THE UNIVERSITY OF TEXAS AT AUSTIN · JACKSON SCHOOL OF GEOSCIENCES · 2017 NEWSLETTER

2017 Newsletter

Chicxulub Revealed

A first look at rocks from the crater left by the asteroid that wiped out non-avian dinosaurs

TEXAS Geosciences

The University of Texas at Austin
Jackson School of Geosciences

THANK YOU!

Your gifts help students achieve their dreams.

Dear Alumni and Friends

The devastation that Hurricane Harvey brought to Texas communities in August was a tragic reminder of how vital it is to understand our planet and its processes.

Shortly after the hurricane struck, our scientists, through our Rapid Response program, began to conduct research to understand how Harvey has impacted the coast and offshore Gulf of Mexico. This research will help determine the best ways to deal with many coastal issues in the aftermath of the storm, and how we might better prepare for such events in the future. You can read more about the mission on page 18.

Rapid response efforts on the effects of abrupt, catastrophic geoscience events provide critical science that can benefit society. This is what we strive to do here at the Jackson School of Geosciences. This year's *Newsletter* holds some tremendous examples.

I'd like to draw your attention to the story on page 58 about the scientific coring mission led by Peter Flemings to bring back samples of methane hydrate from beneath the Gulf of Mexico. This is a cutting-edge research project on a potential future energy source that very few schools in the world would be able to mount. We should all be very proud of Peter and his team.

On page 98 you can get a first look at the cores brought up by a team co-led by Sean Gulick from the Chicxulub crater—the impact site of the asteroid that killed all non-avian dinosaurs. On page 68, you will see a roundup up of the work our scientists and researchers are doing on Mars. Here again, these are large scientific missions with breadth and depth few schools could match.

It has been a successful year of science and education at the Jackson School, but one also punctuated by loss. We lost a tremendously talented researcher and friend with the passing of Kirk McIntosh, and a giant in the field with the passing of former UT President and Bureau of Economic Geology Director Peter Flawn. They will be sorely missed, but not forgotten. You will find a memorial to each in the back of the *Newsletter*.

Many of our own in the Jackson School family live and work in communities ravaged by Harvey. We hope that reading this year's *Newsletter* will give you a little respite from the hard work of putting your homes and lives back together. We also hope it will make you proud to be part of the Jackson School family.

We are thinking of you, and you will continue to be in our thoughts.

Sharon Mosher, Dean

COVER: GRANITE FROM THE PEAK RING OF THE CHICXULUB CRATER FORMED BY THE ASTEROID STRIKE THAT WIPED OUT ALL NON-AVIAN DINOSAURS

ABOVE: MEMBERS OF THE JACKSON SCHOOL-LED TEAM CORING FOR SAMPLES OF METHANE HYDRATE IN THE GULF OF MEXICO

OPPOSITE PAGE: ABOVE: PH.D. STUDENTS STEPHEN FERENCZ (LEFT) AND MIKE O'CONNOR IN THE KUPARUK RIVER WATERSHED, NORTH SLOPE, ALASKA. BELOW: THE 2017 GEO 660 FIELD CAMP IN MONTANA'S SAWTOOTH MOUNTAINS

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Core samples from the crater tell the story of the day all non-avian dinosaurs died.

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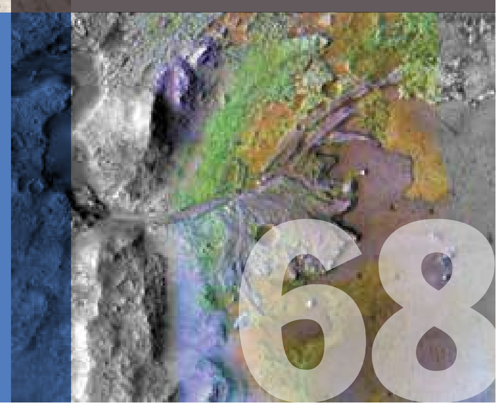
BREAKING BARRIERS

EXPLORING NEW WORLDS



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THE NEWSLETTER, A TRADITION SINCE 1950, IS PUBLISHED ANNUALLY FOR FRIENDS AND ALUMNI OF THE JACKSON SCHOOL OF GEOSCIENCES AT THE UNIVERSITY OF TEXAS AT AUSTIN.

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RESEARCH HIGHLIGHTS

THE IMPACT THAT FORMED THE MOON MAY HAVE SENT VAPORIZED LIGHT IRON ISOTOPES INTO SPACE AND LEFT HEAVIER IRON ISOTOPES BEHIND.

- *Climate, Carbon & Geobiology*
- *Energy Geosciences*
- *Marine Geosciences*
- *Planetary Sciences*
- *Solid Earth & Tectonic Processes*
- *Surface & Hydrologic Processes*
- *Other*

Finding the Origin of Earth's Iron

Planetary Sciences

The iron at our planet's core is unique among known worlds, having a higher level of heavy iron isotopes than anywhere else in the known solar system. The reason why our planet ended up with the heavy stuff has long thought to be linked to the formation of the Earth's core. But new research led by the Jackson School of Geosciences is calling into question the prevailing theory on the events that shaped our planet during its earliest years.

The research, published in *Nature Communications* in February 2017, opens the door for other competing theories about why the Earth, relative to other planets, has higher levels of heavy iron isotopes.

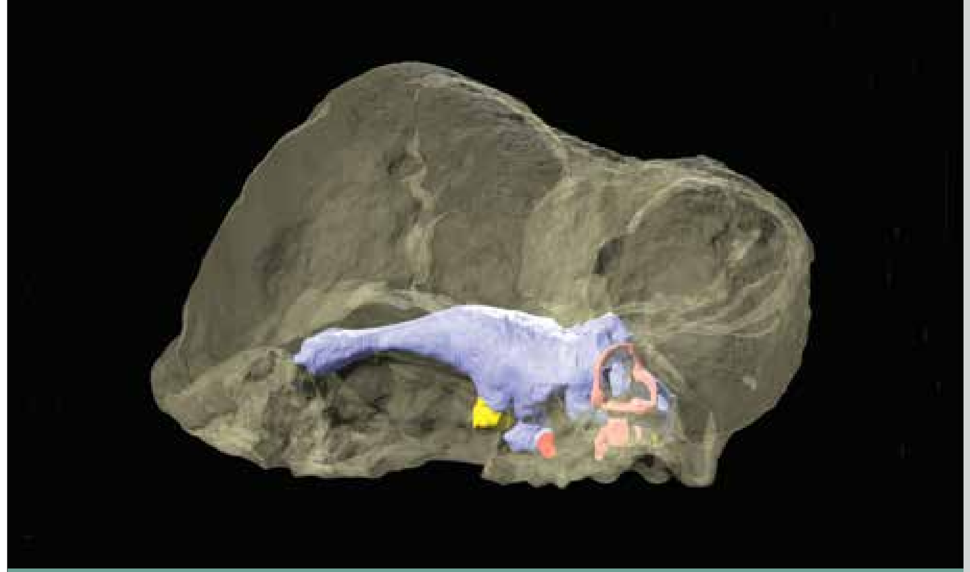
"The Earth's core formation was probably the biggest event affecting Earth's history. Materials that make up the whole Earth were melted and differentiated," said Jung-Fu Lin, an associate professor in the Department of Geological Sciences and one of the study's authors. "But in this study, we say that there must be other origins for Earth's iron isotope anomaly."

Lin said that one of the most popular theories to explain the Earth's iron signature is that the relatively large size of the planet (compared with other rocky bodies in the solar system) created high pressure and high temperature conditions during core formation that made different proportions of heavy and light iron isotopes accumulate in the core and mantle. This resulted in a larger share of heavy iron isotopes bonding with elements that make up the rocky mantle, while lighter iron isotopes bonded together with other trace metals to form the Earth's core.

But when the research team used a diamond anvil to subject small samples of metal alloys and silicate rocks to core formation pressures, they not only found that both types of iron isotopes stayed put, but that the bonds got stronger. Instead of rebonding with common mantle or core elements, the bonds the heavy and light isotopes were already in got sturdier.

Jin Liu, now a postdoctoral researcher at Stanford University, led the research while earning his Ph.D. at the Jackson School. Collaborators include scientists from the University of Chicago, Sorbonne Universities in France, Argonne National Laboratory, the Center for High Pressure Science and Advanced Technology Research in China, and the University of Illinois at Urbana–Champaign.

EARTH'S IRON: NASA/JPL-CALTECH. ANCIENT REPTILE: WITMERLAB AT OHIO UNIVERSITY. TITAN LAKES: CYRIL GRIMA/UT.



A TRANSPARENT VIEW OF THE DOMED SKULL OF *TRIOPTICUS PRIMUS* AND BRAIN

Ancient Texas Reptile Discovered After 70 Years

Climate, Carbon & Geobiology

An extinct reptile that roamed Texas more than 200 million years ago had a strikingly dome-shaped head with a very thick skull and a large natural pit on top that lends the appearance of an extra eye.

The skull of the new species, called *Triopticus primus*, meaning "the first with three eyes," was scanned at the Jackson School of Geosciences CT lab, which allowed the researchers to reconstruct the skull's internal anatomy. Researchers at Virginia Tech led the study that looked at the 230-million-year-old skull found in the Jackson School collection.

The findings, published in September 2016 in the journal *Current Biology*, reveal new clues about the evolutionary history of dinosaurs because the thickened skull roof is nearly identical to that of the distantly related *pachycephalosaur* dinosaurs that lived more than 100 million years later.

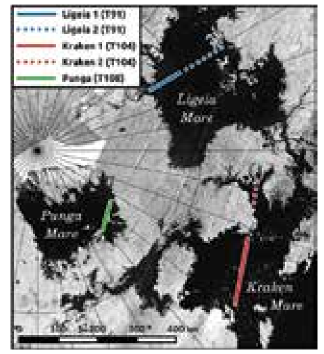
Complete details of what *Triopticus primus* looked like and how big it was are not yet known. For now, researchers only have a fragment of skull.

The team's discovery of this specimen—originally collected by the Work Projects Administration (WPA) in 1940—happened in the Jackson School's Texas Vertebrate Paleontology Collections in 2010, where it had been lying in plain sight for 70 years. Lead author Michelle Stocker was a Ph.D. student and co-author Sterling Nesbitt was a postdoctoral researcher, both at the Jackson School, when they found the specimen. Stocker is now a research scientist and Nesbitt an assistant professor, both at Virginia Tech.

It is not uncommon for new species to be found in fossil collections around the world. The WPA, a Depression-era work program, found so many fossils during its short span of work that they didn't have time to clean all of them.

"These collections are the foundation of natural history research, and this new animal illustrates how exciting discoveries are continually made thanks to the forethought and investment of past generations," said Matthew Brown, co-author and director of the Texas Vertebrate Paleontology Collections.

Jackson School Professor Timothy Rowe was a co-author, as were former Jackson School students Katharine Criswell, now a Ph.D. student at the University of Chicago, and William Parker, now a paleontologist at Petrified Forest National Park.



TITAN'S THREE LARGEST LAKES AND THEIR SURROUNDING AREAS AS SEEN BY THE CASSINI RADAR INSTRUMENT. THE RESEARCHERS USED THE INSTRUMENT TO STUDY WAVES ON THE LAKE SURFACES.

Smooth Lakes on Titan

Planetary Sciences

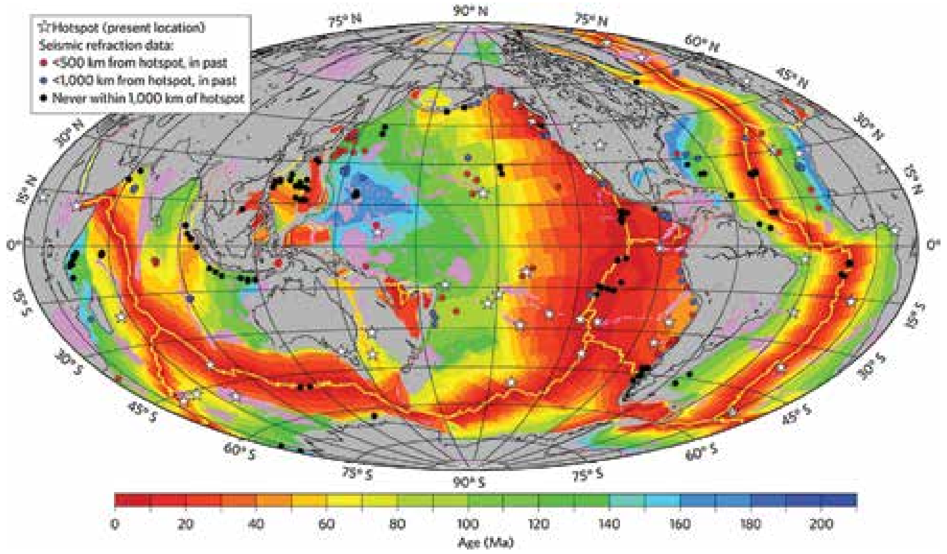
The lakes of liquid methane on Saturn's moon, Titan, are perfect for paddling but not for surfing. Research led by the Jackson School has found that most waves on Titan's lakes reach only about 1 centimeter high, a finding that indicates a serene environment that could be good news for future probes sent to the surface of that moon.

"There's a lot of interest in one day sending probes to the lakes, and when that's done, you want to have a safe landing, and you don't want a lot of wind," said lead author Cyril Grima, a research associate at the University of Texas Institute for Geophysics. "Our study shows that because the waves aren't very high, the winds are likely low."

The research was published in the journal *Earth and Planetary Science Letters* on June 29, 2017. It specifically looked at waves on the three largest lakes in Titan's northern hemisphere: Kraken Mare, Ligeia Mare and Punga Mare. Grima and his team found that waves across these lakes are diminutive, reaching only about 1 centimeter high and 20 centimeters long.

Titan is the largest moon of Saturn and one of the locations in the solar system that is thought to possess the ingredients for life.

Collaborators include researchers from Cornell University, NASA's Jet Propulsion Laboratory and The Johns Hopkins University Applied Physics Laboratory. The research was funded by NASA and the California Institute of Technology Jet Propulsion Laboratory.



A MAP CREATED BY UTIG RESEARCHERS DEPICTING FEATURES OF THE OCEANIC CRUST. THE COLOR INDICATES THE AGE OF THE CRUST. THE MODERN MID-OCEAN RIDGE SYSTEM IS MARKED BY A YELLOW LINE, AND AREAS IN VIOLET OUTLINE LARGE IGNEOUS PROVINCES.

Breakup of Pangea Cooled Mantle and Thinned Crust

Solid Earth & Tectonic Processes

The oceanic crust produced by the Earth today is significantly thinner than crust made 170 million years ago during the time of the supercontinent Pangea.

The thinning is related to the cooling of Earth's interior prompted by the splitting of the supercontinent Pangea, which broke up into the continents that we have today, said Harm Van Avendonk, the lead author of the study and a senior research scientist at the University of Texas Institute for Geophysics (UTIG). The findings were published in *Nature Geosciences* in December 2016.

"What we think is happening is that the supercontinent was like an insulating blanket," Van Avendonk said. "So when these continents started opening up and the deeper mantle was exposed, more or less, to the atmosphere and the ocean, it started cooling much faster."

The research started when Van Avendonk and Ph.D. student Jennifer Harding, a study co-author, noticed an unexpected trend when studying existing data from young and old seafloor. They analyzed 234 measurements of crustal thickness from around the world and found that, on a global scale, the oldest ocean crust examined—170 million year old rock created in the Jurassic—is about one mile thicker than the crust that's being produced today.

The link between crust thickness and age prompted two possible explanations, both related to the fact that hotter mantle tends to make more magma: Mantle hot spots—highly volcanic regions, such as the Hawaiian Islands and Iceland—could have thickened the old crust by covering it in layers of lava at a later time; or the mantle was hotter in the Jurassic than it is now.

Van Avendonk mentioned this problem during a casual conversation with Joshua "Bud" Davis, a Ph.D. student in UTIG's plate tectonics research group and co-author, who said that the group could investigate both of the explanations using computer models of plate movement since the Jurassic and a global database of hotspots.

The analysis ruled out the hot spot theory—thick layers of old crust formed just as easily at distances greater than 600 miles from hotspots, a distance that the researchers judged was outside the influence of the hotspots. In contrast, the analysis supported the hypothesis of mantle heating during the age of Pangea, and mantle cooling after the breakup of the supercontinent.

Paleo Lakes Hold Climate Clues

Climate, Carbon & Geobiology

In Antarctica, some lakes that formed during the last ice age stuck around for up to 10,000 years. The sediment these "paleo lakes" left behind could provide a record for investigating the continent's climate.

"We think of Antarctica as only producing climate history information from ice cores, but these lakes were probably much longer lived than previously thought," said then University of Texas Institute for Geophysics Research Associate Joseph Levy, who led research on the ancient lake remains.

The study was published in April 2017 in the *Geological Society of America Bulletin*.

The research used both old-fashioned radiocarbon dating and newer optically/infrared stimulated luminescence (OSL) dating techniques. The OSL technique dates sediment directly, instead of relying on algal mats and other organic matter as used by radiocarbon methods. The research found that radiocarbon dates were consistently older than OSL results, in some cases up to 10,000 years.

"I hope that it sheds light on the fact that there were relatively recent, long-lived lakes in the terrestrial parts of Antarctica that could be used to collect paleoclimate proxies for reconstructing what's going on at the Antarctic coast," Levy said.

THE REMAINS OF A PALEOLAKE IN GARWOOD VALLEY, ANTARCTICA

PANGEA BREAKUP: HARM VAN AVENDONK. PALEO LAKES: JOSEPH LEVY. DINO-KILLING ASTEROID: JACKSON SCHOOL.

UTIG'S SEAN GULICK (RIGHT) AND IMPERIAL COLLEGE LONDON'S JOANNA MORGAN INSPECTING CORES PULLED FROM THE CHICXULUB CRATER

Dino-Killing Asteroid Made Rocks Behave Like Liquid

Marine Geosciences

When the asteroid that wiped out the dinosaurs slammed into the Earth 66 million years ago, solid rock flowed like a fluid.

The finding was revealed by examining cores taken from the Chicxulub crater during a scientific drilling mission led by the Jackson School of Geosciences and Imperial College London in spring 2016. The results were published in the journal *Science* in November 2016.

The research validates the theory that asteroid impacts cause the surface of planets to behave like a fluid, said study author Sean Gulick, a research professor at the University of Texas Institute for Geophysics (UTIG). It also puts a definitive end to an alternative explanation that suggested that such impacts, which are common on other planets and moons, deform the surface by melting most of the rock around the impact.

"It is the same exact kind of feature that we see on all large impacts on rocky planets, whether it be on Venus, on Mercury or on the moon," said Gulick, who was the expedition's co-principal investigator.

The team took core samples of the peak ring, which is now covered by water and the limestone of the modern Gulf floor. They found that the asteroid, which hit with the force of 10 billion atomic bombs, quickly opened a massive hole nearly 19 miles deep and 120 miles wide.

Gulick said he knew they had solved the mystery of how large impacts affect the surface when the cores revealed an unmistakable pink granite, which is found deeper in the Earth, as opposed to the limestone that was present at the time of the impact.

Researchers found that the roughly 10-mile-wide Chicxulub asteroid, which hit in the Gulf of Mexico near the Yucatán Peninsula, pushed rock up from six miles below the surface to form the peak ring. Those rocks travelled approximately 20 miles in a few minutes, first being pushed outward from the impact, then rebounding upward above the Earth's surface and finally collapsing outward to form a ring of peaks around the center of the impact.

The expedition was conducted by the European Consortium for Ocean Research Drilling as part of the International Ocean Discovery Program and was supported by the International Continental Scientific Drilling Program. The Yucatán Government, Mexican federal government agencies, and scientists from the National Autonomous University of Mexico and the Yucatan Center for Scientific Research also supported the expedition.

Carbon Dioxide Monitoring Down Under

Energy Geosciences

Carbon capture and storage injects carbon dioxide (CO_2) produced by industrial processes deep underground, while environmental monitoring of such sites makes sure the CO_2 gas stays put. Katherine Romanak, a research scientist at the Bureau of Economic Geology's Gulf Coast Carbon Center, travelled to Queensland, Australia, in spring 2017 to run environmental monitoring experiments for a carbon capture and storage project in its preliminary stages.

The Carbon Transport and Storage Corporation Pty. Ltd. Surat CCS Demonstration Project is designed to demonstrate the technical viability, integration and safe operation of carbon capture and storage in Australia's Surat Basin. Currently in the preliminary stages, the project is undergoing assessments and approvals in environmental, social and technical aspects under various government regulations.

Romanak's research involves testing different leak detection methods. One involves testing if simple soil gas ratios can be used for real-time leak detection in hydrocarbon-rich environments. Another project involves testing the degree to which isotopes can be used for leak detection. Romanak's research project is funded by the Australian National Low Emissions Coal Research and Development Ltd. on behalf of the Australian coal industry and the Australian Commonwealth government.

Sweltering Recipe for Southeast Asia

Climate, Carbon & Geobiology

Scientists at the University of Texas Institute for Geophysics (UTIG) have found that a devastating combination of global warming and El Niño is responsible for causing extreme temperatures in April 2016 in Southeast Asia.

The research, published in June 2017 in *Nature Communications*, shows that El Niño triggered the heat, causing about half of the warming, while global warming caused one-third and raised the heat into record-breaking territories. El Niño is a climate pattern that impacts the tropical Pacific, and usually brings warmer temperatures to Southeast Asia in April.

In April 2016, high temperatures in mainland Southeast Asia broke all previous records, exacerbating energy consumption, killing crops and causing human suffering in Cambodia, Thailand and other countries in the region.

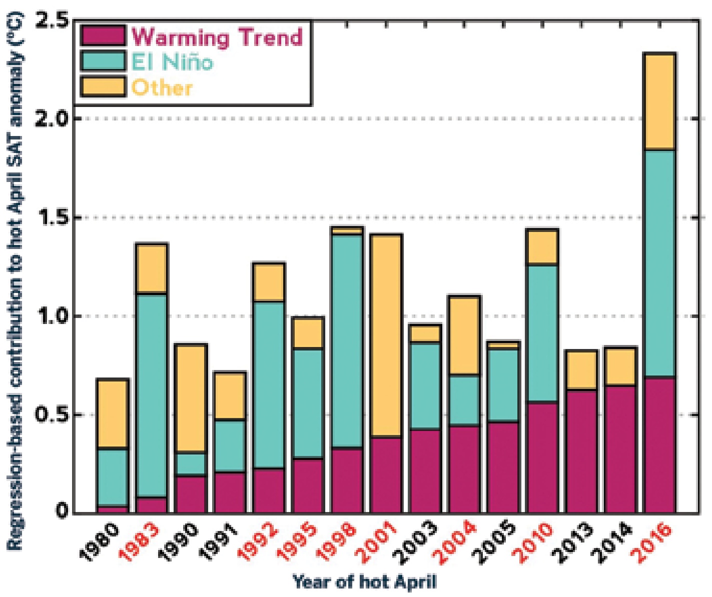
The researchers used computer model simulations designed to disentangle the natural and human-made causes of the extreme heat. They also used observations from land and ocean monitoring systems and found that long-term warming has played an increasing role in rising April temperatures in Southeast Asia. Since 1980, this trend has caused a new temperature record each April following an El Niño.

"The El Niño system primes mainland Southeast Asia for extremes, although long-term warming is undoubtedly exacerbating these hot Aprils," said UTIG postdoctoral fellow Kaustubh Thirumalai, who led the study.

The researchers used statistical techniques to quantify the contributions from El Niño and from long-term warming. Their analysis looked at the 15 hottest April temperatures over the past 80 years. All occurred after 1980, and all but one coincided with El Niño. They found that while the impact of El Niño fluctuated over the years, the impact of global warming has steadily increased over time. Looking at the model predictions for the next 50 years, researchers found that climate change could further amplify the effects of El Niño.

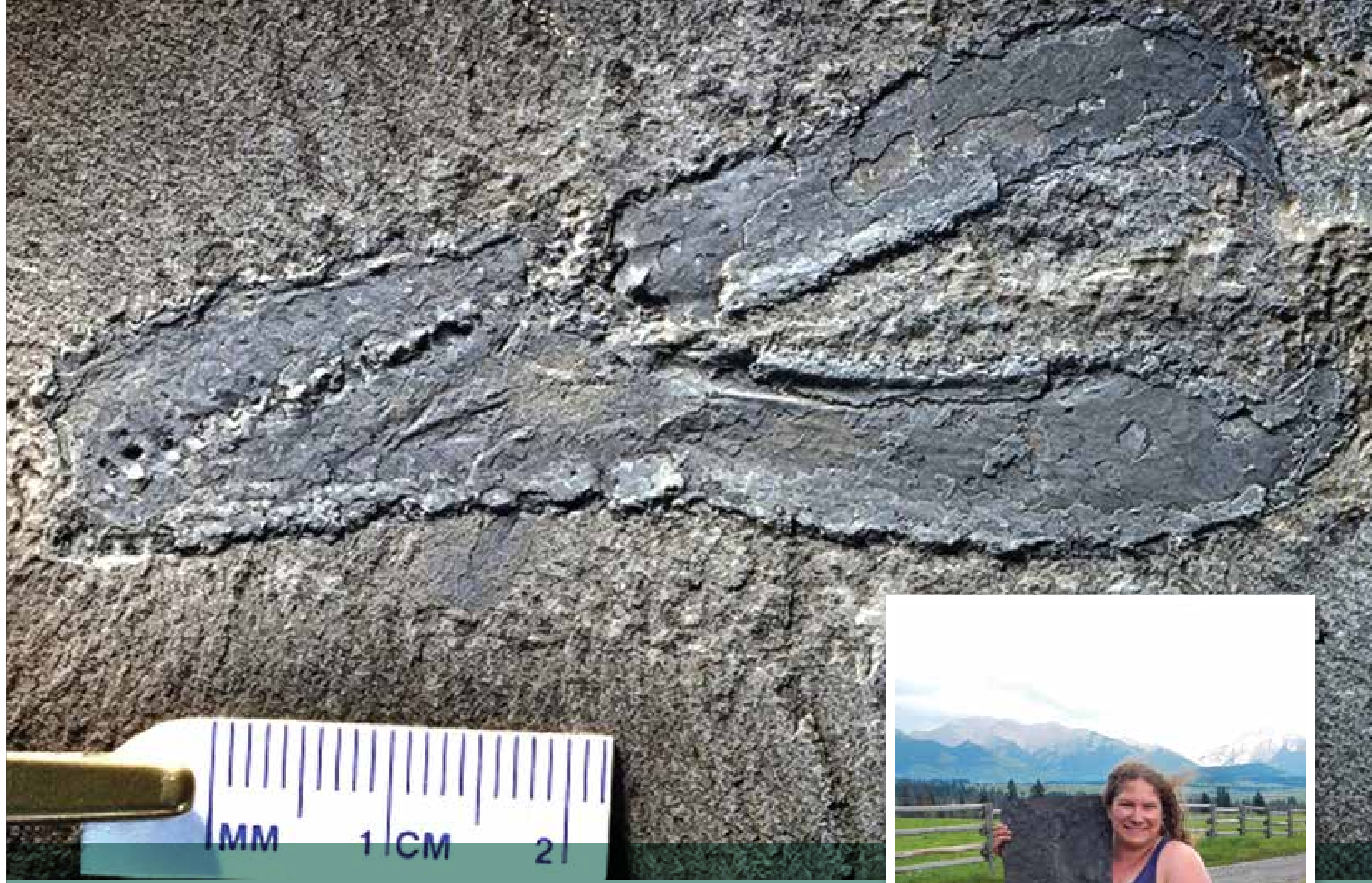
"Because of long-term warming, even a weaker El Niño than the 2015-16 event in the mid-to-late 21st century could cause bigger impacts," said co-author Pedro DiNezio, who is a research associate at UTIG.

Other co-authors include UTIG research associate Yuko Okamuro and Clara Deser, a senior scientist at the National Center for Atmospheric Research.



A GRAPH SHOWING THE RELATIVE CONTRIBUTION OF EL NIÑO (GREEN BARS) VERSUS GLOBAL WARMING (RED BARS) FOR THE 15 HOTTEST APRILS ON RECORD IN MAINLAND SOUTHEAST ASIA

SWELTERING RECIPE: KAUSTUBH THIRUMALAI; EXCEPTIONALLY PRESERVED FOSSILS: ROWAN MARTINDALE.



ABOVE: A LOBSTER CLAW THAT MAY COME FROM A NEW SPECIES FOUND AT YA HA TINDA RANCH IN ALBERTA. **RIGHT:** ASSISTANT PROFESSOR ROWAN MARTINDALE WITH A SLAB OF FOSSILIZED BIVALVES

Exceptional Fossil Site Records Jurassic Reef's Decline

Climate, Carbon & Geobiology

About 183 million years ago in what is now the Canadian town Banff, a marine ecosystem was teeming with shrimp, vampyropods and ichthyosaurs. But then a period of low ocean oxygen made life perish and perish beautifully, turning delicate exoskeletons that aren't usually preserved into exceptional fossils.

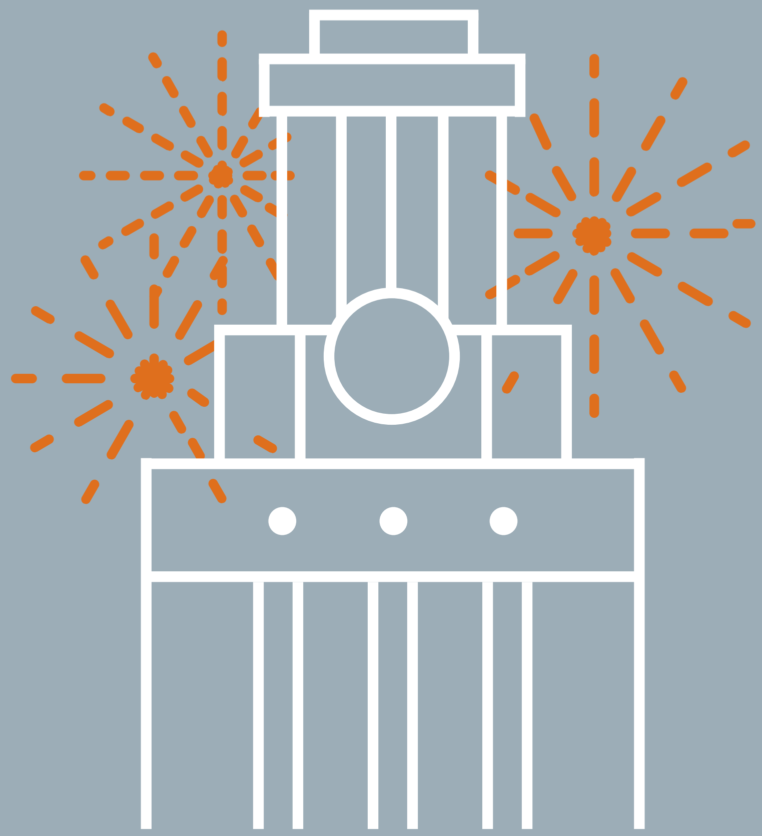
Research led by Rowan Martindale, an assistant professor at the Jackson School of Geosciences, documented the diversity of fossils and investigated the impact the low oxygen event had on the marine ecosystem. The findings were respectively published in *Geology* in January 2017, and in *Palaeogeography, Palaeoclimatology, Palaeoeconology* in July 2017.

Both studies investigate a recently discovered fossil site in Canada located at Ya Ha Tinda Ranch near Banff National Park in southwest Alberta. The site records fossils of organisms that lived about 183 million years ago during the Early Jurassic in a shallow sea that once covered the region.

The fossil site broadens the scientific record of the Toarcian Oceanic Anoxic Event, a period of low oxygen in shallow ocean waters that is hypothesized to be triggered by massive volcanic eruptions.

The fossils show that before the anoxic event, the Ya Ha Tinda marine community was diverse and included fish, ichthyosaurs (extinct marine reptiles that looked like dolphins), sea lilies, lobsters, clams and oysters, ammonites, and coleoids (squid-like octopods). During the anoxic event, the community collapsed, restructured, and the organisms living in it shrunk.

Since the oceanic anoxic event was a side effect of climate change, looking back at ancient marine communities could be a window into the potential impacts of ongoing and future climate change.



Jackson School Ranks Among **Best in the World**

Research Excellence

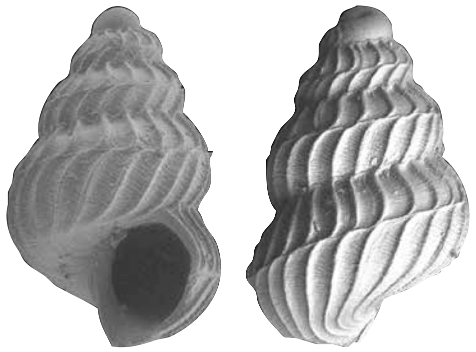
The Jackson School of Geosciences has one of the best geosciences research programs in the world according to two global rankings that came out in spring 2017.

The Nature Index of scientific productivity ranked UT No. 4 globally among academic institutions for Earth and environmental sciences. The Center for World University Rankings, the largest academic ranking of global universities, ranked UT No. 3 globally for geology. Both rankings are based on publication of peer-reviewed research in top-tier journals.

In the most recent ranking of graduate education programs from *U.S. News & World Report*, UT ranked No. 5 for geology. The combination of rankings underscores the productivity and excellence of UT's Jackson School of Geosciences, which is the largest geosciences program in the country with nearly 600 undergraduate and graduate students.

"It's rare to find a school that is the largest in a discipline and also operates at an elite level in both education and research," said UT President Gregory L. Fenves. "These rankings are a reminder of the global distinction and impact of geosciences at the University of Texas."

The Jackson School consists of three world-class academic and research units — the Department of Geological Sciences, the Institute for Geophysics and the Bureau of Economic Geology. Combined, these institutions offer a depth and breadth of geosciences matched by few universities. They spearhead research vitally important to Texas, the country and the world.



The Great Dying

Climate, Carbon & Geobiology

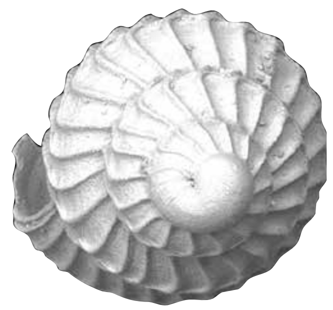
Millions of years before the mass extinction that wiped out the dinosaurs, there was the Permian extinction, or Great Dying, the planet's deadliest mass extinction event, and the event that had the longest recovery.

Two studies led by Jackson School of Geosciences postdoctoral researcher William Foster have shed light on how marine ecosystems recovered from the catastrophic mass extinction event 252 million years ago, and why the overall recovery afterward was slow. Both center on research of marine fossil beds in Italy.

The Permian extinction is linked to climate change caused by prolonged volcanic eruptions in Russia's Siberian Traps. The eruptions covered an area larger than Alaska with lava and released massive amounts of greenhouse gasses into the atmosphere, which had dire consequences for life across the planet.

The first study, which was published in the *Journal of Systematic Paleontology* in November 2016, found that fossils show that some species thought to have died out during the Permian extinction had actually survived the event, and others originated tens of millions of years earlier than previously believed.

Many of the fossil shells are unusually small, only a few millimeters in size. But they are so well-preserved that they reveal new details of their body shape and early life stages.



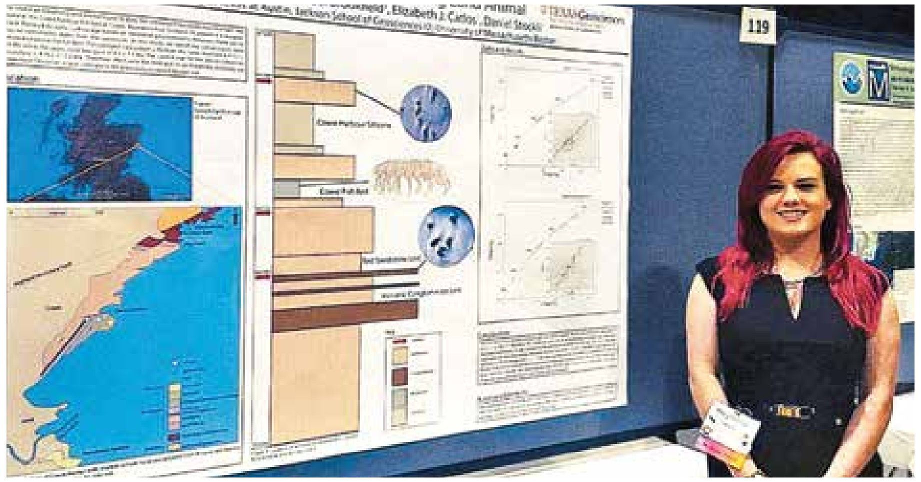
ABOVE: A CLOSE-UP VIEW OF SHELL FOSSILS FROM PERIOD FOLLOWING EXTINCTION. **BELOW:** A 20-CENT EURO NEXT TO TINY SHELL FOSSILS.

"The exceptional preservation of the fossil shells show how marine ecosystems survive global warming," Foster said.

The second study, published in the journal *PLOS ONE* in March 2017, found that life recovered slowly after the Great Dying because of two smaller extinction events that followed the mass extinction.

The extinction events are linked to climate change also caused by massive volcanic activity, said Foster. He added that the study is a step toward understanding how lifeforms survived during the extinctions, which could help scientists understand how modern ocean life evolved and how it might respond to climate change in the future.

GREAT DYING: WILLIAM FOSTER/NATURAL HISTORY MUSEUM LONDON. FOSSIL LOSES CLAIM: UT'S DIVISION OF DIVERSITY AND COMMUNITY ENGAGEMENT.



SENIOR STEPHANIE SUAREZ DISPLAYS HER RESEARCH THAT KNOCKED THE ANIMAL THAT WAS PREVIOUSLY KNOWN AS THE OLDEST LAND-BREATHER FROM ITS PLACE.

Fossil Loses Claim to Fame

GeoFORCE Texas Update

Some good scientific sleuthing by an undergraduate at The University of Texas at Austin has helped rewrite one of the earliest chapters in the planet's evolutionary history. The research, led by the Jackson School of Geosciences, has shown that the millipede thought to be the world's oldest known air-breathing land creature is in fact about 14 million years younger than previously thought and cannot be the original land breather.

The paper was published June 28, 2017, in the journal *PLOS ONE*. The study focuses on a species of millipede called *Pneumodesmus newmani*, which was thought to have been breathing air on solid ground during the late Silurian period some 428 million years ago. All other animal fossils discovered before this time have been from animals that lived and breathed under water.

The millipede fossil was discovered in 2004 in Aberdeenshire, Scotland, and dated by testing plant spores in sediment found in the general area, a method that contains a significant amount of scientific uncertainty compared with radiometric dating methods, said Elizabeth Catlos, a study author and associate professor in the Jackson School's Department of Geological Sciences.

Catlos, who obtained the soil samples from co-author Michael Brookfield of the University of Massachusetts Boston, tasked Jackson School senior Stephanie Suarez, the paper's lead author, with finding grain-sized zircons in the sediment that could be dated in the Jackson School's Laser Ablation Inductively Coupled Plasma Mass Spectrometry Laboratory. Zircons are minerals that trap radioactive elements inside of them when they form, which can help scientists more accurately determine the age of rock or sediment where they are found.

Suarez was introduced to the geosciences in high school through the Jackson School's GeoFORCE Texas outreach program. The handful of zircons she found that are younger than 428 million years old definitely show that the *Pneumodesmus newmani* specimen was not the first organism on Earth to breathe air while on land.

"This wasn't it," Catlos said. "We have to keep looking."

Jackson School Professor Daniel Stockli was a co-author on the study. Funding was provided by the Geological Society of America South Central Section.

Snow Data from Satellites Improves Seasonal Temperature Predictions

THE HIMALAYAN MOUNTAINS BORDER THE TIBETAN PLATEAU, THE REGION THE RESEARCHERS INVESTIGATED.

Climate, Carbon and Geobiology

Computer climate models that include data about snow coverage can significantly improve seasonal temperature predictions.

The findings, published in November 2016 in *Geophysical Research Letters*, could help farmers, water providers, power companies and others that use seasonal climate predictions—forecasts of conditions months in the future—to make decisions. Snow influences the amount of heat that is absorbed by the ground and the amount of water available for evaporation into the atmosphere, which plays an important role in influencing regional climate.

"We're interested in providing more accurate climate forecasts because the seasonal timescale is quite important for water resource management and people who are interested in next season's weather," said Peirong Lin, the lead author of the study and a graduate student at the Jackson School of Geosciences.

The researchers found that incorporating snow data from the Northern Hemisphere collected by NASA satellites improved regional temperature predictions by 5 to 25 percent. These findings are the first to go beyond general associations and break down how much snow can impact the temperature of a region months into the future.

The study examined seasonal data from 2003 through 2009, so the researchers could compare the model's predictions to recorded temperatures. The model ran predictions in three-month intervals, with January, February and March each used as starting months.

The study's other co-authors are Jackson School researcher Jiangfeng Wei, Ph.D. student Kai Zhang, and Yongfei Zhang, a former Jackson School Ph.D. student who is now a postdoctoral researcher at the University of Washington.

The research was funded by a grant from the National Natural Science Foundation of China and the Jackson School of Geosciences.

Natural Methane Linked to Groundwater in Parker and Hood Counties

Surface & Hydrologic Processes

Scientists from the Jackson School of Geosciences have found that high levels of methane in well water from two counties near Fort Worth are probably from shallow natural gas deposits, not natural gas leaks caused by hydraulic fracturing operations in the underlying Barnett Shale.

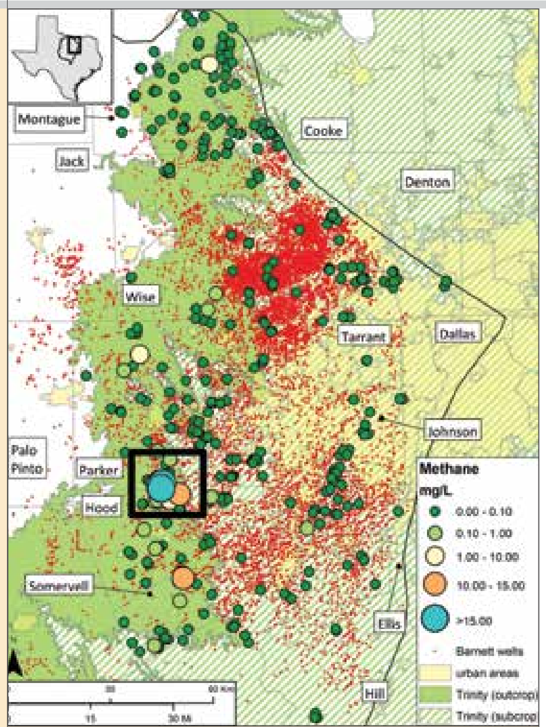
The research, published in the journal *Groundwater* in March 2017, builds on previous studies on well water quality in the Barnett Shale, and uses chemical and geographic evidence to tie the elevated methane level in certain water wells to methane in natural shallow deposits. The research was led by J.P. Nicot, a senior research scientist at the Bureau of Economic Geology. Collaborators include Toti Larson, a researcher from the Jackson School's Department of Geological Sciences, and scientists from the University of Michigan.

The Barnett Shale, located in the Fort Worth region, is one of the largest and most productive natural gas fields in the United States with about 20,000 wells. As production has boomed, questions have been raised about the connection between hydraulic fracturing and potentially dangerous levels of methane in some water wells, most notably wells in the Silverado neighborhood in Parker County.

The researchers analyzed samples from more than 450 wells across 12 counties in the western Barnett Shale. About 85 percent showed very low methane levels in the groundwater of less than 0.1 milligrams of methane per liter of water. However, a cluster of 11 wells in the vicinity of the Silverado neighborhood had methane levels above 10 milligrams per liter of water, a level that can trigger venting of well water systems to ensure the flammable gas does not become hazardous. These 11 wells are found in a roughly 6-by-8-mile area that also includes wells with low levels of methane.

Researchers used carbon isotope analysis to determine that the methane was thermogenic, which ruled out biogenic sources but didn't pinpoint whether the gas came from the deeper Barnett or a shallower reservoir in the study area called the Strawn Group. Additional analysis of the samples' noble gases conducted by members of the same research team and led by University of Michigan researchers linked the methane to the natural gas deposits of the Strawn. The results were complemented by another of the team's studies in 2015 that found nitrogen isotopes associated with the Strawn.

"Combining alkane, noble gas and nitrogen compositions, and isotope ratios allowed us to distinguish natural gas sourced from the deep Barnett Shale from the shallow Strawn Group," Larson said.



DISTRIBUTION OF DISSOLVED METHANE ACROSS THE BARNETT SHALE PLAY. EACH SMALL RED DOT REPRESENTS A BARNETT SHALE GAS WELL. THE OTHER COLORED DOTS REPRESENT GROUNDWATER SAMPLE LOCATIONS. THE BLACK SQUARE SURROUNDS A HIGH-METHANE AREA WHERE RESEARCHERS CONDUCTED IN-DEPTH ANALYSIS OF GROUNDWATER SAMPLES.

Drawing from a Primordial Reservoir Deep in the Earth

Solid Earth and Tectonic Processes

The Earth's mantle—the layer between the crust and the outer core—is home to a primordial soup even older than the moon. Among the main ingredients is helium-3 (He-3), a vestige of the Big Bang and nuclear fusion reactions in stars. And the mantle is its only terrestrial source.

Scientists studying volcanic hotspots have strong evidence of this, finding high helium-3 relative to helium-4 in some plumes, the upwellings from the Earth's deep mantle. Primordial reservoirs in the deep Earth, sampled by a small number of volcanic hotspots globally, have this ancient He-¾ signature.

Inspired by a 2012 paper that proposed a correlation between such hotspots and the velocity of seismic waves moving through the Earth's interior, UC Santa Barbara geochemist Matthew Jackson teamed with the authors of the original paper—Thorsten Becker of the Jackson School of Geosciences and Jasper Konter of the University of Hawaii—to show that only the hottest hotspots with the slowest wave velocity draw from the primitive reservoir formed early in the planet's history. Their findings appeared in February 2017 in the journal *Nature*.

For their study, the researchers used the latest seismic models of the Earth's velocity structure and 35 years of helium data. When they compared oceanic hotspots with high levels of He-¾ to seismic wave velocities, they found that these represent the hottest hotspots, with seismic waves that move more slowly than they do in cooler areas. They also analyzed hotspot buoyancy flux, which can be used to measure how much melt a particular hotspot produces.

SNOW DATA: NASA. METHANE: J.P. NICOT/UT.

ABOVE: A RECONSTRUCTION OF QUETZALCOATLUS IN THE TEXAS MEMORIAL MUSEUM. BELOW: A GROUP OF RESEARCHERS WHO WERE ALSO FRIENDS OF WANN LANGSTON HAVE BEEN STUDYING THE PTEROSAUR FOR YEARS.

Getting to Know the Texas Pterosaur

Climate, Carbon & Geobiology

The 35-foot wingspan of *Quetzalcoatlus*—the largest known flying animal to ever exist—has made it the subject of documentaries and museum exhibits. However, very little has been published based on data from the actual bones of the pterosaur, which were discovered in Big Bend National Park by UT geology graduate student Douglas Lawson in 1971.

A group of researchers plans to change that by publishing a monograph giving a comprehensive overview of the ancient reptile's anatomy and physiology. The group consists of Brian Andres, a paleontologist and UT geosciences alumnus (B.S. 2000); John Conway, an artist specializing in prehistoric animals; James Cunningham, a civil engineer; Tom Lehman, a paleontologist and professor at Texas Tech University; and Kevin Padian, a paleontologist and professor of integrative biology at the University of California, Berkeley.

Each researcher got to know the pterosaur through a connection with the late Wann Langston, a professor at the UT Department of Geological Sciences. The group sees the monograph as completing work that Langston wasn't able to finish before his death in 2013.

"Everybody knows about [*Quetzalcoatlus*] but very few people have actually seen it, and we're the only ones except Wann who have worked on it," Padian said.

Cunningham added: "Essentially we're all here because at one point or another, Wann invited us in."

Since Langston's death, the group has been making yearly visits to the pterosaur remains—316 bones from multiple individuals—stored at the Jackson School Museum of Earth History. They said that they will finish the monograph in 2017 and submit it for publication.

If accepted, they expect the manuscript to be published early in 2018. In the meantime, you can see a reconstruction of the pterosaur at the Texas Memorial Museum on the UT Austin campus.

Water in the Earth's Crust

Solid Earth & Tectonic Processes

A geothermometer may sound like a mercury-laden probe you stick in a rock, but in reality it's a feature of the rock itself: a mineral signature scientists use to understand the cooling history of the rock in question.

Postdoctoral fellow Nick Dygert applied a new geothermometry analysis technique to rock that formed in the Earth's mantle and made a discovery that helps explain the crust formation process: water probably penetrates deep into the crust and upper mantle at mid-ocean spreading zones, the places where new crust is made. The finding adds evidence to one side of a long-standing debate on how magma from the Earth's mantle cools to form the lower layers of crust.

The research was published in May 2017 in the print edition of *Earth and Planetary Science Letters*. Collaborators include Peter Kelemen of Columbia University and Yan Liang of Brown University.

To learn more about the conditions under which magma turns into crustal rock, Dygert and his collaborators examined rock samples that were part of the Earth's mantle 100 million years ago, but are now part of a canyon in Oman.

"One can effectively walk down 20 kilometers in the Earth's interior," said Kelemen. "This allows scientists to access rocks that formed far below the seafloor which are not available for study."

The team turned to geothermometers to calculate temperatures and reveal the cooling history of the rock, including a new geothermometer developed by Liang, which records the maximum temperature a rock attained before it cooled.

The temperatures recorded in the rocks show that the lower crust and uppermost mantle cooled and solidified almost instantly, while the deeper mantle cooled more gradually. The temperature change is indicative of water circulating through the crust and uppermost mantle beneath mid-ocean spreading centers, and the heat from deeper portions of the mantle being dissipated through contact with the cooler upper rocks.

The research was supported by the Jackson School of Geosciences, the National Science Foundation, the Alfred P. Sloan Foundation and an International Continental Drilling Program grant.

PTEROSAUR: JEFF STVAN. GROUP SHOT: JACKSON SCHOOL. GLACIER: TIM BARTHOLOMAUS.

Glacier Shape Influences Susceptibility to Thinning

Surface & Hydrologic Processes

THE TERMINUS OF KANGERLUGSSUUP SERMERSSUA, A GLACIER IN GREENLAND

Glaciers around the world come in all shapes and sizes. Research led by the University of Texas Institute for Geophysics (UTIG) indicates that this fact should be kept in mind when predicting how much mass a glacier stands to lose.

Using a newly developed method, researchers have identified glaciers in West Greenland that are most susceptible to thinning in the coming decades by analyzing how they are shaped. The research could help predict how much the Greenland Ice Sheet will contribute to future sea-level rise during the next century, a number that currently ranges from inches to feet. The study was published in *Nature Geoscience* in April 2017.

"There are glaciers that popped up in our study that flew under the radar until now," said lead author Denis Felikson, a graduate research assistant at UTIG and a Ph.D. student in the Cockrell School of Engineering's Department of Aerospace Engineering and Engineering Mechanics.

The Greenland Ice Sheet is the second-largest ice sheet on Earth and has been losing mass for decades, a trend scientists have linked to a warming climate. However, the mass change experienced by individual coastal glaciers is highly variable, which makes predicting the impact on future sea-level rise difficult.

Of the 16 glaciers researchers investigated in West Greenland, the study found four that are the most susceptible to thinning: Rink Isbrae, Umiamako Isbrae, Jakobshavn Isbrae and Sermeq Silardleq.

Umiamako Isbrae, Sermeq Silardleq and Jakobshavn are already losing mass, with Jakobshavn being responsible for more than 81 percent of West Greenland's total mass loss during the past 30 years.

"Not long ago we didn't even know how much ice Greenland was losing. Now we're getting down to the critical details that control its behavior," said Tom Wagner, director of NASA's cryosphere program, which sponsored the research.

The analysis works by calculating how far inland thinning that starts at the terminus of each glacier is likely to extend. Glaciers with thinning that reaches far inland are the most susceptible to ice mass loss.

The research revealed that most glaciers are susceptible to thinning between 10 and 30 miles inland. For Jakobshavn, however, the risk of thinning reaches over 150 miles inland—almost one-third of the way across the Greenland Ice Sheet. Ginny Catania, an associate professor in the Department of Geological Sciences and research associate at UTIG, said the group has plans to apply the shape analysis technique to other glaciers in Antarctica and Greenland.

UTIG SENIOR RESEARCH SCIENTIST FRED TAYLOR IN THE MANGROVE SWAMPS IN THE FEDERAL STATES OF MICRONESIA

Micronesia Coral Cores Record Sea Level

Climate, Carbon & Geobiology

For the foreseeable future, rising sea level is, and will be, an issue facing coastal regions, including Middle Pacific islands. A seed grant from the Jackson School of Geosciences is supporting research into past sea level changes, work that could provide insight for what the future has in store.

Fred Taylor, senior research scientist with the University of Texas Institute for Geophysics (UTIG), and Jud Partin, a UTIG research associate, are leading the research, which involves conducting fieldwork in the Federated States of Micronesia (FSM) to determine if high-precision paleosea level records exist.

This kind of data could help address uncertainties in the past sea level record.

In summer 2016, Taylor joined forces with co-investigators Andrew Kemp of Tufts University and Simon Engelhart of the University of Rhode Island to conduct preliminary surface sampling on the islands of Phonpei and Chuuck. They sampled sediment cores from mangrove swamps, searching for foraminifera, a microorganism very sensitive to sea level. In addition, they sampled two dead coral microatolls to find out what age ranges could be investigated in the region using dead corals.

The researchers hope to receive additional funding so they can obtain more samples and ultimately show a record of time versus elevation of sea level over the course of the past few thousand years. Having visited the islands for many years, Taylor understands the pressing nature of the issue of sea level rise for the locals.

"All pacific island nations, including the FSM, are very concerned about sea level rise and climate change," Taylor said. "We want to collaborate with the local authorities and have been welcomed and accepted by the state governments, fisheries departments and non-governmental organizations."

Bureau Projects Activity in Bakken Shale

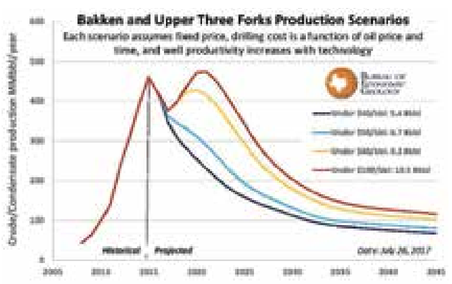
Energy Geosciences

The Bureau of Economic Geology conducted a comprehensive study of the Bakken unconventional shale resource in North Dakota and Montana and found that it will remain a substantial contributor to U.S. oil production for several decades through a range of projected oil prices.

The study forecasts a wide variation of production outlooks from the Bakken and the Three Forks formations depending primarily on potential future oil prices. The study does not predict oil prices but looks at scenarios reflecting the economics of the resource development.

For instance, according to the study, future West Texas Intermediate (WTI) oil prices remaining near $40 per barrel would likely lead to declining production from the Bakken and Three Forks formations, resulting in about 14,000 future drilled wells and estimated ultimate recovery of about 5.4 billion barrels of oil. However, if WTI oil prices were to recover to $100 per barrel, it could lead to 60,000 wells added, capturing 10.5 billion barrels of oil, with production increasing to 1.5 million barrels per day.

The study was funded by the Alfred P. Sloan Foundation. The initial results were presented in a series of presentations at the Unconventional Resource Technology Conference in Austin, Texas, on July 25, 2017. Final results will be published in industry journals in the coming months.



A CHART SHOWING PRODUCTION SCENARIOS IN THE BAKKEN BASED ON POTENTIAL OIL PRICES

MICRONESIA: FRED TAYLOR. EARTHQUAKE MONITORS: BEG. BAKKEN: BEG. PLATE BOUNDARIES: NATHAN BANGS.

Exploring Plate Boundaries

Marine Geosciences

ABOVE: PH.D. STUDENTS BROOKLYN GOSE (LEFT) AND KELLY OLSEN ON THE CEVICHE CRUISE. **LEFT:** UTIG SENIOR RESEARCH SCIENTIST NATHAN BANGS.

Nathan Bangs, a senior research scientist at the University of Texas Institute for Geophysics (UTIG), has been funded by the National Science Foundation to lead three international seismic surveying cruises on the Research Vessel Langseth to study plate boundaries and subduction zones off the coast of Chile and New Zealand.

Subduction zones are a type of fault that cause the largest and most powerful earthquakes and tsunamis in the world, such as Sumatra 2004, Chile 2010 and Japan 2011. The Hikurangi subduction zone, for instance, potentially poses the largest earthquake and tsunami hazards in New Zealand.

"It is poorly understood why some subduction zones slip quickly and produce great earthquakes and large tsunamis, while others slip slowly or slip without generating notable earthquakes at all," Bangs said. "Seismic surveys like the ones we are acquiring on the Langseth will help us see the structure of these subduction zones down 10–20 kilometers below the seafloor to assess the conditions and processes that control how these plates interact. These observations are critical for understanding all subduction zones, including those that will impact the U.S. such as Cascadia and the Aleutians."

The first cruise took place in January and February 2017. The Crustal Experiment from Valdivia to Illapel to Characterize Huge Earthquakes (CEVICHE) expedition conducted a seismic exploration of the source regions of the 2015 Illapel and 2010 Maule earthquakes and the northern half of the rupture zone of the great 1960 Valdivia earthquake. Ph.D. students Brooklyn Gose and Kelly Olsen, UTIG postdoctoral researcher Shuoshuo Han and UTIG Research Associate Adrien Arnulf also helped at sea during CEVICHE.

Bangs is also leading a cruise in October and November 2017 and another in January and February 2018 off the eastern coast of New Zealand's North Island that will study the Hikurangi subduction zone to determine controls on subduction zone earthquakes generally and risks to New Zealand specifically. The Hikurangi subduction zone is a plate boundary where the Pacific tectonic plate dives underneath the Australian tectonic plate.

Jackson School Researchers Converge on Harvey Destruction

Rapid Response Program

ABOVE: A FLOODED NEIGHBORHOOD IN SOUTHEAST TEXAS. BELOW: HURRICANE HARVEY APPROACHES THE TEXAS COAST.

Shortly after Hurricane Harvey devastated Texas communities in August 2017, Jackson School of Geosciences researchers began drawing up plans to determine how Harvey impacted the Texas coast and bay system. The projects are part of the school's Rapid Response program, which supports research in areas recently affected by natural disasters.

"As geoscientists, it is critical that we use our expertise to help find ways to mitigate the effects of such catastrophic weather events, particularly right here at home in Texas," said Jackson School Dean Sharon Mosher. "This research will investigate the impacts of abrupt, catastrophic geoscience processes on coastlines. Most importantly, this research will help determine the best ways to deal with many coastal issues in the aftermath of Hurricane Harvey, and how we might better prepare for such events in the future."

In the days following the storm, researchers at the Bureau of Economic Geology began an airborne LIDAR and imagery survey of parts of the Texas coast. The LIDAR data and imagery is being used to assess storm impacts on the beach and dune system along the Texas Gulf shoreline, identify debris and infrastructure damage in central Texas bays, and establish a baseline for monitoring beach and dune recovery in the months and years to come. These surveys are part of the General Land Office's comprehensive response to the ongoing effects of Hurricane Harvey.

At the time the *Newsletter* went to print, researchers at the University of Texas Institute for Geophysics were resurveying the Lydia Ann Channel and Aransas Pass with marine geophysical instrumentation, and collecting sediment samples. Researchers believe that these locations have been subjected to substantial and measurable erosion and sediment transport by the storm surge and its ebb, and that investigating these locations will provide valuable insights into the impact of storm surges on barrier and estuarine systems.

Jackson School researchers and students have previously surveyed these areas during their Marine Geology & Geosciences field camps in 2009 and 2012, which is providing important baseline data to compare with the post-Harvey findings.

Other Jackson School Rapid Response projects were being discussed when the *Newsletter* went to press.

FLOODED NEIGHBORHOOD: NATIONAL GUARD/STAFF SGT. DANIEL J. MARTINEZ. HURRICANE: NOAA/CIRA/RAMMB. SLOW SLIP MAP: JACKSON SCHOOL. WALLACE: LIZ BRENNER. UPLIFTED COAST: GNS SCIENCE.

Earthquake Triggers "Slow-Motion" Quakes in New Zealand

Solid Earth & Tectonic Processes

Slow slip events, a type of slow motion earthquake that occurs over days to weeks, are thought to be capable of triggering large, potentially damaging earthquakes. In a study led by the University of Texas Institute for Geophysics (UTIG), scientists have documented the first clear-cut instance of the reverse—a massive earthquake immediately triggering a series of large slow slip events, with some of the slow slip events occurring as far away as 300 miles from the earthquake's epicenter.

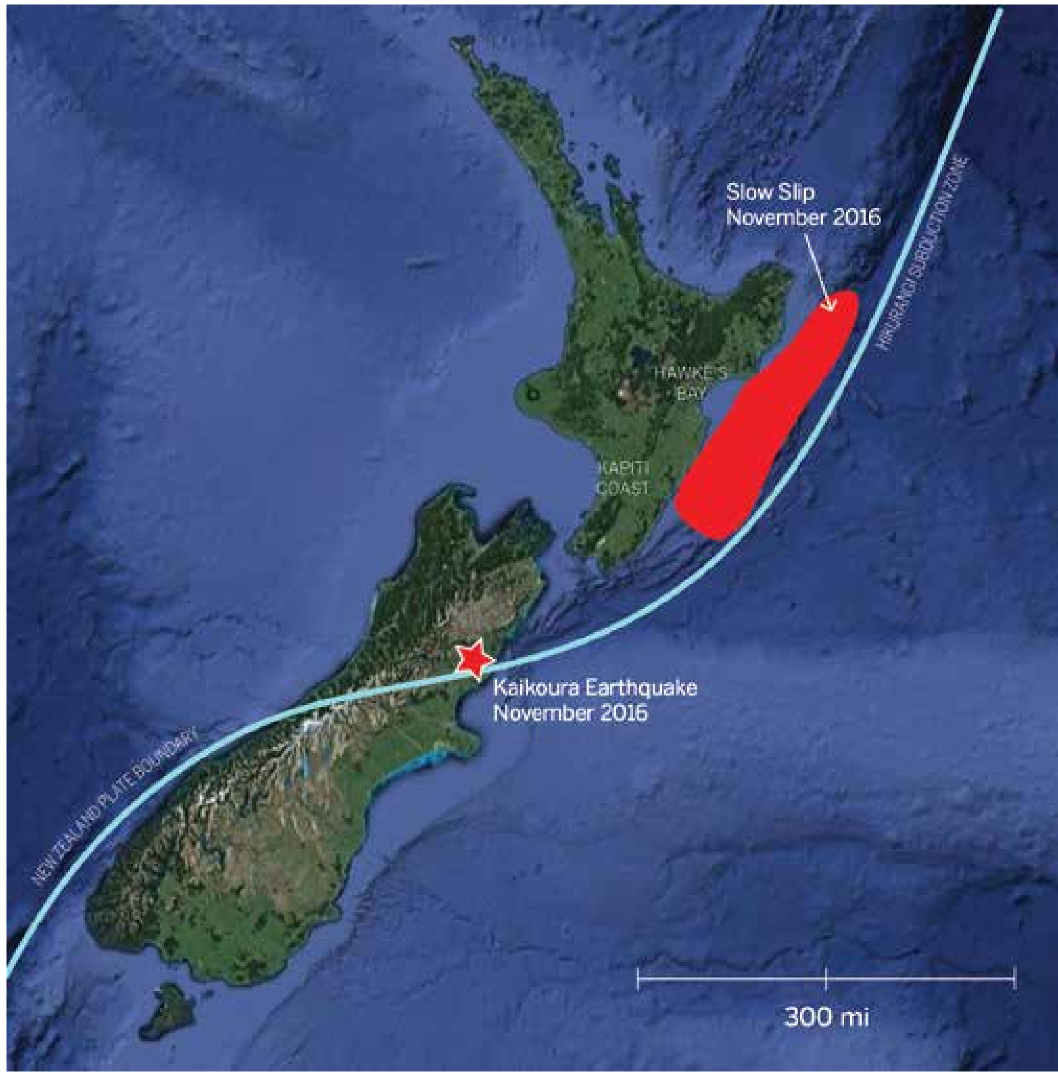
The study of new linkages between the two types of seismic activity, published in *Nature Geoscience* on Sept. 11, 2017, may help promote better understanding of earthquake hazards posed by subduction zones—areas where a tectonic plate subducts beneath an adjacent tectonic plate. These types of faults are responsible for some of the world's most powerful earthquakes.

"This is probably the clearest example worldwide of long distance, large-scale slow slip triggering," said lead author Laura Wallace, a UTIG research scientist. She also holds a joint position at GNS Science, a New Zealand research organization that studies natural hazards and resources.

Co-authors include other GNS scientists, as well as scientists from Georgia Tech and the University of Missouri.

In November 2016, the second largest quake ever recorded in New Zealand—the 7.8 magnitude Kaikōura quake—hit the country's South Island. A GPS network operated by GeoNet, a partnership between GNS Science and the New Zealand Earthquake Commission, detected slow slip events hundreds of miles away beneath the North Island.

The researchers have also found that the slow slip events triggered by the Kaikōura quake were the catalyst for other quakes offshore the North Island's east coast, including a magnitude 6.0 just offshore from the town of Porangahau on Nov. 22, 2016.



CLOCKWISE: 1. A MAP OF NEW ZEALAND. THE STAR REPRESENTS THE KAIKOURA EARTHQUAKE. THE RED AREA REPRESENTS A SLOW SLIP EVENTS AREA. 2. A PORTION OF THE NEW ZEALAND COAST UPLIFTED BY THE KAIKOURA EARTHQUAKE. 3. UTIG RESEARCH SCIENTIST LAURA WALLACE.

Study Quantifies Potential for Water Reuse in Permian Basin Oil Production

Energy Geosciences

Hydraulic fracturing has once again made the Permian Basin one of the richest oil fields in the world. But the improved reserves come with some serious water management issues.

Research led by the Bureau of Economic Geology highlights key differences in water use between conventional drill sites and sites that use hydraulic fracturing. The study, published in *Environmental Science & Technology* in September 2017, also found that recycling the water produced at hydraulic fracturing sites could help reduce potential problems associated with the technology. These include the need for large upfront water use and potentially induced seismicity or earthquakes triggered by injecting the water produced during operations back into the ground.

"In the Permian we have a good opportunity for reusing or recycling produced water for hydraulic fracturing," said lead author Bridget Scanlon, a senior research scientist at the bureau and director of the bureau's Sustainable Water Resources Program.

Scanlon co-authored the study with bureau researchers Robert Reedy, Frank Male and Mark Walsh.

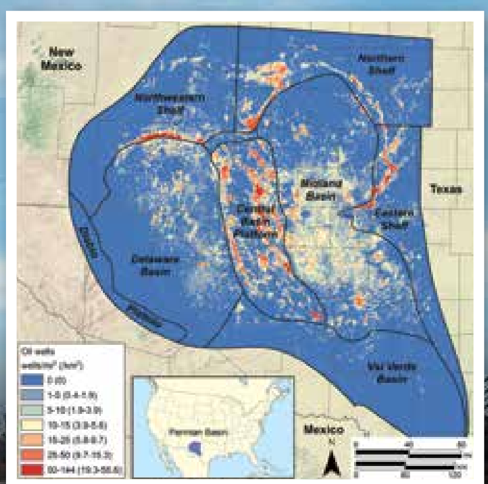
Since the 1920s, the Permian Basin has been a very active area for conventional oil production, peaking in the 1970s and accounting for almost 20 percent of U.S. oil production. Hydraulic fracturing technology has revived production in the Permian by allowing companies to tap into immense oil reserves held in less permeable unconventional shale formations.

The study analyzed 10 years of water data from 2005 to 2015.

Up front, unconventional wells use much more water than conventional wells. But unconventional wells produce much less water than conventional wells.

For conventional operations, the produced water is disposed of by injecting it into depleted conventional reservoirs. Unconventional wells generate only about a tenth of the water produced by conventional wells, but this produced water cannot be injected into the shales because of the rock's low permeability.

The study points out that instead of injecting the produced water into these formations, operators could potentially reuse the water to hydraulically fracture the next set of wells.



LEFT: A MAP SHOWING THE RANGE OF THE PERMIAN BASIN AND THE DISTRIBUTION OF OIL WELLS IN THE REGION. ABOVE: A HYDRAULIC FRACTURING WELL SITE IN THE PERMIAN BASIN.

MAP: BRIDGET SCANLON. WELL SITE: U.S. GEOLOGICAL SURVEY. INSTALLATION OF MONITORS: JACKSON SCHOOL.

Installation of Earthquake Monitors Complete

Solid Earth & Tectonic Processes

LEFT TO RIGHT: BUREAU RESEARCH ASSOCIATE BISSETT YOUNG, PARKER COUNTY COMMISSIONER LARRY WALDEN, AND BUREAU RESEARCH SCIENTIST ASSOCIATE TANIA MURKHERJEE.

The Bureau of Economic Geology installed the final permanent TexNet seismic station in August 2017, completing the system of 22 permanent sensors that will monitor earthquakes around the state and provide scientists the seismicity data to help determine what's behind a recent increase in seismic activity.

TexNet and its related research, led by the bureau, were authorized by Texas Gov. Greg Abbott and the legislature in June 2015 with $4.47 million in state funding. Since then, Research Scientist Alexandros Savvaidis and his crew have been traveling the state surveying potential sites and, with the help of former landman and bureau Director of External Affairs Mark Blount, negotiating leases for the locations of the permanent seismic sensing stations. The system also includes 36 portable seismometers, many of which have already been installed.

With these additional stations now operating, TexNet has been recording dozens of seismic events a month, most of them very small. Monitoring is only part of TexNet's mandate. In parallel with the Center for Integrated Seismicity Research (CISR), a multidisciplinary research team led by bureau Research Scientist Peter Hennings and Professor Ellen Rathje in the Department of Civil, Environmental and Architectural Engineering, TexNet is working to conduct fundamental research to better understand natural and induced earthquakes in Texas.

At issue is how an extremely small subset of wells used to dispose of wastewater, co-produced with oil and gas, could be triggering faults and causing earthquakes, when the vast majority of disposal wells do not. Mounting, yet still circumstantial, evidence points to a link between deep disposal of fluids and earthquakes, but comprehensive data and necessary interpretations are ongoing. The lack of data, coupled with the complexity of the science, makes definitive, causal answers difficult at the current time.

"TexNet will help collect the hard scientific data, and conduct scientific and engineering analyses required to understand an issue that affects many stakeholders—industry, government, academia and the public," said bureau Director and State Geologist Scott W. Tinker. "Energy production is important to the citizens of Texas and the nation, but so is safe disposal and management of fluids. I am proud of our bureau team for working thoughtfully and objectively with all stakeholders in this difficult space."

VIEW TEXNET INTERACTIVE SEISMIC DATA AT WWW.BEG.UTEXAS.EDU/TEXNET

NEWSMAKERS

Experts from the Jackson School were featured in news outlets, documentaries and even a science show for kids. In addition, research findings — from what killed Lucy, to ice reservoirs on Mars, to exceptional fossil finds — made news across the world.

CLOCKWISE: 1.UTIG'S JUD PARTIN WAS FEATURED IN A SCIENCE PROGRAM ABOUT GLOBAL CATASTROPHES. 2. SATURDAY NIGHT LIVE GOT IN THE ACT WHEN THE JACKSON SCHOOL HELPED FIGURE OUT HOW LUCY DIED. 3. BEG'S SUSAN HOVORKA DISCUSSES HOW TO STORE CARBON UNDER GROUND ON PBS NEWSHOUR.

PHOTOS: HISTORY CHANNEL, SATURDAY NIGHT LIVE, PBS NEWS HOUR.

IN THE NEWS

"Having returned samples from a known context/location on Mars would open up a huge suite of analysis techniques that the rocks could be subjected to." Analyzing the rocks in an Earth-based laboratory "will allow us to understand the geologic history of the samples in a way that we couldn't accomplish in situ on Mars."

Timothy Goudge
Postdoctoral Fellow,
Department of Geological Sciences
Christian Science Monitor, Feb. 14, 2017

"This is a vote of confidence that the energy reform is moving forward and for the geological potential of the Mexican Gulf deep waters. Everybody paid a premium and that premium indicates the potential of the blocks."

Jorge Piñon
Director,
Jackson School Latin American and Caribbean Energy Program
New York Times, Dec. 5, 2016

"It has taken some time, but to our thinking it is better to do this slower and more methodically and the state will greatly benefit, rather than us rushing in and picking sites that are not very good. We want to get the sensors in the ground, but in the right way."

Michael Young
Associate Director,
Bureau of Economic Geology
Fort Worth Star Telegram, March 4, 2017

"We wanted to try to go into this business of 'attribution,' in which people try to parse out the temperature differences that are caused because of natural variability or man-made anthropogenic variability."

Kaustubh Thirumalai
Postdoctoral Fellow,
University of Texas Institute for Geophysics
Washington Post, June 6, 2017

"These uncertainties limit our ability to accurately predict the future of the ice sheet. We are in for a lot of change in Greenland in the future. The question remains — how quickly will it happen?"

Ginny Catania
Associate Professor & Research Associate,
Department of Geological Sciences and University of Texas Institute for Geophysics
Live Science, Dec. 7, 2016

"What interested us was how long it took life to recover afterward. Because not only was this the worst mass-extinction event, but recovery took millions of years."

William Foster
Postdoctoral Fellow,
Department of Geological Sciences
The Atlantic, March 15, 2017

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SCIENTIST PROFILE

ASHLEY MATHENY

Rodent-proofing moisture sensors and plowing through dense forest undergrowth gives Ashley Matheny a glimpse into the survival dance of trees. *by Barbra A. Rodriguez*

If not for the pliable nature of water, Ashley Matheny's career might have followed a different course. Back in 2010, the West Virginia native was studying water interactions with dams for the U.S. Army Corps of Engineers after completing a bachelor's degree in civil engineering. One summer morning, she witnessed a phenomena on the Ohio River that would forever change the way she viewed hydrology.

Matheny saw a front of rapidly moving water develop where there were no rocks or objects to raise the water height. The water rushed downstream to slam into slower water, and piled up chaotically behind it.

"I had heard about hydraulic jumps in hydrology class, but it was like some mythical creature," said Matheny, who joined the faculty of the Jackson School of Geosciences Department of Geological Sciences in fall 2017. "When I saw a real hydraulic jump in person, I thought, 'Huh, maybe hydrology is more interesting than I realized and deserves another look.'"

Luckily, Matheny's not one to approach scientific disciplines lightly. Growing up in a small town along the Ohio River water skiing, canoeing and camping meant her passion for nature runs deep. As an undergraduate at The Ohio State University, she immersed herself in measuring water use by trees in a section of Michigan forest under environmental stress. Combining her passions, the project turned into her master's and doctoral theses (and her first National Science Foundation grant). She has since built a reputation for ground truthing the water dynamics of trees to inform conservation efforts.

PHOTO: ASHLEY MATHENY.

Matheny expanded her research focus during a postdoctoral position at her alma mater last summer to incorporate detailed tree hydrology data into computer models of the cycling of water and bioactive elements between the earth and the atmosphere. Jackson School Professor Jack Sharp noted that researchers have been "pretty ignorant" about how vegetative hydrological processes impact land surface models because plants have been harder to evaluate than satellite-accessible attributes like cloud moisture.

"Understanding vegetative water use is a missing key to the local and global modeling puzzle," he said. "Matheny's developed some effective, relatively low-cost ways of measuring water flow and storage in trees that could markedly enhance modeling efforts."

For her part, Matheny looks forward to working on hydrology projects with Jackson School faculty. She plans to work on water research with Daniella Rempe, also an assistant professor of hydrologic and water sciences; on climate modeling with professors Zong-Liang Yang and Bob Dickinson; and on soil moisture analyses with Todd Caldwell and Michael Young of the Bureau of Economic Geology's Texas Soil Observation Network.

> "Understanding vegetative water use is a missing key to the local and global modeling puzzle."
>
> *–Jack Sharp*

Matheny will "go local" by expanding her work to include studying native Texas trees. Yet she intends to keep in mind the broader need for enhancing land surface models' representation of vegetation. Current models often incorporate measurements of moisture and other features for dozens of soil and atmospheric layers, while plants might occupy a single sliver of information between those data stacks. Moreover, modelers often represent all trees in one category as if they impact resource cycling equally.

"If we could make it so that temperate deciduous forests are not represented as one big leaf, but as the individual hydraulic classes that the trees actually represent, we could reduce the uncertainty in our models," Matheny said.

The Michigan tree study highlights why lumping tree species fosters such uncertainty by showing that different species have a different way of handling water storage. Traditionally, modelers have measured gaseous exchange at leaf pores (stomata) as a catch-all for understanding plant interactions with water and gasses. Leaf stomata capture carbon dioxide needed for photosynthesis and growth. They also release water through transpiration, the conversion of ultraviolet radiation from sunlight into water vapor. That process helps trees shed heat and water.

To enhance vegetative details, Matheny has spent eight years studying how native tree species adjust their water content in their leaves, woody material and roots in response to changing rainfall and other stressors. Without doing so, a plant could become dehydrated during a drought.

"It's a delicate dance a tree is trying to pull off," Matheny said. "To take in enough carbon from the atmosphere to avoid starving to death, but not release too much water to avoid drying out."

She developed probe-like sensors that can be inserted into tree trunks to capture information on water storage and flow through them. These sensors measure water characteristics in straw-like spaces of the xylem inside tree trunks and branches. By combining this data with water-isotope data taken from core samples of tree xylem, she extrapolates how deeply a tree's roots extend.

Matheny has built hundreds of probes over the years that have become increasingly sensitive, while still withstanding attacks to their wiring from hungry forest dwellers. The work resulted in being lead author on a November 2016 article in *Ecohydrology* that demonstrated that red oaks in Michigan outperform red maples in their hydraulic strategy.

The red oaks were found to sink their roots into deeper water pockets. The deeper roots allowed the oaks to access more water to store in woody material. As a result, the oaks could continue transpiring during dry spells that have become increasingly common. Meanwhile, equally prevalent red maples turned out to have shorter roots and smaller water reserves. They closed their stomata during a drought, eschewing the ability to synthesize nutrients and grow in exchange. By clarifying their reduced fitness during water stress, the work could help inform forest management plans and improve modeling of how forests might shift arboreal species under future climate scenarios.

Not all of Matheny's projects have been in temperate regions such as Michigan. As a master's student at Ohio State, she spent weeks on a Panamanian island walking straight transects through a forest and dodging bullet ants, poisonous snakes and more. The work to catalog a vine's presence in the tree canopy also required carrying LIDAR equipment.

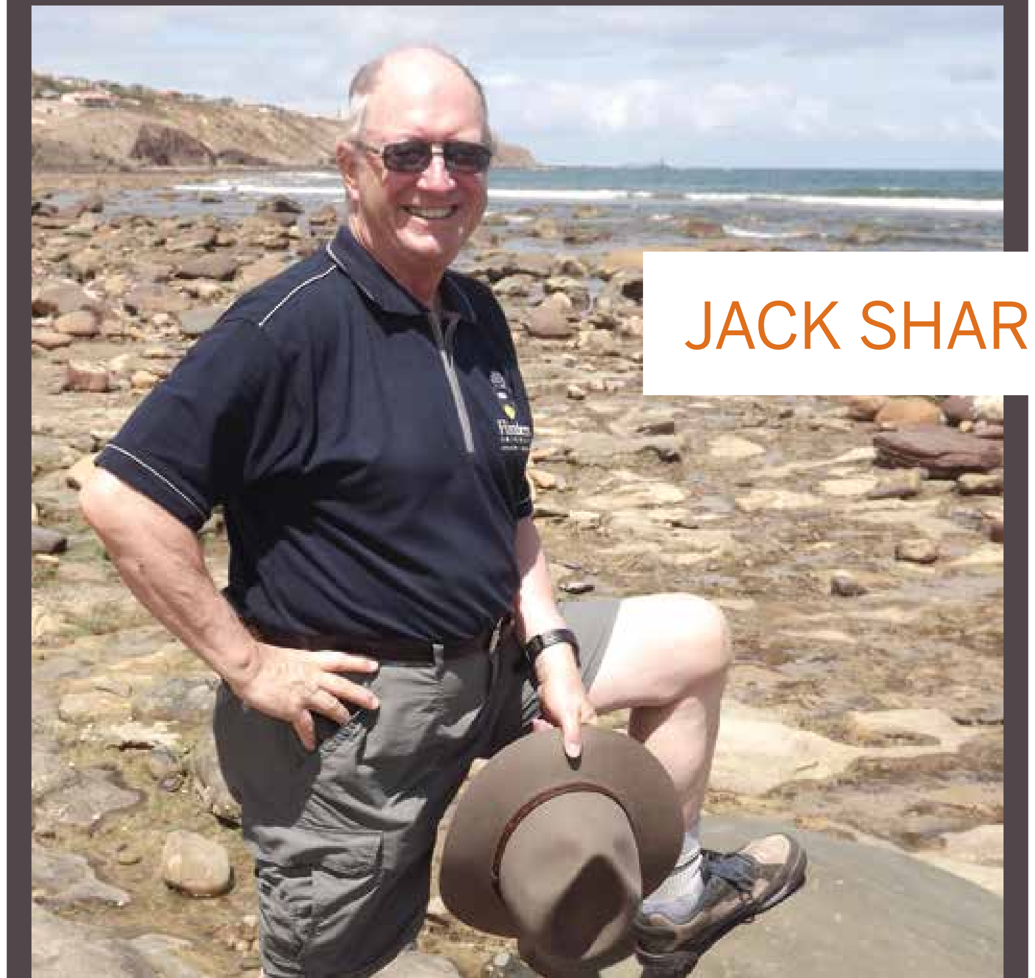
"Hiking in 100 degrees with 100 percent humidity while carrying 50 pounds was not fun," she admitted.

Knowing the value of field work, though, her first priority in Texas has been establishing study sites, including of water-stressed mangroves along the Texas Gulf Coast. Matheny may eventually compare their water use with that of mangroves along an arid coast, such as in Oman, to help clarify hydraulic functions of Lone Star mangroves.

She noted that discussing the field experiences that sustain her spirit, and the multidisciplinary aspects of her research, help her bring research alive while teaching.

"It's exciting to continually learn new things," said Matheny, who has presented at 15 scientific meetings since she was an undergraduate. "My tree research extends into engineering, hydrology and hydrogeology, but also into chemistry and biology, so there are always new possibilities to investigate."

OPPOSITE PAGE: ASHLEY MATHENY INSTALLS A MOISTURE SENSOR WITHIN A RED MAPLE TREE'S TRUNK AT A RESEARCH SITE IN PELLSTON, MICHIGAN.



JACK SHARP

Inquisitive researcher. Giving educator. Dedicated citizen. John M. (Jack) Sharp Jr. is known as a hydrogeologist who approaches his professional life at full throttle. As a testament to his active 43 years of professordom, the four-foot-wide set of Longhorns above his office desk is dwarfed by a sea of plaques around it—a reflection of a commitment to serving his profession that takes five pages to recap on his CV. *by Barbra A. Rodriguez*

Sharp has also built a reputation during 35 years on campus as a scientist whose wide-ranging interests have extended from basic research on groundwater recharge to understanding the formation of deep sinkholes.

"There are some people who know exactly what they're going to do as a career," Sharp noted. "But mine … it's just been an adventure."

To analyze a Mexican sinkhole that is the Earth's third-deepest, he helped obtain funding from NASA to build a rover that plunged 300 meters into Cenote Zacatón. He also is known for developing the first mathematical model of the effects of physical changes that occur on the surfaces of fractured rocks and of how layers of water with different densities can overturn of their own accord in sedimentary systems. As an offshoot of his analyses of natural springs in Central Texas, Washington D.C., and elsewhere, he uncovered the way waterborne contaminants use the sandy material that surrounds underground utility pipes as conduits for transport.

Sharp initially studied geological engineering at the University of Minnesota on the advice of that state's Geological Survey director, a family friend. A sense of duty led him to Air Force officer training school instead of accepting Peace Corps or graduate school offers. While stationed in Wichita Falls, Texas, during the Vietnam War, he married his wife of 50 years, Carol, and began contemplating teaching.

The four-year break helped him refocus. He earned a doctorate in hydrogeology from the University of Illinois at Urbana–Champaign, studying the movement of heat through layers of sediment. The work earned Sharp the O.E. Meinzer Award—hydrogeology's highest honor. Other awards have since followed from organizations large and small. In fall 1974, he first began sharing his love of learning on faculty at the University of Missouri–Columbia and came to The University of Texas at Austin in 1982. Over 100 graduate students and postdoctorates have benefited from his guidance.

Wendy Robertson, an assistant professor at Central Michigan University, completed her Ph.D. with Sharp at the Jackson School of Geosciences in 2014, and recalls his inspirational energy. She can still imitate his voice from when he awakened field camps at dawn with a song of reveille. His unguarded support for students' projects she remembers especially, referring to it as being "like air underneath your wings." For instance, he supported Robertson's development of a side project that has led her to consult on water resources in Haiti and Africa.

"His cheerleading really did shape me as a scientist because it allowed me to step out on the edge and think about what's practical," she said. "I definitely credit the independence he instilled with my current success."

Robertson also notes benefiting from the community of colleagues Sharp has made while collaborating on research and educational projects, and spearheading or contributing to professional meetings and endeavors. He has given keynote addresses in five countries, is a past president of the Geological Society of America, and a past president and treasurer for the U.S. chapter of the International Association of Hydrogeologists, among a multitude of professional roles.

Sharp also helps citizens consider water-related challenges. Buried amidst mementos coating his office door is a bumper sticker with a quote from a character by author Robert Heinlein: "A generation, which ignores history, has no past and no future." Sharp said that hydrogeologists are particularly poised to help explain resource challenges.

"We deal with the present, try to understand the past, and often project into the future with almost any water issue you look at," he said.

His focus on the impact of urbanization intensified after moving to Austin to join the geology faculty in 1982. Among the dozens of talks he has provided pro bono, for have been several for West Texas residents wondering how Balmorhea Springs could be affected by possible hydraulic fracturing for oil.

"It's important to put out the current science as best as we understand it [to foster wise decision making]," Sharp noted. "Sometimes it's not appreciated, but it's something every scientist should do."

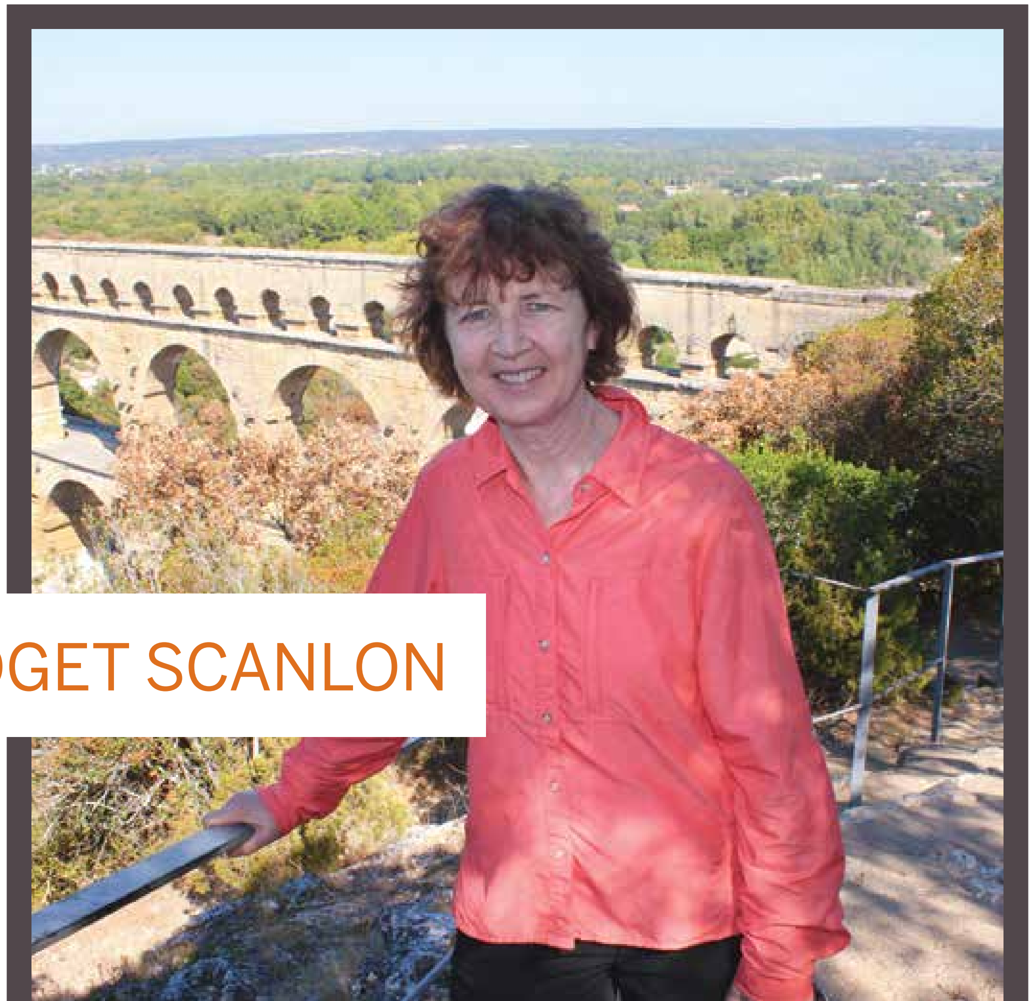
As for retirement, he still has presentations and manuscripts such as a dense memoir about the Edwards Aquifer to help develop, and classes to teach. When he accepts full retirement and shorter office hours next summer, a hydrogeology glossary beckons, and a monthly newsletter must be kept alive.

"I'll continue to learn—and hopefully contribute—to science," Sharp said.

> "There are some people who know exactly what they're going to do as a career. But mine … it's just been an adventure."
>
> *-Jack Sharp*

PHOTOS: JACK SHARP.

OPPOSITE PAGE: SHARP AT HALLETT COVE IN AUSTRALIA. ABOVE: SHARP IN BIG BEND WITH FORMER STUDENT FU LI .



BRIDGET SCANLON

Bridget Scanlon's contribution to understanding our most precious resource cannot be overstated. As a world-leading authority on water research, her career has been characterized by a commitment to data as well as innovative approaches that cut across disciplines. *by John Holden*

During her 30-year career at the Bureau of Economic Geology, Scanlon has published over 100 articles in numerous peer-reviewed journals, such as *Groundwater*, *Water Resources Research*, and *Environmental Science & Technology*. She has served on National Academy of Sciences committees, been involved with U.S. Department of Energy scientific endeavors, and has been a member of the NASA GRACE science team, a group dedicated to using satellite data to study Earth.

In 2016, she was elected as a member of the National Academy of Engineering, one of the highest professional honors a scientist can receive. Also in that same year, she received the National Ground Water Association's M. King Hubbert Award for major science contributions to the knowledge of groundwater. Recently, she was appointed to the Jackson School's William L. Fisher Endowed Chair in Geological Sciences, a distinction that recognizes research scientists, research professors or faculty members for their excellence in research, teaching and service.

"The Bureau of Economic Geology is fortunate to have a research scientist with the dedication, expertise and vision of Dr. Bridget Scanlon," said bureau Director Scott W. Tinker. "Bridget is widely considered one of the foremost authorities on water resources. She is passionate about her work and what it means to the conservation and wise utilization of water sources in Texas, nationally and globally. I'm honored to call Bridget a colleague and friend."

WATER, WATER EVERYWHERE

While Scanlon is widely versed in the elements that impact water usage, storage and conservation, she is particularly active in certain research areas: studies of groundwater recharge; the impact of climate extremes and land-use changes on hydrologic processes; water use and availability related to energy; and use of underground aquifers as water storage facilities.

Born in County Kerry, Ireland, Scanlon first studied geology at Trinity College in Dublin and also worked as a field assistant with the Geological Survey of Ireland. This field work formed the basis of her 1983 master's in geology undertaken at the University of Alabama. Its focus on the hydrogeology of karst landscapes was a preamble to her chemical and physical work as a Ph.D. student at the University of Kentucky in the karst central Bluegrass Region.

After her Ph.D., she spent a year working for the S.S. Papadopulos consulting firm in Washington, D.C., and then interviewed for positions in research and teaching in various U.S. universities.

"That's how I ended up in Texas," she said.

Scanlon was first offered a position as research associate at the bureau in 1987. Her decision to remain for three decades is due mainly to the independence afforded to active researchers and the avenues such flexibility allows for collaboration across disciplines.

"The range of things we do at the bureau cannot be understated," she said. "From satellite to deep subsurface, we go the whole gamut.

"The bureau model has always impressed me," she stressed. "They really promote collaboration. Every project is a team effort. This is quite different from working in traditional university departments where professors are frequently lone rangers in their respective fields. Fostering a collaborative spirit is so beneficial, particularly from a research perspective."

BEYOND OIL & GAS

It is sometimes assumed the bureau is focused solely on oil and gas research and funded almost exclusively by major private energy producers. This is a misconception, and Scanlon's tenure at the bureau is a testament to how diverse the research can be.

"When I first started here, my focus wasn't on oil and gas at all, but various environmental issues, including low-level radioactive waste disposal," she said. "Over the years, the bureau has worked with the Texas Water Development Board, Texas Commission on Environmental Quality, the EPA, and is currently conducting a major study into carbon sequestration with the support of the Department of Energy."

More recently, however, Scanlon has found her expertise becoming increasingly relevant to oil and gas, given how central water is to the process of hydraulic fracturing.

"There is a lot of concern over the large amounts of water needed in order to hydraulically fracture wells in the first place," she said. "Given its high premium in a state like Texas, much attention is focused on where water can be sourced to service major plays where hydraulic fracturing is being conducted."

Another challenge is managing the water produced as a byproduct of hydraulic fracturing along with oil and gas. This "produced" water needs to be disposed of in some way, and there is often a lot of it.

"The U.S. produces about 10 barrels of water for each barrel of oil," she stated.

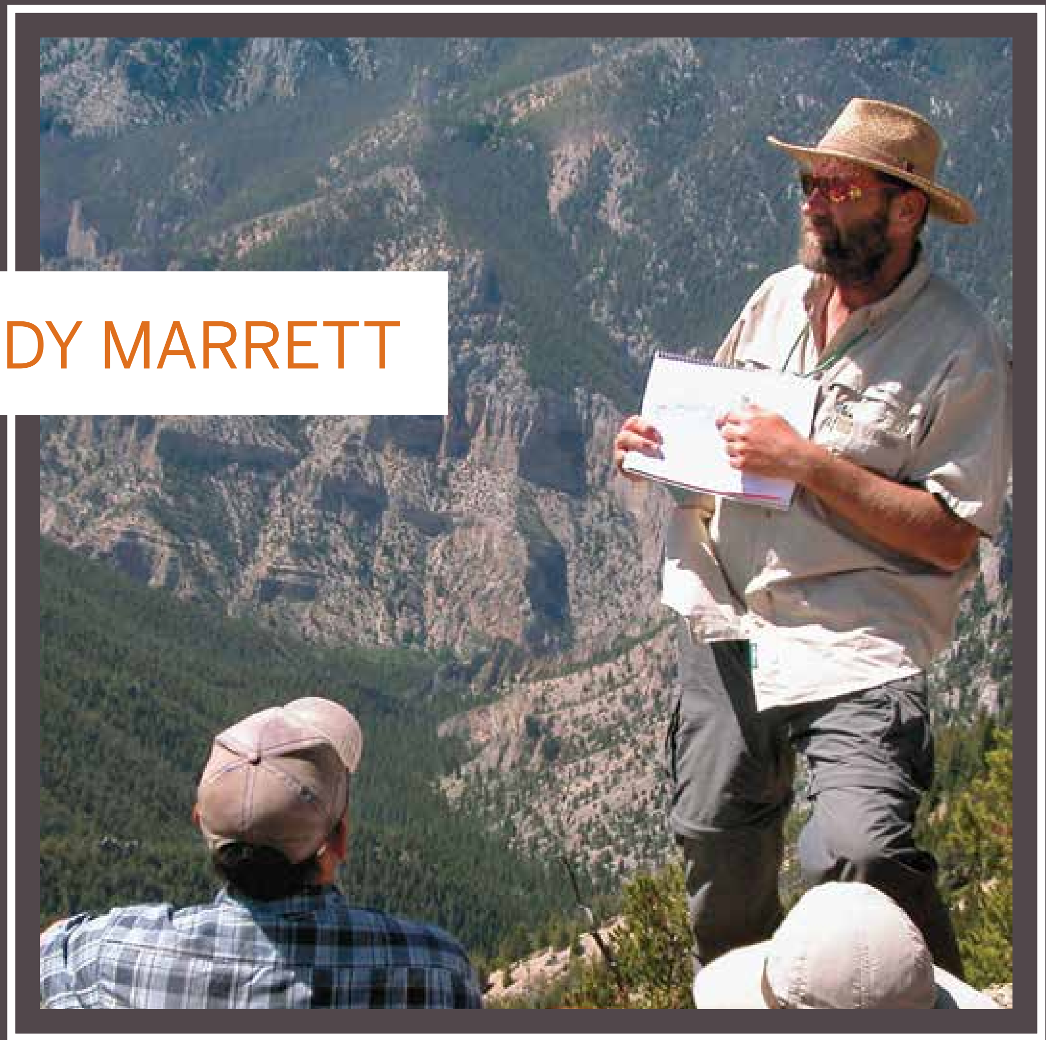
Between the water used in hydraulic fracturing operations and the water produced as a result of those operations, water management is a critical issue for industry. However, it is important to consider water use for the energy sector in a broader context with irrigated agriculture being a major water user in many semiarid regions.

"There is no one size fits all model," Scanlon said. "Each play has its own particular set of variables that must be assessed individually. By studying the details of each play, then putting all those pieces together and taking a step back, we then begin to understand the broader picture. For me, this approach to research has frequently led to the discovery of workable solutions to the many challenges faced when it comes to water supply and demand."

OPPOSITE PAGE: SCANLON NEAR THE PONT DU GARD AQUEDUCT NEAR THE CITY OF NIME IN FRANCE. **RIGHT:** SCANLON AT HER INDUCTION INTO THE NATIONAL ACADEMY OF ENGINEERING WITH PRESIDENT C.D. MOTE (RIGHT) AND CHAIRMAN GORDON ENGLAND

AWARD: BUREAU OF ECONOMIC GEOLOGY. AQUIFER: BRIDGET SCANLON.

RANDY MARRETT



Professor Randy Marrett, a structural geologist, retired this summer after 23 years of research and teaching in the Department of Geological Sciences. *By Monica Kortsha*

Marrett was a world-class educator and researcher whose work primarily focused on rock fractures and how fluid flows through them. It's a key concept in geology, but a difficult one that often ends up frustrating many who try to take on the challenge, said Bureau of Economic Geology Senior Research Scientist Stephen Laubach, a longtime collaborator of Marrett's.

"The path to solving any of these basic problems is just fraught with so many basic impediments ... it takes a certain stubbornness to stay in the fight," Laubach said.

Research on fractures is so challenging in part because it's difficult to study fracture systems that exist deep underground, and understand how fractures behave as the environment changes. Marrett's most highly cited papers use thorough field observations, combined with conceptual and mathematical insights on fracture and fault behavior. One of these papers, a 1991 publication that is one of the most highly cited papers published in the *Journal of Structural Geology*, found that when it came to brittle faults, most methods were underestimating the number of fractures present in a given area—a point of particular importance to oil and gas companies interested in mapping out paths where hydrocarbons could go.

While at the Jackson School, Marrett conducted much of his fieldwork in the Sierra Madre Oriental Mountains in Northern Mexico, and in the Central Andes of Argentina and Chile. He is fluent in multiple dialects of Spanish. His and his students' research in Mexico ranged from regional structure of the Sierra Madre Oriental fold-thrust belt and timing of thrusting to structural studies of detachment folds and structure and stratigraphy within the evaporate decollement. In the Andes, they studied the intracontinental deformation and magmatism responses to late Cenozoic South American plate motion reorganization.

PHOTOS: JACKSON SCHOOL.

Marrett was always more interested in sharing fracture research with those who could apply it, than rushing to publish in journals, Laubach said. To that end, in the 1990s, he and Marrett and collaborators in the Department of Petroleum & Geosystems Engineering (PGE) founded the Fracture Research and Application Consortium (FRAC)—an academic and industry partnership dedicated to studying fracture questions of interest to both groups.

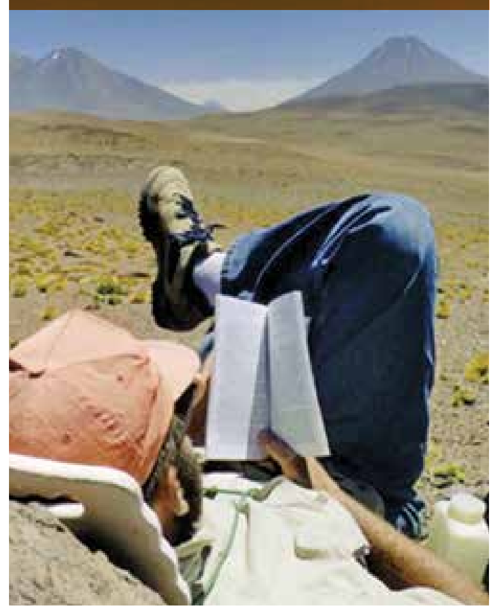
Laubach credits FRAC's success in part to Marrett's skill in explaining the science of fracture research to any audience. Marrett, Laubach and Jon Olson, the PGE department chair and FRAC collaborator, used to run a lecture series on fractures in reservoirs for the American Association of Petroleum Geologists. Marrett consistently received high rankings for his presentations.

New research ideas could come to Marrett in a flash of brilliance. Laubach recalls a flight to Mexico where he saw Marrett doodling on a napkin. The sketch outlined a new technique for quantifying how fractures were arranged in a particular area.

"The new technique sprung out of his head fully formed," Laubach said. "He is probably the closest thing to a genius the Jackson School ever had."

Marrett was an educator extraordinaire. Known widely for his teaching, he earned the ranking of "Awesome!" from the website Rate My Teachers. For many years, he taught GEO 428 Structural Geology and GEO 420K Stratigraphic and Field Methods courses, as well as Advanced Structural Geology and Brittle Structure for graduate students. His devotion to teaching was most evident in his yearly participation in GEO 660, an undergraduate field camp course. Marrett excelled at teaching in the field, both traditional fold-thrust belt mapping and interpretation and integration of thrust kinematics and dynamic processes during deformation.

ABOVE: RANDY MARRETT
BELOW: MARRETT IN THE ANDES



Mark Helper, field camp director and longtime co-instructor with Marrett, was quick to point out his contributions.

"In 20-plus years of team teaching with dozens of faculty, Randy was simply the finest field instructor I've worked with," Helper said. "He trained hundreds of undergraduates. His field skills are unparalleled and his creative teaching methods brought something new to our classes every year. Like the best teachers, he has the ability to explain complex ideas in simple terms and sketches. His contributions to our field program will be sorely missed."

During his time at the university, Marrett supervised 20 M.S. and seven Ph.D. students and published 57 papers, which have been cited more than 3,608 times.

Elizabeth McKinnon, a master's student of Marrett's, said that he helped build confidence in her that all ideas are worthy of consideration.

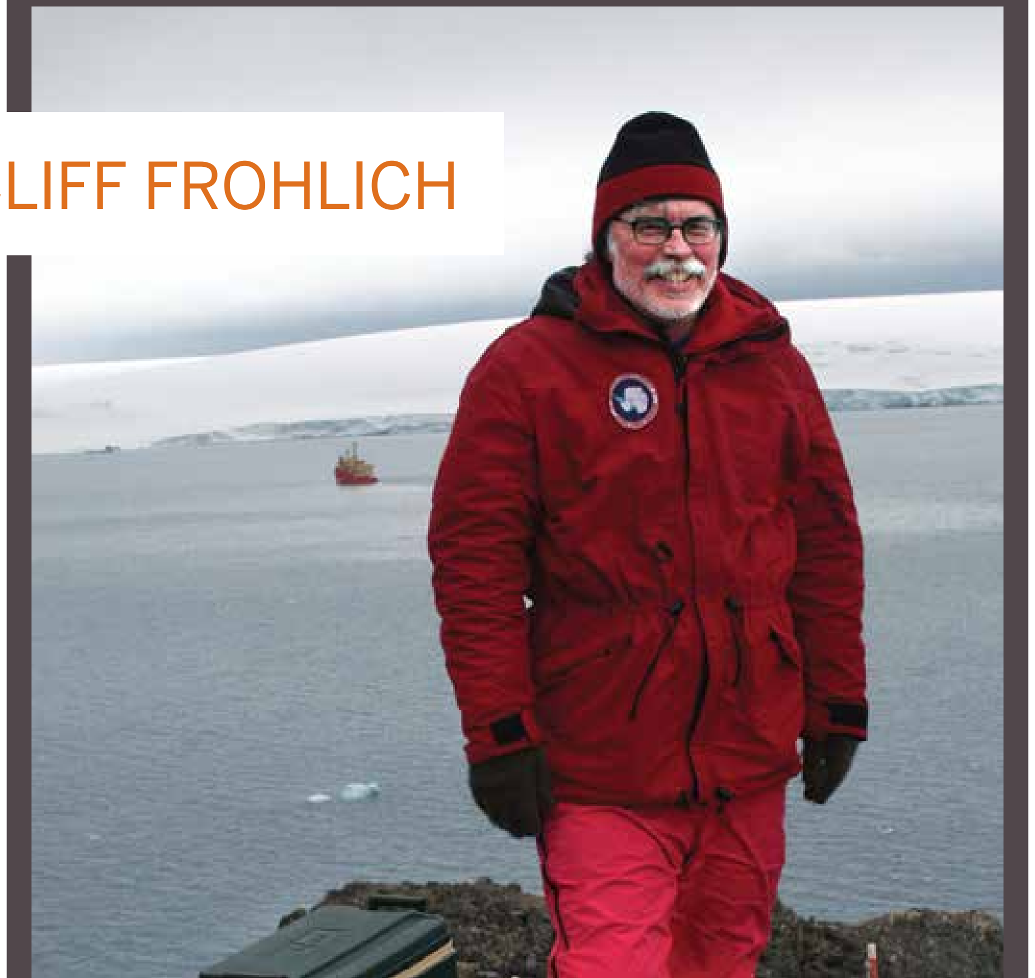
"Randy is good at helping people think for themselves," McKinnon said. "If you have 20 ideas and even if only two of them could be plausible, he still wants you to be able to come up with those 20 ideas and expand your mind, and think of all the possibilities."

Marrett was drawn to the field at an early age. A great lover of the outdoors and fishing, he moved to his cabin in Idaho when he retired and is now living off the grid. Far away from publications and people, McKinnon envisions Marrett spending the day going where his ideas lead him, with geology front and center.

"He takes things he's heard, stories that don't seem geology-related, and he can always see why geology is the most important part of the story," she said.

OPPOSITE PAGE: MARRETT IS IN THE BIG HORN BASIN, NEAR GREYBULL, WYOMING

CLIFF FROHLICH



When Cliff Frohlich joined the University of Texas Institute for Geophysics in 1978, he didn't move to Austin, he moved to Galveston, where the institute was originally located. His specialty was on ocean bottom seismography, but from the moment he was hired, he was told to focus on science. *By Jessica Hall*

"One of the wonderful things about the institute is that from the beginning they basically said, 'you're a research scientist, we don't know what you should be thinking about, but figure it out. As long as some of it is earth science, do the best science that you can,'" Frohlich said. "I've had a career where nobody has ever prevented me from thinking about something I'm curious about and that's something special because I've done a lot of things."

And that's exactly what he did for the past 40 years—the research that interested him. Over the years he has studied the ocean bottom, earthquake statistics, deep earthquakes, Texas earthquakes and manmade earthquakes. The latter is what Frohlich is most known for recently; his phone regularly rings as soon as an earthquake is felt in Texas. His interest in manmade or induced earthquakes began thanks to a graduate student, Scott Davis, who Frohlich began to work with when Davis' original advisor, who didn't see a future in studying induced earthquakes at the university, left UT.

"I said [to Davis], 'if you're working with me you need to work on deep earthquakes and earthquake statistics because there is obviously no future in manmade earthquakes,'" Frohlich recalls. "[Davis'] approach to my advice was he continued to work on induced earthquakes and also worked on deep earthquakes and earthquake statistics. And of course the result was that he drew me into discussions about manmade earthquakes."

This led to Frohlich's "hobby" on Texas-induced earthquakes. With no funding or great interest outside of his own, it was something he studied for years, leading him to become an expert when manmade earthquakes became a hot topic in recent years. When two earthquakes near Dallas occurred in 2008, he collaborated with colleagues at Southern Methodist University (SMU) to study the incidents. They turned out to be first manmade earthquakes of the new era.

"I was on the forefront of the renaissance of manmade earthquakes," Frohlich said. "I've often said, 'an expert is somebody who was publishing on something before the smart people thought it was important.'"

Growing up in a family of writers, Frohlich determined that he was the third best writer and that maybe he'd try a different route. When Sputnik went into orbit, he remembers hearing that math and science were the future for careers, so he thought he'd try that. The joke was on him though, as he estimates a large majority of his job is actually writing.

"In my career, publishing has been hugely important," he said. "I think a lot of people publish because they have to because of a grant or otherwise. I'd say that many of my papers, I didn't have to write. My knee jerk reaction as a scientist: if I figure something out, I should write about it."

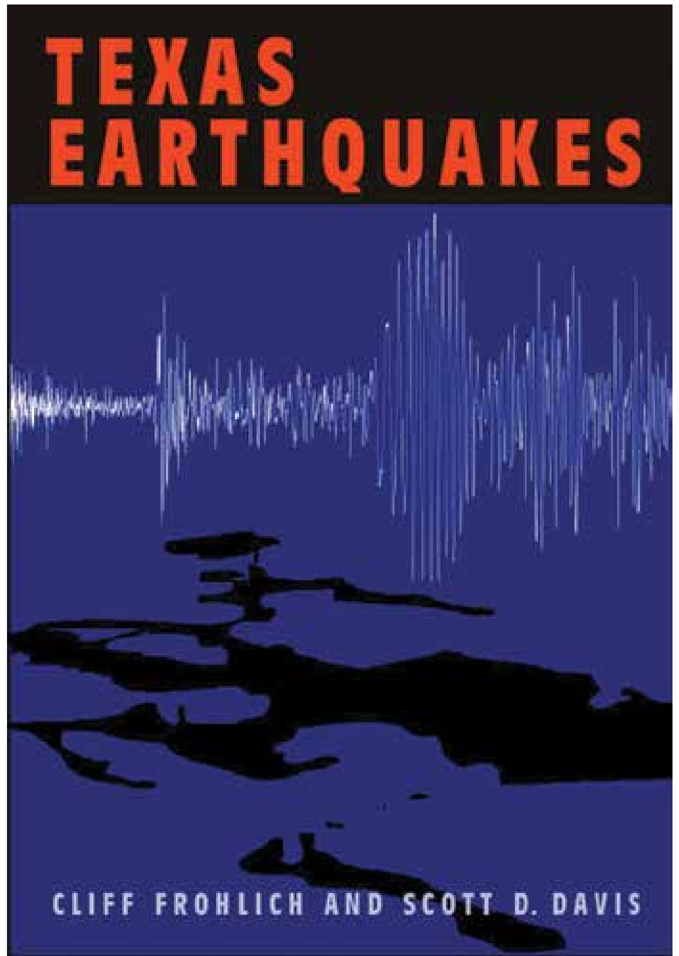
His advice to new researchers is to find problems that are important and do the best science that they can.

"On one hand, be careful to publish as much as you can, but two, be careful to work on important problems. Take the time to do it right," Frohlich said. "Those are kind of opposite—taking the time to do it right and working on a hard problem means that you publish less, but publishing a lot means that you've got to get something out, and they are both true."

While Frohlich has spent most of his time at UTIG studying what interested him, he also served as associate director for the past 20 years. UTIG Director Terry Quinn said that he and the institute as a whole have benefited from having Frohlich at the helm for the past two decades.

"Cliff has provided wise counsel and guidance to previous directors and me," Quinn said. "I am especially grateful to Cliff for his friendship over the years as well."

So what are Frohlich's plans now that he's retiring? He'll still be around UTIG as a researcher emeritus, and will be a visiting scientist at SMU. He also plans to spend more time with family and working on some hobbies, like woodworking, cycling and writing.



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– Cliff Frohlich

PHOTOS: UNIVERSITY OF TEXAS INSTITUTE FOR GEOPHYSICS.

OPPOSITE PAGE: FROHLICH IN ANTARCTICA
ABOVE: BOOK COVER FOR *TEXAS EARTHQUAKES*

Jackson School Hosts Four International Science Meetings

FROM CAVES AND LASERS TO TECTONICS AND TOMOGRAPHY, THE SCHOOL WAS A SITE FOR DIVERSE SCIENTIFIC EXCHANGE.

Karst Record Conference (KR8)

The Karst Record Conference, a four-day, international conference dedicated to sharing the latest progress in cave-based paleoclimate research, convened at the Jackson School of Geosciences on May 21-24, 2017.

Jay Banner, the director of the Jackson School's Environmental Science Institute, and Kathleen Johnson, a professor at the University of California Irvine, hosted the conference, called KR8 for short. The program included three full days of oral and poster presentations, and mid-conference workshops. The 115 attendees came from 18 countries and 18 U.S. states.

Caves form in karst—a geological term for landscapes made up of rocks that are easily eroded by water, such as limestone and dolomite, and form underground drainage features, like caves and sinkholes. With that in mind, the karst landscape of the Texas Hill Country was an ideal locale to hold a conference dedicated in large part to sharing the latest research on how stalactites, stalagmites and other speleothems are used to study ancient climates.

Optional field trips to Inner Space Cavern, Natural Bridge Caverns, Barton Springs and West Cave gave conference attendees the option to see some of the most famous karst features of Central Texas during their stay.

Sarah Truebe, Director of Community Engaged Learning in Environmental Sustainability at Stanford University, enjoyed the mid-conference trip to Barton Springs—a trip that included a tour led by a U.S. Geological Survey hydrologist and an option to take a dip in the main pool—but was excited for the next day of scientific talks back at campus.

"So far, every talk has something interesting," she said.

A KR8 ATTENDEE LOOKS FOR SALAMANDERS DURING A CONFERENCE TRIP TO BARTON SPRINGS.

PHOTOS: JACKSON SCHOOL.

North American Workshop on Laser Ablation (NAWLA)

A who's who of laser ablation and inductively coupled plasma mass spectrometry converged on Austin in May 2017 to share knowledge about this powerful analytical technology.

The meeting—the North American Workshop on Laser Ablation—was also the second time the group has come to the Jackson School of Geosciences. The three-day workshop was spearheaded by a small group that includes Jackson School Laser Ablation and ICP-MS Lab Manager Nate Miller, who wanted to help create a workshop environment where scientists and instrument vendors could exchange information about a rapidly changing field.

NAWLA CONFERENCE ATTENDEES ON THE UT CAMPUS

"The best way to learn something is from an expert, and very few of us get the chance to go visit an expert in a lab to learn a technique," he said. "We're trying create a workshop with shared experiences and opportunities where you can learn."

The workshop constituted a snapshot of state-of-the-art laser ablation research. Some 130 scientists and vendors from 12 countries attended the workshop, including two internationally known pioneers in the field: Sam Houk of Iowa State University and Henry Longerich of Memorial University of Newfoundland. Jackson School research was presented by professors Richard Kyle and Daniel Stockli, postdoctoral fellow Federico Galster, and graduate students Stephanie Wafforn and Kylie Wright.

The workshop is now being held every other year—on the off-years of the long-running European workshop on the same topic. Miller doesn't know yet if the Jackson School will be the permanent home of the event, but said that the group is committed to keeping the meeting going. That's good news for Longerich, who said he found the workshop much more constructive than some larger and better-known scientific conferences.

"It's a perfect size," Longerich said of the workshop. "That makes this meeting, for me, more productive. I can just sit there and soak it all in."

Tomography for Scientific Advancement Symposium (ToScA)

For the past 20 years, The University of Texas at Austin's High-Resolution X-ray Computed Tomography Facility, or UTCT, has been hard at work in the Jackson School of Geosciences, giving researchers a nondestructive look inside specimens ranging from dinosaur eggs to ancient meteorites.

On June 6–8, 2017, the far-reaching research facilitated by UTCT and other CT-scanning facilities was on display at the Jackson School of Geosciences for the first North American meeting of ToScA, the Tomography for Scientific Advancement Symposium. Hosted by UTCT and the Jackson School, and managed by the Royal Microscopical Society, the event brought together about 70 attendees from 31 different academic institutions and companies, and four countries, all united by a common research interest in CT-scanning.

Farah Ahmed, the head of imaging and analysis at the Natural History Museum London and ToScA founder, suggested the Jackson School as the site of the first North American meeting, said UTCT research scientist associate and facility manager Jessie Maisano, who co-chaired the meeting with Ahmed.

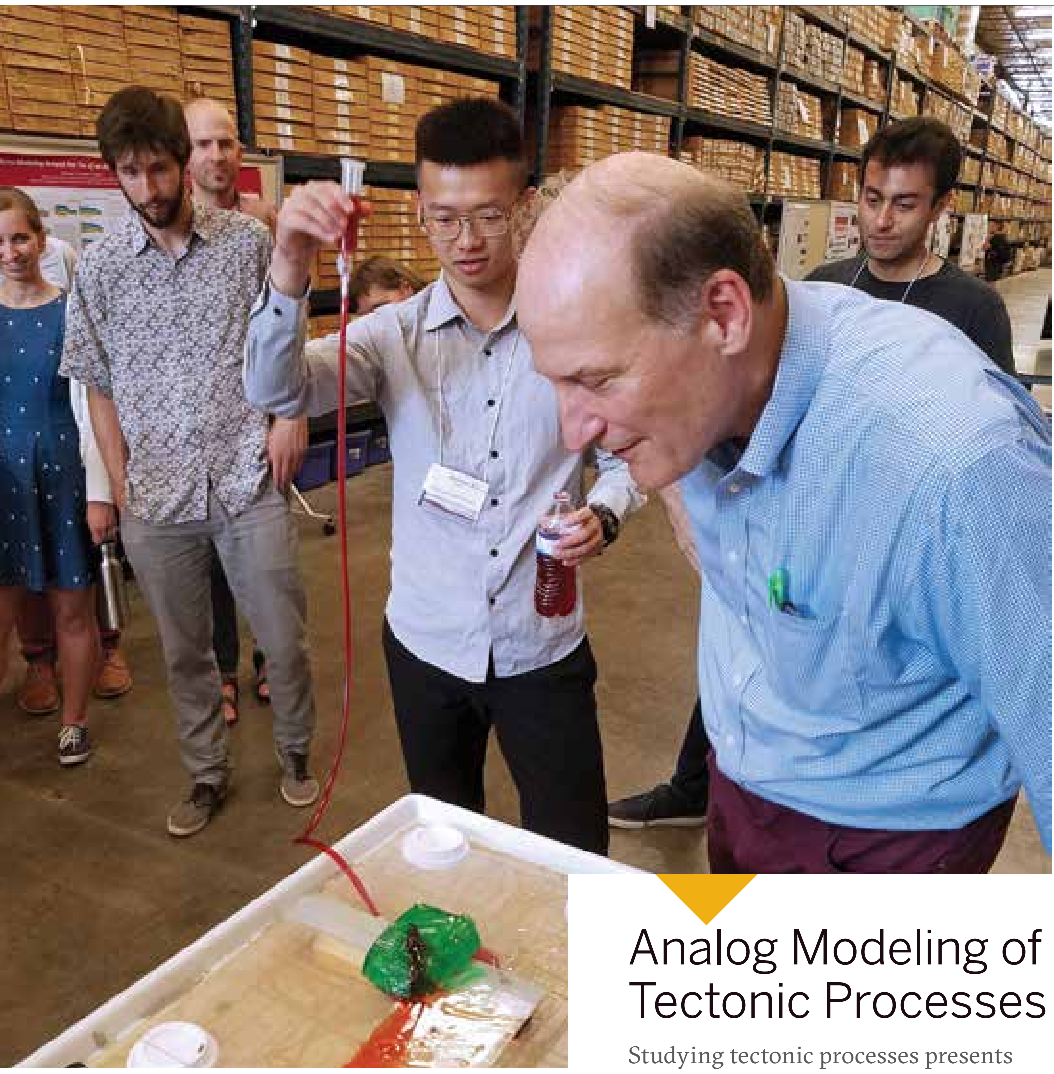
CONTINUED ON NEXT PAGE

A CT-SCAN OF A KOMODO DRAGON HEAD THAT WAS CREATED IN THE UTCT FACILITY.

"She approached us because we've been doing this for 20 years, and we were the first academic research lab in the United States to provide this kind of technology to academic researchers, as far as we know," Maisano said. "The program has been amazingly strong, especially for a first meeting."

The program included lectures on scanning and analysis techniques, as well as on how the technology was being applied in different scientific areas, including geology, materials science, and medical and biological science.

The UTCT lab got its first CT scanner in 1997. Before that, researchers had to rely on military or medical contacts to scan specimens, said UTCT Director Richard Ketcham. By scanning specimens for all sorts of research ends, the UTCT lab has developed a broad expertise, and developed relationships with scientists across disciplines.



RESEARCH PROFESSOR ROGER BUCK (RIGHT) AND GRADUATE STUDENT XIAOCHUAN TIAN, BOTH OF COLUMBIA UNIVERSITY, PERFORM AN EXPERIMENT SIMULATING CRUSTAL BREAKUP DUE TO MAGMA INTRUSION BY USING GREEN GELATIN AND RED WATER.

Analog Modeling of Tectonic Processes

Studying tectonic processes presents geoscientists with a multitude of difficulties, but none of the challenges are more daunting than dealing with the scale of the science: tectonic processes are large and take place over a long period of time. Given these issues, models can be a very effective way of understanding some of the processes governing tectonic deformation.

Analog, or physical, models contribute substantially to the development of new tectonic concepts, as well as benchmarking numerical models. Still, the analog modeling community is dispersed and small, and its interaction and collaboration with the numerical modeling community is limited.

The National Science Foundation sponsored an international Analog Modeling of Tectonic Processes workshop at the Bureau of Economic Geology in May 2017 to bring the two modeling communities together. Bureau researcher and workshop co-organizer Tim Dooley points to the success of a session where the attendees ran an analog and a numerical model of an extensional rift system. The results stimulated discussions on the strengths and limitations of both approaches, as well as ways to increase collaboration between the two scientific modeling groups.

"This hands-on approach during the workshop led to a direct exchange of ideas and facilitated networking between the different communities," Dooley said.

The group visiting the bureau consisted of about 50 modelers from six countries and included early-, mid- and late-career geoscientists. The three-day workshop included 10 oral presentations on topics such as the application of model results to field and seismic data, different experimental techniques, and scaling and reproducibility issues. Some 22 posters and two teaching examples of modeling methods were presented.

The workshop concluded with a discussion where participants agreed that a better system was needed to exchange teaching material on analog models in classrooms, and that there is an ongoing need for a system or database to store and exchange model results, as well as a database of different model materials.

PHOTOS: JACKSON SCHOOL.

BEG Launches EarthDate Radio Program

The Bureau of Economic Geology has created a new radio program—EarthDate—which informs listeners of all ages about Earth science topics in two-minute episodes narrated by bureau Director Scott Tinker. EarthDate is currently on more than 100 radio stations in 35 states, as well as available for free at earthdate.org. The topics covered in the first 23 episodes include landslides, the Earth's changing gravity, magnetic storms and mass extinctions. The program will feature 13 new installments each quarter and will draw on experts from around the world, including researchers from the Jackson School of Geosciences. Listen to the programs online at: earthdate.org.

Jackson School Launches Two New Blogs

TWO NEW BLOGS ARE GIVING AN INSIDER LOOK INTO SCIENCE AND EDUCATION AT THE JACKSON SCHOOL OF GEOSCIENCES. READ BOTH AT: JSG.UTEXAS.EDU/NEWS/BLOGS

Texas Geosciences

Texas Geosciences gives an on-the-ground look into education and research at the Jackson School of Geosciences. The blog features posts from faculty, research scientists, and members of the Jackson School's communications office.

Science, Y'all!

Science, Y'all! is a blog run by graduate students in the Jackson School of Geosciences. The purpose of this blog is to provide graduate and undergraduate students with a platform to share their research and experiences with their peers and the general public.

SARAH GEORGE (LEFT) AND TOMAS CAPALDI AT THE U.S. CAPITOL BUILDING.

JSG Students Represent Geosciences at NSF Expo

Jackson School of Geosciences graduate students Tomas Capaldi and Sarah George took Texas geosciences to Capitol Hill in May 2017, meeting with members of Congress and their staffs to discuss the importance of supporting geosciences research and education.

They were both part of the Coalition for National Science Funding Expo, a meeting that highlights research and education programs funded by the National Science Foundation (NSF), and creates an opportunity for NSF-funded scientists to engage with lawmakers. Both Capaldi and George's research is supported by NSF grants, and George is funded by an NSF graduate research fellowship.

The coalition includes over 130 professional organizations, universities and businesses dedicated to increasing funding for the NSF and the research and education programs it supports. Capaldi and George represented the geosciences as a whole at the event, including the Geological Society of America and the American Geophysical Union.

During their time on the Hill, Capaldi and George met with the staffs of Sen. John Cornyn of Texas and Rep. Lamar Smith of Texas to explain how NSF-funded research at the Jackson School is beneficial to Texans.

"We let them know what we're researching, and what we can give back," George said, mentioning how research on sedimentary basins is key for hydrocarbons exploration.

George said the experience illuminated how science is often an overlooked topic when it comes to policy. She noted how slips of paper used to document topics constituents called about have pre-printed check boxes for health care and jobs, but no such box for science.

"No one is calling on behalf of science," she said.

Update on the Future of Undergraduate Geoscience Education

The National Science Foundation (NSF) sponsored initiative on the Future of Undergraduate Geoscience Education continues to work on changing undergraduate education to meet the needs of the workforce and society.

The recommendations of this national effort involved input from over 1,000 academics and geoscience employers. About 100 department heads and chairs nationwide have started implementing these recommendations into their undergraduate programs and curricula. The organizing committee, led by Jackson School Dean Sharon Mosher, is evaluating the heads and chairs successes and problems in implementing change over the past 18 months. The goal is to find solutions that will help others in similar types and sizes of departments overcome roadblocks and obstacles to change. Over the next year, the organizing committee hopes to codify the recommendations and best practices for implementation into a "Vision and Change" document.

At UT, this effort dovetails with President Greg Fenves' Undergraduate Degree Transformation initiative and Project 2021. This past year, the Department of Geological Sciences degree transformation committee formulated preliminary plans for enhancing our undergraduate degree to increase undergraduate research and experiential learning and incorporate the recommendations of the national initiative.

The national effort is a response to the growing realization that future generations of geoscientists will need a wider variety of skills than past generations, and a looming workforce shortage, in part because a large number of geoscientists are nearing retirement age. Recognizing this also applies to graduate students and that only about 50 percent of students who earned a Ph.D. go into academia, the NSF has funded Mosher to expand this initiative to consider the skills and competencies needed by all geoscience graduate students whether they have future careers in industry, government, academia or non-governmental organizations, or are studying Earth, atmosphere or oceans.

You can keep up to date on the initiative and view all the materials at jsg.utexas.edu. Click on the "Future of Geosciences Education" link.

NSF EXPO: GEOLOGICAL SOCIETY OF AMERICA.

GEOSCIENCES ACROSS TEXAS

From exploring energy frontiers to monitoring earthquakes, the **Jackson School of Geosciences** benefits Texans statewide.

1. TEXNET/CISR STATEWIDE SEISMIC MONITORING SYSTEM AND RESEARCH (See page 21).

2. TXSON
A network of ground-based monitors throughout Texas that measures soil moisture to better understand and predict intense droughts and floods.

3. SHALE RESOURCE AND RESERVE STUDIES
The most comprehensive public study of six major shale plays in the nation — with half in Texas. (See page 16).

4. MG&G FIELD COURSE ON THE TEXAS COAST
A one-of-a-kind class that is training the next generation of geophysicists for the energy industry. (See page 50).

5. GEOFORCE TEXAS
A program that teaches high school students from underserved areas in Texas about the geosciences and helps prepare them for college and careers. GeoFORCE recently received the Presidential Award for Excellence in Science, Mathematics and Engineering Mentoring, the highest such honor from the United States government.

6. THE STATE OF TEXAS ADVANCED OIL AND GAS RECOVERY PROGRAM
A state-funded program that assists oil and gas operators using the latest technology, geoscience and engineering understanding to increase production in existing fields and regional exploration projects.

7. HURRICANES AND COASTAL EROSION
From using state-of-the art LIDAR techniques to map the Texas coast to the Rapid Response program, which places scientists at the scene of natural disasters soon after they occur, UT is helping the state understand and prepare for the effects of natural hazards. (See page 18).

8. FORT WORTH METHANE IN WATER STUDY (See page 12).

9. WATER SCARCITY RESEARCH
Leading research on the impact that energy production and agriculture have on water use and on how to manage the state's limited water resources. (See page 28).

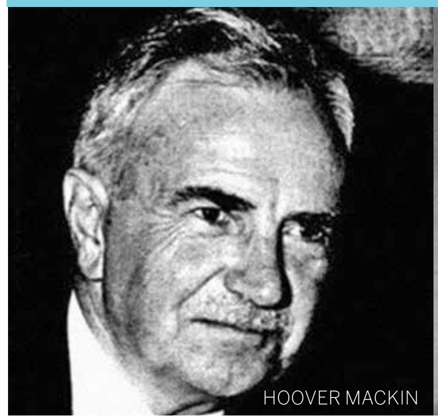
10. STUDYING METHANE HYDRATE AS A FUTURE ENERGY SOURCE (See page 58).

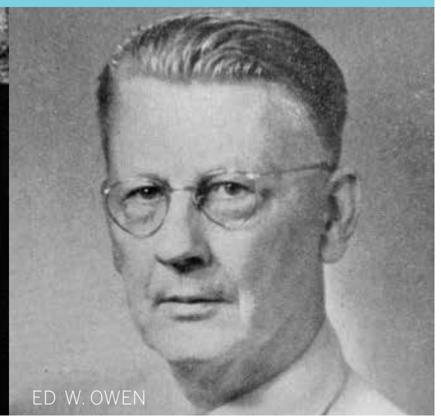
11. GULF BASIN DEPOSITIONAL SYNTHESIS PROGRAM
GBDS builds an ever-evolving picture of Gulf of Mexico geology using data from academic and industry partners. The data recently gave companies a first look into previously off-limits waters around Mexico, an area of critical interest and importance to the Texas oil and gas industry.

12. HR3D GULF SURVEYS
High resolution 3-D marine imaging technology is giving researchers a better look at Gulf of Mexico subsurface for the potential to store large volumes of carbon dioxide emissions and create a new industry in Texas.

13. CORE REPOSITORIES
More than 1.5 million boxes of rock core and cuttings are available for study at each of the Bureau of Economic Geology's three core repositories in Austin, Houston and Midland.

14. PETRA NOVA CARBON MONITORING (See page 84).


HOOVER MACKIN


ED W. OWEN

Mackin and Owen Added to Hall of Distinction

The Jackson School of Geosciences inducted two new members into its Hall of Distinction, an honor that recognizes individuals with a strong affiliation to the school who have made high-level accomplishments in academia, industry or government. Both are posthumous inductions.

Hoover Mackin was recruited by The University of Texas at Austin Department of Geology in 1961 to occupy its first endowed faculty position, the William Stamps Farish Professorship (later Chair). Mackin was first appointed as a visiting professor at UT to provide an opportunity for him to get a feel for the department and the Austin community. He liked what he saw and joined the faculty of the university permanently a year later.

Mackin was a distinguished scientist. He was a member of the National Academy of Sciences and served a two-year term as chairman of the Earth Sciences Division of the National Research Council. His early work was in geomorphology and his concept of "the graded river" became a mainstay in fluvial geomorphology. He later undertook research in engineering geology, structural geology and field petrology. Mackin was also involved in the mission to land a man on the moon and was one of four experts selected by NASA to study the first lunar rock samples returned to Earth. Both a lunar crater and Antarctic plateau are named in Mackin's honor.

He taught for 28 years at the University of Washington before joining UT, where he supervised four master's students and five Ph.D. students while a faculty member of the department.

Ed W. Owen was a lecturer in the UT Department of Geology from 1952–1976, where he moderated Tech Sessions, participated in graduate seminars, counseled students, served on the advisory council, and helped organize a history of geology course—all while refusing a salary during his entire tenure. Owen was active in local and national scientific and professional geological societies, serving as president of the American Association of Petroleum Geologists (AAPG) from 1941–1942. The material he developed for his history of geology course was later published by the AAPG as "Trek of the Oil Finders," and has become a classic reference.

Owen served in WWI and WWII, serving in the Army in 1918, and enlisting in the U.S. Army Air Corps in 1941. In 1942, as a captain in the Air Corps, he served in New Guinea and Australia in the photographic intelligence division. Attaining the rank of lieutenant colonel, he was awarded four campaign ribbons, five battle stars, a distinguished unit citation, and the Legion of Merit. Owen was key in organizing the Geology Foundation and served on its advisory council.

Julia Clarke Recognized for Research Career with Humboldt Award

Julia Clarke, a professor in the Jackson School of Geosciences Department of Geological Sciences, received a 2016 Humboldt Research Award. The award is granted by the Alexander von Humboldt Foundation, which promotes academic cooperation between scientists and scholars in Germany and other countries.

The award recognizes a researcher whose fundamental discoveries, new theories, or insights have had a significant impact on their own discipline and who are expected to continue producing cutting-edge achievements in the future. Award winners are invited to spend a period of up to one year cooperating on a long-term research project with colleagues at a research institution in Germany.

Clarke's research focuses on using phylogenetic methods and diverse data types to gain insight into the evolution of birds and avian flight. She is particularly interested in the evolution of living bird lineages and how the diversity, shape and form of birds have changed across their deep histories.

MACKIN: THE NATIONAL ACADEMIES PRESS. ALL OTHER PHOTOS: JACKSON SCHOOL.

Jay Banner Receives UT Award for Great Teaching of Undergrads

Jay Banner, a Jackson School of Geosciences professor and director of the UT Environmental Science Institute, is a 2016–17 recipient of the President's Associates Teaching Excellence Award. The award is bestowed by the president of The University of Texas at Austin and recognizes great teaching of undergraduates in the core curriculum. He is one of eight UT educators who received the award.

Banner's research and teaching interests focus on Earth surface processes with the goal of understanding the interactions that occur between the atmosphere-land-ocean systems and how these interactions are preserved in the geologic record.

As director of the Environmental Science Institute, a collaborative Jackson School and College of Natural Sciences program, Banner oversees a range of interdisciplinary programs for basic scientific research, education and outreach related to the environment and sustainability.

Scanlon Receives Hubbert Award, Appointed Fisher Endowed Chair, and Named Prieto Memorial Fellow

Bridget Scanlon, a senior research scientist and hydrologist at the Bureau of Economic Geology, was the 2016 recipient of the M. King Hubbert Award from the National Ground Water Association (NGWA). The award recognizes major science contributions to the knowledge of groundwater.

She was also was recently appointed as the William L. Fisher Endowed Chair in Geological Sciences, as well as being named a fellow of the Prieto Memorial Excellence Endowment, which benefits the Fisher Chair.

Scanlon leads the bureau's Sustainable Water Resources Program, a research group that combines a variety of analysis methods—from local field measurements to data from NASA's GRACE satellite—to provide insight on water in the environment at a variety of scales.

Katherine Ellins Gets Neil Miner Award

Katherine Ellins, the program director for geoscience education research at the Jackson School of Geosciences, is the 2017 recipient of the National Association of Geoscience Teachers Neil Miner Award. Presented each year since 1953, the award honors an individual for exceptional contributions to the stimulation of interest in the earth sciences and is presented at the association luncheon at the national meeting of the Geological Society of America. Ellins is the third person from the Jackson School to receive this award. The other recipients are Professors Emeriti Bob Folk and Robert Boyer.

Ellins' efforts to improve science learning and public engagement include curriculum development for earth science, professional development for teachers, multi-institutional collaboration to promote diversity in geosciences at the K–12 and undergraduate levels. Her work has been supported by state agencies and federal grants, primarily the National Science Foundation, and carried out in collaboration with geoscientists and learning scientists.

Chuck Abolt Receives NASA Fellowship

Chuck Abolt, a Ph.D. student, received a NASA Earth and Space Science Fellowship for his research on arctic soils titled "Feedbacks between topography and three-dimensional fluxes of heat, water, and carbon in ice wedge polygons."

Abolt is one of just 69 awardees chosen from 385 applicants in the earth science field. His award was based on scientific merit, relevance to NASA's objectives in earth and space science, and academic excellence. Working with Ph.D. advisor and Bureau of Economic Geology Associate Director Michael Young as principal investigator, Abolt will explore two hypotheses regarding changing topography and the interrelationships between heat, water, and soil carbon levels of ice-wedge polygons to better understand the geomorphology of the Alaskan tundra.

The study also includes development of a software application to survey a study area of more than 480 square kilometers of tundra to estimate rates of groundwater release at a landscape scale.

Bell Appointed New Associate Dean for Academic Affairs

Professor Chris Bell has been named the Jackson School of Geosciences' associate dean for academic affairs, replacing Professor Richard Ketcham, whose term ended this summer.

"I'd like to personally thank Rich for his fine service in the positon," said Dean Sharon Mosher. "Chris is an outstanding researcher, educator and mentor and will be a tremendous fit as associate dean for academic affairs."

Bell is exceptionally qualified for this position, where he will be responsible for academic affairs for the Jackson School, including the undergraduate program, student affairs and admissions. He is an outstanding educator as shown by his numerous teaching awards, including The University of Texas at Austin's Chancellor's Council Outstanding Teaching Award, Texas Exes Teaching Award, Jackson School's Outstanding Educator Award, and five-time winner of the department's Knebel Teaching Award, among many others. Bell just finished a four-year term as graduate adviser in 2016, and along with Bill Carlson, started the Jackson School's Undergraduate Research Honors Program in 2005.

Bell, who joined the Department of Geological Sciences in 1997 as an assistant professor, is the John A. Wilson Fellow in Vertebrate Paleontology. His research centers on understanding the complex dynamics of vertebrate faunal communities during the Quaternary Period. He is interested in investigating patterns of vertebrate evolution, biodiversity and biogeography throughout the Quaternary, and the responses of different vertebrate groups to the various changes in climate that took place during the past two million years.

PHOTOS: JACKSON SCHOOL.

Christeson and Sen Named UTIG Associate Directors

The Institute for Geophysics has selected Gail Christeson and Mrinal Sen to be its new associate directors.

Gail Christeson is a senior research scientist at UTIG and Mrinal Sen is a professor and Jackson Chair in Applied Seismology.

"UTIG is fortunate to have such capable scientists who are willing to help with the administration of our group," said UTIG Director Terry Quinn. "I look forward to working with them in their new roles."

As associate directors, Christeson and Sen will assist Quinn in leading the institution and provide guidance and counsel. Both are looking forward to the opportunity to take on the leadership position in the institute.

"I would like to help in bridging between our four existing research themes using quantitative and computational methods and in establishing stronger ties with industry," said Sen about his goals.

Christeson said she wants to ensure good work is recognized within the institute, and to reach out to the UTIG community on how the institute can be improved further.

"I have two projects I'd like to tackle during the upcoming year," said Christeson. "First, I'd like to continue efforts to secure award nominations for UTIG scientists and staff so that they can be recognized for their achievements. Secondly, I'd like to meet individually with UTIG scientists, staff and students to learn more about concerns, and any recommendations anyone has on improving the work environment to make us all more effective."

Until this fall, Cliff Frohlich and Jamie Austin, both senior research scientists, served as associate directors. Frohlich is retiring after nearly 40 years at UTIG. He served for 20 years as an associate director, offering support and guidance to the director.

Jamie Austin will be continuing his work at UTIG and serving as the Integrated Ocean Drilling Program (IODP) forum chairperson.

Awards

Common Abbreviations:

AAPG	American Association of Petroleum Geologists
ACM	Association for Computing Machinery
AGS	Austin Geological Society
AGU	American Geophysical Union
AIPG	American Institute of Professional Geologists
BEG	Bureau of Economic Geology
DGS	Dept. of Geological Sciences
GCAGS	Gulf Coast Association Geological Society
GSA	Geological Society of America
GSEC	Graduate Student Executive Committee
JSG	Jackson School of Geosciences
SEG	Society of Exploration Geophysicists
SEPM	Society for Sedimentary Geology
UTIG	Institute for Geophysics

Faculty and Researchers

WILLIAM AMBROSE
Southwest Section's Levorsen Memorial Award, AAPG

ROBERT BAUMGARDNER
2017 Tinker Family Publication Award, BEG

WHITNEY BEHR
Faculty Annual Evaluation Award Assistant Professor, DGS

THORSTEN BECKER
Director's Circle of Excellence, UTIG

DONALD BLANKENSHIP
Director's Circle of Excellence, UTIG

BAYANI CARDENAS
Faculty Annual Evaluation Award Full Professor, DGS

GINNY CATANIA
Faculty Annual Evaluation Award Associate Professor, DGS

Director's Circle of Excellence, UTIG

ELIZABETH J. CATLOS
Max Kade Distinguished Visiting Professor, University of Heidelberg

JACOB A. COVAULT
2016 James Lee Wilson Award, SEPM

JULIA A. CLARKE
Provost's Teaching Fellow, The University of Texas at Austin

Humboldt Research Award, Humboldt Foundation

Knebel Outstanding Teaching Award, Graduate Course, DGS

STEVE DAVIS
2016 Tinker Family Publication Award, BEG

PEDRO DINEZIO
Director's Circle of Excellence, UTIG

Young Researcher Award, UTIG

PETER EICHHUBL
2016 Tinker Family Publication Award, BEG

ANDREAS FALL
2016 Tinker Family Publication Award, BEG

PETER FLEMINGS
Director's Circle of Excellence, UTIG

Joseph C. Walter Jr. Excellence Award, JSG

WILLIAM FOSTER
2017 Geo.X Postdoctoral Fellowship, Geo.X

TIMOTHY GALLAGHER
Earth Sciences Postdoctoral Fellowship, NSF

John Dorr Graduate Academic Achievement Award, University of Michigan

JAMES GARDNER
Knebel Outstanding Teaching Award, Undergraduate Course, DGS

GULF COAST CARBON CENTER
Outstanding Research Award, JSG

SEAN GULICK
Director's Circle of Excellence, UTIG

SCOTT HAMLIN
2017 Tinker Family Publication Award, BEG

WONSUCK KIM
2016 Geoscience Information Society Best Paper Award, Geoscience Information Society

STEPHEN LAUBACH
2016 Tinker Family Publication Award, BEG

JOE LEVY
Outstanding Educator Award, JSG

ROBERT LOUCKS
2016 Best Poster Award, GCAGS

ROWAN MARTINDALE
Knebel Outstanding Teaching Award, Introductory Course, DGS

ASHLEY M. MATHENY
2nd Place Oral Presentation, 32nd Conference on Agricultural and Forest Meteorology

KITTY MILLIKEN
2017 Runner-up Tinker Family Publication, BEG

MAHDI HEIDARI MOGHADAM
Future Leader, American Rock Mechanics Association

STEPHEN C. PHILLIPS
Visiting Fellowship, University of Minnesota Institute for Rock Magnetism

KATHERINE ROMANAK
2016 Friend of Water–Rock Interaction Award, International Association for Geophysical Contractors

MRINAL SEN
Director's Circle of Excellence, UTIG

Outstanding Researcher Award, UTIG

KRISTA SODERLUND
Director's Circle of Excellence, UTIG

MATTHEW B. WELLER
The ExxonMobil Outstanding Graduate Student Award, Rice University

CHOCK WOODRUFF
2016 Outstanding Educator Award, GCAGS

XINMING WU
2016 Best Paper in Geophysics, SEG

MICHAEL H. YOUNG
Fellow, Soil Science Society of America

TIEYUAN ZHU
First Author Publication Awards, BEG

Promotions

GAIL CHRISTESON
Associate Director, UTIG

JOEL JOHNSON
Associate Professor, DGS

OSARENI CHRISTOPHER OGIESOBA
Research Scientists, BEG

MARIA NIKOLINAKOU
Research Scientist, BEG

ALEXANDROS SAVVAIDIS
Research Scientist, BEG

MRINAL SEN
Associate Director, UTIG

ALEXANDER SUN
Senior Research Scientist, BEG

Students

DANNY ANDERSON
Austin Geological Society, DGS

YASER A ALZAYER
Meckel Family Named Grant, AAPG

HANNAH BRAME
Outstanding Teaching Assistant, DGS

KERI L. BELCHER
Ronald K. DeFord Field Scholarship, JSG

AAPG Grants-in-Aid, AAPG

JAMES BIEMILLER
Outstanding Graduate Student Award, UTIG

EMILIE BOWMAN
Estwing Hammer, DGS

RACHEL BERNARD
GSA Research Grant, GSA

NSF Graduate Research Internship Program, Smithsonian National Museum of Natural History

TOMAS N. CAPALDI
Student Research Grant, SEPM

Graduate Research Fellowship: Honorable Mention, NSF

BENJAMIN T. CARDENAS
2017 Travel Grant to the Fifth Planetary Dunes Workshop, NASA/Mars Exploration Program

JSG Seed Grant, JSG

SOL COOPERDOCK
Duchin Endowed Presidential Scholarship, The University of Texas at Austin

Student Research Grant, GSA

KRISTOPHER N. DARNELL
Ewing/Worzel Fellowship, UTIG

MACKENZIE DAY
DeFord Technical Sessions Best Speaker Spring Ph.D., DGS

SARAH DAVIS
Outstanding Teaching Assistant, DGS

Graduate Research Fellowship, NSF

SCOTT A. ECKLEY
Outstanding Undergraduate, Planetary Geosciences Institute

Gordon Award for Professional Promise, The University of Tennessee, Earth and Planetary Sciences

NICHOLAS ETTINGER
DeFord Technical Sessions Best Speaker Spring M.S., DGS

STEPHEN FERENCZ
Groundwater Field Methods Award Graduate, DGS

REYNALDY FIFARIZ
Ronald K. DeFord Field Scholarship Fund, JSG

MEGAN E. FLANSBURG
Graduate Student Research Grant, GSA

2017 Off-Campus Research Award, JSG

Jackson School Early Recruitment Fellowship, JSG

MASON FRIED
Outstanding Graduate Student Award, UTIG

JAKE GEARON
Folk/McBride Petrography Contest 2nd Undergraduate, DGS

SARAH GEORGE
Charles A. & June R.P. Ross Research Fund, GSA

William R. Muehlberger Field Geology Fund, JSG

MICHELLE GEVEDON
Folk/McBride Petrography Contest 1st Graduate, DGS

PETER O. GOLD
E.D. Farmer International Fellowship, The University of Texas at Austin, Mexican Center of the Teresa Lozano Long Institute of Latin American Studies

JENNIFER HARDING
Outstanding Graduate Student Award, UTIG

HIMA HASSENRUCK-GUDIPATI
GSEC Student Service, DGS

MENAL GUPTA
Outstanding Teaching Assistant, DGS

LILY JACKSON
GSA Research Grant, GSA

SEPM Foundation Grant, SEPM

Graduate Research Fellowship,NSF

Off-Campus Research Award, JSG

ALISSA J. KOTOWSKI
Muehlberger Graduate Research Fellow (Structural Geology and Tectonics Discipline), JSG

Graduate Research Fellow, NSF

DYLAN W. MEYER
GeoPRISMS Student Presentation Honorable Mention, GeoPRISMS

GAIL MULDOON
DeFord Technical Sessions Best Speaker Spring Ph.D., DGS

STEFANO NEROZZI
Graduate Student Travel Award for 6th Mars Polar Science Conference, European Geophysical Union

ELYSE NICHOLS
Groundwater Field Methods Undergraduate Award, DGS

MICHAEL NIETO
DeFord Technical Sessions Best Speaker Fall M.S., DGS

MARGARET ODLUM
Statoil Fellowship

NATALLIA PIATRUNIA
Outstanding Teaching Assistant, DGS

EDGARDO PUJOLS
Folk/McBride Petrography Contest 2nd Graduate, DGS

EVAN J. RAMOS
Duchin Endowed Presidential Scholarship, The University of Texas at Austin

Ronald K. DeFord Field Scholarship Fund, JSG

VALENTINA ROSSI
DeFord Technical Sessions Best Speaker Fall Ph.D., DGS

JASON SANFORD
JSG Best Graduate Paper, DGS

STEPHANIE E. SUAREZ
Minority Student Scholarship Program, GSA

JOHN M. SWARTZ
Travel Grant, GSA

MURAT TAMER
2017 Honorary Research Associate, University of Melbourne

Nomination for the best Ph.D. talk award, 15th International Conference of Thermochronology in Brazil

CAROLYN TEWKSBURY CHRISTLE
Graduate Student Fellowship, The University of Texas at Austin

Academic Promotion to Assistant Professor, United States Air Force Academy

DAMIAN WAHLMEIER
Austin Geological Society, DGS

ANNA M. WEISS
2017 DeFord Field Scholarship, JSG

JING "JILL" YANG
Best Poster Award, Consortium for Materials Properties Research in Earth Sciences

DANIEL YOUNG
Folk/McBride Petrography Contest 1st Undergraduate, DGS

Staff

DAN DUNCAN
Outstanding Staff Award, UTIG

KEVAUGHN EVANS
Guion Library Staff Honors, DGS

KATELYN HELBERG
Guion Library Staff Honors, DGS

NATHAN IVICIC
2016 Staff Excellence Award, BEG

ELSA JIMENEZ
Staff Excellence Award, DGS

JESSICA KOLSTAD KIM
Outstanding Staff Award, UTIG

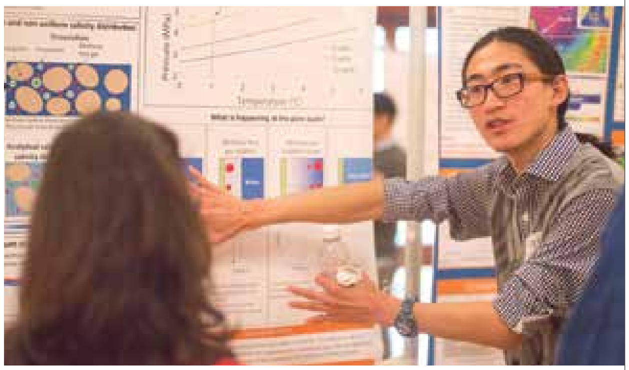
JULIE LAKE
Staff Excellence Award, DGS

STACI LOEWY
Staff Excellence Award, JSG

SARA SIEBERATH
Picard Excellence Award, UTIG

JON VIRDELL
Outstanding Staff Award, UTIG

BRIAN ZAVALA
Outstanding Service Award, JSG



STUDENT RESEARCH SYMPOSIUM AWARDS

In February 2017 the Jackson School's Graduate Student Executive Committee organized its 6th Annual Research Symposium. Winners and honorable mentions are as follows:

LATE CAREER PH.D. STUDENT

1st Place: Douglas Barber (Solid Earth & Tectonic Processes): Linkages between orogenic plateau build-up, fold-thrust shortening, and foreland basin evolution in the Cenozoic Zagros (Iran-Iraq)

2nd Place: Tomas Capaldi (Solid Earth & Tectonic Processes): Neogene foreland basin evolution during a shift to flat-slab subduction in Argentina (30.5°S)

Honorable Mention: Margaret Odlum (Solid Earth & Tectonic Processes): Detrital zircon (U-Th)/(He-Pb) double dating of Southern Pyrenees foreland basin fill: implications for sediment routing during tectonic inversion and orogenesis

LATE-CAREER MASTER'S STUDENT

1st Place: Nicholas Ettinger (Climate, Carbon & Geobiology): A Multiproxy record of the Toarcian Oceanic Anoxic Event in Shallow-Water Carbonates from the Adriatic Carbonate Platform

2nd Place: Reinaldo Sabbagh Maciel (Climate, Carbon & Geobiology): Sensitivity analysis of Lower Miocene sandstones to CO2 saturation in the inner continental shelf of the Texas Gulf of Mexico

Honorable Mention: Juan Munoz (Solid Earth & Tectonic Processes): Holocene Geologic Slip Rate for the Mission Creek Strand of the southern San Andreas fault, Indio Hills, California

EARLY-CAREER GRADUATE STUDENT

1st Place: Allison Lawman (Climate, Carbon & Geobiology): A Coral-based Reconstruction of Interannual Climate Variability at Vanuatu during the Medieval Climate Anomaly (950–1250 CE)

2nd Place: Kelly Thomson (Solid Earth & Tectonic Processes): Tracing Environmental Signals from Source to Sink: Zircon (U-Th)/(He-Pb) Double Dating Applied to the Foreland Basins of the South Central Pyrenees, Spain

Honorable Mention: Brandon Shuck (Marine Geosciences): Evolution of the Upper Lithosphere in the ENAM Area from 3-D Wide-Angle Seismic Data

UNDERGRADUATE

1st Place: Emilie Bowman (Solid Earth & Tectonic Processes): Investigating Magma Chamber Evolution using Mafic Enclaves and Plagioclase Zoning: Grasberg Igneous Complex, Papua, Indonesia

2nd Place: Cole Speed (Marine Geosciences): Late Quaternary Paleochannel Systems of the East Texas Inner Continental Shelf

Honorable Mention: Cody Draper (Solid Earth & Tectonic Processes): Trace Elements and Oxygen Isotope Zoning of the Sidewinder Skarn

BEST REPRESENTED RESEARCH GROUP

1st Place: Whitney Behr Research Group

2nd Place: Sergey Fomel Research Group

CLOCKWISE: 1. WHITNEY BEHR (FOURTH FROM RIGHT) AND HER RESEARCH GROUP. 2. DGS DEPARTMENT CHAIR CHARLES KERANS (LEFT) WITH NABIEL ELDAM. 3. TIANNONG "SKYLER" DONG.

Walter Geology Library 2016–17 Annual Report

In keeping with the new organizational changes in the UT Libraries, The Walter Geology Library has begun redefining spaces by taking down two ranges of shelving and replacing them with additional study tables, making room for 20 more seats. Over the next several years, we plan to shift much of the legacy print collection to off-site storage and continue this transition to a more service focused facility. The majority of our journals are now available only by E-access, and historical access online is available for many of them. Improved scanning and delivery will help us provide needed access to the older print materials.

As the library's reorganization takes effect, duties and responsibilities are shifting to provide more efficiency without sacrificing our standards of service. The librarian will focus more on collections, research services and outreach, while the ongoing daily responsibility for the unit will shift to Stacy Ogilvie, our onsite unit manager, and a new branch management structure. To prepare for these various changes, the Walter Library is starting the next phase of a de-duplication project. This means removing multiple copies of titles that are not circulating enough to warrant their retention, and shifting some materials to storage or to units where they may get more use.

We are still exploring the idea of converting our periodicals reading area to a display space for gem, mineral and fossil collections and a small seminar room. We will be able to put more specimens on display for more hours in a more secure environment than is now available, free up a room on the main floor, and the additional seating space will give us an opportunity to host small group meetings. This is a small remodeling project, and we have some seed money, but not enough to make it happen yet. Stay tuned!

Looking ahead, Library Storage Facility #3 is under construction at the Pickle campus; we expect to have it open next year. This is just in time, as LSF #1 and #2 are full, and one of our current facilities is in the way of the expansion plans for the medical school.

A couple of collections news items are notable. We have acquired hundreds of sheets this year to complete coverage of Italy, Greece and Western Australia at 1:100K or finer scales, as well as numerous atlases and other far-flung materials to support research. In addition, we teamed up with the other science libraries to pool funding and acquire e-access to almost 3,000 legacy physical sciences monographs from Elsevier at substantial discount, which we hope will make everyone very happy. Our colleagues at the American Geosciences Institute have also donated more than 20 cartons of pre-selected foreign geology periodicals and monographs, adding some hard to get new resources to our holdings.

On other fronts, the UT Libraries have hired a GIS data coordinator and a GIS technical staff person to help us push forward our vision of a geospatial data server and more involvement in GIS services for the wider campus community. We are also proud to note that some of our Texas ScholarWorks open access materials have been highly successful. We are making steady headway getting author permission to digitize theses, and we have added a number of meeting abstract volumes and other materials in ScholarWorks, ranging from historical to brand new, many of which have been getting a great deal of use. You can visit the open ScholarWorks repository here: repositories.lib.utexas.edu.

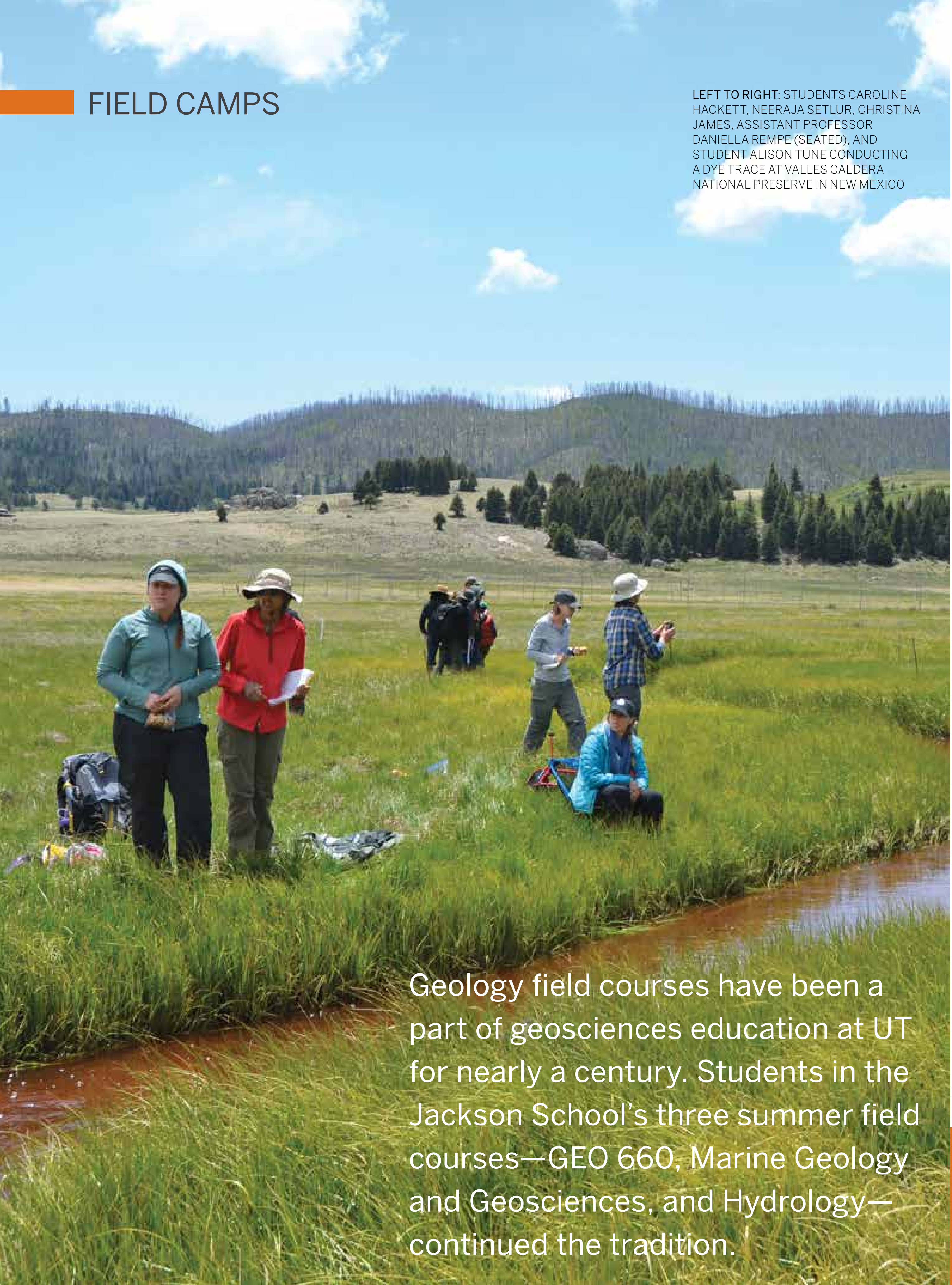
Last year, we mentioned the massive new UT Press book edited by Andre Bober, The Collections, featuring materials from our Tobin Map Collection, Barron Gem and Mineral collection, and other collection materials. The book is now available online for those that might want to browse it here: thecollections.utexas.edu.

Our social media presence is strong, with almost 700 people following our Facebook page (you should too!), and the Walter Library twice sponsored local therapy dogs near exam time to provide stressed out students with some fur-time.

In staff news, Stacy Ogilvie is working on several website projects, most especially the sprawling geoscience thesis index, which we are expanding to include abstracts and links to e-versions, and consolidating into a single searchable file.

Four student workers graduated over the course of this year after many semesters of service with us: Hector Peralez, Daniela Jauregui, Kevaughn Evans, and our GRA, Katelyn Helberg. We wish them well in their future endeavors. This year's winners of the Guion service award were Kevaughn Evans for her efforts on our thesis database revision, and our GRA Katelyn Helberg for all of her excellent cataloging work on our large cataloging backlog. Head Librarian Dennis Trombatore attended the GSA meeting in Denver, continued to serve as chair of the AGI GeoRef advisory committee, and reached a milestone with his 20th year of pottery contributions to the Austin Empty Bowl Project for the Central Texas Food Bank.

Dennis Trombatore
Librarian



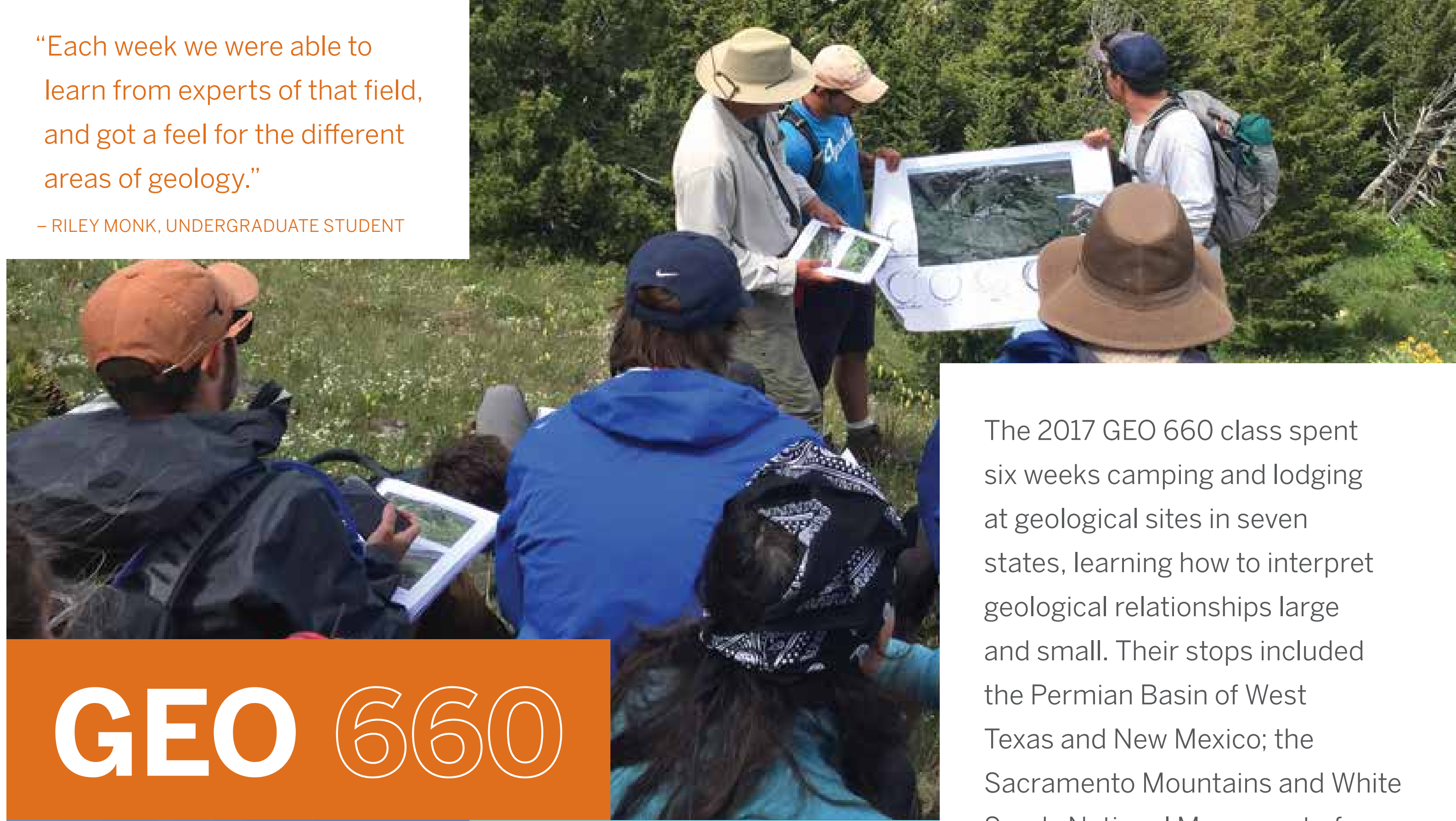
LEFT TO RIGHT: STUDENTS CAROLINE HACKETT, NEERAJA SETLUR, CHRISTINA JAMES, ASSISTANT PROFESSOR DANIELLA REMPE (SEATED), AND STUDENT ALISON TUNE CONDUCTING A DYE TRACE AT VALLES CALDERA NATIONAL PRESERVE IN NEW MEXICO

Geology field courses have been a part of geosciences education at UT for nearly a century. Students in the Jackson School's three summer field courses—GEO 660, Marine Geology and Geosciences, and Hydrology—continued the tradition.

PHOTOS: JACKSON SCHOOL.

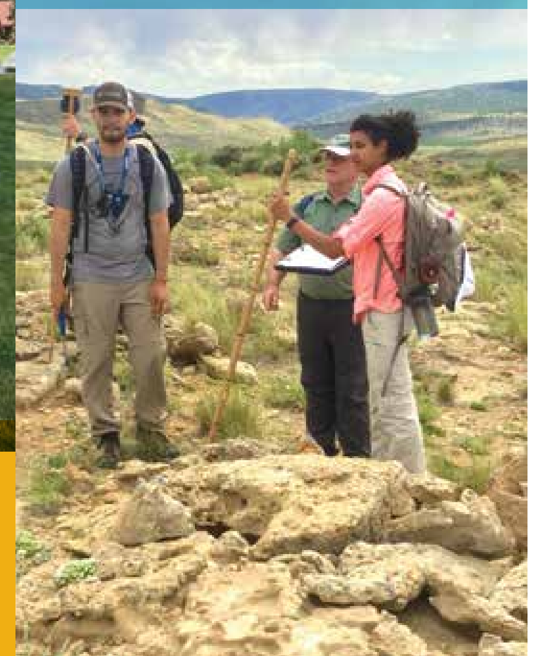
"Each week we were able to learn from experts of that field, and got a feel for the different areas of geology."

– RILEY MONK, UNDERGRADUATE STUDENT



GEO 660

ABOVE: BEG RESEARCH SCIENTIST PETER HENNINGS AND ASSISTANTS BEN SMITH AND TOMAS CAPALDI EXAMINE A HANGING WALL ANTICLINE WITH STUDENTS NEAR THE TERMINATION OF THE FRENCH THRUST AT MCCARTY HILL, SOUTHERN SAWTOOTH MOUNTAINS, MONTANA.



ABOVE: CAMPING ALONG THE SUN RIVER, SAWTOOTH MOUNTAINS, MONTANA. RIGHT: DYLAN RASCH (LEFT) AND JESSICA VIERA MEASURE A STRATIGRAPHIC SECTION WITH PROFESSOR RON STEEL (CENTER) NEAR ROCK SPRINGS, WYOMING. BELOW: GEO 660A CLASS ATOP CLIFFS OF ARCHEAN GRANITE AT FREMONT CANYON

The 2017 GEO 660 class spent six weeks camping and lodging at geological sites in seven states, learning how to interpret geological relationships large and small. Their stops included the Permian Basin of West Texas and New Mexico; the Sacramento Mountains and White Sands National Monument of New Mexico; the Sawtooth, Big Belt and Pioneer Mountains of Montana; and the Valles Caldera of The Jemez Mountains, New Mexico. The group conducted about 15 projects that taught new skills and honed existing ones in sedimentary geology, structural geology and mapping, igneous and metamorphic geology and economic geology. Distinguished Senior Lecturer Mark Helper led the class, which included site-specific instruction by other faculty experts including Whitney Behr, James Gardner, Peter Hennings, Brian Horton, Charles Kerans, David Mohrig, and Ronald Steel. Faculty were assisted by assistant instructor Tomas Capaldi and six teaching assistants who rotated through three-week appointments.

MG&G

ABOVE: (LEFT TO RIGHT) STUDENTS DOMINIK KARDELL, KELSEY ROLL, PAULINE TOLENTINO, NAOMA MCCALL AND WILL PINKSTON DURING AN OFFSHORE GALVESTON SURVEY. BELOW: UTIG RESEARCH SCIENTIST DAN DUNCAN AND STUDENTS (LEFT TO RIGHT) ALLISON LAWMAN, WOONG MO KOO, CONRAD SUEN AND SIMA DANESHVAR (AT COMPUTER) ON THE R/V SCOTT PETTY

The summer of 2017 marked the 10th year of the Marine Geology and Geophysics field course. The class began with three days of classroom and lab instruction from experts at the University of Texas Institute for Geophysics (UTIG). The class then travelled to Galveston for seven days of at-sea fieldwork and on-shore lab work. Students rotated daily between an on-shore lab facility and two small research vessels: the R/V Scott Petty for multibeam, sidescan and sediment sampling; and R/V Manta for multichannel seismic reflection, chirp and coring. This year's course imaged and mapped the buried river valley and associated channels of the Trinity River beneath Galveston Bay and the Texas shelf. Back in Austin, students, integrated and interpreted data for a final project that examined the geologic history of the survey area.

"All our amazing instructors have obviously put their expertise into the class. The main benefits of the class came from the field survey in the Gulf of Mexico and the final group presentation. I hope that all Jackson School students can take this class."

– WOONG MO KOO, GRADUATE STUDENT

UTIG RESEARCH SCIENTIST DAN DUNCAN (IN BACKGROUND) AND STUDENTS (LEFT TO RIGHT) KELLY OLSEN, CALEB MELANCON, WILL PINKSTON AND ZONGPEN "FRANK" CHEN CONDUCTING CORING OPERATIONS ON THE R/V MANTA IN GALVESTON BAY

PHOTOS: JACKSON SCHOOL.

Hydro

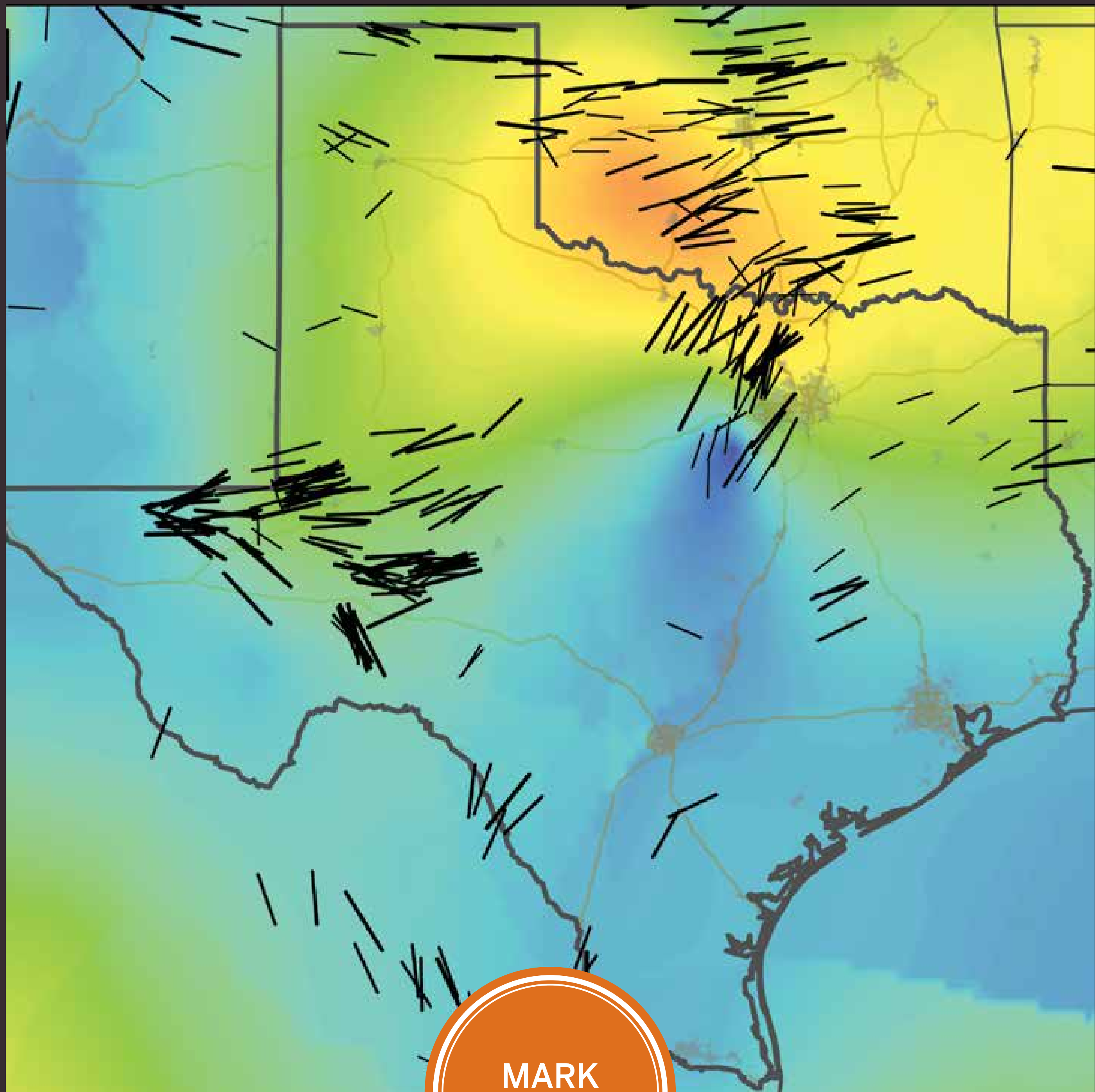
ABOVE: (CLOCKWISE) STUDENTS LANE COCKRELL, STEPHEN FERENCZ, CHRISTINA JAMES, CAROLINE HACKETT AND NEERAJA SETLUR.

Students in the 2017 hydrology field course applied the knowledge and skills they learned in the classroom to investigate hydrogeologic processes in diverse settings. With the generous help of Geoprojects International (owned by Jackson School alumnus Pat Goodson) and hydrogeologists from the Bureau of Economic Geology, students drilled new wells and performed pump tests along the Colorado River in Hornsby Bend. Students then traveled to the Valles Caldera National Preserve in New Mexico where they used geophysical imaging, geochemical sampling, hydrological monitoring, and stream gauging to probe connections between groundwater and surface water dynamics.

LEFT: STUDENTS SEBASTIAN MUNOZ (LEFT) AND NATHAN HSU. BELOW: STUDENT CAROLINE HACKETT WITH EQUIPMENT.

"We were given the reins to develop our own research questions, design a field methodology, process our data, and synthesize conclusions to help tell the hydrologic story of the caldera. This type of field experience is invaluable to me as I prepare for a career in hydrogeology in Texas and beyond."

– CAROLINE HACKETT, GRADUATE STUDENT



MARK ZOBACK

MANAGING WASTEWATER INJECTION

By Sarah Bloodworth

STRESS MAP: JENS-ERIK LUND SNEE. ZOBACK: ZOBACK.

In 2012, the U.S. Geological Survey reported that Oklahoma experienced 34 earthquakes. By 2015, the number increased to over 880, an increase largely attributed to the surge in wastewater injections following hydraulic fracturing, or fracking, operations.

Mark Zoback, professor of geophysics at Stanford University, gave a presentation at the Bureau of Economic Geology in June about the connection between earthquakes in Oklahoma and wastewater injection sites.

The talk centered on research published in *ScienceAdvances* in June 2015 that linked earthquakes to wastewater injection sites. Using a new statistical model developed by Zoback and Stanford postdoctoral fellow Cornelius Langenbruch, the researchers predicted that high magnitude earthquakes will decline significantly if Oklahoma reduces wastewater injection.

"Our model allows us to forecast the rate of potentially damaging earthquakes associated with water injection in north-central Oklahoma and parts of Kansas in response to reduced injection rates," Zoback said.

The physics-based model relies on information about pore space, stress state and fault orientation.

Wastewater collected during hydraulic fracturing, a process that injects water and chemicals into the earth to extract oil or gas, is disposed of in deep wells at high pressure. According to Zoback, billions of tons of wastewater are injected into deep layers of the Arbuckle formation and the underlying crystalline formation in Oklahoma. He said this pressure causes the fault slip that produces earthquakes.

Zoback added that earthquakes often occur on permeable, preexisting faults.

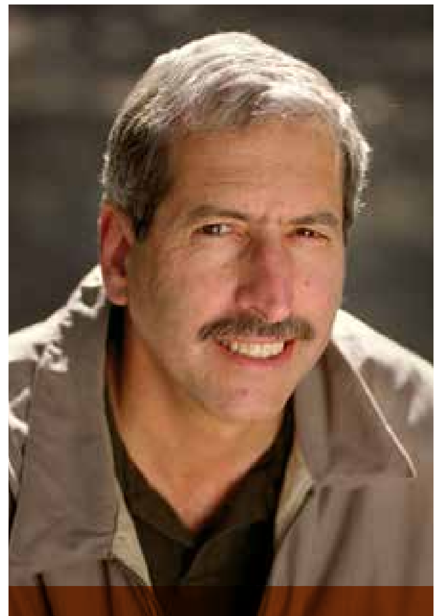
"Potentially active faults extend from the crystalline basement up to the Arbuckle," Zoback said. "The pressure in the Arbuckle was really small, but it's so permeable that the pressure spreads out and finds a critically stressed fault, called an active fault … which allows a pressure change at this depth to trigger seismicity."

Zoback and his team modeled potentially active faults by assessing whether the injection increases pore pressure in the rocks. Also, fault orientation, or the angle and compass direction of the fault relative to the ground, factors into fault slip probability.

"Fault orientation is very important," Zoback said. "In general, few preexisting faults are likely to be problematic. They [preexisting faults] are either too perpendicular to the fault and have too much normal stress to slip, or are too parallel and have too little shear stress to slip."

Zoback and his team concluded that all relatively large recent earthquakes in Oklahoma occurred on "predictable" faults, or those that show evidence for vulnerability to earthquakes. But the great majority of earthquakes do not occur on mapped faults.

This data can be used to predict future earthquakes, Zoback said, but cautioned that even with their exceptional stress data, there are many unknown fault sites.



MARK ZOBACK, A PROFESSOR OF GEOPHYSICS AT STANFORD UNIVERSITY

"The important thing is not only identifying potentially problematic faults but identifying faults that aren't problematic," Zoback said. "But the weakness is, we don't know about the number of faults … so only half the problem is solved. We know there are a lot more faults but they are just not on the maps."

Despite some uncertainties, the study results spurred a recent decision by the Oklahoma Geological Survey to issue a statement that recognized injection of wastewater into wells, specifically in the Arbuckle formation, as the cause of the state's recent earthquakes.

In 2016, regulators in Oklahoma mandated a 40 percent reduction of wastewater volumes, which Zoback said contributed to the reduction in earthquakes.

"We forecast that the probability an earthquake will exceed a magnitude of 4.5 in 2017 is 70 percent," Zoback said. "These high probabilities are basically cut in half from years ago, since injections have decreased."

The work of Zoback and his team has pushed regulators to acknowledge the source of the recent earthquakes in Oklahoma, but hydraulic fracturing and wastewater disposal continues in the area.

Potential solutions to induced seismicity include completely halting injection of produced water into the Arbuckle formation entirely. Rather, Zoback suggests injecting the waste back into producing formations such as the Mississippian Lime, a limestone layer where much of the produced water in Oklahoma originates.

Zoback said his team also plans to continue developing a Texas stress map as hydraulic fracturing operations continue to increase in the state.

"They [oil companies] are still injecting, and our model shows that, at least in respect to magnitude five earthquakes, we are still on track," Zoback said. "We are going to know in the next few years how the model is holding up. The problem, while not solved, is at least getting better."

OPPOSITE PAGE: A MAP OF STRESS ALONG FAULTS IN TEXAS AND OKLAHOMA. BLACK LINES INDICATE STRESS ORIENTATION. BLUE-GREEN COLORS INDICATE REGIONS OF EXTENSION IN THE CRUST, WHILE YELLOW-ORANGE AREAS ARE INDICATIVE OF CRUSTAL COMPRESSION.

Studying Alaska's Glaciers from Land and Air

I am in Alaska surveying glaciers for NASA's Operation IceBridge. I work with Chris Larsen and Martin Truffer of the Geophysical Institute at the University of Alaska, Fairbanks (UAF). Chris is the principal investigator and Martin and I are co-investigators on the project. UAF has a decades-long history of monitoring the surface elevation of Alaskan glaciers using airborne LIDAR, and we are continuing that tradition with the addition of radar sounding to measure the thickness of the ice. That's my main responsibility. It's quite a challenge to sound Alaskan glaciers because they are warm, wet, heavily crevassed and usually close to mountains and valley walls that reflect the radar energy, obscuring echoes from the base of the glaciers. But it is all new information and important for understanding the rapidly changing ice of Alaska, so it's also rewarding work.

In order to do this, we outfitted a turbine Otter aircraft that operates on wheel-skis so we can land on hard surfaces or snow, as needed. We sometimes land on glaciers just to have a convenient spot to add fuel from drums. Our "home base" is a remote lodge that is only accessible by bush aircraft, nestled against the Chitina River and surrounded by Wrangell-St. Elias National Park. Paul Claus of Ultima Thule Outfitters owns and pilots the Otter, and he is one of the most experienced bush pilots in Alaska. This is important due to the steep terrain, some of the steepest in the world, and rapidly changing weather with the potential for strong winds and turbulence at any time.

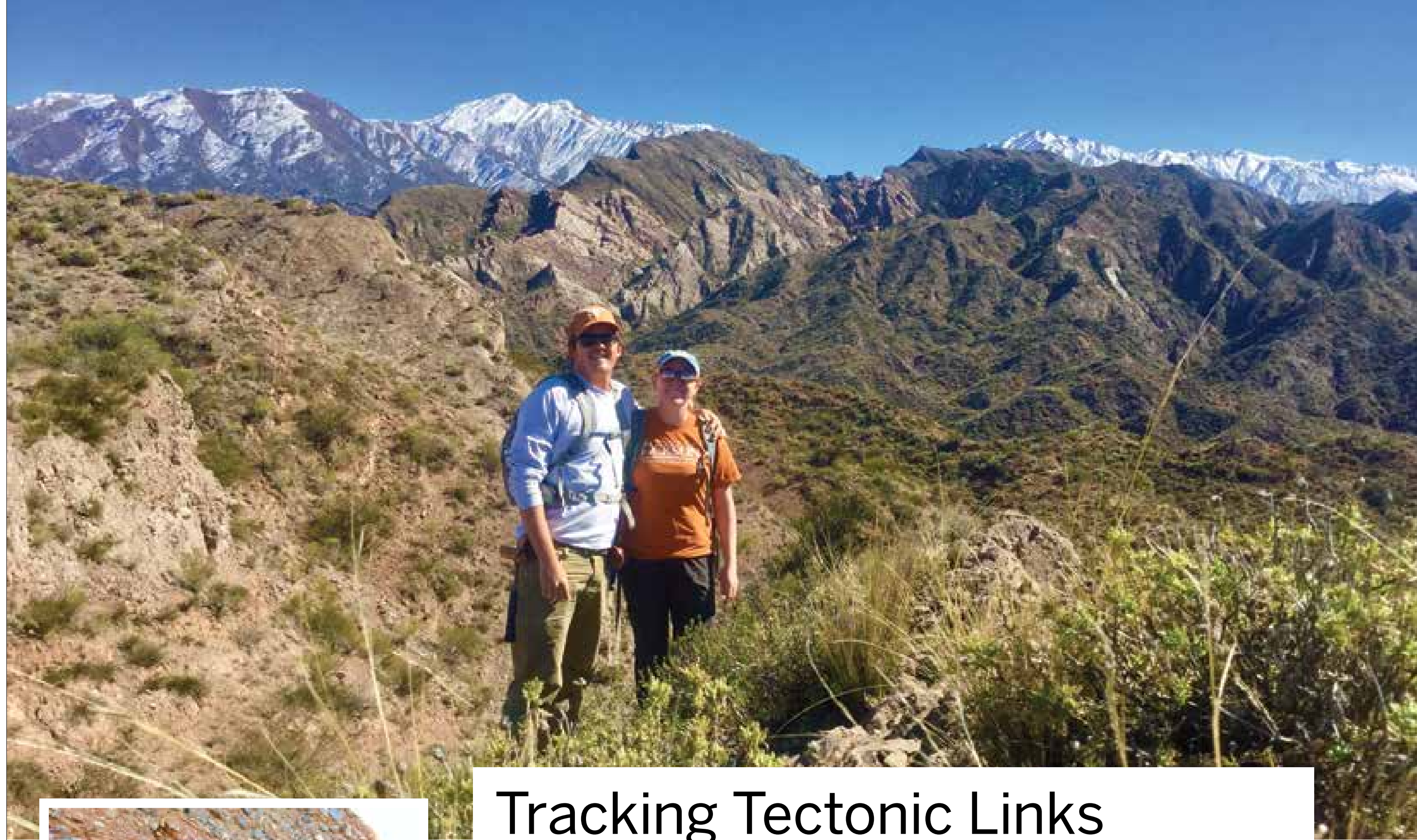
From this outpost in the wilderness we cover all of the major Alaskan glaciers, from the Juneau icefield in the southeast to the Kenai Peninsula in the west. We put in some very long days when weather is good, and can rarely make specific plans beyond what the 24-hour weather forecast holds. Even then, it is often a matter of heading out for a flight half expecting to turn back. When it's clear and calm, it is some of the most spectacular scenery anywhere.

When we are grounded but local weather is okay, I try to fit in some work on nearby debris-covered glaciers for Mars analog work. Just today I flew out to a nearby airstrip and hiked up to a debris-covered glacier where my students Eric Petersen and Stefano Nerozzi have conducted a great deal of surface geophysics. I checked on a weather station we installed to make sure it's operational before winter sets in. A nice way to spend a "day off." As long as I don't encounter a grizzly up close.

Jack Holt
Research Professor,
University of Texas Institute for Geophysics

TOP: SURFACE SURVEY WORK ON THE BAGLEY ICEFIELD, THE LARGEST NON-POLAR ICEFIELD.
RIGHT: STUDENTS STEFANO NEROZZI (LEFT) AND ERIC PETERSEN INSTALL A WEATHER STATION ON SOURDOUGH ROCK GLACIER.

ALASKA GLACIERS: JACK HOLT. TRACKING TECTONIC LINKS: TOMAS CAPALDI. GEOFORCE: KATHLEEN HAGERTY.



Tracking Tectonic Links Among Andean Mountains

Tomas Capaldi, a Ph.D. student who studies mountain building in the Argentine Andes with Professor Brian Horton, spent time this summer in Argentina conducting field work in the San Juan province two hours north of the city of Mendoza. His research involved studying Andean tectonic provinces and the respective sediment record during mountain building by conducting geologic mapping, measuring stratigraphic sections, and collecting rock samples for sediment provenance analysis.

This actively deforming mountain belt has produced destructive earthquakes greater than 7.0-magnitude. The goal of his research is to understand the tectonic links among Andean mountain building and foreland basin evolution during Miocene to modern low-angle subduction of the Nazca oceanic plate.

Capaldi was assisted in the field by Margo Odlum, a Ph.D. student who studies Pyrenean tectonics with Professor Daniel Stockli. Distinguished Senior Lecturer Mark Helper and Jackson School Dean Sharon Mosher joined the group for a week to help map the geology around the seismically active Sierra Villicum and Sierra Pie de Palo ranges in San Juan, Argentina.

TOP: TOMAS CAPALDI AND MARGO ODLUM AT THE PRECORDILLERA FOLD-THRUST BELT
LEFT: ODLUM WITH ANGULAR UNCONFORMITY BETWEEN SILURIAN OLISTOSTROMES AND MIOCENE CONGLOMERATES.

GEOFORCE TEXAS GIVES A HOOK 'EM ON MT. HOOD.

GeoFORCE Field Update

GeoFORCE Texas students on Mt. Hood in Oregon during a summer field trip. GeoFORCE is a unique outreach program of the Jackson School of Geosciences that helps high school students from disadvantaged areas in inner-city Houston and rural Southwest Texas pursue an education and career in the sciences, particularly the geosciences and engineering.

Ocean Front Property in Colorado

The most wonderful time of the year for a paleontologist is field season. It's when new discoveries are made, and friendships and collaborations are strengthened. This year's field season was special for me because I began what will be a long-term project in the Upper Cretaceous Mancos Shale of Colorado. Those rocks represent almost 15 million years of deposition in a shallow ocean, one that stretched from the modern-day Gulf of Mexico to the Arctic.

My long-term research goal is to understand the evolution of ecosystems throughout the greenhouse climate of the Cretaceous, with an eye toward using those data to hypothesize how ecosystems of the future may respond to warmer global climate. For my dissertation, I am focusing on one particular group of marine reptiles called mosasaurs. Mosasaurs were a group of fully marine lizards that ranged in size from a couple of meters up to 18 meters. My investigation of the Mancos Shale in western Colorado was originally motivated by a mosasaur specimen collected by Brigham Young University (BYU) in 1975. That specimen has a 1.2 meter lower jaw and represents an important part of the story of mosasaur evolution. I wanted to find this animal's type locality to better understand its stratigraphic position within the Mancos. Very few notes were kept during the excavation, but I was ultimately able to track down the locality using Google Earth and a grainy photo of the excavation in a master's thesis. It was extremely helpful that the vegetation had not changed much in 42 years!

The Mancos is typically mapped as one homogenous unit—4,000 feet of mud. However, on the Western Slope of the Rockies, Dr. David Noe (a UT geology grad) spent a major part of his career at the Colorado Geological Survey mapping the Mancos and correlating it with the sections across Colorado and Utah. Using Dr. Noe's maps and expertise, we were able to nail down the unit (albeit a thick one) within the Mancos from which the BYU mosasaur was collected.

The area around Delta, Colorado exposes most of the Mancos Shale, eroding into beautiful badlands that seemed ripe for fossil prospecting. I applied for a Bureau of Land Management survey permit and planned a trip for early August to explore the area. On the first day, Dr. Noe led my volunteers and me to a few localities of interest, explaining the various units he designated within the Mancos. From there, we began prospecting a few select units near Delta. High in section, we found several specimens of the ammonite *Baculites* in the same unit as the BYU mosasaur. Those fossils will be incredibly helpful for refining the stratigraphic position of that specimen with reference to radiometrically dated sections. In the days to follow, a volunteer of mine, Lexy Holfeltz, struck gold by finding fish specimens in carbonate layers that correlate to the Niobrara Chalk of the Front Range and Kansas. These were thin, fragile fossils that are extremely difficult to preserve and find.

I've had the opportunity to work in a lot of field areas over the years, and each one was unique. This first expedition to the Mancos taught me a lot about what units within the formation are most fossiliferous, and what methods are best for finding fossils in each of those units. For just a few days of collecting, we ended up with a tremendous haul of fossils. These thousands of feet of Cretaceous mud were anything but the barren wasteland devoid of fossils that other geoscientists had made them out to be. This year's Mancos field season is just the start of many more to come!

Joshua Lively
Ph.D. student

CLOCKWISE: 1.THE MANCOS SHALE IN DELTA, COLORADO. 2. THE BRIGHAM YOUNG UNIVERSITY MOSASAUR, PROGNATHODON STADTMANI. 3. LIVELY (ON RIGHT) EXAMINES A MAP WITH DAVID NOE, WHO MAPPED PARTS OF THE MANCOS SHALE.

OCEAN FRONT PROPERTY: JOSH UA LIVELY. AMAZON: BRIAN HORTON. ARCTIC FLUX: BAYANI CARDENAS.

LEFT: A VOLCANO ERUPTING IN ECUADOR
RIGHT: THE GEO 391 GROUP NEAR A WATERFALL IN THE AMAZON BASIN

Exploring the Link Between Amazon Ecology and Geology in Ecuador

A 3-credit course in Dynamic Field Stratigraphy (GEO 391) explored the diverse geologic record of the Andes of Ecuador, with emphasis on the sedimentary, stratigraphic, climatic and biological consequences of Andean uplift. The course culminated in a 10-day field trip (April–May, 2017) across the orogenic belt, from the Amazon basin in the east to the Pacific coast in the west. As a region with some of the highest biodiversity on Earth, there remain key questions regarding the interactions of geological processes (tectonic uplift, magmatism, erosion, sedimentation) with the Amazonian biological and climate system. UT students joined forces with Ecuadorian colleagues and worked with UT professors and researchers Brian Horton, Ron Steel and Cornel Olariu to assess the long-term sedimentary and structural evolution of the Oriente foreland basin, Inter-Andean Valley, magmatic arc and western forearc basin, with consideration of active magmatism, active faulting and varied hydrocarbon systems. Several additional highlights included a bewildering array of flora and fauna, huge waterfalls, and the unexpected viewing of an active volcanic eruption from a safe distance. The trip was made possible by funding from Chevron.

Brian Horton
Professor, Department of Geological Sciences
Research Professor, Institute for Geophysics

Studying Flux in Arctic Lagoons

In collaboration with colleagues from the University of Texas Marine Science Institute (MSI), we are trying to understand groundwater fluxes in Arctic lagoons. Groundwater is an unknown component of the coastal water cycle, and it could be an important pathway for nutrients and carbon from land going to the sea. The picture on the left shows Professor Jim McClelland from the MSI. He is looking at a seepage meter which captures and measures groundwater seepage from the sediment. The trip also involved measuring a dissolved gas tracer in seawater across Kaktovik lagoon. The nearby village was a popular hang out spot for polar bears. There were at least 21 bears in the village while we were there!

Bayani Cardenas
Professor, Department of Geological Sciences

PROFESSOR JIM MCCLELLAND OF THE UT MARINE SCIENCE INSTITUTE WITH A SEEPAGE METER IN AN ARCTIC LAGOON

THE HELIX Q4000 DEEPWATER WELL INTERVENTION VESSEL ROUGHLY 140 MILES OFF THE COAST OF LOUISIANA

PHOTO: JACKSON SCHOOL.

A group of Jackson School scientists and students embark on a high-stakes research mission

BY ANTON CAPUTO

Gulf of Mexico — Standing on the helideck of the Helix Q4000 with nothing but waves in sight, Peter Flemings is bleary eyed and exhausted. But, for this moment at least, the Jackson School of Geosciences professor and chief scientist of the coring mission is relieved and something akin to happy.

The scene marks a seminal moment in a ground-breaking project, an $80-million, multi-year national effort that the U.S. Department of Energy (DOE) picked the Jackson School to lead.

Flemings and his team have finally hit pay dirt, pulling a core of frozen methane hydrate from about 1,300 feet under the Gulf floor, through a mile of water, and to the deck of the deep-water coring vessel, while still keeping the methane hydrate under pressure.

Under pressure — that's the important part. Pressure, in many ways, is what this mission is about.

The science crew's chief goal is to return samples of this ice-like, energy-rich hydrate to the surface of the ship under the same immense pressure it is found in its natural state (about 230 times the pressure found on the surface) so they can begin to unravel its properties. This involves keeping the pressure on the cores throughout their mile-plus journey up the drill string to the deck of the coring vessel, and eventually through their 500-mile journey to Austin to the new state-of-the-art lab in the Jackson School.

The ultimate goal is to figure out how to one day tap the potentially enormous energy resource.

"This is the start of a systematic experimental and theoretical effort to understand the potential to produce methane hydrates in an environmentally sustainable, safe and economic manner," Flemings said.

It's big science. Important science. And it involves lots of pressure.

Flemings and his team have felt immense pressure of their own during the mission, particularly in the early days of coring. They were met with failure after failure when the experimental coring tool didn't work properly and returned a soupy, muddy mess to the deck instead of the pressurized cores they were seeking.

On this particular day in the middle of the operations the team was feeling relieved, at least temporarily, with the first successful core. But soon after this success, the pressure would return as core after core afterward came back a failure, prompting Flemings to halt operations and consider abandoning the coring altogether.

"We spent the first 10 days out here in a state of complete and utter failure," he would later remember. "I was within 24 hours of abandoning the expedition and cutting our losses. Each day, we would update our budget and would find us $350,000 further in the hole with nothing to show for it."

At risk was the future of the project, including a much larger coring mission planned for 2020 in partnership with the International Ocean Discovery Program (IODP). Ultimately, Flemings didn't abandon the mission but halted operations and instructed the team to do what scientists and engineers do: work through the problem and find a solution — all with the clock ticking and budget mounting.

The pressure was on.

MORE THAN FIRE AND ICE

Much about methane hydrate is a mystery even to the small group of scientists who study it. To the general public, it's largely unknown. There have been a smattering of news stories about the energy-rich substance, many focusing on the peculiar and entertaining fact that even though methane hydrate appears and feels like ice, you can light it on fire. It's a trick that is easy to find on YouTube, although it's nearly always accomplished with a small sample created in a lab, not methane hydrate found in nature.

This much is known about methane hydrate — there's a lot of it. It is found all over the planet in places where methane is under sufficient pressure and low temperatures, generally under frozen permafrost or beneath the ocean floor.

The substance is made up of water molecules that form a crystal lattice, which traps the methane inside. The

dense, ice-like structure holds more than 100 times the energy per unit of volume than methane found at the atmospheric pressure of the surface of the Earth. That's why people like Jackson School postdoctoral fellow Stephen Phillips made the trip to the Gulf in May, working 12-hour shifts (and often much longer) to set up labs, plot the best coring locations, and process and analyze core samples as they are pulled on deck.

"One liter of methane hydrate down below the seafloor, if you bring it up here, is 160 liters of methane," said Phillips, smiling from beneath the brim of his ever-present Cubs hat. "But if you bring it up to the surface, it's basically going to melt and the methane will escape, and you'll be left with just water."

This difficult-to-reach methane—the chief constituent in natural gas—represents a potentially vast energy resource for the future, especially for coastal nations with limited resources striving for energy security. Japan, China, South Korea and India, for instance, have active programs trying to tackle many of the same questions as Flemings' group.

The estimates of how much energy is held in methane hydrate throughout the world vary greatly, but they are enormous. Some estimates contend these deposits hold more energy than all other fossil fuels on the planet combined. Flemings mostly discounts those numbers because they are based on flimsy extrapolations, and so little is really known about the properties and concentration of methane hydrate deposits throughout the world.

In addition, much of the hydrate that's been studied to date is found in shale and mudrocks, geological formations whose characteristics make recovery more difficult. Flemings' team is looking at methane hydrate in areas that should theoretically be easier to one day produce.

"What's different here is that we are directly targeting sand layers that have, we think, high concentrations of methane hydrates," he said.

That was the thinking when he and a group of like-minded scientists from around the country wrote a proposal to the DOE to core and study methane hydrate in 2014. Back then, the whole proposition seemed relatively straight forward.

"To be frank," said Flemings, "we had no idea of the complexity of what we were proposing to do."

PHOTOS: JACKSON SCHOOL.

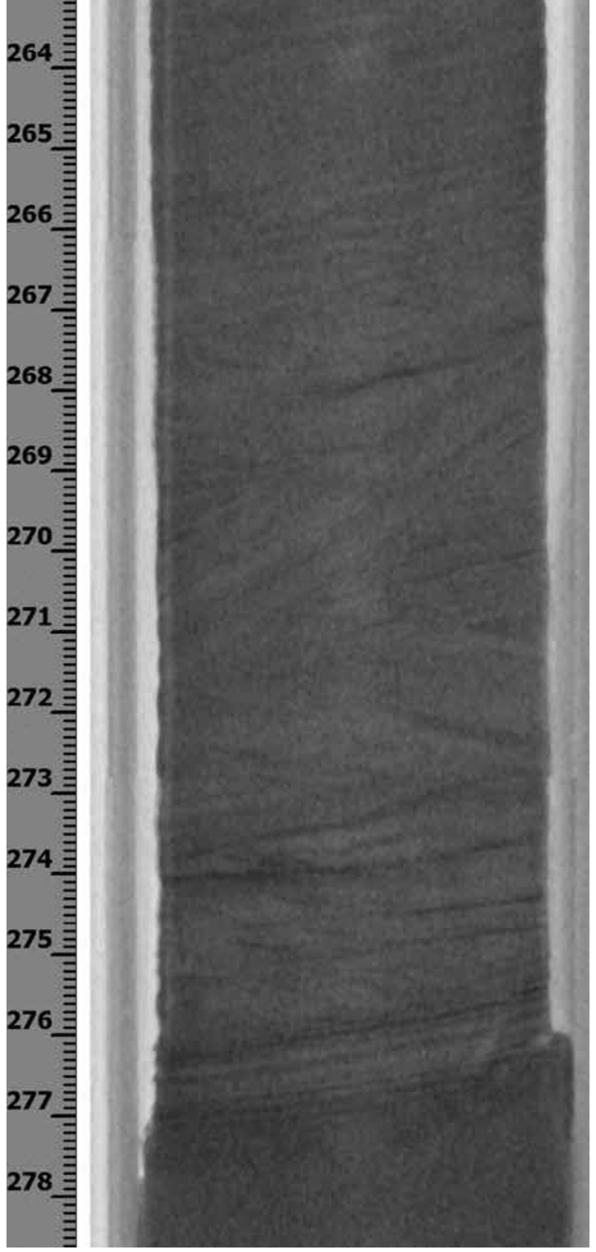
UNFAMILIAR SURROUNDINGS

The deck of the Q4000 is an alien and dangerous place for anyone not used to deepwater operations. Jackson School Research Engineer Associate Ethan Petrou is in that group. Petrou, who hails from the United Kingdom, had never been on a large boat before and finds the setting formidable and exciting.

"The actual magnitude of the equipment is insane," he said. "Humans constructed this. We engineered this. We thought of a way to build a city on the ocean. Seeing it come to life is quite inspiring."

Petrou is among a handful of young Jackson School scientists who made the trip in May with Flemings, a group that includes two graduate students. Petrou did a year abroad at the Jackson School in 2015–16 where he took Flemings' energy exploration course. He jumped at Flemings' offer to join the mission after graduating and is using the experience as an opportunity to judge whether he's cut out for a career in energy exploration. His mind is far from made up at this point, but Petrou said he'd definitely go offshore again.

LEFT: THE HELIX Q4000 IS EQUIPPED WITH THOUSANDS OF FEET OF DRILLING PIPE TO CONDUCT DEEPWATER MISSIONS. **ABOVE:** AN EXHAUSTED PETER FLEMINGS, A JACKSON SCHOOL PROFESSOR, LOOKS OFF INTO THE HORIZON.



"YOU CAN'T REALLY COMPREHEND IT UNTIL YOU'RE HERE."

- ETHAN PETROU

LEFT: JACKSON SCHOOL RESEARCH ENGINEER ASSOCIATE ETHAN PETROU (LEFT) AND PH.D. STUDENT KEVIN MEAZELL HOLDING UP DEPRESSURIZED CORE SAMPLES. CENTER: A CORE CONTAINING ABOUT 80 PERCENT METHANE HYDRATE SATURATION. RIGHT: THE HELIDECK OF THE HELIX Q4000 IS ONE OF THE FEW PLACES THE CREW CAN FIT IN A LITTLE RECREATION.

PHOTOS: JACKSON SCHOOL.

"You can't really comprehend it until you're here, but once you get adjusted, life out here is rather fun," he said. "Everybody is like a little family."

The vessel itself is a semi-submersible, meaning it doesn't anchor to the Gulf floor. It stays in one location during operations through the use of a dynamic positioning system that employs six thrusters to continually move the vessel minute distances to keep it zeroed in on the right spot. On deck are massive cranes capable of moving loads of hundreds of tons. The main tower, which is used to build a drill string pipe by pipe to the Gulf floor and beyond, rises more than a couple hundred feet above the deck.

You can't just come aboard a vessel like the Q4000 when it's engaged in operations. Every member of the science crew was required to take and pass several certification courses. One focused on teaching you how to react, and hopefully survive, if the helicopter that ferries people to and from the vessel goes down. Another is a basic safety course for simply setting foot on a deepwater vessel. These courses are also required of the crew, although most have training well beyond the basic classes.

The lessons learned in these courses are further drilled into you by the Helix safety team and the crew itself. Among the lessons: always wear full protective equipment on deck and look up before doing anything or going anywhere. A few days of working around the massive cranes instills the sense and necessity of this rule pretty deeply. Another rule: keep your hands off everything except safety rails unless you have a specific need and the correct training. Why? Because everything on deck is metal and massive, and putting your hand in the wrong place could be a potentially dangerous—or even fatal—mistake if a load unexpectedly shifts or powerful equipment starts moving. And finally, if you're doing most anything on the deck—like say, taking pictures or videos—fill out a permit that explains exactly where you'll be, when you'll be there, what you'll be doing, and what safety precautions you are taking, and get it signed by the officer on duty and the tool master.

In very short order, everyone on the science team seemed to understand that the rules are sensible and important and help instill a sense of order and familiarity in a setting that first seemed chaotic and unrecognizable.

"It's an interesting environment," said Jackson School graduate student Kevin Meazell. "You have to focus on safety at all times."

SCIENCE AND EDUCATION IN THE DEEP WATER

Adapting to life on a deepwater oil and gas vessel is not a seamless process for professors, scientists and students used to the classroom and the lab. The quarters are tight and noisy, the hours are long and the overall setting is unlike most anything the science team had ever dealt with.

There are 24 members of the science team in all. In addition to the Jackson School cadre, there are professors and students from The Ohio State University and Columbia University Lamont-Doherty Earth Observatory as well as scientists from the DOE, the U.S. Geological Survey (USGS) and Geotek, a scientific coring company.

Peter Polito, the Jackson School's methane hydrate laboratory director, has literally spent months preparing for the mission, working countless hours to make sure nothing was forgotten. Now that he's in the middle of the Gulf, he can only shake his head and manage a

TO VIEW A VIDEO OF THE MISSION, GO TO WWW.JSG.UTEXAS.EDU.

CLOCKWISE: 1.MOVING A CORE ACROSS THE DECK OF THE HELIX Q4000 TO THE LABORATORY FACILITIES. 2. (RIGHT TO LEFT) JACKSON SCHOOL POSTDOCTORAL FELLOW STEPHEN PHILLIPS, PH.D. STUDENT TIANNONG "SKYLER" DONG, PROFESSOR PETER FLEMINGS AND LAB MANAGER JOSH O'CONNELL IN THE DEGASING LAB. 3: FLEMINGS IN THE "DOG HOUSE" WATCHING THE DRILL MAKE ITS MILE-LONG JOURNEY TO THE GULF FLOOR THROUGH A LIVE FEED FROM THE Q4000'S REMOTE-OPERATED VEHICLES.

PHOTOS: JACKSON SCHOOL.

scornful laugh at the things he, and the team, overlooked.

"I can't tell you how many times we've called back and asked people to bring things when they come out—power strips, thumb drives, ink cartridges," he said. "You think about this huge big project and we've done all of the big stuff. We've done everything we need to pull cores out of the ground, but we need to be able to print plots in real time, we've got to be able to take notes, we've got to be able to transfer data in a quick and easy way."

The deck of the Q4000 is about the size of a football field. The only empty space of any size is the green octagon of a helideck that crewmembers use for exercising or playing the occasional game of corn hole in their very minimal free time. It is in this setting that the science crew has set up a series of labs in shipping containers where they conduct the first analysis of the cores as they hit the deck.

In one container, there's a workshop where Geotek engineers assemble and repair the specialized coring tool. In another container, there is a large apparatus called the pressure core analysis and transfer system (PCATS) where the cores are transferred to more portable containers capable of holding them under pressure for X-rays and scans of velocity and density measurements.

This is also the area where samples are cut so they can be transferred to other labs on the ship for a first blush analysis. These are places like the mudlab, where scientists prepare core samples for microbiological and chemical analyses.

Another container holds the lab where scientists run quantitative degassing. This involves holding the core in a pressurized vessel and slowly bleeding off the methane hydrate and water into a bubbling chamber, and then carefully measuring as the pressure rebounds. This occurs because the frozen methane hydrate, which is under intense pressure, contains roughly 160 times the methane per volume as it would under surface pressure. As pressure is reduced, the methane hydrate dissociates, or melts, and the methane in the hydrate expands, causing pressure to spike again. By carefully conducting this test over a long period of time, the scientists are able to obtain exact measurements of the amount of methane in the core sample.

"We need to know the amount of methane in the core because it gives us a good metric to quantify how much methane is in the area where we took the core from," explained Josh O'Connell, lab manager of the UT Pressure Core Center. "And then we can actually extrapolate that out further across the area."

When the first pressurized core came in, the degassing duties were shared among the team through the night and into morning, as members took turns bleeding off the gas and taking measurements every hour.

O'Connell and Jackson School Ph.D. student Tiannong "Skyler" Dong pull the first duty. Dong has studied all facets of methane hydrate, and found the process of working with real pressurized cores particularly exciting. This, he said, is when scientists will finally begin to understand if their more theoretical analysis of the substance has been accurate or off-base.

"Usually we just drill a hole and put some sensors into it and take some geophysical measurements," he said. "With those geophysical measurements, we try to infer the concentration of methane hydrate, but we cannot verify the interpretation. By taking this [gas] out, we can actually know very precisely how much methane hydrate is in the sediment."

When outside the lab, much of the work is being conducted in a cramped office space just off the deck where scientists and students huddle over seismic and borehole data. Theirs isn't the first trip to the area by a group of scientists interested in methane hydrate. There was a mission here in 2009 to drill and collect some data. Amazingly, the Q4000 was able to find the same hole on the floor of the Gulf with remote-operated vehicles it employs during operations.

Postdoctoral Fellow Manasij Santra spent six months pouring over seismic data from this part of the Gulf before boarding the Q4000. He was looking at the acoustic picture of the land under the seafloor, he explained, and closely

PHOTO: JACKSON SCHOOL.

“A YEAR FROM NOW I’M GOING TO KNOW THINGS THAT NO ONE KNEW TODAY.”

- PETER POLITO

ABOVE: PETER POLITO, THE JACKSON SCHOOL’S METHANE HYDRATE LABORATORY DIRECTOR, UNLOADS A PRESSURIZED CORE OF METHANE HYDRATE AND WHEELS IT INTO THE UT PRESSURE CORE CENTER IN THE BASEMENT OF THE JACKSON SCHOOL. AFTER THE REMARKABLY SUCCESSFUL MISSION, 21 OF THESE CORES WERE TRANSPORTED TO AUSTIN AND STORED IN THE NEWLY BUILT LAB.

examining the boundaries of sediment layers for the telltale signs that methane hydrate was present.

“There has been a test in this area, so we know the presence of methane hydrate and what we see in the seismic data also matches that,” he said. “We really think we will get methane hydrate in this area.”

All the tests being conducted are first-order science to determine not only the concentration and amount of methane hydrate in the sediment, but how it will react or change when depressurized in the event the methane is ever harvested.

Beyond the science, the mission, Flemings said, offers a learning environment for students and young scientists that no classroom can match. The multidisciplinary nature of ocean drilling is like few other settings. It brings together geology, geophysics, chemistry and engineering.

“By them being in the middle of this and seeing how all these pieces fit together, this is an environment that literally drives students to whole different levels,” Flemings said.

Petrou was particularly struck by the experience of being part of a team that was collecting data directly in the field and then working with it in real time, an experience not often replicated in an academic setting.

“It’s definitely helping me grow as a scientist,” he said. “To actually see things I’ve read in text books. I’m developing new ideas and talking to people I never would have come in contact with. It’s definitely given me a lot of ideas to think about.”

The extreme deadlines placed on the students to plot data in real time and come up with solutions to critical problems, is also a driving force in their education, said Flemings.

“You need to make a decision, and you have to come up with your best estimate or your best analysis in the time you’ve got, and that’s it,” he said. “I can see the students, they’re like, ‘Holy cow, now Flemings is asking me where to locate exactly where to drill on the ocean floor. No one has ever asked me to do that before and that’s a multimillion-dollar decision. I better not screw it up.’”

The young scientists aren’t the only ones learning. Flemings, who has been on many drilling missions and sports more than a few gray hairs, said the mission has stretched him in surprising ways.

“The logistics and the paperwork alone associated with getting a vessel like this to come to the middle of this particular spot is challenging in a way I never imagined,” he said. “It’s like trying to grab a hold of a bear. It sort of overwhelms you, just planning the pieces and keeping the things from falling off the tracks.”

TURNING IT AROUND

May’s coring mission was a trial of technology and methods pioneered to bring up samples of methane hydrate under the same pressure and temperature where they are found under the seafloor. The tool being used is called the pressure core tool with ball valve, or the PCTB for short. It’s basically a long tube that is lowered within the pipes of the drill string and pulled up the same way after it has retrieved a sample. It is capable of coring samples about 10 feet long. But in order to retrieve the cores under pressure, the ball valve must close correctly to seal the container, and a nitrogen boost within the container has to fire.

The team tested two versions of the tool on land at Schlumberger’s test facility in Cameron, Texas in December 2015 before taking them to the Gulf. After all the preparation, Polito said the team was flush with optimism. That optimism was soon tempered in the deep water, as the tool failed on all but one of its eight first attempts.

“You have this expectation because you’ve been planning it so long that you’re going to get 20 cores,” Polito said. “You don’t stop to think about how difficult this really is.”

But before the mission was over, the team would engineer an amazing turn-around, pivoting from almost universal failure to overwhelming success.

“Engineer” is the key word. When Flemings called a halt to operations mid-way through the coring expedition, the team scrambled to try to determine what was going wrong. They dug deep into the data, looking for clues that might reveal the source of the problem. They studied images of the tool as it came out of the bore hole, looked at sediment in the tool’s moving parts, and poured over engineering drawings.

While they were doing all this, the crew of the Q4000 was logging and cementing the first borehole and moving to the second coring location. It would take 30 hours. That’s how long the science team had to come up with a solution.

The chosen fixes involved: grinding grooves into a component of the tool assembly that was binding and restricting high-pressure fluid from passing through; replacing the ball valve seal in an attempt to achieve a tighter fit; and welding small tabs onto teeth-like grabbers that pull the core liner inside the tool as the ball was closing in an attempt to keep the liner from slipping and obstructing the ball valve.

“We must have done something right because after that change, we had nearly 100 percent core recovery,” Flemings said.

Polito was even more succinct.

“Thank God,” he said.

Ultimately, the team brought up just over 90 feet of pressurized core to analyze, process and cut on the ship. Afterwards, they continued their work for two weeks in Port Fourchon, Louisiana, where the science facilities were relocated after the mission.

From there, 21 pressurized cores of between one to three feet long were loaded on a truck and brought to the Jackson School, where Polito and O’Connell wheeled them into the newly built UT Pressure Core Center. This is where an integrated team of scientists and engineers from the Jackson School and UT’s Department of Petroleum and Geosystems Engineering will continue their research. At the heart of the analysis is a desire to understand the dynamic evolution of hydrate reservoir properties as methane is extracted.

The Jackson School will be the hub of the ongoing work, but it’s a national effort. A multidisciplinary team of scientists from institutions around the country is also joining the research. Depressurized core samples recovered during the mission have been sent to The Ohio State University, University of Washington, University of New Hampshire, Oregon State University, ExxonMobil and USGS. Eventually, pressurized cores will be sent to the USGS in Woods Hole, Massachusetts, to the DOE National Energy Technology Laboratory, and perhaps other locations.

“I’m really excited for the science that’s going to come out of this,” Polito said. “A year from now I’m going to know things that no one knew today. That’s really exciting to me.”

Now that the cores are safely in the Jackson School’s lab, the real work is just beginning. Still, Flemings can’t help but think about how close the line is between success and failure when trying to pull off something big, especially when the pressure is on.

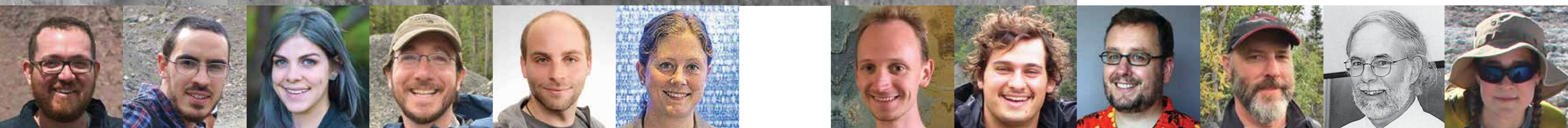
“I guess what I learned, once again, is that unbelievable focus and really, truly working the problem can lead to amazing achievements,” he said. “When everybody truly gives their all to make it happen, you can actually pull these things off.”

MARS GEOLOGY MISSIONS

Learn more about Jackson School research sites on the Red Planet and the people behind them.

ABOVE: JEZERO CRATER. **BELOW:** MARS RESEARCHERS AT THE JACKSON SCHOOL: (LEFT TO RIGHT) BENJAMIN CARDENAS, STEFANO NEROZZI, CASSIE STUURMAN, JOSEPH LEVY, CYRIL GRIMA, MACKENZIE DAY, ERIC PETERSEN, TIMOTHY GOUDGE, DAVID MOHRIG, JACK HOLT, GARY KOCUREK, SARAH BROTHERS.

JEZERO CRATER: NASA/JPL/JHUAPL/MSSS/BROWN UNIVERSITY. RESEARCHER PORTRAITS: RESEARCHERS.



BY MONICA KORTSHA

As technology has advanced, the planet Mars has gone from a faintly glowing red orb in the night sky to a familiar landscape. The NASA rover Curiosity releases new pictures of the surface of Mars every day while the Mars Reconnaissance Orbiter, a NASA satellite, monitors the planet from space.

An eclectic group of researchers at the Jackson School of Geosciences is studying the Red Planet from afar using the constant stream of data provided by these NASA probes. Their work is taking them deep inside craters, through millions of years of ice deposits at the Martian north pole, and over sedimentary rock that was deposited when Mars was wet and has since been sculpted by wind into mile-high mounds.

Members of the same group are also studying Mars-like locales on Earth to learn more about what the two worlds have in common.

"Terrestrial analog work is a strength of UT," said Jack Holt, a research professor at the University of Texas Institute for Geophysics (UTIG) who is leading research on Mars glaciers and similar glaciers on Earth. "We have a really strong, field-based geology program, and when people in the Jackson School do planetary science, they bring a very strong background in the fundamentals in geology based on fieldwork on Earth."

The Mars researchers are helping develop an understanding of the geological history of our planetary neighbor, and how its distinctive landmarks formed over time. This in turn can improve the understanding of how similar forces shape our own planet and planets outside of our solar system. It is also vital knowledge to have when planning future missions to Mars, whether it's sending more advanced rovers, or placing the first pair of astronaut boots on the ground.

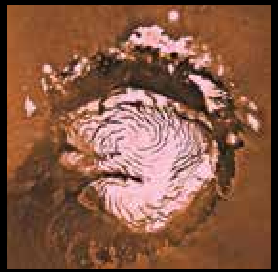
Two recent Jackson School graduates exemplify how conducting Mars research builds skills that can be used for studying Mars or our home planet. Cassie Stuurman, M.S. '17, will be working at Planet Labs, a company in San Francisco that builds Earth-monitoring satellites. And Mackenzie Day, Ph.D. '17, will be continuing her research on Mars at NASA's Astrobiology Institute in Seattle, with the goal of one day making it to Mars herself.

"It's Mars or bust," Day said.

Turn the page to learn more about Mars geology, Mars-like places on Earth, and discoveries made in both places by Jackson School researchers.

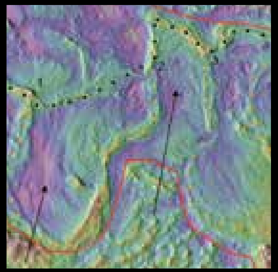
RESEARCH ON THE RED PLANET

Mars research at the Jackson School of Geosciences spans across the Red Planet. The findings are helping us learn more about our planetary neighbor, including the best spots to potentially look for signs of ancient extraterrestrial life, and where future Mars colonists could go to find water. This basic research on Mars could become vital information for future space missions.



Paleoclimate on Ice

Ice deposits on Mars record the planet's climate history. Ph.D. students Stefano Nerozzi and Dan Lalich are researching the climate history of Mars by analyzing ice deposits layer by layer, a feat made possible with ice-penetrating radar on NASA's Mars Reconnaissance Orbiter.



River Research

Ancient eroded river deposits on Mars called "sinuous ridges" are leftovers from a time when Mars was a wet world billions of years ago. By comparing a locale on Mars with similar ridges on Earth, Ph.D. student Ben Cardenas has found they likely formed along an ancient coastline and retain the curvature of the Martian rivers that formed them.

Dunes on Mars and Beyond

In 2016, Mackenzie Day (Ph.D. '17) found that wind likely shaped Mount Sharp, a mile-high mountain inside Gale Crater and the destination site for the NASA rover Curiosity. For her thesis, she compared dune patterns on Earth, Mars and Saturn's moon Titan and found that dune fields form similar patterns across planetary bodies.

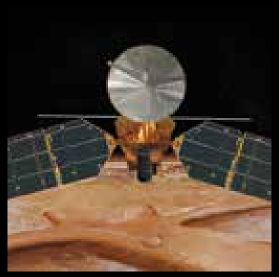
Chasma Boreale

Dunes of ice and sand are at the bottom of Mars' Chasma Boreale, a deep indention at the planet's north pole. Sarah Brothers (Ph.D. '16) studied the processes that shape these modern dunes to understand how ancient dunes, now covered by ice, were formed millions of years ago. Brothers is now a postdoctoral research associate at Texas A&M University.

NOTE: RESEARCH SITES LISTED ABOVE ARE NOT VISIBLE FROM VANTAGE OF MARS ON LEFT. **PHOTOS:** NASA.

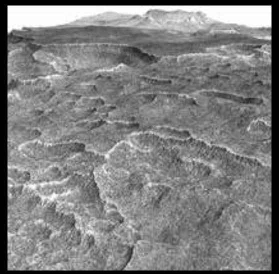
Holt at the Helm of SHARAD

Research Professor Jack Holt is the co-principal investigator for SHARAD—a radar instrument on NASA's Mars Reconnaissance Orbiter. Holt's radar expertise, honed on ice sheets and exotic terrain on Earth, prepared him for managing an instrument than can see about half a mile below Mars' surface. Much of the Mars research at UT—and around the world—depends on SHARAD data.



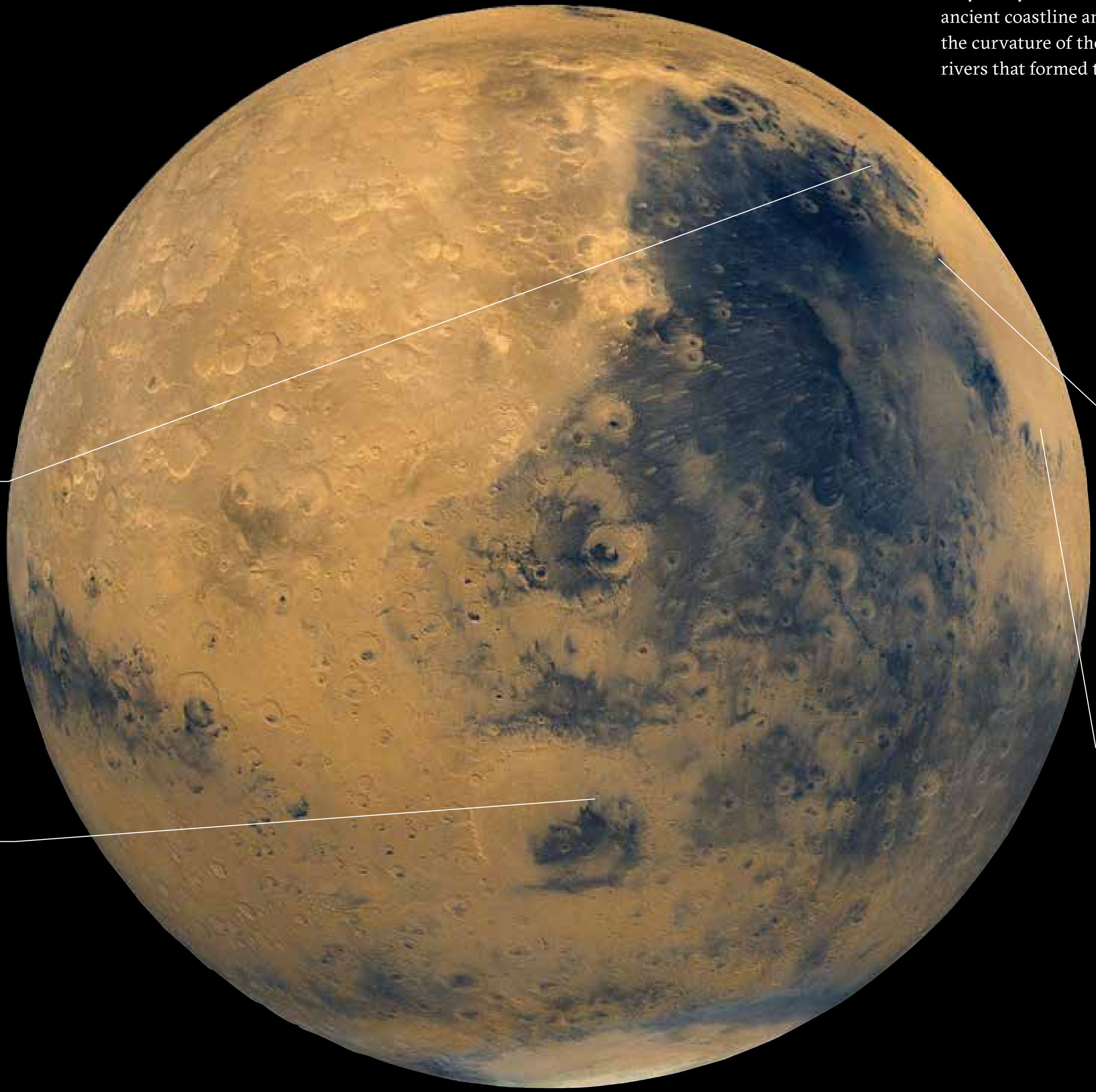
The "Great Lake" of Utopia Planitia

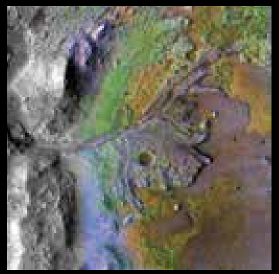
Cassie Stuurman (M.S. '17) discovered a buried ice deposit in Mars' Utopia Planitia region that holds as much water as Lake Superior and creates distinctive "ice-cream scoop" surface terrain.



The Ice Cauldron of Hellas Basin

A volcano beneath an ice sheet—a structure called an "ice cauldron"—is likely responsible for creating a funnel-shaped depression in Mars' Hellas Basin. UTIG Research Affiliate Joe Levy found the structure after noticing a bull's-eye pattern in the ice that resembled marks made by ice cauldrons on Earth.





Scientists Prefer Jezero

At a meeting in February 2017, scientists selected Jezero Crater as their top pick to send a new NASA Mars rover set to launch in 2020. Postdoctoral Fellow Timothy Gouge proposed the site because his research on the crater indicates it was once a wet, mineral-rich lake. Jezero is now among the top-three landing sites under NASA's consideration.

NASA Scout

UTIG Research Associate Cyril Grima helped NASA select the Elysium Planitia region of Mars as the landing spot for its InSight lander, a probe scheduled to land in 2018. Grima used a statistical technique he developed to analyze the surface roughness of the site.

LEFT: SOURDOUGH ROCK GLACIER, A ROCK-COVERED DEBRIS GLACIER IN THE WRANGELL-ST. ELIAS MOUNTAINS OF ALASKA. **RIGHT:** A DEBRIS-COVERED GLACIER ON MARS. SIMILAR TO THE SOURDOUGH ROCK GLACIER, ITS ICY CORE IS COVERED BY METERS OF DEBRIS. THE FOLDED SURFACE TEXTURES ON BOTH GLACIERS ARE FORMED BY THE FLOW OF ICE. **BELOW:** JOSEPH LEVY, A UTIG RESEARCH AFFILIATE, OBSERVES SIGNS OF GROUND ICE MELTING IN ANTARCTICA'S GARWOOD VALLEY, A MARS-LIKE LOCATION ON EARTH.

Visiting Mars on Earth

Some environments on Earth have a lot in common with places on Mars. Conducting fieldwork here gives researchers a chance to study features found on Mars and familiarize themselves with our own world at the same time.

WET STREAKS IN DRY VALLEYS

Antarctica's McMurdo Dry Valleys are the most Mars-like landscape on Earth, said UTIG Research Affiliate Joe Levy, an assistant professor at Colgate University. These isolated, desolate lands have been frozen for more than one million years, with huge deposits of buried ice beneath the ground. In 2016, Levy co-led a mission to map the valleys using airborne LIDAR laser scanning. The project was specifically looking for areas where ice deposits showed signs of melting since the last scan in 2001. These melt features resemble those on Mars that have been observed flowing down certain slopes in warmer seasons.

BURIED GLACIERS

Jack Holt, a research professor at UTIG, is tracking the ice at the center of rock-covered debris glaciers on Earth and Mars. On Sourdough Rock Glacier in the Wrangell–St. Elias Mountains of Alaska, Holt and his students are using airborne photogrammetry, a technique that allows the team to calculate the glacier's flowrate by studying its surface folds. Ph.D. student Eric Petersen is studying similar glaciers on Mars, using radar data to determine the composition of the ice inside and the thickness of their debris covering. He points out his research might come in handy to future astronauts looking to tap the glacier as a water source.

GARWOOD VALLEY: JOE LEVY. SOURDOUGH ROCK GLACIER: JACK HOLT. MARS GLACIER: NASA.

John Dewey

Thoughts from one of the founding fathers of the theory of plate tectonics on geology, education and his own illustrious career

BY ANTON CAPUTO
ILLUSTRATION BY JOHN MAISANO

There are few living geologists who have shaped modern scientific thought as much as John Dewey. Since his first field studies in Newfoundland in the 1960s, he has helped build the foundation of the theory of plate tectonics and continental drift, specifically laying out how tectonic movements explain the geology of mountain belts.

Dewey, now an emeritus professor of geology at Oxford, has lived and participated in a history that students, and many professors, can only read about. And with a personality and wit straight from central casting, the noted scholar is a master of bringing that history to life.

Over the past few years, select Jackson School students, faculty and even alumni have experienced Dewey's brilliance firsthand thanks to a longstanding friendship with Jackson School Dean Sharon Mosher that dates back to her days as a master's student at Brown University. Dewey led field trips for the Jackson School as a visiting professor emeritus in the summers of 2014, 2015 and 2016.

In 2014 he led a group to Ireland and in 2016 to western Newfoundland to visit the very locations where he first discovered a half century ago that the two regions on opposite sides of the Atlantic Ocean had nearly identical geology. Sandwiched in between, in 2015, he led a group to northern England and Scotland, to visit some of the most famous formations in the world in an area credited with being the birthplace of geology.

Dewey's tenure as a Jackson School visiting professor is over, but he happily shared his thoughts on the state and future of the science he loves and more.

Q: You've had an extremely long and prestigious career in geology. What are you doing these days?

A: I spend time at home in Oxford writing. I'm writing my memoirs at the moment, which is great fun. You remember things you think you've forgotten. Plus I do a lot of little bits of local geology around Scotland and England, France, Switzerland, within Europe. I've given up all the field work in South Africa and New Zealand and California.

Q: You've conducted research all over the world. Is there one spot you haven't been that you would still like to visit?

A: Yes, Antarctica. That's the only continent I have not been on. [Jackson School Professor] Ian Dalziel has been trying to get me there quite a lot, but something always transpires, and I can't go. Trying to go down there is awkward in a way, because I did much of my work when I was gainfully employed during summer vacation. But of course in Antarctica, you've got to go in our winter.

Q: How did you come to be connected to the Jackson School?

A: When I retired I was in my 70s, and I thought, 'Well do I want to keep on going until I'm old and decaying or do I want to sort of pull out now of a full-time university job and just do research at my own pace?' If you're teaching a course, you can't just take off for field work in Australia or something like that. You've got students to look after.

I thought perhaps the way to do it is to not go anywhere permanently, but simply attach myself for a few weeks or months every year. Go somewhere and talk to the students so I haven't got a long-term commitment, and I haven't got masses of teaching to do.

So I wrote to [Jackson School Dean] Sharon Mosher and said, 'Would you like some sort of short-term arrangement? I'll run a field trip every year. I'll come for a few weeks every year and you can give me a consulting fee to cover my costs.' It has worked very well.

Q: What's your impression of the students at the Jackson School?

A: Really top-class. Absolutely top-class. Both the undergraduate and the graduate students are very, very good. The reason of course is they're very fussy about who they take as graduate students here. I guess undergraduates, too. It's highly competitive, so they can afford to be picky and choosy about who they have.

Q: One of the Jackson School's major focuses is to make sure that undergraduates have time in the field. Do you think that is an important part of an undergraduate geosciences education?

A: It is essential and has become a problem. Geological research, and obviously the people who do it, are becoming much more quantitative and machine driven. [There are] lots and lots of new techniques [to] measure the ages of rock. A lot of really fantastic new techniques, so people are really going straight into that more and more. They're spending time doing that rather than spending time in the field looking at rocks and teaching students how to look at rocks.

I'm not saying it's decaying, and [UT] Austin is much better than most places in terms of going out into the field. [Jackson School Professor] Danny Stockli goes out in the field even though he's a machine man. [Jackson School professors] Mark Cloos, Randy Marrett, Ian Dalziel are often out in the field. But in many places they've stopped teaching optical mineralogy, for example. What I would call basic core disciplines in geology have stopped being taught. But Austin is very unusual in the modern world in keeping core disciplines going. I think that's very important.

Q: So you are seeing field work de-emphasized at some schools?

A: Yes. Training the students to look at rocks and how to analyze and understand them; some departments do it by remote sensing and virtual geology. That's not the way to do it. You need to go in the field and look at rocks. Francis Pettijohn, the great sedimentologist, once said, 'The truth resides in the rocks.' You can model it all you want, but ultimately you've got to go look at the rocks and see what they say.

And the students love it of course. They love being in the field. That's why many kids go into geology. They want to go in the field and look at rocks and study the Earth that way. And many kids get upset at some universities when they find they're spending all their time doing chemistry and physics and god knows what in the lab.

Q: What was your first teaching job?

A: I came through undergraduate and graduate school in '55 through '60 at Imperial College in London, and then I got my first teaching job. In those days you could get a teaching job in academia straight away if you were any good. Nowadays people have postdocs and fellowships. It's now tough to get an academic position. Some people are 30 or 31 by that time. I was 23 when I got my first academic position as a lecturer in Manchester (the University of Manchester).

Q: You are credited with being one of the pioneers of plate tectonics. Can you discuss those early years of your career and how you became interested in plate tectonics?

A. I spent four years in Manchester. Then I got a job in Cambridge University from '64 to '70, and most of that time I was working away at structural geology. I was invited to Nova Scotia in 1964 to join an expedition looking at some Silurian and Ordovician rocks. I loved that. First of all it was great fun. It was the first time I'd been to the North American continent.

I started mapping with a variety of people, and these rocks were fantastic over the whole area of Nova Scotia. And I realized some of these rocks were quite like some of the rocks I'd looked at in Ireland. It's not surprising because actually the Caledonian belt comes through Scandinavia, through Scotland, through Ireland, is chopped off by the Atlantic and reappears in Newfoundland and Nova Scotia. It's the same belt on both sides of the Atlantic. All that happened is that the Atlantic pulled it apart. They obviously do fit, you know, and that's what I worked on a lot.

That, in 1964, opened my eyes to the Appalachians. And I got very interested because I'd been in the Caledonian belt until then looking at small-scale structures. And then I got the opportunity to spend a sabbatical leave in Columbia at Lamont-Doherty. I was getting interested then in the correlation across the Atlantic and how the Appalachian Caledonian chain worked, what it was made of. I thought the way I should find out is this: I'm going to make a map, an incredibly long detailed map from Newfoundland all the way through to Alabama.

I went through all the state geological maps: Vermont, New Hampshire, Maine, right down through the Carolinas, right down to Alabama. I synthesized and generalized the geology, and I put it on this map. And gradually, it was amazing, there was a belt of Ordovician volcanics that runs right down through there. It runs right down through Vermont, down through New York. It goes down to Pennsylvania; what is it? And I started to see patterns of rock associations. And then I said, 'What do they mean?' They must mean something in terms of the modern world—this was in 1967. And it's got to have something to do with this new emerging plate tectonics that was developing at the time with Tuzo Wilson and people like (Dan) McKenzie and (Walter) Pitman and god knows who. I was in Lamont at exactly the right time. Serendipity. I was just dead lucky.

Q: What was your role in the emerging research?

A. I was doing this great map, which was emerging as a fossil example of things that are happening in the world today in plate tectonics. And I realized that this is a place where an arc has collided with a continental margin in mid-Ordovician times 470 million years ago.

It's the sort of thing that's happening in northern Australia in present day. It was kind of exciting. Lamont was the hotbed of the development of plate tectonics. Princeton, Scripps in California and Lamont in New York and Cambridge, too. So I just got swept up in it completely.

My role was taking old rocks, looking at the history of the world and saying, 'Can we explain all this in terms of this new emerging science of plate tectonics?' And I said, 'Yes, you can do it, at least back for 600 million years.' Before that, things are different, but for that Phanerozoic time, it clearly is the result of the evolution of plate motion going on, making arcs and splitting and pulling continents apart and colliding them again and making mountains and all that kind of stuff. So that's how I got into it.

Q: Was the plate tectonics theory controversial at the time?

A: In the early days BPT—before plate tectonics—the world was divided into the bulk of the people who thought continental drift was rubbish, and a small group including me and Lester King in South Africa and probably 20 or 30 people in the science who thought it must have happened because if you compare West Africa and South America, A, they fit together perfectly and B, you find old mountain belts coming through and it continues where they fit. It's like a jigsaw, and jigsaws don't lie. Obviously, there had been continental drift taking place by some mechanism.

There was a man called Harold Jeffreys who was extremely anti-continental drift. He said, rightly in a sense, that the continents are made of weak rocks, rocks that deform and squash easily. Oceans are made of strong rocks. The continents are dominated by quartz, whereas the oceans are dominated by olivine, which is a very strong mineral. So if oceans are strong, how can you have continents plowing through hard stuff?

But he thought of it wrongly. The continents don't plow around. They split, and then you have seafloor spreading, which means the middle opens up. There is a gap, which keeps on filling up, and the continents are basically just passive passengers on the plates. They keep moving around where the plates move. They are not plowing through anything at all.

Harold Jeffreys had a big influence on the world, particularly Britain. He was a professor at Cambridge, and what he was saying was rubbish because he hadn't thought about it in quite the correct way. That happens in science a lot.

Nevertheless, in Britain there were a lot of geologists who thought continental drift must have happened. In North America, it was different. It was a very anti-continental-drift nation at the time. They said in the '50s, if you espoused the idea of continental drift you would never get a job at a university in America.

There was a change. It was progressive, and it was partly generational. The people who were proposing plate tectonics were mostly the younger generation, including me, Walter Pitman, Lynn Sykes. The only one who was older was Tuzo Wilson.

If you asked who was the founder of plate tectonics, it was a number of people of course, but it was really Tuzo Wilson who had the idea in 1965. He wrote a really classic paper in '65. He didn't call it plate tectonics back then, but all the classic elements of plate tectonics were in it. And then, by 1968, the cat was out of the bag. 1965 to '68 was the period where the idea was proposed and then it became generally accepted. But there was still a rear-guard action by some of the older people who didn't like it. But basically by '68 the thing had taken off, and it was all over. It was taught in some university courses in '68 to '70.

And then in the '70s and even today lots of ideas are developing on the theme and how it works. There's a huge amount of work left to be done, but the basic theory is there. It looks pretty good. It may be all wrong, but I'd be amazed if it is wrong. I take Karl Popper's view of science. You can never prove anything right. All you can do is prove things wrong.

Q: How has geology changed since you started?

A: Geology has changed a great deal. For the better and the worse. There have been some wonderful developments in geology, mostly new ways of measuring things. The machines we have now were unthought-of even 20 years ago.

Danny Stockli's lab, for instance, is just state-of-the-art. Right at the cutting edge of the science. You can actually measure the ages of the rock vastly more accurately right down to plus or minus a million years. It's incredible. It's unbelievable the things you can do. And you can do the chemistry of rocks very thoroughly and the physics of rocks. You can really pull rocks apart right down to the submicroscopic level. There's an amazing lady at the Bureau of Economic Geology, (Research Associate) Esti Ukar, the things she can do would make your mind boggle.

For somebody in the last century, they would say it couldn't be done. It's just necromancy. They wouldn't believe it. But on the other hand, we're losing sight of some of the classic core of geology, which is very important. Not here. Not in Austin. I think it's maintained very well.

This is partly because at one time you went around a geology department 50 years ago and everyone had a degree in geology. Now you go around a geology department, and there are people with degrees in physics, materials science, engineering, biology. It's good. It's become multi-and interdisciplinary, and that is what you want in science. You want people coming at things from a range of angles, but that in itself has taken its toll on the science. It's lessened the basic core of geology. I'm afraid it's gone too far for the moment. It'll come back. Things go in cycles. In another 10 years we may have the young people saying, 'Oh, this crazy instrumentation period back then.' Attitudes change always, and old people tend to complain about the young. It's inevitable. It's probably healthy. It keeps the young under control (laughs).

Q: What advice do you have for young geoscientists?

A: I think I would tell them, 'Don't do what old people tell you to do. Follow your own nose. If you have an idea, a series of ideas, just follow it.' If old people say, 'No you shouldn't do that, do something else or come into my lab or work with me,' ignore them. Forge your own career doing your own thing. Most of the great ideas in science come from relatively young people. So forge your own career, and don't kneel or bow before the old. I think that's about it.

DEWEY IN NEWFOUNDLAND IN 1968. IN 2016, HE LED A JACKSON SCHOOL FIELD COURSE ON TECTONICS IN THE PROVINCE.

PHOTO: BRITISH LIBRARY.

Fossil Feathers, Winging & Singing

VEGAVIS: GABRIEL LIO/CONICET. CLARKE: JACKSON SCHOOL.

The Breakthrough Bird Research of Julia Clarke

BY MONICA KORTSHA

Antarctica wasn't always a frozen, desolate continent. About 70 million years ago during the Cretaceous Period, it was green, lush and teeming with dinosaurs. Thanks to discoveries made by Jackson School of Geosciences Professor Julia Clarke and her collaborators, we know that during the Age of Dinosaurs the continent was also home to a much more familiar looking inhabitant: *Vegavis iaai*, an extinct member of the modern bird group that resembled a duck or goose and may have honked like one, too.

Argentine researchers found the first *Vegavis* fossil on Antarctica's Vega Island in 1992. In 2005, Clarke, then a research curator at the North Carolina Museum of Natural Sciences, led a detailed examination of the fossil and found that it belonged to the same evolutionary order as modern-day ducks and geese. The finding was the first hard proof of modern birds living during the Cretaceous, a theory that evolutionary research suggested but needed bones to confirm.

"The really exciting thing about *Vegavis* was that, in most people's minds, it was the first really, really good fossil evidence for a modern bird—in this case the duck group—living in the Age of Dinosaurs," said Matt Lamanna, a curator at the Carnegie Museum of Natural History and a co-leader with Clarke of a 2016 fossil-hunting expedition to Antarctica supported by the National Science Foundation.

In the fall of 2016, Clarke and another team of collaborators announced that a second, even better preserved *Vegavis* fossil included the syrinx, the bird vocal organ. Its presence in the ancient bird, but not in other dinosaurs, indicates that the organ was not something birds likely inherited from their theropod dinosaur forefathers and mothers. (In case you missed it: scientists classify birds as living dinosaurs, the sole dinosaur lineage that survived the asteroid impact at the end of the Cretaceous that snuffed out all the others.) According to Clarke, the syrinx discovery could open the door to a new type of research into sound generation in extinct animals, and how it relates to sounds made by animals living today.

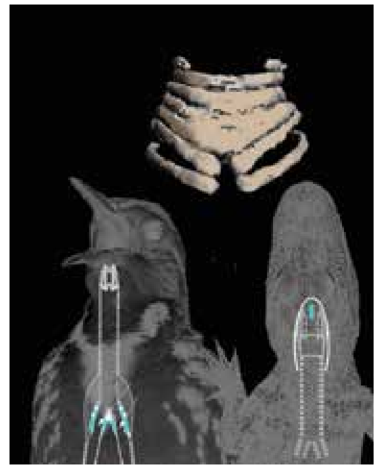
"I think that our work on the syrinx sets a starting point for studying other fossil records of vocal behavior or vocalization," Clarke said. "We're doing this in birds, but it can become a model for looking at similar questions in other animals."

Clarke's *Vegavis* discoveries are all smaller parts to a bigger question she's chasing: how and why do unique bird characteristics—from feathers to birdsong—arise? Her *Vegavis* research exemplifies that these big questions can help strengthen current fields of study, while forging brand new research

"I think that our work on the syrinx sets a starting point for studying other fossil records of vocal behavior or vocalization."

– JULIA CLARKE

OPPOSITE PAGE: AN ARTIST'S INTERPRETATION OF *VEGAVIS IAAI*, A BIRD FROM THE AGE OF DINOSAURS AND DESCRIBED BY CLARKE. **LEFT:** CLARKE WITH FOSSIL.



directions. As a part of the Jackson School faculty since 2009, Clarke has been mentoring the next generation of geosciences researchers as they take on their own big questions, showing that the so-called "impossible questions" can have big returns.

"I really like the hard questions," Clarke said. "The ones we think we can't answer."

Clarke's *Vegavis* research is just part of the story. She has been part of ground-breaking discoveries on feather evolution and coloration, and lately, bird vocalization. It's work that benefits from Clarke's curious worldview that has resulted in numerous international collaborations and fossil-hunting excursions across the globe.

"If we want to understand the world, it's a global enterprise," Clarke said. "A big component of my research is international research, and I think it's key to get data points from some of the most remote and inaccessible places."

Feather Finds

When Clarke started graduate school at Yale in the 1990s, the first feathered dinosaurs had just been discovered. That new finding, combined with field experience in Argentina with a paleontologist who was working on the evolution of birds, made a compelling case for studying birds in the fossil record, Clarke said.

"It was a lot of new data and a lot of possibilities the year I started grad school," Clarke said. "I could have asked similar questions about a lot of different groups and been really happy, but it was just timely to work on bird origins."

Early in her career, Clarke dedicated a large amount of time to describing fossils, honing her observational skills, and building a strong foundational knowledge of animal anatomy. Clarke said that this strong technical knowledge is at the core of the questions she asks.

"I don't think we can even imagine the questions you want to ask until you have that basis in anatomy and how we study anatomy and what are cutting edge tool kits for studying anatomy generally," Clarke said. "And once you get into that you can go, 'How does this structure work, why is that that shape, that's weird,' and let basic curiosity take you to some new area."

Her sharp eye led to an important discovery in 2008. On a fossil hunting expedition in Peru, her research team discovered a gigantic species of extinct penguin, dubbed *Inkayacu*, which lived about 36 million years ago during the Eocene and stood about five feet tall. But the most exciting part of the discovery was that the penguin's feathers were preserved.

The feathers contained impressions of melanosomes, color-containing organelles, which allowed the team to learn that the penguin was gray and reddish brown rather than the tuxedo that's in vogue for most of its relatives living today. The pigment in the melanosome had long degraded; to determine the color of the feathers, the research team studied the shape of the preserved melanosomes—a feature determined in part by the pigment they once contained. The penguin discovery was important for its own sake, making the cover of the journal *Science* when it was published in 2010. But it's also significant because it helped pave the way for research into feather coloration in general.

Shortly after the publication of the penguin research, Clarke and a team of collaborators deciphered the plumage colors of chicken-sized dinosaurs with more than a passing resemblance to modern birds. In 2010 they found that *Anchiornis huxleyi*—a four-winged dinosaur that lived 150 million years ago during the Jurassic in China's Liaoning Province—had distinctive black, white and red markings similar to a modern red-bellied woodpecker. Two years later, Clarke and collaborators found that *Microraptor*, a Cretaceous dinosaur from the same province as *Anchiornis*, was a shiny, iridescent black, like the feathers of starlings and grackles today.

VEGAS ISLAND: ANTARCTIC PENINSULA PALEONTOLOGY PROJECT; SYRINX AND LARYNX: JULIA CLARKE/UT.

Clarke's research on feather coloration is helping us envision the feathered dinosaurs of the Mesozoic Era more than 100 million years later, from the Holocene. However, she notes that studying the plumage color of individual birds and feathered dinosaurs is a means to understanding the bigger evolutionary picture. Her latest paper on feather coloration, published in *Nature* in 2014, integrated the dinosaur findings and compared them to nearly 200 melanosome samples taken from across vertebrates, including specimens of animals living today and fossils. The research found that an increase in melanosome diversity—and hence color—appeared with the first feathers.

"What I like to think I'm good at asking is, 'Well, OK, we can say something about a dinosaur's coloration, but what does that tell us about a major system that governs animal coloration,'" Clarke said. "The last major paper we had on coloration was about the melanin-based color system and how that evolved."

She adds that the work the team did on plumage coloration was important to the field of paleontology because it helped prove that fossils record evidence of ancient colors.

"Only a few years ago, we never thought we could use the fossil record to study coloration," Clarke said.

Bird Calls to Dinosaur Booms

These days, Clarke has set aside most of her feather-coloration research to focus on the evolution of bird vocalizations. The discovery of the *Vegavis* syrinx last year opened doors to comparing the sound structures of living birds with ancestors from the Age of Dinosaurs, Clarke said, a field of study that has hardly been touched on by other scientists.

"The starting point here is the discovery of the fossil avian vocal organ, but we are also doing really core work on trying to figure out what's changed," Clarke said. "I don't just describe fossils. I do a lot of work on living organisms so I can ask new questions about fossils."

In some cases, the research on modern birds can not only give insight into a particular fossil, but a behavior of a range of extinct animals. Last year, Clarke and her collaborators turned their attention to closed-mouth vocalizations in birds and related reptiles, such as the coos of doves and the booming rumbles of crocodiles that are generated through throat inflation rather than by passing air through the syrinx, an organ that's unique to birds.

"The starting point here is the discovery of the avian vocal organ, but we are also doing really core work on trying to figure out what's changed."

– JULIA CLARKE

TOP: A VIEW FROM VEGAS ISLAND IN ANTARCTICA. **RIGHT:** THE *VEGAVIS* SYRINX COMPARED WITH A SYRINX FROM A LIVING BIRD AND THE LARYNX OF A CROCODILIAN.

AN EXAMPLE OF IRIDESCENT FEATHERS ON A GRACKLE. A LOOK THE MODERN BIRD MAY HAVE SHARED WITH *MICRORAPTOR.*

Not all birds and reptiles can make these closed-mouth sounds. By statistically analyzing the characteristics associated with the ability or lack of it across 208 bird species, Clarke and her team determined that closed-mouth vocalization evolved at least 16 times in living archosaurs, the group that includes birds, crocodiles and alligators, and is associated with having a relatively large body size. Since dinosaurs are also part of the archosaur group, Clarke and her collaborators suggest that it's not a stretch to think that some of the larger-sized ones—and there were plenty—could also make closed-mouth sounds.

"This makes for a very different Jurassic world. Not only were dinosaurs feathered, but they may have had bulging necks and made booming, closed-mouth sounds," Clarke said in the news release announcing the research finding.

Impossible Questions, Innovative Research

From feathers to vocalization and a variety of other research streams along the way, Clarke has always kept the big picture in mind as she conducts her work. Lamanna said that Clarke's clear focus on larger research objectives is an asset for any research team, especially in Antarctica, where the environment can cause its own set of distractions.

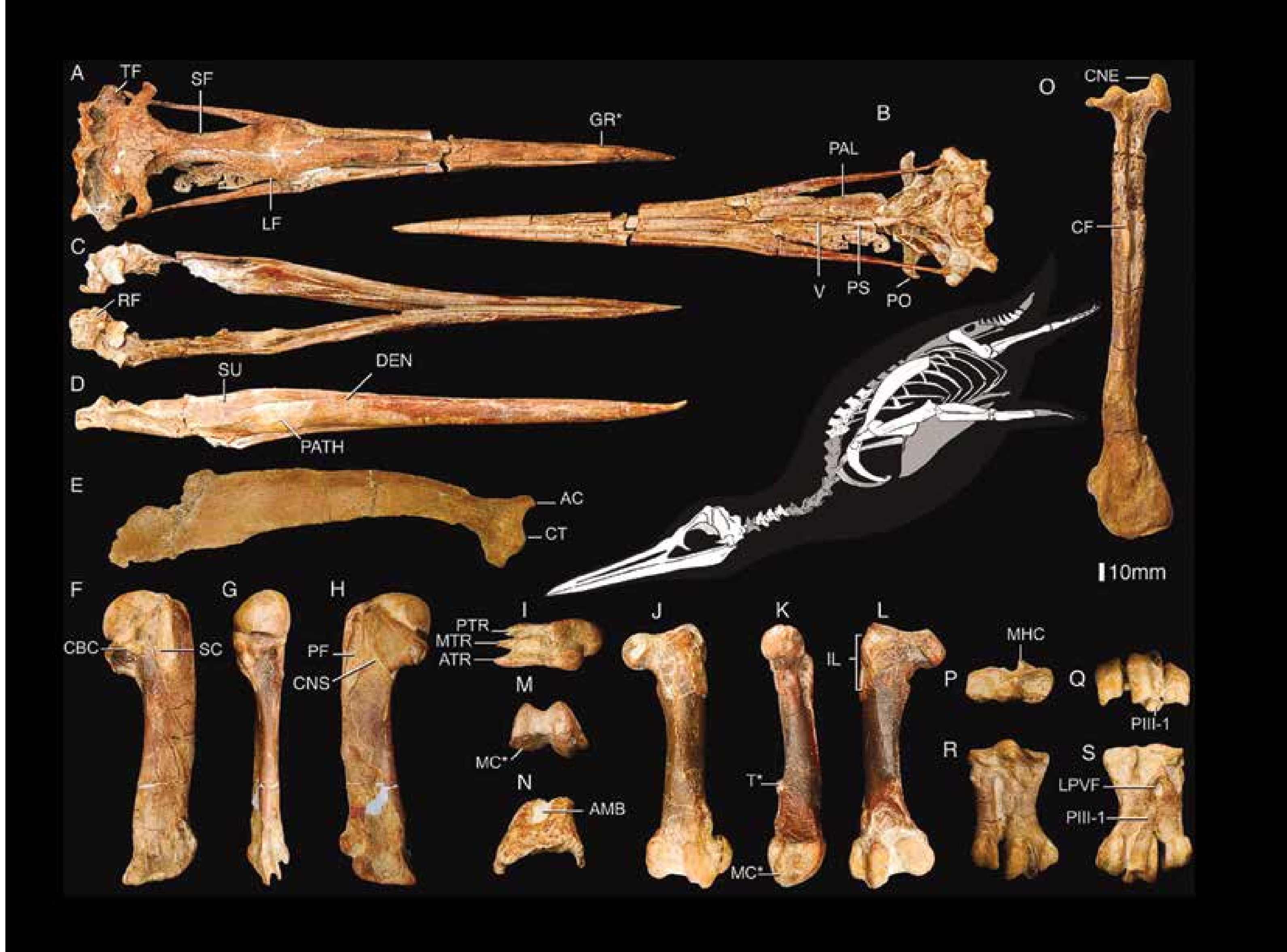
"Julia is super driven and focused, more so than almost anyone I've ever worked with," Lamanna said. "Given the conditions in Antarctica, it can be easy even for seasoned field workers to lose track of goals, or to focus on things that don't matter so much; but Julia just never loses sight of why we're there."

But Clarke doesn't view her research approach as something unique to her. This spring, she spent a semester teaching a joint undergraduate and graduate course called Curiosity to Question about how to approach and conduct research. The new class encouraged students to embrace questions that they couldn't answer and then develop research around related questions that they could, with students getting hands-on experience conducting research under Clarke's guidance.

"People were surprised with how much they could get done," said Sarah Davis, a first-year Ph.D. student advised by Clarke and a student in the course. "Julia was helpful in that narrowing-down process."

As her own research findings show, Clarke's advice to pick a supposedly unanswerable question and then chip away at it with available data has made real scientific progress into what were once thought of as impossible research areas. From melanosomes came a colorful Jurassic world. And from a fossilized syrinx and modern analytical techniques came the calls of extinct birds and dinosaurs.

PENGUIN BONES: JULIA CLARKE. *MICRORAPTOR*: MICK ELLISON/AMNH. *ANCHIORNIS HUXLEYI*: MICHAEL DIGIORGIO/COURTESY YALE. GRACKLE: NAATHAS/FLICKR COMMONS.



ABOVE: THE BONES OF THE EXTINCT PENGUIN *INKAYACU*. **RIGHT:** THE FEATHERED DINOSAURS (TOP) *MICRORAPTOR* AND (BOTTOM) *ANCHIORNIS HUXLEYI*.

Clarke's own crop of Ph.D. students is asking "impossible" questions of their own. For example, Davis is researching feather coloration. But unlike Clarke's research, which focused on feathers colored by melanin, Davis is branching off into a new direction with potentially even more avenues to explore. She's studying feather pigments made from carotenoids, a class of organic molecules that come strictly from an animal's diet. They're responsible for vibrant bird feathers, such as the pink of flamingos and the red of cardinals, as well as vital functions like immune system response and vision.

"It's an interesting mechanism that's unique and has the potential to have been around for a very long time because it's seen in a lot of modern-day birds," Davis said. "So I'm interested when this basic, fundamental nutritional thing got co-opted to make the really bright and pretty colors."

In true Clarke fashion, Davis knows she's on the right track because of the constant questions her work keeps uncovering.

"The more I continue on my current project, the more questions I find," Davis said.

Petra Nova

Producing power and trapping CO_2 underground

BY ANTON CAPUTO

LEFT: PETRA NOVA IS THE WORLD'S LARGEST POST-COMBUSTION CO_2 CAPTURE FACILITY INSTALLED ON AN EXISTING COAL-FIRED POWER PLANT.

ABOVE: THE PETRA NOVA PROJECT IS STORING CO_2 UNDER THE WEST RANCH OIL FIELD, WHERE IT WILL HELP ENHANCE OIL RECOVERY.

PHOTOS: NRG ENERGY.

Deep underneath an old Texas oil field in Jackson County, science and economics have come together to achieve something unique. For the first time in this country, a commercial-scale project is taking carbon dioxide emissions (CO_2) from a coal-fired plant and storing them in rocks beneath the ground so they cannot escape into the atmosphere and impact the Earth's climate.

The project—Petra Nova—is removing CO_2 from a unit of the W.A. Parish power plant near Houston and piping it some 80 miles to the southwest where it is pumped approximately a mile beneath the West Ranch oil field. The greenhouse gas is not only being trapped underground at the field, but is also being used to improve oil production through a technique known as enhanced oil recovery. It is a key aspect to making the $1 billion project economically viable by using the profit from the sale of oil to pay for the carbon capture system.

The job of monitoring the CO_2 deep underground falls to the Bureau of Economic Geology, which is working with Texas Coastal Ventures, a partnership of Petra Nova and oil field operator Hilcorp Energy Co.

"We really need to have not only the expertise of the UT Bureau of Economic Geology, but the independence," said Greg Kennedy, senior project director of asset management for NRG Energy, a main partner in the Petra Nova project, and the project's liaison to the bureau. "We need the University of Texas for an independent, high-quality assessment of that side of the project so we can actually determine that the captured CO_2 is staying underground and not entering the outside environment."

The idea of storing CO_2 emissions is not new. The bureau's Gulf Coast Carbon Center has been leading research on the issue for more than a decade, helping perfect the technology in a series of pilot projects around the country. Given the bureau's long history with the technology and its focus on research that tackles tough problems that combine energy, the environment, and the economy, it was well-positioned to assist with the ground-breaking project, said bureau Director Scott W. Tinker.

"Petra Nova is a natural fit for us," Tinker said. "The project is at the intersection of government, private industry, the environment and public policy. It's an area I like to call the radical middle—an area where solutions to tough problems are found and things get done."

Capturing Carbon

Although the project has been in the design phase for many years, Petra Nova started operating in December 2016, taking more than 90 percent of the CO_2 from 240 megawatts of power production (enough power to serve about 200,000 homes) and piping it to the West Ranch oil field. Petra Nova is capturing more than 5,000 tons of CO_2 per day, according to NRG Energy, which is equivalent to taking more than 350,000 cars off the road for a year.

The U.S. Department of Energy has been encouraging such projects for years through a series of programs and grants, but no commercial scale project had come to fruition in the U.S. before Petra Nova for a variety of reasons. First and foremost is the costs that carbon capture and storage add to power production.

NRG Energy and partner JX Nippon Oil & Gas Exploration were able to make the $1 billion project economically viable by using the captured CO_2 to increase oil production at the West Ranch field. The project was also the beneficiary of a $190 million grant from the Department of Energy's Clean Coal Power Initiative Program, which helped pay for the carbon capture unit.

The resourceful approach earned the praise of Texas Gov. Greg Abbott.

"NRG and JX Nippon's Petra Nova is the type of innovative, technologically advanced project that proves time and again that Texas is the world leader in energy innovation," Abbott said in a prepared release.

The enhanced oil recovery at West Ranch is expected to boost oil production from around 500 barrels per day to as much as 15,000 barrels per day, Kennedy said. This technique involves pumping CO_2 into the field, where it mixes with oil and helps release it from the rock formation so it can be pumped to the surface. The CO_2 is removed from the oil above ground and then injected back into the ground where it is trapped.

At that point it's up to researchers from the bureau to monitor the CO_2 to ensure it stays put. They are accomplishing this through a combination of techniques that monitor deep subsurface pressure, groundwater, soil gas and other parameters that provide information on the status of the CO_2 after it is stored underground.

Tracking Carbon

The monitoring project is being led by Susan Hovorka, a senior research scientist and principal investigator of the bureau's Gulf Coast Carbon Center. Hovorka and her colleagues carefully studied the subsurface environment under the field for more than a year to understand conditions before the project began.

One of the main issues, Hovorka said, is that pumping CO_2 into the ground elevates pressure in the injection zone, which could theoretically lift fluids containing dissolved CO_2 through damaged or flawed wells toward the surface. Once out of the ground, the greenhouse gas would escape into the atmosphere. To ensure this doesn't occur, Hilcorp Energy has inspected each existing well and brought all up to current standards so they do not exceed the original natural pressure of the oil field. As an extra precaution, researchers have installed pressure gauges in deep wells more than 3,000 feet below the surface. These gauges act as an early warning system for potential CO_2 leaks because they are above the zone where the CO_2 is injected. Increases in pressure at this level would indicate that fluids may be leaking upward, giving the operator time to find and repair wells if needed.

RIGHT TO LEFT: BEG RESEARCHERS SUSAN HOVORKA, REBECCA SMYTH, DAVID FREEMAN (SANDIA TECHNOLOGIES) AND JIEMAN LU AT THE STORAGE SITE

RESEARCHERS: BUREAU OF ECONOMIC GEOLOGY. BENEFICIAL USE: NRG ENERGY.

The extensive CO_2 monitoring at Petra Nova is a precaution, Hovorka said. She stressed that she does not expect any leaks to come bubbling from below and that none have occurred to date.

Hovorka said that crews are also monitoring groundwater and soil gas for signs of CO_2 leakage. To do so, scientists are watching parameters that would change during a spill or leak, specifically, the ratios of nitrogen, CO_2, methane, strontium isotopes, carbon isotopes, light hydrocarbons and noble gasses. Hovorka described these parameters as "distinctive markers" of fluids from deep areas. They have a different chemical signature than fluids from shallower areas, a difference that makes for a good indicator to identify CO_2 that leaked toward the surface from the deep subsurface.

"Stakeholders could be concerned about any one of a number of environmental changes, and without these markers it would be hard to say for sure if the change is because of fluid from the project or some other shift in the environment," she said.

The Gulf Coast Carbon Center has developed these methods through pilot projects across the country over the last decade. The big difference in Petra Nova, said Hovorka, is the full industrial scale.

"It is really exciting to take what you have been working on in R and D and take it to commercialization," she said.

Petra Nova is unique for now. But the project was designed with replication in mind, using commercially available technology. The carbon capture system was jointly developed by Mitsubishi Heavy Industries Ltd. and the Kansai Electric Power Co. Kennedy said the system could be used by any existing or new coal power plant.

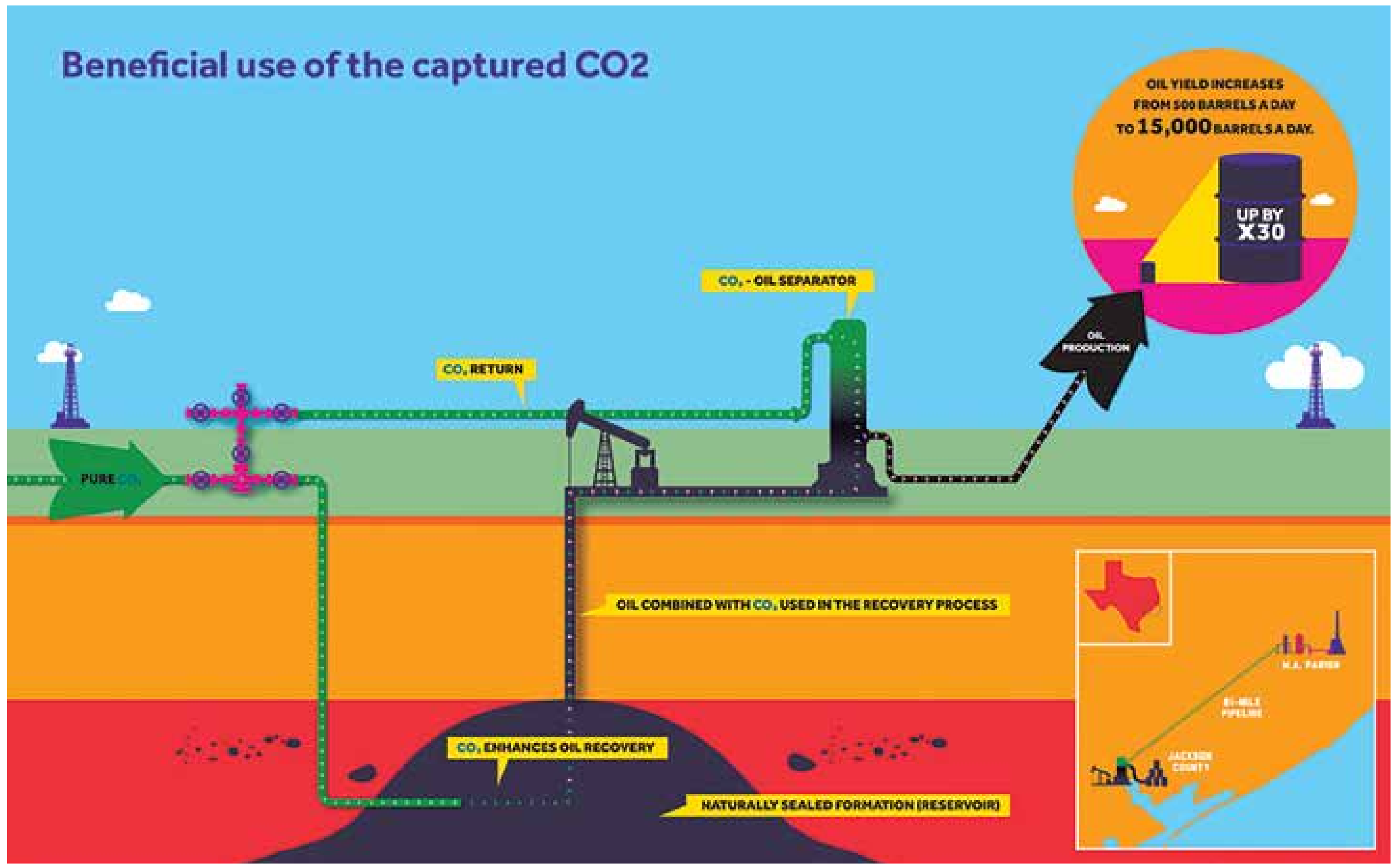
The equipment Hovorka and her team use to track carbon at the oil field employs off-the-shelf technology for the same reason. The goal is to work out any kinks in the monitoring protocol, so it can be used by other companies, a goal she believes is well within reach.

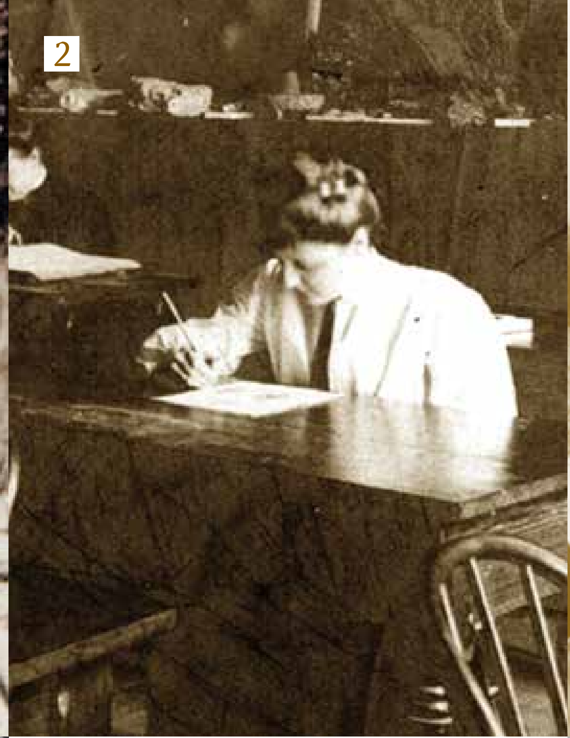
"It's not super hi-tech, wizbang. It's regular old equipment and a clever inversion," she said. "Get it cheap, get it practical, and get it ready to hand off. This is a tremendous opportunity."

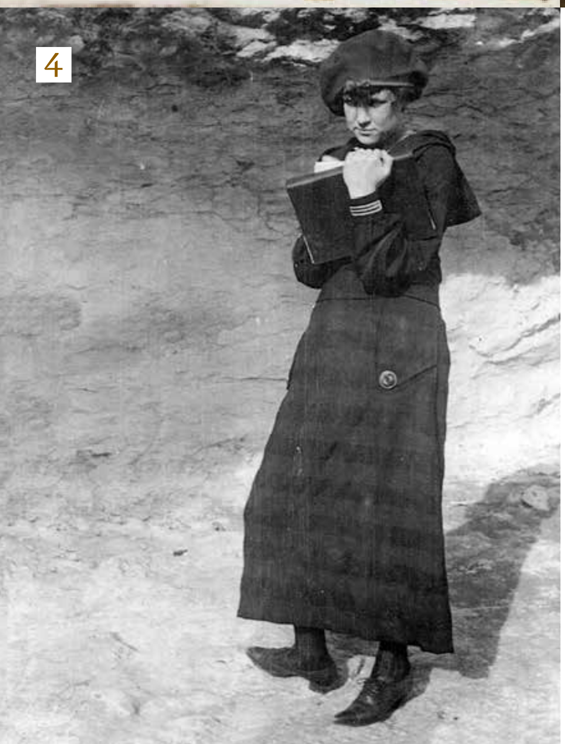
Ultimately, Tinker said Petra Nova can act as a model for others interested in reducing CO_2 emissions from coal-fired power plants.

"The combination of carbon capture and sequestration from a coal plant, enhanced oil recovery to provide additional energy and offset costs, and monitoring and verification of the CO_2, is an important step along the path towards capturing and storing CO_2 at a much larger scale," he said.

CO_2 FROM PETRA NOVA WILL BE PIPED TO THE WEST RANCH OIL FIELD WHERE IT WILL BE USED FOR ENHANCED OIL RECOVERY AND TRAPPED UNDERGROUND.







Women in UT Geology

BY MONICA KORTSHA

From independent oil finders, to pioneering micropaleontologists, to academic leaders, UT women have been making history since the beginning.

In 1966, while on geology field camp at Colorado State University, Robbie Gries spotted a boulder as big as a house from the window of the class van as it moved through the White River Plateau.

"I think that's granite over there!" Gries shouted to the other students—all men, save for the journalism-major wife of one of her classmates. Women were usually banned from the course, but Gries got in thanks to a mixture of the chairman being on sabbatical, other faculty being willing, and her offer to cook. She suspects her classmate's wife came so she wouldn't be the lone woman on the three-week course, and to help with the cooking.

Gries' classmates disputed her granite claim: "You can't have granite here! We've got Pennsylvanian-aged rocks on top, how would granite get on top of that? That's such a dumb observation!" But the professor turned the van around. The class ended up learning about glacial erratic boulders—large hunks of granite deposited by ice sheets as they carved the landscape during the last ice age. It wasn't the last time Gries' roadside observations made the professor do a U-turn.

"I loved field camp because I figured out that I really had an eye for geology in the field," said Gries, who went on to earn her Master of Science in geology at The University of Texas at Austin, and serve as the first female president of the American Association of Petroleum Geologists (AAPG). "Many times on field trips I had experiences like that, and it gave me a lot of confidence."

Gries' story of overcoming gender barriers like the field-camp ban to find success in the geosciences is one of dozens compiled in "Anomalies: Pioneering Women in Petroleum Geology," a new book about female AAPG members from the past 100 years. Gries wrote the book and released it at the 2017 AAPG annual meeting in Houston, along with a documentary, and a monumental 60-foot-long poster featuring the first 100 female members of AAPG. The roster starts in 1917, the year the AAPG was founded, and ends in 1945—a date much earlier than Gries expected when she began the research in 2013.

"I was just amazed at how deep and rich [the history] was. I was amazed at how little I knew," Gries said.

Women from UT played a notable role in AAPG's early history—nearly 15 percent of the first 100 female members of AAPG either graduated or studied at some point at UT. The Department of Geological Sciences also educated female students who made important contributions outside of petroleum geology, and provided a space for mentorship, often from male members of the school who supported female students and researchers, and female student bonding.

At the same time, the school was also a reflection of larger cultural biases and expectations. Women were banned from going on undergraduate field camp until about the 1950s; the UT chapter of the geological honors society, Sigma Gamma Epsilon, excluded women for most of its existence; and a 1960s-era bulletin about the department for high school and college students could more easily envision male geologists on other planets than women having a significant role in the field. One paragraph reads:

"A geologist's activities may take him throughout the world. He may climb mountains, wade through swamps, descend into deep mines, brave the desert and attack jungles. ... He may well be the first person to land on another planet." Women are mentioned later in the passage: "A few women are engaged in geological work. ... Successful outdoor women field geologists are rare."

Reading the biographies collected by Gries, combing through UT archives, and listening to the recollections of Jackson School alumnae and faculty, gives a nuanced view of the history of women in geosciences at UT and in geosciences research and industry over the past century. It's far from a simple story.

1. ESTHER RICHARDS IN THE FIELD NEAR MERIDIAN, MISSISSIPPI IN 1923. **2.** AN EARLY PHOTO OF A WOMAN IN A GEOLOGY CLASS AT UT. **3.** A UT GEOLOGY FOSSIL-HUNTING TRIP. HEDWIG KNIKER IS SECOND FROM THE LEFT. PROFESSOR FRANCIS WHITNEY IS MAN ON LEFT. **4.** GEOLOGY STUDENT ANN HAMILTON CIRCA 1920. **5.** GEOLOGY STUDENT DOROTHY OGDEN CARSEY. HER GRADUATE THESIS, "FORAMINIFERA OF THE CRETACEOUS OF CENTRAL TEXAS," WAS PUBLISHED IN 1926. A JACKSON SCHOOL SCHOLARSHIP FUND IS NAMED IN HER HONOR. **6.** AN EARLY PHOTO OF A WOMAN IN A GEOLOGY CLASS AT UT. **7.** IN 1935, THE DEPARTMENT ALLOWED THREE WOMEN TO ATTEND FIELD CAMP. LEFT TO RIGHT: MILDRED WINAN, KATHERINE ARCHER AND MARIE GRAMANN. **8.** WOMEN EMPLOYED AT EMPIRE OIL CO. IN THE EARLY 20TH CENTURY WERE REQUIRED TO LEARN HOW TO DRIVE AND REPAIR AUTOMOBILES SO THEY COULD TRAVEL FOR COMPANY BUSINESS.

The Start

LEFT: HEDWIG KNIKER, A PIONEERING MICROPALEONTOLOGIST AND MEMBER OF THE JACKSON SCHOOL'S HALL OF DISTINCTION. **MIDDLE:** ALVA ELLISOR'S GRADUATION PHOTO IN THE 1915 CACTUS YEARBOOK. **RIGHT:** INDEPENDENT GEOLOGIST REBA MASTERSON IN 1926 AT AN AAPG MEETING

The Department of Geology was founded in 1888 by Robert T. Hill, an orphan from Tennessee who earned his Bachelor of Science from Cornell University before coming to Texas at the invitation of the university regents. In an inaugural address to the university's faculty, he emphasized that the state benefits when both men and women receive an education based on technical, cutting-edge knowledge.

In accordance to Hill's vision, women were part of these early geology classes. One such student was Harriet "Hattie" Whitten, who enrolled in the university in 1896. Although having no experience in geosciences, she convinced the school to allow her to take an introductory geology course because of a deep calling she had for the subject.

"From my ancestors I inherited a liking—no, I shall put it stronger, a love—for the studies of geology and geography in all of their different phases," she wrote in a letter to her mentor Frederic Simonds, who replaced Hill as chairman of the department in 1890 and served as the department's sole geology instructor for the next 10 years. "I begged to be granted the privilege of taking Geology I, as an extra, solely for the love of it."

While enrolled in school, Whitten became Simonds' assistant, earning a salary for her work. In 1899 she earned her Bachelor of Science, the first woman to do so from the department. That was followed a year later by her master's degree—the first graduate degree bestowed by the department.

It's likely that Simonds' mentorship and encouragement factored into her decision to continue her studies. According to her obituary in the 1959 edition of the *Newsletter,* Whitten taught for one year as an instructor in "hard rock subjects" after earning her graduate degree, while continuing to assist Simonds in his courses on general geology, mineralogy and petrography. She also co-led field trips to Marble Falls, a group of waterfalls that has since been flooded by a dam.

"All over Texas there can be found boys and girls—men and women now—who treasure recollections of this trip with the keenest pleasure," wrote Simonds in Whitten's obituary. "For a number of years [Whitten] shared with me the responsibilities of this field day and I am glad to say we never had an accident."

Another important mentor of early women in UT geology was Francis Whitney, the department's first paleontology professor and third chairman. He advised Hedwig Kniker and Alva Ellisor, whose collaborative research on microfossils in the 1920s revolutionized how oil and gas companies explore for hydrocarbons. Kniker, who earned her master's in 1917, was the second student and second woman to earn a graduate degree from the department; Ellisor wrote her thesis, but never received a master's degree because, according to a note from Kniker in the 1960 *Newsletter,* she never met the language requirements needed for the degree.

Nevertheless, it's notable that at a time in U.S. history when women were largely seen as extensions of their fathers or husbands—not being able to vote in federal elections and often prevented from working if married—it was women who wrote the first three master's theses at the department, an endeavor rooted in independent research and discovery. Like Whitten, Knicker and Ellisor were also part of the department's faculty, each serving as instructors for a few years in the late 1910s.

But not all UT students aspired to academia. The 1900s was the "gusher age" for Texas oil, and Reba Masterson—who attended UT from 1908 to 1912—put her geology education to use as an independent geologist, showing up at new oil wells and offering her geological expertise in exchange for mineral rights.

Her father, Branch Masterson, was the director of two oil companies as well as an independent investor. She likely learned the lay of the land from him, but after graduating from the University of Colorado in 1916, she was in business for herself. Armed with a .32-caliber pistol and her best friend, Eunice Aden, a physical education instructor she met while studying at UT who often acted as a de facto bodyguard, she traveled in her Ford Model T across the South and Midwest scouting out shares in oil and gas leases. According to family legend, she lost one such lease in a poker game with Columbus Marion "Dad" Joiner, the famed Texas oilman who discovered the East Texas oil field in 1930 (the best-producing field ever discovered in the U.S.).

When she joined the AAPG in 1923, Masterson's geology experience included conducting reconnaissance work in oil fields in Kansas, Illinois, West Virginia, Pennsylvania, Indiana and Kentucky, and studying the structural geology of Oklahoma, Louisiana and Texas. According to surviving relatives, Masterson was at Damon Mound Field, a famous Texas gusher that kicked off years of oil and gas production in the area, and, by the time of her death in 1969, had mineral rights in more than 20 Texas counties and a tungsten mine in Colorado.

The Masterson legacy lives on at UT. Her great niece, Amanda Masterson, is an administrative associate at the Bureau of Economic Geology. And her great-great nephew, Wilmer Dallam Masterson IV, earned his graduate degree in geology from UT in 1981 and now works in the petroleum industry.

Gries said that when she learned about Masterson's work on well sites, she was floored. When she began her career in the oil and gas industry in the 1970s, companies didn't allow women to work on wells. And yet, here was a woman from the 1910s, showing up at well sites and parlaying her geological knowledge for some skin in the game.

"The history of women being present and competent on well sites had been completely lost and forgotten," Gries wrote in the introduction of an "Anomalies" chapter on well-site work. "A new generation of women had to 'fight for' the right to well sit—for the opportunity to have a complete exploration geologist's experience and set of responsibilities."

The 1970s started to overturn the restrictive gender norms that crystallized during the post-World War II years. But before that, there was a flourishing of women in geology, especially in the area of micropaleontology.

Riding on the heels of the 19th amendment in 1920, which granted women the right to vote, was an era of collaboration and mentorship by the women of UT geology—both students and alumnae.

> "From my ancestors I inherited a liking—no, I shall put it stronger, a love—for the studies of geology and geography in all of their different phases."
>
> *Hattie Whitten, 1896*

ELLISOR: UT CACTUS YEARBOOK. MASTERSON: AAPG ARCHIVES. PREVIOUS PAGE: 1: PATTY KELLOGG. 2: DGS ARCHIVES. 3: THE DOLPH BRISCOE CENTER FOR AMERICAN HISTORY. 4: DGS ARCHIVE. 5: DGS ARCHIVE. 6: DGS ARCHIVE. 7: KITTY MILLIKEN. 8: LIBRARY OF CONGRESS.

TOP: AN OUTING, POSSIBLY TO ENCHANTED ROCK, FROM THE DEPARTMENT ARCHIVES. BOTTOM: A 1922 MEETING OF THE SOUTHWESTERN GEOLOGICAL SOCIETY. REBA MASTERSON (MIDDLE ROW, FOURTH FROM LEFT) IS ONE OF THE SIX WOMEN IN THE PHOTO.

OUTING: DEPARTMENT OF GEOLOGICAL SCIENCES ARCHIVES. MEETING: 1964 DEPARTMENT OF GEOLOGICAL SCIENCES NEWSLETTER. KNIKER, RICHARDS AND ELLISOR: PATTY KELLOGG. ELLISOR AT MICROSCOPE: F.W. ROLSHAUSEN AND R.D. WOODS.

LEFT TO RIGHT: MICROPALEONTOLOGISTS HEDWIG KNIKER, ESTHER RICHARDS AND ALVA ELLISOR IN FRONT OF THE APARTMENT HOUSE THEY SHARED

ALVA ELLISOR AT WORK IN THE HUMBLE OIL CO. MICROPALEONTOLOGY LAB IN 1946, THE YEAR BEFORE SHE RETIRED

Foram Revolution

In 1919, E.T. Dumble, a former bureau director and then chief geologist of the Rio Bravo Oil Co., wanted to investigate the connection between macrofossils, such as shells, and Gulf Coast stratigraphy. So, he called the University of California, Berkeley Geology Department looking for a paleontology expert who could spend the summer in Houston conducting research.

"We haven't a man; Will a woman do?" asked the head of the department.

"I don't see why a woman couldn't do it better than a man," responded Dumble.

The conversation laid the groundwork for a paleontology renaissance in oil and gas, led by a close-knit group of three women: Esther Richards, a Berkeley graduate, and Hedwig Kniker and Alva Ellisor, both graduates of UT.

Richards arrived in the summer of 1919 to work for Dumble, and was hired on the following year, after she earned her master's, to conduct research on macrofossils and share her findings with a consortium of four oil companies: Rio Bravo Oil Co., Humble Oil Co., Gulf Oil Co., and the Texas Co. It didn't take long for two of the companies to hire their own paleontologists. Ellisor went to Humble, and Kniker to the Texas Co. The companies encouraged collaboration between the women. The women took it further and moved in together.

"It was a splendid arrangement," wrote Richards in her journal. "We spent most of our evening talking over the day's accomplishments and problems."

Macrofossils proved difficult to work with; the drill bit would shatter the specimens, making them hard to distinguish. Ellisor found that a type of microfossil—a single-celled protozoan called foraminifera, or forams—proved perfect for stratigraphy; the variety of types were closely correlated with different geological strata. And their microscopic size made them small enough to avoid the drill bit. When she told her boss Wallace Pratt, Humble's chief geologist, about her discovery he told her to keep it a secret. But he couldn't keep it quiet himself, leaking the news to Richard's boss, Dumble.

"When I got home, Esther Richards greeted me with the news of my discovery," recounted Ellisor in the 1962 University of Texas Bulletin. "… Of course, the news of the foraminifera were out."

But it took some work to convince the larger scientific community of the value of forams—a creature then considered too simple to display the diversity needed to map geologic strata. When Richards presented a paper authored by Dumble on forams at a 1921 meeting of the Geological Society of America, she was immediately challenged.

"I knew that it would take a while to convince people in regard to the value and usefulness of our work," wrote Richards in her journal. "So, I wasn't too surprised when Prof. Galloway [of Columbia] got up just after I had finished and said, 'Gentlemen, here is this chit of a girl right out of college, telling us that we can use Foraminifera to determine the age of formation. Gentleman, you know it can't be done."

Four years later, Ellisor, Richards and Kniker let their research do the talking. The three women co-authored a seminal paper in the 1925 AAPG bulletin titled "Subsurface Stratigraphy of the Coastal Plain of Texas And Louisiana" that used forams to unravel the region's geology.

Their early work turned forams into the gold standard for stratigraphic correlation, a position the tiny fossils maintained for decades until the invention of geophysical well logging and seismic reflection surveys.

Throughout their lives, the three women continued to make important contributions in micropaleontology. Ellisor stayed at Humble her entire career, growing the lab's personnel and prominence; Kniker started a consulting business and then founded a micropaleontology lab in Punta Arenas, Chile, for what would become the country's national oil company. She was later inducted into the Jackson School of Geosciences Hall of Distinction in 2008 for her research and philanthropic accomplishments, which include buying 39 of the 56 bells in the UT Tower's Kniker Carillon; Richards set up a consulting business, had a short stint as an instructor at the UT Department of Geology, and worked for the U.S. Geological Survey.

Both Ellisor and Kniker never married and retained their AAPG memberships throughout their lives. However, Richards' membership was brief. It ended when she married Paul Applin, a fellow geologist who retained his membership. It was common practice for the memberships of women to end upon marriage, especially if they weren't working full-time.

ANNY BUCHSTAB COURY (B.S. 1949) ON AN OFFSHORE PLATFORM WITH COLLEAGUES FROM WESTERN NATURAL GAS. SHE WAS OVERSEEING HER FIRST OFFSHORE DISCOVERY WELL.

Women on Campus

Back at the University of Texas, women were a growing part of the student body. From 1928–1942, women earned 13 percent of master's degrees, and one of the five doctoral degrees awarded during these years. Marion Isabelle Whitney, the daughter of Professor Francis Whitney, earned the doctoral degree in 1937, the first woman to earn her Ph.D. from the department.

At the undergraduate level, women had enrolled in the department in sufficient numbers by 1926 to revive a UT chapter of Chi Upsilon, a national honor society for women studying geology. Records stored at the Dolph Briscoe Center for American History indicate that the UT chapter had also been active in 1921, and counted both Alva Ellisor and Esther Richards as honorary members. Membership required being in good academic standing and "interest in geology as a science, as a work, and as a pleasure."

UT was one of four chapters active during the pre-WWII years, with the others being at the University of Oklahoma, Cornell University and the George Washington University. A society newspaper kept the chapters informed on each other's happenings, and included original contributions from members. The first issue, released in 1941, is marked with the society's coat of arms—two monkeys atop a shield marked with a moon and stars, crossed rock hammers, a trilobite, and a mineral—and prefaced by a poem, written by Beatrice Raw, a member of the George Washington University chapter, that captures the transformative experience of pondering deep time (poem on right).

Chi Upsilon provided a chance for women to get out into the field, with records showing trips to Enchanted

BUCHSTAB COURY: COURY FAMILY. CHI UPSILON: DOLPH BRISCOE CENTER FOR AMERICAN HISTORY.

THE COAT OF ARMS OF CHI UPSILON, A NATIONAL HONOR SOCIETY FOR WOMEN IN GEOLOGY ACTIVE IN THE MID-20TH CENTURY.

To a Geologist:

Alone, you sit beside the little stream,
The highway thronged with traffic, the airplane
Roaring above, cannot disturb your dream,
Nor yet the gathered clouds which threaten rain,
Lost in a prehistoric mist, you sit,
Forgetting everything entirely
Because in the gray rock your pick has split,
You found a creature of an ancient sea.
Warm waters flow around you, overhead
Strange armored fishes swim with pulsing fin;
Weird cephelopods [sic] crawl slowly past your head,
Creatures of some far away age which long has been.
You have gone backward from this age of men,
And you are an invertebrate again.

Rock and Hamilton Pool. However, it couldn't help with larger institutional barriers at UT banning women from field camp. Until the 1950s, women were not allowed on the weeks-long field geology course, save for one year in the mid-1930s when undergraduate student Marie Gramann "raised a ruckus," in Gries' words, so she could earn her Bachelor of Science—a degree that required field camp. The department allowed her and two other female geology students, Mildred Winans and Katherine Archer, to attend. It then swiftly reinstated its ban on women.

Post-War Years

World War II decreased enrollment in the department for both men and women. College-aged men were off fighting the war, while women supported the effort by taking jobs the men left vacant or by joining the military. Esther Applin (formerly Richards) commuted from Fort Worth to teach geology classes at UT when several professors went to war. Julia Gardner was a geologist who mapped tertiary beds from Maryland to Mexico, was a key mapmaker for bureau on the first geologic map of Texas, and performed biostratigraphic work for dozens of oil companies in the 1920s and '30s. During WWII she joined the U.S. Military Geology Unit and identified beaches in Japan where balloon-borne bombs were coming from by analyzing fossilized shells in the sand used to stabilize the devices.

But once the war ended, many women had to give up their positions.

The AAPG membership file exemplifies the point. Before the war, only one or two women were joining the organization each year. However, between 1939 and 1945—the war years—50 women joined the AAPG. After the war, only 14 of them remained in the industry.

Female enrollment in the Department of Geological Sciences faced similar issues. From 1943–1973, woman earned only 3 percent of master's degrees.

Kitty Milliken, a senior research scientist at the bureau, conducted research on the history of women in the geoscience department while she herself was a postdoctoral researcher in the department in the 1990s. She found that the participation of women in the department had an early peak in the 1920s through 1940s, when micropaleontology became imperative to oil companies, and then faced a 30-year lull after WWII before beginning to rise again in the mid-1970s.

"It made me realize that what seemed normal to us—to not have many women in the program—was not normal," Milliken said about her research, which was published in the *Journal of Geological Education* in 1995. "It was the result of this big disruption."

There were many reasons why women left the workforce or didn't enroll in higher education after WWII. Post-war attitudes on working women and an expectation that women would give up their jobs to men limited career opportunities, while the domestic "ideal woman" found on TV shows and advertisements became a figure that many actual women sought to embody. Gries herself said she looked up to June Cleaver, the suburban mom on the 1960s TV show "Leave it to Beaver."

"I thought, 'If I'm like June Cleaver, then what goes with that is this perfect life,'" Gries said. "It meant so much to me for people to say, 'You're such a good cook, this is so creative.' And I love the day I woke up and said, 'I don't think I need this anymore.'"

Women who did decide to pursue education or a career had to overcome or tolerate these expectations and biases, and often go along with them to advance their careers. For example, after earning

SUSAN CAGE IN GULF OIL'S HOUSTON OFFICE IN THE 1980S

her bachelor's in geology in 1950, UT alumna Susan Cage started off her career as a file clerk at Gulf Oil, and after three years of working, was promoted to a geologist. In contrast, when her husband was hired by the same company two years later, he immediately started as a geologist with a salary 60 percent higher than her own.

Cage said that, although not judged on the same standard as her male colleagues, she was able to advance (eventually holding a managerial position) because her geology skills spoke for themselves.

"When you do a good job of it, people are aware of it and that makes a difference," Cage said. "They liked you, respected you, and that was it."

However, she mentioned that whenever she joined a new office, she had to start the process of proving herself all over again.

While women were working to advance their own careers, activists in the civil rights and women's liberation movements of the 1960s and early 1970s were working for equitable treatment of minorities on a larger scale. And in 1972, when affirmative action legislation passed, it impacted the lives of individual women across the U.S, including Cage. When she retired in 1983, the value of her pension was adjusted so that it was equal to men with the same experience and contributions to the company.

"Sometimes you can change things from within, not fighting the system, just going after your own goals and achievements," Gries said. "But I sure appreciate the women who made an effort to change things for everyone."

Reclaiming Spaces

The diversity requirements legislated by affirmative action, combined with the oil shortages of the early '70s, created high demand for women geoscientists in oil and gas companies. Once hired, women started to push from the inside to open up the industry further. In "Anomalies," there are multiple accounts of women challenging company policies that banned them from going on offshore rigs, in underground mines, and on well-sites—places where some men considered women "unlucky"—and pushed against male-only petroleum social clubs and dining suites.

Around this time enrollment of women in graduate studies in the geology started to rebound. From 1974–1993, women earned 27 percent of master's degrees and 8 percent of Ph.D.s bestowed by the geology department, up significantly from the post-war years.

It was during this revival that current Jackson School Dean Sharon Mosher joined the faculty of the Department of Geological Sciences, the only woman faculty member at the time, accepting a position as an assistant professor in 1978. Within weeks, she was leading field camp and by the first semester she was advising four graduate students, and frequently leading field trips to nearby sites. She remembers a faculty luncheon where the late Bill Muehlberger, a professor in the department, asked her about a fieldtrip she just led.

"The students say you found isoclinal folds in the Llano uplift," Muehlberger said to her.

The room went quiet. Prevailing wisdom was that the Llano uplift was essentially undeformed with only open upright folds. After describing what she had found, Muehlberger exclaimed, "Well, damn, if she can't teach us something, we shouldn't have hired her!"

Mosher became the first tenured female professor in the department in 1990, chair of the department in 2007, and has been serving the school as dean since 2009.

Around the time that Mosher received tenure, in the early 1990s, Pat Dickerson, a Jackson School visiting research fellow, and Pamela Owen, the associate director of the Texas Memorial Museum, were Ph.D. students at the school. They both note that they felt included and accepted by their peers and advisors. Dickerson, who earned her Ph.D. in 1995, worked alongside Muehlberger, her advisor, training astronauts, including John Glenn, on geological formations that could be documented and studied from orbit. Owen recounts how Chris Bell, a professor in the department, sought her out to co-author a paper on a rare fossilized black-footed ferret skull.

"That was the first time that I really felt that I got excellent mentorship researching and writing a professional scientific paper," Owen said. "He was instrumental in helping me to develop those skills."

Women Today

The role and prominence of women in the Department of Geological Sciences—and the Jackson School as a whole—have only continued to grow. As of fall 2016, woman made up 42 percent of undergraduate students and 39 percent of graduate students. The school is led by a female dean and women are part of the faculty and research staff at all levels of seniority. And in spring 2017 the school's advisory council, a group of industry and academic leaders, elected its first female chair, Annell Bay, a department alumna whose own story is part of "Anomalies." Bay begins her term in fall 2017.

Following in the footsteps of Chi Upsilon, the women's honor society of the 1920s, is GLOW, the Geoscience Leadership Organization for Women. The group provides mentorship and support for women in the Jackson School of Geosciences, said President Caroline Nazworth, as well as outreach to students of all ages.

As part of her job at the Texas Memorial Museum, Owen also frequently participates in geosciences outreach in classrooms. She said that simply letting kids know that she herself is a scientist can make a big impact, recalling how one first grade class said, "She's a mom!" the moment she walked into their classroom with a trunk full of fossils.

"I think that was their way of expressing, 'That is not who we expected as the scientist,' and they were just thrilled," Owen said. "And it just thrilled me because I totally smashed any preconceived notions of who was coming to talk to them."

Gries' "Anomalies" serves a similar outreach function. The collection of stories—many written by individual women themselves—gives women a voice to tell their stories, and provides an array of role models that women didn't know they had. Most importantly, it shows that women—though not always acknowledged or appreciated—were always part of the story.

"There are no excuses anymore to not know," Gries said.

TOP: ROBBIE GRIES (THEN RICE) IN 1966 DURING FIELD CAMP AT COLORADO STATE UNIVERSITY. BOTTOM: GRIES AND HER DAUGHTER IN THE FIELD IN THE SAN JUAN SAG IN SOUTHERN COLORADO.

Anomalies: Pioneering Women in Petroleum Geology is available for purchase on Amazon.com. For a copy signed by Robbie Gries, please email mkortsha@jsg.utexas.edu.

CAGE: SUSAN CAGE. GRIES PHOTOS: ROBBIE GRIES. MILLIKEN: AAPG EXPLORER.

KITTY MILLIKEN, A SENIOR RESEARCH SCIENTIST AT THE BUREAU OF ECONOMIC GEOLOGY DRILLING NANKAI MUD ON THE CHIKYU, THE DEEP SEA SCIENTIFIC DRILLING VESSEL, WITH ARITO SAKAGUCH.

Chicxulub Revealed

ILLUSTRATION: SCIENCE PHOTO LIBRARY. CHICXULUB CRATER: JACKSON SCHOOL/GOOGLE MAPS.

Rocks record what happened to the Earth the day the dinosaurs died.

BY MONICA KORTSHA

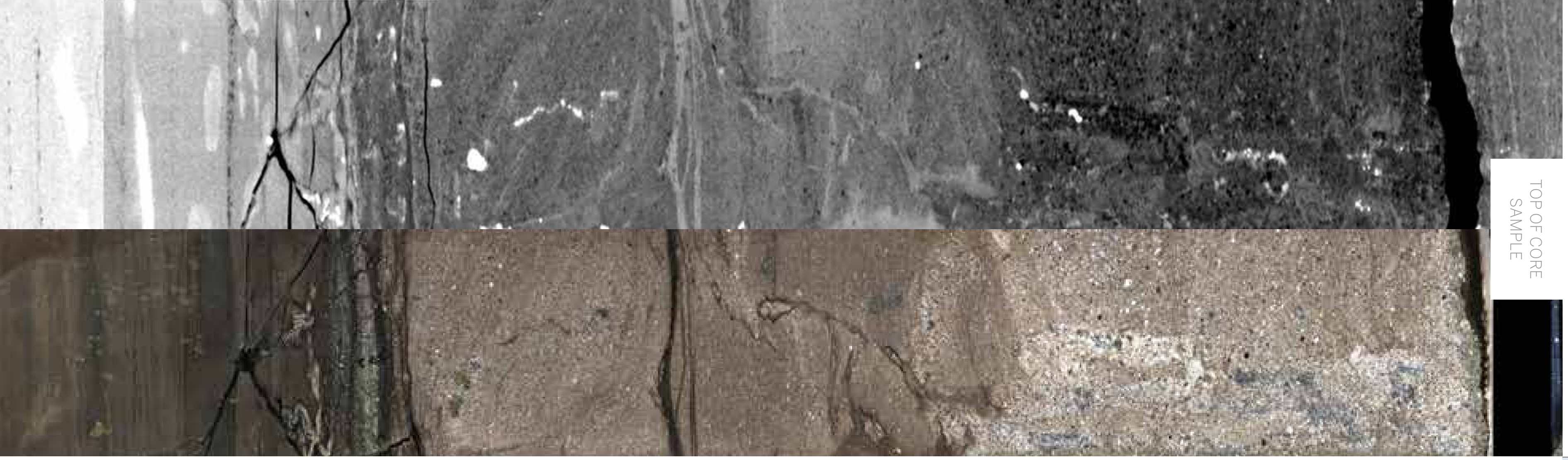
Deep beneath layers of limestone on the Yucatán Peninsula and continental shelf is Chicxulub—the best preserved large impact crater on Earth. It was created by an asteroid that slammed into the planet 66 million years ago and wiped out 75 percent of life on Earth, including all non-avian dinosaurs. In May 2016, the Jackson School of Geosciences helped lead International Ocean Discovery Program (IODP) Expedition 364, to drill into the peak ring of the Chicxulub Crater to learn more about how the Earth responded to that catastrophic impact.

Co-led by University of Texas Institute for Geophysics Research Professor Sean Gulick, the mission pulled more than 800 meters of core from the depths of the seafloor. But sheathed in plastic casing and stored in a tightly packed, refrigerated shipping container, the cores couldn't be closely examined aboard the lift-boat where they were pulled from the sea.

That changed in fall 2016 when the IODP Chicxulub research team converged in Bremen, Germany. They conducted intensive analysis on the core samples using high-resolution photos and CT-scans that revealed the position of mineral grains and fractures throughout the cores.

The rocks themselves contain the truth about the impact and the recovery that followed. Each section has a story to tell. The science will go on for years, but you can turn the page and see what some of the cores tell us about the day the dinosaurs died.

AN ARTIST'S RENDERING OF THE CHICXULUB ASTEROID STRIKING THE EARTH. THE ASTEROID WIPED OUT 75 PERCENT OF LIFE ON THE PLANET.



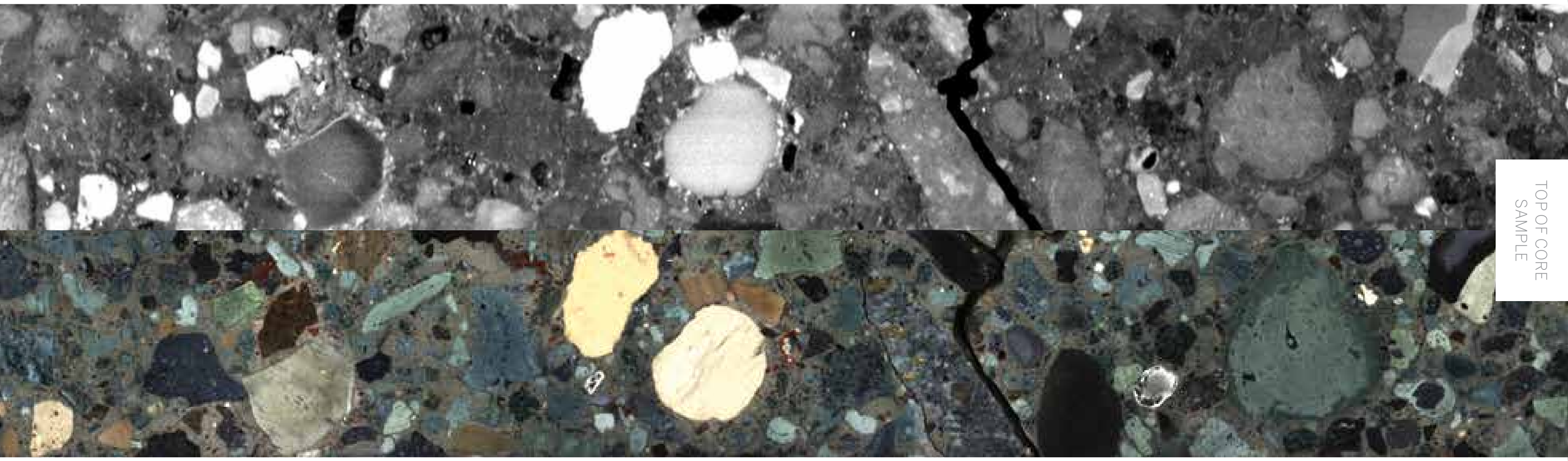
TSUNAMI DEPOSIT

CORE 40-1

COMPOSITION
Tsunami layer: sand-sized impact debris and glass. Settling layer: silt-sized particles including surviving plankton.

RECOVERY DEPTH
618–619 meters

A major result of the Chicxulub impact was a monstrous tsunami that reached up to modern day Illinois. When the water rushed back into the crater it brought untold amounts of impact debris with it. This core shows debris from the tsunami (lighter in the picture and darker in the CT-scan), including cross-bedding from the tsunami waves, and the transition to settled particles on the seafloor. Note the white particles of melt rock flecking the tsunami in the CT-scan. The material in the settling layer includes the particles and surviving plankton that filtered down from the water column. The debris and glass from the tsunami were deposited the first day after the asteroid hit, but scientists are still unclear on how long it took the debris in the settling layer to filter down. Theories range from a matter of weeks to tens of thousands of years. It is a hot topic of current research.



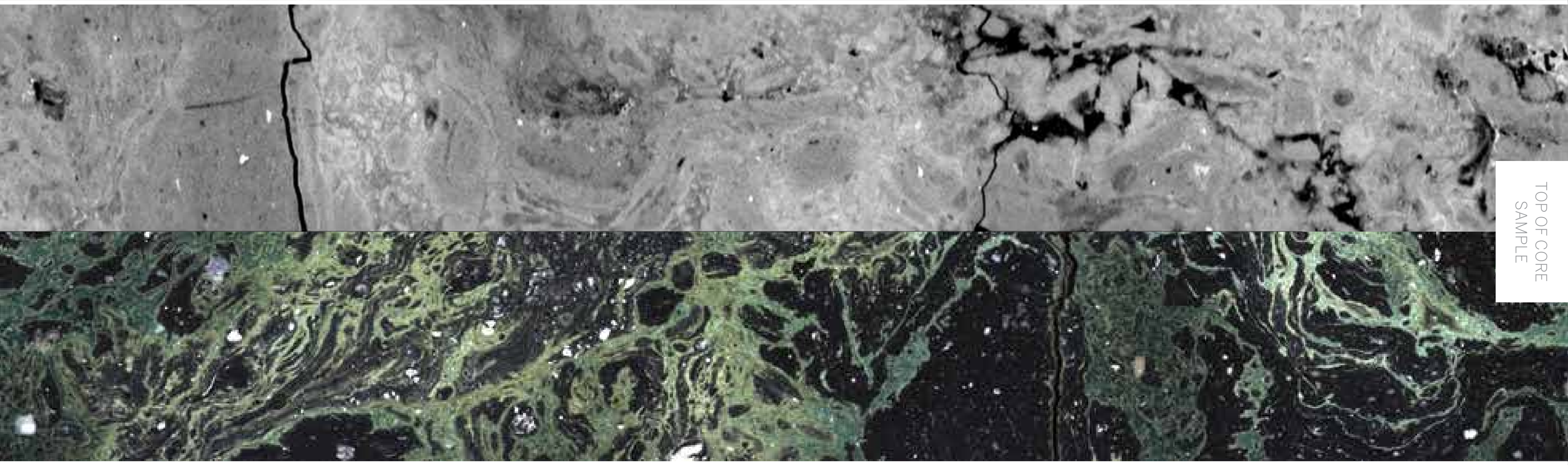
END OF AN AGE

CORE 76-1

COMPOSITION
Suevite breccia

RECOVERY DEPTH
703–704 meters

The Chicxulub asteroid impact marks the end of the Cretaceous Period and the beginning of the Paleogene Period. When the asteroid hit, shallower rocks were vaporized or shattered. A small amount of that rock was left behind in a layer of shattered suevite depicted in this core. These include chunks of pulverized sandstone, limestone and granite that are now mixed and jumbled together. Most of the chunks are angular, which means that they were deposited very rapidly after the impact—probably within minutes—and therefore didn't have time to roll around and soften their edges.



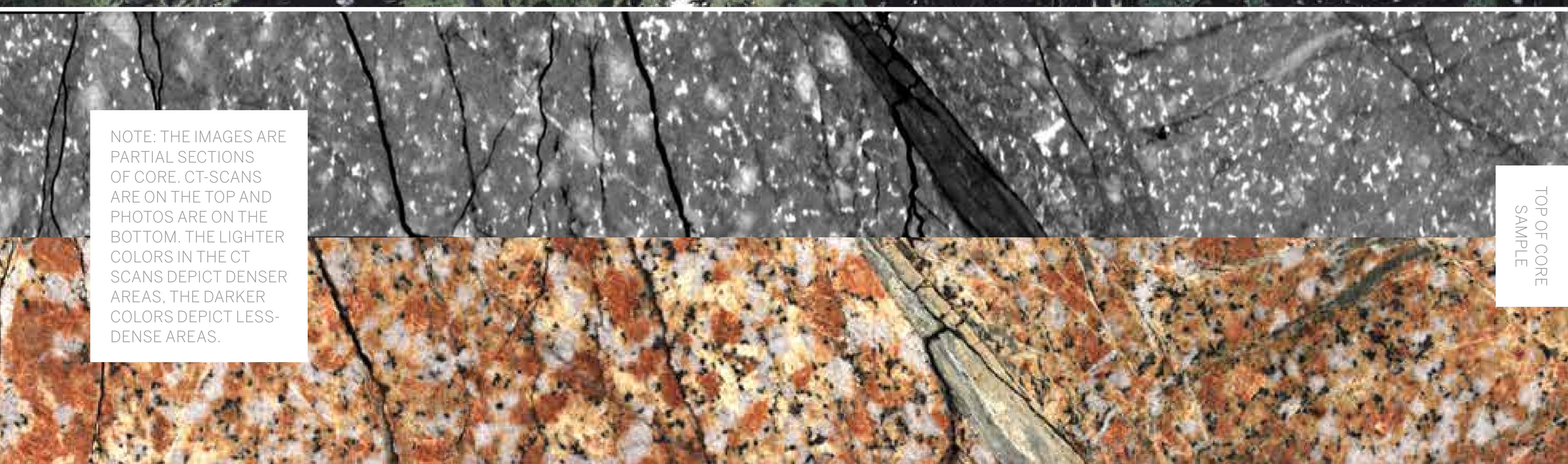
UNDER PRESSURE

CORE 92-2

COMPOSITION
Impact melt rock

RECOVERY DEPTH
738–739 meters

The Chicxulub impact generated 9.6 million PSI of pressure—a force roughly equivalent to 10 billion of the atomic bombs detonated on Hiroshima in World War II. The immense pressure and heat melted the underlying granite and some of the overlying limestone (the rest was vaporized), creating swirls of black silica-rich melt rock and green carbonate melt rock in a pattern known as a schlieren texture. Roughly 10 to 15 meters of melt rock is found capping the peak ring where the scientists drilled. A sheet of melt rock almost 2 miles thick is at the center of the crater.



NOTE: THE IMAGES ARE PARTIAL SECTIONS OF CORE. CT-SCANS ARE ON THE TOP AND PHOTOS ARE ON THE BOTTOM. THE LIGHTER COLORS IN THE CT SCANS DEPICT DENSER AREAS, THE DARKER COLORS DEPICT LESS-DENSE AREAS.

PEAK RING

CORE 197-2

COMPOSITION
Granite

RECOVERY DEPTH
1018-1019 meters

When the Chicxulub asteroid hit, the Earth rebounded, bringing pink granite from 6 miles below the surface. The force of the impact made the surrounding rock temporarily behave like a slow-moving liquid, with deep granite rocks moving upwards and collapsing outwards to form a ring of peaks surrounding the center of the crater. The dark color of the fault zone in the CT-scan shows that the zone was porous and likely a pathway for fluids. The porosity makes it an intriguing place for scientists to look for the recovery of life in the form of microbes in the peak ring.

Honoring a Mentor

Blended gift pays off now and later

BY GEORGIA SANDERS

Ken Neavel's attraction to geology started at an early age. Growing up as the son of one of ExxonMobil's preeminent coal scientists, he knew that a degree in geoscience could lead to an intriguing career. Additionally, Boy Scout adventures to Big Bend National Park fostered dreams of a career in the outdoors, specifically, in the mountains. These dreams were, in part, fulfilled. Now, he is helping provide others the opportunity to follow their passion by establishing an annual scholarship at the Jackson School of Geosciences to help support undergraduate students as they begin their college education.

Neavel named the scholarship in honor of his friend and mentor, Dean Sharon Mosher. He began his geological studies at UT in 1978—the same year that Mosher joined UT's Department of Geological Sciences as an assistant professor. Mosher taught structural geology to Neavel and soon after hired him as a student assistant. She later made a critical introduction to Professor Nicholas Rast at the University of Kentucky, who Neavel studied under while achieving his master's degree.

"Without the encouragement of Dean Mosher and the experiences that I had working with her as a student, I am not sure where my path may have taken me," Neavel said.

Neavel is an independent geoscientist in the oil and gas industry. He volunteers regularly in public 5th grade classrooms, teaching earth and planetary sciences to students who might not otherwise be exposed to these subjects. He has developed a curriculum for his volunteer efforts which he plans to employ through a nonprofit organization to help provide advanced earth and planetary sciences to public schools.

"There is no greater feeling than seeing a young person getting excited about earth and planetary sciences," Neavel said.

Neavel said that he felt it was a particularly important time for him to support the Jackson School because state funding is steadily declining, prompting universities to rely more and more on private funding. He said that it just made sense to name the scholarship after someone who has influenced his life and the lives of so many other students. He welcomes others who have been influenced by Dean Mosher's teaching and leadership to contribute to this fund that will support young geoscientists. In addition to establishing the annual scholarship, Neavel provided a very generous planned gift in his estate to continue supporting the scholarship fund in perpetuity.

The scholarship prioritizes freshmen and sophomores in good academic standing who are first-generation college students or those from historically underrepresented groups, which is a primary goal of the Jackson School's outreach efforts.

A geosciences education changed Neavel's life. He hopes that the Sharon Mosher Scholarship Fund—as well as the scholarships that he established at the University of Kentucky and Purdue University, where he earned his master's and doctoral degrees, respectively—will help students realize their full potential, and experience the transformative power of a geosciences education and the career paths that it paves.

"I am humbled and honored by Ken's decision to establish a scholarship in my name," said Dean Sharon Mosher. "His generous gift will play a direct role in educating the geoscientists of the future. Nothing could be more important. I am thankful for Ken's support."

To contribute to the Sharon Mosher Scholarship Fund or for more information about how to recognize a mentor or friend with a blended fund or estate gift, please contact Belle German, Executive Director for Development and Alumni Relations at 512-471-1993 or bgerman@jsg.utexas.edu.

KEN NEAVEL IS RECOGNIZED BY DEAN SHARON MOSHER AS A NEW MEMBER OF THE KATIE SOCIETY.

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Texas Leadership Society

The Texas Leadership Society is composed of a distinguished group of friends and alumni who have included The University of Texas at Austin in their estate plans. Estate gifts support faculty and research, provide scholarships and graduate fellowships, and keep libraries, laboratories and facilities up to date. We would like to recognize those members who have designated the Jackson School as their beneficiary.

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Flawn Circle of Excellence

The Flawn Circle of Excellence recognizes individuals who have given cumulative gifts of $1 million or more. Established in 2014, this society is named after Peter T. Flawn, former president of The University of Texas at Austin, professor emeritus at the Jackson School of Geosciences and lifetime member of the Geology Foundation Advisory Council.

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Katie Society

The Katie Society recognizes individuals who have given cumulative gifts of $500,000 or more. It was established in 2014 in fond remembrance of Katherine G. "Katie" Jackson, beloved wife of the late John A. Jackson. Katie was a great philanthropist and Jack's partner in all things, including the creation and naming of the Jackson School of Geosciences.

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L.T. Barrow Founders Circle

The L.T. Barrow Founders Circle recognizes friends and alumni who have given cumulative gifts of $100,000 and above. Named after Leonidas T. and Laura T. Barrow, creators of the first Geology Foundation endowment in 1953, Barrow Founders Circle members honor the legacy of these two guiding spirits of geoscience education at The University of Texas at Austin.

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The Hill Society honors friends and alumni who have given $10,000 or more over their lifetime in support of the Jackson School. This society is named after Robert T. Hill, the first professor and chair of the Department of Geology and a founding member of the UT Mineral Survey, which would later become the Bureau of Economic Geology.

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ALUMNI NOTES

1940s

Howard R. Lowe (B.S. '48) shares, "Old age has finally caught up. We are moving to Ft. Worth to a retirement facility to be near our daughter. We are in good shape, but my 94 years has slowed me down a bit—in fact, a helluva lot. I am continuing to work with a group of 35 retired NASA scientists and engineers on climate change. I also recently published a Kindle book on Amazon, Beyond Our Control: Debunking Manmade Global Warming. I have lunch occasionally with Dan Smith, and talk to Tom Burke frequently by phone. Time marches on. I have a photo of the Geology 660 Field Course crowd in summer 1948. As soon as I locate it, I'll send it to the Jackson School."

1950s

Raymond "Pat" Anderson (B.S. '56) writes, "Joanne and I still enjoy frequent trips to Colorado Rockies. I still enjoy my bird dogs and quail lsc. I can't believe we're producing frac., shale Eagleford, etc. Hook 'em horns!"

Philip Braithwaite (M.A. '58) says, "Barbara and I continue to enjoy retirement together in Dallas. This year will be our 59-year wedding anniversary. I have been retired for 19 years and did a fair amount of consulting and traveling in the first 10 years. I try to keep up with geological developments through AAPG, DGS and UT Dallas seminars."

Robert E. Doyle (B.S. '55, M.S. '57) shares, "I am still in the business of completing and patenting inventions. These include oil spill containment systems, marine current power generation and wildfire control. Just received acceptance of patent No. 9745951 from the USPTO. This renewable energy power generating system will be available for public review through the internet beginning August 29, 2017. The system is called SEAVOLT, a large, mobile subsea turbine/generator that will create electricity from the Florida Straits, arguably the fastest ocean current body in the world. This has never been done before. This device is robotic in that it is self-propelled, self-anchoring and is maintained in a submerged position below large ocean vessels through remote control by onshore personnel. SEAVOLT is environmentally friendly since it contains both fish deterrent systems and water intake conduits covered by protective grids. Each system is designed to generate power for some 60,000 households. I had the pleasure of meeting UT President Greg Fenves again at his excellent presentation on November 1, 2016, at the Houston Country Club. The turnout was wonderful, and the attendees were spectacular. Feel free to call me should you wish to discuss the patent or just to catch up on earlier times: 713-334-4464." Bob can also be reached at red.aeig@att.net.

Jimmie Russell (B.S. '52, M.A. '54) reports, "THE GOOD, THE BAD, THE UGLY: The GOOD, maybe, is that I seem to have become a Father Figure to the Fraternity that put up with me when I was a student at UT, during a time when you did not have to put some geography after "The University of Texas." The "Good-Ole-Days" - the OLD is NOW!! The BAD, is the baggage that comes free(?) with the title "Senior Citizen"—Senior to The UGLY, Look in the mirror, DUDE!!! Most of the time this year, I was at home doing very little. I don't do NOTHING, and it takes me all-day to NOT do it! Otherwise, a major percentage of my time is visiting many different members, and facilities, of the medical profession. One highlight was the visit I had with the young lady that was a teacher when I worked with/ for her as an assistant teacher, working with Special Needs Middle and High School students in Round Rock, Texas. She was home for a visit from working with very young children in Rwanda, Africa. Other highlights were spending some time, in various ways, with friends of days of yore. The very best of all during this, was/is my dearest, my love, my wife, Rita. Remember dear hearts, there is always something wonderful, that hopefully will come to pass. With luck, the powers that be, will get it figured out WHICH TOILET WE NEED TO GO TO!!! Contact me when you can, keep the faith, & HOOK 'EM!"

Floyd F. Sabins (B.S. '52) says, "The 3rd Edition of my book "Remote Sensing - Principles and Interpretation" was published in 1997 and has been reprinted numerous times. There have been major advancements in the past 20 years. The publisher, Waveland Press, has requested a 4th Ed, which I am writing with a co-author, Jim Ellis, who is a long-term colleague. Jim brings a wealth of experience in non-geologic applications, which are essential in a modern textbook. My company, Remote Sensing Enterprises, Inc., has completed a series of projects for the U.S. DOD in a SE Asia country. Among other results, we processed and interpreted satellite images to identify a major new coal basin. Father Time has slowed me down, and I have foregone my annual fly-fishing trips to Alaska, Mexico and western U.S. I do have good memories of great fish that were landed, admired, photographed and released to fight another day."

Leslie P. White (B.S. '56) says, "Dianne and I continue on in SW Austin. The grandkids are close by and they are a great pleasure. We are so proud of JSG, and we enjoy staying in touch. I look forward to reading the *Newsletter* cover-to-cover every year. Your effort in making this publication so good is greatly appreciated."

1960s

Russell S. Harmon (B.A. '69) shares, "I completed my 5½-year appointment as Director of the

International Research Office of the USACE Engineer Research & Development Center at the end of May and have left life in London for retirement back in NC. Life should continue to be busy though, with a continuing appointment as Adjunct Associate Professor in the Department of Marine, Earth & Atmospheric Sciences at North Carolina State University and much unpublished stable isotope and laser spectroscopy research still to be written up for publication. But, Karen and I will begin by celebrating our retirements with a September excursion to Botswana, Zimbabwe and South Africa."

J. Phil Jones (B.S. '64) writes, "2017 has thus far been a year of remembrance. On April 30, I made it to 80 years. On June 2, my wife and I, with children and grandchildren, celebrated our 50th wedding anniversary. We traveled to Branson and enjoyed a week of entertainment and scenery in the Ozarks. The scenery was as beautiful as ever with lots of wild flowers and geology to explore. The area had experienced massive rains earlier and the lakes were still 20' or so above the usual level. In the event you have opportunity, don't miss the College of the Ozarks and the great food and museums on the campus. Having retired in June of 2012, we have made multiple trips to upstate NY (Richfield Springs and Cooperstown) with lots of history and geology to be enjoyed. We have since assisted our daughter, son-in-law, and 4 grandchildren in a big move from NY to OK. They now reside in Edmond, OK as does our son, daughter-in-law and their 2 children. All within a stone throw from where we abide. While we greatly enjoyed the scenery of Upstate NY, we no longer have the burden of 1,500-mile trips to and from, and we now enjoy lesser fuel consumption and cost. Just returned from wonderful trip visiting both Glacier and Yellowstone National Parks with brother, son, grandson, son-in-law and son. Wow, what a wonderful way to enjoy God's creation and to see it sustain and increase it's beauty. The sight seeing, hiking and fishing are beyond comparison. I urge anyone not having visited these awesome places to include them in any bucket list. Most of our crowd spent 4 days in Glacier and 4 days in Yellowstone. I had two extra days in Yellowstone with my brother fishing. He has caught nearly every fish in the Gallatin and Madison Rivers and released every one. He ties flys, builds rods and teaches kid at camp fly fishing. We enjoyed the food of Bozeman and the wonderful Flathead Cherries. What a way to escape 100+ temps in OK and the cool summer mornings of Montana! Hoping this finds all of you in good health. You can reach me at philj1@cox.net."

Jereld E. McQueen (B.S. '61, M.A. '63) reports, "Continuing to pursue investment opportunities. I am always amazed by and proud of the Jackson School of Geosciences' excellent accomplishments."

William Allen Monroe (B.S. '63) shares, "My wife Debbie and I continue to travel extensively with a cruise through the Panama Canal, trips to Kauai and Tahiti early in the year, and a planned trip to The Balkans and the Danube River coming up at the end of August. We continue to be active in the AAPG Foundation Trustee Associates group with a meeting planned in Maine in September. I assist in scoring requests for grants through the L. Austin Weeks student grant program so it gives me a connection to the cost of education worldwide. Always enjoy getting back to Austin for the Jackson School functions and seeing old friends."

Tom S. Patty (M.A. '68) writes, "Still drilling in sand and gravel deposits as well as crushed stone for clients in Central Texas. Continued tending to wife JoAnn's needs for 57 years and able to be with the kids and eight grandkids. Son John still working with major contractor in Austin, one daugther moving into a new home in Williamson County, another remodeling historical home on ranch in Hamilton County."

Peter D. Rowley (Ph.D. '68) says, "Had a busy year in my consulting business. But more fun was for free, on our Markagunt gravity slide, the world's largest terrestrial slide, over 2,000 square miles in extent where the southern side of the Marysvale volcanic field failed about 21 Ma. Lots of mapping yet to do here in Central Utah with colleagues (Utah Geological Survey, Kent State University)."

Rubin Amos Schultz, Jr. (B.S. '61) shares, "Still enjoying retirement and some traveling. Spent some time in Branson, MOo last fall. Also enjoying grandkids and two of them are expecting in August and October. So I will soon be a Great grandfather!! Where did all the years go? Anyway, it's nice to see family grow. Still enjoy visiting UT and seeing places I once called home. The wife and I are planning our annual Branson, MO trip in November. Would love to see any of my old classmates."

William Feathergail Wilson (B.S. '60, M.A. '62) reports, "Still working as a geologist at the age of 82. Working as a petroleum and a groundwater geologist in West, Central and South Texas. Published two historical Texas novels last year, Nueces and La Tierra, with Amazon. Working on a third entitled The Golden Lane. All three are based on my own experiences in Texas and Mexico as a rancher and geologist."

William C. Young (B.A. '61) shares, "I'm still able to travel and enjoy life. Glaucoma is hampering my vision, but still have one good eye."

1970s

Patrick Abbott (Ph.D. '73) writes, "My life is still geology. Leading Smithsonian Journeys to all continents; 10th edition of textbook out; doing TV news; writing "legacy" books. Work is more fun than play."

Janie Bell (B.S. '78) says, "Living half-time in Dallas and half-time in Nashville. Come visit me class of '78!"

C. Elmo Brown (B.A. '76) shares, "I am still working in Denver at The Discovery Group, a small consulting firm known worldwide for its geology and petrophysical expertise. Kathy and I are still traveling around the globe, this year to Vietnam, Cambodia and Thailand (and Billings, MT, Casper, WY, Houston and Austin for geoscience meetings)."

Royce P. Carr (B.S. '76) reports, "I am still working in the Permian Basin and reside in Mount Pleasant, Texas. My wife, Deborah and I went to Italy this year with the Flying Longhorns. What a beautiful place! I now understand why one of my professors, Dr. Robert Folk, spent as much time as he could there."

Frank G. Cornish (M.A. '75) writes, "In October 2016, the company I explored for in Corpus Christi, SV Energy became Texegy, an acquisition company and was no longer in the conventional exploration business. I've been consulting for Suemaur Exploration, a conventional exploration company since then and nursing old prospects. Hurd Enterprises, San Antonio will drill one of them this August 2017. This summer at NAPE 2017 we will see how the industry pulse is, if alive at all. Our local SIPES group hosted the 2017 national convention in Vail, Co. I presented "Hydrocarbon Traps Associated with Upper Wilcox Canyons, Middle Texas Gulf Coast" which had been a poster session at the GCAGS 2016 convention. Along the way to and from Vail, I had selected excellent sights for geological and picturesque photos for my photography website, FrankGCornishPhotography.smugmug.com. I've put the geological pics on facebook, Frank G Cornish Photography. Let me know what you think, it's ever expanding. They can be used in education with permission, so point teachers there, and I'll allow classroom usage at their request. Hope you see you all at UT Jackson School alum events wherever they might be."

Patricia Wood Dickerson (B.A. '70, Ph.D. '95) writes, "I'm in countdown mode as I write this – anticipating explorations by plane, train, boat, bus and boots in Iceland, then in Machu Picchu and the Galapagos (instructing once again for Smithsonian groups). Eager to pursue my evolving hypothesis on Andean archaeological stone work. Midway between the Equator and Husavik (near the Arctic Circle) is the Big Bend, scene of fine late fall field forays with stimulating colleagues and students. Returned to the Solitario and the oldest rocks exposed there – still investigating the ancient bones of Laurentia. Enjoyed the culminating session of paleomagnetic sampling (Sul Ross University master's study) along Tascotal Mesa fault zone on Alazan Ranch, which was home during my dissertation field research. Many a story was told, refined over time (like the raconteurs!). Here at UT, the senior thesis project on age and origin of deeply buried Proterozoic to Cambrian metamorphic rocks in SW Texas is complete. Both students ably presented their findings at a regional GSA meeting, and our manuscript re the Precambrian study is now taking shape. GeoRef work with favorite folks at AGI and UT continues to be educational and enjoyable. And the musical accompaniment to all this flows from volunteering for Austin Classical Guitar and dancing Argentine tango and blues."

Abelardo Garza-Hernandez (B.S. '75) shares, "I continue living in Parral, Chihuahua, Mexico, since 1976, married to Carolina, with four children and 8 grandchildren, running my own mining consulting business, providing services to several major and junior mining and mineral exploration companies, as well as being involved in other mining ventures in México." He can be reached at abgarza@grupogamo.com.

S. Lance Jackson (B.S. '79) writes, "Still enjoying the work at ExxonMobil, everything from unconventionals to current day deep water. Crossed the 38-year mark in the industry on June 4th, and plan to keep going at for a while longer! I never seem to get tired of searching for oil and gas. On a personal note, the kids are all grown and we now have we have five grandchildren. Time has just flown by."

Robert Alan Levich (M.A. '73) currently resides in Las Vegas, Nevada and can be reached at cpgeologist@gmail.com.

John W. Preston (B.S. '70) shares, "I retired end of last year and started this year on a retainer for the same company. Still having fun looking for grease in all the wrong places."

Stephen L. Shaw (B.S. '71, M.A. '74) reports, "With Firstview Resources still working oil & gas and water projects, but now from San Angelo area instead of Midland. I helped Dr. Joe Satterfield lead Angelo State University students on a field trip to Balcones Research Center campus and tour the Bureau of Economic Geology. We were warmly greeted and given a very full tour and three technical presentations in our 5 hour visit." Steve can be reached at sshaw99@yahoo.com.

Bren Sidereas (B.S. '74) says, "I'm now in my third year of retirement and getting pretty good at keeping up a minimal amount of activity to keep somewhat fit but not stay completely bored. I'm enjoying my 4 grandkids, ages 2-6, all of whom live very near us in the Lake Ray Hubbard area east of Dallas. We've been to the Grand Canyon with my son's family (2 grandsons), and Florida's Panhandle beaches with my daughter's family (2 granddaughters) over the last couple of years. Last year my wife and I made it to Cape Town, South Africa for a very memorable and wonderful experience. Just by freak chance when we visited the Mount Rochelle Winery in Franschhoek, my wife exchanged pleasantries with Sir Richard Branson, the winery's owner (huge highlight picture). Obama doesn't have anything on her! About the only geology I do now is picking up a few clams and snails out of the Glen Rose

Formation when spending a long weekend in the Austin area. The ever beautiful Hill Country of course was where I took my first field geology course in the summer of 1972. Fun fossil hunting, great BBQ & beer and fall Longhorn football—some things don't change too much."

Raymond P. Sorenson (M.A. '75) currently lives in Tulsa, Oklahoma and can be reached at sorensonrk@sbcglobal.net.

1980s

Fred (B.S. '83) and Teresa Harkrader Becker (B.S. '82) share, "We are enjoying retirement here in beautiful Marble Falls. We recently travelled to the Amazon and to Iceland with the Flying Longhorns and are active in our local Highland Lakes Chapter of the Texas Exes. Would love to hear from any of our classmates!"

Julie Bonner (B.S. '83) writes, "Retired by choice last year and enjoying it! Hit my 50th country this summer and pondering what I want to be when I grow up!"

Richard Carroll (B.S. '80) reports, "I am still gainfully employed in the oil and gas industry and working the greater Permian Basin for Caza Petroleum. I can be reached at rcarroll@cazapetro.com."

Charles Goebel (B.S. '80) says, "Hanging in there, oil & gas wise. Good news is all three heirs are now UT Austin graduates!"

Gary George Gray (Ph.D. '85) writes, "I retired from ExxonMobil research in 2013. Have been teaching and advising students at Rice U part time since. The Mexico consulting business has finally picked up, and so I'm getting to do some nice fieldwork with Jim Pindell's group. Two grandkids in Providence, Rhode Island, and kids on both coasts, so visiting keeps our carbon footprint fairly high! Still located in Bellaire, Texas, so stop by and check out my Bonneville salt flats race car … "

John Heberling (B.S. '85) shares, "I have not looked much at comments in recent years. Seemed very distant. But then I received a message from a fellow student back in January. Her messaged changed the course of my life. A line from the movie Appaloosa. 'Life has a way of making the foreseeable that which never happens, and the unforeseeable, that which your life becomes.' So true. Life is good! Hope everyone is well." John can be reached at johnheberling92@gmail.com.

Christoph Heubeck (M.A. '88) reports, "I am busy as a professor at the University of Jena in central Germany. My field is General and Historical Geology, so my interests range widely. In the past few years, I have become somewhat of an expert on interpreting extremely old rocks, especially those in the Barberton Greenstone Belt of South Africa and Swaziland."

Jim Immitt (M.A. '81) shares, "Pam and I are in Spring, Texas and our children (Adrian and Angela) are enjoying living in Colorado. After a fun and challenging stint generating deep water prospects in the subsalt Miocene of the Gulf of Mexico for ENI, I got caught in the downturn and am in transition again. The twists and turns continue in a career that has included both exploration geoscience and corporate finance. Hello to my fellow Longhorns, and onto the next chapter!" Jim can be reached at jim.immitt@yahoo.com.

Charles Graham Johnson (B.S. '83) writes, "Three out of college, one a senior at Portland State and also a seventh grader. Ellen and I stay busy keeping up with all of the activities. It hardly seems like 35 years since my UT days. My company just made a major acquisition into the legacy Texas Woodbine at Cayuga Field. Hopefully we can bring our Frio/Yegua operational skills to bear on the Cretaceous. Strong water drives, high permeability and low oil gravity make for high hopes. Maybe oil can get back above $50. I never thought I would be saying that 20 years ago. Something tells me our oil patch won't look the same 20 years from now."

Richard Alan Kolb (M.A. '81) says, "I continue to work as a consulting geologist for a small firm in the suburbs of Raleigh, North Carolina. I am in my seventh year on the North Carolina Board for the Licensing of Geologists, and in my third year as chair. We recently added a continuing education requirement, 12 hours a year, to maintain one's license. The many comments from the pubic to the proposed rules change were interesting, with the older licensees often against the requirement and the younger licensees overwhelmingly in favor.
I attended the Council of Examiners meeting of the Association of State Boards of Geology (ASBOG) in Flagstaff in April, and stopped in Austin for a few days on my way there to visit my kids. Daughter Jennifer will begin her second year of school at the UT School of Social Work this fall, where she's working on her M.S. degree. Son Travis recently began work at GeoSearch after graduating from Texas State in 2016 with a degree in geography. Austin and Raleigh are quite similar, both being the state capitals and home to several universities, many tech firms, and numerous microbreweries (to the delight of all geologists). I am active in the Carolinas Chapter of the Association of Environmental & Engineering Geologists, and am one of the planners for our second vapor intrusion conference, this time in Charlotte, on October 5 and 6, 2017, with speakers from all over the U.S. We had over 200 attend our first conference in Raleigh in 2014. VI is becoming more and more of an issue in contamination assessments and real estate transactions."

Bruno Maldonado (B.S. '82) writes, "Hello fellow Longhorns! I am still involved with the Jackson School of Geoscience's FANs Board and attending alumni events. It sure is great to see those of you who have attended. I hope to see more of you at future events, so that we can catch up with each other and see how we have aged. I have lots of gray hair and a few wrinkles. I guess living in NW Houston with high humidity has helped keep the number of wrinkles down. As for work, I am still doing a bit of geoscience consulting, mainly overseas in China and Africa. I am hoping to stay closer to home and attempting to get some gigs in Latin America. Best of luck to all and hope to see you at the SEG conference here in Houston in September … Hook 'em!" Bruno can be reached at bmaldon444@utexas.edu.

Jason Nicholas Moore (B.S. '84) says, "I now live in a town about an hour south of Austin called Seguin. I have had three books on Soviet Second World War aircraft published in the last two years, and I am finishing up my fifth (the fourth, a book on post-war Soviet strategic bombers should be out this year). I am now a full-time author, with contracts for books up to 2022. That should keep me busy!"

Marian Morris (B.S. '81) reports, "I have been working for Statoil since 1996 and still love geophysics! Currently I live north of the Arctic Circle in Harstad, Norway. Please get in touch if you are in town :-) There is wonderful hiking, riding, skiing and scuba diving here, never a dull moment! You can email me at marmor@online.no."

James Mark Null (B.S. '87) shares, "I currently serve as the Director (Hydrologist-in-Charge) of the National Oceanic and Atmospheric Administration's (NOAA) West Gulf River Forecast Center in Fort Worth, one of 13 such river forecast centers across the nation. I am responsible for ensuring that citizens of Texas, New Mexico, and portions of Colorado and Louisiana, receive timely and accurate river and flood forecast information for the protection of life and property. I have served in numerous leadership positions within the Federal government including the U.S Geological Survey, the U.S. Army Corps of Engineers, and the U.S. Naval Oceanographic Office. Prior to my civilian career, I served as a U.S. Navy Meteorologic and Oceanographic officer retiring at the rank of Commander. Also, I actively involved with the TEXAS EXES and have been recently selected as the President of the Fort Worth Chapter! We have a great group here in Cow Town with many networking and scholarship fund raising activities for our next generation of Longhorns!"

Jerry Schwarzbach (B.A. '83) says, "Enjoying life in Tyler. My daughter graduates UT in '18. Seems like yesterday I was there. Great memories! Picture from dig for Royal Tyrrell Museum of Paleontology in Alberta, Canada summer 1984 with fellow Longhorn Clayton Wilson. Working, flying, raising cattle."

Scott Simmons (B.S. '87) reports, "I am still having a great time as the chief standards nerd for the Open Geospatial Consortium (OGC). The work keeps me engaged with plenty of geologists and some of my old pals from the oil and gas industry (and even one of my favorite members of OGC: UT!). Life remains pretty perfect up here in Fort Collins - enjoying the great outdoors and abundant craft beer. I continue to drive my kids nuts by stopping at roadcuts and providing lectures on why the Triassic rocks are so red."

Margaret Sipple Srinivasan (B.S. '82) writes, "I'm in my 17th year at the Jet Propulsion Lab in California and my hats include Manager of the JPL Center for Climate Sciences, and Deputy Program Applications Lead for the SWOT, Sentinel-6 and Jason-3 satellite missions. In my spare time (!), I'm getting an M.S. from Johns Hopkins in Environmental Science and Policy. Good times! Cheers to all of my former UT colleagues!"

Stephen W. Speer (M.A. '83) says, "Life is good. Still kicking and enjoying life with Therese in SC. What could be finer? Cheers to all my fellow UT grad school sojourners, may your life still be filled with joy and wonders … and may your aches and pains be tolerable."

George Brian Sutherland (B.S. '84) currently resides in The Woodlands, Texas and is President of Kinetic Upstream Technologies, LLC. He can be reached at gbsutherland@utexas.edu.

Bruce Swartz (B.S. '82) shares, "Sold all my production in late '16. Starting over with some consulting in both exploration and production. In a few years I hope to quit chasing rigs and just slide logs." Bruce can be reached at bruce.swartzoil@gmail.com.

Mark C. Walker (B.A. '81) is now with national law firm Dickinson Wright PLLC, and continues to practice from the El Paso office, for which he acts as managing partner. Among others, Mark is delighted that life and law partner Kathleen Campbell Walker (J.D.

’85, former Masked Rider, Rodeo Queen and distinguished alumna of Texas Tech) is also a member of Dickinson Wright. Earlier this year Mark worked with Arkansas Representative Warwick Sabin to pass Arkansas H.B. 1666, an important bill that requires all incoming college students in Arkansas to receive orientation on mental health awareness and suicide prevention. H.B. 1666 follows and expands on Texas S.B. 1624, which Mark helped draft and pass in 2015 in honor of the wonderful memory of his son, Lee Middleton Hooper Walker, who left us in May, 2014. Mark can be reached at mwalker@dickinson-wright.com.

Steve (M.A. ’81) and Kathy Hubby Weiner (B.S. ’83) share, “We were fortunate enough to be able to travel to Italy again this year. We enjoyed our time in Positano and Cinque Terre, among other areas. This beautiful region is part of a Tertiary fold and thrust belt, which left many cliff faces rising from the sea. Steve was pleased to be able to help a number of JSG students with their interviewing skills again this past year, while also serving on the FANS board, and as a judge in the student resume writing contest. Both he and Kathy are happily retired in the Central Texas area.”

Clayton Hill Wilson (B.S. ’83, M.A. ’85) currently resides in Houston, Texas and can be reached at chwilson@exxonmobil.com.

David Laurence Work (B.S. ’84) says, “Recently moved to Deepwater GOM after years of Eagle Ford at Anadarko. Enjoy coming back for UT football and Geo Alumni events, especially getting to do some fossil hunting with wife Lesley (retired XOM geologist) and sons Evan and Henry … thanks to Dr. Sprinkle for the tip! Wishing all the mid 80’s grads well!”

1990s

Darcy (Brooks) Cuthill (B.S. ’93) is currently living and working in Merida, Yucatán, Mexico.

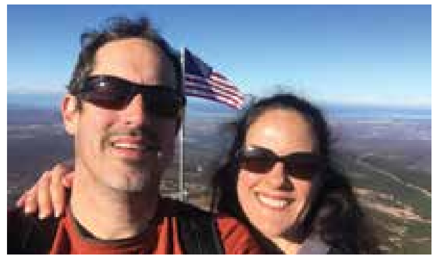
Rimas Gaizutis (B.S. ’91) writes, “Back in Houston working as Petrotechnical Manager Americas for REPSOL. Got to spend some quality time over the past year with fellow geology grad Doug Bowling where we shared a hunting lease. Mike Whittaker was able to join us out there one weeekend as well. Lots of great stories shared around the campfire especially about Field Camp … ” Rimas can be reached at rgaizutis@yahoo.com.

Christi Gell (B.S. ’96) reports, ‘I just started a new job as Associate Director of Technical Sales at IHS Markit. This followed an awesome summer which culminated in an epic geology-focused road trip with my kids through West Texas, eastern New Mexico and Colorado and a week in Breckenridge with all of us. The kids got their first taste of swimming at Balmorhea State Park and seeing the Marfa Mystery Lights. I’ll never forget hyrdo field camp in 1996: I begged Jack Sharp to take us to Marfa to see the lights. He told me if I could convince a TA to drive me then he’d let us go. I begged our TA, James, to drive me to Marfa from Ft. Davis and he graciously said yes, the whole way telling me, “You know, Christi, these probably aren’t real.” But they were, and are! The kids now have been bitten by the West Texas bug and are little rock hounds of course. Charlie, the kids, and I have all been doing karate together for the last 14+ months so don’t mess with the Gells! Drop me a line if you are ever in Houston or want to meet up: christigell@utexas.edu.”

Nikolas A. Hazel (B.A. ’93) says, “2016–2017 exciting year for us with a new baby boy! Now 1 year old! Moved back to Austin, Texas in 2014. Started my own business: Nikolas Alan Fine Jewelry Design. Bought a house in Lakeway a month ago near Lake Travis. Happy to be back in Austin after 14 years in Phoenix Arizona and 2 years in South Florida.”

Sachin Shah (B.S. ’98) is the Chief for Hydrologic Studies and Research at the USGS Texas Water Science Center Gulf Coast Program in Houston, Texas. He has been part of the development a new interactive web application on groundwater level changes and subsidence in the Houston region.

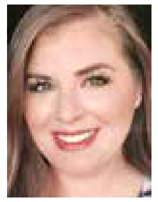
Becky Smyth (M.A. ’95) will be retiring from BEG after more than 20 years and return to private consulting.



Frank ‘Trey’ Wagner (B.S. ’96) shares, “I recently moved with the family from Houston to Anchorage, Alaska. Enjoying the cooler temperatures and hiking in the mountains.”

Hugh Winkler (M.A. ’92) says, “Geophysics this year published my paper, “Geosteering by exact inference on a Bayesian network” which treats geosteering as a probabilistic inverse problem, and shows how to use techniques from machine learning to solve it. The algorithm gives the most likely estimate for the lateral change in geology and the well path. After four years at Drilling Info, I’ve left to found a new company, Factor Technology, which uses that algorithm in a software product that advises directional drillers how best to keep the well path in zone, while drilling.”

2000s



Terra J. George (M.S. ’08) reports, “After 10 years with ConocoPhillips, I accepted a new position as Sr. Staff Geologist at Diamondback Energy. I am currently the asset geologist for the “Brigham” area in the Southern Delaware Basin.” Terra can be reached at tgeorge@diamondbackenergy.com.

Thomas Tydings Thacker, Jr. (B.A. ’08) writes, “My wife, Mary-Alex, and I welcomed our first child, a happy, healthy boy, to the world on March 23, 2017. Thomas Tydings Thacker III. I also launched my own company, Wolfcamp Royalty Partners, LLC, which is a mineral and royalty acquisition fund focused on the Permian Basin. To date, the fund has closed over 75 transactions covering mineral/royalty interests in over 100 producing wells, under 20+ of the premier operators of the Permian Basin, across 7 counties and WRP is continuing to grow.” Thomas can be reached at thomas@3texploration.com.

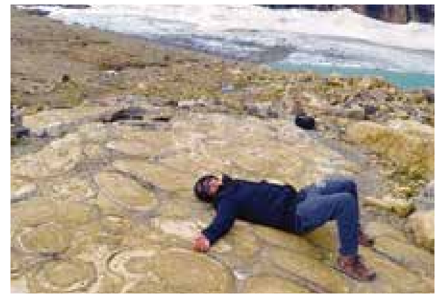
2010s

Gabriel Aguilar (M.S. ’14) currently works as a Wellsite Geologist in Denver, CO and can be reached at aguilar.gabe7@gmail.com.

Randy Caber (M.S. ’10) says, “I entered the investment banking side of the oil and gas industry in January 2017 and am currently working for Simmons & Company International | Energy Specialists of Piper Jaffray as a Staff Geologist in Houston, Texas. At Simmons, I assist oil and gas firms with acquisitions and divestitures, corporate financing, drillco’s, and other strategy needs by clients. I also recently passed the exams for FINRA 63 and 79 licenses.”

Marcus Chroback (B.S. ’10) writes, “I am enjoying my time on the Jackson School’s FAN’s board. It is so great to see the cutting edge research projects that are always going on at the school. I am looking forward to the alumni tailgate weekend in November, they are always so well attended! Lastly, I transferred from EOG’s San Antonio division to EOG’s Midland division last February. I am very much enjoying my new home!”

Joseph Cleveland (B.S. ’14) shares, “I am currently a 4th year medical student at Texas A&M Health Science Center College of Medicine. I will be graduating May of 2018 with an Doctorate of Medicine and intend to pursue Medical Residency in Internal Medicine, planning to specialize in Oncology. Although I am not specifically practicing a profession in the Geological Sciences, I am using all of the skills I obtained in the Jackson School on a daily basis to help others. Some of the happiest moments of my educational career and life in general, have been with the Jackson School. The people I came to know on a personal basis in the Jackson School are friendships I cherish to this day, and that I know I will hold close for the rest of my life. I wish all the best to this school and all of the students that are fortunate enough to call it home.” Joseph can be reached at jcleveland@medicine.tamhsc.edu.



Nick Danger (M.S. ’16) says, “I am currently working at SQ Environmental as a project geoscientist and environmental consultant. I am based out of Austin but conduct field work and commercial drone operations across the United States for several multinational corporations. When I have free time, I enjoy hiking, disc golf and van camping in National and State Parks.”

Mackenzie Day (Ph.D. ’17) reports, “I began a NASA Postdoctoral Fellowship with the NASA Astrobiology Institute at the University of Washington in Seattle. I plan to continue my study of dunes on Mars with an eye to understand whether dunes could have supported early life."

Tian Y. Dong (B.S. '13) says, "After receiving a M.S. in Earth Science at Rice University in 2015, I am continuing as a Ph.D student and expecting to finish in 2019."

Hector K. Garza (B.S. '16) is currently a consultant geologist at Premier Oilfield Laboratories in Houston, Texas and can be reached at hector.garza@utexas.edu.

Emma Heitmann (B.S '16) spent about 5 months in Brazil managing the fieldwork for a cave monitoring project with Corinne Wong, and has now returned to Austin.

Michael Lis (B.S. '16) says, "I will be attending the University of South Carolina Fall 2017 and getting my Masters in Geology. I can be reached at Michael.lis@utexas.edu."

Lorena Martinez (B.S. '16) will pursue a M.S. in biology at Texas State starting next fall.

Frank Morgan (B.S. '11) writes, "I am working for Devon Energy in Oklahoma City with the Rockies exploration team with focus on the Powder River Basin." Frank can be reached at frankmo0053@gmail.com.

Alif Musa (B.S. '16) reports, "I recently landed a job with Halliburton as a technical consultant."

Rebecca Nunu (B.S. '16) is starting graduate studies in hydrogeology at UT San Antonio.

Evan Pearson (B.S. '10) writes, "I've enjoyed life as a geologist working for Pinnacle Potash International for six and a half years, but I'm ready to embark on my new adventure - law! Both my school and work experience have inspired me to pursue a career on the legal side of natural resources. I found my path in a roundabout way, but wouldn't trade any memories from Jackson for a degree in political science. I look forward to what the future brings and I know that the Jackson School has prepared me for whatever my next career brings. Hook 'em!"

Bridget Pettit (B.S. '15) says, "I recently graduated with my M.S. in Geology from the University of Kansas studying under fellow JSG grad Dr. Mike Blum, and am excited to begin my career as a geologist with ExxonMobil."

Rania Eldam Pommer (B.S. '13) shares, "Hello! As you may know, I self-published two STEM-related children's books in 2016 (MD and Finn Go Camping, and MD and Finn: Solar Power! Both are available on amazon.com!), but 2017 has been a pretty darn exciting year too! I'm working with my illustrator on a potential new MD and Finn project (coming 2018), I'm well on my way into my Ph.D. at Colorado School of Mines, and I recently got hitched to another Jackson School alum - Maxwell Pommer! This year has been good to us so far, and I can't wait to see where the next one takes us!"

Makoto Sadahiro (M.S. '14) recently moved to Japan and can be reached at sadahiro@utexas.edu.

Nikki Seymour (M.S. '15) shares, "Here are Dr. John Singleton and his three advisees doing field work along the Atacama Fault System in northern Chile. All four are JSG alumni! Pictured left to right: Rachel Ruthven (BS 2016, honors advisor Rich Ketcham), John Singleton (Ph.D. 2011, advisor Sharon Mother), Nikki Seymour (MS 2015, advisor Daniel Stockli) and Evan Strickland (BS 2010, honors advisor Mark Cloos)."

Michelle Stocker (Ph.D. '13) writes, "I accepted a position as Assistant Professor of Paleobiology in the Department of Geosciences at Virginia Tech starting January 2017. I am a Faculty Affiliate in the Global Change Center at Virginia Tech while also holding research positions at the Virginia Museum of Natural History, the Smithsonian's Natural History Museum, the North Carolina Museum of Natural Sciences, and the Jackson School's Vertebrate Paleontology Lab at UT Austin. My research group focuses on the evolution of reptiles, and I am looking for curious and driven M.S. and Ph.D. students to apply to my lab for Fall 2018!"

Chak Hau Michael Tso (B.S. '12) shares, "After getting my BSGEH degree from UT, I moved to University of Arizona for a M.S. in hydrology. Now my wife Elizabeth and I live in the beautiful countryside of Lancaster, United Kingdom, where I am working on a Ph.D. on hydrogeophysics."

Kristopher James Voorhees (B.S. '14, M.S. '16) writes, "I graduated with a Masters from the Jackson School in 2016, where I also received a Bachelor's degree in 2014. Since graduating from the Masters program, I started my career with Apache Corporation in June 2016 where I completed a rotation for a year with the International New Ventures group. I have since begun my second year rotation in Midland with the Conventional Exploration team working the Midland Basin and am thrilled to be working carbonate rocks again, considering I studied under "the Guadfather" himself, Dr. Charlie Kerans. Since graduating, I have made it a point to travel to new places such as Canada, Thailand, Bali, China, Japan and throughout the central U.S. My next adventure will be over Thanksgiving this year trekking to the base camp of Mount Everest in the Himalayas."

Angela Wu Li (B.A. '15) writes, "I spent the year after graduation in Austin, working and travelling for Apple Maps. Then the west coast called my name and I'm now in San Francisco working at a startup. Though the beloved 512 will always be home, I will have to say that the hills out here are pretty impressive. Always up for coffee if anyone finds themselves out here studying faults and grains!"

William I (Bill) Woods (retired executive assistant in the Department of Geological Sciences) shares, "This has been another full year. In March and April, Francisco and I spent 3 weeks in El Salvador visiting family and another week in Big Bend National Park with friends. Both were fun, interesting trips. In June, we traveled to Toronto to visit his sister there. I have taken on a volunteer position at the Heart Hospital of Austin, working at their conceiege desk; I enjoy being around people and helping out. I still go to GRE to work out, MWF. Francisco retired from UT at the end of February, so we have time to travel more and are planning a trip in November to Australia, New Zealand and Tasmania. I always enjoy hearing from my GS friends. I can be reached at billw@utexas.edu."

Professors Emeriti

Robert L. Folk writes, "Semi-Scandaloso Reminiscences from RL Folk: I came south from Penn State to work in Houston for an oil company research lab. After less than a year I decided to teach and do my own style of science. On an errand I stopped by the University of Texas unannounced just as Sam Ellison and Ronald DeFord were taking over the Department and shortly they offered me a prof's job and $4,200/year. So I began in September 1952 teaching Structural Geology (all four 3-hour labs a week, no TA's) and Economic Geology. In those "good ole days" one taught wherever the Boss needed to fill in a hole. Thank God he did not need a paleo guy! Next, Sam told me (not asked) to teach summer field camp in torrid East Texas (Bastrop-Smithville-La Grange). Of course I had to say "yes Boss" even though as a carbonate petrographer I knew nothing at all about that kind of field geology – soils, trees, tire traction, etc. But I found that I loved it (and became good at it). Then I got to teach sedimentology and sedimentary petrography – the first class in carbonate petrography in the U.S. In those days one did not have to bring in huge amounts of grant money. Students and I could do research on anything that looked interesting. So we are able to work on sandstones and shales in West Virginia and East Texas, and local Austin limestones or carbonate sands in Yucatan, pebble shapes in the Colorado River and Tahiti, grain size sands on the Texas coast and the red desert of Australia. In 1959 something great happened. Ellison hired Earle F. McBride from Johns Hopkins and we worked together symbiotically on Devonian cherts in Trans-Pecos Texas and Jurassic "deep (shallow?)-water" certs in Italy. When two guys with different ideas work together on the same project you get a very fruitful outcome and make lots of new discoveries. I spent 6 months in Australia (1965) and another 6 months in Milano, Italy (1973) at the invitation of Riccardo Assereto. This was a soul-enriching experience for me, my wife Marjorie and daughter Jenny. Later I greatly enjoyed taking students there (alternating boy vs. girl – no sexism here!) and most found that very enriching too. Financing by the BEG allowed me to work on travertines with Hank Chafetz. Why work such an unimportant rock? Well it turns out that they were made by "real" bacteria (not algae). This completely changed both of our research foci into the role of bacteria in making all sorts of minerals. Subsequently at Viterbo in 1990 I discovered the minute universe of dwarf forms (nanobacteria) which were later found on the meteorite from Mars. Biologists rushed in to deny it, but this has been my research focus ever since. Right now with Earle McBride I'm studying Fe oxide in sandstones and looking for the inorganic vs. bacteriological origins of those cements."

William Galloway (M.A. '68, Ph.D. '71) reports, "The industry-funded project began more than 20 years ago, the Gulf Basin Depositional Synthesis (better known as GBDS), continues. It has expanded, first to include the Mesozoic, and most recently to encompass the wealth of data now becoming available for Mexico. Though long officially retired, I've continued part-time collaboration with the GBDS group at UTIG, and was finally persuaded to co-author a book (in preparation) that will synthesize the Gulf and its geologic history. Travel remains a major past-time, both for leisure and for landscape/wildlife photography. I spend a lot of time in the digital darkroom, working on the images collected over the past 10 years.

Alaska, the Pacific Northwest and Yellowstone are favorites. Fall foliage most anywhere is a close second."

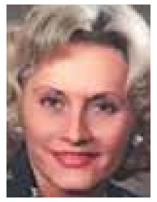
Lynton Land writes, "I continue my quest to improve Chesapeake Bay water quality. Meaningful changes in agricultural crop fertilization practices must occur, such as replacing conventional chemical fertilizers with slow-release products. Equally important, sewage sludge, poultry litter and manure disposed cheaply by land application must be limited to supply the phosphorus needs of the crop, but no more. Current permissive regulations favor the waste-producers and guarantee much more nitrogen and phosphorus pollution than is caused by chemical fertilization. Quantitatively meaningless changes, like growing more oysters, must not substitute for changes in crop fertilization practices, as explained in the July 2014 issue of the "Bay Journal" and doi: 10.1007/s10498-014-9226-y. I grow and sell fertile (diploid) seed oysters. The more oysters the better, they make great meals and are good for the ecosystem. But they can't solve the Bay's nutrient overload problem. Since retirement, I have concluded that scientists must actively use their knowledge and positions to contribute toward solving societal problems. Just having fun doing research and herding students, as I did, while ignoring the frustrating political arena, is selfish and unacceptable."

Ernest Lundelius (B.S. '50) shares, "Although retired I still go to the Vertebrate Paleontology Lab at Pickle Research Campus nearly every day. I am just finishing a long-term study on a Pleistocene cave fauna from Western Australia. We are also involved in a study of a new locality north of Houston that so far has produced the first record for the U.S. of a South American animal, a toxodont. This animal was about the size of a small rhino. I have given several talks about the late Pleistocene fossils from Inner Space Cavern near Georgetown. I also spend a little time trying to keep with three grown grandchildren. I stay busy!"

Earle F. McBride writes, "Just after the first of the year The Rocky Mountain Geology journal published my contributions on the sedimentology, petrography and diagenesis of the Lower Pz clastics that overlie the Precambrian basement in the area between Durango and Silverton, CO. I collected the first samples for this study on Geo 660 in the 1980s. Some projects move very slowly. Stratigraphic and editorial input from Jim Sprinkle was helpful over the years. The allegedly Cambrian Ignacio Quartzite is almost certainly Devonian. Luigi Folk and I have started a study of "ferricrete" (iron-oxide-cemented sandstones and conglomerates) in central Texas. At our ages (RLF = 91; EFM = 85) progress is a bit slow!"

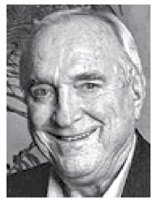
James Sprinkle shares, "I've been retired as a Professor Emeritus for 4 years now, so I'm not doing any teaching or supervising students, except for serving on one M.S. Committee in 2014-2015. However, I still do research on early echinoderms and Paleozoic marine communities with several co-workers and former graduate students. I usually come in to the Department 3 days a week and on Sunday afternoons, and go out to the Non-vertebrate Paleontology Laboratory (NPL) at the Pickle Research Center the other 2 weekdays to work on some of my fossil collections and to photograph specimens. 2015 was the last year that I did any extensive field work out in our major fossil collecting areas in Utah and Nevada, but I've made several shorter trips up to southern Oklahoma this year to visit fossil collecting localities and other workers up there. During the last 4 years, I've published 9 papers or book chapters, 6 abstracts for talks or posters at GSA or other conferences, and a book review. I still have at least 20 additional fossil echinoderm projects that I've accumulated over the years that need to be written up before I "really retire". Our family is doing fine here in Austin and elsewhere. Wife G.K. retired 2½ years after I did. However, she then got hired to do some consulting work for a client during last spring's Texas Legislative Session. Son David still lives and works in Austin, so we see him about once a week to help out with yard work and to keep our computers and electronics working. Daughter Diana, the artist of the family, recently got a full-time job with a graphics company in St. Louis, Missouri, and moved there in April; we see her whenever we talk on the phone."

MEMORIALS



Dorothy W. Alcorn (spouse of the late Charles W. Alcorn, Jr., B.S. '52) higher education advocate and community leader, died at her home in Victoria on Sunday, February 26, 2017. She was predeceased by her husband of 45 years, Charles W. "Chuck" Alcorn, Jr.

H. Warren Bell (B.S. '53) died at home on December 26, 2016. He was born March 20, 1933, to Daulty and Marzee Bell in the community of Minter, in Lamar County, Texas, where he lived throughout his youth, graduating Deport High School in 1949. He attended TCU from 1949–1950, then transferred to The University of Texas at Austin where he earned a Bachelor of Science in geology in 1953. Warren worked as an exploration geologist with Union Sulphur in Lake Charles and Superior Oil in New Orleans, and in 1969 relocated to Houston where he worked for Kilroy Company through 1974. He then took a position with McCormick Oil & Gas where he remained until 1978 when he became an independent geologist. He was an independent geologist for the rest of his career. While working in Lake Charles, he met and married Jeannette Sutter in 1956. They have two children, Katherine Shipley (husband Tom), and Brian (partner Michael Cammareri), grandchildren William and Anne Marie Shipley. Warren greatly enjoyed the outdoors, with a lifelong love of hunting, fishing, and scuba diving, as well as traveling the world and reading literature. But his greatest joy, devotion and love were for his wife, children and grandchildren, who will keep his memory each day along with surviving sister Wanda Porterfield and husband Ray, cousin Waylon Norrell and wife Pat, sister-in-law Dorothy Mims, his other relations and many friends.



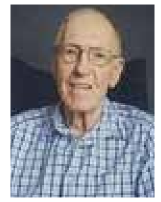
Robert L. Bluntzer (B.A. '60) age 83, passed away on December 2, 2016. He was born in Cuero, Texas to Cornelius Sixtus Bluntzer and Loraine Tietz Bluntzer. After he graduated from high school in Cuero, he served in the U.S. Army and earned a bachelor's degree in geology in 1960 at the University of Texas. Bob worked in the oil patch early in his career and then as a groundwater geologist for various Texas water agencies for 32 years. After retiring, he was a hydrogeological consultant for 10 years and was involved in restoring the first water well on the State of Texas Capitol grounds. Bob was a very dedicated, loving and fun husband for 48 years, father, grandfather and friend. He loved Austin, Longhorn football, hunting, cultural activities, fossils, genealogy, history and traveling. Bob was very active in his children's and grandchildren's lives, attending countless sporting and school events. He was a member of the UT Quest Continuing Education Group and Texas Board of Professional Geoscientists. Bob is preceded in death by his wife, Josephine Bluntzer, and his parents. He is survived by his son, Peter Bluntzer, of Austin, Texas; daughter and son-in-law, Alice and Joshua Ley, and grandchildren Andrew and Kate, all of Englewood, Colorado.

Jean I. Bowman (B.A. '54) was born in Houston, Texas on September 5, 1929, to Agnes Baker Ingram and Leon Ingram. She attended Austin High School where she was an officer in the Scottish Brigade. After graduation, she earned a Bachelor of Science in geology from The University of Texas at Austin in 1951. She frequently referred to herself as a proud "tea-sip" and remained a lifelong Longhorn sports fan. She was a member of Alpha Delta Pi sorority where she made lifelong friendships. Following college, Jean returned to Houston to begin a teaching career in the Spring Branch ISD and to raise her sons. Later, she worked with her husband Jess C. Bowman in their insurance business. Jean lived in Austin for the last 6 years of her life at Brookdale Gaines Ranch where she enjoyed the care and attention she received from the outstanding staff. Jean is preceded in death by her parents, siblings and husband. She is survived by her four sons Dan W. Jackson III, Todd Johnson, Bart Johnson and Matt Johnson.

Claude A. Campbell (B.S. '50) The Reverend (retired) Claude Alan Campbell passed away July 13, 2017, in San Antonio. He was born in 1927 and had recently celebrated his 90th birthday. Alan was a native San Antonian. He was the youngest child of Claude Amos Campbell and Kate Kone Campbell. Alan graduated from Thomas Jefferson High School in San Antonio at the close of World War II. He enrolled in Trinity University eventually transferring to The University of Texas at Austin where he earned a bachelor's degree in geology in 1950. He worked as a petroleum geologist for Union Producing and then as an independent geologist for several years, retaining a life-long interest in minerals and geological formations, especially those of West Texas, which he loved. In his 30s, he decided to change careers and enrolled in Virginia Theological Seminary in Alexandria. After graduating in 1964, he served the Episcopal Church in Texas parishes including St. Matthews in Edinburg and the Church of the Incarnation in Dallas before accepting a position at Deaconess Hospital in St. Louis as a clinical pastoral education supervisor. He was married to Katherine Elaine McDaniel from 1958 to 1972 and the couple had two children, Allison and Callan. In 1979, he met and married Linda Crick Campbell, his wife of 37 years. Alan was predeceased by his parents and his sister, Cathryn Smith. He is survived by his wife, Linda, who works for his former undergraduate institution - Trinity, son Callan Andrew Campbell, daughter Allison Kone Campbell, niece Cathryn "Tinka" Watts Langfeld, nephew David Watts, Jr., and his herd of "livestock," his favorite term for several beloved pets.

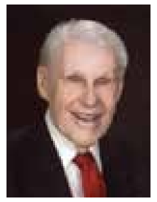
Calvin A. Chimene (B.S. '50) 89, passed away on Friday, December 23, 2016. He leaves behind his three sons, J.B., Andre, and Beau, and eight grandchildren, Daniel, Gabrielle, David, Zachary, Beverly, Cooper, Coby, and Daisy. His first wife, Katie Allen Chimene, and his second wife, Ann Carol, both preceded him in death. A fifth generation Houstonian and native Texan, Calvin spent almost all of his life in and around Houston, Texas. The son of Julius and Fannie Chimene, Calvin grew up in Houston's Third Ward and later in West University, where he went to Lamar High School. He attended the University of Texas at age 17, then left to join the U.S. Army for World War II. After serving in the occupation of Japan, he returned to the University of Texas where he graduated with a Bachelor of Science in geology. He then attended the University of Houston, where he acquired a Master of Science in geology with a minor in Physics. He was selected as a member of the SGE, the national geology honors fraternity. Some of Calvin's papers on exploration have been published in articles by The Oil & Gas Journal, other Exploration periodicals, the Journal of Sedimentary Petrology and Paleontology, and two separate Memoirs of the American Association of Petroleum Geologists. He has lectured extensively at AAPG conventions, Houston Geological Society, and meetings of the Houston Mesozoic Geologists Group. He was selected to present one of his papers during the World Geological Congress in Washington D.C. in 1989. His master's thesis in 1952 was the first one published from the University of Houston by an outside publishing company. Following his employment with the Quebec Minister of Mines he worked in the corporate world for 33 years, rising to the position of VP in charge of domestic exploration for hydrocarbons of a large American corporation, heading a staff of roughly 100. Retired in 1985, he formed a family corporation to carry on his interests in oil and gas exploration and raising pecans. Calvin also spent his working years raising three sons with Katie Chimene, providing them with life skills from dinosaur bone and rock identification to floundering to working with all types of tools. All three sons followed their father to the University of Texas, and shared his passion for Texas football and Austin. He began writing fiction in 1988 and has published three volumes of short stories and one novel. He was also an artist, creating charcoal drawings of fossils. Calvin played handball and table tennis into his eighties, and won several medals in competition at the local Senior Olympics.

William W. Curtis (B.A. '82) age 59, formerly of Austin and Oklahoma City passed away on September 19 in Crested Butte, CO. Bill was born on May 22, 1957. He was the youngest son of Lawrence W. Curtis and Marilyn Buescher Curtis. He graduated from Heritage Hall in Oklahoma City in 1975 and from Southwestern University in Georgetown in 1980 with a degree in political science. He also earned a degree in geology from The University of Texas at Austin in 1982. Later in life, he returned to school and received a Masters in Education from Oklahoma City University. In 1982 he married Elizabeth McAllister and went to work as a geologist in Oklahoma City. Later, he became a pharmaceutical representative for McNeil. That job allowed him to move back to Austin with his family. In 2008, he married Kristine Stepan and joyfully added her three children to his family. Later in life, he made his home in Crested Butte. Bill loved football, especially his beloved Sooners, being at the lake, movies, fishing and reading. He was renowned for his generosity and his larger-than-life personality, for which he will always be remembered. He is survived by his wife, Kristine Stepan Curtis; his three biological children: Samantha Winn Curtis, Adam Buescher Curtis and Walter Alexander Curtis; his step-children Boyd Ryan Stepan (fiancée: Lauren), Ashley Stepan Ihemelu (husband: Ugo), Trevor James Stepan (wife: Jenny) and his grandchildren, Izu and Amara as well as his nieces and nephews. He was preceded in death by his parents Lawrence W. Curtis and Marilyn Buescher Curtis and his brother Robert L. Curtis.

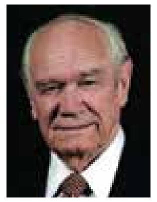


Kenneth L. Diebel (B.S. '50) died peacefully May 30, 2017, in Austin. Kenneth was born February 13, 1926, at home in Meyersville, Texas to Erwin and Erna Diebel. He was the oldest of two brothers. His daddy died of appendicitis when Kenneth was seven. His mother never remarried, and she struggled valiantly to support and raise the two boys with a strong Lutheran sense of values and an unswerving moral compass. The Diebel family spoke German at home, and Kenneth did not learn English until he began first grade. As a boy Kenneth was active in Boy Scouts and earned the rank of Life Scout, but soon the six-foot six-inch redheaded boy was discovered by the Cuero High School basketball coach. Basketball games interfered with Boy Scouts, so "Red" Diebel switched his focus to become the star center of the Cuero Gobblers basketball team. After high school, he attended the University of Texas for a year on a basketball scholarship and studied chemistry before he was drafted into the Army. During World War II, Private First Class Diebel put his German language skills and his knowledge of chemistry to good use as a translator and medic in a hospital in Germany. After the War, he returned to UT and finished his degree on the GI bill. After enduring (and failing) a chemistry lab in the un-air-conditioned basement of the chemistry building one summer, he decided chemistry was not for him and (luckily for us) changed his major to geology. All his life Kenneth loved to visit the UT campus to see his old college haunts. After earning a B.S. in geology, Kenneth went to work in Conroe for the Humble Oil Company (later Exxon). He met the love of his life, Nita Samuel, at the Conroe First United Methodist Church where she was the organist. They soon married and had two girls, Kay and Ann. Kenneth had a very successful career as an exploration geologist and manager with Exxon, and the family traveled all over the world, living in Houston, Tyler, Dallas, Libya, London and Norway. Ken and Nita made many lifelong friends through Exxon. Ken loved to play the guitar and was well known for the song parodies honoring coworkers. Kenneth retired and moved home to Conroe in the early 1980's. He was a very active member of Conroe First Presbyterian Church, where he attended Sunday school, delivered Meals on Wheels, and worked on many Habitat for Humanity houses. He also greatly enjoyed "guitaring" with a group of musicians that met at the Montgomery County Administration Building. At the age of 80, he would go and entertain with his guitar at the "old folks' home." Ken was always up for a challenge. He was very proud of his linguistic abilities and became fluent in Norwegian and French in addition to the German and English he grew up speaking. He jogged a minimum of three miles every morning and often bragged that he had gone much further. Kenneth never faltered in his belief in the saving grace of God the father and his son Jesus Christ. His well-worn Bible provided him with comfort and wisdom all his life, and his belief in his Lord was a guiding principal upon which he measured all his actions and decisions. Ken was preceded in death by his parents, his brother Dr. Burton E. Diebel, and his beloved wife Nita. He is survived by daughter Kay Diebel Brock and husband Bradley Brock of Austin, daughter Ann Diebel and husband Keith Lutsch of Houston, grandchildren Alexiy, Rita and Kenny Brock, and numerous nieces and nephews.

Dennis Adolph Drake (M.A. '58) 81, of Dallas, Texas, passed away on September 13, 2016. Dennis was born in Beaumont, Texas. He graduated from Lamar College and the University of Texas. Dennis proudly served in the Army National Guard. He was a petroleum geologist. His 50-year career in the exploration for oil and gas took him to Louisiana offshore, and the Texas Gulf Coast on and offshore. Dennis also traveled to China for oil and gas study and research. He often spoke of his goal to leave much energy for the future generation. He served as Vice President of Exploration for Strata Energy-Armco Steel and worked for other companies. Dennis retired from Devon Energy Houston. His survivors are his wife of 56 years, two children, four grandchildren and a sister.



Robert B. Gaines (B.S. '49, M.A. '51) passed away peacefully in his home in Midland, Texas on November 27, 2016. "Bob" Gaines was born in Fort Worth on February 9, 1923, to Robert Byron Gaines Sr. and Gertrude Spear. Eleven years later an event occurred that would change Bob's life forever when he was run over by a truck that crushed his right leg. He would spend the next two years in a wheel chair and undergo numerous surgeries that would ultimately leave that leg 3 inches shorter then his left leg. While perhaps this was a disability, it was never a handicap. Bob became a cheerleader at Arlington Heights High School. After graduation he attended the University of Texas where he earned Bachelor of Science and Master of Arts degrees in geology. While in school, he took up fencing and became the captain of the university fencing team. He was a member of the Delta Sigma Phi Fraternity. At the university, Bob met his wife, Betty Land. They were married on June 6, 1949. In 1951 they moved to Midland, Texas. They lived in a small apartment before building a home on East Oak Street where their first son, Robert Vallee was born. In 1956, the family moved to Omaha when Bob began to work for Northern Natural Gas. While in Omaha they added two more children to the family, Richard Spear and Gayanne. In 1970, the family was transferred back to Midland. In Omaha, Bob began a long time association with the Boy Scouts when his two sons joined Cub Scouts. He took on many roles as a scout leader, merit badge counselor and was also a leader of the adult scout leaders, helping to train them to train the boys. Bob earned the highest Scouting award for an adult leader, the Silver Beaver award. Bob continued in scouting for more than 50 years helping boys learn the ways of scouting. Professionally, Bob was a geologist and petroleum engineer. In the mid-60s he received his Professional Engineer license. He was awarded the Pioneer Award by the West Texas Geological Society in 2005. He retired in 1988. Bob was a member of the Downtown Midland Lions Club and won the Jack Welch Fellow Award for service to Texas Lions Camp for Crippled Children. He was a 32nd-degree mason and received the honorary Red Hat award. His love for children and devotion to those with hardships were keen driving forces in Bob's life. Bob became a Shriner. As a Shriner he rose through the ranks and was the Potentate of the Suez Shrine club in 2001-2002. He also served on the Board of Directors for the Shrine Hospital in Houston, Texas. Bob loved sports. As his children grew he naturally became a coach, first as a Little League coach for the boys then as a softball coach for his daughter. He also had a rule that every child no matter their level of talent would get to play in the game. Sometimes that didn't work for the team's advantage, but Bob thought that it was more important that the team learn to live with all of their advantages and disadvantages. Bob loved to hunt and fish and took the family on numerous trips. He also played golf and was on the Shriner golf team that would travel and play in different parts of the country. He loved to ballroom dance with his beautiful wife Betty and they could be seen dancing as members of the Ballroom Dance club Bob was a member of and held numerous offices with St. Andrews and Trinity Presbyterian churches in Midland and First Presbyterian Church in Omaha. Bob was also a member of Grace Presbyterian Church. Bob was a founder of the St. Andrews Mission and Clinic. Bob is preceded in death by his parents, Robert Byron Sr. and Gertrude Spear Gaines and by his youngest son, Richard Spear Gaines. He is survived by his wife Betty Land Gaines, his son Robert Vallee Gaines and wife Edellweiss; his daughter Gayanne Bett and husband Tom and their three children, Sarah, Tommy and Rachel Bett.



Thurman B. Geddie (B.S. '45) died November 5 at his home in Austin surrounded by his family after a long battle with sarcoma cancer. He celebrated his 95th birthday just days prior to his death. He was born in Grand Saline, Texas to Emma Elizabeth Riggs Geddie and James Prentice Geddie. He attended high school in Grand Saline and entered The University of Texas at Austin in 1940, graduating in 1945 with a B.S. degree in geology. There he met Sharon Haden Smith of McAllen, Texas and they were married in 1945. Together they had three children, Sharon April, Carey Leigh, and James Anthony. He began his career at Barnsdall Oil Company in Corpus Christi in 1945 near the end of WWII. Barnsdall transferred Thurman to Lake Charles, LA in 1950, where he served as head geologist overseeing exploration and on-site drilling. Thurman moved to Houston in 1951 where he partnered with Hedley & Jordan Oil & Gas for many years as an independent geologist. In 1965, Thurman married Beverly Lowry of Houston and together they had one child, Susan Elizabeth. Beverly brought two children to the marriage, Linda Kay and Bruce Wayne Lowry. In 1974 he partnered with J.W McFarlane of McFarlane Oil Company where he managed all phases of drilling, exploration, production and property acquisition. Together they developed a successful oil producing field in Placedo, Texas. They worked together for many years discovering and developing oil and gas wells in south and east Texas. In 1977 Thurman and his brother Prentice Odell Geddie, formed Geddie Oil Co. where they worked together on many oil and gas ventures until Prentice died in 1991. In 1979, McFarlane Oil Company merged with Global Natural Resources in Houston where Thurman worked till 1985 when he moved to Austin. There he worked for Larry Barnes Petroleum for 10 years while also continuing his work with Geddie Oil Company. During this time he helped develop several new discoveries and one major gas field. Thurman loved his profession and continued to work until just a few months before his death. Thurman was predeceased by his parents Emma Elizabeth and James Prentice Geddie, his daughter, Carey Leigh Chastain, and his brother Prentice Odell. He was a member of University Avenue Church of Christ, The American Association of Petroleum Geologist, Houston Geological Society, and the Society of Independent Professional Earth Scientists (SIPES). He is survived by his wife, Beverly, his children, April and husband Robert Watson, Tony and wife Teresa Geddie, Susan and husband Steve O'Brien, stepdaughter, Linda Lowry, stepson, Bruce and wife Pam Lowry and son-in-law, Steve Chastain. He leaves a legacy of 15 grandchildren, 19 great grandchildren, and 4 great-great grandchildren. Thurman loved his family, his friends, and the Texas Longhorns. He attended nearly every home football game at Memorial Stadium for over 60 years.

Clement "Clem" E. George (B.A. '47, M.A. '48), a Midlander since 1948, passed away March 22, 2017. An only child, Clem grew up in Tucson, Arizona. He entered his beloved University of Arizona in 1938, joined the Sigma Nu fraternity, and studied Mining Engineering and Business Administration. He has been an avid Arizona Wildcat for over 80 years. Clem met Betty Suggett of Ft. Worth, Texas in 1941, at a Sigma Nu/Chi Omega dance and they married on December 29, 1943. Betty predeceased Clem on September 6, 2011. As with many college ROTC cadets at the time, in May of 1942, Clem was inducted into the United States Army Air Corps as a Second Lieutenant. He served as Head of the Air Corps Supply stationed at Boling Field - Washington D.C. and at La Guardia Field - New York City. While in New York, his fondest memory was dancing with Betty to Guy Lombardo at the Roosevelt Grill. One of Clem's primary duties in the Air Corps was the responsibility for the control and maintenance of President Truman's airplane, as well as being a supervisor over 200 civilians and 16 enlisted men. He ended his military service as a Captain in January 1946. After the war, Clem entered graduate school at The University of Texas at Austin and graduated in 1948, number one in his class with a master's degree in geology. On March 1, 1948, Clem rode the train from Ft. Worth to Midland to report to work with Stanolind Oil and Gas. In September of 1950, Clem went to work for Anderson Pritchard, and then in January 1954, became an independent geologist and oil and gas operator. Clem served as the Chairman of the Society of Independent Geologist in 1968 and served on The University of Texas Geological Foundation in Austin for seven years (1970-1977). Clem served as a director of Midland Commercial Bank & Trust from 1970 to 1984. In 2015, he was awarded the Pioneer Award with Midland Geological Society. Clem's interest in the stock market dominated his time from 1990 on. All children and grandchildren had to know daily how GE closed. Clem's love of history, travel, sports, and old movies was ingrained into his two children, Meredith and Kenn, and his six grandchildren. Clem's children and grandchildren have all been part of the Boston Red Sox Fan Club, because of Clem's unwavering support since 1936, in spite of the curse of the Bambino. What a joyous day for Clem when the curse was broken. Clem hosted multiple grandchildren, Meredith, and Kenn to relish in person three World Series wins. Clem is survived by two children, Meredith and husband Ed of New Mexico and Kenn and wife Tricia of Dallas; grandchildren, Kenneth George II and wife Carolyn, and great-grandchildren, Kenneth III and John, of Chevy Chase, Maryland, Patrick George and wife Elizabeth, Clement George and wife Molly, Elizabeth Gosselin and husband Chase, all residing in Dallas, Edward Tinsley IV and wife Kelly, and Ede Booth and husband Morgan; great-grandchildren Lawler and Scarlett, all residing in Houston.

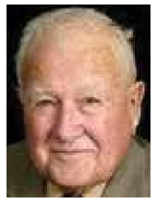
Conley Ray Goodrum (B.A. '57) was born on October 24, 1934 and passed away on February 9, 2017. Conley was a resident of Baytown, Texas at the time of passing. Conley attended college at The University of Texas at Austin and was a longtime Longhorn fan.

Joanne W. Harvard (spouse of H. Lee Harvard, B.A. '55) passed away on Thursday, April 20, 2017. Joanne was a resident of Roswell, New Mexico at the time of passing. She attended The University of Texas in Austin and was married to Lee Harvard.

Robert S. Houston (B.A. '50) was born on August 18, 1924, and passed away on December 15, 2016. Robert was a resident of West Boylston, Massachusetts at the time of his passing. He graduated from the University of Texas and later earned a master's degree from Worcester Polytechnic Institute. He served in the United States Navy during World War II. He was married to Blanche.

Edward W. Hughston (M.A. '50) Long-time Dallas resident Edward Wallace Hughston died peacefully on May 28, 2017, at his home in Taos, New Mexico at the age of 87. Ed was born in Hillsboro, Texas, where he spent the first five years of his life. The stock market crash of October 1929 set the stage for his Great Depression childhood. "But this childhood was wonderful," he said, "and any notion of the Depression came much later." After eight years in Tyler, Ed's family moved to Dallas, where he attended Highland Park High School, from which he graduated at 15. In the autumn of 1945, Ed enrolled at Southern Methodist University, where he met Joan Lorraine Palmer, whom he married three days after graduating from SMU in 1949. Obtaining a Master of Arts in geology from the University of Texas at Austin, he then embarked on a career in oil and gas spanning seven decades, based first in Corpus Christi, where his three sons were born, then Dallas and McKinney, and finally Taos, where Ed moved with Joan in 1979 and spent many happy years, making numerous good friends. He is survived by son Lane Hughston, son Mark Hughston and his wife Marla Hughston, son Thomas Hughston, granddaughter Katherine Kennedy and her husband Walter Kennedy, grandson Christopher Hughston and his fiancé Bridget Jernigan, grandsons Benjamin Hughston and Parker Hughston, and great-grandson Wyatt Kennedy. He was preceded in death by his wife Joan Palmer Hughston, father Thomas Dudley Hughston Sr, mother Margaret West Hughston, brother Thomas Dudley Hughston Jr. and sister-in-law Betty Briggs Hughston.

Gordon L. Ingram (B.A. '49) 92, of Evanston, died peacefully on May 5, 2017. He is survived by his beloved wife of 59 years, Judy Ingram. He was the cherished son of the late Raymond and Glennah Ingram; loving brother of the late Boots (Betty Lou) Ingram and Kenny (Betty Kay) Ingram; adored father of Betsy (Gary) Ingram, Kay (Matt) Frank, Margaret Ingram, and Michael (Rosina) Park Ingram. He is survived by six grandchildren who thought the world of him. His brilliant mind, gracious spirit and favorite expressions will also be remembered with love by his nieces and nephews, who called him Uncle Gordy and his many, many friends, including the magnificent caregivers he knew at the Presbyterian Home, who called him Coach. The Rev. Dr. Gordon Ingram was born on April 9, 1925 in La Porte, Indiana. He grew up in Elkhart, Indiana, where in high school he was not only a state championship center for the basketball team, but also played violin in the orchestra. In later years, listening to classical music became his favorite pastime, whether it be sitting in his VIP chair listening to the Grant Park Orchestra in Millennium Park, Friday afternoon concerts at The Chicago Symphony, concerts on the lawn at Ravinia or listening to his vast collection of CDs. He attended DePauw University, was appointed to the U.S. Naval Academy, and graduated from The University of Texas at Austin. He played left end for the Longhorns and shared a dorm room with Tom Landry. From 1950-1955, he was a corporate financial officer for a natural gas pipeline company. In 1955, he was called to the ministry and served as student pastor at the Fourth Presbyterian Church in Chicago while attending McCormick Theological Seminary. In 1958, Gordon married Judy Keig. They served the following Presbyterian churches: Glenwood Springs, CO; Wheaton, IL; Bensenville, IL and Marquette, Michigan. He was very proud of being "let go" from the church in Wheaton in 1965 for preaching against housing discrimination and in favor of Martin Luther King's civil rights activism. Finding a more open minded congregation in Bensenville, the church embarked on many amazing projects for those in need. They included a preschool, a well-baby clinic, an adult health care clinic and the Home Assistance Foundation which helped 18 Mexican immigrant families come to own their own homes. He received his Doctor of Ministry degree in 1982, then founded the Institute for a Theological Future. He conducted seminars for a wide range of participants at the Aspen Institute and St. Benedict's Monastery in Snowmass. He was passionate about fly fishing and taught this art to his children and grandchildren on the Roaring Fork River in his beloved Colorado. Dinner with family and friends was a priority. He and Judy were particularly fond of sitting outside at Hackney's on Harms. A few of his memorable and oft-used expressions: "You are the best of the best!"; "Take what the course gives you"; "Hook 'em Horns"; and the many phrases he quoted from his brother Boots, such as "Not too shabby," and "Everybody be where they want to be." Gordon was a wonderful sermon writer and always showed up when and where he was most needed. Larger than life and truly one of a kind.



Charles R. Jones (B.S. '50) died peacefully on Nov. 29, 2016, in Austin at the age of 94 years. Charles was born to Charles F. Jones and his wife, Mary Lee Ila Sigmon, in Fort Worth. He attended Paschal High School. He enlisted as a technical sergeant in the U.S. Army Air Force 1942–1945. He flew 30 bombing missions in B-24s over France and Germany during World War II. After discharge, he attended Texas Christian University and University of Texas earning a Bachelor of Science in geology. His profession was exploration petroleum geology working for Cities Service Oil Co. for 27 years and later Texas Pacific Oil Co. and Davis Oil Co. He met the love of his life and married Bettye LaRue Johnson in June 1947. They had three daughters. They enjoyed raising cattle, golfing and travel. Charles was preceded in death by his wife, Bettye, in 2012 and his daughter, Fran Norwood, in 2016. He is survived by his daughters, Claire Hinkle of Kennesaw, Ga., and Charla Jones of Driftwood; and his grandsons, Carl and Kirt Hinkle of Atlanta, and Bradford Norwood of Houston and Clifton Norwood of Tyler.

Dean L. Leyerly (B.S. '50) 93, of Odessa, Texas passed away on November 9, 2016. Dean was born in Caldwell, Kansas on June 8, 1923 to C.E. and Maude Leyerly. He graduated from Caldwell High school and he married Margy Lou Crumbliss on June 8, 1941, and soon after entered the USAAF, where he served as a radio operator and waist gunner. During Dean's service to this country, he was shot down in combat and became a POW. He was awarded the Purple Heart, and other medals of honor. Upon returning home, he continued his education to receive a B.A. degree from The University of Texas. Dean began a 35 year career with Hughes Tool Company in 1945. At the time of his retirement, he was District Zone Manager in Midland, Texas. Dean was preceded in death by his wife of 64 years, Margy, his daughter Dana Gibbs Copeland and his sister June Strevel. He is survived by his wife, Mickey; his daughter Jo; grandson Kenny; granddaughter KaDee, all of Midland and Odessa, and sister Lois Morris of Wichita, Kansas.

Clifford R. McTee (B.S. '54) was born on September 1, 1933, and died on December 8, 2016, at the age of 83. He was born in Houston to Clifford Ray McTee, Sr. and Gladys Lucille (Harris) McTee. Cliff had a degree and postgraduate work in geology from The University of Texas at Austin, where he belonged to Acacia Fraternity. He worked for Tidewater Oil and Gas Company as an exploration geologist. He also worked in Houston for both Midwest Oil and Gas Company and International Nuclear Corporation. In 1970 he moved his family to Corpus Christi. There he ran the exploration department for Texas Oil and Gas. He enjoyed a stellar reputation and was widely known and respected in the South Texas Oil and Gas community. After four years, he opened his own office and practiced petroleum geology for the next 20 years as an independent geologist. During this time, he served as the treasurer and later as the president of the Corpus Christi Geological Society and the Petroleum Data Service. Cliff was active in his sons' Boy Scout troop, having been initiated into the Order of the Arrow at the same time as his son, Ford. He immensely enjoyed hunting and many good times were spent with friends and relatives in pursuit of game. Cliff was also active in several other businesses; he ran a cattle ranch in McMullen County, Texas for many years. He was also very proud of his board position and work with the McMullen County State Bank. Cliff is preceded in death by his parents. He is survived by his loving wife of 63 years, Elsie (Wheeler) McTee; sons, Clifford "Ford" R. McTee, III and wife Barbara of Austin and Charles Dewey McTee and wife Kimberley of San Antonio; daughter, Shelly Marie McTee and fiancé Jay Miller of Phoenix, Arizona and brother, Ronald James McTee of Spring Branch, Texas. Cliff is also survived by his four grandchildren, Taylor Marie McTee Parsons and husband Rob, Clifford Ray McTee, IV, 1st Lt. Blake Daniel McTee and Michaela Elizabeth McTee and great granddaughter, Zella Marie Parsons.

Herbert G. Mills (friend and donor to the Jackson School) 86, passed away November 22, 2016, in San Antonio. Born February 20, 1930, in San Antonio, to Eben Herbert Mills and Rose Mangold Mills, he was preceded in death by his parents, his sister Rose Ann Northway, and brother Eben Mangold Mills. Herbert graduated from Alamo Heights High School in 1947 where he played football and was president of his class. In 1951 he was a proud graduate of Texas A&M where he earned his B.S. in geological engineering. His experience in the Corps of Cadets was quite memorable and very formative. He was a Ross Volunteer and Commander of the Armor-Engineer Regiment. Following two years of service in the U.S. Army, he worked for Exxon Company USA which took him from various South Texas towns to New Orleans, New York City and ultimately back to Houston. After retirement in 1987, he and his wife formed Mills Exploration. Herbert was a member of the Houston Geological Society, the AAPG and SIPES. He was an active member of St. John Vianney Catholic Church in Houston for 43 years. In addition to being a member of the Knights of Columbus, he found great satisfaction in volunteering in various ways through his parish and community. Of particular note was his work with the parish school board of St. Francis of Assisi Catholic School, one of Houston's inner city Catholic schools. Dedicated to his family, he was available to help whenever and wherever needed. Herbert is survived by wife, Martha Bybee Mills; children Ruth and husband Mark Oordt, Herbert G. Mills, Jr., wife Cindy, and Peter B. Mills and wife Cheryl; grandchildren Andrew, Martha Rose, Carol, Ellen and Catherine Oordt; Anne Marie, Christopher and wife Andrea, Molly and Matthew Mills; Alissa Varga and Josef Varga, wife Sarah and children Charlotte and Landon; and numerous nieces and nephews.

Josh W. Oden (B.S. '56, M.A. '58) age 86, of Corpus Christi passed away Sunday, April 23, 2017. Josh was born July 26, 1929, to Lora Lee and Wm Hale Oden who preceded him in death. Josh graduated from Tarleton High School in 1944 and moved to Austin to begin school at the University of Texas. He left Austin to join the Army in 1950 and proudly served in the Korean War earning the rank of 1st Lieutenant. In 1956, he was honorably discharged and completed both his bachelors and master's in geology at UT. August 3, 1956, he married Diana Etchison. He began work as a geologist for Humble Oil Company in 1958 subsequently worked for J3 Oil Company and Winn Exploration ultimately retiring in 1995 and returning with Diana to Corpus Christi. He had a passion for hunting and fishing and most enjoyed wading along the shoreline or sitting in a deer stand in the early morning hours. Josh was preceded in death by his parents, his wife Diana and his son Robert Hale Oden. He is survived by his daughter Lee Michelle Gibson and grandson Joseph Hale Gibson.

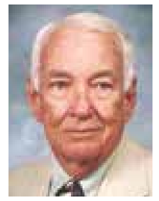
John C. Osmond (B.S. '47) was born in Germantown, Philadelphia, PA. As a boy he loved exploring the woods and ponds near his house. His mother often said he would come home from exploring covered with mud and a couple of turtles in his pocket. His favorite saying was "Like a herd of purple turtles in a mud hole." He and his father were close; they spent hours looking for mineral specimens in the nonworking mines and hillsides of Pennsylvania, displaying those in a mineral case and trading them with the Smithsonian Institute. From those experiences he developed his love of geology and his decision to be a geologist. He studied geology at The University of Texas at Austin, but his studies were interrupted by WWII. He served in the U.S. Army, Company C, 410th Infantry Regiment, 103rd Division 1943–1945 in the U.S. and Europe. After the war, John returned to the University of Texas and earned a Bachelor of Science in geology in 1947. He was President of the Phi Delta Theta fraternity. John married Nancy Huff, a fellow UT graduate, in Wichita Falls, Texas and moved to Cheyenne, Wyoming where he earned his Masters of Science in geology from the University of Wyoming. They then moved to New York where his son Robert N. Osmond was born and he received his doctorate in geology from Columbia University. He and Nancy made their home in Salt Lake City where he worked for Gulf Oil Company until he became an independent consultant. In 1965 John traveled throughout the U.S. as a lecturer and recognized expert on the geology of the Uintah Basin for the Geological Distinguished Lecture Series presented by the American Association of Petroleum Geologists. He was published in many scientific journals, with his latest publication in the Journal of Sedimentary Research 2006. He served as president of the Utah Geological Society and Intermountain Association of Petroleum Geologists. He and Nancy Huff divorced in 1969. In 1970, John married June Marie Brown and gained stepdaughters Claudia Brown, Vicki Al-hamoodah, stepson Fred Brown, and by adoption another son, Kirk Osmond. John and June then moved to Tiburon, California where he served as Vice President of PG&E. After a move to Denver, he resumed being an independent consultant until his retirement at age 90. John always liked the ocean and the beach. Some of his favorite stories were of taking a toy ship with his parents and playing with his sister Bea in the waves. He loved to body surf in Newport Beach, California on annual vacations. He loved sailing and would rent sailboats when on vacation. He also liked playing tennis and played for most of his life. He was always quick with a joke and a smile to make those around him feel good and laugh. John and June both loved to travel. Some of their favorite vacations were taking cruises to Europe, Greece, and Alaska. We will all miss him a great deal. John was preceded in death by his parents, Eva Buckman and John Chambers Osmond, Sr. and by his wife, June Marie. He is survived by his sister, Beatrice Millar, his sons, his stepson, his stepdaughters, and his grandchildren: Elise Thomas, Janeen Hathcock, Ethan Cardwell, Devin Dolphin, Leila Al-Hamoodah, Tiffany Osmond, John Wilson Osmond, John Alan Osmond. Also surviving are nine great-grandchildren.

Calvin G. Percy (B.S. '48) was born on November 10, 1926, and passed away on January 25, 2017. Calvin was a resident of Georgetown, Texas at the time of his passing. Calvin attended grade school in Jonah Calvin was graduated from Georgetown High School in the class of 1944. Calvin served in the Navy from 1944 to 1946 and again from 1952 to 1954. He was married to Veta.

Earl W. Shahan (B.S. '56) was born on April 11, 1930, and passed away on July 16, 2017. Earl was a resident of San Angelo, Texas at the time of passing. He then went to the University of Texas and after graduating, started his career as a geologist with Exxon Co., U.S.A. Earl served in the Army during the Korean War at Ft. Sill, OK from 1948 to 1951.

Frederick C. Smyth (B.S. '47) 91, died April 10, 2017, at home with his son Frank by his side. Born May 18, 1925, in Victoria, Texas, he was the second of three sons born to W. O. Smyth and Norma Leuschner Smyth. He was preceded in death by his parents and his two brothers W. O. Smyth, Jr. and George H. Smyth as well as his wife of 55 years, Margaret Mary Heye Smyth. Fred was one of the last members of the greatest generation. He served his country in WWII as a navigator of B-24 bombers when he was assigned to the 767th Bomb Squadron 461st Bomb Group, Foggia Main, Italy. On December 17, 1944, his plane came under enemy fire. Rather than parachute to safety the uninjured crew members decided to land the plane in order to try and save the crew members who had been injured in the attack. The plane and crew crashed-landed in enemy territory. Fred was captured and became a POW until his release in May 1945 when the European conflict ended. He was awarded three Bronze Stars and the Air Medal and has a Purple Heart pending. Upon his return to the United States, Fred enrolled at The University of Texas at Austin where he met the love of his life, Margie. In 1948 he graduated with a degree in geology. He and Margie married that same year. Fred spent his career with Sun Oil Company before retiring in 1985. Together he and Margie raised their family until her death in 2003. Fred was full of life and loved his Colorado cabin getaway and his dog, Boone. He is survived by his five children Patricia Sue, James Scott (Audrey), Michael (Kathy), Frank (Ellen), and Robert (Angela) as well as six grandchildren: Penny, Paige, Heather, Marie, Megan and Philip. He also has six great-grandchildren.

Donald J. Stanley (B.A. '55) died in his sleep December 20, 2016, after a long illness. He was born in Wichita, Kansas on September 4, 1930, to Hebert M. and Anne Stanley. He moved to Dallas as an infant. He grew up in Highland Park, attended Holy Trinity School, and graduated from Jesuit High School in 1947. He remained lifelong friends with five Jesuit men, "The Brotherhood." They were 'bros' 70 years before the current craze. Don, an ATO was graduated from the University of Texas with a degree in geology in 1952. He learned the oil business from the ground up, starting with his father's drilling company. In later years, he was a real estate broker and investor. He married Linda Sargent in 1985. Don suffered a severe stroke in 1999. The last 17 years of his life, he showed us how to gracefully accept physical limitations. He is preceded in death by his parents, his wife Linda, and his sister Ann Stanley. He is survived by his sister Peggy Gormley, and brothers Herb Stanley of Midland and Edward Stanley of Dallas. Also surviving are his stepchildren Lydia Dean and John Sargent, and 14 nieces and nephews.

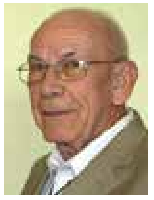


Carroll E. Stroman (M.A. '58) age 86, of Sweetwater, Texas, passed away on September 9, 2016, at Hendrick Medical Center in Abilene, Texas. Carroll was born on April 28, 1930, in Hylton, Texas to Roy and Grace (Campbell) Stroman. He had been a resident of Sweetwater for over 50 years. He married the love of his life, Dorothy Farley, on April 3, 1953, in Sweetwater, Texas. He was a longtime member of First Presbyterian Church in Sweetwater where he served as an Elder. Carroll was a U.S. Air Force veteran serving in Japan during the Korean War. After his service, Carroll lived in Austin from 1953 to 1978. In Austin, Carroll and Dorothy raised their four children while Carroll attended the University of Texas and graduated with a B.S. in geology. Carroll continued to be an avid Texas Longhorn fan throughout his life. He then worked for the State of Texas Land Office for six years. His love and compassion for people with special needs led him to work with Goodwill Industries in Austin where he became the Executive Director for 11 years. Carroll, Dorothy and children then moved west living in San Angelo, Blackwell, and then Sweetwater. Throughout this chapter in life, Carroll continued to work on different programs and projects to develop business opportunities in which to teach and employ people with special needs. In 1979, Carroll and Dorothy opened the first private residential care facility in the State of Texas for individuals with special needs in Sweetwater. This program was owned and operated by Carroll and Dorothy from 1979 until 2001. During that time it grew to several different training and employment opportunities for these residents. Later in life Carroll earned a Bachelor of Social Work from Abilene Christian University in Abilene, Texas. He is survived by his wife, Dorothy Stroman of Sweetwater, Texas and four children; Brent Stroman and Cindi of Waco, Texas; Scott Stroman and Julie of Sweetwater, Texas; Pam Stroman and Cecile of Austin; Kirk Stroman of Sweetwater, Texas; five grandchildren: Stephanie and Nick Depauw of Boston; Kyle Stroman of Austin; Brett Stroman and Tana of Midland, Texas; Aaron Stroman and Becky of Lubbock, Texas; and Cory Stroman and Ashley of Sweetwater, Texas; four great grandchildren and one on the way; his brother Pat Stroman and Patricia of Waco, Texas; numerous nieces and nephews; and dear friends Michael and Dustin Hammit and their family of Sweetwater, Texas. Carroll was preceded in death by his parents, Roy and Grace Stroman of Sweetwater.

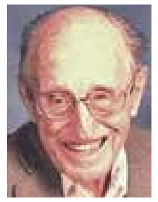
Hal S. Stubblefield (B.A. '54) 84, passed away January 14, 2017, in Kingwood, Texas. Hal's career included working for GSI, Occidental Petroleum Co, and retiring from Mosbacher Energy in 1997. Hal was born to Ross and Zella Jo Stubblefield in Electra, Texas. He met the love of his life, Barbara Muir Bays at Church Sunday School in Lake Charles, LA and they were married in 1956. They were blessed with three children, Susan Gail in 1959, Amy Lynn in 1961 and Stuart Hal in 1965. Hal was employed as a supervisor with GSI from 1954 to 1969, then in exploration with Occidental Petroleum Co in Houston from 1969 to 1980, followed by his position as V.P. of Exploration with Mosbacher Energy in Houston from 1980 to 1997 until his retirement. Hal is preceded in death by his daughter, Amy and his brother Joe Stubblefield. Hal is survived by wife Barbara Bays Stubblefield; daughter, Susan Gail Laible (Jim) and son Stuart Hal Stubblefield; grandchildren, Chad Francis, Kathryn Brewer, Conner Francis, Martha Bea Francis, Rebecca Francis, Henry Francis, Erica Laible and Miranda Laible.

Don E. Wade (M.A. '54) died peacefully on Wednesday, October 19, 2016, at the age of 85. Surrounded by his family and friends, he decided he was unable to live through another presidential debate. After a life of grand adventure, filled with laughter and shenanigans, this world-class man left us all to ponder why we don't eat more dessert. His life was made better by the love of his wife, Mariah Wade, and together they created a love story more passionate than any best selling Nicholas Sparks novel. Don traveled the world as a successful geologist, and upon retirement decided he needed a hobby and became a lawyer. A man famous for his wit, bad jokes and endless doodling on every piece of paper he could find, he attracted some of the best friends he could have ever hoped to have. More important, he leaves behind his musical compositions such as, Ol' MacDonald had a Butt, his extensive shoe collection, and the important lesson that life should be measured by the amount of laughter and love you share with others. He will be greatly missed.

T. J. "Tommy" Waggoner (B.A. '57) passed away peacefully in Wichita Falls, Texas, on June 20, 2017 at the age of 83. Tommy was born on March 6, 1934, in Wichita Falls to Jane and T.J. Waggoner, Jr. and was the grandson of Wichita County pioneers, Mary and Jeff Waggoner. He was a graduate of Wichita Falls High School and an Eagle Scout with Troop 1. Tommy was a member of the Kappa Sigma fraternity at both Southern Methodist University and then The University of Texas at Austin. He graduated from UT with a Bachelor of Science in geology. Tommy married the love of his life, Marilyn Wheeler Waggoner, on June 23, 1956. Subsequent to his graduation, he served in the United States Air Force. Upon discharge, he was a geologist with the Bridwell Oil Company in Wichita Falls until moving with his family to Dallas in 1969. There, he was the founder and chairman of the board of Trans-Western Exploration Company. He was a member of the Salesmanship Club of Dallas, Highland Park Presbyterian Church, the Dallas Country Club and the North Texas Oil and Gas Association. Upon his retirement in 1994, Tommy and Marilyn moved from Dallas to Barton Creek Lakeside in Spicewood, Texas, and then in 2002 they moved again to Bigfork, Montana. In 2015, Tommy and Marilyn's journey came full circle when they moved back to Wichita Falls. Tommy was grateful to be back in North Texas, surrounded by family and lifelong friends. Tommy and Marilyn traveled the world and had many adventures together in their 60+ years of marriage. He was an avid sportsman who loved hunting, fly fishing, summers at Possum Kingdom Lake, golf, butter, jellybeans, and, most of all, his family. He was preceded in death by his parents, Jane and T.J. Waggoner, Jr, his brother and wife, Richard Moore "Dick" Waggoner and Lucia Hartgrove Waggoner, and his sister-in-law and her husband, Barbara Wheeler Cullum and James A. "Old Sport" Cullum as well as many wonderful friends. He is survived by his wife, Marilyn Wheeler Waggoner, and his children, T. J. "Jeff" Waggoner, IV, his daughters, Jill Louise Waggoner and Amy Jeannette Waggoner, his granddaughter, Jamie Wheeler Waggoner, as well as his beloved dog, Clover. He is also survived by his brother John Stephens Waggoner and wife Elizabeth "Betsy" Denman Waggoner as well as his sister, Judy Waggoner Lambert. He also had many loving and caring nieces and nephews who doted on him and brought much joy to his life.



William Edward Watkins (B.A. '54) passed on November 15, 2016, to be with our Lord at the age of 85. He was born and raised in the Dallas area and known by all as Ed. While attending the University of Texas at Arlington, he met Clydene Gartman and was married on May 29, 1951. He achieved a bachelor's degree in geology from The University of Texas at Austin. Ed and Clydene raised five strong and independent children. Ed felt it was very important to not only be loving and kind, but to lead his family by setting an example for them to follow. He enjoyed camping,sailing, hunting, fishing and traveling with his family and friends, he was also a big sports fan and liked to watch his Longhorns and the Dallas Cowboys. Ed & Clydene settled in Duncanville and then Cedar Hill both just south of the Dallas area. Ed owned and operated Acme Rubber Stamp Co. in Dallas, which has remained within the family. Ed and Clydene retired to Austin, for 10 years during this time they bought an Airstream and continued to travel. Clydene is very thankful for all her family and friends, especially those in the Airstream Community. Survivors: Clydene Watkins married to Ed 65 years. Children: Carol and her husband Larry Sams, Susan Adams, Bill and his wife Vicki Watkins, Diane and her husband David Fonzi, and Denise Watkins. Grandchildren: Stephen, Mark and Stacy Sams, Shawn Adams, Christopher and his wife Erin Watkins, Brian Watkins and Mary DeMoss, Alyssa and her husband Edgar Paz, Erin and her husband Alex Denton, Andrew, Ryan and Tyler Fonzi, Brandy and her husband Jason Pinkham, Bobby and Billy Isbell. Great Grandchildren: Philip and Archer Paz, Ashley and Sean Pinkham.



John B. Wesselman (B.A. '54) died September 6, 2016 at Broadmoor at Creekside Park in The Woodlands at the age of 88. He was born in Moberly, Mo. on October 21, 1927, the son of Irene and Bernard Wesselman. He is preceded in death by his parents and his wife of more than 60 years, Pauline Wesselman, who died July 7, 2016. He was the eldest of seven siblings, with three brothers and three sisters, Vivian, Roy, Jean, Patricia, Donald, and Robert. He grew up in Salisbury, Mo., where his family operated three grocery stores, and he attended St. Joseph's School through eighth grade. He later attended public high school briefly until his family moved to Cape Girardeau, Mo., where his father trained pilots for the U.S Air Force. He graduated with honors from St. Mary's High School in Cape Girardeau and enlisted in the U.S. Army shortly after graduation. He served in Japan with the Allied occupation forces and was placed in charge of a commissary as a result of his family grocery experience. He returned from military service to find his family had moved to Palacios, Texas, to begin a cattle and farming operation. He soon went to work as an oilfield roughneck throughout southern and eastern Texas. He later enrolled at The University of Texas, where he studied geology and met his future wife, Pauline Anna Paulissen of Austin. He graduated from UT with a geology degree in 1954. Later in life, he earned a Master of Business Administration from the University of Southern Mississippi in 1979. After graduating from UT, he worked in oil field jobs that took his growing family to Shreveport, La. and eastern Texas. He was offered a job with the state of Texas to map the groundwater in West Texas, which he did for four years, moving from Fort Stockton to Pecos, and finally San Angelo. He moved to Houston in 1959 and joined the United States Geological Survey, where he continued to research and publish reports often cited in the study of Texas public ground water supply. In 1972, he took a new position within the USGS to study the feasibility of tapping into the geothermal layer of the earth to produce energy. This required a move to Bay Saint Louis, Miss., where John retired in 1983. After John retired, his family built a new home in the Sam Houston National Forest, west of New Waverly. John and his family cleared some of the forest, making way for space to grow blueberries, Christmas trees, and catfish, before he focused on his favorite endeavor, raising grandchildren. As the last of John and Pauline's eight children left home, the forest home became a favorite gathering spot for children, grandchildren, and great grandchildren. Family gatherings included work in the forest, hearty meals, the occasional fireworks display, and, of course, legendary bonfires. In retirement, John and Pauline traveled across the nation and to countries on four continents to keep up with adult children working in Australia, Japan, South America, England, and elsewhere. John and Pauline were members of St. Joseph Catholic Church in New Waverly for more than 30 years. He is survived by his eight children: Francis Wesselman of Palmer, Texas; Catherine Neff of Corinth, Miss.; William Wesselman of Knoxville, Tenn.; Carol Gaytan of Angleton, Texas; Alice Wesselman of Greensboro, N.C.; Michael Wesselman of Montgomery; Timothy Wesselman of Albany, Ga.; and James Wesselman of West Columbia; 10 grandchildren; and five great grandchildren. He is also survived by his six previously named siblings and their extended families.

Davida Word (Spouse of the late Charles F. Word (B.S. '37)) was born on September 15, 1918, and passed away on March 22, 2017. Davida was a resident of Kerrville, Texas at the time of her passing. graduated from Abilene High School in 1935 and attended Abilene Christian College. She was married to Charles Freeman Word.

Vestal "Pappy" Yeats (B.S. '58) passed away peacefully in his sleep on July 28, 2017. He was a veteran serving in the Navy during World War II, an Antarctic explorer, and a professor of geology at Texas Tech. Pappy was born in Fort Worth in 1919, and later moved to the Rio Grande Valley where he grew up. He discontinued his studies at the University of Texas to enlist in the Navy after Pearl Harbor. Stationed in New Orleans between tours of duty in the Pacific, he met his future wife, Ouida Mae. After the war, they moved to Austin where Pappy completed his degree in geology and later moved to Lubbock to complete his master's degree. As a professor of geology, he taught the freshmen classes, mineralogy and ran the geology labs. During his tenure, he participated in three Texas Tech expeditions to Antarctica, mapping areas of the Shackleton and Beardmore Glaciers. Yeats Glacier is named for him. Ouida passed away in 2003. He is survived by his son Austin, daughter-in-law Nina, grandson Tyler, and nephew, Robert Haynes.

Researcher

Kirk McIntosh, a talented marine seismologist who specialized in mapping and imaging deep-sea trenches, continental margins, and mountain belts, died unexpectedly in Austin at the age of 59, after an 18-month battle with leukemia. Kirk, a senior research scientist at the University of Texas Institute for Geophysics, passed on June 1, 2017.

Kirk was born and raised in Boulder, Colorado, the son of a cryogenic engineer and a homemaker. He received a Bachelor of Science in geophysical engineering from the Colorado School of Mines in 1980, then began his career as an exploration geophysicist at Atlantic Richfield in Plano, Texas. In 1986 he left the petroleum industry for graduate school at the University of California, Santa Cruz. There, under Eli Silver's supervision, Kirk investigated the tectonics of the California margin and the Costa Rica subduction zone. When he finished his Ph.D. in 1992, he joined the Institute for Geophysics at the University of Texas at Austin, where he spent the rest of his career working on a variety of tectonic problems in settings as structurally diverse as the Mississippi River, New Zealand, and the deep ocean trench near Taiwan.

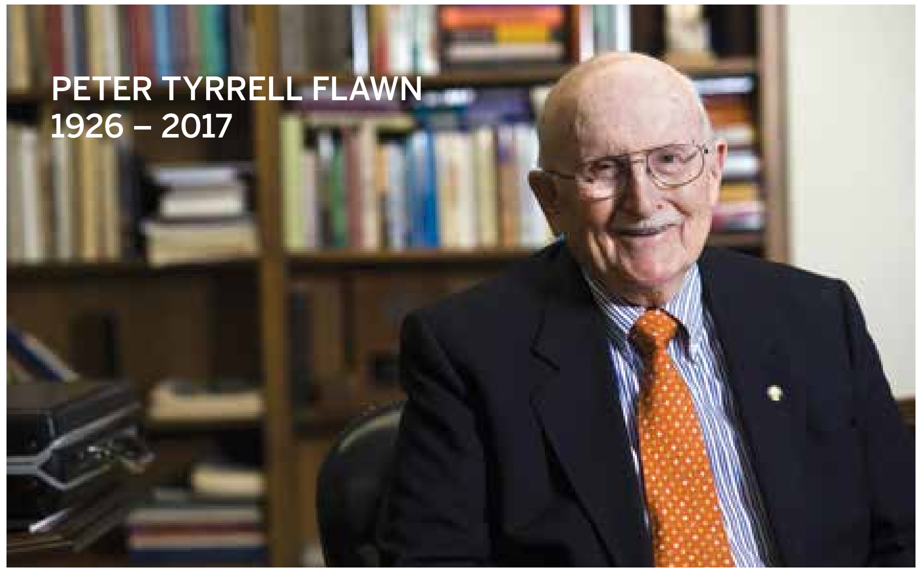
An especially skilled hand in the field, Kirk was a sought-after collaborator. He mapped ocean morphology; he drilled for core samples into the Costa Rica subduction zone; and he dove in the Alvin submersible to a depth of 4,500 meters, using Alvin's robotic arm to collect samples on the ocean floor. Kirk was chief or co-chief scientist on twelve major marine seismic experiments, a task involving months of prior planning and coordination both of multiple ships and scientists from different countries. He wrote his last grant between rounds of chemotherapy and succeeded in getting funding.

Kirk's particular gift was in processing marine seismic data. In the Middle American subduction zone, he produced detailed seismic images of dewatering sediments, normal faults, and fluid seeps, documenting the stratigraphic response of the forearc to plate deformation and clarifying processes of sediment underplating and seamount subduction. In his (co-led) active-source seismic study of the collision that created Taiwan, a collision between the Luzon arc and the rifted margin of the South China Sea, Kirk demonstrated that the extensional faults and crustal blocks that form when a new ocean opens also play a large role when oceans close, in this case forming a new mountain belt.

Kirk was responsible for the innovation of adapting deep-ocean imaging techniques to investigate continental structure. His project in Lake Nicaragua examined a paradigmatic forearc basin with high-resolution "marine" seismic techniques; another more recent project on the Mississippi River near New Madrid located faults related to intracontinental historic earthquakes. Whatever the location, Kirk's scientific claims, supported with high-quality imaging data, were careful, clear, and solidly logical.

An easy-going and humble man, Kirk was also sociable, opening his house to relatives, friends, and students. He was an enthusiastic gourmand, and he successfully imitated at home the dishes he had sampled on his travels around the world. But Kirk was above all a dedicated husband and father, and his family was always his foremost concern. He was simply a great human being. He is survived by his wife, Diana Chavez McIntosh, whom he married in 1989; his daughter, Julia McIntosh, a graduate student in hydrology at Southern Methodist University in Dallas; and his son, Victor McIntosh, a sophomore at Concordia University in Austin.

President & Faculty



Peter Tyrrell Flawn, prominent geologist, prolific researcher and author, and renowned leader in higher education, died May 7, 2017, at age 91.

Peter Flawn was a native of Florida but grew up in New Jersey. In 1943, at the age of 16, he was offered admission and a full scholarship to Oberlin College. In just 6 years he completed a B.S. at Oberlin, which was interrupted midway with a stint in the U.S. Army Air Corps, worked a summer for the U.S. Geological Survey, and completed an M.S. degree and residence requirements for the Ph.D. at Yale. At age 23, he embarked on a career as a research geologist at the Bureau of Economic Geology at The University of Texas at Austin. Peter Flawn was a quick mover early on, and he never slowed up.

Peter's first assignment at the Bureau—studying the geology and resources of the Van Horn area in Trans-Pecos Texas—became his dissertation, which was supervised by the legendary Philip B. King. In fact, it was at Yale that Peter saw a notice on the bulletin board that the bureau was offering financial support to Ph.D. students working in Texas. His bureau assignment on the Precambrian rocks and associated mineral deposits of the Van Horn area was completed in 1951. Results were published in a Bureau of Economic Geology publication authored jointly by Flawn and King. The first part of the study—Pegmatites of the Mica Mine Area, Culberson and Hudspeth Counties, Texas—was the subject of Flawn's dissertation at Yale, where he received his Ph.D. in geology in 1951. His Precambrian work evolved into an interest in basement rocks, where Flawn began subsurface work, coupled with surface geology work in the Franklin Mountains and Sierra Blanca area. The results of that work were published by the Bureau under the title "Basement Rocks of Texas and Southeast New Mexico." He was to chair a major committee of the American Association of Petroleum Geologists compiling data for a basement rock map of the United States, a project that was ultimately completed by Bill Muehlberger.

In the latter part of the 1950s Peter pursued an extensive subsurface and surface study of the Ouachita System, a largely concealed belt of deformed Paleozoic rocks that borders the southern edge of the Central Stable Region of North America in the same way that the Appalachian system delimits the eastern margin. Results of that effort were published by the Bureau in 1961 as part of the University Publication series. Flawn was senior author with co-authors August Goldstein, Philip King, and C. E. Weaver. And Flawn was to initiate work in northern Mexico with a paper on metamorphic rocks in the Sierra del Carmen of Coahuila, Mexico. His love of Mexico and its metal mineral resources was a longtime affair. He became fluent in Spanish and in 1964 while a Visiting Professor of Geology at the Instituto de Geología, Universidad Nacional Autónoma de México, he proudly lectured in his acquired tongue.

In the fall of 1960, Bureau director John Lonsdale died suddenly of a massive heart attack. Peter Flawn, at age 34, was named the fifth director of the Bureau of Economic Geology in its 52nd year of operation. At that time the bureau had a research staff of 10, five positions of which were at the doctoral level. Though modest in size, the bureau had a long history of publication and through the years had a number of prominent geologists on its staff. During his 10 years as bureau director Flawn managed to maintain the strong tradition of basic and applied research while moving the bureau into certain policy areas and later into environmental geology. Seeing the need to communicate with policymakers and the general public, he launched the first Annual Report, a series that continues today. Flawn maintained research and lectured frequently, coloring many of his talks with provocative titles such as "borehole myopia," "granite wash is hogwash," and "too much oil in the eyes of Texas?" Flawn wrote two books while serving as bureau director—Mineral Resources: Geology, Engineering, Economics, Politics, Law, published in 1966 by Rand McNally, and Environmental Geology: Conservation, Land-use Planning, and Resource Management, published in 1970 by Harper and Row. He published a paper in 1966 titled "Geology and the New Conservation Movement," which anticipated the national concern for environmental issues that were to come in the late 1960s and later.

When Peter Flawn was appointed bureau director he was also named a professor in the Department of Geological Sciences and would later serve as professor of public affairs in the LBJ School of Public Affairs. An active participant in the affairs of the department, he taught a course on mineral resources and supervised a number of graduate students, mostly doctoral aspirants.

In 1970 Flawn left the bureau to launch what was to become an impressive career in higher education administration. That year he was appointed vice president for academic affairs and in 1972 rose to Executive vice president at UT before being appointed the president of The University of Texas at San Antonio (UTSA) in 1973. He would remain at UTSA for five years. When he arrived at UTSA, there were a few planners and administrators in rental offices. Five years later, UTSA was a beautiful 600-acre campus, with 300 faculty, 8,800 students, and all infrastructure in place; first classes started in 1975 under Flawn's watch.

Peter returned to Austin in 1977 for a research leave 19 years in the making, but in short order he was serving as acting director of the University of Texas Marine Science Institute and acting chairman of the Department of Marine Studies. In 1979 he was appointed president of The University of Texas at Austin, a position he would hold through 1985. Early on as president, Peter declared a "war on mediocrity," which would earn him a piece in Doonesbury. He was later to admit to only one vice—a passionate addiction to Doonesbury, saying that he had quit smoking (Roi-Tan cigars and a pipe) and alcohol gave him a headache.

Peter Flawn pushed the university to pursue greater academic rigor and excellence. He was to comment upon the occasion of receiving the Santa Rita Award in 2001 that "there is abroad in the land an extreme form of egalitarianism that holds that excellence is undemocratic. This is a particularly insidious doctrine that takes political form in attempts to divert resources from public flagship universities. It holds that all public universities should be equal. After all, a university is a university and they all award degrees. Having spent a half-century building universities that is to me a most repugnant view. Excellence is not undemocratic! It is precisely through the recognition and reward of merit and achievement that democratic societies have triumphed. If we as a society come to believe that the quest for excellence is somehow undemocratic, the intellectual integrity of the university is at risk." Those were words Peter Flawn lived by.

While president, Flawn convinced the regents to establish a program of matching private gifts to the university, and during the Centennial Celebration Campaign, which he launched, the number of faculty endowments rose from 112 to 851. Sponsored research grew to $100 million, or $225 million in current dollars. The Academic Center next to the Main Building was renamed the Peter T. Flawn Academic Center in 1985 when Peter retired and became president emeritus.

Much of what The University of Texas at Austin is today owes to the direction, guidance, and insight of Peter Flawn.

At 60, Flawn knew that retirement was not his style. He found time to write four more books — A Primer for University Presidents: Managing the Modern University, a memoir on his days as Texas geologist with the Bureau of Economic Geology, another on his experience in heading the Texas National Research Laboratory Commission and the quest for the Superconducting Super Collider, and finally a book recalling his sojourn into northern Mexico and opening a silver mine with his good friend Phil Beckley. He remained active in affairs of the university and the state and maintained close contact with Texas and university leaders, who frequently sought his counsel.

He served on 15 corporate boards of directors, some while president of UT, but most afterward. He was sought after by numerous noncorporate organizations as well. He served on the Advisory Board of the National Defense Fund, the Texas Nature Conservancy Advisory Board, the Governor's Energy Council, the Governor's Advisory Committee on the Superconducting Super Collider, the National Science Board and the National Science Foundation Advisory Committee, St. David's Hospital Board, the Southwest Research Institute Board, as well as its Foundation for Research and Education and its Center for Nuclear Waste Regulatory Advisory Committee on Research, the Texas National Research Laboratory Commission, the Texas Scientific Advisory Council, UT Austin Development Board, Department of Computer Sciences Development Committee, the Marine Science Institute Advisory Council, the College of Natural Sciences Advisory Council, the UT Press Advisory Council, the McDonald Observatory and Department of Astronomy Board of Visitors, the Institute of Latin American Studies, Mexican Center Advisory Committee, Laguna Gloria Art Museum Board, Yale University Council Committee on Physical Sciences and Engineering, and the Foundations of the American Geosciences Institute and the Geological Society of America.

As if those activities did not fully occupy his time, in 1997, at age 71, Peter Flawn agreed to serve as President ad interim while UT began a search for a new leader. He resigned from the many corporate and nonprofit boards on which he was then serving and accepted a salary of $1. The only condition he made was that it be understood he was not going to mark time as a caretaker, as if anyone would ever imagine otherwise. He launched another capital campaign with the ambitious goal of raising $1 billion. He dealt with the fallout from the Hopwood v. Texas decision banning racial considerations in admissions. His wife called it his "second coming," but Flawn called it "waiting for Larry." Flawn recalled that when Larry Faulkner walked into the President's Office, he was pleased to be able to deliver to him an institution without the burden of unmade decisions.

Of Peter Flawn's wide interests and involvements, he was a geologist at heart, and he kept his dedication to the geological professional societies and to UT geology, in particular. He long served on the Geology Foundation Advisory Council, of which he was an honorary member, as well as the Bureau of Economic Geology Visiting Committee. He worked closely with his good friend Jack Jackson, and after Jack's bequest was received and the Jackson School of Geosciences formed, Peter chaired the Jackson School Vision Committee, created and formed by President Larry Faulkner. Fundamental recommendations were made to the president and accepted by him. The School owes its existence to Flawn's direction of that critical committee.

Peter was always involved in the professional geological societies, serving as president of the Association of American State Geologists, the Geological Society of America, the American Geosciences Institute, and the first president of the Austin Geological Society. Appropriately, Peter was honored by his professional peers. He was elected to the National Academy of Engineering and The Academy of Medicine, Engineering and Science of Texas. He received an honorary doctorate from Oberlin and a Presidential Citation from UT. He received the Cross Medal from Yale, the Parker Medal from the American Institute of Professional Geologists, the Lamar Medal from the Association of Texas Colleges and Universities, the Campbell Medal from the American Geosciences Institute, and the Santa Rita Award from The University of Texas System. Flawn received the Condecoracion de la Orden del Sol del Perú. He held the Barrow Chair in Mineral Resources and the Regents Chair in Higher Education Leadership at UT.

Perhaps his greatest achievement was convincing the engaging and vivacious Priscilla Pond to marry him in 1946 and be his life's companion and counselor for 70 years. She was the First Lady of UT, and he would be the first to say that without her he would have accomplished but a fraction of what he did. When he lost her a year before his own death, he was never quite the same. Peter lost his youngest daughter, Dr. Laura Flawn, in a tragic car accident in 2001. He is survived by his oldest daughter, Tyrrell Flawn, and a host of grandchildren and great-grandchildren.

It will be long before we see the likes of Peter Flawn again.

— *William L. Fisher*
Professor and Leonidas T. Barrow Centennial Chair in Mineral Resources

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All personal and work information submitted is confidential and will not be shared outside of The University of Texas at Austin. All fields are optional but we appreciate your effort to help us keep your information accurate and current.

All alumni, former researchers, faculty and staff affiliated with JSG and its research units are encouraged to submit. If you are not receiving the *Newsletter* in the mail, this form will ensure you receive future copies.

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Research Unit Experience:
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Additional details on UT Austin or JSG experience:

Class Notes for the 2018 Newsletter

Attach a separate sheet or use the online form at **www.jsg.utexas.edu/alumni** for longer entries.

Check if you would like more information on:
- ❍ Alumni events in your area or at upcoming geoscience meetings
- ❍ Mentoring and recruiting students
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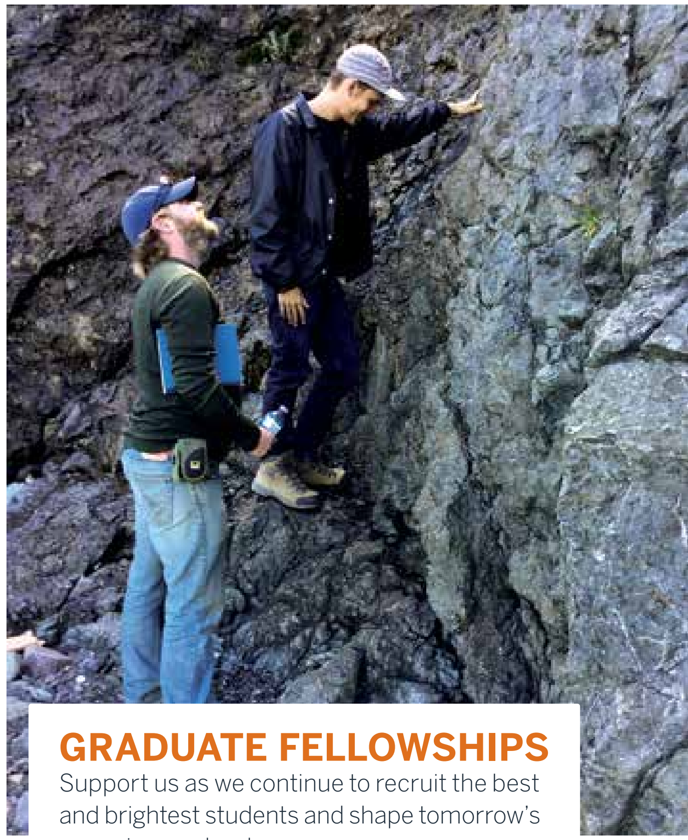

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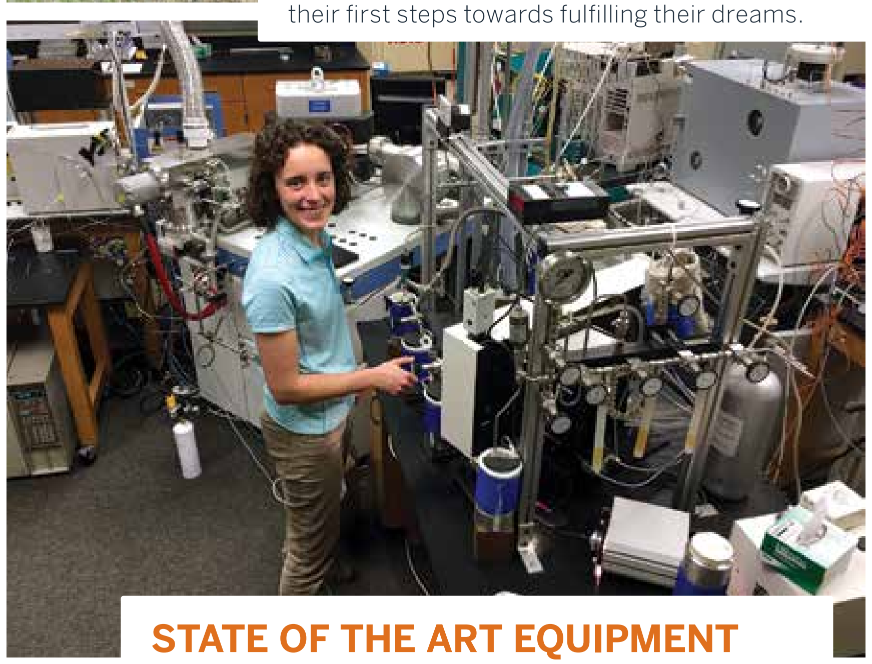

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