the study found that cities with higher population densities generally have lower per capita carbon dioxide emissions, in line with previous bottom-up studies based on emissions inventories. But the satellite data provided new insights.

"Our motivating question was essentially: When people live in denser cities, do they emit less carbon dioxide? The general answer from our analysis suggests, yes, emissions from denser cities are lower," said Eric Kort, principal investigator and associate professor of climate and space sciences and engineering at the University of Michigan. "It isn't a complete picture, since we only see local direct emissions, but our study does provide an alternative direct observational assessment that was entirely missing before."

The Density Factor

Scientists have hypothesized that more densely-populated urban areas generally emit less carbon dioxide per person because they are more energy efficient: that is, less energy per person is needed in these areas because of factors like the use of public transportation and the efficient heating and cooling of multi-family dwellings. Satellite data can improve our understanding of this relationship because they describe the combined emissions from all sources. This information can be incorporated with more source-specific, bottom-up inventories to help city managers plan for more energy-efficient growth and develop better estimates of future carbon dioxide emissions.

The OCO-2 data show that not all densely-populated urban areas have lower per capita emissions, however. Cities with major power generation facilities, such as Yinchuan, China, and Johannesburg, had higher emissions than what their population density would otherwise suggest.

"The satellite detects the carbon dioxide plume at the power plant, not at the city that actually uses the power," Lin said.

"Some cities don't produce as much carbon dioxide, given their population density, but they consume goods and services that would give rise to carbon dioxide emissions elsewhere," Wu added.

Another exception to the higher population density/lower emissions observation is affluence. A wealthy urban area, like Phoenix, produces more emissions per capita than a developing city like Hyderabad, India, which has a similar population density. The researchers speculate that Phoenix's higher per capita emissions are due to factors such as higher rates of driving and larger, better air-conditioned homes.

Looking Ahead

The researchers stress there's much more to be learned about urban carbon dioxide emissions. They believe new data from OCO-2's successor, OCO-3—which launched to the International Space Station last year—along with future space-based carbon dioxide-observing missions, may shed light on potential solutions to mitigating cities' carbon emissions.

"Many people are interested in carbon dioxide emissions from large cities," Wu said. "Additionally, there are a few places with high emissions that aren't necessarily related to population. Satellites can detect and quantify emissions from those locations around the globe."

Launched in 2014, OCO-2 gathers global measurements of atmospheric carbon dioxide—the principal human-produced driver of climate change—with the resolution, precision and coverage needed to understand how it moves through the Earth system and how it changes over time. From its vantage point in space, OCO-2 makes roughly 100,000 measurements of atmospheric carbon dioxide over the globe every day. JPL manages OCO-2 for NASA's Science Mission Directorate in Washington.

While OCO-2 wasn't optimized to monitor carbon emissions from cities or power plants, it can observe these targets if it flies directly overhead or if the observatory is reoriented to point in their direction. In contrast, OCO-3, which has been collecting daily

Photo credit: NASA

measurements of carbon dioxide since last summer, features an agile mirror-pointing system that allows it to capture "snapshot maps." In a matter of minutes, it can create detailed mini-maps of carbon dioxide over areas of interest as small as an individual power plant to a large urban area up to 2,300 square miles (6,400 square kilometers), such as the Los Angeles Basin, something that would take OCO-2 several days to do.

For more information on OCO-2 and OCO-3, visit:
https://www.nasa.gov/oco2
https://ocov3.jpl.nasa.gov/

CRACKS IN ARCTIC SEA ICE TURN LOW CLOUDS ON AND OFF

In the wintertime Arctic, cracks in the ice called "leads" expose the warm ocean directly to the cold air, with some leads only a few meters wide and some kilometers wide. They play a critical role in the Arctic surface energy balance. If we want to know how much the ice is going to grow in winter, we need to understand the impacts of leads.

The extreme contrast in temperature between the warm ocean and the cold air creates a flow of heat and moisture from the ocean to the atmosphere. This flow provides a lead with its own weather system which creates low-level clouds. The prevailing view has been that more leads are associated with more low-level clouds during winter. But University of Utah atmospheric scientists noticed something strange in their study of these leads: when lead occurrence was greater, there were fewer, not more clouds.

In a paper published in Nature Communications, they explain why: wintertime leads rapidly freeze after opening, so most leads have newly frozen ice that shuts off the moisture supply but only some of the heat flow from the ocean, thus causing any low-level clouds to dissipate and accelerating the freezing of sea ice compared to unfrozen leads. Understanding this dynamic, the authors say, will help more accurately represent the impact of winter-time leads on low-level clouds and on the surface energy budget in the Arctic –especially as the Arctic sea ice is declining.
-Paul Gabrielsen

Going Super Small To Get Super Strong Metals

By Paul Gabrielsen, science writer, Marketing & Communications

You can't see them, but most of the metals around you—coins, silverware, even the steel beams holding up buildings and overpasses—are made up of tiny metal grains. Under a powerful enough microscope, you can see interlocking crystals that look like a granite countertop.It's long been known by materials scientists that metals get stronger as the size of the grains making up the metal get smaller—up to apoint. If the grains are smaller than 10 nanometers in diameter the materials are weaker because, it was thought, they slide past each other like sand sliding down a dune. The strength of metals hasa limit. But experiments led by former University of Utah postdoctoral scholar Xiaoling Zhou, now at Princeton University, associate professor of geology Lowell Miyagi, and Bin Chen at the Center for High Pressure Science and Technology Advanced Research in Shanghai, China, show that that's not always the case. In samples of nickel with grain diameters as small as 3 nanometers, and under high pressures, the strength of the samples continued to increase with smaller grain sizes. The result, Zhou and Miyagi say, is a new understanding of how individual atoms of metal grains interact with each other, as well as a way to use those physics to achieve super-strong metals. Their study, carried out with colleagues at the University of California, Berkeley and at universities in China, is published in Nature."Our results suggest a possible strategy for making ultrastrong metals," Zhou says. "In the past, researchers believed the strongest grain size was around 10-15 nanometers. But now we found that we could make stronger metals at below 10 nanometers."

Lowell Miyagi

> ***"If you've ever played around with a spring, you've probably pulled on it hard enough to ruin it so that it doesn't do what it's supposed to do. That's basically what we're measuring here."***

Pushing past Hall-Petch

For most metallic objects, Miyagi says, the sizes of the metal grains are on the order of a few to a few hundred micrometers—about the diameter of a human hair. "High end cutlery often will have a finer, and more homogeneous, grain structure which can allow you to get a better edge," he says.The previously-understood relationship between metal strength and grain size was called the Hall-Petch relationship. Metal strength increased as grain size decreased, according to Hall-Petch, down to a limit of 10-15 nanometers. That's a diameter of only about four to six strands of DNA. Grain sizes below that limit just weren't as strong. So, to maximize strength, metallurgists would aim for the smallest effective grain sizes."Grain size refinement is a good approach to improve strength," Zhou says. "So, it was quite frustrating, in the past, to find this grain size refinement approach no longer works below a critical grain size."The explanation for the weakening below 10 nanometers had to do with the way grain surfaces interacted. The surfaces of grains have a different atomic structure than the interiors, Miyagi says. As long as the grains are held together by the power of friction, the metal would retain strength. But at small grain sizes, it was thought, the grains would simply slide past each other under strain, leading to a weak metal.Technical limitations previously prevented direct experiments on nanograins, though, limiting understanding of how nanoscale grains behaved and whether there may yet be untapped strength below the Hall-Petch limit. "So, we designed our study to measure the strength of nanometals," Zhou says.

Under pressure

The researchers tested samples of nickel, a material that's available in a wide range of nanograin sizes, down to three nanometers. Their experiments involved placing samples of various grain sizes under intense pressures in a diamond anvil cell and using X-ray diffraction to

watch what was happening at the nanoscale in each sample.

"If you've ever played around with a spring, you've probably pulled on it hard enough to ruin it so that it doesn't do what it's supposed to do," Miyagi says. "That's basically what we're measuring here; how hard we can push on this nickel until we would deform it past the point of it being able to recover."Strength continued to increase all the way down to the smallest grain size available. The 3 nanometers sample withstood a force of 4.2 gigapascals (about the same force as 10 10,000-pound elephants balanced on a single high heel) before deforming irreversibly. That's 10 times stronger than nickel with a commercial-grade grain size. It's not that the Hall-Petch relationship broke down, Miyagi says, but that the way the grains interacted was different under the experimental conditions. The high pressure likely overcame the grain sliding effects."If you push two grains together really hard," he says, "it's hard for them to slide past each other because the friction between grains becomes large, and you can suppress these grain boundary sliding mechanisms that turns out are responsible for this weakening."When grain boundary sliding was suppressed at grain sizes below 20 nanometers, the researchers observed a new atomic-scale deformation mechanism which resulted in extreme strengthening in the finest grained samples.

Ultrastrong possibilities

Zhou says that one of the advances of this study is in their method to measure the strength of materials at the nanoscale in a way that hasn't been done before. Miyagi says another advance is a new way to think about strengthening metals—by engineering their grain surfaces to suppress grain sliding."We don't have many applications, industrially, of things where the pressures are as high as in these experiments, but by showing pressure is one way of suppressing grain boundary deformation we can think about other strategies to suppress it, maybe using complicated microstructures where you have grain shapes that inhibit sliding of grains past each other."

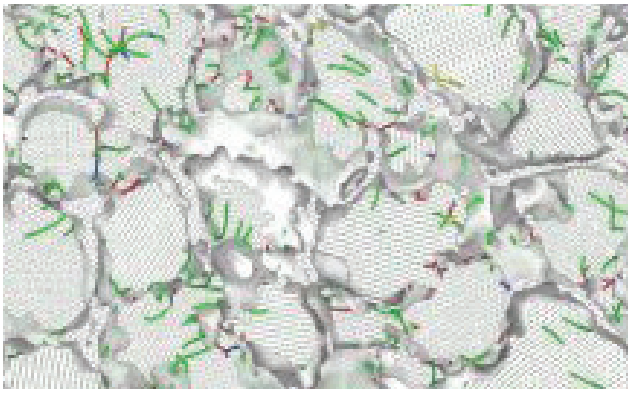


Photo credit: Zhou et al.

A simulation of 3-nm-grain-sized nickel under strain. Colored lines indicate partial or full grain dislocation.

Identifying Vulnerabilities in SLC Water

Researchers in the Departments of Atmospheric Sciences, Geology and Geophysics, and Civil and Environmental Engineering are collaborating with the Salt Lake City Department of Public Utilities to help ensure a stable and high quality water supply through the end of the century. This five year project, led by professor Court Strong (ATMOS/CMES), is a unique partnership between the University and the City to investigate vulnerabilities in the City's water systems and identify 'no regrets' solutions to address the challenges posed by growing population, aging infrastructure, and a rapidly changing climate.

Combining expertise across departments is critical for addressing water supply challenges. Students in Atmospheric Science develop new understanding of how and why climate patterns develop, using this knowledge to provide ensemble climate projections through 2100. Students in Geology and Geophysics combine these climate projects with historical data on stream flow, groundwater recharge, and water quality to develop water supply and water quality predictions. Students in Civil and Environmental Engineering integrate these climate and hydrology predictions in to a coupled model of the City's water supply system to assess climate vulnerabilities and analyze potential solutions over a range of future scenarios. The project uniquely brings together a wide range of expertise both at UU and at the City in a dedicated effort to address sustainability issues facing the largest metropolitan area in the state.

The multi-year commitment allows researchers and the City to simultaneously advance the fundamental understanding of how climate, hydrology, and management interact while rapidly including new knowledge generation into decision making. Two key examples of new knowledge developed under this project are: 1) Atlantic Ocean variability appears to be an important climate driver of multi-year cycles of precipitation in the study region; and 2) surfacewater yield is highly sensitive to groundwater recharge dynamics which are regulated by multi-year variations in precipitation. These two discoveries reinforce the concept that climate vulnerability critically hinges on sequences of multiple wet years and sequences of multiple dry years.

By understanding the atmospheric and oceanic drivers of these climate sequences and how they project onto hydrology and system dynamics, the University team is able to develop cutting edge guidance for water system planning, operations, and infrastructure. The co-generation of knowledge between stakeholders and university researchers reduces the delay between research and practice developing solutions based on state of the art science and engineering. This approach is being replicated in projects with other water management agencies throughout the state and region allowing the University to more efficiently serve the state and nation in addressing pressing challenges of water supply in response to changes in population, demography, and climate. *-Paul Brooks*

They Pay Me To Do This?!?

Predict Weather

Andy Park was a Hotshot. That is, he was on the Lone Peak Hotshots fire crew that fights the most intense wildfires in the West. Seeing how weather could impact fires sparked a passion in Park. The senior, studying atmospheric sciences, works for his department maintaining weather stations around the Salt Lake Valley. He also works on air quality monitors on the valley's TRAX light rail. He's gaining a greater appreciation for what goes into forecasting. "It takes years of experience to understand the weather station data," he says. "This job is helping me do just that." After graduation, he wants to be a meteorologist in Alaska or maybe Oregon.

Fly Drones

It's a bird! It's a plane! No, it's a drone. And they're used for a whole lot more than hobbies these days. In fact, graduate student **Bonnie Erdenekhuyag** (BS'18) is one of the first students to use drones as part of a mining engineering master's program. She recently finished an internship at Rio Tinto's copper mine where she used drones to create extremely accurate (within just a few centimeters) maps of the region. The research assistant originally from Mongolia is now using drone data to examine different mineral makeups in a region of Utah. Drones have made a massive impact on the mining industry, she says. They can be used to determine vegetation and for environmental monitoring. And with cages to protect them, they're able to fly into caves and in confined spaces. "Drones are the future of mining. They're going to make it safer and more efficient and have less environmental impact," she says. "And it's a pretty fun way to make a living."

Study Salt

Jeremiah Bernau is obsessed with salt. The doctoral candidate has been studying it for years across several states. In Utah, Bernau has been making treks out to the Bonneville Salt Flats for three years now. It's dirty, challenging work that goes on, come freezing brine or blinding salt. And it's a two-hour drive. But it's worth it," he says. "The salt flats tell an important story," he explains. "It's a system that connects scientists, other people, and nature." His group is investigating how humans interact with the varying landscape and environment. Whether it's speed racing, mining, or the changing climate, it all affects the flats," he says. *Credit: Utah Magazine Spring 2020*

Photo Credits: Dave Titensor

Student Research continued from page 4

Metallurgy Graduate Students Develop Molten Salt Reactor Technology for DOE

Beginning Fall 2020, metallurgical engineering PhD students **Jarom Chamberlain** and **Matt Newton** started working on projects to support advanced nuclear energy under the financial support of the U.S. Department of Energy's Nuclear Energy University Program. Jarom and Matt, who work for Dr. Michael Simpson, were both awarded 3-year NEUP Graduate Fellowships worth $161,000. Jarom will be working on a new method for converting spent nuclear fuel in oxide form into a molten salt that can be used to fuel molten salt reactors (MSRs). Matt will be working on developing electrochemical methods for measuring actinide concentrations in molten fluoride salts, which also supports MSRs. If successful, Jarom and Matt's work will enable the use of commercial spent nuclear fuel in MSRs and provide technology to optimally control the reactors and safeguard the fissile fuel.

Pluton Investigations

Travis Parsons conducted undergraduate research with Dr. Peter Lippert and Dr. John Bartley starting January 2019 in order to gain a better understanding of how plutons develop. Travis used remnant magmatism in rocks from Yosemite National Park to create an instrument to measure changes. This helped test the hypothesis that plutons, igneous rocks cooled inside the earth, are emplaced as sheets, dikes, sills, etc. over a series of events and time as opposed to a single magma bubble, as was widely accepted. Travis valued applying his knowledge from the classroom. "Research is a much more active learning process than just simply taking classes. It provides a more in-depth learning experience and the opportunity to apply the knowledge you've gained through classes to work through a problem."

Strontium Isotopes in Archeologic Studies

Riley Murray, an undergraduate student in Geology and Geophysics, and Dr. Diego Fernandez are studying trends in strontium (Sr) isotopes from vegetation in parks around New York City. Sr isotopes can be used to study migration by comparing the isotopic ratio in skeletal remains with the isotope ratios of available material from the local surroundings, such as twigs and seeds. The Sr ratio is preserved by plants and is then retained through the trophic levels in herbivores and the carnivores that eat them. "Our results suggest that vegetation is a promising material with which to measure bioavailable Sr and map how Sr isotopes may or may not change in an urban environment over time," said Riley. "Even in a complex urban environment like Manhattan, we have evidence that vegetation may be an excellent proxy for the uncontaminated baseline strontium signature."

Chemical Variability in San Carlos Olivine

Olivine is used in mineral physics, CO_2 sequestration, rock mechanics and experimental petrology, among other fields. **Sarah Hamilton**, an undergraduate student in Geology and Geophysics, conducted research with Dr. Sarah Lambart on the chemical variability in San Carlos olivine. This work will be of potential interest to the science community as the present characterization of San Carlos olivine is rather limited. Sarah is working on a manuscript to be submitted in an international peer-reviewed journal. "It helped solidify my understanding of geochemical concepts and gave me direction for future goals in research."

Pine Tree Isotopes

Since January 2020, Hayley Lind, an undergraduate researcher in Geology and Geophysics, has been analyzing isotope data from pine trees grown in Arizona and Utah to see how seasonal precipitation impacts growth. By analyzing sugar and starch concentrations and oxygen isotope ratios, Hayley can determine differences between trees lacking summer precipitation (Utah) versus trees that experience monsoon precipitation throughout the summer (Arizona). Her research will be of direct interest to her advisor, Rich Fiorella, who will use it to further his project studying seasonal precipitation and monsoons recorded by isotopes in trees. Hayley appreciates the opportunities undergraduate research has provided her. "It has given me access to one of the best stable isotope facilities in the world, and I've learned a great deal not only from my advisor but from the rest of the staff and students involved in the lab."

Forensic Seismology

Jonathan Voyles, a recent graduate of Geology & Geophysics and former researcher with University of Utah Seismograph Stations, spent three years working with Dr. Keith Koper on nuclear discrimination, a discipline within the field of forensic seismology. They researched techniques and strategies to identify movement of the earth that resemble earthquakes, such as nuclear and mining explosions. Jonathan enjoyed applying his knowledge from the classroom to an interesting and unique research project. "You learn fundamental ideas in classes. With research you can build on them, be creative, and problem solve which allows you to learn innovative, interdisciplinary, never-done-before things." In 2020, Jonathan was lead author on a paper published in the peer reviewed journal Seismological Research Letters on his research with Dr. Koper and others. Jonathan is currently enrolled in the PhD Geophysics program at Stanford University.

FACULTY NEWS

Geology and Geophysics Associate Chair

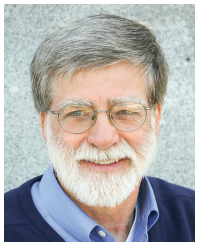
The department of geology and geophysics is excited to announce that **Brenda Bowen** will serve as our Associate Chair for the 2020-2021 academic year. Dr. Bowen is a highly respected associate professor and is the Director of the Global Change and Sustainability Center. She is a skilled leader and known for her collaborative approach and interdisciplinary focus. She is also an active mentor and advisor to graduate students in our department as well as in a variety of interdisciplinary programs.

New Associate Professor

Peter Lippert, department of geology and geophysics, was promoted to associate professor and given tenure.

Retirements

Dr. John Bowman started at the U as an assistant professor in 1977. His research, which yielded more than 70 publications, studied fluid-rock interactions and the mechanisms and rates of reaction during metamorphism of crustal rocks. He uses multiple tools to investigate the history of metamorphic systems, including zircons, quantitative textural analysis, isotopes and trace elements.



He is a five-time recipient of department teaching awards, and has also been recognized for distinguished or outstanding teaching by the college and the university. In 1991 he redesigned the undergraduate petrology course to emphasize modern petrologic theory, petrogenetic processes, observations, and problem-solving skills. Six years later, he chaired the Curriculum Revision committee which developed the undergraduate core curriculum that was taught for the next twenty years. With significant roles in shaping the Reactive Earth and Petrology and Petrogenesis courses, Bowman's impact on teaching in the department will be long felt.

Dr. Felipe Calizaya joined the University of Utah's department of mining engineering as an associate professor in January of 2002. During his time at the at the University of Utah he has participated on numerous committees as well as professionally through the Society for Mining, Metallurgy, and Exploration. In 2009 and again in 2014 he was awarded the College of Mines and Earth Sciences Outstanding Teaching Award. He served as the director of graduate studies in the department and coordinated graduate seminar for many years. In addition, he was graduate advisor to 12 students as well as serving on graduate committees during his tenure.

The author or co-author of more than 65 publications, his research has involved studies to examine pressure balancing techniques to control the risk of spontaneous combustion in coal mining operations. He has investigated methods to improve ventilation and ventilation equipment performance in order to improve the health and safety of miners in the working environment.

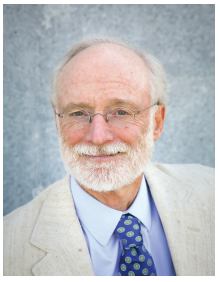
Professor Calizaya regularly taught several courses in the mining engineering program in addition to helping with the department seminars. His contributions to the department, college, and university and his service as a faculty member will be missed by students, faculty, and staff.

Dr. Erich Petersen arrived at the U in 1983. His research concerned the fluid-rock interactions leading to metamorphism and particularly the conditions leading to economic mineral deposits.

For around ten years, Petersen team-taught the Earth Materials course with John Bartley, and afterward developed courses based in field trips to Utah mining areas including Alta and the Tintic mining district. His research frequently took him to Latin America, including Peru where he was born and his father and grandfather worked in the mining industry.

He served as department associate chair to Marjorie Chan in the early 2000s, and then as acting chair during the move to the Frederick Albert Sutton building.

A collaboration with Bill X. Chavez of the New Mexico Institute of Mining and Technology yielded numerous field trips in multiple countries through the Society for Economic Geologists to give students firsthand experience in economic geology.



Dr. John Bartley, a faculty member in the department of geology and geophysics since 1985, chaired the department twice from 1995-1999 and from 2013-2016. Bartley is a fellow of the Geological Society of America and, among other honors, has been recognized by the U Center for Disability Services for "distinguished and exemplary service to students with disabilities." Much of his work involves studies of igneous plutons of the Sierra Nevada and of the Wasatch Mountains, and he taught courses in structural geology, tectonics, and plutonic geology. He advised 18 graduate students and 9 undergraduate research projects.

Alumni News

Thank you to those who responded to our recent alumni news query. Check out what alumni are doing throughout the world!

Atmospheric Sciences

Kerry Challoner Anderson *BS'83* is currently forecasting winds for Weatherflow and teaching at BYU Idaho and American Public University. She previously worked as a TV Meteorologist in Rochester, NY and raised 5 children.

Brian Blaylock *BS'14 MS'16 PhD'19* is a post doctorate research associate at the Naval Research Laboratory's Marine Meteorology Division in Monterey, CA.

Brett Brailsford *BS'16 MBA'19* earned an MBA at the U and now works as a project manager at Huntsman Cancer Institute.

Jordann Brendecke *MS'18* started grad school at the University of Arizona.

Deborah Danielson *BS'92* worked for the National Weather Service in Spokane, Sacramento and Pocatello and was a broadcast meteorologist in Idaho Falls, Boise and Santa Barbara. She now teaches math at a Santa Barbara High School. Her two daughters will be Utes this fall (Jr. & Fr.)

Scott Goeckeritz graduated PA school at Long Island University and is now doing locums-tenens work as a physician assistant in NY and UT. He is currently in New York City helping with the COVID-19 pandemic.

Don Griffith *BS'67* has 49 years of experience in meteorology. From 1999 to 2019 he served as the President of North American Weather Consultants, where he directed weather modification activities since 1977. He has authored or co-authored 44 journal articles, over 200 technical reports, and made more than 90 technical presentations at a variety of professional conferences.

Daniel Hartsock *MS'07* is working for the National Weather Service as a meteorologist. He and his family recently moved from Juneau, AK to Portland, OR.

Dan Herbert *BS'05 MS'15* spent 2 years as Chief Meteorologist for KTWO-TV in Casper, WY and then returned to the U of U for an MS in Civil Engineering. He now works for Sunrise Engineering doing hydrology and hydraulics, and acts as the design lead for their transportation group.

Alyssa Jenkins *BS'13* lives in Moorcroft, WY with her husband and two children which keeps her very busy. She has found a passion in weather education and does occasional social media videos explaining weather phenomenon and facts. She is also registered as a Severe Weather Spotter for the National Weather Service.

Dallin Lewis *BS'10* earned MS degrees in Secondary Education and Management Information Systems. He taught high school for a few years and now works for a cloud software company as an education specialist, where he trains corporate contact center managers how to use software applications.

Jeana Mascio *PhD'18* is currently a Senior Research Associate at Atmospheric and Environmental Research, Inc. in Lexington, MA.

David F. McGinnis *MS'77* worked a variety of positions in Utah, Minnesota, California, and was able to travel all over the world doing tropical meteorology - including Madras India and Coquimbo Chile, Kentucky coal country, and finally Key West. He is now retired in Florida and reports that weather was a great gig!

Trinity Robinson *BS'18* is a first year PhD student at UCSD's Scripps Institute of Oceanography studying climate science, specifically the radiative impacts of dust.

Steven Root *BS'76 MS'80* is AccuWeather's Senior VP of Strategic Initiatives. He builds historical and predictive weather data sets as inputs to estimate energy demand, predict consumer buying behavior, and plan labor scheduling. He is also involved in numerous renewable wind, geothermal and solar energy projects across the western US and mid-continent.

Andrew Snyder *MS'09* started his career as a National Weather Service meteorologist in Wilmington, OH before moving to Sterling, VA where he was promoted to NWS lead meteorologist. He married, bought a home, and got in his first overseas travel after winning airline tickets.

Tyree Wilde *BS'82 MS'84* spent 11 years as a weather officer in the US Air Force, then spent the last 25.5 years at the National Weather Service, most recently as the Warning Coordination Meteorologist at the NWS office in Portland, OR.

H. Michael Yeh *PhD'81* is president and co-owner of Caelum Research Corp., providing technical services to DOD, NOAA, NASA, and GSA.

ALUMNI NEWS (continued)

Geology & Geophysics

Nathan Anderson *BS'15* completed a MS at Idaho State University in 2017 and has since been a geologist at Halliburton.

Steve Burgon *BS'05* has enjoyed almost 30 years in his SL County Flood Control Water Quality job and is active in the Stormwater Coalition programs. With 2 grown children and 2 wonderful dogs, he is happy!

Jonathan Caine *PhD'99* is happily working with the USGS in Denver, focused on the Northern Cordillera with holistic fault zone characterization to better understand tectonic and geologic framework and metallogeny. He has had a number of exciting recent collaborative projects. He reports - all and all life is good, and he has fond memories of his time and the people at the U!

Samuel Carter *BS'19* worked at a local brewery in SLC before accepting a job as a hydrologic technician with the National Park Service (Southwest Alaskan Network - SWAN) in Katmai and Lake Clark National Parks. For the 2020 season, he hopes to be monitoring lake levels, logging temperature profiles and precipitation chemistry, and monitoring salmon populations for methylmercury concentrations.

Jenna Chamberlain *BS'19* Is a geotechnical engineer at Rio Tinto Kennecott. She rotates tasks every 6 months and gains practical knowledge about hydrogeology applications and project management.

Timothy Chisholm *MS'90* has had a busy 30-year career in the oil and gas industry, helping to uncover over 10 billion barrels of oil equivalent commercial resource. This work included stints with Exxon, Shell, Apache, and now Hess, that took him to areas across the US, Venezuela and Brazil, NW Borneo Malaysia, Egypt, and now the frontier Guyana-Suriname basin. In his free time he enjoys travel, cycling and hiking.

Diane Doser *MS'80 PhD'84* has been a professor at the University of Texas at El Paso (UTEP) since 1986. She received the 2016 Distinguished Service Award from the Seismological Society of America, UTEP's 2017 Outstanding Graduate Mentor Award, and 2019 Fellow of the Geological Society of America. Congratulations Diane! She teaches geophysics classes with research focus on local topics (groundwater availability, agricultural soils, volcanic features) as well as larger scale studies (neotectonics of Alaska, geoscience education).

Thomas Etzel *BS'12 MS'16* completed his PhD at the University of Texas this past spring. His time in Austin has been exciting, stimulating, and unpredictable. He will be starting his professional career at ExxonMobil this fall.

Alex Gonzalez *MS'13* worked for 6 years at Apache Corp and is currently Senior Geologist at Percussion Petroleum II, LLC in Houston TX.

William Haddick *BS'19* has been working as a mine geologist for Graymont, a multinational lime company. Will's work provides geologic support to update block models for limestone quarries in the U.S., Australia, and New Zealand.

Ronald Hansen *MS'80* enhanced his education with a MS in Computer Science, which fueled his career in that field from 1986 to 2015. Now he is relaxing in retirement.

John Hoggan *BS'07, PSM 2011* has worked 12+ years as an LEHS (licensed environmental health scientist) and Emergency Response Coordinator for Salt Lake County Health Department. They have surely had a busy 2020!

Spencer Hollingworth *BS'17* is currently pursuing a Masters in Geology at New Mexico Institute of Mining and Technology.

Saijin Huang *MS'95* enjoys working as a geophysicist with Chevron in Houston.

James (J.D.) Keetley *BS'86* retired after more than 25 years with the Utah Department of Environmental Quality. He now spends his free time searching for the Lost Dutchman Gold Mine (almost found it…)!

Briant Kimball *MS'78* spent 37 Years with the USGS as Hydrologist, with an emphasis on hydrologic tracers to quantify mountain streamflow affected by mine drainage. This work helped government agencies make decisions on where they could do the most good with limited resources, to clean up watersheds. In retirement he still enjoys helping with studies in Italy and the US, and talking shop with a geologist daughter.

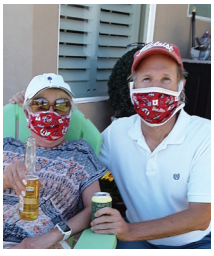
Kelly Kore *BS'02* completed a MS in in Geophysics from UA-Fairbanks (2006) and has since had positions at UNAVCO and TerraSond, before landing in her current position as Geodesist/ Geophysicist at ExxonMobil (2009 - present).

Carrie Levitt-Bussian *MS'13* is the Paleontology Collections Manager at the Natural History Museum of Utah. She curates fossil specimens with her team of students and volunteers, but also facilitates trips with visiting researchers from all over the world. She was honored with the Linda K. Amos Award in 2018 for improving the educational and working environment for women at the U. She spends busy summers on digs and excavations across the western U.S. and is co-developer, scientific expert and star of a series of educational videos called Research Quest.

ALUMNI NEWS (continued)

Cheryl Brown Manning has been teaching Earth and Environmental sciences for the last 24 years at middle and high school levels. With husband **Andy Manning,** (U MS '93, PhD '02) she raised two amazing (adult) children who also love Earth science. In 2019, Cheryl was at NSF-GEO as an Albert Einstein Distinguished Educator Fellow and is now back to teaching while working remotely on a PhD in Geoscience Education at N. Illinois University.

Terry Massoth *BS'77 MS'82* had a great 23 year run as an exploration geologist, initially with Utah International Inc. and then for Australian-based mining giant BHP, spanning 24 countries from north of the Arctic Circle to Ushuaia, Argentina. After being a consultant for 10 years, he is now happily retired by the 18th fairway of Southgate Golf Course in St. George, UT where he enjoys awesome geologic views!



Keegan Melstrom *MS'16 PhD'19* is currently a postdoctoral fellow at the Natural History Museum of Los Angeles County where he is studying how dinosaur teeth change through the Mesozoic and how this is associated with shifting climates and the appearance of new plant groups, such as flowering plants.

Craig Morgan *BS'75* retired in 2018 after a long career in oil and gas exploration (12 years) and serving as senior geologist at the Utah Geological Survey (28 years).

Alex Moyes *BS'09 MS'13 MBA'16* is Director of Geoscience & Engineering for Dominion Energy, overseeing exploration and production of natural gas for customers in Utah and Wyoming. He also completed his MBA and is currently working on a PhD in mining engineering at the U.

Jon Primm *MS'16* celebrated 1 year working as a geoscientist for ExxonMobil and is planning a wedding to fellow geoscientist, Dr. Sharon McMullen coming up soon.

Don Runnells *BS'58* went on for MA and PhD degrees from Harvard that led to his specializations in geochemistry and mineralogy. After stints with Shell Inc., and teaching at UC Santa Barbara, he spent 24 years as Professor and Chair at CU Boulder, teaching and directing 50 graduate degrees. He continued consulting for another 25 years but is now fully retired in Fort Collins, CO with Erika, his wife of 62 years. They've had a tremendous partnership!

Bob Smith *PhD'67* had a very busy 2019! As Distinguished Prof. of Geophysics, he packed in large crowds for his 7 guest lectures affiliated with the Yellowstone Volcano Observatory (YVO), in CA, MT, and WY. As the original founder of YVO, he received a special career award from the Yellowstone Big Horn Research Association. He was also highlighted in a National Geographic documentary on the Yellowstone hotspot that should be coming out soon.

James Smith *BS'72* worked 14 years for oil and gas companies with a break for MS in Geology from BYU, followed by 19 years with the State of Utah on enforcement of coal mining regulations. He retired in 2011 and he and his wife enjoy frequent travels, but not to excess!

Mark Smith *BS'87* spent 12 years with Westinghouse Remediation Services cleaning up hazardous waste and Superfund properties throughout the U.S., which then led to his position as CEO of Soil Safe, Inc., headquartered in Columbia, MD for the last 15 years. His brownfield reclamation and soil recycling company (4 U.S. locations) recycles an average of 2 million tons of petroleum contaminated soil annually.

Peter Stifel *PhD'64* is still enjoying life on his farm on the Chesapeake Bay- growing fresh tomatoes and vegetables, plus watching his lambs and ewes! He had a delightful 3 months in Vero Beach FL, chilling out before COVID-19.

Bill Tafuri *PhD'87* is enjoying retirement in Park City, UT after working in the mining industry for 51 years.

Bob Thinnes *BS'60* spent 40 years in New Hampshire in the steel fabrication and nuclear industries. He reports every day seems like a vacation day being so close to everything.

David Turner *MS'85 PhD'90* is Assoc. Prof. of Environmental Science at St. Mary's University in San Antonio, TX after 20+ years at Southwest Research Institute. He currently is Project Director for an HSI-STEM grant from the U.S. Dept of Education.

Dale van Dam *MS'85* is Vice President of Instruction at Reedley College. He previously spent several years as a groundwater geologist and consultant for the State of Wyoming and private environmental companies (two of which he owned). He also taught part or full time at California State University at Sacramento, American River College and Yuba College.

Chuck Williamson *MS'73* is on his last year of public board service and is looking forward to more time at his home in Sonoma and spending time with his two grandsons in Bellingham, WA.

Taylor Witcher *BS'15* completed her MSc in Geology at LMU Munich, Germany (2017), and is now at Uppsala University, Sweden getting her PhD, studying mechanical deformation of magma in the shallow crust.

ALUMNI NEWS (continued)

Metallurigcal Engineering

Adam Burak *BS'12, PhD'19* joined the Nuclear Engineering & Radiological Sciences Department at the University of Michigan. He has been focused on Versatile Test Reactor projects as well as managing the Thermal Hydraulics lab with Dr. Xiaodong Sun.

Steven Cochran *BS'68* is retired after a metal casting career that lead to positions as chief metallurgist, quality assurance manager, technical director, and general manager of a division. He celebrated his 56th wedding anniversary and is now retired in Ohio.

Nikhil Dhawan *PhD'13* is an Assistant Professor in the Department of Metallurgical & Materials Engineering, Indian Institute of Technology, IIT-Roorkee. He was recently awarded the 2019 Minerals Engineering International Young Person's Award. Congratulations!

Casey Elliott *BS'17* is currently head coach and teacher of physics and calculus at the Climbing Academy, an internationally traveling high school for rock climbers.

Andrew Jamieson *BS'16* completed an MS in Materials Science & Engineering at Virginia and joined the US Naval Air Systems Command (NAVAIR) as a materials engineer, focusing on metals. He has also been gaining experience in propulsion and aerodynamics.

Hyrum Lefler *BS'15 PhD'18* is currently working as a senior metallurgist in the Powder R&D group at Carpenter Technology Corp in Reading, PA. He works primarily with spherical and angular Ti-metal powders for applications in additive manufacturing and powder metallurgy.

Manolete Mena *MS'06* spent 8 years in the investment casting industry as a process/product engineer and metallurgist before moving to National Oilwell Varco 6 years ago. He is the metallurgist for the NOV Orange, CA facility, helping with casting improvements and representing the company in American Petroleum Institute conferences.

Amr Mohamed *PhD'18* is an Asstistant Professor in the Chemical Engineering Department at Cairo University. He started his own company, El Refay for Engineering Services, which is a sub-partner for ANSYS in Egypt. He lives just 3 miles away from the great pyramids!

Devin Rappleye *PhD'16* recently accepted a faculty position in the Department of Chemical Engineering at Brigham Young University.

David Taylor *BS'11* is with FLSmidth Digitalization R&D in Salt Lake City, working on wireless sensor systems for SmartCyclone, with a patent-pending optimizing control strategy and other wireless sensor technology for grinding mills and filtration. From 1996 to 2012 he was a partner in Process Engineering Resources, Inc. (PERI) and primary software developer for the PERI PX2100 XRF On-stream Analyzer.

Tammy Taylor *BS'93* worked in steel sales, fabrication, and design and then for Intel before taking time off to raise 5 children (including triplets). She recently joined Arizona State University as an online enrollment advisor.

Don Wardell *BS'85 MS'87* is Prof. of Operations Management and Francis A. Madsen Scholar at the U's David Eccles School of Business. He recently received the Calvin S. & JeNeal N. Hatch Prize in Teaching – a high honor! He married classmate (and now fellow alumnus), Megan Peterson and they have four children and grandchild #6 is on the way. (pictured above)

J. Richard Wood *BS'66 MS'68* owns Investment Properties LLC, a private real estate investment firm in the Western U.S. and in Mexico. Having been born at a Kennecott Copper Mine in Chile, he does Hispanic Law work and occasionally consults on special accident investigations and metallurgical projects. J.R. is now in semi-retirement from Metallurgy after an exciting career which included work in failure analysis/air craft accident investigation, education, semiconductor memory production and development of several consumer electronic patents. He has enjoyed participation in competitive tennis, soccer, racquetball and darts.

Mining Engineering

John Ballantyne *BS'96* started Forward Motion Medical, a medical manufacturing business, which has grown to be one of the largest manufacturers of foot orthotics and braces in the US. He credits his degree in mining engineering as the catalyst to his success.

Nathan Bench *BS'15* is working for Lhoist North America on a steeply dipping karsted, limestone mine near Virginia Tech. He has worked on major vent changes, DIY location tracking with Raspberry Pi's and geotechnical grouting. (pictured above)

ALUMNI NEWS (continued)

Timothy Hilderman *BS'87* retired after 40+ years in the mining industry. He spent 15 years in WY in the soda ash industry and later was responsible for 16 surface and underground mining operations as NA Director of Mining Operations for the world's largest lime producer.

Bob King *BS'69* (Mining Engineering and Geological Engineering) retired from Colorado School of Mines and is now Emeritus Professor of Mechanical Engineering.

Thomas Lingard *BS'11 JD'18* worked at DMC mining services, a small underground hard rock contractor, before completing law school. He now practices patent law at Ray Quinney & Nebeker in Salt Lake City.

See more alumni spotlights on our website at https://cmes.utah.edu/alumni/index.php

We'd love to add your bio to our webpage and feature you in future communications.

Please send updates to: travis.mcmullin@utah.edu.

CMES Ranked #5 on Giving Day

This past February the College of Mines and Earth Sciences participated in the University of Utah's second annual Giving Day. Thanks to our generous donors, we finished #5 out of 58 participating campus areas in dollars raised. 135 donors gave a total of $26,586 for the CMES Student Support Fund to help with interdisciplinary student groups and student health and wellness. We are so grateful for our Giving Day supporters, and many other generous donors who give throughout the year. Each of you makes a significant impact in the lives of students and on the excellent education and research we strive to provide. If you would like to contribute to the College, you can call TJ McMullin at 801-581-4414, follow the QR code, or give online at https://cmes.utah.edu/development/giving.php. Checks can also be mailed to the Utah Advancement Office at P.O. Box 410481, Salt Lake City, UT 84141-0481. Please indicate how you would like your gift used on the check or online special instructions. Thank you!

Newmont Safety Classroom

The Department of Mining Engineering is excited to announce the completion of the Newmont Safety Classroom renovation in the William Browning Building. The Newmont Safety Classroom and adjacent space housing the Center for Mining Safety & Health Excellence, will be ready to use at the beginning of the Fall 2020 term. This educational space highlights Newmont's dedication ongoing commitment to safety in the mining industry and will be used to proactively build and continuously reinforce a culture of safety that eliminates all workplace injuries and illness through a focus on behaviors, leadership and risk management.

Through this renovation and future equipment installations, the Department will be able to access new teaching technologies to allow better course delivery and provide a modern space for professional development, student education and community outreach. This was all made possible through Newmont's generous $500,000 contribution to the project. Thank you to our friends at Newmont!

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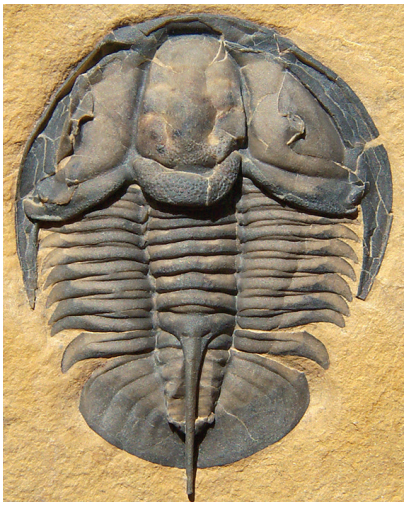
University of Utah Fossil and Mineral Collection



From Cambrian-age jellyfish to topaz and rare red beryl, the state of Utah is home to some amazing fossils and minerals! The University of Utah fossil and mineral collection webpage showcases some of these amazing materials which have been gathered by professors, graduate students, and local rock-hounders for almost 100 years!

The U of U collection is housed on campus in the Fredrick Albert Sutton Building (FASB), and much of the materials may be seen mounted on walls or in display cases all around the building. Quintin Sahratian, rock prep manager for the Department of Geology and Geophysics, curates these rare and wonderful specimens. Quintin has spent a great deal of time maintaining and organizing these materials as they are a significant departmental resource for teaching and as a record of amazing localities to find geological specimen.

However, unless one is taking a geology class at the U or working in FASB, these wonderful specimens are inaccessible. With this in mind, we put together a website to display these materials, and make them more accessible to a wider audience. Check out the website: https://fossil.utah.edu/.

The website is organized by geological formation, all of which are found here in Utah. Some favorite fossils in this collection are the 520-million-year old jellyfish! Carbonized jellyfish from the Cambrian-aged Marjum Formation, House Range, UT, are very rare fossils. Although jellyfish have been around for hundreds of millions of years, these animals are usually very rare to find. This is because jellyfish lack hard body parts. Hard body parts like shells, teeth, and bones typically fossilize more easily than soft body parts and tissues. To fossilize a jellyfish, it must be buried in sediment quickly so that scavenging animals and bacteria do not have a chance to gobble it up.

With this first version of this website, which went live in February, we showcase rarer examples in the U of U collection. These fossils and minerals, however, only scratch the surface of the drawers and drawers of fossils, minerals, and rocks in the basement of FASB. Moving forward, we plan to continue updating the website with more images from the extensive fossil collection, adding geologic maps and detailed rock descriptions of significant Utah formations, and uploading legacy curation notes detailing the human history which led to the U of U collection.

Please enjoy perusing some of Utah's beautiful rocks and fossils! Remember that geology is all around you. Some of these cool fossils can be found right here in the foothills of the Wasatch! - *Zachary Wistort*

For more news:

https://cmes.utah.edu

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