WHAT ON
FALL 2021

EARTH

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

BEAUTY IN THE EARTH SCIENCES

CROSS CAMPUS COLLABORATION

MORE FOR U

College of MINES & EARTH SCIENCES
THE UNIVERSITY OF UTAH

Photo credit: Kristan Jacobsen

The William Browning and Frederick Albert Sutton buildings - not just buildings but a destination.

Hello friends of the College of Mines and Earth Sciences. As we start our 2022 academic year, we are back to in-person classes, research is going strong, and we are functioning with as much normalcy as possible during these anything-but-normal times. Last year when we were teaching and collaborating entirely through Zoom or Teams, time seemed to blur, and I think it's fair to say that none of us felt quite right at times. It's not the way humans were meant to interact.

Although challenges remain, we are excited to be back to a three-dimensional experience. I was talking to a colleague in the confluence of the Sutton building recently and they remarked, "this place has a great vibe. It's different from other places on campus", referring to energy and atmosphere that is present daily in our buildings again. You can feel the collegiality and collaboration everywhere you go. The Browning and Sutton buildings have become destinations for people across campus to meet, study, or just hang out. We are also privileged to work in buildings that serve both as teaching tools and architectural examples of earth-art.

In this volume of What on Earth, you will learn about some of the collaborative and interdisciplinary work happening in the hallways, classrooms, and indoor and outdoor laboratories of CMES. Much of this volume is focused on the important work that our students, faculty, and staff are doing to better understand, monitor, and communicate issues associated with our environment. In addition, you'll find some fun but important stories on collaborations and communication through the arts. Take special note of the cover of this volume which highlights a spectacular creation donated to the college by students in our art department (see details on pages 1 and 17). This mural, entitled Walking in Beauty, is now a fixture of the Browning Building, accenting the wonderful collection of art and artifacts that decorate the corridors and offices of our buildings.

While the pandemic has helped us see many efficiencies and opportunities for interacting through our computers, I'm constantly reminded of the value of face-to-face communication, hands-on learning, laboratory and field experiences, and ubiquitous interactions with three-dimensional humans in the hallways. The College of Mines and Earth Sciences is an inclusive and welcoming place. If you happen to be in the neighborhood, please stop by for a cup of coffee, wander around and enjoy our displays, or just say hi. Stay vigilant and happy. Wishing all of you a healthy and increasingly-more-normal year. - *Dean Darryl Butt*

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Photo credit: Allyson Rocks, CSME

Photo credit: Clement Bataille, University of Ottawa

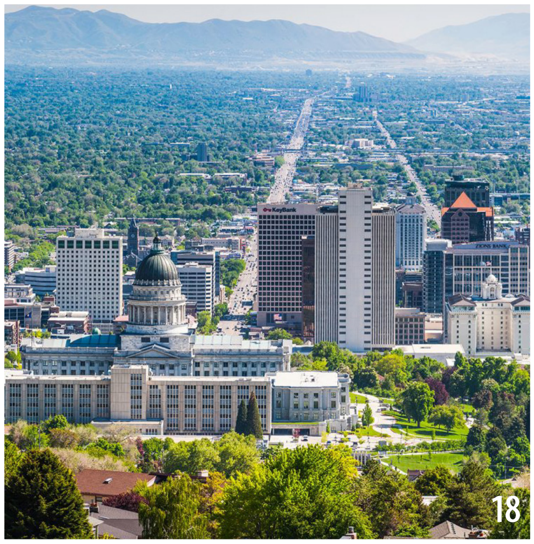
Wasatch Environmental Observatory Watershed

Photo credit: Thad Kelling

ON THE COVER: *'Walking in Beauty,' a mural created in collaboration with the University of Utah's Department of Art and Art History. Professor V. Kim Martinez worked with the following students to create a community based mural that reflects both the hard sciences and the human nature of art: Mikee-A-Lah Parrish, Victoria Dennis, Casidy Giles, Nelson Morales, William Oviatt, Haydar Rasoulpourarnaei, and Connor Weight.*

Photo credit: Anton Wroblewski

Photo credit: David Prettyman



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Revolutionizing Science Classrooms

Master of Science for Secondary School Teachers

By Lisa Potter, science writer, Marketing & Communications

Photo credit: Allyson Rocks, CSME

This year, Utah's students are entering revolutionary science classes. It's not just about COVID-19 — the Utah State Board of Education approved new science standards that shift the learning framework from a lecture-based model to one where students think and act like scientists as they explore real-world phenomena. Graduates of the University of Utah Master of Science for Secondary School Teachers (MSSST) program are uniquely prepared to meet the challenge.

The program supports teachers who want to earn a master's in science while still actively teaching in their classrooms. The scientific disciplines vary between cohorts, but the aim remains consistent — to master in-depth content knowledge, learn pedagogical techniques, and develop leadership skills. The program culminates in an intensive 8-week research experience with a U scientist and a presentation of their findings to a committee. The students graduated with their M.S. in December.

"Because science teachers are in high demand, many find themselves teaching in 'out-of-field' areas; teachers trained as biologists are expected to teach physics, etc.," said Jessica Cleeves, program director of MSSST and associate director for Equitable Instruction & Clinical Support at the U's Center for Science and Mathematics Education. "MSSST isn't about writing lesson plans. It develops educator capacity by building teachers' content expertise and research experience.

The 2018-2020 MSSST cohort of 22 teachers focused on earth sciences through significant support from the College of Mines and Earth Sciences (CMES).

"It's been a really important program to create awareness of the importance of the earth sciences in Utah for middle and high schoolers. The extractive industries are a large part of the state's exports, and preserving land and water resources is incredibly important for Utah's future," said Darryl Butt, dean of CMES. "It's a wonderful program and a great non-traditional outreach tool."

"My driving force this year is to put real science in the hands of kids. They don't have to become scientists, or even be super interested in science. But I want to teach them how to identify truth."

After two years of rigorous coursework, COVID-19 hit and made the in-person lab- and field-based experience impossible. Through teachers' resilience, faculty's flexibility and commitment, and a tirelessly creative program director, the MSSST graduates entered the school year prepared to transfer virtual research skills into their own modified teaching environments.

Research in a socially distanced world

As faculty strove to understand restrictions and opportunities, Cleeves scrambled to identify new scientists, brainstorm potential virtual projects, and set guidelines about remote mentoring. Ultimately, 14 U faculty members from many disciplines stepped up, with some taking on more students than they had initially planned. Gabriel Bowen, professor of geology and geophysics, mentored three MSSST students over the summer.

"It's a pretty unique opportunity for the teachers, but also for the faculty to have this structured program with highly motivated secondary school science teachers already at the U engaged in science training," Bowen said. "We benefit from having an extra set of eyes, hands, body and brain on site, while providing the enriching experience."

For Bethany Alston, biology teacher at Riverton High School, the MSSST program was a dream come true. She earned a Bachelor of Science in biology but was teaching earth sciences to 7th graders at the time.

"When I started MSSST, my goal was to get a masters and bulk up my scientific knowledge. That goal has expanded astronomically," Alston said. "My driving force this year is to put real science in the hands of kids. They don't have to become scientists, or even be super interested in science. But I want to teach them how to identify truth."

Alston worked with Bowen, whose lab focuses on how carbon and water cycles through ecosystems. Alston's piece of that research was to nail down when forests transitioned between seasons by measuring

REVOLUTIONIZING SCIENCE CLASSROOMS (continued)

the greenness of a given area. She had planned to go on a ten-day road trip to collect data from sites around the United States. The pandemic forced Alston and Bowen to pivot to a virtual project using a database that stores images from phenocams, which take digital, repeated images of ecosystems.

Photo credit: Allyson Rocks, CSME

"At first I was frustrated because that wasn't what I signed up for. Over time, I realized that it helped me understand remote learning and what it would be like for my students," Alston said.

Whitney Beckstead, a fellow 2018-2020 MSSST cohort member, teaches chemistry and environmental science at American Fork High School. She got her bachelor's degree in chemistry from the U and loved teaching but wanted to go farther.

"The thing that's been most impactful is learning about more science. The more I've learned, the more I've been able to make real-world connections to the subject I'm teaching," she said. "Chemistry is everywhere, it's part of life."

A new Earth Sciences cohort, with involvement from CMES, is continuing with the model of online coursework. This new cohort started in Summer 2021 and features 29 teachers from across the state. "The push to move everything online with COVID-19 turned into an opportunity for us to expand the program beyond the Salt Lake Valley," said Ally Rocks, administrative program coordinator of MSSST.

Mining Engineering Department to Assist Greenland Training

The Mining Engineering Department is happy to announce that the University of Utah's proposal to the US Department of State was selected for a $1.2M cooperative agreement to assist Greenland with mine training.

The team, consisting of a partnership between the University of Utah and the University of Alaska Fairbanks, and possessing decades of mining and training experience in the circumpolar north, has come together to assist the Greenland School of Minerals and Petroleum (KTI Råstofskolen, Aatsitassalerinermik Ilinniarfik or KTIR) in advancing its training capabilities to address the growing mining sector in Greenland.

The project will expand KTIR's capacity in terms of facility, expertise and curriculum by developing six courses that enhance KTIR's training offerings in the mining sector, providing training in mine search and rescue, and advising KTIR on the design and construction of an underground mine training facility.
-Kitzia Casasola

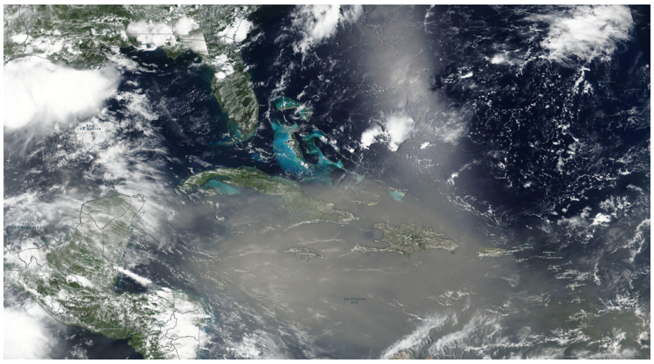
ATMOS 1000: Secrets of the Greatest Snow on Earth

It's no secret that Utah is known for its winter sports. With 13 resorts across the state and the "greatest snow on Earth," our ski industry draws in people from across the world. That's why the Department of Atmospheric Sciences has begun offering an online course to cater to winter enthusiasts: ATMOS 1000, Secrets of the Greatest Snow on Earth. The class teaches students practical skills to prepare for their winter adventures like safely navigating the backcountry and forecasting great snow days. Students also learn the climatological reasons behind Utah's incredible snow, as well as the issues facing the industry and the potential impacts of climate change on mountain sports. The class was taught in Spring 2021 by Jim Steenburgh, professor of atmospheric sciences, and is being offered again in Spring 2022.
-Jake Luman

Courtesy of Jim Steenburgh, Atmospheric Sciences

Undergraduate Research Symposium

Tracking Saharan Dust in the U.S.



This satellite image shows the 2020 Saharan dust plume impacting the Caribbean on June 23, 2020. Source: "NASA Worldview." Image from the Visible Infrared Imaging Radiometer Suite (VIIRS) onboard the NASA/NOAA Suomi National Polar orbiting Partnership Satellite (Suomi NPP).

Every year, varying amounts of dust from the Saharan desert is transported across the Atlantic Ocean, reaching the Western Hemisphere. In July 2020, a significantly large dust plume impacted North America at a record high, presenting concerns for public health and the environment. Atmospheric sciences student **Erin Barry** worked with associate professor of atmospheric sciences Gannet Hallar to map data on concentration and verticality of dust. Her analysis profiled the health and environmental impacts of dust at varying altitudes, and can be used to identify the characteristics of other dust events.

Two New Horned Dinosaurs Discovered in Utah

Geology student **Savhannah Carpenter** worked with associate professor of geology and geophysics Mark Loewen to analyze fossils of two previously undescribed species of horned dinosaurs discovered in the Campanian Wahweap Formation in Utah. These discoveries helped fill out the family tree of the Ceratopsidae, or horned dinosaurs. This family is divided into the Chasmosaurs, which include triceratops, and the Centrosaurs, which include the two new species described by Carpenter.

Photo credit: Patrick Cunningham

Resonant Frequency of a Freestanding Rock Tower

Geology student **Alex Dzubay** and assistant professor of geology and geophysics Jeff Moore used seismic tools to analyze the resonant frequencies of Kane Springs Ledge, a freestanding rock formation in Moab, Utah. Their measurements allow a deeper understanding of the interior structure and stability of the rock formation, as well as how external stimuli such as human-produced vibrations impact the frequencies of Kane Springs Ledge. Dzubay and Moore's work shows that understanding these hidden vibrations of rock formations can help us protect and maintain them.

Mapping the Moon with Moonquakes

Using data collected during the Apollo missions, geology student **Boe Ericksen** and associate professor of geology and geophysics Michael Thorne measured seismic events on the moon. Their study found complexity and variation in seismic data; Ericksen hopes that further research will reveal the presence of layering in the moon's interior.

Winter Water Makes Up for Summer Rain

Despite summertime dry heat, Utah's extreme climate is still home to water features like streams, creeks, and rivers. Geology student **Mallory Philliber**, with mentoring from professor of geology and geophysics Gabriel Bowen, studied the different concentrations of hydrogen and oxygen isotopes in water to determine its source. Precipitation in the winter, typically in the form of snow, has a different concentration of these isotopes than summer rainfall. By analyzing the isotope profile of water in the Red Butte Watershed, Philliber determined that snowmelt is a larger contributor to streamflow than summer precipitation.

Knowlton's Fork in Red Butte Canyon (Jim Ehleringer).

Photo Credit: Jim Ehleringer

Assessing Fire Risks Near Powerlines

Rocky Mountain Power supported research done by atmospheric sciences student **James Powell** and John Horel, chair of atmospheric sciences, to analyze fire weather conditions along powerline corridors in Utah. With nearly 700 miles of Rocky Mountain powerlines across the state, Powell examined climate and weather conditions near these utilities to determine wildfire risks and factors. The findings can be used to better understand and anticipate these wildfires and the risk they pose to power and electricity in Utah. *-Jake Luman*

Photo credit: John Horel

Field Work During the Pandemic

The COVID-19 pandemic brought on an onslaught of sudden changes. Students had to adjust to completing all coursework entirely online, while everyone but essential workers found themselves telecommuting. Zoom became a household name as friends, classmates, and coworkers saw each other only through their screens. But how did the shutdown impact research in labs and in the field?

Pandemic on Storm Peak

Photo Credit: Maria Garcia

Storm Peak Laboratory, Steamboat Springs, Colorado

Dr. Maria Garcia is a research associate at the University of Utah who specializes in aerosols. "The aerosols we measure are anything, man-made or natural," says Garcia. "We're measuring dust, we're measuring aerosols that come from tail pipes, from trees. Trees have this chemical called terpenes — when you smell pine trees, it's because you're smelling that terpene from the pine. We can measure that with instruments."

But much of this research, from data collection out on the field to isotope studies in laboratories, had to be adjusted as the pandemic arrived. "It was difficult; we had to do things mostly alone where it was safe. It delayed our research in some locations," she says. "I was lucky — the morning before they sent us home, I was able to get the instrumentation up in Alta to measure dust. The next day, when I was going to come in, they said, 'Stay home, a pandemic has been declared!'"

Over the last few years, Garcia has been working on continuing research at a lab known as Storm Peak. The mountaintop lab, currently managed by a Desert Research Institute in Nevada, is in the process of being transferred to the University of Utah. At an elevation of over 10,000 feet, Storm Peak draws in researchers from around the world looking to utilize its continuous aerosol measurements — "Often, in the winter, the lab is literally inside clouds, so you can study ice particles and cloud particles directly," says Garcia.

While the pandemic continues, many facilities are reopening in (sometimes limited) capacities — and Dr. Garcia is excited to continue collecting data out in the field, which she believes is vital to solving today's problems. "A lot of people think that scientists study really broad subjects and know everything, but really, we study small parts of larger problems. If we can make contributions in small scales, each solving a piece of a larger puzzle, then we can make big contributions to society." -*Jake Luman*

Perspective of a Lab Specialist

I frequently hear conversations about how much work productivity has been lost over the past few years due to the COVID-19 pandemic. I won't deny that it was hard to transition from working nearly entirely on-site to primarily remote working as U students and employees adapted to a strange new normal, but it's important to recognize what positive lessons were learned during this experience.

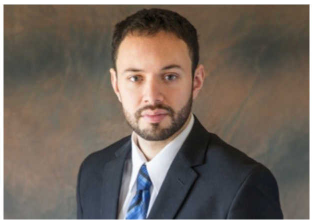
During the initial phases of the pandemic, we all found ourselves suddenly at home juggling work, school, and family, all in the same environment. It wasn't an easy transition for everyone, but we still found ways to make progress on our responsibilities and not let our productivity come to a screeching halt. In the College of Mines and Earth Sciences, we tried to focus our attention on administrative tasks and housekeeping items that are too often overlooked. Because researchers and lab staff were unable to be in the labs doing in-person research, much of their time was devoted to developing and refining standard operating procedures, working out new and innovative theories that could be applied when a return to the laboratory was possible, and writing research grants and going after funding sources.

Research and field operations were more complicated to continue in the midst of the pandemic. The ever-changing recommendations from administration and health officials were hard to keep up with at first. Practicing social distancing in a work environment where collaboration is key was difficult, but we found ways to adapt. The College of Mines and Earth Sciences got to work creating procedures that allowed faculty and researchers to safely return to labs as soon as research operations transitioned from essential to limited, with many research groups jumping right on board and resuming limited operations where possible.

Every group who wanted to restart research operations or conduct field work had to submit a research continuity plan. Each plan had to contain all aspects of the intended research as well as how it would be safely executed. Once all the documentation was submitted, the research group would participate in a discussion with the dean and members of the college safety committee, where they would be updated on new information as well as possible enhancements or adjustments to the specified work plan. The same procedure was followed for field work, allowing researchers to resume field work operations in a limited capacity.

Though there were and are many challenges in our way, our researchers have been able to make progress in labs and out in the field. As the situation continues to change, we will continue to adapt and learn. -*Wil Mace*

Outstanding Teaching Assistant Award



Kevin Mendoza received the 2021 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. Kevin is a geology and geophysics Ph.D. candidate and has been a teaching assistant for several years, this year working under Drs. Peter Lippert and Fan-Chi Lin. Kevin was selected for his unwavering commitment to helping students have a meaningful learning experience and his talent for teaching and communicating with students. One student commented, "I have never in my life met or had a better teacher than Kevin. He makes you feel like you could ask him any question ever and he could explain it so you would end up a master at it."

Outstanding Undergraduate Research Award

Jerry Howard is the recipient of the 2021 Outstanding Undergraduate Research Award for the College of Mines and Earth Sciences. Jerry, who graduated in metallurgical engineering, was nominated by Dr. Krista Carlson. Jerry studies the development, properties, and applications of oxide and metallic glasses. "My undergraduate research experience has been the most important part of my undergraduate education — I have accomplished things and learned skills that will be invaluable to me for my entire career," said Jerry.

NSF Graduate Fellowship

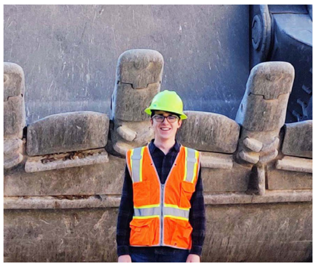
In addition to his OUR award, **Jerry Howard** was also selected to receive an NSF Graduate Fellowship to support his planned doctoral studies at the University of Nevada at Reno. The National Science Foundation graduate research fellow program recognizes and supports outstanding graduate students in NSF-supported science, technology, engineering, and mathematics disciplines who are pursuing research-based masters and doctoral degrees.

Williamson Science Communications Fellowship

The Chuck and Cathy Williamson Science communication fellowships are supported by University of Utah geology alumnus Chuck Williamson and his wife Cathy. This program trains graduate students in science communication and outreach, where the fellows engage with grade 7-12 students to share stories about earth sciences.

Geology graduate students **Hannah Hartley**, **Sam Lopez**, and **Brenden Fischer-Femal**, with help and guidance from Holly Godsey, assistant professor of geology and geophysics, partnered with local schools and teachers to provide learning opportunities for young students. Because of the pandemic, the students had to quickly adapt to a virtual learning style and create virtual learning activities for young students across the Salt Lake Valley.

The Oblad Silver Medal of Excellence



Oliver Holdsworth received the Oblad Silver Medal of Excellence for Mining Engineering, which recognizes senior students with the highest academic achievement. Oliver Holdsworth has accepted a full-time position with Nevada Gold Mines in the Greenfield Talent Program. **Jerry Howard** received the Oblad Silver Medal of Excellence for Metallurgical Engineering. Jerry attended a computational physics workshop at Los Alamos National Laboratory and began his PhD in materials science at the University of Nevada Reno this fall.

Outstanding Student Presentation Award

Courtney Wagner, a PhD

graduate from the Department of Geology & Geophysics, received a 2020 Outstanding Student Presentation Award (OSPA) from the American Geophysical Union for her presentation, "Diversification of iron-biomineralizing organisms during the Paleocene-Eocene Thermal Maximum: Evidence from quantitative unmixing of conventional and giant magnetofossils." OSPAs are awarded to promote, recognize, and reward undergraduate, MS and PhD students for quality research in the geophysical sciences.

Valedictorian

Alex Anderson, an atmospheric sciences graduate, was the 2021 CMES valedictorian. In addition to his outstanding scholastic achievements overall, receiving an honors bachelor of science in atmospheric sciences with a minor in geography, Alex has been active in the atmospheric sciences department and College in many ways. He was the department social media & website assistant, a participant in the Utah Weather Center, an officer in the student chapter of the American Meteorological Society, and a College Student Ambassador. Alex is an effective leader among his peers. He was the top-ranked student academically in the 2021 graduating class and in the top 5 over the past decade.

Outstanding Faculty Teaching Award

Dr. Brenda Bowen, professor of geology and geophysics and Director of the Global Change and Sustainability Center, received the 2021 Outstanding Teaching Award. This student-driven award is considered the highest teaching honor in the College of Mines and Earth Sciences. Students describe Dr. Bowen as energetic, enthusiastic, contagious, passionate, creative, helpful, relaxed, fun, and patient. She has a unique approach to teaching and effectively uses guest lecturers and project-based learning. Dr. Bowen is also an extremely approachable and inclusive teacher; she encourages students and finds new ways and approaches to make projects creative, fun, inclusive and conducive to all learning types.

Honorary Faculty Teaching Award

Dr. Taylor Sparks, associate professor in the department of materials science engineering, received the 2021 Honorary Faculty Teaching Award. The Department of Materials Science & Engineering is in the process of merging with the Department of Metallurgical Engineering within our college, and as such this award was given to Dr. Sparks to honor his dedication to the classroom and his students. Students consistently note the friendly environment that he fosters in his classroom and laboratory courses, and how much he truly enjoys the material that he teaches. They also note his adaption to the challenges caused by the pandemic, indicating that his use of online resources has been incredibly helpful. Overall, students believe that Dr. Sparks is an effective instructor who is rigorous, but wants his students to succeed and will put in the effort to make it possible. They also feel he focuses on making sure students can apply the material to real-world problems.

AGU Fellow

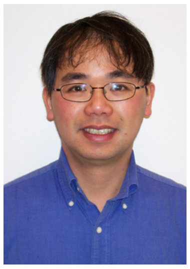
Dr. Tonie van Dam, professor of geology and geophysics, is among the 62 earth scientists named fellows of the American Geophysical Union. Fellows are recognized for exceptional contributions in the earth and space sciences community through breakthrough, discovery, or innovation in their disciplines. Dr. van Dam is the fourth AGU Fellow at the U, joining professor Gabriel Bowen, distinguished professor Thure Cerling, and former associate vice president for research Diane Pataki.

General Patrick E. Connor Award

Dr. Michael G. Nelson, professor of mining engineering, was the recipient of the 2020 Utah Mining Association General Patrick E. Connor Award. This award is given to an individual who has made significant and sustained contributions to Utah's mining industry.

Earth Leadership Program Fellow

Dr. John Lin, professor of atmospheric sciences, is among the newest class of fellows of the Earth Leadership Program. The Earth Leadership Program is a program of Future Earth in collaboration with the Stanford Woods Institute for the Environment and the University of Colorado, Boulder. The Gordon and Betty Moore Foundation and the David and Lucile Packard Foundation also provide funding for the program. Lin will embark on a year-long training program that, "prepares researchers to work together as effective agents of change by providing tools and perspectives to help participants cross traditional disciplinary and sector boundaries."



Online Excellence Award

Dr. Swomitra (Bobby) Mohanty, assistant professor of metallurgical engineering and chemical engineering, was part of the College of Engineering team that received an Online Excellence Award from the University. Alongside Dr. Anthony Butterfield, associate professor of chemical engineering, and Dr. Stacy Firth, assistant professor of chemical engineering, Dr. Mohanty helped develop an online lab course for a first-year class. Additionally, they rewrote assignments to develop projects related to the public health crisis and helped students figure out substitute materials they could find around them, including delivering supplies to students at home.

SEG Ralph W. Marsden Award

Dr. Erich Petersen, professor emeritus of geology and geophysics, is the 2021 recipient of the Society of Economic Geologists Ralph W. Marsden Award. The award was established to recognize "outstanding service to the Society" and is awarded to persons that have a record of exceptional stewardship and contribution to Society affairs.

Evergreen Needles Act as Air Quality Monitors

By Paul Gabrielsen, science writer, Marketing & Communications

Every tree, even an evergreen, can be an air quality monitor. That's the conclusion of researchers at the University of Utah who measured the magnetism of particulate matter on the needles of evergreen trees on the U campus. That measurement, they found, correlated to general air quality, suggesting that analysis of the needles — a relatively simple and low-cost process — could provide a high-resolution, year-round picture of air quality.

"Wherever you have a tree you have a data point," said Grant Rea-Downing, a doctoral student in geology and geophysics. "A tree doesn't cost $250 to deploy. We'll be able to map particulate matter distributions at a very high resolution for very little cost."

The results are published in GeoHealth.

How magnetic particles end up on leaves

Rea-Downing and his colleagues, associate professor Pete Lippert and fellow graduate students Courtney Wagner and Brendon Quirk, are all geoscientists in the Department of Geology and Geophysics whose regular research is on a much different scale than pine needles.

"Day to day," Lippert said, "we move mountains and close ocean basins by using the magnetism of rocks to figure out the geography of former continents."

In a course titled "The Magnetic Earth," Lippert introduced Rea-Downing, Wagner and Quirk to papers by U.K. researchers who measured the magnetism of deciduous leaves to assess air quality.

Particulate matter in the air comes from many sources, including natural windblown dust, brake dust and the byproduct of burning solid or fossil fuel.

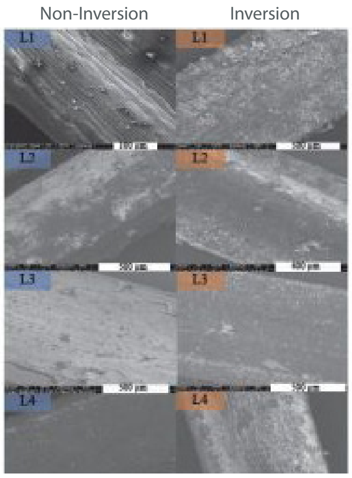
"That's stuff in the air," Lippert said, "and it's got to come out sometime."

When it falls out of the air, some of it falls on tree leaves — and pine needles. Some of the particles contain iron, with enough to be detectable by the kind of high-precision magnetometers that Lippert uses in his geological work. The iron-bearing particulate matter in the air can be too small to see, but magnetism, he said, is a way to see the unseen.

The papers made an impression on Rea-Downing, who saw Salt Lake City's air quality in stark contrast to the normally clean air of his native coastal California. He could easily apply the method in Lippert's research lab.

> *"We're not the first to explore the magnetism of pine needles to monitor air quality, but no one has tried this to study winter inversions in the basins of the American West."*

"The kind of hill to climb to do this was actually quite flat," Rea-Downing said. "We have trees outside, we have seasonally bad air quality and we have a fully equipped paleomagnetic lab, which means that I literally just had to walk outside and pull some leaves off some trees and stick them in a magnetometer."



Scanning electron photomicrographs of evergreen needle surfaces.

"We're not the first to explore the magnetism of pine needles to monitor air quality," Lippert said, "but no one had tried this to study winter inversions in the basins of the American West."

With financial support from the U's Global Change and Sustainability Center, the researchers went to work.

Sylvan sentinels

The team selected four Austrian pine trees on the U campus to sample. Three of the trees were in a line perpendicular to North Campus Drive, a heavily-used campus artery, with each tree successively farther from the roadway. The fourth was near the Union building, away from traffic. They collected pine needles twice: once in June 2017 after a summer of relatively good air and again in December 2017 during some of that winter's worst air quality.

With her particle-filtering dust mask on, Wagner collected the December samples in the hazy inversion she described as a "freezing death fog." Back in the lab, the team carefully prepared the needles into short segments and put them in the magnetometers.

One of their experiments revealed that the magnetization of the December needles was nearly three times higher than the June needles. Another magnetic experiment, conducted at super-low temperatures, suggested the iron-bearing particles deposited during the inversion are extremely small (some as small as 1/5000 the width of a human hair) and found that they're composed of magnetite, a naturally magnetic iron mineral. The team also examined the needles under an electron microscope and confirmed that the December needles were significantly dirtier. The concentration, size, and composition of the particles have all been linked by other studies to the health risks of air pollution.

Other elements in the particulates were associated with catalytic converters, he said, which use chemical catalysts to detoxify exhaust. "And those concentrations, no surprise, are highest near the roadside."

Comparing the trees at various distances from the roadway showed a drop-off in the concentration of magnetic particles over a distance of 50 to 150 feet. That may be due to distance from the cars, the researchers say, but also possibly to elevation, as the transect of trees went up a slight hill.

Artificial pine

PhD student Grant Rea-Downing (left) and Dr. Peter Lippert examine a pine needle site on campus as part of their air quality monitoring study.

Now the team has joined forces with atmospheric scientist Gannet Hallar and chemical engineer Kerry Kelly to explore other questions that the study raised. They developed a new kind of passive air monitor — a 3-D printed artificial pine branch with needles to catch particulates. The artificial needles are installed alongside natural needles and can serve to more clearly understand how and when particles settle on evergreen needles, results they can compare directly to particle distributions measured by equipment in Hallar's and Kelly's labs.

"If we get a strong rain we can go and collect before and after that rain and see if this signal is just being washed away every time you have a rain event," Rea-Downing said. "Or are the biological needles actually absorbing material and actually holding onto that signal for longer than the synthetic needles?"

With every tree as a potential data point, pine needle analysis could give a more comprehensive insight into the what, when and why of air pollution in urban areas, showing variation in air quality on the scale of tens of feet. The analysis is straightforward and inexpensive, Lippert said. "This is easily exportable to any community. It allows us to do more with less, or that's our hope."

Your Hair Knows What You Eat

Millimeter by millimeter, your hair is building a record of your diet. As hair strands are built from amino acids that come from your food, they preserve the chemical traces of the protein in that food. It's a strong enough record to show whether you prefer veggie burgers or double bacon cheeseburgers.

Stephannie Covarrubias Avalos, undergraduate researcher in Ehleringer Lab

A study led by University of Utah distinguished professors Jim Ehleringer, Denise Dearing, and Thure Cerling and colleagues finds that this record reveals a divergence in diet according to socioeconomic status (SES), with lower-SES areas displaying higher proportions of protein coming from cornfed animals. It's a way, the authors write, to assess a community's diet and their health risks. The study is published in Proceedings of the National Academy of Sciences.

For livestock raised in concentrated animal feeding operations, the corn that they eat is incorporated into their tissues. Corn is in a group of plants called C4 plants, which include sugarcane, and photosynthesizes differently than C3 plants, a group that includes legumes and vegetables. So, depending on if the protein you eat was fed C3 or C4 plants, your hair will have an isotope signature reflecting that diet.

To collect samples, the researchers went to barbershops and hair salons in 65 cities across the United States. They also collected samples from 29 ZIP codes in the Salt Lake Valley to intensively study a single urban area.

The results showed variations in hair isotope ratios, both locally and nationally, but within a relatively narrow range. Within that variation, the researchers found, carbon isotope values correlated with the cost of living in the ZIP codes where the samples were collected. The authors found corn-like isotope signatures more predominant among lower SES areas, and that the meat-eaters in the samples got their protein from cornfed animals, likely from concentrated animal feeding operations.

Hair isotope analysis "is not biased by personal recollections, or mis-recollections, that would be reflected in dietary surveys," Ehleringer said. "As an integrated, long-term measure of an individual's diet, the measurement can be used to understand dietary choices among different age groups and different socioeconomic groups." *-Paul Gabrielsen*

Taking Greenhouse Gas Analysis on the Road

Research-grade air quality sensors are costly — around $40,000. For cities trying to monitor their greenhouse gas emissions, the cost may limit the number of sensors they can install and the data they can collect.

But since 2014, the University of Utah has maintained research-grade suites of air quality instruments installed on light rail trains that move throughout the Salt Lake Valley every day. These mobile sensors, researchers estimate in a new study, cover the same area as 30 stationary sensors, providing the Salt Lake Valley with a highly cost-effective way to monitor its greenhouse emissions and fill in gaps in emissions estimates. The study is published in Environmental Science & Technology.

The story of mounting sensors on the trains of the Utah Transit Authority's TRAX system begins in 2009 with then-doctoral student Heather Holmes installing a particulate matter sensor on a train for a study (Holmes is now an associate professor of chemical engineering). With support from UTA, Logan Mitchell, research assistant professor of atmospheric sciences, revived Holmes' project in 2014 with faculty advisors Jim Ehleringer, distinguished professor of biology, and John Lin, professor of atmospheric sciences and co-author of the current study.

The test was a success, and Mitchell partnered with professor John Horel's research group to launch a full-fledged research effort to monitor air quality and greenhouse gases.

Now the program has expanded to additional TRAX lines, and ongoing state funding supports the air quality-monitoring while additional funding from the National Oceanic and Atmospheric Administration supports this study on greenhouse gas emissions.

The cost savings of such an approach is staggering. One research-grade mobile sensor costing $40,000, the authors find, can cover the same area as around 30 stationary sensors costing upwards of $1.2 million.

"Long story short," Mitchell said, "based on our preliminary analysis, semi-continuous mobile measurements on public transit vehicles are a very cost-effective strategy for monitoring emissions in cities." *-Paul Gabrielsen*

Earliest Evidence of Mammals at the Seashore

Today, the rocks of the Hanna Formation in south-central Wyoming are hundreds of miles away from the nearest ocean. But around 58 million years ago, Wyoming was oceanfront property, with large hippo-like mammals traipsing through nearshore lagoons.

In a study published in Scientific Reports, geologist Anton Wroblewski, an adjunct associate professor in the Department of Geology & Geophysics, and applied biodiversity scientist Bonnie Gulas-Wroblewski of the Texas A&M Natural Resources Institute report the discovery of several sets of fossilized tracks, likely from the brown bear-sized Coryphodon, that represent the earliest known evidence of mammals gathering near an ocean.

"Trace fossils like footprints record interactions between organisms and their environments, providing information that body fossils alone cannot," Wroblewski said. "In this case, trace fossils show that large-bodied mammals were regularly using marine environments only eight million years after non-avian dinosaurs went extinct."

Now preserved in sandstone, the tracks are more than half a mile (one kilometer) long and were made by two different animals, one with four toes and one with five. The five-toed tracks are consistent with *Coryphodon*, a semi-aquatic mammal similiar to a hippopotamus.

Today's large mammals congregate near marine environments for a variety of reasons, including protection from predators and biting insects, foraging for unique foods, and access to salt sources, which may have been limited in the tropical forests of North America during the Paleocene. The researchers say ancient mammals may have had similar reasons for seeking out a day at the beach.

According to Wroblewski, the research shows that hypotheses of behavior and evolution based on isotopic, molecular and body fossil data can be empirically tested using trace fossils. "No other line of evidence directly records behaviors of extinct organisms preserved in their preferred habitats," he said. "There's still a lot of important information out there in the rocks, waiting for somebody to spot it when the lighting is just right!" - *Paul Gabrielsen*

Photo credit: Anton Wroblewski

Dr. Anton Wroblewski points to an underprint of a track made by a bear-sized mammal called a Pantodont walking across a tidal flat in southern Wyoming 58 million years ago.

Mysterious Magnetic Fossils

There are fossils, found in ancient marine sediments and made up of no more than a few magnetic nanoparticles, that can tell us a lot about the climate of the past, particularly episodes of abrupt global warming. Now, researchers including Dr. Courtney Wagner and associate professor Peter Lippert from the University of Utah have found a way to glean valuable information in those fossils without having to crush the scarce samples into a fine powder. Their results are published in Proceedings of the National Academy of Sciences.

Magnetofossils are microscopic bacterial iron fossils. Some bacteria make magnetic particles 1/1000 the width of a hair that act like a nano-scale compass. These "magnetotactic bacteria" can then use this compass to align themselves to the Earth's magnetic field and travel efficiently to their favorite chemical conditions within the water.

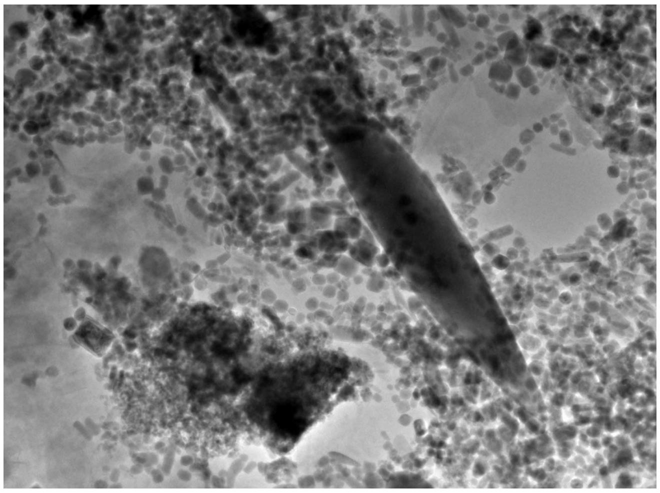
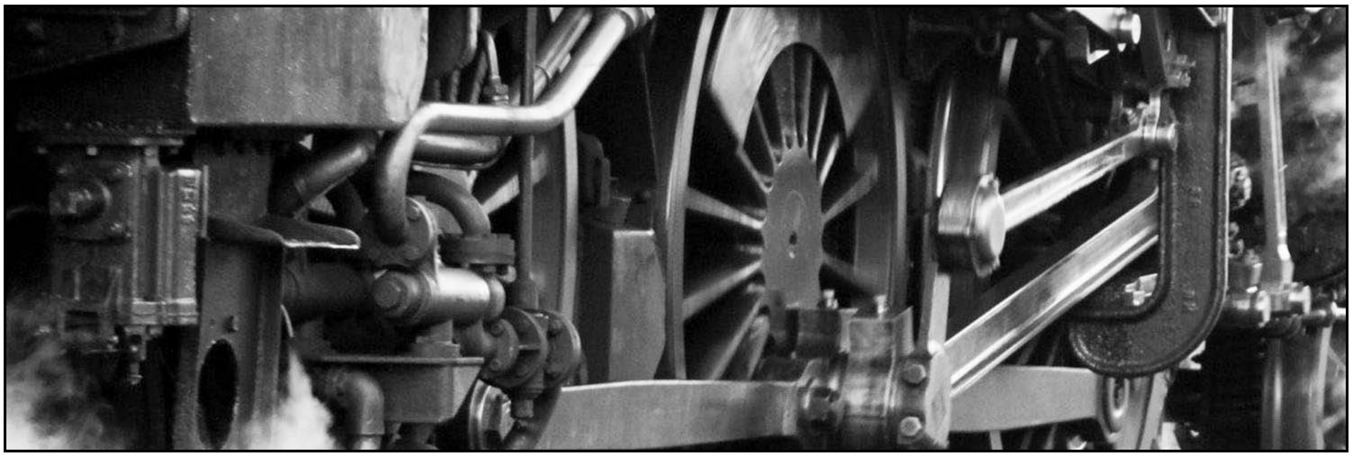


Photo credit: Kenneth Livi, Courtney Wagner, and Ioan Lascu

Giant, spindle-shaped magnetofossil surrounded by conventional magnetofossils from the Paleocene-Eocene Thermal Maximum

At the beginning and middle of the Eocene epoch from 56 to 34 million years ago, some of these biologically-produced magnets grew to "giant" sizes, about 20 times larger than typical magnetofossils. Because the bacteria used their magnetic supersense to find their preferred levels of nutrients and oxygen in the ocean water, and because giant magnetofossils are associated with periods of rapid climate change and elevated global temperature, these fossils can tell us a lot about the conditions of the ocean during that rapid warming, and especially how those conditions changed over time.

Wagner, Lippert and colleagues including Ramon Egli from the Central Institute for Meteorology and Geodynamics and Ioan Lascu at the National Museum of Natural History, found a way to study these fossils without destroying them. They designed a new way of conducting an analysis called first order reversal curve (FORC) measurements. "FORC measurements probe the reaction of magnetic particles to externally applied magnetic fields, enabling to discriminate among different types of iron oxide particles without actually seeing them," said Egli. The information contained in magnetofossils helps scientists understand how oceans responded to past climate changes — and how our current ocean might respond to ongoing warming. *-Paul Gabrielsen*



Our Energy Hunger is Tied to Our Economic Past

By Paul Gabrielsen, science writer, Marketing & Communications

Just as a living organism continually needs food to maintain itself, an economy consumes energy to do work and keep things going. However, that consumption comes with the cost of greenhouse gas emissions and climate change. So, how can we use energy to keep the economy alive without burning out the planet in the process?

In a paper in PLOS ONE, University of Utah professor of atmospheric sciences Tim Garrett, mathematician Matheus Grasselli of McMaster University, and economist Stephen Keen of University College London report that current world energy consumption is tied to unchangeable past economic production. And the way out of an ever-increasing rate of carbon emissions may not necessarily be ever-increasing energy efficiency — in fact, it may be the opposite.

"How do we achieve a steady-state economy where economic production exists, but does not continually increase our size and add to our energy demands?" Garrett said. "Can we survive only by repairing decay, simultaneously switching existing fossil infrastructure to a non-fossil appetite? Can we forget the flame?"

Thermoeconomics

Garrett is an atmospheric scientist. But he recognizes that atmospheric phenomena, including rising carbon dioxide levels and climate change, are tied to human economic activity. "Since we model the earth system as a physical system," he said, "I wondered whether we could model economic systems in a similar way."

He's not alone in thinking of economic systems in terms of physical laws. There's a field of study, in fact, called thermoeconomics. Just as thermodynamics describe how heat and entropy (disorder) flow through physical systems, thermoeconomics explores how matter, energy, entropy and information flow through human systems.

Many of these studies looked at correlations between energy consumption and gross domestic product. Garrett took a different approach; his concept of an economic system begins with the centuries-old idea of a heat engine, which consumes energy at high temperatures to do work and emits waste heat. But it only consumes. It doesn't grow.

Now envision a heat engine that, like an organism, uses energy to do work not just to sustain itself but also to grow. Due to past growth, it requires an ever-increasing amount of energy to maintain itself.

"We looked at the economy as a whole to see if similar ideas could apply to describe our collective maintenance and growth," Garrett said. While societies consume energy to maintain day-to-day living, a small fraction of consumed energy goes to producing more and growing our civilization.

"We've been around for a while," he adds. "So it is an accumulation of this past production that has led to our current size, and our extraordinary collective energy demands and CO_2 emissions today."

Growth as a symptom

To test this hypothesis, Garrett and his colleagues used economic data from 1980 to 2017 to quantify the relationship between past cumulative economic production and the current rate at which we consume energy. Across this period, they found that every trillion U.S. dollars (inflation-adjusted to 2010) of economic worldwide production corresponded with an enlarged civilization that required an additional 5.9 gigawatts of power production to sustain itself. In a fossil economy, that's equivalent to around 10 coal-fired power plants, Garrett said, leading to about 1.5 million tons of CO_2 emitted to the atmosphere each year. Our current energy usage, then, is the natural consequence of our cumulative previous economic production.

They came to two surprising conclusions. First, although improving efficiency through innovation is a hallmark of efforts to reduce energy use and greenhouse gas emissions, efficiency has the side effect of making it easier for civilization to grow and consume more.

Second, the current rates of world population growth may not be the cause of rising rates of energy consumption, but a symptom of past efficiency gains.

"Advocates of energy efficiency for climate change mitigation may seem to have a reasonable point," Garrett said, "but their argument only works if civilization maintains a fixed size, which it doesn't. Instead, an efficient civilization is able to grow faster. It can more effectively use available energy resources to make more of everything, including people. Expansion of civilization accelerates rather than declines, and so do its energy demands and CO_2 emissions."

A steady-state decarbonized future?

So, what do those conclusions mean for the future, particularly in relation to climate change? We can't just stop consuming energy today any more than we can erase the past, Garrett said. "We have inertia. Pull the plug on energy consumption and civilization stops emitting but it also becomes worthless. I don't think we could accept such starvation."

But is it possible to undo the economic and technological progress that brought civilization to this point? Can we now "forget the flame," in Garrett's words, and decrease efficient growth?

"It seems unlikely that we will forget our prior innovations, unless collapse is imposed upon us by resource depletion and environmental degradation," he said, "which, obviously, we hope to avoid."

The kind of future Garrett envisions, then, is one where the economy manages to hold at a steady state — where the energy we use is devoted to maintaining our civilization and not expanding it.

"At current rates of growth, just to maintain carbon dioxide emissions at their current level will require rapidly constructing renewable and nuclear facilities, about one large power plant a day. And somehow it will have to be done without inadvertently supporting economic production as well, in such a way that fossil fuel demands also increase."

It's a "peculiar dance," he said, between eliminating the prior fossil-based innovations that accelerated expansion while innovating new non-fossil fuel technologies. Even if this steady-state economy were to be implemented immediately, atmospheric levels of CO_2 would still reach double their pre-industrial level before equilibrating.

By looking at the global economy through a thermodynamic lens, Garrett acknowledges that there are unchangeable realities. Any form of an economy or civilization needs energy to do work and survive. The trick is balancing that with climate consequences.

"Climate change and resource scarcity are defining challenges of this century," Garrett said. "We will not have a hope of surviving our predicament by ignoring physical laws."

The Spontaneous Combustion of Coal

Spontaneous combustion, called "sponcom" in the mining industry, is a serious health and safety hazard in underground coal mines, accounting for roughly 20% of underground coal mine fires recorded in the U.S. since 1990. Mining engineering professor Felipe Calizaya and research associate professor Jeff Johnson of the University of Utah are studying a way to prevent sponcom.

Sponcom typically occurs in underground coal mines when coal self-heats in mined-out areas. Depending on factors such as the ventilation system and mining method, coal can begin self-heating at temperatures as low as 35° C (95° F). This starts a chain reaction that, if not stopped, will lead to ignition and fire, presenting a serious health risk as well as causing the temporary or permanent closure of mines.

Calizaya and Johnson have proposed the construction and operation of two pressure chambers within an operating mine. The chambers will use monitors to measure pressure differences within the mine, and nitrogen to pressurize the chamber and eliminate air flow. The researchers hope that by using the principles of pressure balancing, they can better understand and prevent sponcom in coal mining operations. *-Jake Luman*

Ancient Ammonoids

Ammonoids, ancestors of today's octopus, squid, and cuttlefish, bobbed and jetted their way through the oceans for around 340 million years beginning long before the age of the dinosaurs. If you look at the fossil shells of ammonoids over the course of those 340 million years, you'll notice something striking — as time goes on, the wavy lines inside the shell become more and more complex, eventually becoming frilled, almost like the edges of kale leaves.

Photo credit: David Peterman

These wavy lines are called sutures, and they reflect the complexity of the edges of septa, the walls that separated the chambers in the ammonoids' shells. Researchers previously focused on the roles of these complex structures in resisting pressure on the shell, but University of Utah researchers provide evidence for a different hypothesis. Complex sutures, they found, retained more liquid through surface tension, possibly helping the ammonoids fine-tune their buoyancy. Their results are published in Scientific Reports.

Using virtual modelling, the researchers custom-designed example septal surfaces in various sizes and with varying levels of complexity. According to David Peterman, lead author of the study and a postdoctoral scholar in the Department of Geology and Geophysics, virtual modeling allowed for the fabrication of hypothetical surfaces as well. The results showed clearly that the more complex structures held more water. And the more complex folds were especially effective at holding water in larger models. The results suggest, Peterman says, that complex septal surfaces may have helped with more precise and active buoyancy control. *-Paul Gabrielsen*

U Students Launch Instruments to Study Utah's Windstorm

On the morning of Sept. 8, 2020, as the Wasatch Front braced for a catastrophic windstorm, three University of Utah seniors lofted a small scientific instrument from a parking lot near Red Butte Canyon, tied to a balloon, that would ride through the storm and collect data and help the student-researchers learn from a severe weather event.

Forming the plan

The three students are Eric McNamee, James Powell, and Andrew Park, all atmospheric sciences majors. All three have been involved in research; Powell has worked with Rocky Mountain Power to predict wildfire risk, and McNamee and Park have worked with the National Weather Service, researching snowfall events and lightning activity respectively. McNamee is also the director of the Utah Weather Center, a student-run weather forecasting service, where Powell is a forecaster. So when the forecasts of heavy winds took shape, the students saw an opportunity.

"Essentially," McNamee said, "we wanted to diagnose the wind and temperature profile of a downslope windstorm at the base of the mountains." Although the National Weather Service routinely launches weather balloons from the Salt Lake City airport, the researchers wanted their instrument to fly near the base of the mountains, where the strongest winds in the storm blew.

James Powell (left) and Andrew Park with weather balloon.

For that, they decided to launch at the mouth of Red Butte Canyon, where the balloon would be in some of the strongest airflow.

Launching the instrument

What they launched isn't what you might think of when you hear "weather balloon." In contrast to the large balloons and suite of instruments that professional meteorologists release, this instrument was tied to a small balloon and housed in a Styrofoam cup.

Powell said the morning was beautiful, with the sun peeking over the mountains. McNamee said the colorful clouds made for a surreal sunrise. "The wind was blowing very hard, with gusts that would blow you a few steps back sometimes," he said. "We even had some snow flurries fall on us before sunrise."

"Launching in the morning was nice," Park adds, "because my car A/C is broken and I got to use my heater."

The data

As they watched the windstorm unfold throughout that Tuesday, the researchers' meteorological training helped them notice things like standing lenticular clouds — long, linear clouds that run parallel to the mountain ranges and form in several lines. These are also called "lee clouds." McNamee said they form when air that has slid down a mountain face bounces off the ground and lofts up to where it can form a cloud, then sinks back down again.

"In spaces where there are no clouds, air is sinking," Powell adds. "Where clouds are, air is rising."

Park said that while many people might think that winds are stronger at higher altitudes, this windstorm featured the highest winds closer to the ground.

Their instrument used 400hz radio communication to transmit temperature and moisture data, which gave insight into the stability of the atmosphere. A GPS transmitter allowed the researchers to see how fast the balloon was rising or descending and provided horizontal velocity data.

The researchers are still studying the data and comparing it to previous weather events to determine why this event was so powerful. The highest winds they measured, more than 80 mph, were about 1500-2000 feet above the ground at the base of an "inversion" temperature layer indicating air descending rapidly down the Wasatch slopes. Normally the air temperature goes down with elevation, while in an inversion, warm air sits above cool air.

The benefits of research

After about 40 minutes, the team lost contact with the instrument, and it likely landed somewhere (safely, due to its small weight) in the south Salt Lake Valley. But the data it transmitted helps these researchers understand the serious impacts of the windstorm and could potentially help residents know what to expect along the entire Wasatch Front if and when these conditions happen again.

McNamee said that at the time he was focused on getting good data from the experiment. "As the windstorm has passed, though, it's cool to reflect back on what we did during an event that is rare for the area based on its magnitude and the effects it had on the Wasatch front," he said.

"The atmospheric sciences department is great at helping students get out and do research," Powell said. "We are a small department where everyone knows each other and the professors and staff really do care. With their encouragement, we are able to add valuable real-world experience to our resumes making us more prepared to enter the workforce." *-Paul Gabrielsen*

Photo credit: Keith Ladzinski, National Geographic

Atmospheric Dust Levels Rising in the Great Plains

Got any spaces left on that crisis bingo card? Pencil in "another Dust Bowl in the Great Plains." A study from University of Utah researchers and their colleagues finds that atmospheric dust levels are rising across the Great Plains at a rate of up to 5% per year.

The trend of rising dust parallels expansion of cropland and seasonal crop cycles, suggesting that farming practices are exposing more soil to wind erosion. And if the Great Plains becomes drier, a possibility under climate change scenarios, then all the pieces are in place for a repeat of the Dust Bowl that devastated the Midwest in the 1930s.

Photo credit: U.S. Department of Agriculture

The research is published in Geophysical Research Letters and was funded by the Utah Science Technology and Research (USTAR) initiative, the Global Change and Sustainability Center at the University of Utah, and the Associated Students of the University of Utah.

In the 1930s, a drought blanketed the Great Plains, from Mexico to Canada. A decade earlier, Midwestern farmers had converted vast tracts of grassland into farmland using mechanical plows. When the crops failed in the drought, the land, now bare dirt, was vulnerable to wind erosion.

"The result was massive dust storms that we associate with the Dust Bowl," said Andy Lambert, lead author of the study and a recent U graduate. "These dust storms removed nutrients from the soil, making it more difficult for crops to grow and more likely for wind erosion to occur."

Around the 2000s, the growth in demand for biofuels spurred renewed expansion of farmland to produce the needed crops. This expansion once again replaced stable grasslands with vulnerable soil. Over five years, from 2006 to 2011, 2,046 square miles (530,000 hectares) of grassland in five Midwestern states became farmland — an area a little smaller than Delaware.

At the same time, the potential for a warmer, drier Great Plains has Lambert and co-author Gannet Hallar, associate professor of atmospheric sciences, fearing for potential desertification.

The focus of the study by Lambert, Hallar and colleagues from the U, the University of Colorado-Boulder and Colorado State University, was to quantify how much the amount of dust in the atmosphere over the Great Plains had changed in recent decades. To do that, they tapped into instrumentation that measures atmospheric haziness from the ground up and from space down.

Altogether, the data cover years from 1988 to 2018. Dust, they found, is increasing in the atmosphere over the whole of the Great Plains by as much as 5% per year.

"I think it's fair to say that what's happening with dust trends in the Midwest and the Great Plains is an indicator that the threat is real if crop land expansion continues to occur at this rate and drought risk does increase because of climate change," Lambert said. "Those would be the ingredients for another Dust Bowl."

"This is an example of the need for the agricultural community in the U.S. to think about adapting and mitigating to a changing climate," Hallar said. "So, if we become more arid, we will need to think about the impacts of land degradation in that changed climate. What we did in the past isn't necessarily what we can do in the future." *-Paul Gabrielsen*

FACULTY NEWS

New Professors

Dr. Huiwen Ji joined the Department of Materials Science & Engineering as an assistant professor as of January 2021. She is a materials chemist studying solid-state properties and their application for energy storage materials. Ji completed her Ph.D. in chemistry at Princeton in 2014, and was previously employed as a research scientist at Lawrence Berkeley National Laboratory in the Energy Storage and Distributed Resources Division.

Ji was drawn to the U for its research-focused and interconnected environment. "My academic experience and research have been highly interdisciplinary," Ji said, "so I really appreciate the U as a place where faculty from different disciplines would come together and have strong collaboration."

Dr. Charles Kocsis was hired as a professor in the Department of Mining Engineering in January 2021. With over 24 years of experience in the mining industry, including 9 years of teaching undergraduate and graduate level mining engineering courses, Kocsis is excited to continue his research and career at the University of Utah.

He is focused on the development of the Mine Ventilation Research Program, researching efficient ventilation systems, cooling methods, and coal dust respiratory disease prevention, and improving the health and safety of the mining industry. "I strongly believe that through the advanced facilities and resources provided by the University of Utah and through constructive collaboration with faculty in the Mining Engineering Department, the College of Mines and Earth Sciences, and the University, these objectives can be achieved," said Kocsis.

Dr. Kocsis was also recently named as the Western Mining Presidential Endowed Chair in Mine Safety.

Dr. Tonie van Dam was hired as a professor in the Department of Geology and Geophysics in 2020. Van Dam has been working in geosciences research since 1993 in various laboratories, later conducting research at the University of Luxembourg as a professor in La Faculté des Sciences, de la Technologie et de la Communication (Faculty of Sciences, Technology and Communication).

She joined the University of Utah because of the reputation of the Department of Geology & Geophysics and its research. "My interests in geodesy as it applies to present-day dry ice melting, changes in the water cycle, and geodynamics fit well with the interdisciplinary research already undertaken by my colleagues in the department," van Dam said. "I was also excited to return to the Rocky Mountains — I did my PhD in Boulder, Colorado."

Research Professor Kris Pankow Named as SSA Secretary

Dr. Kris Pankow, Associate Director of the University of Utah Seismograph Stations and Research Professor of Geology and Geophysics, was recently named as board secretary for the Seismological Society of America (SSA).

The assignment was made earlier this year when the previous secretary became the president-elect of SSA. Dr. Pankow was nominated and then elected by the board to fill the vacancy. The secretary typically serves for over five years (longer than most board members), contributes to several committees, and plays a key role in the governance of the Society.

Dr. Pankow has been a member of SSA for almost 30 years. Before being named as secretary, Dr. Pankow served as guest editor for Seismological Research Letters (SRL), reviewed countless papers, co-chaired annual meeting sessions, and participated on various committees. "I enjoy SSA because it's a smaller group that is really focused on seismology," Dr. Pankow said. "Things pertaining to observational or network seismology are well represented within SSA. I like the meetings and how focused they are. SSA is a great group of people and they excel at bringing the seismology community together."

Professor Keith Koper Directs SSA's New Journal

Starting a new journal is no easy feat. In the 100 plus years the Seismological Society of America (SSA) has existed, they have only launched two journals: Bulletin of the Seismological Society of America (BSSA) and Seismological Research Letters (SRL). But now SSA is adding a third journal into the mix. The Seismic Record is a new journal headed up by none other than **Dr. Keith Koper,** Director of the University of Utah Seismograph Stations and professor of geology and geophysics.

Dr. Koper leads a 12-person editorial team for the new journal. As editor-in-chief, Koper oversees the deputy editor-in-chief, the editor-at-large, and nine associate editors. The Seismic Record differs from SSA's other journals with its short format and quick turnaround publication time as well as being open access. Koper also hopes to provide an opportunity to cover emerging subfields of seismology.

"One of my goals with the new journal is to broaden the scope a little bit," Koper said. "We are hoping to attract manuscripts in the exciting new fields or subfields seismologists are venturing into."

The most exciting and most requested part of the new journal is that it is open access. There's no pay wall and no institution subscription. It is available to scientists and the general public alike, nationally and internationally.

Beauty in the Earth Sciences

By Jake Luman, assistant editor/writer

"Walking in Beauty"

Students and faculty of the College of Mines and Earth Sciences collaborated with the U's Department of Art and Art History to create a community mural "that combines reflections of both the hard sciences and human nature of art," said **V. Kim Martinez**, professor of art and art history.

Following a dialogue between Martinez and Dean **Darryl Butt**, students and staff from both departments met to discuss what to include in a collaborative mural. The resultant ideas were displayed online and put to a vote to determine which mural best represented the college; the winner, "Walking in Beauty," is now displayed in the second-floor entrance to CMES in the William Browning Building and graces the cover of this magazine!

Photo credit: Jorge Arellano & Josh Scheuerman, College of Architecture

Lighting the Night Sky

The first undergraduate cohort of the Dark Sky Studies minor, launched in 2019, finished the year strong with capstone projects focused on outreach and collaboration. Overseen by program director and research assistant professor of atmospheric sciences **Daniel Mendoza**, these projects incorporated research, community advocation, and art to help scientists and the public better understand the importance of eliminating light pollution.

Two capstone groups partnered with mechanical engineering students to deploy drones over Ensign Elementary and the Salt Lake Center for Science Education to measure brightness, while others worked with the Natural History Museum of Utah's Youth Teaching Youth program to present to high school students and community councils. Their collaboration extended as far as New York, as dark sky studies worked with Indigenous artist collective All My Relations to create a 30-foot dark sky mural. All My Relations also collaborated with Mendoza to create an immersive theater piece titled "Revolving Sky," which will debut in 2022.

Stone Voices

Acclaimed American essayist and University of Utah alumnus Terry Tempest Williams worked with **Jeff Moore**, assistant professor of geology and geophysics, and graduate students to learn about how large rock formations communicate — and how they're in danger. In her essay "The Resonance of Stone," Williams meets with Moore and discusses his work studying Castleton Tower, a free-standing rock tower in Utah. Moore and his team of graduate students studied the resonant frequencies of these formations as they hum along to seismic activity, as well as to the loud sounds of human activity, such as helicopters. As Williams writes, "Castleton Tower has a pulse. We have a pulse. The Earth has a pulse." Their study also shows that the human sounds contributing to this pulse might be jeopardizing the structural integrity of stone formations, many of which, such as Rainbow Bridge, are considered sacred by Native cultures such as the Navajo Nation.

"Breath" – Musical Carbon Dioxide

Artivism4Earth, an interdisciplinary environmental activism group based out of the University of Utah, worked with professors **John Lin** and **Tim Garrett** of atmospheric sciences to create a multimedia project centered on air pollution and climate change. Titled "Breath," the piece features 20 years of Salt Lake City carbon dioxide emission data collected by Lin and transcribed by Garrett into discordant and increasingly frantic music performed on the oboe. University of Utah professor of environmental humanities Julia Corbett speaks as the music plays, talking of the air we take into our bodies and the harmful substances we put into it.

Taking the Glitter from Gold to Time Square

New York-based artist Jessica Segall worked with **York Smith**, assistant professor in metallurgical engineering at the University of Utah, to create a video of gold dissolving that was showcased in a digital gallery in Time Square. The video, in which gold coins are shown slowly dissolving in a solution called aqua regia, is part of Segall's exhibition "Reverse Alchemy," which centers on returning gold to the environments from which it was extracted. Segall and Smith also devised a method to transform pure, processed gold into lumpy, unassuming rocks.

"At first, this project seemed ridiculous," Smith said, "but it got me thinking about our research and looking at it from a different point of view."

Clearing the Air with Daniel Mendoza

By Paul Gabrielsen, science writer, Marketing & Communications & Jake Luman, assistant editor/writer

Anyone who lives in Utah knows that air quality is a constant concern. From our summer spikes in ozone and incidences of wildfires

to our infamous winter inversion bringing a thick haze to the city skyline, the urban density and unique geography of the Salt Lake Valley brings health challenges to its inhabitants. Since joining the University of Utah in 2014, first as a postdoctoral researcher and later as a research assistant professor of atmospheric sciences, Dr. Daniel Mendoza has researched Utah air quality and climate change and their relationship to socioeconomic status, public transit, and other factors.

Air quality and social inequality

In an urban area, how do meter-by-meter patterns in land use correlate with zip code-level variations in air quality? And how do both of those dimensions tie into socioeconomic disparities?

These are the questions Mendoza asked as he explored the correlations between land use, air quality, and economic status in Salt Lake County.

He used land cover data from a 1m-resolution LiDAR survey of Salt Lake County that show with high resolution what areas feature tree cover, bare soil, built cover, or open water. Air quality data came from a growing network of stationary and mobile particulate matter sensors throughout the county that is providing an ever-sharpening picture of how air quality differs across an urban area.

"This facilitates an analysis that shows disparities in environmental health along socioeconomic lines," Mendoza says.

The major findings were unsurprising: a higher proportion of tree cover was correlated with higher per capita income, and higher particulate matter exposure was correlated to increased built cover and higher amounts of households living under poverty.

But Mendoza was surprised by how closely tree cover correlated with per capita income, and how closely that tree cover also correlated with longitude, highlighting Salt Lake County's east-west economic divide that becomes an environmental divide when air quality is also factored in.

"Socioeconomically challenged communities suffer from both a lack of green spaces and their related mental and physical health benefits," Mendoza says, "in addition to worse environmental conditions shown by elevated pollutant levels."

"Since the start of the stay-at-home directives, we have actually found that there is a significant drop in traffic with an associated drop in pollution," says Mendoza. "But what we have seen when we look at a zip code analysis is that the traffic drops have been less noticeable in lower income zip codes. We think that it's primarily due to the fact that those populations do have to go to work, whereas higher income populations could telework."

How's the transit weather?

If the words in a weather forecast, such as "cool," "sunny," or "windy," can influence the way you dress for the day, can they also influence whether or not you take public transit?

Mendoza previously studied how transit ridership along the Wasatch Front on the buses and trains of the Utah Transit Authority (UTA) impacted air quality. The impact is greater when more people are riding since low-ridership trips, particularly on older buses, can actually have a net contribution to air pollution.

Around the same time, Dr. Tabitha Benney, an associate professor in the Department of Political Science, was looking at surveys of Utahns that included their reasons for using transit or not. "We were surprised at some of the responses," she says, "and that led me to pursue asking questions about what matters in terms of what could be in the media or how it could be influencing people."

So Mendoza and Benney, along with co-authors Martin Buchert and Dr. John Lin, looked at how media coverage of the weather and air quality correlated with transit ridership. For the years 2014-2016, they scanned 40 local Utah media outlets for words related to weather (such as "cloudy," "freezing," or "summer"), air quality (red, yellow, orange, or green air day, according to the state's color-coded air quality system) and air pollution (such as "ozone," "PM2.5," or "particulate matter"). Then they looked at the transit ridership the day after the media coverage and noted the actual air quality of that day.

Within bus ridership variation, a few media terms related to weather stood out. On average, more usage of the term "good weather" was correlated with more ridership the following day. Similarly, more usage of "winter" was associated with increased ridership, but that may be related to the seasonal nature of U students, the authors say, as the U is the single largest paid pass purchaser from UTA.

When looking at color-coded air quality terms, the researchers found less ridership on the bus system on days following use of "orange air day" and "red air day." That could be due to non-commuter bus users who ride the bus for option transportation choosing to stay home to avoid poor air quality and the cold temperatures that typically accompany these days.

How Salt Lake County's buildings affect its climate future

With warmer temperatures in both the summer and winter, we'll need less natural gas to heat buildings and more electricity to cool them — but what's the balance between those two effects? University of Utah researchers, including Mendoza, used hyper-localized climate models and building projections to find out. The answer, they write, is that buildings' energy use in the future varies wildly, depending on the climate scenario, and that local building policy now could have a big impact on energy use in the future.

For the purposes of this study, Mendoza and his colleagues chose a hyper-local model focused on Salt Lake County. Next, the team built a model of how changes in air temperature would affect the energy usage of buildings. They included the five commercial building types most common in the county: large office buildings, small office buildings, primary schools, full-service restaurants, and high-rise multi-family apartment buildings.

They also looked at building energy standards, which are determined largely by the age of the building. Then, they put in the possible composition of building types that might be present in Salt Lake County by 2040, based on projections by the Wasatch Front Regional Council.

It's not surprising that, with annual average temperatures in Salt Lake County expected to rise between 1.6 and 4.3 °F (0.9 and 2.3 °C) by 2040, less natural gas will be needed for heating in the winter and more electricity will be needed for cooling in summer.

But the researchers found substantial variability in energy use according to building type. Small and large office buildings saw reduced natural gas usage of up to 75% and 30%, respectively, in the 2040 projection. Those types of buildings are projected to comprise a quarter of Salt Lake County's commercial buildings, so the reduction is substantial.

But it is offset by the increased demand for cooling — up to 30% more electricity needed by schools and restaurants and 20% more by high-rise apartments and office buildings, which together comprise more than half of all commercial buildings.

Given the anticipated demand for cooling electricity, Mendoza says, Salt Lake County could choose to generate that electricity through renewable sources, reducing the fossil fuel emissions that underlie the anticipated warming.

VPCAT Research Scholars

Mendoza is part of the 2021-2022 cohort of the Vice President's Clinical and Translational (VPCAT) Research Scholars Program at University of Utah Health. A mentorship program for scientists early in their careers, the Research Scholars Program offers classes, projects, and guidance on "soft skills" such as public outreach, leadership, policy, and authorship, skills which Mendoza says researchers often leave graduate school lacking.

The VPCAT Program lasts two years, during which scholars attend regular meetings on critical research topics that set them on the path to effectively navigating the academic world. Scholars also meet with a mentor every six months to propose career development goals and work on a project in community engagement.

Mendoza is the first faculty member from the College of Mines and Earth Sciences and from the College of Architecture + Planning to join the program, which is generally focused on public health and social sciences. In addition to developing his career skills and knowledge, Mendoza is excited about the interdisciplinary opportunities afforded by his unique background. He is currently working on combining his extensive work in air quality and demographic data with genetics research and public health concerns, such as the COVID-19 pandemic. Through his VPCAT research, Mendoza hopes to foster a better understanding of how groups are impacted differently by disease outbreaks.

Echoes of Pandemic

Canceled events. Shuttered businesses. Debates about face coverings. Although the beginning of the COVID-19 pandemic in spring of 2020 seems like a century ago, an actual century ago, in fall of 1918, the Spanish Flu pandemic rolled through most parts of the globe — including Utah. The newspaper headlines of the time show not only the concern and caution in the early stages of the pandemic but also the eventual drop in cases and easing of restrictions.

The J. Willard Marriott Library launched a digital exhibit to explore the 1918 flu pandemic in Utah through newspaper articles. The articles show how the issues and divisions that have appeared in the COVID-19 pandemic are, unfortunately, nothing new.

Utah Digital Newspapers currently has over 24 million newspaper pages and articles freely available to researchers everywhere. Using this resource, Logan Mitchell, a research assistant professor in the Department of Atmospheric Sciences, developed a research document collecting themes and timelines of the 1918 flu pandemic and collaborated with Marriott Library Digital Library Services Staff to develop an interactive exhibit that features a timeline, topics to explore, and information on how to do your own research using Utah Digital Newspapers. "Seeing the parallels between the 1918 flu pandemic and the current COVID-19 pandemic made working on this project exciting," says Anna Neatrour, Digital Initiatives Librarian at the Marriott Library.


'FLU' MASKS READY TO CHECK EPIDEMIC

Photo credit: Marriott Library

"Looking back at our history helps us put the current pandemic in context," Mitchell says. "It was surprising to me that some of the same interventions we're using today were also used a century ago. Also, some of the challenges we're facing today are reminiscent of what happened back then, despite a century of advances in health research and technology."

"Working on this exhibit has been such a unique opportunity as the research I'm doing is so relevant to my own life and everyone I know," said Kallin Glauser, digital exhibits assistant. "Though the events of the Spanish Influenza happened over 100 years ago, it's like I'm doing history in real-time. And the fact that all my work has been done from home really does make it feel like I'm living through 1918." *-Paul Gabrielsen*

Metallurgy with Marina

Metallurgical Engineering alumnus Marina McNeill Gish, reaches out directly to the public, visiting local high schools and creating content on social media platforms to spread awareness of the vital role metallurgy plays in our daily lives.

McNeill Gish first became interested in engineering in high school, when she worked on a science fair project alongside her brother and former metallurgical engineering associate professor Krista Carlson at the U, studying water purification. By her senior year of high school, the small, personal, and hands-on nature of metallurgical engineering classes at the U drew her in. She graduated with a bachelor's in metallurgical engineering in 2018.

After meeting the VP of Freeport McMoran at a job fair, McNeill Gish began work in hydrometallurgy, using her experience in water purification to develop techniques to extract copper from mineral wastewater. The resultant copper plates were sold to consumers, with the byproduct being safer, cleaner water!

In spring 2021, McNeill Gish began working on outreach efforts for the department and now the college. Her job is to reach out to prospective students and the public to educate them on the research and careers within metallurgical engineering. And what better way to reach modern students than through TikTok? McNeill Gish operates various social media accounts, where she creates videos promoting metallurgical engineering and the College of Mines and Earth Sciences by demonstrating applications of metallurgy and highlighting opportunities within the college.

"Metallurgical engineering is important because we've been using metals for thousands of years," said McNeill Gish, "and we'll continue to use them for thousands of years. Rocket launches, computers, rovers on Mars, laptops, cell phones — our tech is getting faster, more compact, and more advanced. Metals, and metallurgy, drive this process."

McNeill Gish hopes that her work on social media and in classrooms will educate the public on what the college has to offer and will inspire budding earth scientists and engineers to enroll in our programs. Her content can be found on TikTok, YouTube, Facebook, and Instagram @metallurgywithmarina.
-*Jake Luman*

Celebrating our Graduates

The College of Mines and Earth Sciences Convocation, celebrating the classes of 2020 and 2021, was held May 6, 2021 at the Red Butte Gardens Amphitheater. The event was also broadcast via livestream.

Here is what a few of our recent graduates had to say about their next steps:

Chris Rapp (BS'21 Atmospheric Sciences)

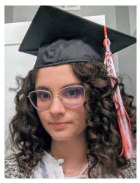
"As an undergraduate student researcher in the Atmospheric Sciences Department, I've developed exceptional research abilities while working with phenomenal faculty. Receiving the 2020 Outstanding Undergraduate Research Award was a great validation of my developing research skills. The award was a strong addition to my graduate school applications. I received 4 PhD offers and ultimately decided to attend Purdue University for a PhD in Atmospheric Sciences. I'll be working with Dr. Dan Cziczo researching aerosols, ice nuclei, and clouds using aircraft instrumentation."

Courtney Wagner (PhD'21 Geology)

"I am starting a 2-year postdoctoral research fellowship at the Smithsonian Museum of Natural History."

Jano Farah (BS'21 Metallurgical Engineering)

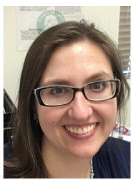
"I recently graduated in the Spring of 2021 from the Department of Material Science with a Bachelors in Metallurgical Engineering. Thanks to my experience working in department labs and from the degree's curriculum I have been able to confidently work at my new job with Ultra Safe Nuclear Corporation (USNC). Not only have I used the skills I've learned, I have also used the skill of learning to work on problems I have not worked on before. I hope to grow with this young company and move up to higher positions as I gain experience."



Oliver Holdsworth (BS'21 Mining Engineering)

"As a recent graduate from the Department of Mining Engineering I could not be happier with how my education facilitated generous and exciting employment opportunities. The student-focused education I received during my undergraduate degree ensured that I entered the workforce at Nevada Gold Mines with ample experience and industry knowledge."

Tennille Jones (MS Earth Sciences Teaching)



"I am currently working as a 7th grade science teacher at Summit Academy Charter School in Draper. I plan to continue working there and have really appreciated how I have grown as a teacher from my master's program. I plan to apply everything I have learned to serving my students and improving education in my school."

Congratulations to all of our recent graduates. We wish you great success and hope you will stay in touch with us. You are always welcome at the College of Mines and Earth Sciences!

Thank You to Our CMES Donors!

Despite the pandemic-induced challenges of the past year, CMES alumni and friends continued to show their dedicated support for our students and faculty through generous philanthropic contributions. Here are a few highlights:

This past February, **226 donors gave $94,132 to support student scholarships and other initiatives in the College as part of the University of Utah's third annual UGiving Day.** Thanks to UGiving Day contributions, as well as other donations, we were able to award $743,800 in scholarship funding to 155 students. These scholarships make a world of difference to our students as they pursue their degrees. Thank you to all our wonderful donors and friends!

Earlier this year, **Michael and Diana Yeh established the Professor Kuo-Nan Liou Endowed Scholarship in the Department of Atmospheric Sciences**. Professor Liou spent 22 years as part of the atmospheric sciences faculty, including time as department chair. During his time at the University of Utah, he mentored over two dozen MS and PhD students, including Michael Yeh (PhD 1981). Unfortunately, Liou passed away while the scholarship was being set up, but it will provide a meaningful way to honor his legacy in the department. Thank you, Michael and Diana, for establishing this scholarship endowment in his name!

We were saddened by the recent passing of Marelynn Zipser, wife of professor of atmospheric sciences Ed Zipser. Marelynn and Ed have been very generous philanthropic supporters over the years and provided a very generous bequest to the college upon her passing. Marelynn's memory and legacy will live on in the lives of our students, faculty, and staff. Thank you, Marelynn and Ed!

For more information on how you can further your legacy and impact in the College of Mines and Earth Sciences, please contact our Development Director, TJ McMullin, at 801-581-4414 or travis.mcmullin@utah.edu. If you are ready to contribute to the college, you can also follow the adjacent QR code or visit https://cmes.utah.edu/development/giving.php. Checks can be mailed to the University of Utah Advancement Office at P.O. Box 58006, Salt Lake City, UT 84158. Please indicate how you would like your gift used on the check or online special instructions. Thank you so much for supporting our efforts! -*TJ McMullin*

How U Alumni Helped Invent the Catalytic Converter

Utah still has hazy, smoggy and even hazardous air days, but the air today is significantly cleaner than it was in the early 1970s. Back then, car tailpipes released pure exhaust practically straight from the engine, clogging the skies. But this changed in the 70s with the invention of the catalytic converter, a device that routes exhaust through a ceramic substrate coated with a catalytic washcoat that can contain platinum, palladium and/or rhodium. These elements act as chemical catalysts to convert toxic gases in exhaust to carbon dioxide, nitrogen and water. The catalytic converter has saved over 40 billion tons of carbon monoxide and other toxic gases from entering the air we breathe.

The ceramic honeycomb structure at the core of the catalytic converter was invented at Corning Incorporated in upstate New York in 1971, and the first name on the patent is Rod Bagley, a University of Utah alum (BS '60, PhD '64). The technology-commercial interface was directed by another U alum, Dave Duke (BS '57, MS '59, PhD '62).

Willard Cutler, a U grad himself (BS '89), is now Division Vice President & Commercial Technology Director for Corning's Environmental Technologies division that focuses on ceramics for emissions control. We spoke with Cutler to hear how the catalytic converter came to be, and how U alumni contributed to an innovation that changed the world.

What's the history behind the catalytic converter?

The idea of a catalytic converter had been around since the 1950s, with various configurations investigated. There were no regulations that required their use at that time. There were three requirements: it had to be relatively cheap, it had to remove the pollution and it had to be durable enough to last the life of the car. In 1970, President Nixon created the Environmental Protection Agency. At the end of that year, the Clean Air Act was signed, which went into effect for model year '75, which practically meant the vehicles sold in '74 had to implement catalytic converters.

Where does Corning enter the story?

Corning had several potential alternatives for how to make a honeycomb-like structure that you can put a catalyst on to do pollution removal. The story intersects with the University of Utah with Rod Bagley, who got his PhD in ceramic engineering from the University of Utah. He had an idea about how to make a honeycomb and he sketched it out on the blackboard, but his colleagues said, "Eh? I don't really see it."

So, he ran out to the high bay area where all the furnaces are, got some soft refractory brick and used a diamond saw to make a 3-D model. When he showed it to them, they said, "Wow, that might work!" So, he filed for a patent on this idea.

Ford was the first car company to adopt this technology and they gave Corning an order. The problem was, we didn't even have a factory. The other problem was that car companies said, "We're going to make our engines so good that we won't need your device after about five years." So, Corning built a factory in a year and depreciated it over five years. That was 1972. And, of course, it's been nearly 50 years. Now there are many factories all over the world making these, but that's, in a nutshell, how these two guys from the U made a tremendous contribution.

Billions of tons of pollution have been removed because of this invention. Now almost every car in the world has this ceramic honeycomb underneath it. I tell this story to students to inspire them with how individuals can make a difference and although not everybody can have the brilliant idea, it takes literally hundreds and thousands of people to make these ideas work pragmatically. It's a cool story. -*Paul Gabrielsen*

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Mummy Pigments

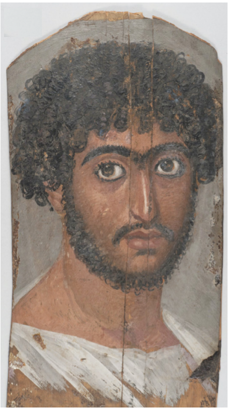

Photo Credit: "Portrait of a Bearded Man" (Walters Art Museum #32.6), dated c. 170-180 CE from Roman Imperial Egypt

How much information can you get from a speck of purple pigment, no bigger than the diameter of a hair, plucked from an Egyptian portrait that's nearly 2,000 years old? Plenty, according to a new study. Analysis of that speck can teach us about how the pigment was made, what it's made of, and maybe even a little about the people who made it. The study is published in the International Journal of Ceramic Engineering and Science.

"We're very interested in understanding the meaning and origin of the portraits and finding ways to connect them and come up with a cultural understanding of why they were even painted in the first place," says materials scientist Darryl Butt, co-author of the study and dean of the College of Mines and Earth Sciences.

The portrait that contained the purple pigment came from an Egyptian mummy, but the mummy wasn't decorated the way you might usually associate with Egypt — not like the golden sarcophagus of Tutankhamen, nor like the sideways-facing paintings on murals and papyri.

The portrait, called "Portrait of a Bearded Man," comes from the second century when Egypt was a Roman province, which is why it's more lifelike and less stylized than Egyptian art of previous eras. Most of these portraits come from a region called Faiyum, and around 1,100 are known to exist. They were painted on wood and wrapped into the linens that held the mummified body. The portraits were meant to express the likeness of the person, but also their status — either actual or aspirational.

The man in this particular portrait is wearing purple marks called clavi on his toga, a symbol of his status. "Since the purple pigment occurred in the clavi — the purple mark on the toga that in Ancient Rome indicated senatorial or equestrian rank — it was thought that perhaps we were seeing an augmentation of the sitter's importance in the afterlife," says Glenn Gates of the Walters Art Museum in Baltimore, where the portrait resides.

Through a microscope, Gates saw that the pigment looked like crushed gems, containing particles ten to a hundred times larger than typical paint particles. To answer the question of how it was made, Gates sent a particle of the pigment to Butt and his team for analysis. The particle was only 50 microns in diameter, about the same as a human hair. With that particle, as small as it was, the researchers could create even smaller samples using a focused ion beam and analyze those samples for their elemental composition.

Ancient purple dyes initially came from a gland of a genus of sea snails called Murex. Butt and his colleagues hypothesize that the purple used in this mummy painting is something else — a synthetic purple. The researchers also hypothesize that the synthetic purple could have originally been discovered by accident. The final color may be due to the introduction of chromium into the mix.

From there, the mineralogy of the pigment sample suggests that the dye was mixed with clay or a silica material to form a pigment. Butt, an accomplished painter himself, says that pigments made in this way are called lake pigments (derived from the same root word as lacquer). The purple pigment was further mixed with a beeswax binder before finally being painted on linden wood.

This isn't Butt's first time using scientific methods to learn about ancient artwork. He's been involved with previous similar investigations and has drawn on both his research and artistic backgrounds to develop a class called "The Science of Art" that included studies and discussions on topics that involved dating, understanding, and reverse engineering a variety of historical artifacts ranging from pioneer newspapers to ancient art.

"Mixing science and art together is just fun," he says. "It's a great way to make learning science more accessible." - *Paul Gabrielsen*

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