2019 ANNUAL REPORT

Bureau of Economic Geology
Scott W. Tinker, Director

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Cover image: Jason Suarez

Message from the Director

For my 20th year at the Bureau, I was on "two-thirds" sabbatical, made possible by encouragement from Jackson School Dean **Sharon Mosher**, the talented leadership of Associate Directors **Mark Shuster**, **Michael Young**, and **Jay Kipper**, and outstanding support from **Theresa Caillouet**, **Kim LaValley**, and **Dena Miller**, among others.

When most people hear "sabbatical," they think "vacation." Well, not really. For one-third of my time, I worked with **Mark Blount** on the 86th Texas Legislative Session to ensure that the Bureau maintained its State funding—we were successful. I worked with several folks to build new Bureau funding—we were partially successful. I gave 41 invited talks and keynote lectures to just shy of 10,000 people across the world, creating broad exposure for the Bureau.

I spent the other two-thirds of my time with the Switch Energy Alliance (SEA), the 501(c)3 that we started to conduct nonpartisan energy education. With Harry Lynch directing, we made a sequel to the energy documentary *Switch*, called *Switch On*. Filmed in Colombia, Kenya, Ethiopia, Nepal, and Vietnam, this film sheds light on energy poverty, a major issue involving about one-third of the world's poor, who either lack access to energy or cook inside with wood or dung.

At SEA, we worked with high school Advanced Placement Environmental Science teachers to develop Switch Classroom, which provides energy materials for a course taken by over 200,000 high school students annually. We also began making a 4-minute film for major science museums that illustrates the critical importance of energy. Derek Tinker and Brian Zavala developed a world-class website. We piloted energy case-study competitions on several higher ed campuses and are now "concepting" a third documentary on the energy transition.

None of this happens without the support of my wife Allyson and my family. I can't wait to come back from vacation!

A Quantum Leap in the Beauty and Functionality of the Bureau of Economic Geology

Welcome to Our New Core Research Facility!

Core Research Facility Opens

A great year for the Bureau

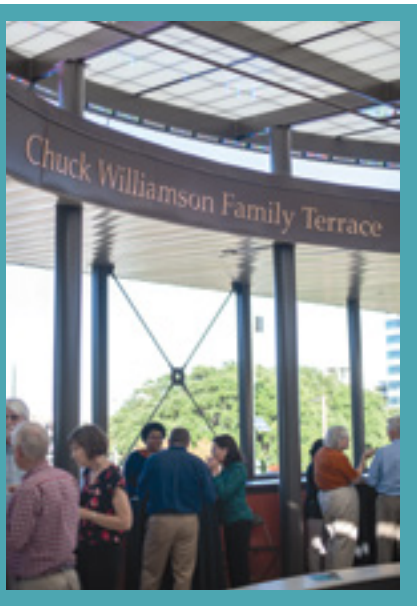
At the Corner of Exploration Way and Creativity Trail

For the past few decades, and especially during the height of the shale boom, the Bureau's Core Research Center (CRC), Building 131, began bursting at its seams, mostly because of the high demand for the CRC's core inventory. The core-viewing room was continually packed with industry geologists from around the world analyzing shale; as a result, Bureau researchers and students not only had long wait times to view requested core samples, they also had to store pulled core in closets and hallways.

Associate Director **Jay Kipper** observed that because "so many of Texas' unconventional plays have either opened up or advanced through analysis of Bureau core, it has really struck home to me how relevant our rocks are: they are an irreplaceable treasure—you simply couldn't replicate what we have." In a word, Bureau researchers need to have ready access to these invaluable rocks.

It eventually became obvious that a new core research building was needed—one that would predominantly support internal research—and so plans were drawn up and construction estimates began to be considered. During the planning process, it was decided that the new building would also be the best home for Bureau scanning electron microscopes (SEMs), which require low vibration and hence a special foundation. The idea of using the roof of the new building as a gathering space also began to take shape. In addition, it was decided that because Building 131's aging labs needed to have their safety features updated and brought into a state-of-the-art condition, inclusion of these renovations in the overall project made perfect sense.

With $7.5 million from the University that Dr. Scott Tinker and then-president Bill Powers worked out, plus significant financial contributions from friends of the Bureau—along with other Bureau funds—the building project moved forward. After its completion in 2019, the award-winning facility now had a spacious core-viewing room, a beautiful rooftop terrace, and a cutting-edge SEM lab in addition to other labs. The renovated Building 131 now boasts new lighting; more spacious, functional, and safer laboratories; and an impressive lobby. The Bureau's newly remodeled CRC can now host innovative research for years to come.



A Gathering Place

The Core Research Facility is topped by the Chuck Williamson Family Terrace, a breezy covered-rooftop terrace suitable for all types of gatherings. The terrace commands a beautiful 360° view of its surroundings, and its ceiling fans and unique roof design ensure comfortable temperatures for most of the year. Colorful computerized lighting will complement any event, and its curved stone benches provide comfortable places to rest.

The terrace served as the venue for the Jackson School Spring Advisory Council Luncheon and the festive 200-person reception that followed the building's dedication. But it is also an accessible and contemplative space for individual researchers, staff, or students to retreat to and recharge.

Grand Opening Celebration

Design and construction was a team effort

A team of remarkable people contributed their talents and skills to the new building. From concept to design and through construction, the Core Research Facility was a labor of love for all involved. Beyond its scientific functionality, unique features and special touches abound. The Bureau's innovative new building won the 2019 Associated Builders and Contractors Excellence in Construction Eagle Award, Central Texas Chapter (shown at right).

(Left to right) B. B. Burklund, Kim LaValley, Marissa McKinney, Lauren Alexander, Nathan Ivicic, Jay Kipper, Scott Mokry, and Toby Smith.

A special thanks to those who presented at the dedication ceremonies:

(Left to right) Scott Tinker, Sharon Mosher, William Fisher, Dick Stoneburner, Jay Kipper, and Toby Smith.

The Dedication

The Core Research Facility Dedication program was hosted by Bureau Director **Scott W. Tinker**, who related the story of the genesis of the building project and thanked all involved. Speakers included Jackson School of Geosciences Dean Sharon Mosher; Jackson School Inaugural Dean and Professor Emeritus William Fisher; Richard Stoneburner of Pine Brook Partners, a donor to the project and member of the Bureau's Visiting Committee; Bureau Associate Director of Operations **Jay Kipper**, and Toby Smith, project director of the Flintco, LLC, construction effort. Their remarks helped tie together the historical perspective behind Bureau facilities and core research, and why the Core Research Facility will be so important to energy, environmental, and economics research for scientists and students for generations to come.

New Equipment Means Better Viewing at the Austin Core Research Center

The Bureau collections in Austin, Houston, and Midland contain some 2 million boxes of core and cuttings from wells drilled throughout Texas, the United States, and the world. Demand for viewings of the more than 700,000 boxes at the Bureau's Austin Core Research Center (CRC) has reached an all-time high. In anticipation of this need, the Bureau began an ambitious core facilities–renovation program in 2017, completely renovating the Bureau's research laboratories and core-viewing areas in Building 131 at UT Austin's Pickle Campus. That strategic plan now also includes the addition of more than 640 linear feet of new rolling-top conveyor tables in the main core warehouse.

Viewing-capacity expansion initially began in 2014, when demand for additional viewing space was met with a temporary, makeshift collection of various viewing tables placed in the warehouse's center aisle. Through the years, the demand for these viewing tables increased significantly; researchers liked being able to lay out entire sets of core for a single viewing.

Rudy Lucero, Nathan Ivicic, and Brandon Williamson, along with more than 700,000 boxes of core and cuttings in the enlarged warehouse viewing area of the Austin CRC.

In 2018, when viewing tables were moved from Building 131 for renovations, their temporary placement in the warehouse enabled a larger, better warehouse viewing configuration.

Recognizing the need and the opportunity, Associate Director **Jay Kipper** and Warehouse Supervisor **Nathan Ivicic** acquired additional rolling-top conveyor tables—assembled solely by the Austin CRC crew of Ivicic, **Rudy Lucero**, and **Brandon Williamson**—to complete the new viewing space. Not only does the new layout provide substantially more contiguous viewing area—supporting up to 1,000 boxes of core at once—it's also safer and more efficient. Using forklifts, the warehouse team can easily move entire pallets of core into position quickly and safely, reducing both setup times and physical stress.

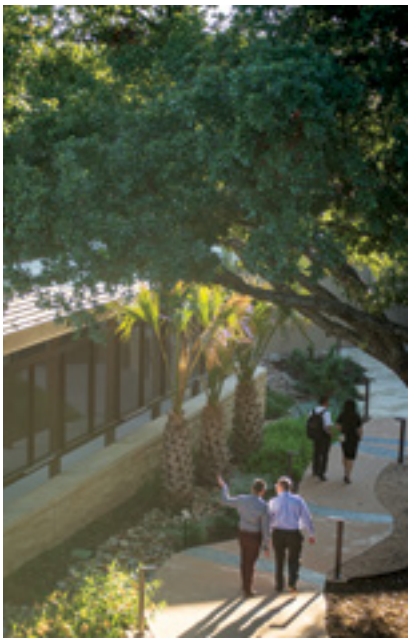
As anticipated, the new viewing area was immediately successful among researchers and the public. The new core-layout tables will play a big role in helping the Austin CRC strive for excellence in service and value for years to come. To learn more about the Bureau's Austin CRC facility and core-viewing opportunities, please contact nathan.ivicic@beg.utexas.edu.

Dick Stoneburner Scott Tinker

After many months of construction, the Bureau's Stoneburner Family Rock Garden opened to the public in 2019. The unique educational and social space lies between the Bureau's new Core Research Facility and the Core Research Center. The 4,000-ft^2 rock garden is the creation of Associate Director **Jay Kipper**, researcher **Chris Zahm**, Warehouse Supervisor **Nathan Ivicic**, Director **Scott Tinker**, and donor Dick Stoneburner.

The garden includes 14 unique features, including the Groundwater of Texas Fountain, the 80-ft-long Western Face of the Guadalupe Mountains Wall, the Rivers across Texas Walkway, and 11 massive rock specimens from across the state. Viewed from above, the rock garden aligns with a section of the Bureau's geologic map of Texas, and each rock specimen is located in its relative area of origin.

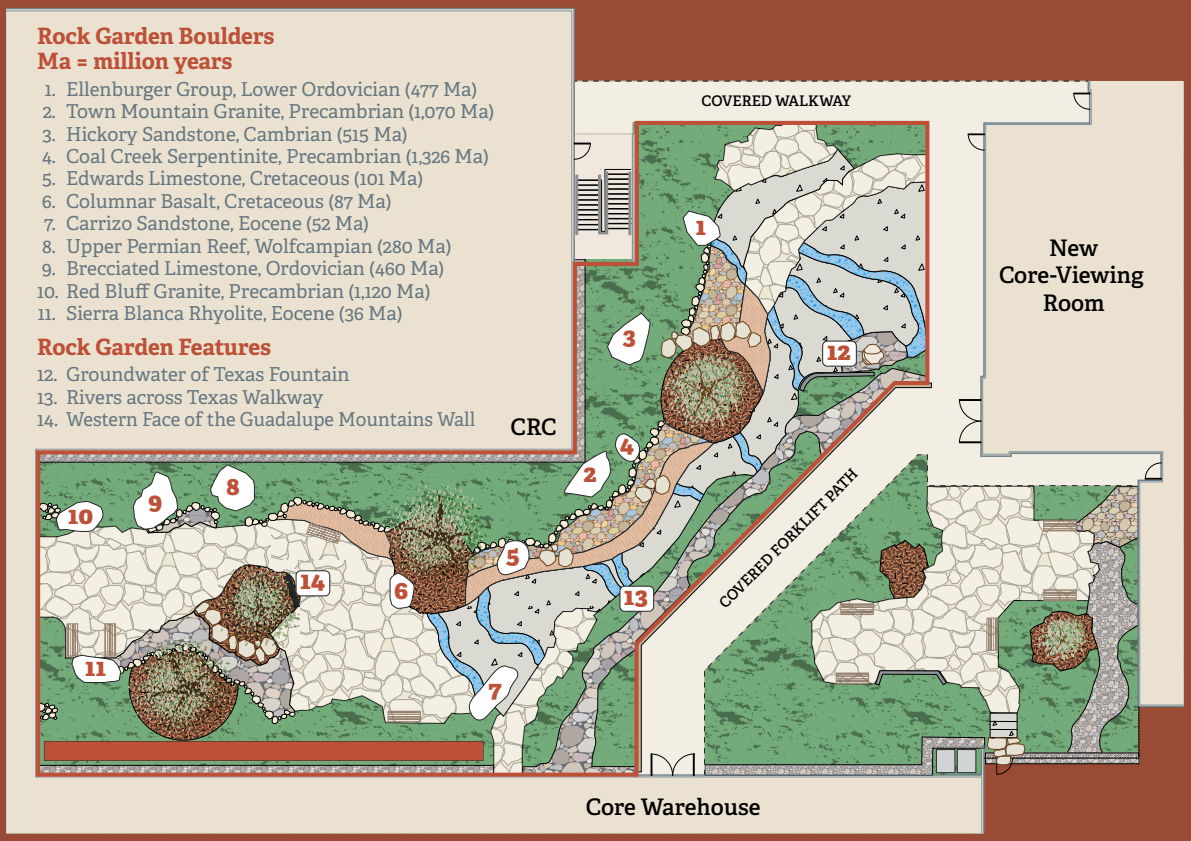
The distinctive boulders—the heaviest weighing nearly 7 tons—were selected for their diversity of rock type, significance to Texas resources and geologic history, and regional origin. Rock types include excellent examples of Precambrian Red Bluff and Town Mountain granites, Cambrian Hickory Sandstone, faulted Ordovician limestone, Cretaceous carbonate-reef Edwards Limestone, Upper Cretaceous columnar basalt, and Lower Oligocene Sierra Blanca Rhyolite. Visitors can hear full audio descriptions in 11 different languages of the history and significance of each rock type and feature by accessing the Bureau's rock garden website with the QR code at each feature's location.



The rock garden offers relaxing and educational respite from the Texas sun, with naturally shaded seating for visitors and staff.

Stoneburner Family Rock Garden Opens to Public

Goundwater of Texas Fountain



Upgraded Labs Usher in New Chapter in Bureau Research

A goal of the new Core Research Facility project was the complete renovation of the Bureau's laboratories. This renovation not only enhanced the building's appearance but also upgraded the labs to state-of-the-art functionality. The results will impact years of future energy and environmental research. Eighteen labs were renovated.

1. Applied Geodynamics Physical Modeling
2. Core Sawing and Processing
3. Experimental Fracture Diagenesis
4. Fluid-Inclusion Microscopy and Microthermometry
5. Geochemistry
6. Hydrology
7. Inorganic and Stable-Isotope Geochemistry
8. Marine Seismic
9. Micro-Model
10. Nanogeosciences
11. Nano-Metrology (VSM)
12. Organic Geochemistry
13. Porosity, Permeability, and Pore-Scale Processes (P4)
14. Rock Mechanics
15. Scanning Electron Microscope (SEM)
16. Sedimentary Analysis
17. Soil Characterization
18. Wet Chemistry

Scanning Electron Microscopy Lab

Priyanka Periwal

The Scanning Electron Microscopy (SEM) Lab uses high-resolution field-emission (FE) SEMs to characterize rocks. The high-magnification and imaging capabilities of FE-SEM, combined with energy-dispersive X-ray spectroscopy and cathodoluminescence techniques, aids in identifying mineralogical composition, textures, pore-system architecture, and microfractures in rocks. Characterizing rocks enables better understanding of the geological processes and conditions in hydrocarbon reservoirs. It also provides insights into diagenesis, depositional environments, fracture systems, and hydrocarbon accumulation in reservoirs.

Sample preparation is critical to high-resolution microscopy, and the lab is researching new methods for approaching this step. One method pioneered by the lab uses Ar-ion milling on rocks, which allows nanopores to be viewed. A discussion of this method has been one of the lab's most cited publications.

The SEM lab is one of the premier labs in the country for both shale and microfracture systems. Its members are excited to employ the capabilities of FE-SEMs in exploring and addressing lithologic challenges in the oil and gas industry.

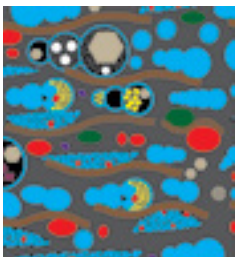
Core-Scanning Lab

Toti Larson

The Core-Scanning Lab consists of the Isocore Mass Spectrometry Facility and the X-ray Fluorescence Scanning Lab. Collectively, these labs focus on making high-resolution elemental, stable-isotope, and rock-mechanics measurements from geological core. Researchers in the Mudrock Systems Research Lab and Reservoir Characterization Research Lab consortia use these data to better understand depositional systems and to identify the centimeter- to meter-scale heterogeneities that exist in cores from carbonate, mudrock, and clastic systems. **James Evan Sivil**, a research science associate, and **Toti Larson**, a research associate, maintain and develop new methods of analysis for core characterization. Using data analytics and Core-Scanning Lab data, researchers build high-resolution mineralogical models and tie key core characteristics to wireline logs from upscale core measurements on an interwell scale.

Fluid-Inclusion and Experimental Fracture-Diagenesis Labs

András Fall



The Fluid-Inclusion Lab includes a FLUID, Inc.–adapted, USGS-type, gas-flow heating/cooling stage and a Linkam THMSG 600°C programmable heating/cooling stage, used on an Olympus BX51 optical microscope fitted for use with transmitted, reflected, and UV light and coupled with a digital camera and imaging software. Microthermometry of fluid inclusions performed in this setting provides valuable information on the temperature, pressure, and composition of fluids trapped as inclusions during host-mineral growth or sealing/healing of microfractures formed during or after mineral growth, along with their subsequent history.

The hydrothermal experimental system used in the Experimental Fracture-Diagenesis Lab consists of six externally heated, cold-seal pressure vessels with operation-temperature and -pressure conditions of up to 800°C and 350 MPa. The lab creates synthetic fluid inclusions in quartz and performs experiments on quartz-cement growth in artificial fractures to explore (1) the interaction between fracture opening and fracture-cement precipitation, (2) growth interactions between host rock and mineral cement, and (3) how these interactions affect patterns of fracture aperture and cement textures. Observations provide calibration for the lab's diagenetic and geomechanical numerical-model efforts, guidance for interpreting fracture-cement patterns such as crack-seal and euhedral cements, and constraints on rates and durations of fracture cementation.

Organic Geochemistry Lab

Tongwei Zhang

The Organic Geochemistry Lab studies hydrocarbon chemistry and source-rock properties. The lab is able to identify and quantify 18 gas components; extract oil from organic-rich shales; identify and quantify liquid hydrocarbon using gas chromatography–mass spectrometry (GCMS); analyze source rocks for surface area, pore volume, and pore-size distribution; and observe gas-adsorption isotherms at high-temperature, high-pressure subsurface conditions Lab equipment includes two custom-built, high-pressure, pure-gas adsorption/desorption systems; an Agilent 7890A gas chromatograph; a custom rock-crusher sample cell and Spex SamplePrep 800M Mixer/Mill for use with a GC system; a Shimadzu GCMS-QP2010S GCMS; a Foss Soxtec 2043 extraction unit; and a Quantachrome Autosorb iQ-MP physisorption analyzer capable of monitoring pores from 0.35 to 300 nm in diameter. These instruments allow detailed characterization of gas and liquid hydrocarbons and source-rock pores.

The organic-rich shale formations the lab has been investigating include the Barnett Shale; the Bakken Shale; the Eagle Ford and Green River Shales; the Longmaxi Shale; the Vaca Muerta Formation; the Woodford Shale; the Wolfcamp and Bond Springs in the Permian Basin; and the Yangchang Formation. **Tongwei Zhang**, a research scientist at the Bureau, is interested in exploring the differences and similarities among these shale systems. Recently he has had the chance to investigate the heterogeneity of produced oil from unconventional reservoirs (Eagle Ford, Austin Chalk, and Wolfcamp). He enjoys applying an advanced molecular-level understanding to reservoirs on a geological scale.

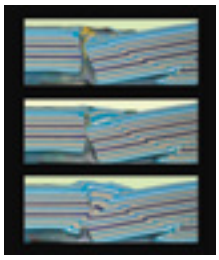
Aqueous Geochemistry Lab

Pat Mickler

The Aqueous Geochemistry Lab provides a dedicated clean space for preparation and analysis of water samples separate from areas in which rock and soil samples are processed. A dedicated clean space for water-sample preparation ensures low chemistry blanks and increases confidence in analytical results as well. Lab equipment includes two ion-chromatograph machines used to analyze major cation and anion compositions of natural waters and aqueous solutions produced in lab water–rock-interaction studies. A high-pressure, high-temperature autoclave is also used for water–rock-interaction studies, and a carbon analyzer is used in dissolved-inorganic-carbon analyses of waters. A deionized water machine is employed in sample dilutions and reagent preparation, as are analytical scales for sample dilution and a fume hood for safe reagent storage and preparation.

Applied Geodynamics Lab

Tim Dooley



The Applied Geodynamics Lab (AGL) is dedicated to producing innovative new concepts in salt tectonics in sedimentary basins worldwide. AGL attempts to understand salt tectonics using three complementary approaches—geologic studies (seismic and fieldwork based), physical models, and a variety of numerical modeling approaches. AGL physical modeling is conducted in the Salt Modeling Labs based in the newly renovated Core Research Center. Since 2003, **Tim Dooley**, a senior research scientist at the Bureau, has run and maintained the modeling labs. Physical models facilitate study of the processes by which salt structures form and how these structures are affected by changing conditions as the salt-bearing basin evolves. With physical models, the parameters can be varied systematically in order to assess their impact on the evolution of salt structures that we see in our geologic studies from locations such as the Gulf of Mexico, the North Sea, the Zagros Mountains in Iran, and the salt-bearing basins in the South Atlantic. After recent renovation, the Salt Modeling Labs have seen a great increase in floor, storage, and worktop space that helps ensure a smoother, safer workplace.

Unconventional Petrophysics Lab

Sheng Peng

The petrophysics of unconventional reservoirs, unlike the well-established petrophysics of conventional reservoirs, requires unconventional techniques. The Unconventional Petrophysics Lab (UPL) develops and applies innovative laboratory, imaging, and analytical techniques for more-accurate and more-reliable measurement and characterization of matrix porosity, permeability, relative permeability, and wettability in unconventional reservoir rocks. These include mudrock/shale and very fine grained sandstones or carbonates that have a dominant pore size at the submicron/nanometer scale and permeability at the nano- to microdarcy scale. The UPL also investigates multiphase fluid flow in the process of hydrocarbon production from unconventional reservoirs by using an understanding of fundamental parameters in the context of real-world problems, such as causes of high percentages of produced water, optimal strategies for completion, and enhanced oil recovery.

We founded the UPL in 2015 and have been building its credentials ever since. We now have nine papers that were published in leading petroleum engineering and geoscience journals, and one provisional patent. Members of the UPL are excited about the lab's capacity and applicability in solving present and future challenges of hydrocarbon production in unconventional reservoirs.

Tinker Shares Global Energy Message

Dr. Scott Tinker and the Switch team spent 8 days in the indigenous Arhuaco village of Gunchukwa in Colombia, and brought their first electricity in the form of a 3.5 kW solar microgrid to power light bulbs and ceiling fans in the mud huts at the village center. Here, in an early-morning ritual with village leaders and families, Scott is helped with hand washing. Gunchukwa is featured in Scott's new film on energy poverty, *Switch On*, created with Director Harry Lynch.

Bureau of Economic Geology Director **Scott W. Tinker** has been tremendously busy during his 2019 sabbatical from the Bureau. In addition to traveling the world to film a new documentary that addresses energy poverty, he has also been raising awareness of the dire global energy-poverty situation via keynote addresses at meetings and conferences to various audiences that include Advanced Placement Environmental Science and National Energy Education Development Project teachers; attendees of the recent Offshore Technology Conference and of the Association of International Petroleum Negotiators Summit; and groups at PricewaterhouseCoopers, Apache Corporation, and BHP. Over the past year, Tinker has shared his crucial energy ideas through some 40 keynote and invited lectures to over 9,000 people.

Tinker's basic message to these groups is straightforward: "Energy transition is often described as the switch from carbon-based fuels to noncarbon fuels. Yet global reserves and production of oil and natural gas continue to grow, and energy demand continues to increase with population and industrialization. It is not the fuels per se that are the problem, but, rather, the atmospheric emissions and, more broadly, the impacts of all forms of energy, at scale, on land, water, and local air. And there is more to the energy transition than just environmental impact. One-third of the global population lives in various states of energy poverty. The real energy transition will happen when humans are lifted from energy poverty; environmental impacts to land, water, and local air are reduced; and greenhouse gas emissions decline. Rather than creating the false political dichotomies of 'good and bad,' 'clean and dirty,' it is vital that the energy dialogue seek compromise and nonpartisan convergence on workable solutions, which will vary by country and region. The good news is such solutions exist."

SWITCH ENERGY ALLIANCE

https://switchon.org/films/

News and Events

New Memorandum Furthers Bureau Research in China

Seated: Ty Helpinstill, associate director, Office of Industry Engagement, UT Austin; and Xingyang Zhang, director, Department of International Affairs, RIPED. Standing, from left to right: Hongliu Zeng, Bureau senior research scientist/geophysicist; Dan Jaffe, vice president for research, UT Austin; Longxin Mu, vice president, RIPED; and Mark Shuster, acting director, Bureau of Economic Geology.

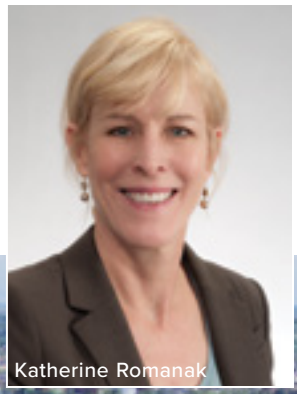
A new memorandum of understanding (MOU) between The University of Texas at Austin (UT Austin) and PetroChina's Research Institute of Petroleum Exploration and Development (RIPED) will expand research opportunities for Bureau of Economic Geology scientists in several key areas. The MOU is another in a series of important research agreements among the Bureau, RIPED, and other PetroChina affiliates, which have collaborated for more than 10 years on multiple studies across China. The MOU reaffirms the strong relationship between the Bureau and RIPED with the intent to develop new collaborative research.

Vice President Mu and Acting Director Shuster

A RIPED delegation, led by the institute's Vice President Longxin Mu, visited the Bureau in 2019 to finalize the MOU, which calls for technical exchange and cooperation in the field of oil and gas exploration and development. Signed during the visit was a sponsored research project agreement for Bureau researchers to study marine carbonate seismic sedimentology in the Tarim Basin of China.

The RIPED delegation expressed strong interest in joint future research over the next 5 years and beyond in seismic sedimentology, fine-grained sedimentation in lacustrine basins, carbonate reservoirs, deepwater clastic reservoirs, fractured-reservoir simulation, and hydraulic fracturing.

Romanak Leads Joint Trinidad and Tobago CCS Initiative


Katherine Romanak

Trinidad and Tobago derives nearly 40 percent of its economy from oil and gas production, although output has fallen in recent years. The new university partnership will work with refineries and other industries not only to create a new workforce to capture emissions and reduce greenhouse gases, but also to create a blueprint for similar efforts worldwide. Photo: Derrick Midwinter.

Katherine Romanak, a research scientist with the Bureau's Gulf Coast Carbon Center (GCCC), is leading efforts in a partnership with two Caribbean universities to create a sustainable program for carbon capture and storage (CCS) in Trinidad and Tobago. The collaboration seeks to build an economically viable program to reduce the nation's greenhouse gas emissions while offsetting recent declines in oil and gas production and exports, the nation's largest economic resources. If successful, the partnership will provide a blueprint for similar efforts throughout the region and around the world.

Through The University of Texas at Austin and UT's Jackson School of Geosciences, the GCCC is teaming with The University of Trinidad and Tobago and The University of the West Indies on the new research effort. In February and April, the universities signed two memoranda of understanding that established plans for organizing scientific meetings and workshops and for sharing facilities, with the objective of deploying CCS technology in Trinidad and Tobago. The initiative was largely facilitated by Romanak in collaboration with Tim Dixon, manager, IEA Greenhouse Gas Research and Development programme (IEAGHG).

The GCCC and Romanak have been key in the development of carbon-storage technologies and research efforts worldwide, with major projects in the Gulf of Mexico, Australia, and Japan. Romanak has also played an active role in CCS initiatives through the United Nations Framework Convention on Climate Change.

GCCC Hosts Annual Summer Sponsor Meeting

In August, the Gulf Coast Carbon Center (GCCC) research consortium held its annual summer sponsor meeting at the Bureau's Houston Research Center, inviting a variety of stakeholders to engage directly with researchers and learn more about carbon capture and storage technology.

GCCC studies carbon capture and storage and ways to facilitate the reduction of carbon dioxide atmospheric emissions. Industrial Affiliates (IAs) of GCCC provide valuable insight into industry practices, including economic and geotechnical strategies, and inform focus on the most relevant and applied research for commercial adoption of carbon capture and storage technology.


Sue Hovorka, PI, GCCC

GCCC is supported in part by an IA program, which consists of industry giants like BHP, BP, Chevron, Equinor, ExxonMobil, NRG Energy, Petra Nova, Shell, and Total. IA funding is matched with large, often multimillion-dollar, grants from federal and state agencies—most notably the U.S. Department of Energy—that support projects such as the Gulf of Mexico Partnership for Offshore Carbon Storage (GoMCarb).

In addition to the sponsor meeting, GCCC held an open house for all industry regulators, executives, and nonprofit workers, regardless of financial affiliation, interested in learning more about carbon capture and storage technology and its application. GCCC also conducted a poster session detailing topics of GCCC's 5-year "Big Plan," an aspirational outline of the consortium's five major research themes: (1) carbon capture, use, and storage ecosystem; (2) preparing for large-volume storage; (3) real-world leakage assessment; (4) "the U in CCUS" (utilization); and (5) monitoring the life cycle.

GCCC sponsor meetings are held biannually, in the summer and in the winter. Winter meetings are held in conjunction with UT Austin's Department of Chemical Engineering.

Mohsen Ahmadian (left) and Lucie Costard (right) log a test well assessing electromagnetic fracture-mapping technology.

Bureau Awarded $1.5 Million to Study Remote Monitoring of Hydraulic Fracture Networks

The Bureau of Economic Geology has been awarded a $1.5 million grant by the U.S. Department of Energy (DOE) to build on previous research by its Advanced Energy Consortium into real-time remote monitoring of hydraulically fractured networks. The goal of the funded project is to create a more efficient and accurate process to characterize the subsurface in real time following hydraulic fracturing operations.

Hydraulic fracturing has evolved into a sophisticated, multistep process that differs from well to well. Operations use varying flow rates, fluids, and proppant amounts and sizes. Current tools, such as microseismic and tiltmeter monitoring, can provide information on fracture extent but provide little or no information on the movement and final distribution of proppants or production fluids.

Project manager **Dr. Mohsen Ahmadian** and his team will build on previous research at the Bureau's Devine, Texas, Intermediate-Scale Field Test Lab to address the DOE's interest in hydraulic fracture mapping and characterization. Ahmadian reports that the goals of the project are to (1) investigate the feasibility of using electromagnetically active proppants (EAP) to demonstrate remote monitoring of relative changes in subsurface geochemistry and pore pressure, (2) advance development of electromagnetic imaging tools to achieve the first objective in near real time, and (3) assess a multiphysics joint inversion package for prediction of changes in flow patterns and physiochemical changes within an EAP-filled hydraulic fracture network.

This DOE-funded project is expected to prove the feasibility of a near-real-time electromagnetic mapping technique for remote monitoring of relative changes in geochemistry and pore pressure. The methods developed and demonstrated during this study will lead to a better understanding of the extent of proppant-filled fracture networks, the stress state of formations, fluid leak-off and invasion, and the characterization of engineered fracture systems in near real time. These are critical data for the efficient production of hydraulically fractured reservoirs. The comprehensive data set collected in this study will be disseminated to the public, laying the foundation for the advancement of additional geophysical fracture-mapping and modeling techniques. After results are analyzed, the team hopes to make the Intermediate-Scale Field Test Lab available as a benchmarked field lab and to collaborate with other scientists interested in this research.

TexNet and CISR Provide New Insights in Fort Worth Basin Earthquake Study

Recent research results from the TexNet Seismic Monitoring Network and Center for Integrated Seismic Research (CISR) provide new insights into the potential for earthquakes in the Fort Worth Basin in north-central Texas. Working with researchers from Stanford and SMU, Bureau researchers have created a comprehensive map of more than 250 faults totaling more than 1,800 miles in length in the region. Among the conclusions of the study is that the majority of faults underlying the Fort Worth Basin are as sensitive to variations in stress that might cause them to slip as those that have produced earthquakes in previous years. The region experienced a significant increase in seismic activity from 2008 through 2015 as energy production ramped up, and a reduction in earthquakes in recent years, as production activity slowed.

Said CISR principal investigator **Peter Hennings**, "We certainly haven't identified all of the faults in the region, but this new work is a big improvement over what was previously available." Published in the July 23, 2019, *Bulletin of the Seismological Society of America*, the new study concludes that left undisturbed, the faults are relatively stable. But the potential of the faults to slip, with resultant earthquakes, increases significantly with wastewater injection—a common practice during oil and gas operations—if the process is not managed properly.

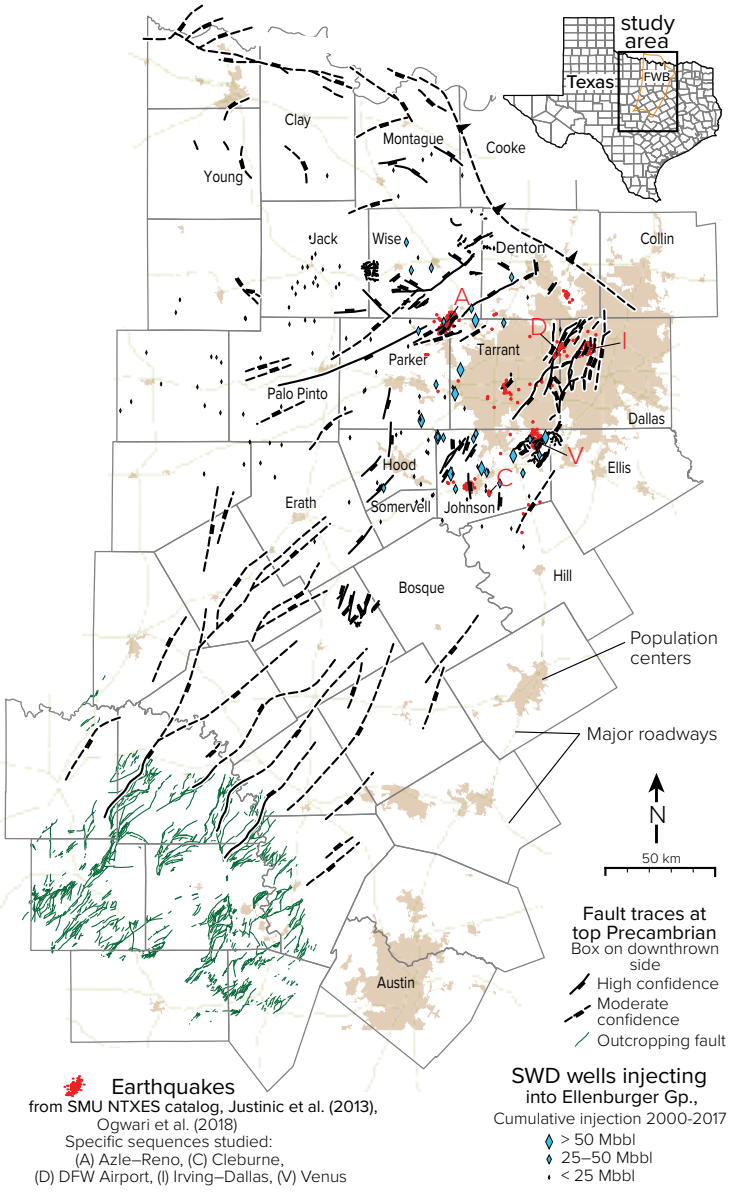
"In 2020, we will be publishing an updated version of the fault map and a comprehensive model that indicates the degree of pressurization that each of the earthquake faults has experienced from wastewater disposal," Hennings said. "Combined with this current work, the future research will give industry and our regulators powerful tools to use in managing the hazard and reducing risk."

TexNet, authorized and funded by the Texas Legislature and Gov. Greg Abbott, has been tracking seismic activity statewide since 2017. Operated and managed by the Bureau, TexNet also provides a public data portal for real-time seismic activity across the state on the TexNet Earthquake Catalog website. CISR is a multidisciplinary consortium of academic and industry partners collaboratively pursuing a wide range of seismicity research topics.

TCCS and Sponsors Meet at Houston Research Center

More than 60 people, including representatives from 8 sponsor companies, attended the Spring Sponsor Meeting of the Texas Consortium for Computational Seismology (TCCS), held at the Bureau's Houston Research Center in April. The meeting was presided over by Bureau postdoctoral fellow **Xinming Wu**.

Nine research presentations by TCCS contributors covered three primary themes: seismic interpretation with deep learning, well-log and seismic data processing with deep learning, and methods from acquisition to processing. Talks included "Automatic Seismic Interpretation: from Conventional to Deep Learning," "Deep Learning for Seismic Imaging," and "Probabilistic Diffraction Imaging." Along with Wu, presenters included **Yunzhi Shi**, **Zhicheng Geng**, **Nam Pham**, **Harpreet Kaur**, **Raymond Abma**, **Luke Decker,** and **Ben Gremillion**.



Map: Peter Hennings, Lily Horne

Mudrock Meeting Held in Austin


Steve Ruppel

The Mudrock Systems Research Laboratory (MSRL), led by PI **Dr. Steve Ruppel**, held its annual meeting for consortium members in April, hosting more than 60 industry geologists representing 14 companies. Over 4 days, members attended 20 oral and 15 poster presentations on the latest research findings in mudrocks. Topics covered a range of subjects, including regional and local stratigraphy, pore systems, petrophysics, hydrocarbon saturation, biomarkers, and flow modeling. A daylong short course provided a more in-depth look at these topics. Core-workshop presentations included cores from the Eagle Ford, Austin, Wolfcamp, and Wolfberry.

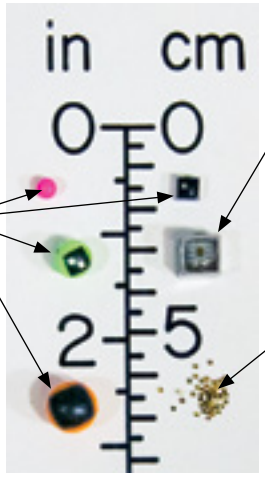
Bureau MSRL presenters included **Robin Dommisse**, **Xavier Janson**, **Farzam Javadpour**, **Toti Larson**, **Bob Loucks**, **Sheng Peng**, **Rob Reed**, **Steve Ruppel**, **Evan Sivil**, **Xun Sun**, and **Tongwei Zhang**. Guest presenters Jonathan Knapp (Bruker Nano, Inc.) and Connor Burt (FEI–Thermo) described how advances in instrumentation are improving our abilities to better measure mudrock attributes.


Scott Hamlin leads core discussion

The mission of TCCS, a joint initiative of the Bureau and the Center for Numerical Analysis at UT Austin's Oden Institute for Computational Engineering and Sciences (ICES), is to address the most important and challenging research problems in computational geophysics confronting the energy industry while educating the next generation of research geophysicists and computational scientists. For more information about TCCS, please contact **Dr. Sergey Fomel**: sergey.fomel@beg.utexas.edu.


TCCS sponsors and team

AEC Nanotech Illuminates Earth's Subsurface



Stacked chip system (5–12 mm) Temp./pressure/time combo. Polymer packaging. Battery 10–40-hr lifetime.

System on a board (8 mm) Temp./pressure/time combo. Steel packaging. Battery 10–16-hr lifetime.

System on a chip (1 mm) Discrete temp., press., resist.; pH thin-film packaging, RF powered (batteryless), 30-yr lifetime.

Testing Activities

Testing sensors

- Report data from within flowlines, and attached to pipeline pigs
- Report temperature and pressure under harsh wellbore conditions

Testing contrast agents

- Track subsurface fluid flow and fracture extent using remote monitoring stations
- Determine downhole cement integrity

Testing of AEC payload delivery nanocapsules

- Delay release of acid for mudcake remediation and matrix acidification

Over the past 11 years, the Advanced Energy Consortium (AEC) has guided the creation of an entirely new area of research: nanotechnology applications that illuminate Earth's subsurface. AEC member companies have invested over $50 million in this research, and over 40 patents have been generated by researchers from universities across the globe. Three practical AEC applications, or use cases, are on track for commercialization and benefit to member organizations and the industry: sensors, contrast agents, and payload delivery systems. AEC has developed viable prototypes in each of these areas, which are being handed off to member organizations for further field testing and, eventually, manufacturing at industry scale.

Tiny AEC computerized sensors are now sophisticated enough to report downhole temperatures and pressures under real-world conditions using several data-transfer methods, and their battery life has been extended exponentially over the past few years. AEC contrast agents help to map fracture patterns, fluid flow, and reservoir extent. Nanoscale electromagnetic proppants were recently validated as effective at mapping the extent of a hydraulic-fracturing operation during a field test in South Texas. AEC payload-delivery systems have been developed to transport various chemicals within tiny capsules that open and release their cargoes with time delay or under predetermined conditions, such as higher temperatures.

For more information about the Advanced Energy Consortium and how to join, contact project managers david.chapman@beg.utexas.edu (512-475-9563) or mohsen.ahmadian@beg.utexas.edu (512-471-2999).

STARR Eastern Shelf Permian Basin Research

In 2019, State of Texas Advanced Resource Recovery (STARR)'s regional study of the Eastern Shelf of the Permian Basin addressed the complex relationships that exist among Pennsylvanian stratigraphy, depositional systems, and tectonics and their controls on sediment-delivery systems and reservoir distribution in this mature and prolific region on the U.S. southern Midcontinent.

STARR is continuing its earlier regional study of the southern part of the Eastern Shelf, published previously in Bureau Report of Investigations No. 282. In 2019, the STARR research team extended its scope of study to include a variety of stratigraphic intervals, including Cambrian sandstones, Ellenburger carbonates, the Bend Conglomerate, mixed Caddo carbonates and clastics in the Strawn Group, and younger units such as Canyon carbonates, deepwater slope sandstones in the Cisco Group, and incised valley-fill deposits of the Tannehill Sandstone of the Cisco Group.

In 2019, the STARR team presented aspects of its Eastern Shelf research at the annual meeting of the Southwest Section of the American Association of Petroleum Geologists in Irving, Texas. These presentations focused on lowstand, incised valley-fill systems in the Tannehill Sandstone in Nolan, Taylor, Runnels, and Coke Counties, and a regional overview of outcrop-to-subsurface linkages in the Canyon and Cisco Groups.

For 2020, STARR has organized a special symposium on the Eastern Shelf of the Permian Basin for the annual meeting of the South-Central Section of the Geological Society of America in Fort Worth. Topics include (1) regional maps of deltaic deposits, relationships between coastal-shelfal tidal siliciclastic systems and ramp carbonates, and carbonate diagenesis in the Strawn Group; (2) autocyclicity in deepwater, slope-channel systems and their controls on reservoir heterogeneity in Lake Trammel South field in the Cisco Group; and (3) relative controls of tectonics, basement structure, sediment supply, and eustasy on sediment-delivery systems in the Cisco Group.

Results of STARR's Eastern Shelf research will lead to a better understanding of hydrocarbon-reservoir distribution on both local and regional scales, providing an improved exploration framework for oil and gas operators in the Permian Basin, currently the most productive basin in the United States.

For more information about the STARR Consortium and how to join, contact Principal Investigator william.ambrose@beg.utexas.edu.

Mark Mills, Manhattan Institute

3E Research Symposium Highlights Breadth of Bureau Science

Industry and agency representatives from organizations large and small recently gathered at the Bureau of Economic Geology for its first 3E Research Symposium. The day of information sharing and networking illustrated how the Bureau's innovative research stems from the confluence of energy, the environment, and the economy—the "3E's."

The day's keynotes included thought-provoking talks by physicist and energy theorist Dr. Mark Mills of the Manhattan Institute; Dr. Jim Reilly, director of the U.S. Geological Survey; and Bureau Director **Dr. Scott Tinker**, whose luncheon keynote touched on his current work addressing global energy poverty.

USGS Director Jim Reilly and Bureau Director Scott Tinker

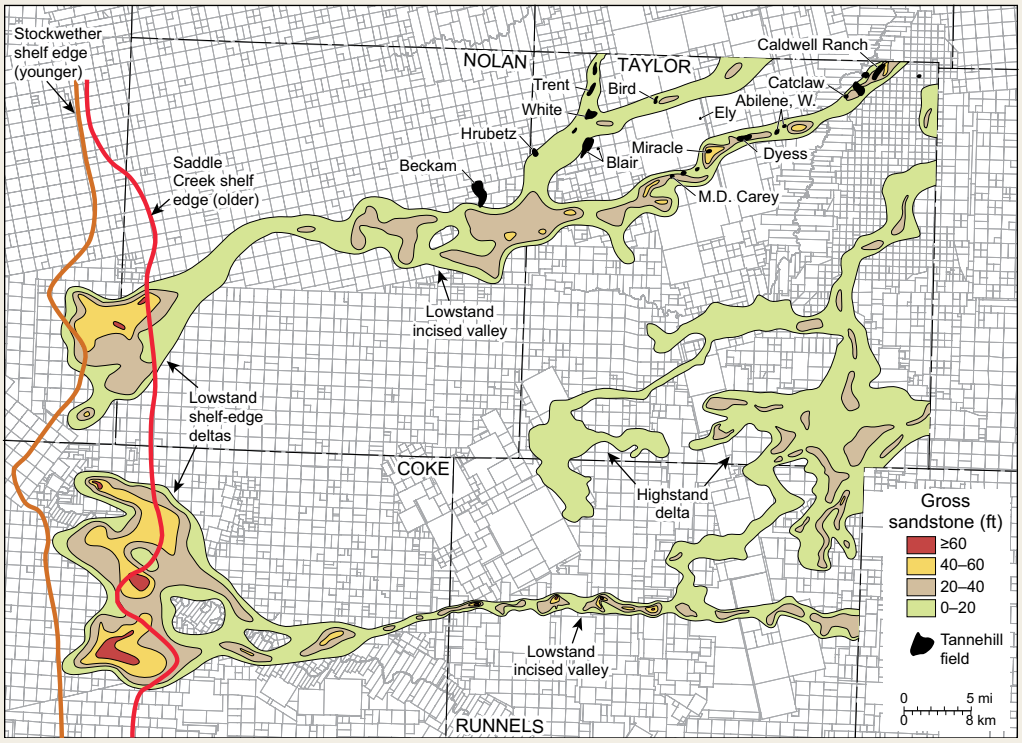
Bureau researchers impressed guests with presentations of their groundbreaking research. Breakout-session topics included the Delaware Basin, carbon capture and storage, water resources, and analytics and modeling applications. Individual talks covered intriguing subjects ranging from mudrocks to clastics, Alaska initiatives to subsurface nanotechnology, and earthquake studies to energy economics.

Research poster presenter, Roxana Darvari

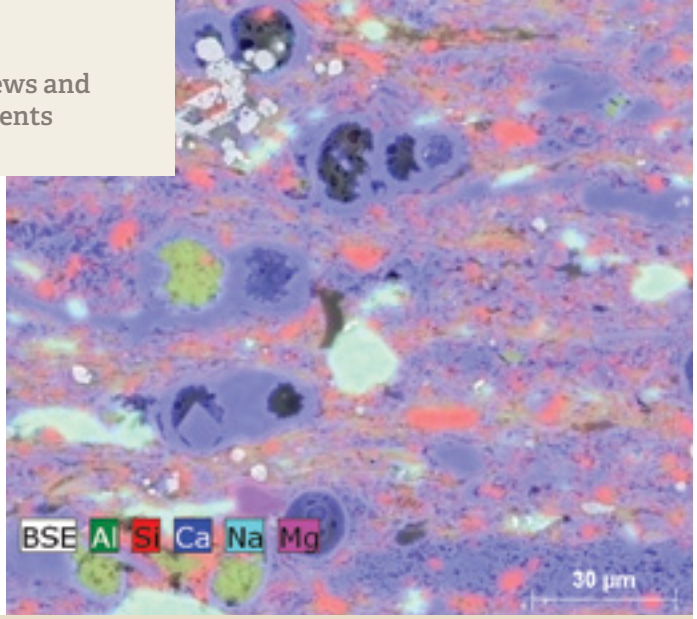
Research posters, created and displayed by Bureau researchers and students to share recent projects, allowed symposium participants to ask in-depth questions and discuss key issues directly with the research authors.

The 3E Research Symposium achieved its objective of bringing people from varied organizations together to learn about and discuss the broad array of environmental, energy, and economic research being successfully undertaken at the Bureau.

STARR's gross-sandstone map of the Tannehill Sandstone of the upper Cisco Group, depicting two primary lowstand, incised-valley systems and their genetically associated lowstand, shelf-edge deltas. A Tannehill highstand, fluvial-deltaic system occurs in the east-central part of the map area. Although occurring at a slightly higher stratigraphic level, this highstand sandstone is part of the overall Tannehill stratigraphic zone.



Map: Tucker Hentz



SEM image showing an Ar-ion-milled surface of the Eagle Ford Shale; image has been color coded to show elemental composition. Note the relatively large pores in the dark-gray organic matter partially filling the foraminifera.

SEM Technologies Reveal New Insights in Rock Properties

The Bureau has long been at the forefront in the use of the scanning electron microscope (SEM) for the detailed characterization of rocks, and the two SEMs in its Scanning Electron Microscopy Lab are making discoveries at the nano scale.

The lab's Zeiss Sigma microscope is a high-resolution SEM with automated, large-area mapping capability for all its detectors, which makes it attractive for many applications. Outside users are interested in many of its capabilities and have varied interests (element mapping of meteorites, biofilms in speleothems, zoning on overgrowths in zircons, titanium concentrations in quartz grains, and defect density in nanofilms for superconductors). From the Bureau, the Fracture Research and Application Consortium (FRAC) is the main user of the Zeiss Sigma. FRAC uses SEM imaging to elucidate the interaction between deformation and diagenesis in both outcrop and subsurface rocks. It focuses on identifying processes that systematically create and destroy fracture porosity and affect fracture size and distribution.

Two techniques using the FEI Nova NanoSEM have yielded significant new insights into mineralogical composition, rock textures, pore-system architecture, and microfractures in rocks. Using this high-resolution field-emission SEM combined with energy-dispersive X-ray spectroscopy and cathodoluminescence methodologies, Bureau scientists are gaining valuable new insights into depositional environments, diagenesis, fracture systems, and the geological conditions, processes, and resource distribution in hydrocarbon reservoirs. Enhanced by Bureau research, these two SEM processes have significantly impacted shale studies by illuminating rock characteristics imperceptible using traditional SEM technologies. The first, a process known as argon-ion milling, shaves an extremely thin layer off of a sample of shale, making it clean and smooth for more-accurate SEM imaging of the surface. The resulting image reveals shale pore structures clearly for the first time and enables researchers to better understand rock properties.

The second process, known as element mapping, makes it possible to see where rock pores are in relation to the mineral phases of shales. This relationship characteristically varies in different rocks, so pore location provides key information regarding the various stages of maturation in different rock types. Recent research has demonstrated the benefit of this method in identifying magnesium in shale samples. X-ray fluorescence interpretations alone could not distinguish whether the mineral hosting the magnesium in the sample was chlorite or dolomite, but when false color was assigned to magnesium and added to an SEM image of a sample, the mineral hosting the magnesium could be easily seen and identified. This interpretation method has significant implications at a variety of scales, from microfractures, to fluid-flow studies, to reservoir characterization. The SEM Laboratory is a tremendous resource for the continuing study of the intricacies of rocks and rock processes at microscopic scale.

Will Shuster—*Ghost Ranch County*, 1960.

What is a "Rainmaker"?

The origin of the term "rainmaker" stems from Native American and other indigenous peoples' ceremonies and dances performed to bring rain for crops where the spiritual or tribal leaders were perceived to be able to modify weather through ritual. The use of the term evolved to describe leaders in companies and organizations that bring business and revenue into an organization.

For the Bureau, an institution funded largely by external grants, contracts, and consortium sponsorships, rainmaking in the business sense is essential for success. The purpose of the Rainmakers' Dinner is to recognize the efforts of those that have been critical in securing significant levels of funding in the previous fiscal year. The individuals honored made it rain in various ways through different grants, contracts, and consortia. As a result, they have benefited their research programs and projects—and the whole of the Bureau.

The Bureau honors the following rainmakers:

Mohsen Ahmadian	Jay P. Kipper	Katherine Romanak
William A. Ambrose	Stephen E. Laubach	Alexandros Savvaidis
David T. Chapman	Robert G. Loucks	Bridget R. Scanlon
Jacob A. Covault	Tip Meckel	Mark W. Shuster
Bill Fairhurst	Jean-Philippe Nicot	Scott W. Tinker
Sergey B. Fomel	Maria Nikolinakou	Ramón H. Treviño
Peter H. Hennings	Iulia Olariu	Michael H. Young
Susan D. Hovorka	Jeffrey G. Paine	Christopher K. Zahm
Xavier Janson	Sheng Peng	Hongliu Zeng
Charles Kerans	Ellen M. Rathje	Tongwei Zhang

Seismic Monitoring Program Links Some West Texas Earthquakes to Hydraulic Fracturing

TexNet seismometers placed throughout the state, like this one in Dallas, monitor seismic activity across Texas.

A new study by scientists of the TexNet Seismic Monitoring Program shows that some of the recent earthquake activity in the Delaware Basin of West Texas may be related to hydraulic fracturing.

TexNet and the Center for Integrated Seismicity Research (CISR) have conducted a number of studies on induced seismicity (earthquakes possibly caused by human activity).

"The research done through this new study in West Texas, using a statistical approach to associate seismicity with oil and gas operations, suggests that some seismicity is more likely related to hydraulic fracturing than saltwater disposal," said **Alexandros Savvaidis**, a research scientist and manager of the TexNet Seismic Monitoring Program.

Hydraulic fracturing is an industrial operation in which large amounts of fluid and sand are injected into rock formations under pressure to fracture the subsurface rocks and release hydrocarbons so they can be recovered and refined into oil or natural gas. The Delaware Basin is a part of the Permian Basin, a prolific oil- and gas-producing province that has seen a significant rise in exploration and production during the past few years. The Permian Basin now produces more than 5 million barrels of oil per day, oil production that is vital to the energy security of the United States.

Hydraulic fracturing has been linked to seismicity in other areas—Oklahoma, China, and Canada—but this is the first study to link it to induced seismicity in Texas. Several years ago, when there was an increase in low-level earthquake activity in other areas of the state, the Texas Legislature asked the Bureau and its director, State Geologist **Scott Tinker**, to create an earthquake-monitoring network to determine the causes of these earthquakes and how to minimize any earthquake impacts. With guidance from State government, the oil and gas industry, environmental organizations, and academe, the Bureau began deploying the network. With State funding, TexNet now consists of 82 broadband seismometer stations, which supplement 18 stations that existed throughout the state before TexNet was created in 2015.

"TexNet and CISR will continue to work very closely with Texas State agencies, especially the Railroad Commission of Texas, which regulates oil and gas activities, the state's oil and gas industry, and many of the state's universities, to share data and information about earthquakes," said **Michael Young**, the associate director of environmental research at the Bureau. "These collaborations help to jointly develop best practices to mitigate potential danger from earthquake activity to citizens or property.

"The Bureau collects high-quality data on earthquakes in Texas, makes all of that data available to the public, and conducts fundamental and applied research to better understand naturally occurring and potentially induced earthquakes and any associated risks," Young said. "This study is an important step in that process."

This paper, "Improving Absolute Earthquake Location in West Texas using Probabilistic, Proxy Ground-Truth Station Corrections," by Anthony Lomax of ALomax Scientific and **Alexandros Savvaidis** of the Bureau, was published October 14 in the *Journal of Geophysical Research: Solid Earth*. This research was funded by the State of Texas through the TexNet Seismic Monitoring Program.

For more information about the TexNet consortium and how to join, contact PI alexandros.savvaidis@beg.utexas.edu.

Leaders in Structural Diagenesis

Structural diagenesis is a new perspective on the interaction of mechanical and chemical processes at high crustal levels in the Earth. Fracture and fault studies rely on primarily structural observations and interpretations based on mechanics, and rigorous structural observations and application of fracture mechanics continue to yield important insights. But, for understanding fractures and faults in the deep subsurface of sedimentary basins (1–10 km), structural geometry and mechanics by themselves provide an incomplete picture. In the presence of reactive fluids like those commonly found at greater depths in the Earth, chemical reactions are an essential consideration. Although sedimentary petrologists typically study chemical reactions that convert sediment to rock—diagenesis—they generally neglect fractures and faults. Structural geologists, on the other hand, typically do not receive intensive training in sedimentary petrology.

Among those leading the way in structural diagenesis research is Bureau Senior Research Scientist **Stephen Laubach**. Laubach, principal investigator for a long-running DOE Basic Energy Sciences (BES) grant on predicting fracture, porosity evolution in sandstone, is a leader of the industry-sponsored Fracture Research and Application Consortium (FRAC). The scope of these projects ranges from the fundamental to the intensely practical, but they share the theme of linked mechanical and chemical processes. In their different ways, both the BES project and FRAC seek to better understand how natural fractures grow in the Earth to improve resource production in oil and gas reservoirs and for other practical applications.

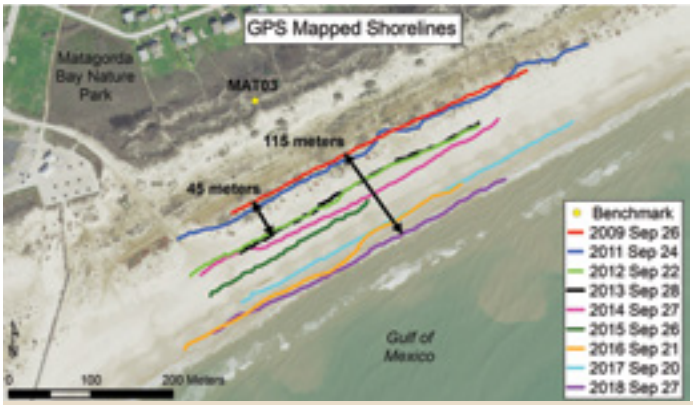
The Bureau's structural-diagenesis community, including **Stephen Laubach, Peter Eichhubl, Julia Gale, András Fall, Esti Ukar, Sara Elliott**, and **Jon Olson**, have been highly productive contributors to the scientific literature.

High School Coastal Monitoring Program Celebrates 23 Years

The Texas High School Coastal Monitoring Program (THSCMP), led by RSA **Tiffany Caudle**, is a research and outreach effort designed to help students living on the Texas coast and their communities develop a better understanding of their natural environment. As participants in a multiyear coastal research project, students enhance their science education and provide coastal communities with valuable data on their changing shoreline. The beach and dune environment provides an ideal setting for teaching students basic and applied science and for illustrating the role that science and good data-collection practices play in public policy decisionmaking.

The THSCMP has created a network of eight coastal schools conducting scientific studies and sharing their observations with other students, schools, and the public. Each school has three field trips per year to survey a shore-normal beach profile from behind the foredunes to the waterline and to map the shoreline and vegetation-line position for change analysis. They also record wind speed and direction; estimate longshore-current speed; record wave direction, height, and period; and take readings of shoreline and foredune orientation.

Since 1997, THSCMP students have monitored changes in beaches, dunes, and vegetation-line position on Bolivar Peninsula, Galveston Island, Follets Island, Matagorda Peninsula, Mustang Island, North Padre Island, and South Padre Island. Data collected by the students have been applied by scientists in investigating impacts and recovery of beach, dune, and vegetation line following several tropical cyclones, including Hurricanes Ike (2008) and Harvey (2017). Data are used to monitor the effects of nourishment projects on Galveston and South Padre Islands, foredune-modification and beach-maintenance practices on Mustang Island, and vehicular traffic and jetty construction on Matagorda Peninsula. All data collected by THSCMP are integrated into past and ongoing Bureau coastal research, including verifying shoreline positions for updates of Texas' long-term shoreline change rates, which are widely used by public officials, corporations, and private citizens. For more information, please visit the program's website at http://www.beg.utexas.edu/thscmp/.



From 2009—2018, shoreline position advanced 115 meters seaward due to entrapment of sediment at the eastern jetty at the Colorado River mouth.

Developments in TORA

The Tight Oil Resource Assessment (TORA) program began over 3 years ago as an industry affiliate program to provide unbiased, independent assessments of U.S. onshore unconventional resource plays. Current focus is the Permian Basin, but the work scope includes the Marcellus, Bakken, Eagle Ford, Fayetteville, Barnett, and Haynesville plays. TORA's mission is "to provide our stakeholders with reliable and up-to-date estimates, projections, models, fundamental understanding, and insights at the basin scale for the major U.S. unconventional plays by conducting innovative, integrated research of in-place resource and recoverable volumes, play/well economics, and production forecasts with their environmental implications." Stakeholders include around 20 sponsors ranging from major integrated energy companies to small independents, utilities, private equity firms, investment banks, national oil companies, and the State of Texas. Key research questions concentrate on the estimation of original oil- and gas-in-place volumes, how much of that is technically recoverable, and how much will ultimately be (economically) produced.

Dr. Emery Goodman joined TORA as project manager and PI in August. With a Ph.D. in Geological Sciences from UCSB, he brings over 32 years of upstream energy experience from ExxonMobil, Shell, and VAALCO Energy, where he worked in a variety of subsurface technical, operations, management, and executive roles.

To answer these questions, TORA has assembled experts in geoscience, petrophysics, reservoir engineering, statistics/data analytics, and economics. This blending of skills; the comprehensive, basin-scale scope of the analysis; and forecasts at the 1-mi^2 scale and analyses of individual wells all combine to set TORA apart from other assessment groups. In 2019, TORA completed a geological model of the entire Delaware Basin and determined that the Wolfcamp A and B and lowermost Bone Spring Formations hold around 560 billion barrels (Bbbl) oil in place, with current work focused on estimating how much of that volume can be recovered. TORA also completed a major revision of its Eagle Ford play analysis, including construction of a new 3D geologic model, with a 30-percent upward revision of the original oil-in-place volume to around 300 Bbbl, with some 14 Bbbl estimated to be technically recoverable.

For more information about the TORA Consortium and how to join, contact PI emery.goodman@beg.utexas.edu.

Jeff Paine (foreground) at the Daisetta sinkhole near Houston in 2008. Photo courtesy of Edward Collins.

GSA Fellowship: Jeffrey Paine

Bureau Senior Research Scientist **Dr. Jeffrey Paine** was made a Fellow of the Geological Society of America by the GSA election council at their spring meeting in May. The GSA Fellowship recognizes "distinguished contributions to the geosciences and the Geological Society of America through such avenues as publications, applied research, teaching, administration of geological programs, contributing to the public awareness of geology, leadership of professional organizations, and taking on editorial, bibliographic, and library responsibilities." Paine was nominated by Bureau Senior Research Scientist and GSA Fellow **Dr. Bridget Scanlon**.

An innovator and pioneer in the application of geophysics to a wide range of environmental and engineering problems—including coastal erosion, groundwater salinization, and land subsidence—Paine employs geophysical and remote-sensing methods to study environmental and engineering issues in the near-surface realm. These practical applications include ground, airborne, and borehole electromagnetic-induction methods; satellite radar interferometry; seismic-refraction methods; and airborne lidar methods.

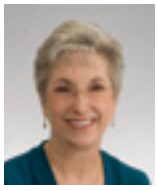
In addition to teaching a UT Austin course in applied hydrogeophysics, Paine has given more than 200 presentations at international, national, and regional meetings and has led conference workshops and technical sessions on topical issues such as hydraulic fracturing, hurricane impacts, and coastal geology. As a lead instructor of the GeoFORCE educational outreach program for high school students, Paine has led 23 field trips to the Pacific Northwest since 2007.

Widely cited, and with 180 articles, reports, and abstracts, Paine has published key research on the depositional record of Quaternary glacial and interglacial cycles on the Texas Coastal Plain. He is also the author or coauthor of 31 open-file maps and more than 90 publicly available technical reports for studies sponsored by Federal and State agencies for which he served as principal or co-principal investigator.

Staff Service Award

Associate Director Mark Shuster and Dena Miller

The winner of the 2019 Bureau Staff Excellence Award, given to administrative and support staff who have made exceptional contributions to the Bureau, is Senior Administrative Associate **Dena Miller**. Dena's outstanding support of the associate directors and focused effort on delivery and improvement of Bureau administrative processes kept the Bureau functioning smoothly.

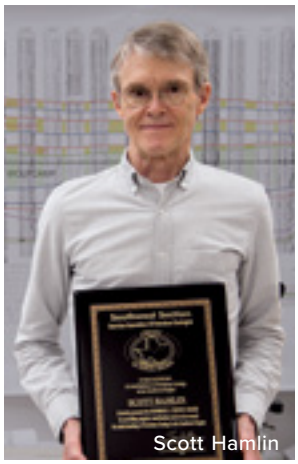


Wanda LaPlante

The winner of the Bureau's 2018 Alumna of the Year award for commitment and impact for one-third of a century went to **Wanda LaPlante**. In her last role at the Bureau, as executive assistant to **Scott Tinker**, he dubbed her, "the ambassador of Bureau hospitality and professionalism!"

Cheney Science Award: Scott Hamlin

Dr. Scott Hamlin was honored with the 2019 Monroe G. Cheney Science Award by the Southwest Section of the American Association of Petroleum Geologists. The award is given "for singular contributions to and achievements in the science of petroleum geology of the southwest region."



Scott Hamlin

Hamlin is an energy geologist and hydrogeologist whose primary research is focused on stratigraphy, depositional systems, and sedimentology. He uses geophysical logs calibrated with well cores and outcrops to construct regional stratigraphies and to map lithofacies for several unconventional oil plays. He has also mapped groundwater aquifers throughout Texas and Louisiana.

Prior Bureau recipients include **Jerry Lucia** (2009), **Bob Hardage** (2006), and **Frank Brown** (1990). Said Hamlin, "To say that I was surprised to receive this award is a huge understatement!"

O. E. Meinzer Award

The Geological Society of America (GSA) Hydrogeology Division has awarded Bureau Senior Research Scientist **Bridget Scanlon** its 2019 O. E. Meinzer Award, which is presented annually to the author or authors of a published paper or body of papers of distinction that advanced the science of hydrogeology or some closely related field.

Scanlon has conducted hydrogeology research in Europe, North America, Africa, and Asia, on topics ranging from karst hydrology to vadose-zone hydrology to groundwater management, at scales from soil ped to subcontinental. Scanlon's selection for the award was based on four highly cited papers that are representative of the scope of her work:

William Cunningham of the GSA

(1) Scanlon, B. R., et al., 2002, Choosing appropriate techniques for quantifying groundwater recharge: Hydrogeology Journal, v. 10, no. 1, p. 18–39.

(2) Scanlon, B. R., et al., 2006, Global synthesis of groundwater recharge in semiarid and arid regions: Hydrological Processes, v. 20, no. 15, p. 3335–3370.

(3) Scanlon, B. R., et al., 2012, Groundwater depletion and sustainability of irrigation in the U.S. High Plains and Central Valley: Proceedings of the National Academy of Sciences, v. 109, no. 24, p. 9320–9325.

(4) Nicot, J.-P., and Scanlon, B. R., 2012, Water use for shale-gas production in Texas, U.S.: Environmental Science & Technology, v. 46, no. 6, p. 3580–3586.

The first two papers helped establish Scanlon as "the leading global expert on groundwater recharge," according to nominator Jack Sharp. Nominator Lenny Konikow noted that the second paper "laid the groundwork for later global analyses based on climate modeling and remote sensing data." The *Environmental Science & Technology* paper was among the first studies to quantify water use for hydraulic fracturing, which is increasingly important in U.S. energy production and is likely to become significant in other countries, particularly China.

Said Scanlon, "I am extremely grateful for my colleagues at the Bureau of Economic Geology, particularly **Bob Reedy**, who has worked closely with me for over 20 years. Within the past 10 years, our research group has begun evaluating the interdependence of water and energy, including energy extraction and electricity generation. I learned from the early work that **J.-P. Nicot** initiated on this topic and enjoyed collaborating with him on many projects related to unconventional energy extraction."

Scanlon also expressed gratitude to Jack Jackson for providing his generous endowment to UT Austin's Jackson School of Geosciences, and to the Fisher Endowed Chair in Geological Sciences for its support. Said Scanlon, "I am very grateful for all the opportunities arising during my career and look forward to continuing much of this work in the future. I greatly appreciate having been given this most prestigious award."

Receiving honors from AAPG (from left to right): Sergey Fomel, Toti Larson, Julia Gale, Steve Laubach, and Reinaldo Sabbagh.

Bureau Researchers Honored at AAPG Annual Convention

At its Annual Convention and Exhibition (ACE), held in San Antonio, Texas, in May, the American Association of Petroleum Geologists (AAPG) recognized a number of Bureau researchers for their accomplishments.

Sergey Fomel received the SEG/AAPG Best Paper in *Interpretation* Journal Award, and **Toti Larson** was among those recognized with the Jules Braunstein Memorial Award for the best poster-session paper presented at the 2018 ACE.

In the AAPG Petroleum Structure and Geomechanics Division, **Julia Gale** and **Steve Laubach** were recognized with Best Recent Publication for 2019 for their paper, "Correlation Analysis of Fracture Arrangement in Space." In the AAPG Division of Environmental Geosciences, **Reinaldo Sabbagh** received the Best Poster Award at the 2019 ACE.

Bureau Acting Director and Associate Director of Energy Mark Shuster (left) presents the 2019 Tinker Family BEG Publication Award to Oliver Duffy, Tim Dooley, Michael Hudec, and Naiara Fernandez.

Fomel and Wu Recognized by SEG

Fomel

Wu

Bureau researchers **Sergey Fomel** and **Xinming Wu** were recognized by the Society of Exploration Geophysicists (SEG) at the group's annual meeting in San Antonio, in September, receiving 2018 Best Paper in *Geophysics* Honorable Mention for "Least-Squares Horizons with Local Slopes and Multigrid Correlations."

Both Fomel and Wu were also selected as SEG lecturers for the coming year. Fomel was named SEG 2020 Distinguished Lecturer and will speak on the topic "Automating Seismic Data Analysis and Interpretation." Wu was selected to be the SEG 2020 Honorary Lecturer for South and East Asia and will speak on "Deep Learning for Seismic Interpretation."

Both scientists have been recognized numerous times by SEG in previous years. Fomel received the J. Clarence Karcher Award in 2001, Top Poster Presentation Awards in 2007 and 2011, and the Conrad Schlumberger Award from the European Association of Geoscientists and Engineers in 2011. Wu received the Best Paper in *Geophysics* Award in 2016 and Top Student Poster Paper in 2017.

Publication Awards

In April, Bureau leaders and researchers held their annual First Author Publication Awards dinner to celebrate another year of influential publications—the Bureau's most vital product. The event recognized 38 first authors of papers written in 2018, a year in which Bureau researchers published 123 peer-reviewed papers and were first authors on 48 of these, or coauthors on another 18 that were first-authored by their students.

The highlight of the evening was the presentation of the Tinker Family BEG Publication Award, "given in recognition of an exemplary publication of demonstrated or expected scientific or economic impact, or that otherwise increases the visibility of the Bureau scientific community." This year's recipients were researchers **Oliver Duffy**, **Tim Dooley**, **Mike Hudec**, and **Naiara Fernandez**—along with coauthors **Martin Jackson**, **Christopher Jackson**, and **Juan Soto**—for "Structural Evolution of Salt-Influenced Fold-and-Thrust Belts: a Synthesis and New Insights from Basins Containing Isolated Salt Diapirs." Runners-up were researchers **András Fall**, **Lucy Ko**, **Steve Ruppel**, **Bob Loucks**, and **Tongwei Zhang**; and **Alexander Sun** and **Todd Caldwell.**

In June, Bureau directors and staff celebrated summer with a special staff-appreciation cookout. More than 100 Bureau employees turned out to enjoy burgers and dogs grilled and served up by Director **Scott Tinker**, Acting Director **Mark Shuster,** Associate Directors **Jay Kipper** and **Michael Young**, and External & Governmental Affairs Manager **Mark Blount**. The directors hosted the event to express their gratitude to, and celebrate the efforts of, all Bureau employees.

Behind the scenes, Administrative Associate **Kim LaValley** coordinated the event with assistance from **Jan Braboy**, **Kyleen Piejko**, **Dena Miller**, **Gale Ashley**, **Theresa Caillouet**, **Lorri McKim**, and **Roanne Draker.** Numerous others—including **Nathan Ivicic**, **Kenneth Edwards**, **Rudy Lucero**, **Brandon Williamson, Melissa Coffman**, and **Francine Mastrangelo**—contributed to make the event a tasty success from start to finish.

Our Mission: To Serve Society

Outreach

2019 Earth Science Week

20th Anniversary!

In October, the Bureau hosted the 20th Annual Austin Earth Science Week Career Day, which introduces students to the wide variety of careers in Earth Science and allows local geoscientists to share their knowledge directly with students. Participants included 230 students from Sunset Valley Middle School, Bastrop Middle School, Thrall Middle School, and the Homegrown Learners home-school group.

In the opening ceremony, Senior Research Scientist **Jeff Paine** gave a humorous and informative presentation, sharing some of his experiences using the theme "You might be a geologist if..." Laura Zahm of

Students and Linda Ruiz McCall at the Annual Austin Earth Science Week Career Day.

Laura Zahm of Equinor presents backpacks to students at the Austin Earth Science Week Career Day.

Tour guides at the Austin Earth Science Week Career Day.

Allan Standen shows minerals to students at the Austin Earth Science Week Career Day.

Equinor showcased some of the career opportunities at her company and talked about her work there.

The day included demonstrations, presentations, and hands-on activities. Topics included choosing careers entailing an earth science degree; exploring aquifers, watersheds, and floodplains; space exploration and earth resources; engineering and earthquakes; Texas weather; world minerals; fossils; and life as a petroleum geologist.

Bureau Information Geologist **Linda Ruiz McCall** organized the event, which was made possible through partnership with 62 geoscience volunteers from the UT Austin Jackson School of Geosciences; Texas Water Development Board; City of Austin; Lower Colorado River Authority; KOKE FM radio, UT Austin Department of Civil, Architectural and Environmental Engineering; NASA Texas Space Grant; and other contributors. Financial sponsors included Austin Geological Society, Enverus, Equinor (underwriting sponsor), and The Subsurface Library of Midland.

Augmented Reality Sandbox

In honor of the 20th anniversary of the Austin Earth Science Week Career Day, Bureau researchers and staff built a new Augmented Reality Sandbox. The AR Sandbox combines 3D visualization applications with a hands-on sandbox exhibit to teach geographic, geologic, and hydrologic concepts, such as the meaning of contour lines on a topographic map and how water flows downhill in watersheds. The AR Sandbox is on exhibit in the Bureau's Resource Center. The project team included John Maisano, **John Andrews, David Chang, Poe Chen, Jay Kipper, Linda Ruiz McCall,** and **Joseph Yeh.**

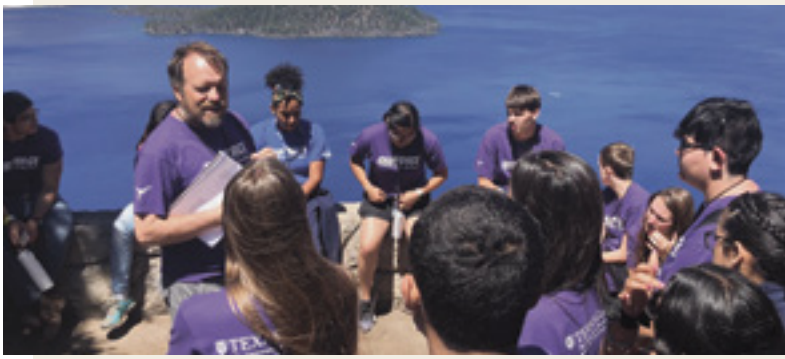
Jay Kipper, Bureau Associate Director, engages students with the new Augmented Reality Sandbox at the Austin Earth Science Week Career Day.

Jay Kipper, John Andrews, and John Maisano discussing the construction of the augmented reality sandbox.

GEOFORCE TEXAS
JACKSON SCHOOL OF GEOSCIENCES™

The Jackson School's GeoFORCE Summer Academy program aims to increase the number and diversity of students pursuing STEM degrees and careers, especially geology. Each summer, GeoFORCE Texas takes high school students on geological field trips in Texas and throughout the United States. Bureau staff **Jeff Paine, Peter Flaig, Tiffany Caudle**, and **Linda Ruiz McCall** served as instructors.

Linda Ruiz McCall and STEMFORCE 12th Grade Academy students.



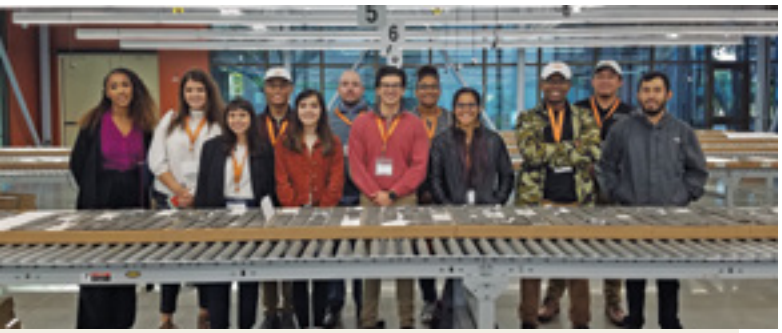
Jeff Paine and GeoFORCE 11th Grade Academy students.

Peter Flaig and GeoForce 10th Grade Academy students.

Tiffany Caudle and GeoFORCE 9th Grade Academy students.

Bureau Facilities Tours

As the Geological Survey for the state of Texas, the Bureau offers pubic access to the new Stoneburner Family Rock Garden, the Austin Core Research Center, and the Resource Center. Please contact us in advance for group tours.



JSG EDGE (Enhancing Diversity in Graduate Education) geoscience graduate students visit the Core Research Center.

Bill Ambrose presents to the Men in Mission community group.

Linda Ruiz McCall leads visitors from the Texas Commission on Environmental Quality groundwater team through the Stoneburner Family Rock Garden.

Nathan Ivicic discusses core curation with the Texas Environmental Educator Advisory Council field trip group.

Broader Impacts

Linda Ruiz McCall leads a geology guided hike in cooperation with the Save Barton Creek Association.

Karst Educational Outreach

The Austin region has many locations where limestone rock formations have been weathered and eroded to produce caves, fissures, and sinkholes, referred to as karst terrain. Karst terrains present stewardship challenges to water resources and construction practices, so the Bureau works to help build public understanding of these natural resources.

In 2019, **Linda Ruiz McCall** led a geology hike for the public along the Violet Crown Trail of the Barton Creek Greenbelt in coordination with the Save Barton Creek Association. Linda also presented on surface water–groundwater interactions at the Austin Cave Festival, organized by the Barton Springs Edwards Aquifer Conservation District and held at the Ladybird Johnson Wildflower Center.

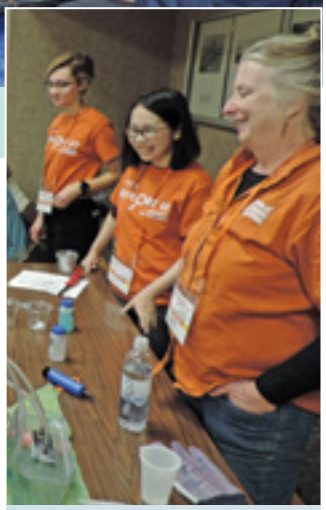
Linda Ruiz McCall demonstrates surface water–groundwater interactions at the Austin Cave Festival at the Ladybird Johnson Wildflower Center.

A Benefit to Our Communities

Letitia Olariu showing children how to "find gold" at Explore UT.

Explore UT

In March, Bureau staff members and volunteers joined in the annual Explore UT campus-wide open house. The Bureau offered four activities: Finding Gold, What to Do with CO_2: Cure for the Feverish Earth; Exploring Earth's Natural Resources with 3D Visualization; and TexNet: Monitoring Earthquakes with the Texas Seismological Network.



Margaret Murakami, Qian Yang, and Sue Hovorka showing carbon capture at Explore UT.

Bureau booth at CAST

CAST and EarthDate

Bureau staff **Scott Rodgers** and **Linda Ruiz McCall** joined educators at the Conference for the Advancement of Science Teaching (CAST) in Dallas. The CAST conference brings together over 5,000 science teachers from across the state. The featured Bureau resource this year was a classroom poster about the EarthDate.org public service radio program, whose mission is to engage listeners in earth science.

Groundwater to the Gulf Summer Institute teachers explore rocks and water.

Educator Workshops

The Bureau is committed to helping classroom educators understand natural resources. On June 11, **Linda Ruiz McCall, Sarah Prentice,** and **Margaret Murakami** presented at the Groundwater to the Gulf Summer Institute held at the Ladybird Johnson Wildflower Center in Austin. Presentations included hands-on activities for exploring rocks and water and carbon capture.

On June 25, participants in the Texas Mining and Reclamation Association's Industrial Minerals educator workshop spent a day at the Bureau. Teachers listened to presentations by Bureau staff and toured the new Stoneburner Family Rock Garden and Austin Core Research Center facility.

Texas Mining and Reclamation Association Industrial Minerals workshop attendees explore the new Stoneburner Family Rock Garden.

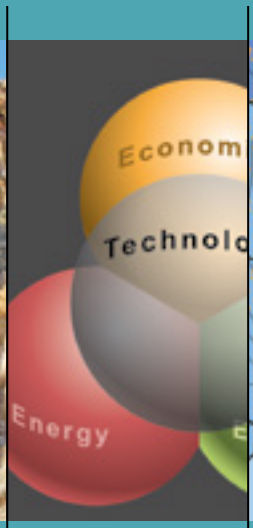
Boy Scouts

On March 30, **Linda Ruiz McCall** joined the Boy Scout STEMboree in Austin. STEMboree offered Scouts and their families hands-on activities to help them work on earning several Scout badges.

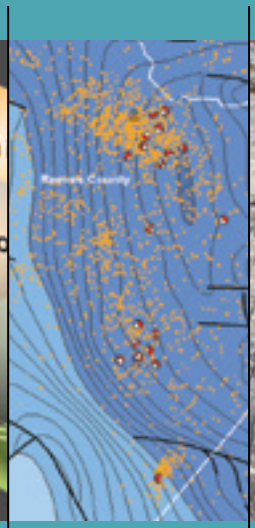
Boy Scouts at the Austin STEMboree learn about rocks.

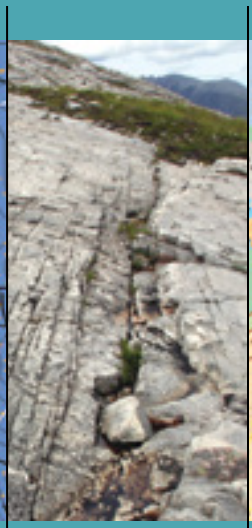

AEC


AGL



CEE


CISR


FRAC


GCCC

Research Consortia

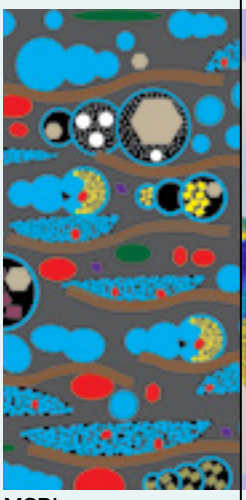
Research Partnerships *with the Bureau of Economic Geology*

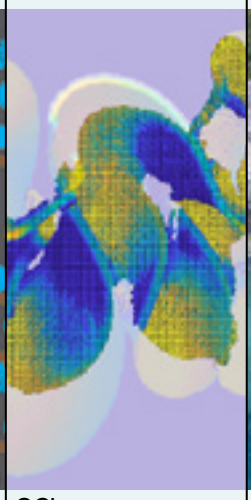
The Bureau of Economic Geology conducts impactful research on subjects of high interest to the energy industry and to environmental firms, and a broad spectrum of companies and other organizations actively participate in its 12 research consortia. These unique partnerships study subjects as diverse as salt tectonics, carbonate reservoir characterization, natural fractures and geophysics, carbon storage, nanotechnology, quantitative clastics, computational seismology, economics, and mudrock reservoirs.

Collectively, these 12 consortia enjoy the support of more than 65 partners globally, with some companies and organizations participating in multiple separate programs. Each research consortium was designed to complement industry efforts to explain a key exploration, production, environmental, and/or economic problem. Participation is on a subscription basis. Member benefits vary but generally include first-look privileges at research outcomes, access to research teams, invitations to annual review meetings, and office visits by researchers for presentation and interaction. Members also benefit from interactions with counterparts in fellow sponsoring organizations.

Each Bureau research consortium has a dedicated team of full-time researchers, including postdocs. Many of them host talented graduate students, the teams combining seasoned experts and early-career specialists. A number of researchers have industry backgrounds, and all share a passion for university-based research.

Contact the PI of any program of interest to you. For further information about these research consortia, and the breadth of your organization's engagement with the Bureau, please contact us at www.beg.utexas.edu or by phone at 512-471-1534. Download the consortia brochure: http://www.beg.utexas.edu/about/reports-and-information.


MSRL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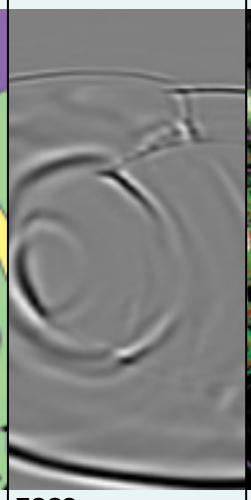
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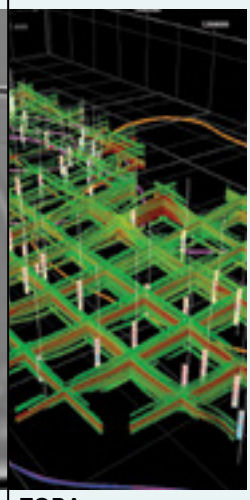
TORA

Advanced Energy Consortium

Mission
Our mission is to illuminate the subsurface reservoir using novel micro- and nanosensing technology developed collaboratively with Advanced Energy Consortium (AEC) members and the global community.

Research Thrusts
This research organization is dedicated to achieving a transformational understanding of subsurface oil and natural gas reservoirs through the deployment of unique micro- and nanosensors. However, the technologies developed by AEC are showing themselves to have much broader potential applications beyond oil and gas. Areas such as wellbore integrity, seal integrity, and cement integrity for additional applications including geothermal energy, carbon capture and storage, nuclear waste monitoring and power generation, and water use optimization and recycling are areas of clear potential impact.

Research Challenges
Since its inception, AEC has invested more than $50 million in research with 30 university and research facilities around the world and has progressed from fundamental to applied research. It is now targeting commercial applications (use cases) that will help its members enhance their commercial extraction of oil and natural gas.

Membership
In only 10 years, progress of the consortium has been remarkable. AEC has created a whole new scientific space, published hundreds of peer-reviewed papers, created a patent portfolio exceeding 50 inventions (including the world record for smallest subsurface-conditions battery and pressure sensor), and is now on the verge of completing commercial-scale proof-of-concept tests. Membership is $375,000 per year, with an initial 2-year membership commitment.

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Applied Geodynamics Laboratory

Mission
Pure and applied research in salt tectonics has been a strong component of the Bureau's research program since the late 1970's. At the heart of this research is the Applied Geodynamics Laboratory (AGL), an industry-funded consortium dedicated to producing innovative concepts in salt tectonics. Research comprises a mix of physical and mathematical modeling; seismic- and field-based mapping; and structural-stratigraphic analysis of some of the world's most spectacular salt basins—including those of the Gulf of Mexico, West Africa, Brazil, the Mediterranean, and the Canadian High Arctic. Research has also been applied extraterrestrially to Mars and Triton.

Research Thrusts
Concepts and terminology pioneered by AGL over the past quarter-century have profoundly influenced salt tectonics and are now widely disseminated throughout the oil industry. AGL strives to effectively communicate these results via a variety of media, including *The Salt Mine: A Digital Atlas of Salt Tectonics,* the leading textbook on the subject in the world.

Research Challenges
The primary goals of AGL are to develop a conceptual framework for the full range of salt tectonics; to analyze connections among physical models, mathematical models, seismic data sets, and field examples from all over the world; and to disseminate complex technical information to a constantly shifting spectrum of industrial and academic supporters. Areas of focus include salt weld; salt canopy; reactive, falling, and squeezed diapirs; shape of passive diapirs and sheets; fault families (with the University of Colorado); extrusive salt sheets (with BP and ExxonMobil); extensional turtle and mock turtle; mechanics of salt-sheet advance; origin of minibasins; intrusive salt plumes; and salt sutures.

Membership
The 29 supporting companies of AGL include a wide range of industry partners from around the world.

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Center for Energy Economics

Mission

Energy-economics research at the Bureau seeks understanding of relationships among energy resources and generation, economics, and environment. We aim at establishing a solution-based platform to help stakeholders make well-informed decisions at each of these related nexuses. Our research is practical; it improves consensus decisionmaking and outcome predictability among energy and economics stakeholders. Research is organized around the Center for Energy Economics (CEE) and is conducted collaboratively with member organizations and companies, in addition to other Bureau research consortia.

Research Thrusts

Accurate characterization of relationships among energy production, electricity generation, and economic and environmental effects holds great potential for improving outcomes for energy producers, local and regional economies, and citizens. Bureau and consortium-member data, and recent advances in modeling and software user experience, enable transformation of available data into a practical, widely adopted tool for consensus decisionmaking. CEE is building a scorecard and pathfinder to simplify and improve energy-economics decisionmaking.

Research Challenges

The human elements in economics and policymaking create inherent uncertainty in forecasing. By creating tools for consensus-driven, collaborative decisionmaking, we minimize the negative effects of this uncertainty for our members.

Membership

Training and outreach on energy economics, markets, and frameworks for commercial and strategic investment are a benefit of membership. Annual meetings cover regional and global economic outlooks; modeling of relationships among energy, economics, and the environment; and innovative energy-economics best practices.

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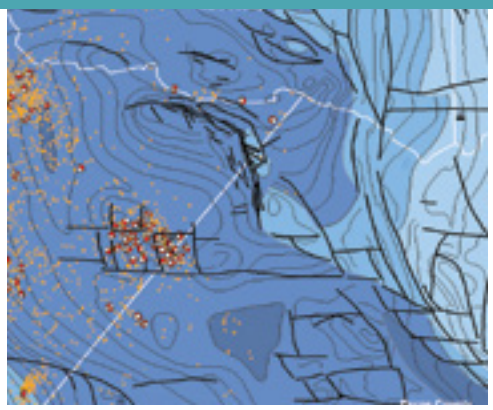
Center for Integrated Seismicity Research



Mission

The Center for Integrated Seismicity Research (CISR) is a multidisciplinary, intercollegiate research consortium managed by the Bureau. TexNet and CISR are two parts of a whole; the former is the State-funded network of seismometers across Texas that conducts research into earthquake causation in key areas. With its industry partnerships, CISR significantly extends and deepens the scope of research and monitoring toward an understanding of the processes that influence seismicity, quantification of hazards, and improvement of standards of practice for mitigation.

Research Thrusts

CISR conducts fundamental and applied research to better explain seismicity of all causes and its associated hazards. CISR brings together UT researchers from the Bureau; the Institute for Geophysics; and the departments of petroleum, geosystems, civil, architectural, and environmental engineering. Researchers at SMU, Texas A&M, the University of Houston, UT Dallas, and UT El Paso also contribute.

Research Challenges

Over the past decade, the rate of seismicity in the south-central United States has increased markedly, especially in unconventional play areas where water management has become an important challenge. Understanding the interplay between complex operational drivers and interdependent subsurface physical processes is a daunting challenge that the Bureau is pursuing head-on.

Membership

Most of the major energy companies that operate in Texas unconventional plays are CISR members. A member of each company serves on the CISR Advisory Committee, which meets quarterly to discuss the design and application of TexNet–CISR research. Member companies are encouraged to contribute proprietary data and information that can guide and advance CISR research. Proprietary data are protected by UT Austin's strong intellectual property controls.

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Fracture Research and Application Consortium

Mission

Fracture research at The University of Texas at Austin seeks fundamental understanding of fracture processes with the aim of finding new geological, geophysical, and engineering methods to explain and successfully predict, characterize, and simulate reservoir-scale structures.

The research is both fundamental and practical, aiming at improving prediction and diagnosis of fracture attributes in hydrocarbon reservoirs and accurately simulating their influence on production. Research is organized around the Fracture Research and Application Consortium (FRAC), conducted together with scientists from member companies. Students are an important part of our program.

Research Thrusts

Accurate prediction and characterization of fractures hold great potential for improving production by increasing the success and efficiency of exploration and recovery processes. New analytical methods produce data that can enhance well-test and seismic interpretations and can be used in reservoir simulators. We are developing new and more-reliable methods to predict hydraulic fracture propagation in naturally fractured and unconventional reservoirs.

Research Challenges

Faults and fractures are difficult or impossible to characterize adequately using currently available technology. Fractures have been challenging to sample and model, posing serious challenges to exploration and development. Our approach is helping to overcome the limitations of current methods.

Membership

Training in techniques, software, and our workflow is a benefit of membership. Annual meetings cover measurement, interpretation, prediction, and simulation of fractures and mechanical properties in carbonate rocks, mudstones, and sandstones.

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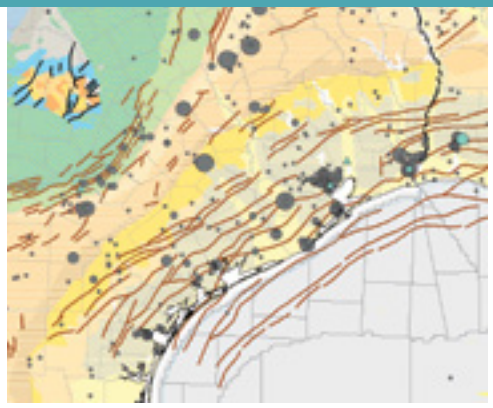
http://www.jsg.utexas.edu/sdi/

Gulf Coast Carbon Center



Mission

The Gulf Coast Carbon Center (GCCC) conducts research and outreach in geologic storage technologies used to reduce emissions of carbon dioxide (CO_2). Carbon dioxide produced by combustion of fossil fuels and by other industrial processes is captured and injected into porous rocks at locations where it is stored.

Research Thrusts

GCCC research into large-volume CO_2 storage (1) improves structural and stratigraphic characterization methods and simulation approaches for identifying suitable locations, (2) increases confidence in these technologies, (3) creates workflows for characterization at basin scale that prepare multiple sites to be operated at maximum injection rates and over prolonged time periods, and (4) assesses storage resources in offshore subsea settings in the Gulf of Mexico and globally.

CO_2-enhanced oil recovery (EOR) research enables assessment of (1) the best methods and economic value for use of CO_2 for EOR in various traditional and novel settings and (2) the intersection of economic value with storage value to develop a transparent life cycle that accounts for storage and EOR.

Research Challenges

Carbon capture and storage (CCS) deployment is not happening at the rate and scale needed to achieve emissions-reduction goals. Many influential stakeholders, from industrial investors to policymakers to journalists, do not have the information needed to see the critical role of CCS in attaining these goals and the viability of CCS.

Membership

Members meet twice a year (sometimes jointly with other related groups) and receive a quarterly newsletter.

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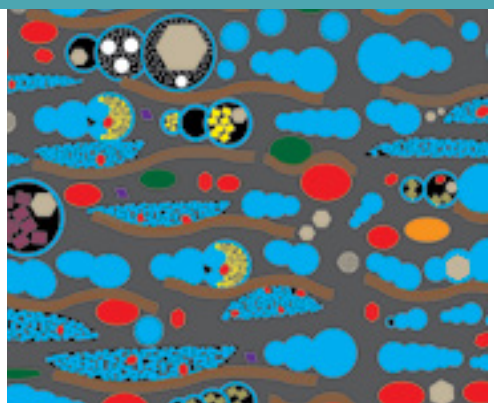
Mudrock Systems Research Laboratory



Mission

The Bureau's Mudrock Systems Research Laboratory (MSRL) program brings together a broad spectrum of research expertise necessary to confront the complicated, multidisciplinary questions key to a better understanding of mudrock systems. The goal of the program is to integrate observations and data from all scales, ranging from nanoscale to basin scale. Only through this kind of integrated analysis can the multiscalar heterogeneities of mudrocks be effectively characterized and models leading to better predictions of reservoir quality be developed.

Research Thrusts

MSRL research activities include the following: field emission scanning electron microscope study of pore architecture, grain types, and diagenesis; analysis of mechanical properties; application of X-ray fluorescence and isotope geochemistry to better define facies and their continuity; delineation and modeling of regional and local trends in depositional and diagenetic facies distribution; development of more-accurate ways to determine porosity, permeability, and flow; critical appraisal of conventional methods of mudrock-analysis techniques, and core-based calibration of borehole geophysical logs for facies mapping.

Research Challenges

Despite their abundance in Earth's crust, mudrocks are not as well understood as other reservoir systems. The current explosion of interest in a better understanding of these rocks stems from the need to devise more-efficient ways of extracting oil and gas from these reservoirs. Our challenge is to develop new methodologies for characterizing these rocks and the fluids they contain. We are meeting this challenge by carrying out integrated studies of rock and fluid attributes on high-precision, high-resolution instruments operated by MSRL researchers.

Membership

Consortium members receive priority access to research data, interpretations, and reports. Results are distributed to members through annual workshops, seminars, field trips, short courses, and the web.

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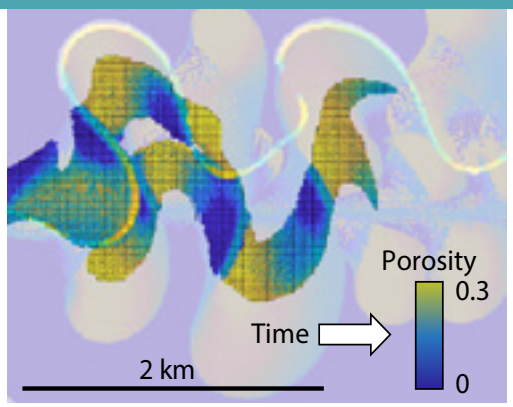
Quantitative Clastics Laboratory



Mission

The mission of the Quantitative Clastics Laboratory (QCL) is to develop a predictive understanding of processes and controls on sediment transport and the stratigraphic evolution of depositional systems, with applications in reservoir characterization, modeling, correlation, and source-to-sink predictions for frontier exploration.

Research Thrusts

QCL researchers leverage the broad, world-class expertise of the Jackson School of Geosciences (JSG)—including collaborations with groups specializing in structural geology, Texas and Gulf of Mexico depositional syntheses, seismic interpretation, and thermochronology—to address key challenges in the exploration and development of natural resources. These challenges include evaluation of reservoir presence and quality in data-limited frontier basins and characterization of connectivity and heterogeneity of reservoirs. QCL has unique clastic research consortia access to industry subsurface data, including global seismic-reflection datasets and Bureau core repositories.

Research Challenges

QCL has two research themes: (1) reservoir-scale depositional system characterization, modeling, and flow simulation for a better understanding of processes that impact connectivity and heterogeneity and (2) exploration-scale source-to-sink analysis to evaluate correlation, reservoir presence, and quality in the petroliferous Permian Basin and circum–Gulf of Mexico. An exciting update to the QCL program is analysis of flow diagnostics of digital stratigraphic models for evaluating the effect of stratigraphic evolution and facies architecture on fluid flow during production.

Membership

Each year's research calendar begins January 1 and runs through December 31. Multiple meetings, workshops, and face-to-face consultations with industry members are held annually. QCL offers industry members unique access to JSG expertise, industry subsurface data, investigations of multiple scales of depositional environments and their interconnections, and an evolving quantitative database on clastic depositional systems architecture.

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Reservoir Characterization Research Laboratory

Mission

RCRL's mission is to use outcrop and subsurface geologic, geophysical, and petrophysical data from carbonate reservoir strata as the basis for developing new and integrated methodologies and concepts to explain and describe the 3D reservoir environment and to improve hydrocarbon recovery factors. In addition, RCRL is dedicated to technology transfer and education and consistently offers state-of-the-art training, such as short courses, field seminars, in-company reviews of assets, and extensive student supervision and guided research.

Research Thrusts

RCRL approaches reservoir characterization through four main scales of investigation: (1) platform-to-basin-scale stratigraphy; (2) reservoir architecture, including both matrix and nonmatrix systems (e.g., fractures and paleokarst); (3) structural and geomechanical properties characterization; and (4) pore networks and their reservoir distribution. Research questions are developed using both subsurface data and outcrop analogs. RCRL emphasizes quantifying what is observed so that its research is applicable to reservoir models and is valuable in providing predictive relationships and conceptual tools for reservoir characterization and play analysis.

Research Challenges

RCRL areas of investigation include Lower Permian shelf-to-basin stratigraphic and structural architecture of the Delaware and Midland Basins; Gulf of Mexico carbonate reservoir settings, pore systems, fracture character, and margin variability; Cenozoic carbonate platform systems, high-resolution stratigraphy, and structural configuration of shelf margins; fractured carbonate reservoir characterization in outcrop and subsurface analogs; origin and petrophysics of tight limestone and dolomite reservoirs; regional reservoir characterization of the Austin Chalk trend; and carbonate rock mechanics and acoustic-properties research.

Membership

The RCRL sponsor contribution to the program is $55,000 per year. Sponsors are encouraged to commit to a 2-year agreement (at $50,000 per year) to better plan a longer-range research program.

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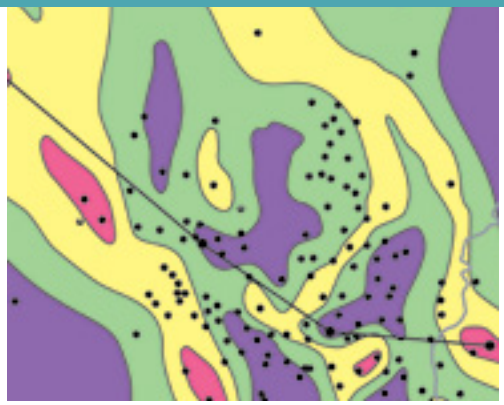
State of Texas Advanced Oil and Gas Resource Recovery



Mission

The mission of the State of Texas Advanced Oil and Gas Resource Recovery (STARR) program at the Bureau of Economic Geology is to conduct geologic research that increases the production of oil and gas in the state of Texas. Since its inception in 1996, STARR has helped raise $515.6 million in severance-tax revenues, offsetting Texas' $39.8 million funding investment. In its more than 20-year history, STARR has undertaken more than 60 field (reservoir characterization) and 15 regional studies, with over 50 Texas oil and gas operators participating in the program.

Research Thrusts

Research thrusts of the STARR program are applied toward technology transfer to operators in the Texas oil and gas industry in three main areas: (1) integrated geologic characterization studies that employ seismic, core, wireline-log, and petrophysical data for documenting areas with additional oil and gas potential; (2) imaging and characterization of lithology, facies, and micropore systems in unconventional reservoirs; and (3) advanced seismic mapping techniques for imaging potential oil and gas reservoirs.

Research Challenges

The main challenge in the STARR group is to explain controls on oil and gas production in reservoirs in Texas. Geoscientists at STARR employ a technical approach that emphasizes rock data for better characterizing reservoir quality and continuity, two important factors in determining oil and gas producibility. The STARR group integrates rock-property data in both field- and regional-scale projects, drawing upon its extensive core collection at the Bureau.

Membership

No costs are associated with participation in the STARR program, which is funded by the State of Texas, although research matching support is encouraged. STARR partners receive a variety of technical products that include stratigraphic and structural interpretations; facies and depositional-systems analysis from cores, wireline logs, and seismic data; and interpretations of geologic controls on reservoir quality.

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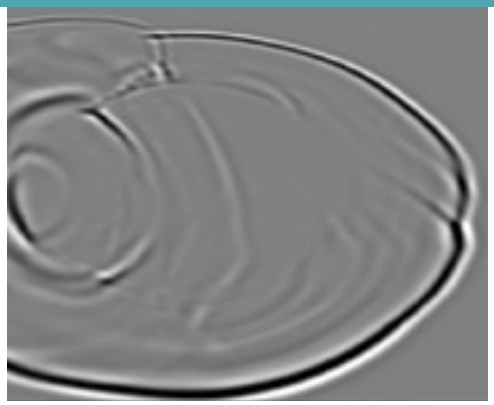
Texas Consortium for Computational Seismology



Mission

The mission of the Texas Consortium for Computational Seismology (TCCS) is to address the most important and challenging research problems in computational geophysics as experienced by the energy industry and to educate the next generation of research geophysicists and computational scientists.

Research Thrusts

TCCS research areas include the following: high-resolution imaging of the Barrolka data set using diffraction attributes; characterization of fractured-shale reservoirs using anelliptic parameters; phase correction of prestack seismic data using local attributes; extracting seismic events by predictive painting and time warping; low-rank, reverse time migration for subsalt imaging; high-resolution seismic attributes for fracture characterization in the Grosmont Formation; waveform tomography with cost function in the image domain; multiazimuth seismic diffraction imaging for fracture characterization in low-permeability gas formations; and seismic-wave focusing for subsurface imaging and enhanced oil recovery.

Research Challenges

TCCS is a collaboration between the Bureau and the UT Oden Institute for Computational Engineering and Sciences, which is involved in estimating seismic velocities by using full waveform information, identifying the most accurate and efficient seismic imaging algorithms while controlling the trade-off between accuracy and efficiency, increasing the resolution of seismic reservoir characterization, and assisting the seismic interpreter by automating common interpretation and signal-processing tasks.

Membership

TCCS publications follow the discipline of reproducible research: results of each computational experiment are supplied with open-source software code required for reproducing and verifying the experiment.

The TCCS group consists of scientists from five countries who are united in their goal to advance science. Research staff includes two principal investigators, six Ph.D. students, and a visiting scientist

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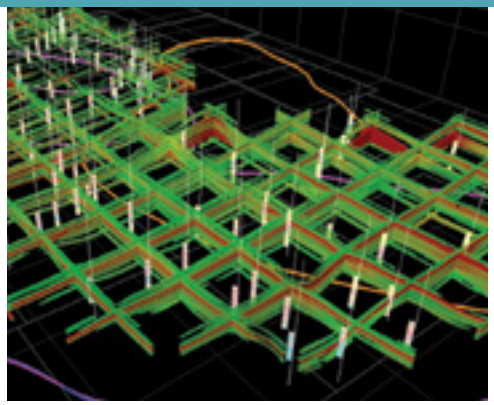
Tight Oil Resource Assessment



Mission

Our mission is to provide all stakeholders with reliable and up-to-date estimates, scenarios, models, fundamental understanding, and insights at the basin scale for the major U.S. unconventional plays by conducting innovative, integrated research of in-place resource and recoverable volumes, play and well economics, and production forecasts with environmental implications.

Research Thrusts

The Tight Oil Resource Assessment (TORA) multidisciplinary team employs a bottoms-up, highly iterative resource evaluation process. The TORA research model allows team members from different disciplines to analyze data, share information, and inform study results. Team members are experts in their respective fields, including geology, petrophysics, basin modeling, engineering, economics, statistics, and data analytics.

Research Challenges

TORA narrows the range of recoverable-resource estimates, building integrated, market-independent basin outlooks. TORA researchers employ a newly developed workflow utilizing 3D geocellular models, statistics, and economics. That workflow will produce estimates of ultimate hydrocarbon recoveries, economic viability, drilling locations, and playwide production outlooks. TORA studies tight oil and gas formations to produce unbiased, comprehensive yet granular, publicly available results. TORA has recently focused on the Permian Basin, where optimization of recovery in thick, tight oil reservoir sections and estimation of associated gas and water production are key research questions. Regular updates are provided for the other major unconventional plays in the U.S., including the Bakken, Eagle Ford, Marcellus, Barnett, Haynesville, and Fayetteville.

Membership

Membership in TORA is $50,000 annually. Benefits to industry partners include (1) detailed insights in the form of semiannual update meetings and annual reports, (2) access to the multidisciplinary TORA research team, (3) leveraged funding through State of Texas support and other operator contributions, (4) consortium-supported data sharing between companies and the Bureau, and (5) 3D geologic models of each basin.

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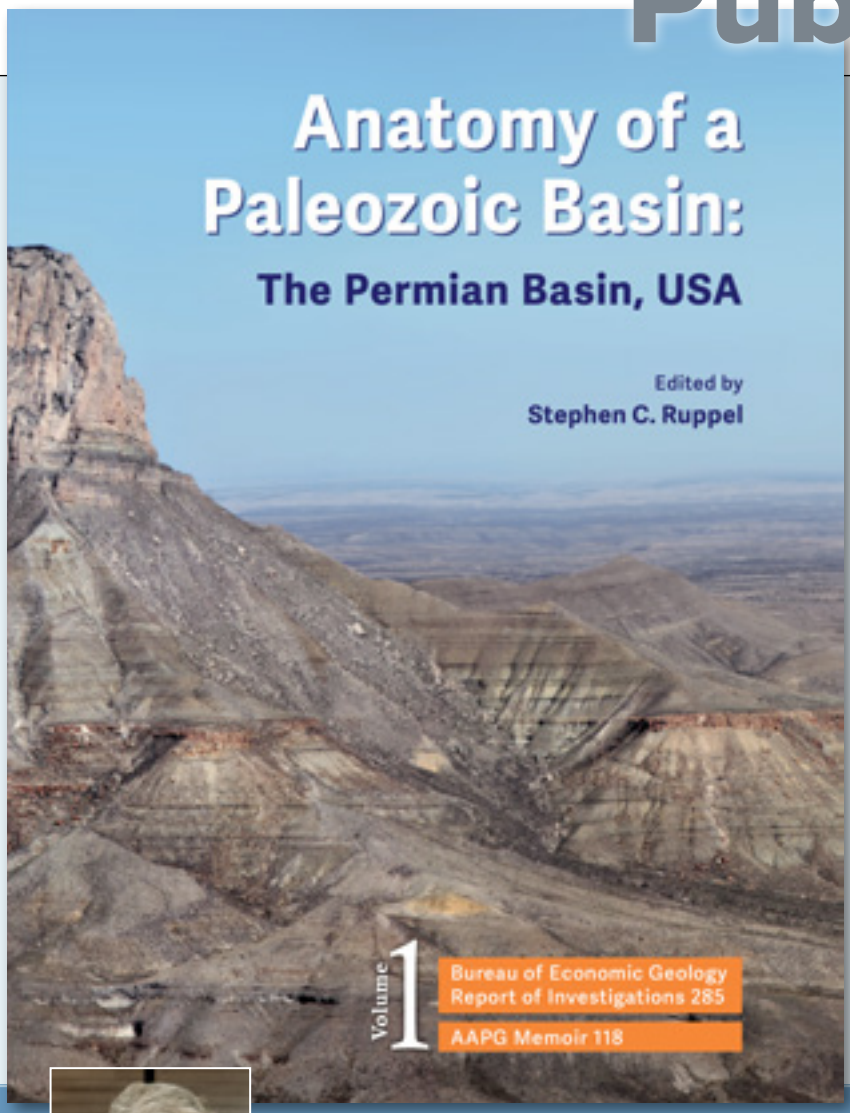
Publications



"The Permian Basin of West Texas is better understood owing to a lifetime of contribution by Dr. Steve Ruppel. He touched many lives, influenced many people, and will be dearly missed."

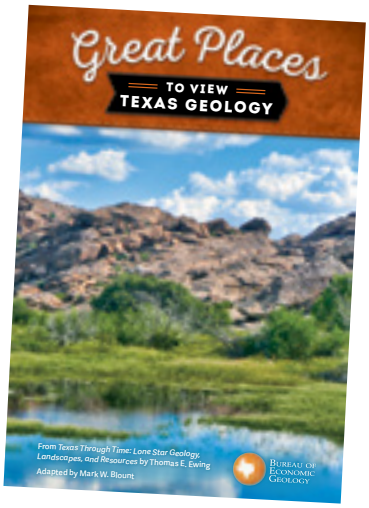
Scott Tinker

Anatomy of a Paleozoic Basin: The Permian Basin, USA, Volume 1

Ruppel, S. C., ed., 2019, Anatomy of a Paleozoic basin: the Permian Basin, USA (vol. 1): The University of Texas at Austin, Bureau of Economic Geology Report of Investigations No. 285; AAPG Memoir 118, 412 p., doi:10.23867/RI0285-1.

Coming soon: Ruppel, S. C., ed., in press, Anatomy of a Paleozoic basin: the Permian Basin, USA (vol. 2): The University of Texas at Austin, Bureau of Economic Geology Report of Investigations No. 285; AAPG Memoir 118, 527 p., doi:10.23867/RI0285-2.

This two-volume set is the first comprehensive analysis of the Permian Basin in more than 60 years. The 26 chapters in the publications cover a breadth of Permian Basin topics, including structural geology, tectonics, and Precambrian geology; paleontology and biostratigraphy; Paleozoic sedimentology and stratigraphy; hydrocarbon production; and a history and synthesis of the major depositional and deformational events that formed the basin during the Paleozoic. Collectively, these chapters provide a spectrum of data and interpretations that characterize one of the largest hydrocarbon-producing basins in the world. This publication will be of interest to all who seek information on the distribution of hydrocarbons in the basin, and to those wanting to better understand the evolution of the basin during the Phanerozoic.

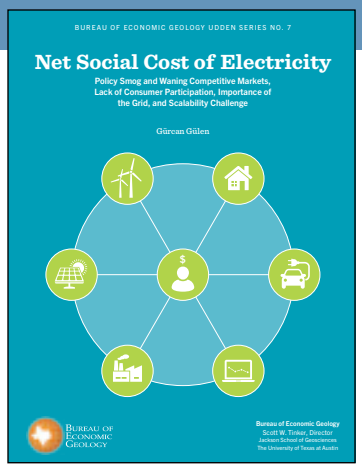


Great Places to View Texas Geology

Blount, M. W., 2019, Great places to view Texas geology, adapted from Ewing, T. E., Texas through time: Lone Star geology, landscapes, and resources: The University of Texas at Austin, Bureau of Economic Geology Udden Series, No. US0006GP, 56 p.

Great Places to View Texas Geology is your handy travel guide to 50 unique, interesting, and spectacular geologic sites in Texas. Adapted from the comprehensive ***Texas Through Time: Lone Star Geology, Landscapes, and Resources*** (2016), this convenient full-color travel booklet shares brief descriptions of the state's beautiful vistas and impressive features from a geologic perspective, giving the reader a better understanding of the earth processes that created them over millions of years. ***Great Places to View Texas Geology*** is an indispensable addition to any trip across Texas—a window on the geologic world that shaped these incredible mountains, waterfalls, caves, canyons, beaches, and forests.

To purchase *Anatomy of a Paleozoic Basin* and *Great Places to View Texas Geology*, visit The Bureau Store:
https://store.beg.utexas.edu/



Udden Series No. 7

Net Social Cost of Electricity: Policy Smog and Waning Competitive Markets, Lack of Consumer Participation, Importance of the Grid, and Scalability Challenge

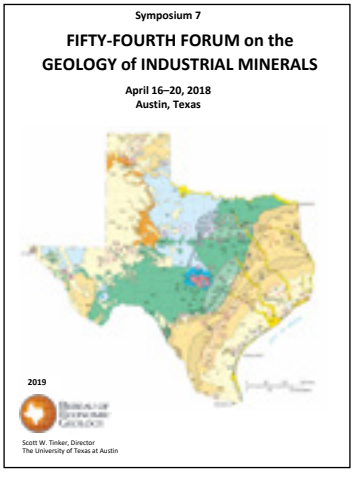
Gülen, G., 2019, Net social cost of electricity: policy smog and waning competitive markets, lack of consumer participation, importance of the grid, and scalability challenge: The University of Texas at Austin, Bureau of Economic Geology Udden Series No. 7, 86 p., doi:10.23867/US0007.

The latest in the Bureau's Udden Series demonstrates that the time is ripe for a rational, multifaceted, fresh look at the technology, economics, and negative—and positive—extern alities of electricity service in the United States. The current approach to energy policy across numerous jurisdictions has turned into a political competition that attempts to level the playing field for favorite technologies via subsidies and mandates. Many of these policies or attendant market design changes lead to litigation. This situation raises the cost of electricity to customers, who are still not full participants in the electricity market, and increases uncertainty for market participants, which in turn encourages further rent-seeking practices.

Author and former Bureau researcher Gürcan Gülen has over 25 years of global experience in research, technical assistance, and capacity building across oil, natural gas, and electric-power value chains.

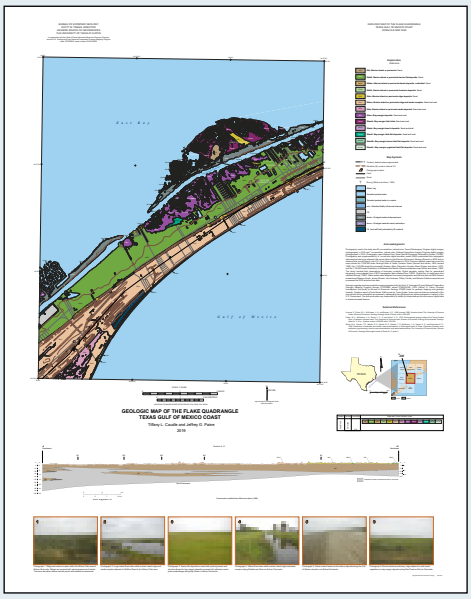
Proceedings: 54th Forum on the Geology of Industrial Minerals

Elliott, B. A., ed., 2019, Proceedings, 54th Forum on the Geology of Industrial Minerals: The University of Texas at Austin, Bureau of Economic Geology Symposium No. 7, 58 p.



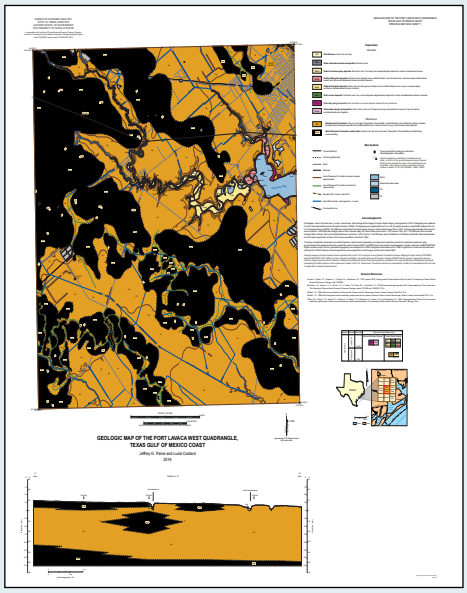
The 54th Forum on the Geology of Industrial Minerals annual meeting was hosted April 16–20, 2018, by the Bureau of Economic Geology at The University of Texas at Austin and co-sponsored by the Texas section of the Society for Mining, Metallurgy & Exploration. Events included three days of presentations in technical sessions addressing industrial minerals and advancements in technology; geology; transportation, regulation, and logistics; and mining and processing.

Project 1: Geologic Mapping of the Upper Texas Gulf of Mexico Coastal Plain

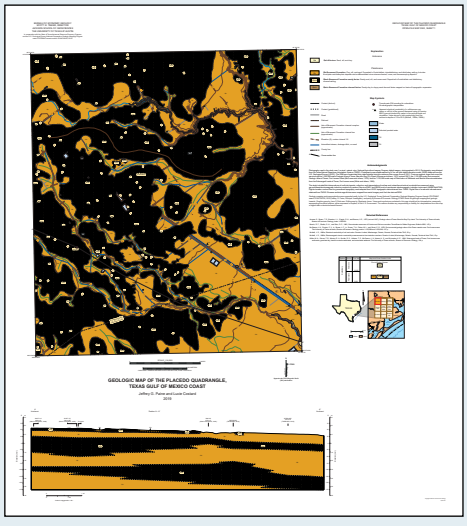


Geologic Map of the Flake Quadrangle, Texas
Caudle, T. L., and Paine, J. G., 2019: The University of Texas at Austin, Bureau of Economic Geology Open-File Map No. 238, scale 1:24,000.

Project 2: Geologic Mapping of the Middle Texas Gulf of Mexico Coastal Plain

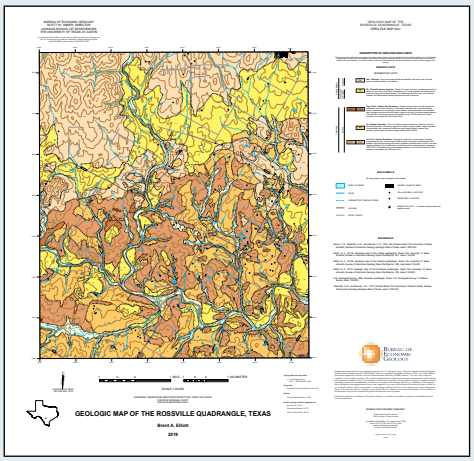


Geologic Map of the Port Lavaca West Quadrangle, Texas Gulf of Mexico Coast
Paine, J. G., and Costard, L., 2019: The University of Texas at Austin, Bureau of Economic Geology Open-File Map No. 239, sheet 1, scale 1:24,000; sheet 2, digital elevation model, time-domain electromagnetic induction soundings, and frequency-domain electro-magnetic induction measurements.

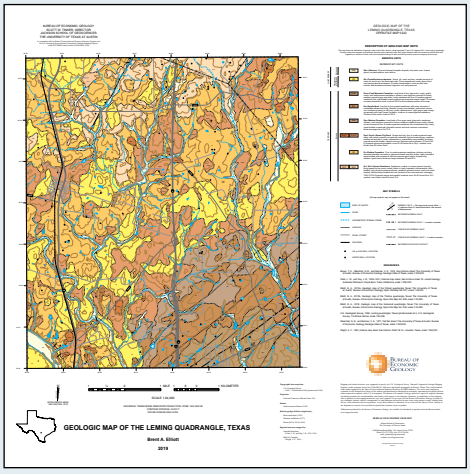


Geologic Map of the Placedo Quadrangle, Texas Gulf of Mexico Coast
Paine, J. G., and Costard, L., 2019: The University of Texas at Austin, Bureau of Economic Geology Open-File Map No. 240, sheet 1, scale 1:24,000; sheet 2, digital elevation model, time-domain electromagnetic induction soundings, and frequency-domain electro-magnetic induction measurements.

Project 3: Geologic Mapping of Mineral Resources, South-Central Texas

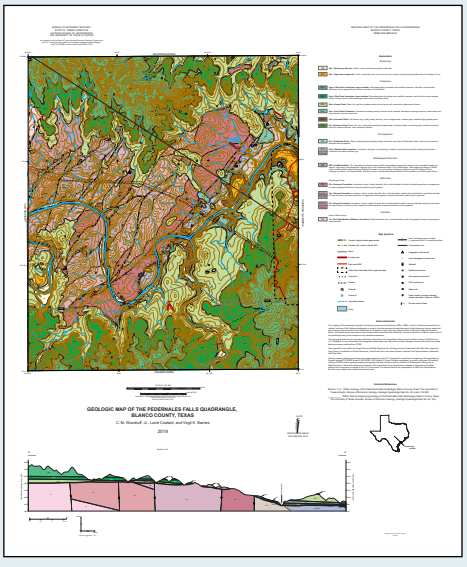


Geologic Map of the Rossville Quadrangle, Texas
Elliott, B. A., 2019: The University of Texas at Austin, Bureau of Economic Geology Open-File Map No. 241, scale 1:24,000.

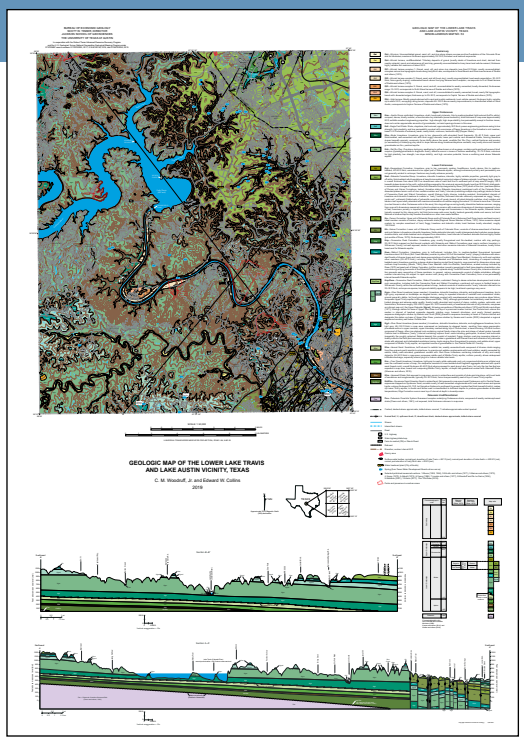


Geologic Map of the Leming Quadrangle, Texas
Elliott, B. A., 2019: The University of Texas at Austin, Bureau of Economic Geology Open-File Map No. 242, scale 1:24,000.

Project 4: Geologic Mapping of the West Austin Corridor, Central Texas



Geologic Map of the Pedernales Falls Quadrangle, Blanco County, Texas
Woodruff, C. M., Jr., Costard, L., and Barnes, V. E., 2019: The University of Texas at Austin, Bureau of Economic Geology Open-File Map No. 243, scale 1:24,000.



Geologic Map of the Lower Lake Travis and Lake Austin Vicinity, Central Texas

Woodruff, C. M., Jr., and Collins, E. W., 2019: The University of Texas at Austin, Bureau of Economic Geology Miscellaneous Map No. 53, scale: 1:50,000.

This map presents geologic information pertinent to engineering, environmental, and resource issues related to rapid population growth west of Austin. It encompasses major impoundments of the Colorado River and includes the western urban edges of Austin and extensive suburban areas interspersed with undeveloped land. The map area is underlain by Cretaceous bedrock units displaced by normal faults composing the Balcones Fault Zone. Local Quaternary alluvial deposits cover bedrock at various topographic levels. The Balcones Escarpment extends across the southeast corner of the map area and separates complex faulted terrain to the east from the Hill Country and dissected remnants of the Edwards Plateau to the west. In addition to showing surface-water resources provided by the lakes, the map area also depicts important groundwater resources, including Barton Springs and part of the recharge zone and upstream contributing watersheds that feed the springs. North of the Colorado River, extensive plateau uplands recharge the northern Edwards Aquifer.

A Dedicated Educator

Map coauthor **Chock Woodruff** is well known in Texas as a leading practicing professional geoscientist and consultant, especially in the field of engineering/environmental geology. Chock came to Texas to pursue his Ph.D. His dissertation (1973) concerned the Lake Travis vicinity. During his long and productive career in Central Texas, his passion for teaching has reached far beyond the conventional classroom, and thousands of colleagues, fellow citizens, and students have benefited from his experience.

Peer-Reviewed Publications by Bureau Researchers

Abolt, C. J., Young, M. H., Atchley, A. L., and Wilson, C. J., 2019, Rapid machine-learning-based extraction and measurement of ice wedge polygons in high-resolution digital elevation models: The Cryosphere, v. 13, p. 237–245, http://doi.org/10.5194/tc-13-237-2019.

Alfi, M., Hosseini, S. A., Enriquez, D., and Zhang, T., 2019, A new technique for permeability calculation of core samples from unconventional gas reservoirs: Fuel, v. 235, p. 301–305, http://doi.org/10.1016/j.fuel.2018.07.114.

Alfi, M., Vasco, D. W., Hosseini, S. A., Meckel, T., and Hovorka, S. D., 2019, Validating compositional fluid flow simulations using 4D seismic interpretation and vice versa in the SECARB Early Test—a critical review: International Journal of Greenhouse Gas Control, v. 82, p. 162–174, http://doi.org/10.1016/j.ijggc.2019.01.003.

Alnahwi, A., and Loucks, R. G., 2019, Mineralogical composition and total organic carbon quantification using X-ray fluorescence data from the Upper Cretaceous Eagle Ford Group in southern Texas: AAPG Bulletin, v. 103, no. 12, p. 2891–2907, http://doi.org/10.1306/04151918090, [Supervised graduate student paper].

Ambrose, W. A., and Loucks, R. G., 2019, Transition from paleosols in the Cenomanian Woodbine Group to carbonates in the Coniacian lower Austin Chalk in East Texas Field: an example of compressed transgressive succession from subaerial processes to deepwater deposition: GCAGS Journal, v. 8, p. 1–21.

Anderson, J. S., Romanak, K. D., Alfi, M., and Hovorka, S. D., 2019, Light hydrocarbon and noble gas migration as an analogue for potential CO_2 leakage: numerical simulations and field data from three hydrocarbon systems: Greenhouse Gases: Science and Technology, v. 9, no. 2, p. 226–244, http://doi.org/10.1002/ghg.1841.

Bader, S., Wu, X., and Fomel, S. B., 2019, Missing log data interpolation and semiautomatic seismic well ties using data matching techniques: Interpretation, v. 7, no. 2, p. T347–T361, http://doi.org/10.1190/INT-2018-0044.1.

Bakhshian, S., and Hosseini, S. A., 2019, Pore-scale analysis of supercritical CO_2–brine immiscible displacement under fractional wettability conditions: Advances in Water Resources, v. 126, p. 96–107, http://doi.org/10.1016/j.advwatres.2019.02.008.

Bakhshian, S., and Hosseini, S. A., 2019, Prediction of CO_2 adsorption-induced deformation in shale nanopores: Fuel, v. 241, p. 767–776, http://doi.org/10.1016/j.fuel.2018.12.095.

Bakhshian, S., Hosseini, S. A., and Shokri, N., 2019, Pore-scale characteristics of multiphase flow in heterogeneous porous media using the lattice Boltzmann method: Scientific Reports, v. 9, no. 3377, 13 p., http://doi.org/10.1038/s41598-019-39741-x.

Beskardes, G. D., McAliley, W. A., Ahmadian, M., Chapman, D. T., Weiss, C. J., and Heath, J. E., 2019, Power density distribution in subsurface fractures due to an energized steel well-casing source: Journal of Environmental and Engineering Geophysics, v. 24, no. 2, p. 285–297, https://doi.org/#10.2113/JEEG24.2.285.

Bhanja, S. N., Mukherjee, A., Rangarajan, R., Scanlon, B. R., Malakar, P., and Verma, S., 2019, Long-term groundwater recharge rates across India by in situ measurements: Hydrology and Earth System Sciences, v. 23, no. 2, p. 711–722, http://doi.org/10.5194/hess-23-711-2019.

Caldwell, T. G., Bongiovanni, T., Cosh, M. H., Jackson, T. J., Colliander, A., Abolt, C. J., Casteel, R., Larson, T., Scanlon, B. R., and Young, M. H., 2019, The Texas Soil Observation Network: a comprehensive soil moisture dataset for remote sensing and land surface model validation: Vadose Zone Journal, v. 18, no. 1, 20 p., http://doi.org/10.2136/vzj2019.04.0034.

Callahan, O., Eichhubl, P., Olson, J. E., and Davatzes, N. C., 2019, Fracture mechanical properties of damaged and hydrothermally altered rocks, Dixie Valley-Stillwater Fault Zone, Nevada, USA: Journal of Geophysical Research: Solid Earth, v. 124, no. 4, p. 4069–4090, http://doi.org/10.1029/2018JB016708.

Caudle, T., Paine, J. G., Andrews, J. R., and Saylam, K., 2019, Beach, dune, and nearshore analysis of southern Texas Gulf Coast using Chiroptera LIDAR and imaging system: Journal of Coastal Research, v. 35, no. 2, p. 251–268, http://doi.org/10.2112/JCOASTRES-D-18-00069.1.

Chen, X., Eichhubl, P., Olson, J. E., and Dewers, T. A., 2019, Effect of water on fracture mechanical properties of shales: Journal of Geophysical Research: Solid Earth, v. 124, no. 3, p. 2428–2444, http://doi.org/10.1029/2018JB016479.

Coleman, A. J., Duffy, O. B., and Jackson, C. A.-L., 2019, Growth folds above propagating normal faults: Earth-Science Reviews, v. 196, 31 p., http://doi.org/10.1016/j.earscirev.2019.102885, 102885.

Covault, J. A., and Sharman, G. R., 2019, Chapter 12 - Tectonostratigraphic evolution of the inner California Borderland: template for fill-and-spill sedimentation, *in* Miall, A. D., The Sedimentary Basins of the United States and Canada (2nd ed.): Cambridge, Mass., Elsevier, p. 511–528, http://doi.org/10.1016/B978-0-444-63895-3.00012-7.

Dashtian, H., Bakhshian, S., Hajirezaie, S., Nicot, J.-P., and Hosseini, S. A., 2019, Convection-diffusion-reaction of CO_2-enriched brine in porous media: a pore-scale study: Computers and Geosciences, v. 125, p. 19–29, http://doi.org/10.1016/j.cageo.2019.01.009.

DeAngelo, M. V., Fifariz, R., Meckel, T., and Treviño, R. H., 2019, A seismic-based CO_2-sequestration regional assessment of the Miocene section, northern Gulf of Mexico, Texas and Louisiana: International Journal of Greenhouse Gas Control, v. 81, p. 29–37, http://doi.org/10.1016/j.ijggc.2018.12.009.

Dillon, P., Stuyfzand, P., Grischek, T., Lluria, M., Pyne, R. D. G., Jain, R. C., Bear, J., Schwarz, J., Wang, W., Fernandez, E., Stefan, C., Pettenati, M., van der Gun, J., Sprenger, C., Massman, G., Scanlon, B. R., and 15 other co-authors, 2019, Sixty years of global progress in managed aquifer recharge: Hydrogeology Journal, v. 27, no. 1, p. 1–30, http://doi.org/10.1007/s10040-018-1841-z.

Ellis, G. S., Zhang, T., Kralert, P. G., and Tang, Y., 2019, Kinetics of elemental sulfur reduction by petroleum hydrocarbons and the implications for hydrocarbon thermal chemical alteration: Geochimica et Cosmochimica Acta, v. 251, p. 192–216, http://doi.org/10.1016/j.gca.2019.02.023.

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Transitions

New Employees

The Bureau of Economic Geology continues to attract some of the most talented geoscientists in the world to conduct impactful research on a wide range of energy and environmental questions—and equally talented support staff to help them in their efforts. The year 2019 was no exception as the Bureau brought a diverse group of 12 new people on board. Please help us welcome them to the Bureau!

Alex Bump
Research Scientist Associate IV

Amanda Calle
Postdoctoral Fellow

Jun Ge
Research Scientist Associate IV

Emery Goodman
Project Manager

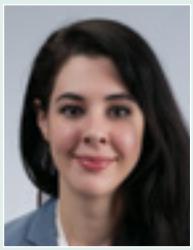
Kelly Hattori
Research Scientist Associate III

Travis Hobbs
Publications Editor

Tim Lawton
Research Scientist

Ning Lin
Program Manager, Chief Economist

Shukuru Makanyaga
Research Scientist Associate I



Emily Moskal
Research Program Coordinator

Victor Ozuna
Financial Analyst

Priyanka Periwal
Research Scientist Associate III

Scotland, 1982

In Memoriam

"Seay was a good friend and a good man. He would send me notes a couple times each year about how great a place the Bureaeu was and how fortunate he felt. That was Seay, always thinking of others"

Scott Tinker

Hardie Seay Nance

Former Bureau Research Associate **Hardie Seay Nance** died peacefully after a long illness on February 15, 2019, at his home in the Texas Hill Country.

Seay began his geology career in 1976 as a student assistant in the Department of Geological Sciences at The University of Texas at Austin. In 1977, he moved to the Bureau of Economic Geology, where he worked in the Well Sample Library and Sedimentology Laboratory while completing his B.S. (1978) and M.S. (1988) degrees at UT Austin. At the Bureau, he initially contributed to the Coalbed Methane, Superconducting Super Collider, and West Texas Waste Isolation projects, among others. After leaving the Bureau for a brief stint as a consulting geologist, he returned in 2001 and retired in 2014, in the meantime earning his Ph.D. in geology in 2010.

His areas of expertise included hydrogeology, sedimentology, and stratigraphy. His late work in the subsurface Permian Basin was a capstone to his early work mapping spectacular outcrops in the Guadalupe Mountains, which provide analogs to Permian Basin reservoirs. Seay's dedicated service to the people of Texas, mapping natural resources and educating industry geologists and State policymakers, was exemplary. He was a true State Geological Survey geologist and public servant.

His colleagues remember him as the "utility infielder" of the Bureau—a personable, straight-talking, broad-thinking contributor to every project he worked on, unusually able and willing to do taxing physical labor when required to get data. He treated everyone, regardless of job title, with respect and dignity and was quick to acknowledge essential behind-the-scenes work that supported his research.

In retirement, Seay applied his talents to 3D abstract drawing, playing guitar and piano, and walking along the banks of Gillum Creek through the woods of Serendipity, the land that he and wife Jean loved to call home.

***Robert W. Baumgardner, Jr.**, The University of Texas at Austin (retired)*

***H. Scott Hamlin,** The University of Texas at Austin*

Stephen C. Ruppel

Dr. Stephen Craig Ruppel died at home in Austin, Texas, on October 21, 2019. A senior research scientist at the Bureau, Steve had more than 40 years of experience in characterizing carbonate and mudrock reservoir systems.

Steve was born in Wabash, Indiana, on January 22, 1946. He obtained his B.S. in geology from the University of Illinois, Urbana, and an M.S. in geology from the University of Florida, Gainesville. His Master's thesis dealt with the conodont biostratigraphy of Mississippian rocks in northern Alabama. Steve then worked as a wellsite geologist for Chevron Oil Co. in New Orleans, studying Miocene and Cretaceous reservoirs in offshore Louisiana and Paleozoic carbonate rocks in the Appalachians. He continued researching carbonate systems while at the University of Tennessee, Knoxville, where he received his Ph.D. in 1979.

After postdoctoral study at McGill University, Montreal, Steve joined the Bureau in 1981, where, until 2009, his research centered on Paleozoic carbonate systems and reservoirs in Texas. He conducted research on many carbonate depositional systems in the Permian Basin, notably the Lower Permian Leonardian Clear Fork Group and the Guadalupian San Andres and Grayburg Formations. For 10 years, along with William L. Fisher, Steve cotaught the carbonate section of a UT Geological Sciences course on advanced reservoir geology. He also supervised seven Master's students and one Ph.D. candidate.

"It's hard for me to believe Steve is gone. He was so vibrant and influential in carbonate science, and to the Buearu as a whole. I owe him a debt of gratitude."

Scott Tinker

In 2009, Steve formed the Bureau's Mudrock Systems Research Laboratory as principal investigator. Steve's recent research focused on two unconventional mudrock reservoir systems: the Lower Permian Wolfcamp Series in the Permian Basin and the Upper Cretaceous Eagle Ford Formation of the South Texas shelf.

Steve published more than 170 articles and reports on Paleozoic and Mesozoic carbonate and mudrock systems. He belonged to AAPG, SEPM, the International Association of Sedimentologists, and the Austin and West Texas Geological Societies.

During his long career, Steve received several awards, including the 2002 Wallace E. Pratt Award for Excellence of Presentation in the AAPG Bulletin, the 2006 Levorsen Memorial Award for best paper presented at the Southwest Section of AAPG, the 2011 Levorsen Award for best paper at GCAGS, and the 2010 Jackson School of Geosciences Outstanding Research Award.

Steve is survived by his wife Gera and his sons Erik and Mark.

***Robert G. Loucks**, The University of Texas at Austin*

Robert J. Graebner

"Bob was a giant in the field of 3D siesmic. He truly had an impact on subsurface understanding."

Scott Tinker

Robert J. Graebner, a geophysicist and former senior research fellow at the Bureau who was known as "the father of 3D seismic technology," died January 28, 2019, just a few weeks shy of his 95th birthday.

Bob's contributions to his field include internationally recognized work in the early advancement and promotion of 3D seismic and 23-plus years of distinguished leadership in the Society of Exploration Geophysicists (SEG). He served as president of SEG (1986–87) and received SEG's highest honor, the Maurice Ewing Medal, in 2005.

After receiving his B.S. in engineering physics and M.S. in physics from the University of Colorado, Bob's career included four decades at Geophysical Service Inc. (GSI) and its offshoot, Texas Instruments. After Halliburton bought GSI, Bob stayed on as chief geophysicist until 1993.

Foremost among the advances made by GSI under Bob's leadership was the development of digital recording of seismic-reflection data. The DFS-1, the first operational digital recorder, introduced the industry to digital recording and was the first giant step in establishing publicly available, digital, 3D seismic technology. Digital data recording was the catalyst that led to the establishment of other building blocks needed for 3D seismic technology, namely 3D data processing, exponential increases in computer technology that allow huge data volumes to be handled at high speed, and development of seismic interpretation workstations and software.

From 1994 through 2012, Bob was a senior research fellow at the Bureau, where his collaborations included using vertical- and horizontal-shear modes for determining anisotropy.

Sharon G. Lowe

Sharon G. Lowe, who worked at the Bureau as an administrative clerk, assistant, and associate from 1985 through 1996, passed away on January 16, 2019, in Lockhart, Texas, at age 75. While at the Bureau, Sharon worked in the Core Research Center and bookstore. After her retirement, she was active in her church and community, including acting as a reading coach for elementary school students.

Living Memorials

In an effort to recognize the lasting contributions of past employees through a living monument, the Bureau adopted the Memorial Tree Program in 2013. Since its inception, donations by Bureau employees have underwritten the planting of a tree in commemoration of employees whose passing occurred or was noted during the year. In 2019, the Bureau honored to the following former employees: Robert J. Graebner, Sharon G. Lowe, H. Seay Nance, and Stephen C. Ruppel. The program is administered by The University of Texas at Austin as part of its Memorial Tree Program; an interactive map can be found at https://facilitiesservices.utexas.edu/divisions/support/urban-forestry/memorial-trees-map.

2019 Visiting Committee

From left to right: Mr. Larry French (Texas Water Development Board, representing Jeff Walker), Mr. Mark A. Houser (University Lands), Ms. Marilu Hastings (Cynthia and George Mitchell Foundation), Mr. John W. Gibson, Jr. (Flotek Industries), Dr. Scott W. Tinker (Bureau of Economic Geology), Mr. Tim Brittan (Infinity Oil & Gas, Inc.), Dr. Claudia Hackbarth (Shell Global Services U.S.), Mr. Bud Scherr (Valence Operating Company), Mr. Scott Anderson (Environmental Defense Fund), Mr. Richard (Dick) Stoneburner (Pine Brook Partners), Dr. Mark W. Shuster (Bureau of Economic Geology), Dr. Kenneth (Ken) Peters (Schlumberger, representing Dan Domeracki), Ms. Carol Lloyd (ExxonMobil Corporation), Mr. Bud Brigham (Anthem Ventures, Brigham Minerals, Brigham Exploration, Atlas Sand), Chairman Jon Niermann (Texas Commission on Environmental Quality), and Mr. Phillip Ashley (Texas Comptroller of Public Accounts, representing Glenn Hegar).

Composed of key State-agency leaders, industry executives, and foundation officers, the Visiting Committee of the Bureau of Economic Geology provides vital counsel to Bureau leadership on issues it faces and on future opportunities and challenges to consider. Whereas the committee receives regular updates from Bureau leaders and key researchers during the year, the meeting allows members to provide input and to suggest new ideas for future research and activity.

At the recent Visiting Committee annual meeting, discussions were far-reaching and insightful. Bureau directors **Mark Shuster**, **Michael Young**, and **Jay Kipper** shared information on the extensive work of their respective teams. Chief Economist **Ning Lin** described plans for a resurgent Center for Energy Economics, Senior Research Scientist **Bridget Scanlon** described the water situation in the Permian Basin, and Research Scientist **Xavier Janson** presented information on the complex productive formations of the Permian Basin and the work of the Bureau to model them. Kipper also led a brainstorming session on how the Bureau could devote more effort to utilizing machine learning and data analytics.

The meeting closed with a tour of the Bureau's new state-of-the-art Core Research Facility, renovated labs, and the beautiful new Stoneburner Family Rock Garden. Visiting Committee members later reported that they were impressed with the Bureau's accomplishments over the past year and appreciative of the creative and useful conversations during the meeting.

For more information about the work of the Bureau or its Visiting Committee, please contact **Mark W. Blount**, External & Governmental Affairs, mark.blount@beg.utexas.edu.

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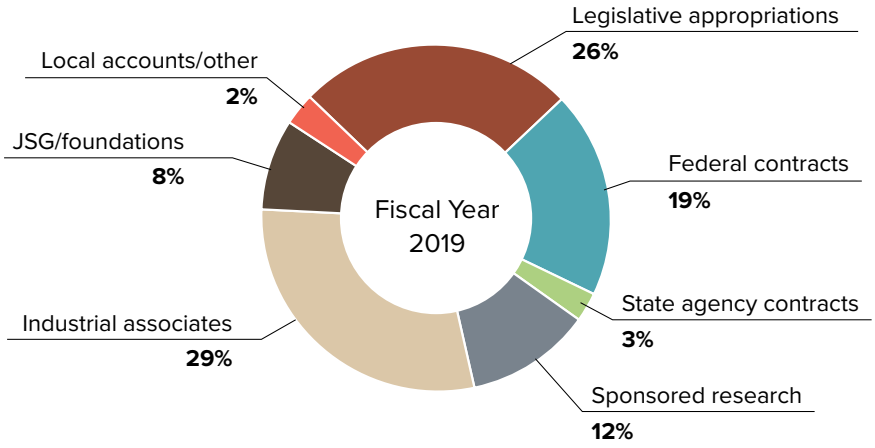
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State agency contracts
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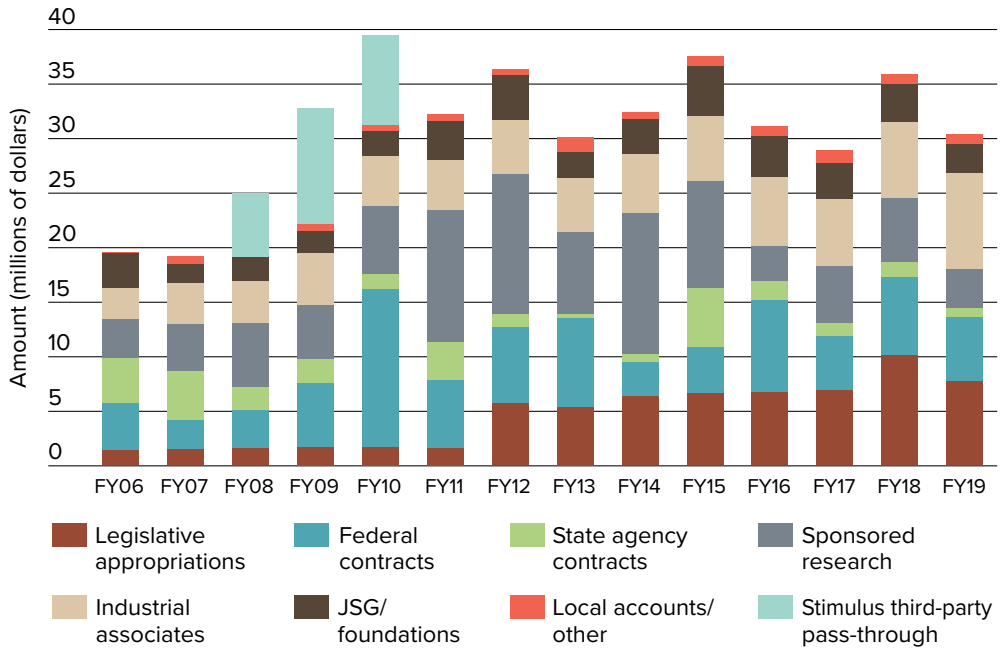
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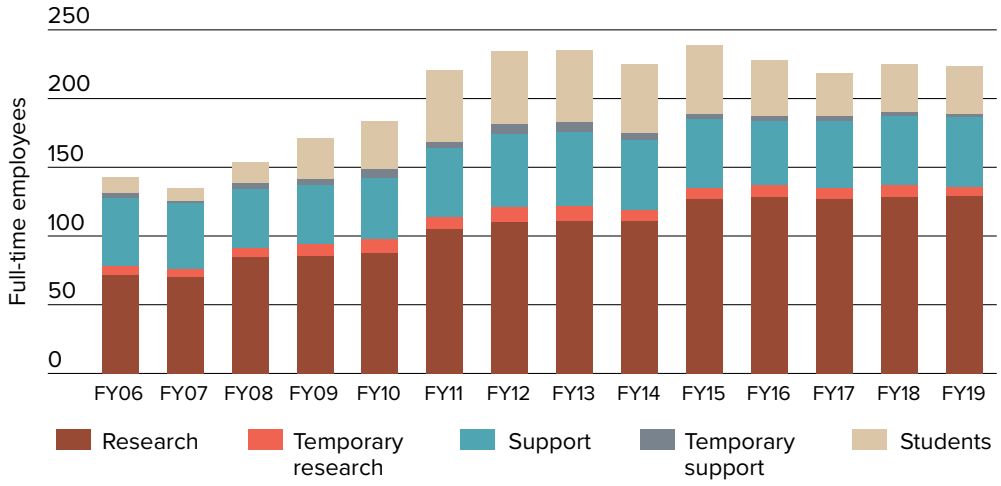
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Scott W. Tinker, Director

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Stoneburner Family Rock Garden at the Bureau of Economic Geology