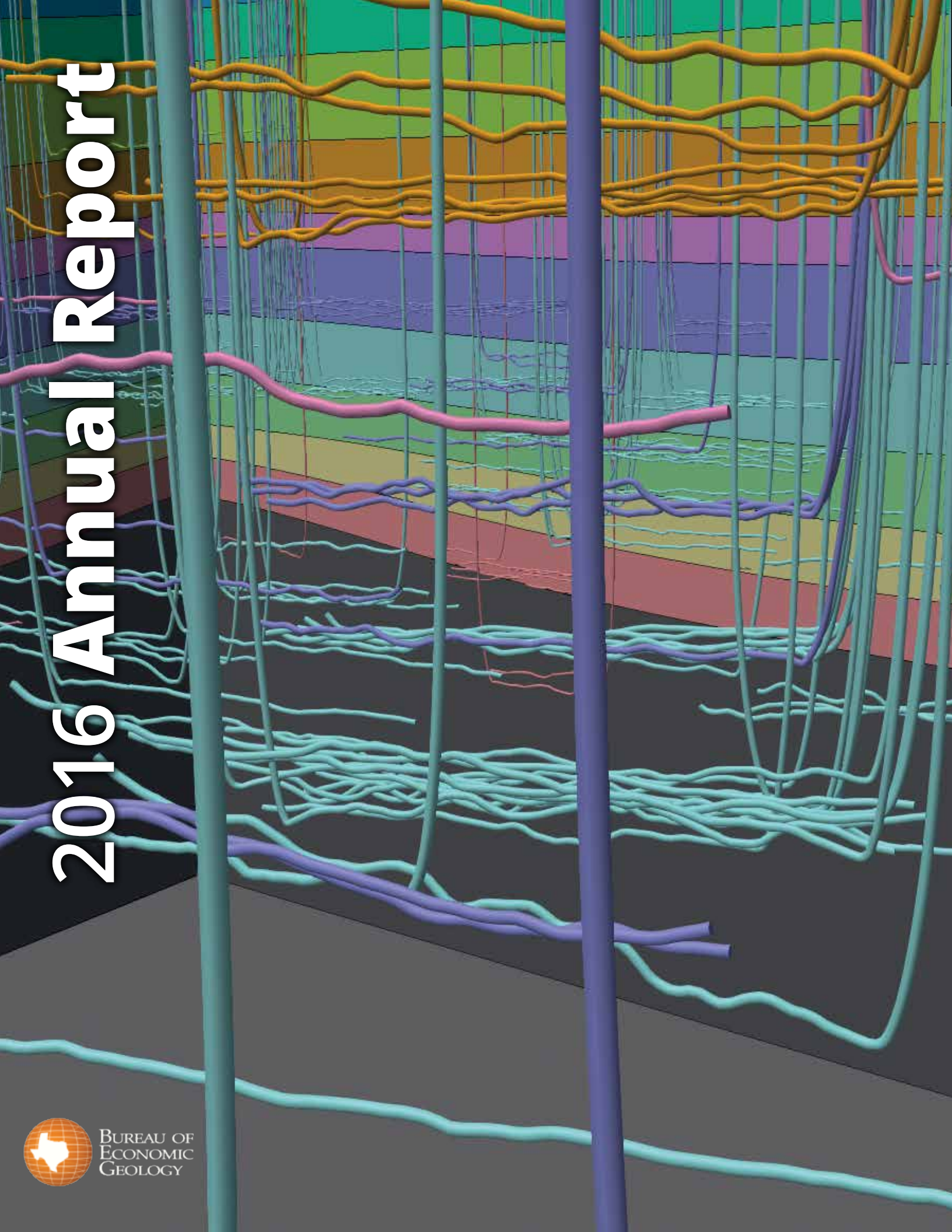
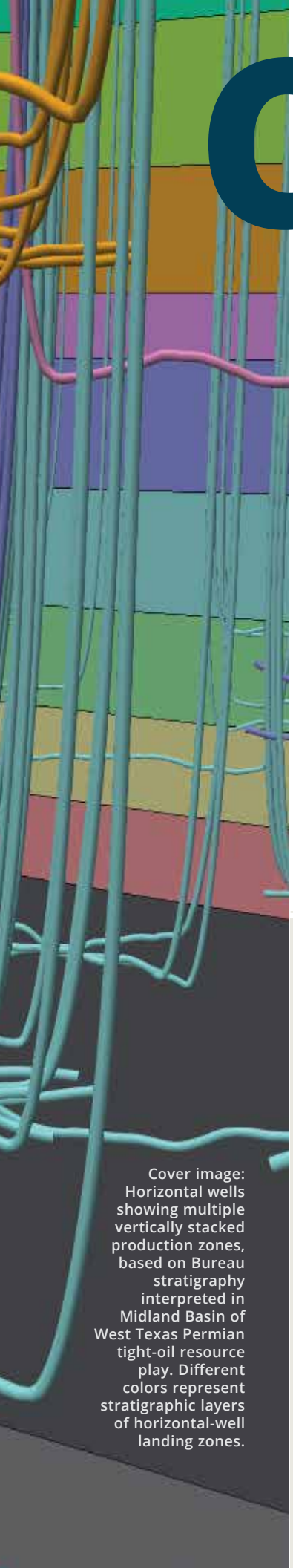
2016 Annual Report



Bureau of Economic Geology



Horizontal wells from upper, middle, and lower members of Bakken Formation shown together with water-cut pie charts for all Bakken wells. 3D pie charts represent water cut; cumulative oil production is shown in green, and cumulative water production is shown in blue. Vertical exaggeration for 3D scene is set to 20x.

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Cover image: Horizontal wells showing multiple vertically stacked production zones, based on Bureau stratigraphy interpreted in Midland Basin of West Texas Permian tight-oil resource play. Different colors represent stratigraphic layers of horizontal-well landing zones.

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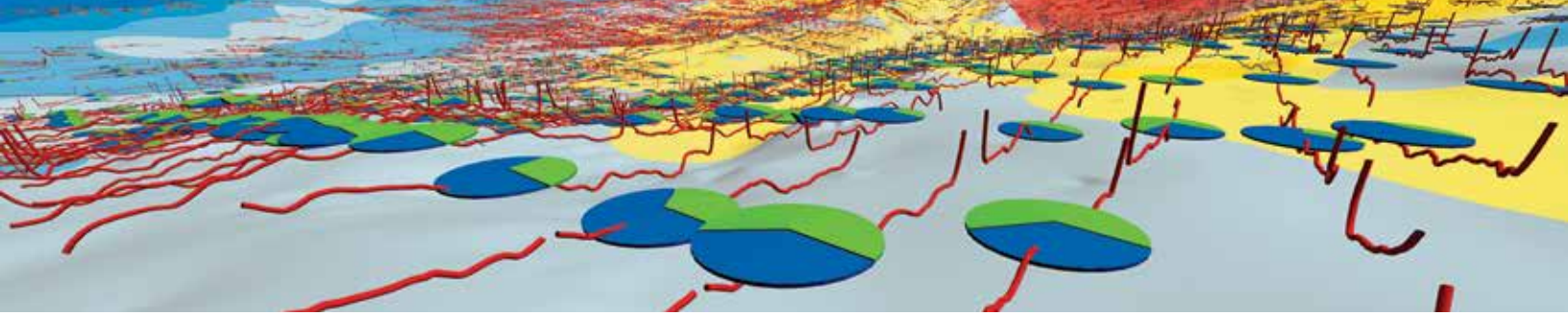


Message from the Director

Although technology surrounds us, it can, as it advances, become less accessible each year to most of us. For example, do I need to know how my microwave works to cook a hot dog? Do I need to appreciate how a fuel-injected combustion engine operates to drive to work? Do I need to understand how a battery is made or how electricity is generated to charge my cell phone? These are common tools available to modern society, but it's not necessary that I, as a consumer, understand their inner workings.

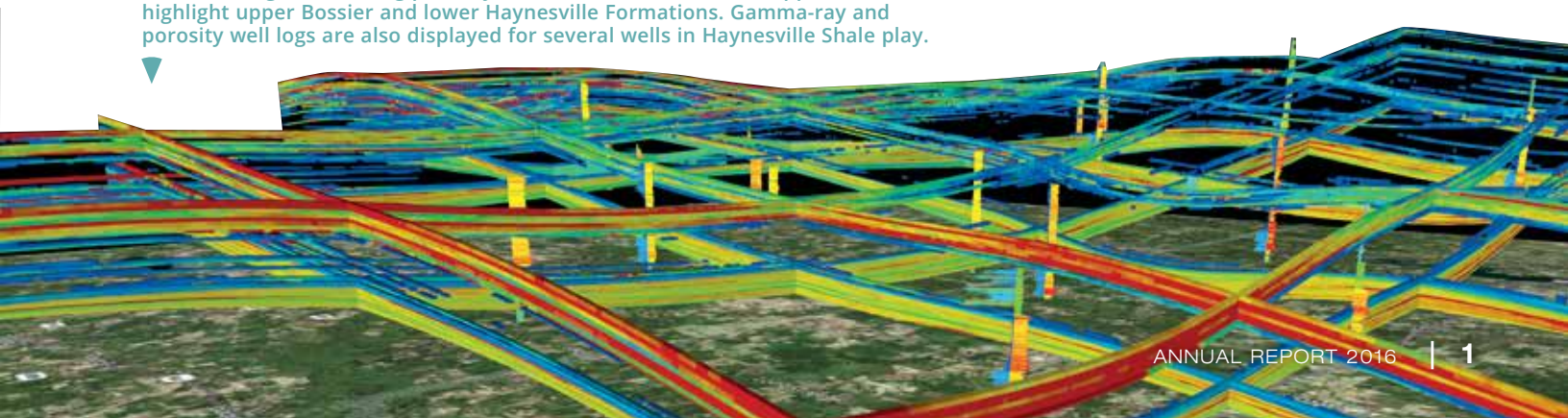
But what if I am a scientific researcher investigating fundamental questions?

I may not understand the fundamental physics and electronics of X-ray fluorescence (XRF) technology. But I do need to understand when that technology is providing bad data and, more importantly, I need to be able to interpret XRF measurements of core. I need to understand mobility in porous media in order to predict how nanosensors will move in subsurface reservoirs. I must be able to grasp the basic rock–fluid physics of shale reservoirs if I am to accurately model future reserve and production scenarios. I need to recognize natural climate cycles in the rock record at 1,000-, 10,000-, and 100,000-year scales to put into context the relative impact of human activities over the past 100 years and, further, be able to model the next 100 years. I need to understand marine sediment deposition, as well as the elastic and acoustic impedance of the resulting rock–fluid systems, if I am to interpret 3D seismic of these rocks for purposes of sequestering hundreds of millions of tons of carbon dioxide offshore. I need to appreciate the deposition, erosion, and resultant geomorphology of river systems if I am to interpret light image detecting and ranging measurements from airborne lidar.

Technology and tools are opening up new worlds at all scales in geosciences, from nanopores in mudrocks, to sedimentary basins, to Earth's atmosphere. But comprehending, reducing, and analyzing the data from lab and field measurements, putting the data in geologic context, and creating mathematical models of future scenarios all require a strong grasp of the physical systems that are being described and modeled.

In this Annual Report, we look at various high-tech tools that are helping us to advance science. Importantly, we at the Bureau also bring a fundamental comprehension of the underpinning rock–fluid system to all of the technological approaches we employ. Without that, we are just cooking hot dogs.

3D fence diagram showing porosity values, with a visual cutoff applied to highlight upper Bossier and lower Haynesville Formations. Gamma-ray and porosity well logs are also displayed for several wells in Haynesville Shale play.



Technology Opens New Worlds in the Geosciences

Robert Reed working at the Bureau's scanning electron microscope.

Texas soil-monitoring station.

Back in 1909, Bureau of Economic Geology geologists would load their gear on horseback and ride out to a rock outcrop somewhere in the vast State of Texas to physically sample and analyze what might be a commercially viable seam of copper ore or some other economically important mineral. Geology at that time was almost as much an art as a science; these early Bureau researchers had to use their experience, and sometimes their imaginations, to characterize what they thought was going on in the subsurface. Today, only 108 years later, technological advances have transformed the way geoscientists study Earth, opening new vistas in our understanding of the geologic processes that have shaped our planet. This year's Annual Report looks at just some of the new technologies that are allowing researchers to answer the important questions that drive the Bureau's energy, environmental, and energy-economics research.

> Today, technological advances have transformed the way geoscientists study Earth, opening new vistas in our understanding of the geologic processes that have shaped our planet.

How can we visualize the complexities of the subsurface and continually update that picture as new data become available? In 2016, the Bureau used a variety of state-of-the-art 3D modeling software tools to build both conventional and unconventional basin and reservoir 3D models based on structural, stratigraphic, and production-history interpretations. The purpose of this effort was to create

integrated visual models serving as relational and object-based databases capable of yielding insights into study areas ranging from regional geology to individual well-production behavior. The Bureau's 3D modeling process combines all available knowledge of an area's geology, petrophysics, seismic, drilling and well completions, and past production performance into an integrated 3D geocellular reservoir model. Recent examples of built 3D models include those characterizing the Marcellus, Haynesville, Barnett, and Bakken shales for the Shale Production and Reserves Study; the Midland Basin for the Tight Oil Resource Assessment project; and the Fort Worth Basin for the Center for Integrated Seismicity Research.

What if we want to know what the pore systems of potentially productive shale formations really look like? What kinds of mineral compositions are most likely to allow for extraction of hydrocarbons from those shales? Advances in scanning electron microscope (SEM) technology and the Bureau's SEMs are providing answers to these questions related to the heterogeneity of productive shale (and other rock) formations. The Bureau's **SEM Laboratory** provides micro- to nanoscale SEM image and chemical analyses of various rock samples using secondary electrons, backscattered electrons, and cathodoluminescence. The lab has the ability to zoom down to the 5-nm scale on samples prepared using the ion-milling process, which provides a smooth rock surface for analysis. The resulting images can be filtered to highlight which minerals are present and in what quantities, key to determining how a particular shale might fracture to free the oil or gas molecules it holds.

The Bureau's 3D modeling process combines all available knowledge of an area's geology, petrophysics, seismic, drilling and well completions, and past production performance into an integrated 3D geocellular reservoir model.

Skilled and experienced personnel are the key to results in the Bureau's XRF Laboratory. Pictured from left to right are Miranda Bernard, lab manager Evan Sivil, and Jarred Garza.

XRF Technology Deciphers Rocks

For decades, drillers have examined core and cuttings to try to understand the depositional environment of rocks and determine the likelihood of a given horizon to carry hydrocarbons in commercial quantities. Now, with X-ray fluorescence, or XRF, geologists have a fast, effective tool to read the mineral composition of rock samples in minute detail. The Bureau's **XRF Laboratory** is perfecting the use of this significant technology every day.

The XRF Laboratory utilizes a suite of equipment, and the work of a number of researchers and students, to analyze core and other rock material, much of which is provided by partners in Bureau research consortia such as the **Mudrock Systems Research Laboratory** and the **Reservoir Characterization Research Laboratory**. The XRF Laboratory can relatively quickly generate high-resolution data from a drill core that fingerprints a particular zone, determining the core's elemental composition and, from that, deducing its mineral content and probable depositional environment.

What distinguishes the work of the Bureau's XRF Laboratory from many common commercial practices is the great care that is taken when conducting each analysis. It is important to understand the limitations of XRF and properly prepare and calibrate the samples. For instance, rocks to be scanned in the lab are thoroughly cleaned before analysis to mitigate any brine buildup from evaporating water or any biological matter that may have grown on the face of the sample.

The expectation is that XRF equipment will get faster and more sensitive and will become a standard approach for geologic analysis. XRF provides an analytical tool for understanding lithologic variability and heterogeneity at a subfacies scale.

TexNet seismic monitoring station.

Darkest spots are nanopores on the surface of an ion-milled shale sample detected by an AFM.

What if we want to know how much groundwater exists in a specific reservoir, or how dry the soil of a region is during a severe drought? For some of these answers, Bureau hydrogeologists can use real space-age technology. In addition to field observations and information from historical studies, researchers can incorporate data from the orbiting GRACE satellite pair, which use gravity measurements to estimate the quantity of water under a specific area. Prolonged dry conditions result in hydrological drought, impacting deep soil water storage that must be replenished before water can enter reservoirs or recharge aquifers. The **Texas Soil Observation Network (TxSON)** uses a system of monitoring stations throughout the Texas Hill Country in conjunction with NASA's Soil Moisture Active Passive (SMAP) satellite to provide scientists with accurate estimates of soil moisture, giving researchers a better idea of the true extent of a drought and how much water will be needed to improve conditions.

Tiny computers are being tested to one day be injected into a formation and relay data to operators concerning downhole pressures and temperatures.

What if we want to better understand what is causing some of the recent earthquake activity in Texas? In 2016, the **TexNet Seismic Monitoring Program** installed its first seismometers and began capturing seismic data. The first network of portable seismometers was installed throughout the Dallas–Fort Worth area, a region that had seen low-level earthquake events, and began streaming vital seismic data to Bureau researchers. And the first group of a planned network of 22 permanent stations statewide was deployed in West Texas. The Bureau's multi-institutional **Center for Integrated Seismicity Research (CISR)** brought together partners from academia, government, and industry to begin analyzing new TexNet data within several research thrusts, and will provide input to policy makers and the general public about any future earthquakes and how to mitigate their impacts.

How do we determine how fluids flow through shale and other tight oil reservoirs? Determining the area, viscosity,

and permeability of a particular shale sample to estimate its fluid-flow properties must be done at nanoscale, which can be daunting. However, fluid-flow modeling developed by the Bureau's **Farzam Javadpour** is promising. An atomic force microscope (AFM), a high-tech device that uses a miniature needle to travel near the surface of a tiny rock sample to detect and characterize its surface topography, offers a better understanding of the pore and pathway structure of the sample's formation. The model then coalesces findings about the specific rock sample from other Bureau researchers, incorporating SEM, AFM, nitrogen adsorption, and other readings into a formula that adequately predicts the sample's fluid-flow properties.

> An atomic force microscope offers a better understanding of the pore and pathway structure of the sample's formation.

How can we accurately survey the most endangered river in the country, the Colorado River? In January 2016, the Bureau's airborne-imaging team from the **Near Earth Observatory** conducted a lidar survey to overfly and map the lower basin of the river along the borders of California and Arizona. The project was underwritten by the U.S. Bureau of Reclamation to understand and chart the overall geomorphology of the river basin, including the water-bottom surface. The survey area consisted of 120 miles of the river, showing varying water clarity, terrain altitude, flow conditions, and depth. Two separate airborne lidar systems were used; the huge topographic and bathymetric data sets had to be combined to create a uniform elevation map that also charted the bottom of the river.

What can we use to better characterize subsurface reservoirs and their fault systems? The Bureau's **Advanced Energy Consortium (AEC)** is very close to the development of commercially viable solutions. The AEC facilitates precompetitive research in micro- and nanotechnology materials and sensors. One such nanosensor that has evolved over the years is its "lab on a chip." These tiny computers—also known as "smart dust"—are being tested to one day be injected into a formation and relay data to operators concerning downhole pressures and temperatures. Such nanosensors were subjected to simulated downhole conditions in 2016 and fared very well in those experiments.

Technicians inject specialized EM contrast agents into injection well to enable remote fracture network mapping at Devine Test Site.

AEC Conducts Devine Test Site Experiment

Over the summer, the Bureau's **Advanced Energy Consortium** (AEC) conducted an extensive subsurface experiment at the Bureau's Devine Test Site, southwest of San Antonio, Texas. Test wells were drilled around a central injection well, which was hydraulically fractured. The AEC's electromagnetic (EM) contrast-agent material was injected into the formation to illuminate the fracture pattern using geophysical tools that are used by industry. The data, still under analysis, look promising.

"Our hope is to better determine where exactly the fractures have gone after a hydraulic fracturing job to help maximize hydrocarbon production from those fractured rock formations," said AEC project manager **Mohsen Ahmadian**. "AEC researchers have worked with us and our industry partners over the years to develop this innovative EM mapping approach, and this experiment at Devine has gone a long way toward proving the viability and importance of this work."

For more information about the Advanced Energy Consortium or to become a partner in its research, contact Bureau associate director **Jay Kipper** (jay.kipper@beg.utexas.edu).

XRF monitoring station.

Transect monitoring station.

AEC monitoring station.

How can we better understand the depositional environment of rocks and determine the likelihood of a given horizon to carry hydrocarbons in commercial quantities? Now, with X-ray fluorescence, or XRF, Bureau geologists in the **XRF Laboratory** have a fast, effective tool to read the mineral composition of rock samples in minute detail. Utilizing a suite of equipment, and the work of a number of researchers and students, the XRF Lab generates high-resolution data from a drill core that fingerprints a particular zone, determining the core's elemental composition and, from that, deducing its mineral content and probable depositional environment.

A handheld XRF scanner, looking like a cross between a large sci-fi ray gun and a supermarket scanner, is portable and can take readings in the field. Data interpretation is key, though, and much of the Lab's research helps to hone those interpretation techniques. It is predicted that XRF will one day soon be in every geologist's toolbox.

It is predicted that XRF will one day soon be in every geologist's toolbox.

If we want to begin storing CO_2 in reservoirs just offshore, how do we ensure that those formations can safely accommodate carbon storage for decades to come? The Bureau's **Gulf Coast Carbon Center (GCCC)** uses a unique ultrahigh-resolution, 3D, marine-seismic technology for carbon-storage monitoring, verification, and accounting. Deployment of P-cable technology (so called because it is towed perpendicular to the direction of a ship's track) provides significantly improved spatial resolution over a commercially meaningful offshore area with improved accuracy and economic viability, thus decreasing cost and uncertainty in measurements. The GCCC received a $2.5 million grant from the Department of Energy in 2016 to validate its methodology at a carbon-storage site offshore of the Japanese island of Hokkaido.

From smartphones to self-driving cars, we live in an age of leapfrogging technological advances. For eons, the world beneath our feet was unknown and mysterious. Today, however, with the help of the amazing technological resources of the Bureau of Economic Geology, we have opened immense doors into the world below us, with an ever-improving understanding of our Earth and what shapes it. ■

Bureau Welcomes
New Associate Director Mark Shuster

The Bureau of Economic Geology is excited to welcome **Mark W. Shuster** as its new associate director (Energy Division). Prior to joining the Bureau in September, Mark worked for Shell and affiliates for 30 years in upstream oil and gas roles around the world. Mark began his professional career as a research geologist working on projects in the Permian Basin, Atlantic margin basins, and Southeast Asia. Subsequently, Mark worked on exploration and appraisal projects in Venezuela, Australia, the Middle East, the Gulf of Mexico, and, most recently, Alaska. Mark received his B.S. in geology from the University of the Pacific and his Ph.D. in geology from the University of Wyoming. He will be bringing his years of experience in management roles within the Shell organization, as well as his deep knowledge of geologic processes, to lead the Energy Division's renowned researchers and their broad portfolio of energy research initiatives. Please join all of us in welcoming Mark Shuster to the Bureau!

Bureau Gets to Core of New Research Building

Core is unquestionably the Bureau's greatest material asset. We may possess more rock core than anyone in the world, and we undoubtedly conduct the best research on core of any geological institution. But why was coring taking place right outside the Bureau's own Core Research Center in 2016? The crew was determining the ability of the rocks underlying the site of the Bureau's new **Core Research Building** to withstand the weight of the construction. Said **Jay Kipper**, associate director of the Bureau: "When it's finished, the building will be a great place for our researchers to study rock samples, and we're looking for support to install a rooftop terrace that will be able to host Bureau events." To learn more about how you can be a partner in the creation of the Core Research Building, its rooftop terrace, and the adjacent scenic rock garden, contact **Jay Kipper** (jay.kipper@beg.utexas.edu).

Rendering of the Bureau's new Core Research Building (foreground left).

DOE and Bureau Continue Successful Collaboration

Bureau Hosts Assistant Secretary Smith

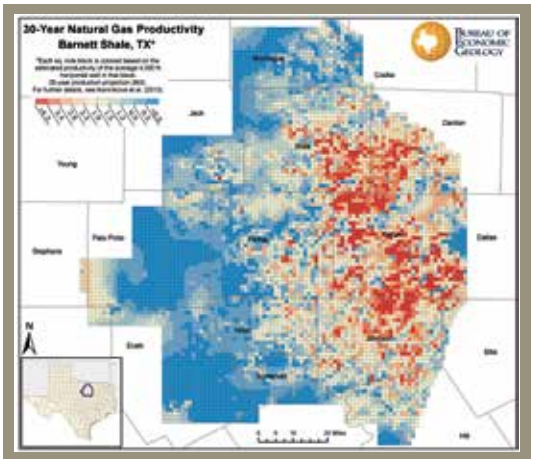
Bureau director Scott W. Tinker (left) and DOE Assistant Secretary for Fossil Energy Christopher Smith.

In the spring, the Bureau was honored to host **Christopher Smith**, Assistant Secretary for Fossil Energy at the U.S. Department of Energy (DOE), for an important discussion about existing and possible future partnerships between the two organizations. Among the topics discussed were offshore carbon capture and storage, nanotechnology applications in the energy sector, energy reform in Mexico and its implications, and the Bureau's ongoing reserves and production study of major American shale gas and shale oil basins. Representing the Bureau in the conversation were Director **Scott W. Tinker**; associate directors **Jay Kipper**, **Michael Young**, and **Eric Potter** (now retired); and research scientists **Tip Meckel** and **Svetlana Ikonnikova**.

Bureau Shale Study Receives DOE Grant

The Bureau's **Shale Production and Reserve Study** has been awarded a grant of $350,000 by the U.S. Department of Energy (DOE) for an 18-month study updating prior analysis of major American shale gas plays. The main objective is to enhance resource assessment work that the shale study team conducted with funding from the Alfred P. Sloan Foundation on the Barnett, Fayetteville, Haynesville, and Marcellus natural gas plays. The study will help to ensure consistency of approach across the four shale gas plays and will incorporate recent data, allowing researchers to capture new market dynamics, emerging technologies, and company strategies that drive shale resource development.

"Our current outlooks were built on relatively short production histories: 6 years of intense horizontal drilling in the Barnett, 5 years in the Fayetteville and Haynesville, and 4 years in the Marcellus," said **Svetlana Ikonnikova**, co–principal investigator of the Shale Production and Reserve Study. "Since we completed these studies, more wireline logs and core analyses have been released, allowing for more accurate geological and petrophysical characterization."



Previous shale studies at the Bureau include this 30-year gas productivity map (Ikonnikova et al., 2013) using assumptions described in "Barnett Shale Reserves and Production Forecast: A Bottom-Up Approach" (from Browning et al., 2013). County and state vector data from the Texas Natural Resource Information System (TNRIS). Well data provided by IHS and Drillinginfo; well raster logs provided by MJ Systems.

Additional years of production data enable the study of emerging drilling and completion technologies. The shale study team will revisit the original production scenarios performed by the Bureau in order to refine well-productivity analyses in each shale basin and set a consistent data year (2015) and future production year (2045) for all four basins. Access to data on hydraulic-fracturing treatment fluids—not available during the original analyses of the Barnett, Fayetteville, and Haynesville shale plays but found to be an important determinant of production in the analysis of the Marcellus play—will enable the enhancement of well-economics and field-outlook analyses.

The Department of Energy grant will fund individual reports on each shale basin based on geologic analysis, decline analysis, production economics, and field outlook. In addition, a collective report will combine the outlooks from the individual plays and discuss alternative scenarios with respect to prices, technology, pace of drilling, and other factors.

For more information on the Shale Production and Reserve Study, see the study's website (http://www.beg.utexas.edu/research/programs/shale) or contact **Svetlana Ikonnikova** (svetlana.ikonnikova@beg.utexas.edu).

Professor Sergey Fomel with international students.

TCCS Hosts International Meetings

The **Texas Consortium for Computational Seismology** (TCCS) held its Spring 2016 sponsor meeting at the Bureau's Houston Research Center in April; it was attended by nearly 60 people, including representatives from eight sponsor companies. TCCS staff, including the consortium's principal investigator **Sergey Fomel** and invited speakers, gave more than 20 research presentations on topics that included seismic interpretation, full waveform inversion, time-lapse seismic, seismic anisotropy, and high-resolution microseismic imaging. The meeting also featured tutorials on Madagascar open-source software and uncertainty quantification using Bayesian inversion.

In September, Fomel chaired the organizing committee for the 17th International Workshop on Seismic Anisotropy in Horseshoe Bay, Texas, which attracted 40 participants from 10 different countries. In October, the group held its Fall 2016 sponsor meeting at the Bureau's campus in Austin; it featured 14 research presentations, an overview of the TexNet seismic-monitoring program, and a tour of the Texas Advanced Computing Center.

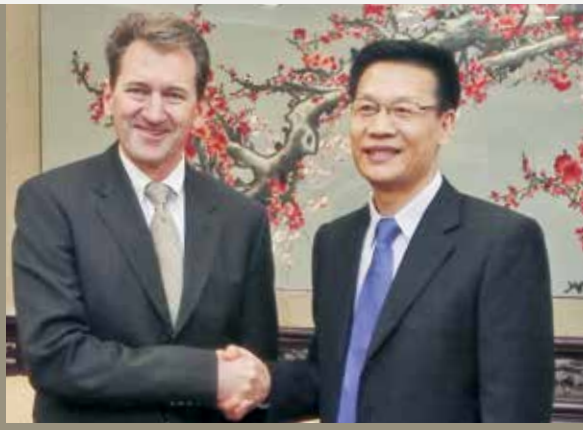
Bureau Team Expands Chinese Partnership

The Bureau's ongoing scientific collaboration with China continued in February and March with a fruitful trip to that country by Bureau director **Scott W. Tinker** and research scientists **Hongliu Zeng**, **Svetlana Ikonnikova**, and **Tongwei Zhang**.

The team first visited Xi-an to attend a final project review meeting for "Lacustrine Shale Gas Reservoir Characterization in the Yanchang Formation," a 2-year project funded by the Yanchang Petroleum Group. Key results and discoveries from the project will be published in a 2017 special section of *Interpretation*: "Lacustrine shale characterization and shale resource potential in Ordos Basin, China." During the visit, Director Tinker and Professor Xiangzeng Wang, vice president of the Shaanxi Yanchang Petroleum Company, discussed future research projects on shale gas and tight oil resources.

The Bureau team then visited the Research Institute of Petroleum Exploration and Development (RIPED) of PetroChina and the Research Institute of Petroleum Exploration and Production (RIPEP) of Sinopec. Director Tinker met with Professor Wenzhi Zhao, president of RIPED, and Professor Zhijun Jin, president of RIPEP, to discuss potential collaborations in unconventional resources. At both institutes, Tinker and Ikonnikova gave presentations on Bureau Industrial Associates programs to geologists, engineers, economists, and managers, encouraging RIPED and RIPEP to consider membership in select consortia.

On the final leg of the journey, Bureau researchers visited the Oil and Gas Survey Center (OGSC), China's Geological Survey of the Ministry of Land and Resources, where Director Tinker and Professor Gangyi Zai, deputy director of the OGSC, signed the framework of a cooperative agreement to jointly collaborate on a wide range of research projects in shale gas and shale oil resources.



Bureau director Scott W. Tinker (left) with Professor Wenzhi Zhao, president of RIPED of Petrochina.

GCCC Leads International Carbon Storage Efforts

Paris and Marrakech Climate Conferences

The **COP21 United Nations Climate Change Conference** held in late 2015 in Paris provided a clear measure of worldwide interest in climate-change mitigation technologies like carbon capture and storage (CCS). Representing the Bureau's **Gulf Coast Carbon Center** (GCCC), Research Scientist **Katherine Romanak** presented "Carbon Capture and Storage (CCS): Achievements and Opportunities for Developing Country Involvement" at the conference, in a session that focused on creating active collaborations in technology transfer, especially among economically emerging societies.

In November 2016, Romanak and GCCC researchers delivered new research insights and plans of action at **COP22** in Marrakech, Morocco, where Romanak joined expert panelists in exploring "Opportunities for Africa in Carbon Capture and Storage," the only sidebar event officially sanctioned by the sponsoring organization, the United Nations Framework Convention on Climate Change (UNFCCC). Romanak addressed specific actions and resources to enable countries in Africa and similar economically depressed regions to begin CCS. Noting the huge offshore CO_2 storage potential and stressing available technical assistance for climate technologies in developing countries, Romanak highlighted efforts by the GCCC, the Carbon Sequestration Leadership Forum (CSLF), and the Climate Technology Centre and Network (CTCN).

Katherine Romanak discusses options and actions for CCS in Africa at COP22 in Marrakech.

International Workshop on Offshore CO_2 Storage

In April, the GCCC hosted the first **International Workshop on Offshore Geologic CO_2 Storage**, organized by Romanak and 2016 Bureau Honorary Senior Research Fellow **Tim Dixon** of the International Energy Agency Greenhouse Gas (IEAGHG) R&D Programme.

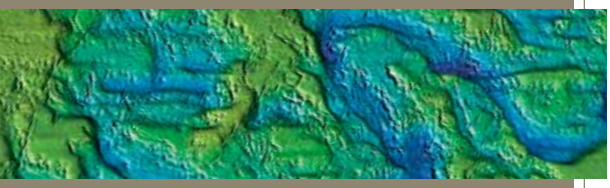
Dixon emphasized the value of bringing together an international contingent to discuss carbon storage in offshore reservoirs: "Over 50 experts from 13 countries came together in a common recognition that there is a nexus of interests and needs converging in progressing CCS offshore, and that momentum is being created toward international collaboration not just in knowledge-sharing but toward pilot and demonstration projects."

The meeting, an outgrowth of the Bureau's interaction with the Carbon Sequestration Leadership Forum and the IEAGHG, is notable as the first carbon sequestration–related effort to take advantage of new financing opportunities from the United Nations' Climate Technology Centre and Network, which provided funding for attendees from Ghana and Nigeria.

Said the GCCC's **Tip Meckel**: "This is the first time that we've ever had so much international diversity and experience all sitting down with the common goal of figuring out how we can work together to make offshore CCS work. You can either dip your toe into the offshore or take a deep dive. This was a deep dive."

Attendees of the Bureau's first International Workshop on Offshore Geologic CO_2 Storage.

A volumetric interpretation based on P-cable ultra-high-resolution 3D marine seismic data from the Gulf of Mexico.



GCCC Awarded $2.5M DOE Grant for 3D Seismic Study

Research Scientist **Tip Meckel** and the Bureau's **Gulf Coast Carbon Center (GCCC)** research team have been awarded $2.5M by the U.S. Department of Energy (DOE) for a new project that will improve monitoring of carbon storage in offshore reservoirs.

The project—"Validation of MVA Tools for Offshore Carbon Capture and Sequestration: Novel Ultra-High-Resolution 3D Marine Seismic Technology Integrated with Coring and Geochemistry"—was one of eight selected under the DOE's Subsurface Technology and Engineering Research, Development, and Demonstration (SubTER) Crosscut initiative, which centers on furthering geothermal energy and carbon-storage technologies.

The research focuses on GCCC's unique ultra-high-resolution 3D marine seismic technology for carbon-storage monitoring, verification, and accounting (MVA) at the fully developed Tomakomai carbon-storage site offshore of the Japanese island of Hokkaido. Deployment of P-cable technology (so called because it is towed perpendicular to the direction of a ship's track) at this location will seek to demonstrate significantly improved spatial resolution over a commercially meaningful offshore area with improved accuracy and economic viability, thus decreasing the cost and uncertainty in measurements. Trailing long streamers equipped with seismic receivers in tight formation, the P-cable provides high-resolution 3D imagery in a region extending from the seafloor down to about 1,500 m. The detailed data can be used to infer the history of fluid migration, which is key to ensuring that carbon dioxide is stored where it will not leak.

"This is an excellent method for GCCC and the U.S. program to advance our expertise in storage in the near-offshore setting via international collaboration with the unique project in Japan," said GCCC principal investigator **Susan Hovorka**.

Shell, Bureau Extend Partnership with SUTUR II

Shell Oil Company and the Bureau have been partners in many endeavors over the years, but none may have had more impact than the **Shell–UT Unconventional Research (SUTUR)** program, launched in 2011 with a $7.5 million grant from Shell to study hydrocarbon production from shale.

In the fall of 2016, a fully integrated team of researchers from the Bureau and Shell met in Houston to set the groundwork for **SUTUR II**, the next phase of the partnership, which will also be funded by Shell. SUTUR II brings together researchers from a large number of geologic and hydrologic disciplines for a 3-year project to study water issues related to tight-oil production in the Permian Basin. Bureau researcher **Julia Gale** will serve as the project's principal investigator.

"We're very excited to be working together with our friends from Shell to look more closely at how water is used and produced in the Permian Basin," said **David Chapman**, Bureau project manager for SUTUR II. "It's not often that you see this level of cooperation and the full integration of academic and industry scientists, and we are really looking forward to seeing the results of this vital research effort in the very near future."

Members of the inaugural conference of the International Soil Modeling Consortium (ISMC).

Bureau Hosts First ISMC Conference

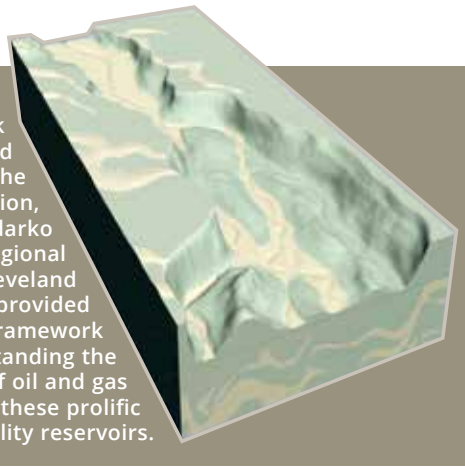
In the spring, the Bureau hosted the inaugural international conference for the establishment of the **International Soil Modeling Consortium (ISMC)**, whose mission is to integrate and advance soil systems modeling, data gathering, and observational capabilities. More than 110 scientists from over 25 countries participated in the event, which featured over 40 presentations and 80 posters covering a broad range of soil-modeling activities. Four working groups addressed key topics dealing with (1) the mission and governance of the ISMC and outreach, (2) model development and intercomparison, (3) linking data with models, and (4) cross-cutting issues in soil research and modeling.

The ISMC was officially founded on March 31, with Harry Vereecken (of Forschungszentrum Juelich, a national laboratory in Germany) and Bureau associate director **Michael Young** elected to 2-year terms as chair and co-chair, respectively. For further information on the ISMC, visit its website: **https://soil-modeling.org/governance**.

Ambrose, Hentz Present STARR Research Results

The Bureau's **State of Texas Advanced Resource Recovery (STARR)** program has been highly successful in its primary objective of increasing severance tax revenues for Texas through research projects that promote the drilling of profitable oil and gas wells in the state. In its 22-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.

Presentations to regional audiences by STARR scientists have helped generate awareness of research results and helped operators understand the value of research partnerships, both key in sustaining interest in ongoing projects and initiating new projects. In April, Bureau research scientist and STARR principal investigator **William Ambrose** presented "Representative Oil and Gas Plays in the East Texas, Fort Worth, and Anadarko Basins" to more than 50 members of the Dallas Geological Society. His presentation was an overview of three prolific oil and gas plays in Texas—the Woodbine, Marble Falls, and Cleveland Formations—that have been the focus of recent research by STARR.



Schematic block diagram of lowstand incised valley in the Cleveland Formation, northwest Anadarko Basin. STARR's regional study of the Cleveland Formation provided a geologic framework for understanding the distribution of oil and gas production in these prolific low-permeability reservoirs.

In May, Bureau research scientist **Tucker Hentz** presented findings of a recently completed STARR project, "New Interpretations of Reservoir Architecture of the Upper Cretaceous Woodbine Group in East Texas Field: Sequence Stratigraphic and Depositional Perspectives," to about 40 members of the Society of Independent Professional Earth Scientists (SIPES) in Austin. The focus of the study is the regional geologic aspects of the Woodbine Group.

For more information, visit the group's website: **http://www.beg.utexas.edu/research/programs/starr**.

Researcher Michelle Foss with colleagues at CEE's Mid-Year Meeting.

CEE Looks to Future of U.S. Electricity Markets

The Bureau's **Center for Energy Economics (CEE)**, world-renowned for its research into issues related to oil and gas markets and their economic impacts, is historically even more strongly rooted in the complex world of electricity markets in the United States, especially in Texas. CEE's Mid-Year Meeting, held at its offices in Houston, showcased the group's electric-power research portfolio for a large group of the Center's donors, advisors, and other invited guests (consultants, economists, and financial analysts) and featured spirited discussion of expectations, uncertainties, and predictions related to U.S. electricity markets.

A vast number of variables influence how electricity markets behave and what they might do in the future. For example, the increased utilization of power generated by wind and solar installations and how that power is accessed by consumers has caused utilities to rethink traditional pricing structures. On the other hand, solar and wind projects require economic consideration of how to provide baseload power—conventionally provided by coal, natural gas, or nuclear plants—to address their intermittency. Gas is often seen as necessary to balance variable wind and solar generation, but such utilization of gas units may not generate revenues sufficient for commercial viability.

Another variable for consideration is the rapid decline of coal and ascendancy of natural gas as the major power-generation fuel in America. Premature nuclear retirements further complicate competitive market designs, reliability considerations, and achievement of greenhouse emissions goals. CEE's dispatch modeling implies that yearly natural gas burned for power generation will increase from about 9.5 trillion cubic feet (Tcf) in 2015 to 13–15 Tcf by the middle of the 2020's, depending on the scenario.

"We devote a great deal of time to thinking about and researching these complex electricity markets, and we appreciate the thoughtful input we received from our colleagues at the Mid-Year Meeting," said **Gürcan Gülen**, CEE research scientist and senior energy economist. "Our objective is to allow our research in this area to guide the decision makers and stakeholders of the electricity sector as they consider the many economic factors affecting the industry."

RCRL Meets for Core Discussion

The **Reservoir Characterization Research Laboratory (RCRL)** held its Spring Workshop in May at the Bureau. Industry participants from 11 companies attended the series of individual seminars designed as a comprehensive review of topics of interest to carbonate geoscientists. Conducted by RCRL principles **Charlie Kerans**, **Bob Loucks**, **Xavier Janson**, and **Chris Zahm**, each of the following five daily stand-alone modules covered carbonate systems as they relate to reservoir characterization:

- Introduction to carbonates and principles of carbonate exploration and exploitation
- Seismic characterization of carbonate systems
- Use of core, log, and seismic data in construction of high-resolution sequence frameworks for reservoir characterization and modeling
- Principles of carbonate karst and associated reservoirs
- 3D fracture modeling using carbonate rock properties and mechanical stratigraphy

In addition to intensive classroom sessions, the event included core workshops at the Bureau's Austin Core Research Center and a field trip to nearby Longhorn Caverns to explore modern karst processes.

In September, the group held its Annual Sponsors Meeting at the Bureau, featuring an all-day core workshop, 2 days of technical presentations, a poster session, and a 3-day field trip to the Glass Mountains–Marathon Basin area.

The RCRL Annual Sponsors Meeting.

At the Annual Sponsors Meeting, RCRL researcher Bob Loucks (right) discusses cores of the Ordovician Ellenburger Formation.

Milliken Explores Seismogenic Zone

From August through October, Bureau senior research scientist **Kitty Milliken** joined 34 international researchers aboard the scientific drillship *JOIDES Resolution* as a participant in the International Ocean Discovery Program (IODP) Expedition 362, "Sumatra Seismogenic Zone." The goal of the expedition was to better understand the evolution of mechanical properties in offshore North Sumatran subduction-margin input sediments that might be influencing seismic activity such as the 2004 magnitude 9.2 earthquake and tsunami generated by unusually shallow megathrust slip.

The samples Milliken collected during the expedition will be examined using electron microbeam imaging techniques—developed at the Bureau for the study of unconventional resources—that will measure the strength of the sediments when buried and how fluids behave within these sediments, both of which are important for understanding how faults develop and their earthquake potential.

Scientists aboard the drillship *JOIDES Resolution*.

Research Consortia

Introduction

Much of the foundational research conducted by the Bureau of Economic Geology originates within the constructs of its 14 research consortia. These partnerships bring organizations and companies together to tackle specific research questions of importance to members, and to engage a broad spectrum of Bureau researchers, graduate students, and postdocs in the search for answers and new insights.

This section sets out the various research thrusts of these consortia—everything from mudrocks to carbon sequestration to gas markets. Three new consortia joined the fold in 2016: the Center for Integrated Seismicity Research (CISR), the Advanced Reservoir Geophysics group (ARG), and the Tight Oil Resource Assessment project (TORA).

Participation in Bureau research consortia is on a subscription basis and benefits vary. Generally, partners receive first-look privileges for research outcomes, access to research teams, invitations to annual review meetings, and office visits by researchers for presentations and interaction. Partners also benefit greatly from collaborations with other consortia members.

For answers to any questions about the Bureau's research consortia, or to join, please contact one of the principal investigators listed for each consortium in this section.

Bureau Welcomes New Consortia Researchers

In 2016, the Bureau welcomed the following distinguished researchers and participants in its consortia.

Carlos Torres-Verdín, the Zarrow Centennial Professor of Petroleum Engineering at UT-Austin, will collaborate on multiple research projects that involve geology, petrophysics, and geophysics, including in the new **Advanced Reservoir Geophysics (ARG)** consortium, where he will work alongside Bureau researchers Bob Hardage and Sergey Fomel.

Peter Hennings, **Ellen M. Rathje**, and **Alexandros Savvaidis** are the co-principal investigators of the new **Center for Integrated Seismicity Research (CISR)**. The three are also involved with the TexNet Seismic Monitoring Program, of which Dr. Savvaidis is the project manager, and will collaborate on earthquake monitoring, crustal velocity, and seismic-hazard research projects.

Dr. Hennings will also participate in other longstanding Bureau programs such as FRAC in addition to lecturing in the Jackson School. Dr. Rathje, an expert in earthquake engineering, is the Warren S. Bellows Centennial Professor in the Department of Civil, Architectural, and Environmental Engineering at UT-Austin. Seismologist Dr. Savvaidis comes to the Bureau from the Institute of Engineering Seismology and Earthquake Engineering in Greece.

Advanced Energy Consortium

The internationally recognized **Advanced Energy Consortium (AEC)** is dedicated primarily to achieving a transformational understanding of subsurface oil and natural gas reservoirs through the deployment of unique micro- and nanosensors. However, given the ongoing push toward reducing carbon-dioxide emissions into the atmosphere, the technology developed by the AEC is also proving to have applications in other industrial spaces. Areas of clear potential include hot dry rock (HDR) geothermal; seal integrity and other applications for measurement, monitoring, and verification (MMV) in carbon capture and storage (CCS); mining applications; cement reliability in nuclear waste; and well-bore integrity and nuclear-power generation.

Founded in 2008, the vision of the AEC is to illuminate oil and gas reservoirs and improve hydrocarbon recovery with novel micro- and nanosensing technology developed collaboratively with the global research community and our members. The AEC has invested more than $50 million in research, with ongoing work in 30 university and research facilities around the world. Since inception, the AEC has progressed from fundamental research to applied research targeting commercial applications ("use cases") that will help our members enhance their commercial extraction of oil and natural gas.

In only 8 years, the progress of the consortium has been remarkable. The AEC has created a whole new scientific space, published hundreds of peer-reviewed papers, created a patent portfolio exceeding 40 inventions, and is now on the verge of completing commercial-scale proof-of-concept tests. We anticipate the generation of real commercial products in the next 12–24 months, as well as the initiation of new areas of research.

Principal Investigators:
Scott W. Tinker and
Jay Kipper (jay.kipper@beg.utexas.edu)

Advanced Reservoir Geophysics

The University of Texas at Austin's Bureau of Economic Geology (Bureau), Department of Geological Sciences (DGS), and Department of Petroleum and Geosystems Engineering (DPGE) have formed a new industry-sponsored research consortium, the **Advanced Reservoir Geophysics Consortium (ARG)**. To improve quantification and monitoring of reservoir conditions and performance, research done by this consortium will develop new geophysical technologies that are production oriented and geologically consistent. The research goal is to increase the resolution with which geophysical measurements are used to detect, quantify, and manage reservoirs containing fluids that need to be extracted, as well as reservoirs where fluids need to be injected and stored.

The ARG will focus on developing new seismic-data acquisition and data-analysis methods that improve target resolution, allow more-accurate estimations of geomechanical rock properties, and provide seismic attributes that better relate reservoir properties to geophysical data. The ARG will use advanced rock-physics methods to estimate lithofacies, petrophysical, and fluid properties within targeted time–depth windows. A sizeable portion of the consortium's work will be directed toward developing and demonstrating new methods for time-lapse data processing, imaging, and interpretation.

ARG research projects will span all aspects of geophysical technology that affect reservoirs: petrophysics; rock physics; software development; seismic-data acquisition, processing, and interpretation; borehole geophysics; numerical modeling; theoretical concepts; spatial/time-imaging principles; inversion techniques; and microseismic applications.

The primary research staff of the ARG will be scientists and students located in existing geophysics-oriented, industry-supported research consortia within the Bureau, DGS, and DPGE. Faculty, research scientists, and students outside of these consortia will participate in ARG projects to the extent that funding will allow.

Principal Investigator:
Bob Hardage (bob.hardage@beg.utexas.edu)

Applied Geodynamics Laboratory

The **Applied Geodynamics Laboratory (AGL)** is dedicated to producing innovative new concepts in salt tectonics. The AGL attempts to understand salt tectonics using three complementary approaches, which work together to build our understanding of salt deformation. The first approach involves kinematic and stratigraphic analysis of salt structures in some of the world's most spectacular salt basins. The second approach utilizes physical models to study the processes by which salt structures form and how these structures are affected by changing conditions. The third approach uses finite-element models to study the influence that salt movement has on stresses and fluid pressures in surrounding sediments.

Research results for 2016 include a new model for the opening of the Gulf of Mexico basin, which allows us to understand the Jurassic evolution of salt structures on both the U.S. and Mexican sides of the basin. Physical modeling successfully simulated compressional inversion of a salt-filled rift system, aimed at improving our understanding of structures in the Moroccan Atlas Mountains. Other physical models showed the structural style of shortening in isolated minibasin provinces and the deformation of weak subsalt sediments caused by welding minibasins.

Subsalt deformation caused by minibasin welding was also studied by finite-element models investigating the sealing capacity of salt beneath translating minibasins. Other finite-element models investigated the development of stresses and overpressures adjacent to salt walls during shortening, the evolution of overpressures below salt sheets during regional shortening, and the relative roles of gravity spreading and gravity gliding in the Needles fault zone in Canyonlands National Park.

Principal Investigator:
Mike Hudec (michael.hudec@beg.utexas.edu)

Center for Energy Economics

The Bureau's **Center for Energy Economics (CEE)** performs research and provides training and outreach on energy-value-chain economics, markets, and frameworks for commercial and strategic investment.

The goal of the Center, which is based in the energy capital of Houston, is to help prepare energy-industry managers, their legal advisors, government policy makers, and regulators for competitive and dynamic global energy markets. Because risk and uncertainty permeate the energy value chains, a better understanding of sources and drivers of risk and uncertainty sheds light on investment and commercial framework requirements to attract and sustain investment.

In 2016, the CEE research team continued work on global and North American natural-gas and liquefied natural gas (LNG) markets, upstream producer finance (U.S. producers and national oil companies), supply chains for critical minerals essential for energy systems (such as lithium), and various electricity-sector issues ranging from market design to modeling the impact of energy and environmental policies on fuel mix. The CEE also has a new Electric Power Research Forum, led by Drs. **Gürcan Gülen** and **Chen-Hao Tsai**, Senior Energy Economist and Research Associate. A summary of the group's research can be found at their Think Corner: **http://www.beg.utexas.edu/energyecon/thnkcrnr.php**.

The Center is externally funded through research grants and contracts, and corporate and government partnerships at the federal and state level, as well as ongoing CEE training programs through UT's McCombs School of Business.

Principal Investigators:
Michelle Michot Foss (michelle.foss@beg.utexas.edu) and **Gürcan Gülen** (gurcan.gulen@beg.utexas.edu)

Center for Integrated Seismicity Research

The **Center for Integrated Seismicity Research (CISR)** hosts a multidisciplinary, intercollegiate research consortium that—together with **TexNet** and its state-funded network of seismometers across Texas—focuses on the integrated study of seismicity within the state and potential applications beyond. CISR will conduct fundamental and applied research to better understand naturally occurring and potentially induced seismicity and associated risks. CISR's research thrusts—including Seismology, Geologic Characterization and Seismicity Analysis, Geomechanics and Reservoir Engineering, Seismic Hazard and Risk Assessment, and Seismic Risk Communication—are designed to understand the subsurface processes that may influence seismicity, and to quantify and reduce risk to the citizens and infrastructure of Texas.

Among the accomplishments of CISR in 2016 was the formal establishment of a broad yet integrated research team that spans six University of Texas System units, as well as Southern Methodist University, Texas A&M University, Sam Houston State University, and Stanford University. In 2016, 10 companies and organizations joined the consortium. In conjunction with TexNet and its research funding, CISR launched 13 active research projects during the year.

Currently there are six major TexNet–CISR initiatives: installing 22 permanent and 36 portable stations across Texas, developing the TexNet earthquake-detection management system, characterizing historical and current seismicity, characterizing the reservoir mechanics of disposal intervals and fault-triggering processes, understanding earthquake hazard and risk in Texas, and conducting studies of earthquake social science.

Principal Investigators:
Peter Hennings (peter.hennings@beg.utexas.edu) and **Ellen Rathje** (e.rathje@mail.utexas.edu)

Deep Reservoir Quality Gulf of Mexico Sandstones

The goal of the **Deep Reservoir Quality Gulf of Mexico** project is to decrease reservoir risk for deep to ultradeep drilling in the Gulf of Mexico (GOM) by providing concepts and assembling data that can be used to forecast reservoir quality and stratigraphic architecture in deep prospects. This multidisciplinary study includes interpretation of depositional environment and sequence-stratigraphic framework, petrographic analysis of rock samples, statistical analysis of porosity/permeability relationships to controlling parameters, and burial-history modeling of key wells.

The project focused on two major topics in 2016: (1) Wilcox sandstones in the Rio Grande delta system in Zapata County in far south Texas, and (2) Jurassic Cotton Valley sandstones in the northeast GOM. Wilcox sandstones from Zapata County provide information about detrital mineral composition and diagenesis of Wilcox reservoirs deposited in the Rio Grande system and are particularly applicable to understanding Wilcox sandstones in the Perdido fold-belt area along the boundary between U.S. and Mexican waters. The regional study of onshore Cotton Valley wells from East Texas to Mississippi is pertinent to deep exploration in the northeast GOM.

In 2017, the Deep Reservoir Quality project will study deepwater Lower Wilcox sandstones deposited in the Lavaca submarine-canyon system in Texas. Lavaca Canyon sandstones were deposited in a variety of deepwater depositional environments and facies, including turbidite channel-fill, levee/overbank, and mass-transport. Research will focus on variation in reservoir quality with depositional facies, particularly variations caused by differences in grain size, sorting, silt content, clay content, ductile-grain content, and diagenesis. These sandstones are good analogs for deepwater Wilcox sandstones in the Gulf of Mexico because they display similar composition, reservoir quality, and thermal maturity.

Principal Investigator:
Shirley Dutton (shirley.dutton@beg.utexas.edu)

Fracture Research and Application Consortium

The **Fracture Research and Application Consortium (FRAC)** conducts basic and applied research leading to accurate characterization and prediction of natural fractures in the subsurface, and to a better understanding of how these fractures influence production operations, including their interaction with hydraulic fractures. Established in 1998, FRAC works with companies engaged in fractured reservoirs, unconventionals in all rock types, and hydraulic-fracturing research ranging from physical and numerical experiments to the development of computer-modeling code.

Accurately predicting the attributes of natural and induced fractures is key to cost-effective resource extraction. FRAC uses a wide range of approaches, from subsurface analysis to outcrop studies; its diverse expertise includes engineering, geomechanics theory, rock testing and modeling, structural geology, advanced microstructural imaging, diagenetic characterization, and diagenetic modeling. The integrated structural-diagenesis approach to fracture and fault analysis began within FRAC.

Highlights in 2016 include advances in combining rigorous mechanics and geochemistry to understand the feedbacks in natural fracture growth, and incorporation of these effects into geomechanical models. Development and testing of these models in collaboration with member companies leads to more-accurate and testable pre-drill fracture predictions. Another area of progress was development of breakthrough analytical approaches to quantify fracture size distributions and spatial arrangements. The associated software is expected to be of great use in reducing costs and uncertainty in horizontal-drilling operations.

Principal Investigator:
Stephen E. Laubach (steve.laubach@beg.utexas.edu)

Gulf Coast Carbon Center

The **Gulf Coast Carbon Center (GCCC)** is an industry–academic partnership conducting research on mitigation of industrial CO_2 emissions by the process of carbon capture and geologic storage. Key areas of research include selecting suitable subsurface settings for storage, optimizing quantification of storage resources, and providing assurance that storage is effective. The GCCC develops practical and informative assessments using numerical models, laboratory studies, and small- and large-scale field studies.

Recent GCCC progress includes improvements in monitoring signal attribution, a skill that recent project experience has shown is of high value when changes are detected during a storage project. Attribution is used to separate natural variability in near-surface environments from leakage or other signals induced by storage activities. The GCCC has also improved and validated efficient analytical methods for assessing the capacity of the subsurface to accept and store large volumes of CO_2. Dynamic pressure-based methods developed by the GCCC provide insight into limits on the availability of storage resources in the short term. Limits on storage quality because of long-term migration have been assessed using laboratory and field validation of capillary-based process to improve upscaling and to constrain CO_2 migration rates.

A major current initiative considers technical, regulatory, and economic pathways for developing volumetrically significant and high-value storage in near-offshore environments. Highlighted activities include developing projects along the Gulf Coast, a collaboration with a unique offshore project in Japan, and successful global networking.

Principal Investigator:
Susan Hovorka (susan.hovorka@beg.utexas.edu)

Mudrock Systems Research Laboratory

The **Mudrock Systems Research Laboratory (MSRL)** continues to focus on defining the interrelationships among rock and fluid attributes in mudrock systems. The Eagle Ford Group remains an area of research interest; the MSRL integrates multiscale (subpore to interwell) data from Eagle Ford, including detailed studies of horizontal core, to construct a geologic model that can be used to examine variations and importance of such key attributes as bed continuity, fluid flow, pore types and distribution, rock strength, and saturation.

New areas of research include the Wolfcamp/Bone Spring section of the Delaware Basin, where the MSRL has assembled a suite of 20 cored wells and is conducting multidisciplinary analyses to define rock/fluid attribute variations at local and regional scales.

MSRL research on the Eagle Ford reservoir system is expanding into secondary targets of the upper Eagle Ford, Austin, and Buda to determine the relative importance of in situ versus migration-related hydrocarbon-charge pathways and the relationship pore systems and mineralogy have to these variations. Associated with this effort is upcoming study of new, immature Eagle Ford cores for information about original kerogen distribution and porosity and organic-matter evolution in the interrelated systems.

The MSRL continues to experiment with varying techniques for obtaining accurate multiscale measurements of petrophysical properties, including relative permeability, in the Eagle Ford and other mudrock formations. Also underway are efforts to apply in situ dynamic micro-CT scanning to investigate fluid movement in mudrocks for a better understanding of multiphase flow and fluid distribution and their interrelationships with mineralogy.

Principal Investigator:
Steve Ruppel (stephen.ruppel@beg.utexas.edu)

Quantitative Clastics Laboratory

The **Quantitative Clastics Laboratory (QCL)** focuses on sedimentary systems, reservoir characterization, and prediction. QCL researchers investigate the sedimentology and stratigraphy of depositional systems for reservoir modeling, uncertainty in subsurface stratigraphic correlation, and source-to-sink predictions for frontier exploration. They develop concepts for the prediction of stratigraphic architecture and controls on the evolution of fluvial, shallow-marine, and deepwater depositional systems with the aim of determining the impact of facies modeling on reservoir performance of these systems. Researchers also use subsurface, outcrop, Earth-surface, and marine-geology datasets to evaluate predictive, source-to-sink relationships between hinterland, fluvial, shoreline, shelf, slope, and deep-basin environments. The QCL provides results to industrial affiliates in a quantitative format, which facilitates probabilistic assessments and modeling of oil and gas reservoirs.

Sponsorship of the QCL grew during 2016, and the research team continues to enlarge its sphere of influence by presenting at international geoscience conferences and universities, and publishing peer-reviewed research in high-impact geoscience journals. The QCL team is expanding in 2017 with the hire of a new research scientist with an international reputation in sedimentology, stratigraphy, and stratigraphic/reservoir modeling.

Sponsors of the consortium—which predominantly comprises oil and gas companies, as well as government institutions such as the U.S. Bureau of Ocean Energy Management—can expect a comprehensive approach as the QCL research team carries out integrated geologic studies at multiple scales to develop models for processes and controls on sediment transport and the stratigraphic evolution of depositional systems.

Principal Investigator:
Jacob Covault (jake.covault@beg.utexas.edu)

Reservoir Characterization Research Laboratory

A hallmark of the **Reservoir Characterization Research Laboratory (RCRL)** program is its recognition of subsurface-characterization challenges that can be enhanced by the use of well-defined outcrop analogs, uniquely combined with a breadth of subsurface-characterization experience applied to problems important to sponsors of the program. In its 30 years of research on carbonate systems, the RCRL has developed techniques that populate the carbonate sequence-stratigraphic framework with reservoir-flow properties to improve hydrocarbon recovery.

Yet many challenges still exist within carbonate reservoirs, especially in the areas of integration of nonmatrix pore systems, pore-network-related diagenesis, and the realistic 3D variability of lithofacies distribution. The 2017 RCRL research program will cover multiple investigations and themes such as (1) platform-scale stratigraphy, (2) reservoir architecture and intra-play evolution, (3) structural and geomechanical characterization, (4) pore-network characterization, and (5) geochemical and chemostratigraphic analysis of carbonate systems.

One example of RCRL research is the role that older Paleozoic structures play both in controlling deformation styles and in the development and fracture intensity of the overlying younger Mesozoic carbonate strata. This concept—with its important implications in deciphering the role of early tectonic history on later fluid migration and potential hydrocarbon production—will form the basis for defining optimal drilling direction for unconventional resources. Another RCRL study utilizes an extensive regional seismic dataset of 2D and 3D lines to highlight the strike variability of Tertiary carbonate-platform architecture along strike of the North West Shelf of Australia. This investigation aids the development of regional-scale principles of carbonate stratigraphic architecture.

Principal Investigators:
Charles Kerans (ckerans@jsg.utexas.edu) and
Robert G. Loucks (bob.loucks@beg.utexas.edu)

State of Texas Advanced Resource Recovery

The goal of the **State of Texas Advanced Oil and Gas Resource Recovery (STARR)** program is to increase royalty- and severance-tax income to the state from oil and gas production in Texas. Significant oil and gas production comes from unconventional shale plays in Texas, including the Eagle Ford and Wolfberry trends, which the STARR program has characterized for the state.

In the 2014–16 biennium, STARR added approximately $54 million to the state's Permanent School Fund and General Revenue Fund from royalties and severance taxes from increased production. This revenue was the result of a wide variety of recent regional- and reservoir-characterization studies that include the Spraberry and Wolfcamp Formations in the Permian Basin, the Eagle Ford Trend in South Texas, the Eaglebine Trend in southeast Texas, Permian and Pennsylvanian reservoirs in the Eastern Shelf of the Permian Basin, the Wilcox Group in the Texas Gulf Coast, and Pennsylvanian-age reservoirs in the Texas Panhandle.

More than 20 oil and gas companies have participated in STARR studies in the last 2 years. Many of these studies have recently been presented in workshops that feature the Woodbine Group in the East Texas field and the Eagle Ford Formation and Wilcox Group in South Texas. These workshops provide up-to-date results of STARR integrated studies of the geologic framework of important oil and gas plays and are a valuable resource for operators and explorationists in Texas.

To date, the STARR program has generated more than 60 field studies. More than 50 Texas oil and gas operators have been involved in the STARR program over the project's 24-year duration. STARR studies have been used to recommend more than 300 infill and step-out wells, as well as many recompletions in a wide variety of oil and gas fields across the state.

Principal Investigator:
Bill Ambrose (william.ambrose@beg.utexas.edu)

Texas Consortium for Computational Seismology

The **Texas Consortium for Computational Seismology (TCCS)** is a joint multidisciplinary project of the Bureau and the Institute for Computational Engineering and Sciences (ICES). TCCS is focused on (1) addressing the most important and challenging research problems in computational geophysics as experienced by the energy industry, and (2) educating the next generation of research geophysicists and computational scientists. The group's research, combining expertise in geophysics and applied mathematics, concentrates on such areas of seismic-data analysis as elastic reverse-time migration, full waveform inversion, automated seismic interpretation, time-lapse seismic-image registration, seismic-diffraction imaging, and seismic anisotropy. For computational experiments, TCCS develops open-source software tools and utilizes supercomputing resources provided by the Bureau and the Texas Advanced Computing Center (TACC). Results are provided to the sponsors in a reproducible form.

Among TCCS research accomplishments in 2016 was the development of highly accurate, fully anisotropic 3D elastic modeling and imaging using (1) the low-rank approximation method, (2) the azimuthal plane-wave destruction and analytical path-integral approach for seismic-diffraction imaging, (3) a powerful optimal transport metric for full waveform inversion, (4) amplitude-adjusted plane-wave destruction for highly accurate registration of time-lapse images in seismic monitoring, and (5) novel anisotropic parameter estimation in orthorhombic media for fractured reservoir characterization. **Zhiguang Xue**, a Ph.D. student with the TCCS, won the Best Student Poster award at the Society of Exploration Geophysicists 2016 Annual Meeting in Dallas, becoming the fourth TCCS student to win a major presentation award during the last 5 years.

Principal Investigator:
Sergey Fomel (sergey.fomel@beg.utexas.edu)

Tight Oil Resource Assessment

The **Tight Oil Resource Assessment (TORA)** project builds upon the exemplary research of the Bureau's national Shale Production and Reserves Study to analyze the complex oil-rich source rocks of the Midland and Delaware Basins of Texas. TORA has adapted this shale study's workflow to help predict ultimate hydrocarbon recoveries, economic viability, and play-wide production rates. It will ultimately address main tight-oil formations such as the Spraberry, Wolfcamp, Bone Spring, and Avalon in order to produce unbiased, comprehensive, and publicly available results.

The project brings together an integrated, multidisciplinary team—including geologists, petroleum engineers, petrophysicists, economists, hydrologists, and GIS/database experts—from across The University of Texas at Austin and beyond, employing a multifaceted approach to analysis of a wide variety of challenging subject areas, including geology and petrophysics, reservoir engineering, energy economics, and water-resource management.

TORA employs a bottom-up approach that starts with detailed geologic mapping and a well-by-well production analysis. Future production outlooks will depend on economic considerations, including various price, cost, and technology-improvement scenarios. In turn, water resources utilized in drilling and production operations, and/or produced from these formations, will be thoroughly studied.

Early in 2016, the consortium's leadership held scoping and formational meetings, inviting input from potential partners. As companies and organizations joined, initial research began. In October 2016, TORA hosted its first meeting of industry sponsors.

Principal Investigators:
Mark Walsh (mark.walsh@beg.utexas.edu)
and **Svetlana Ikonnikova**
(svetlana.ikonnikova@beg.utexas.edu)

Honors and Awards

Scanlon Receives Top Science Honors

Bridget Scanlon, a hydrologist and senior research scientist at the Bureau, received several prestigious professional honors in 2016. Her Jackson School of Geosciences honors include appointment as the **William L. Fisher Endowed Chair in Geological Sciences**, as well as being named a fellow of the **Rodulfo Prieto Cedraro Memorial Excellence Endowment Benefitting the William L. Fisher Chair**.

Bridget Scanlon (right) receives M. King Hubbert Award.

Scanlon also received national recognition. In addition to being elected a member of the **National Academy of Engineering** (NAE), she also received the **M. King Hubbert Award** from the **National Ground Water Association**.

Membership in the NAE, one of the highest professional distinctions accorded engineers and scientists, honors those who have made outstanding contributions to engineering research and practice, including pioneering new and developing fields of technology and making major advancements in the engineering field and profession.

Said **Sharon Mosher**, dean of the Jackson School, "Bridget is one of the leading experts in the world on water resources, and her work is vitally important to help solve some of the pressing issues of the 21st century. Her research has helped improve the understanding of groundwater depletion worldwide and played an important part in informing U.S. water policy, as well as water policy here in Texas."

Scanlon leads the Bureau's **Sustainable Water Resources Program**, a research group that combines a variety of analysis methods—from local field measurements to data from NASA's GRACE satellite—to provide insight on water in the environment at a variety of scales. Recently, Scanlon led the most comprehensive study to date on the water supply of the Colorado River Basin, a water source for over 40 million people.

"I still have difficulty believing that I was elected," Scanlon said. "I wish the process would recognize collaborative efforts because I would like to acknowledge my coworkers, particularly **Bob Reedy** and **J.-P. Nicot**. I am very grateful to [Bureau director] **Scott Tinker** for supporting my career at the Bureau, to **Dean Mosher** for support from the Jackson School, and to **Dr. William Fisher** and many others who made the Jackson School a reality. I also appreciate support from the Mitchell Foundation and Sloan Foundation for our current research related to water and energy issues."

Scanlon received her M. King Hubbert Award from the National Ground Water Association (NGWA) for "major science contributions to the knowledge of groundwater." Said nominator Dr. William Alley, NGWA's director of science and technology, "Dr. Scanlon is an active and energetic scientist devoted to the advancement of geoscience and education. She is a gifted scientist and collaborator, and has made outstanding contributions on cutting-edge science."

Continued on page 24

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Topics of Scanlon's research include groundwater recharge, application of numerical models for simulating variably saturated flow and transport, assessment of natural and anthropogenic contamination of groundwater, impacts of climate and land-use changes on hydrologic processes, and water use and availability for energy.

Scanlon's numerous past honors include being elected a Fellow of the American Geophysical Union and the Geological Society of America (GSA), and serving as the GSA Birdsall–Dreiss Distinguished Lecturer. She has published more than 100 articles in highly regarded peer-reviewed journals such as *Groundwater®*, *Water Resources Research*, and *Environmental Science & Technology*. Scanlon has also served on many National Academy of Sciences committees, been involved with numerous U.S. Department of Energy scientific endeavors, and been a key member of the NASA GRACE Science Team. Scanlon received a B.S. in geology from Trinity College, Dublin, an M.S. in geology from the University of Alabama, and a Ph.D. in geology from the University of Kentucky. ■

2016 AAPG Michel T. Halbouty Outstanding Leadership Award: Scott W. Tinker

The American Association of Petroleum Geologists (AAPG) has honored **Scott W. Tinker**, director of the Bureau of Economic Geology, with the **Michel T. Halbouty Outstanding Leadership Award**.

The prestigious award—the second highest honor given by the AAPG—is given to only one recipient per year and recognizes those who have demonstrated exceptional leadership and extraordinary service to the petroleum geosciences and the association. The award was presented to Tinker at the AAPG Annual Meeting in Calgary in June.

Bureau director Scott W. Tinker (right) receives the Michel T. Halbouty Outstanding Leadership Award from AAPG president John R. Hogg.

"We are all very proud of Scott. He absolutely deserves this honor," said Sharon Mosher, dean of UT's Jackson School of Geosciences. "Scott is nationally and internationally recognized as a leader in petroleum geology and energy geosciences, and the Bureau has thrived with him at the helm."

Tinker was hired to lead the Bureau in January 2000. During his tenure, the Bureau has continued to excel at its core strengths and grow in new directions that include the development of a $50 million partnership with industry and international universities on advanced micro- and nano-subsurface sensors, a $50 million carbon management program recognized both nationally and internationally, a Center for Energy Economics, and a major program in mudrocks and unconventional reservoirs—from pore scale to future production scale. During the 17 years of Tinker's leadership, the Bureau's annual external funding has grown from $10 million to $35 million, its staff from 100 to 250, and its annual peer-reviewed publishing tenfold.

"I was stunned when AAPG president Hogg called with the news," Tinker said. "I deeply appreciate those whose mentorship and support have allowed me to grow and make what I do possible. I would also like to recognize and thank the tremendous team at the Bureau. I work with the best people in the field. I feel extremely fortunate to be a part of such a talented group."

In addition to leading the Bureau of Economic Geology, Tinker has served for over 5 years as acting associate dean for research in the Jackson School, where he is also a professor and the Allday Endowed Chair. He is the State Geologist of Texas and has served as president of the AAPG, Association of American State Geologists (AASG), American Geosciences Institute (AGI), and Gulf Coast Association of Geological Societies (GCAGS).

Other Honors

Distinguished Service Award

In 2016, the AAPG recognized two Bureau scientists with its **Distinguished Service Award**, presented to members who have distinguished themselves in singular and beneficial long-term service to the AAPG.

Stephen E. Laubach, Bureau senior research scientist and leader of its fracture and structural diagenesis programs, has served on the AAPG Executive Committee and was AAPG Elected Editor from 2010 to 2013. During his time of service, he helped found the AAPG's Petroleum Structure and Geomechanics Division; was involved in helping launch the new joint AAPG–SEG journal, *Interpretation*; founded, in 2012, the AAPG Charles H. Taylor Fellowship in support of scientific publishing; restructured the *AAPG Bulletin*'s Editorial Board; founded the AAPG Books Editorial Board; and instituted the *AAPG Bulletin*'s online Ahead of Print publishing and Notable Papers recognition.

Peter H. Hennings, Bureau research scientist and co-PI of its Center for Integrated Seismicity Research, was recognized for his leadership and enthusiasm in the fields of petroleum structural geology and geomechanics, and for his dedication to applied research and teaching. He has greatly assisted the AAPG in its science and outreach mission, especially as it pertains to his discipline area, and has served in numerous leadership capacities for the Association, including as founder and chair of the AAPG's Petroleum Structure and Geomechanics Division (2012–2015), chair of the AAPG Research Committee (2010–2012), and AAPG Associate Editor (2002–2015).

Stephen Laubach (at right in first picture) and Peter Hennings (at right in second picture) receive Distinguished Service Awards from AAPG president John R. Hogg.

Laubach, Young Elected to GSA Fellowships

Bureau researchers **Stephen E. Laubach** and **Michael Young** have been elected Fellows of the Geological Society of America (GSA). GSA Fellows are nominated by existing Fellows in recognition of their distinguished contributions to the geosciences through such avenues as publications; applied research; teaching; administration of geologic programs; contributing to the public awareness of geology; leadership of professional organizations; and taking on editorial, bibliographic, and library responsibilities. Laubach and Young were recognized in September at the 2016 GSA Annual Meeting Presidential Address & Awards Ceremony in Denver, Colorado.

Senior Researcher Laubach was nominated by Bureau director and GSA Fellow **Scott W. Tinker**, who recognized Laubach "for his outstanding accomplishments and research in the geosciences. His contributions to geologic research are exemplified by his publication record and citations, and especially for his service, leadership, mentorship, and research contributions in fracture mechanics, diagenesis, and fracture formation in sedimentary basins."

Associate Director (Environmental Division) Young was nominated by Bureau senior researcher and GSA Fellow **Bridget R. Scanlon** for "research [that] has significantly advanced understanding of water partitioning near the land surface considering climate forcing and ecosystems." Young is the founding chair of the GSA Soils and Soil Processes Interdisciplinary Interest Group and has been instrumental in developing soil studies and water-resource-management research at the Bureau.

Southwest Section A. I. Levorsen Memorial Award

William Ambrose, principal investigator of the Bureau's State of Texas Advanced Oil and Gas Resource Recovery (STARR) program, is the 2016 recipient of the **AAPG Southwest Section's A. I. Levorsen Memorial Award** for his April 2015 presentation of "Tidal Depositional Systems in Pennsylvanian Strata in the Anadarko Basin, Northeast Texas Panhandle" at the Southwest Section Annual Meeting held in Wichita Falls, Texas. The award recognizes the best paper presented at each AAPG Section meeting, with particular emphasis on "creative thinking toward new ideas in exploration."

A Warm Welcome Back and Honor for Campos

The Bureau is pleased to announce the return of our esteemed colleague Sharon Campos. After 26 years with UT-Austin and nearly 12 years with the Bureau, Sharon initially retired as Administrative Manager in February 2016. Luckily for us, she has since returned to the Bureau part-time, lending her expertise to various projects.

In 2016, Director Tinker honored Sharon for her service:

> *Friends,*
>
> *You may know that the Bureau has a Staff Excellence Award—created before the formation of the Jackson School—to recognize an outstanding staff member each year. A plaque on the east lobby wall displays awardee names.*
>
> *Please join me in congratulating Sharon Campos, our Staff Excellence Award winner for 2015. Sharon, who retired from full-time work this year, is no stranger to anyone at the Bureau. In addition to managing staff, she led facilities for the Bureau, as well as helped with many major programs, including the AEC and FutureGen.*
>
> *Congratulations, Sharon!*
>
> Scott W. Tinker

Best GCAGS Poster Award

The GCAGS recognized Bureau senior research scientist **Robert Loucks** with a **Best Poster Award** at the 2016 Houston Geological Society's Applied Geoscience Conference, for "Tying Core Descriptions and Optical Petrography with XRF Geochemical Data for a Detailed Characterization of the Mississippian Barnett Formation in the Southern Fort Worth Basin of North-Central Texas." Coauthors are **Lauren Redmond** and Harry Rowe.

From left: Former Bureau director and Jackson School dean William L. Fisher, Bureau director and Boyd Medal recipient Scott W. Tinker, and GCAGS president Charles A. Sternbach.

GCAGS Convention and Awards

At September's 2016 Annual Convention of the **Gulf Coast Association of Geological Societies** (GCAGS) held in Corpus Christi, Bureau director **Scott W. Tinker** received the **Don R. Boyd Medal for Excellence in Gulf Coast Geology**. The Boyd Medal is the GCAGS's highest award, given in honor of past GCAGS president Boyd to those who have achieved distinguished standing in at least two of the following three areas: (1) Gulf Coast Basin research geology, (2) Gulf Coast Basin oil and gas exploration, and (3) professional leadership in the GCAGS and in at least one of its member societies. The medal has not been awarded since 2011.

Chock Woodruff

The GCAGS also recognized Bureau senior research scientist **Chock Woodruff** with a 2016 **Outstanding Educator Award**, which is presented "in recognition of outstanding contributions in the education and training of geologists." In addition, Bureau senior research scientists **Shirley Dutton**, **Bob Loucks**, and **William Ambrose** received the group's 2015 **President's Award for Outstanding Paper** (GCAGS *Journal*, v. 4) for "Factors Controlling Permeability Variation in Onshore, Deep Paleogene Wilcox Sandstones in the Northern Gulf of Mexico Basin: Targeting High-Quality Reservoirs."

Bob Loucks, Bill Ambrose, and Shirley Dutton with their Outstanding Paper awards. Photo by Arthur Christensen.

Bureau Publication Awards

Each April, the Bureau honors its researchers with a dinner and awards to celebrate their publishing achievements.

In 2016, the recipients of the **Tinker Family BEG Publication Award**—a cash award presented to a Bureau researcher (or researchers) for the best peer-reviewed publication in the previous year—were **Andras Fall** and his co-authors (**Peter Eichhubl**, Robert Bodnar of Virginia Tech,

Peter Eichhubl, Stephen Laubach, Andras Fall, and Director Scott W. Tinker.

Stephen E. Laubach, and Steve Davis of Exxon) for "Natural hydraulic fracturing of tight-gas sandstone reservoirs, Piceance Basin, Colorado," which appeared in the Geological Society of America *Bulletin* (v. 127). Wrote one reviewer of the paper: "Fall et al. is a celebration of natural hydraulic fracturing that started a half century ago.... The driving mechanism debate in the Appalachian Basin has seen plenty of advocates (mainly in the USGS) on the side of the exhumation after glacial rebound explanation... Fall et al. end that debate emphatically."

The Bureau also recognized first authors of papers published in 2015 with its **First Author Publication Awards**. Of the Bureau's approximately 140 publications in 2015 (up from around 120 the year before), 76 were written by 49 first authors. **Tieyuan Zhu**, a postdoc in **Sergey Fomel**'s group, had the most first-author publications in 2016, with four articles. **Bill Ambrose** and **Bob Loucks** shared the distinction of being honored the most years for first-author publications: 8 times each since the award's inception in 2009.

Tieyuan Zhu (left) with Director Scott W. Tinker.

New Orleans Geological Society Best Paper Award: Jake Covault

In 2016, **Jake Covault**, principal investigator of the Bureau's **Quantitative Clastics Laboratory**, received the 2015 New Orleans Geological Society Best Paper Award for his June 2015 presentation in New Orleans of "Predictive Organization of Deep-Water Lobes."

Friend of Water–Rock Interaction Award: Katherine Romanak

Katherine Romanak received Friend of Water–Rock Interaction Award, in recognition of many valuable contributions to the International Symposium on Water–Rock Interaction, 2016. Researchers and scholars from the fields of geochemistry, hydrology, geology and environmental sciences to share scientific findings as part of the tri-annual WRI symposium series sponsored by the IAGC's Water–Rock Interaction Working Group and the local organizers.

New Chair of Department of Geological Sciences: Charles Kerans

Congratulations to Bureau senior research scientist **Charles Kerans** for his 2016 appointment as chair of the Department of Geological Sciences. Said Sharon Mosher, dean of the Jackson School of Geosciences (JSG): "Charlie is committed to moving the department forward and has an excellent understanding of the research breadth of the department and of the undergraduate and graduate programs.... [He] will be an excellent leader for the department and the school." Prior to this appointment, Kerans held the JSG's Robert K. Goldhammer Chair in Carbonate Geology.


Sue Hovorka


Seyyed Hosseini


Jiemin Lu


Patrick Mickler


Tip Meckel


J.-P. Nicot


Vanessa Nuñez


Katherine Romanak


Rebecca Smyth


Alex Sun


Ramon Treviño


Brad Wolaver


Changbing Yang

Jackson School Outstanding Research Award

The **Gulf Coast Carbon Center (GCCC)** is the recipient of the 2016 **Jackson School Outstanding Research Award**, given in recognition of outstanding research accomplishments by an individual or a team of faculty or scientists. Said Jackson School dean Sharon Mosher, "We struggled this year to decide the winner of this prestigious award, but it became easy when we recognized that nearly all of the nominees were part of the internationally renowned Gulf Coast Carbon Center. This group, led by **Sue Hovorka**, has consistently excelled, and individually and collectively deserve this award."

The GCCC is a leader in carbon sequestration, which aims to isolate anthropogenic CO_2 from the atmosphere by capturing it from large point sources and injecting it into the deep subsurface for permanent storage. The group is known for major real-time experiments, such as the Frio Project, where successful injection and monitoring of a unique field experiment in the Frio Formation tested whether carbon dioxide can be stored in underground brine-bearing sandstone. This test was arguably the first successful CO_2 sequestration field experiment in the United States in terms of both its engineering and its scientific results. It was followed by groundbreaking studies on the feasibility of carbon capture and storage (CCS), including the SECARB "Early Test" at the Cranfield Field site in Mississippi, which has been ongoing for 9 years.

The GCCC has become a leader in determining the potential for CO_2 sequestration offshore of the Gulf of Mexico, through a process—now being considered worldwide—that uses a novel high-resolution 3D seismic ("P-Cable") system. **Tip Meckel** leads the team in this research. The group has also developed many innovative techniques to assess reservoir performance and monitor CO_2 behavior, such as a pressure-based monitoring technology for leak detection in carbon storage reservoirs, developed by **Alex Sun**, or soil-gas monitoring techniques, developed by **Katherine Romanak**.

The work by GCCC investigators spans numerical modeling and experimental investigations from the laboratory to the reservoir scale, addressing both fundamental and practical questions. Major continuous funding from the U.S. Department of Energy, as well as from numerous companies, supports their work.

Said Mosher, "All of the researchers of this group (which—along with Hovorka, Meckel, Sun, and Romanak—also includes **Rebecca Smyth**, **J.-P. Nicot**, **Jiemin Lu**, **Patrick Mickler**, **Ramon Treviño**, **Changbing Yang**, **Vanessa Nuñez**, **Seyyed Hosseini**, and **Brad Wolaver**) have contributed significantly to our understanding of the behavior of CO_2 and exemplify interdisciplinary, team-based collaboration that makes the Jackson School outstanding."

The winners will receive $1,000 and recognition on a plaque in the JSG Dean's Office.

Outreach, Events, and Meetings

Jackson School Hosts 10th Anniversary Research Symposium

Portrait of Jack taken after Katie's death, her photo at his side—she was never far from his heart. Photograph by Dick Clintsman. Courtesy of Presbyterian Healthcare Foundation.

When **Jack and Katie Jackson** decided to invest their fortune in The University of Texas at Austin, they envisioned the creation of a world-class school of geosciences to help solve problems important to Texas and the world. Their vision guided a 10-year-anniversary research symposium hosted by the **Jackson School of Geosciences** in January, with research panels organized around the geoscience topics Jack thought essential: geology; geophysics; energy, mineral, and water resources; and broad areas of Earth sciences, including the environment.

In addition to the scientific panels, the symposium included a special panel, "The Jackson Five," dedicated to remembering Jack and reflecting on his influence on the school today. The panel consisted of five people who were close to Jack Jackson and helped secure his estate for the university: **Larry Faulkner**, former president of UT-Austin; **Peter Flawn**, former president of UT-Austin and president emeritus; **Bill Fisher**, the Jackson School's inaugural dean and the Leonidas T. Barrow Centennial Chair in Mineral Resources; **James Langham**, Jackson's longtime financial advisor and executor of his estate; and **Scott W. Tinker**, director of the Jackson School's Bureau of Economic Geology. "These words that we're following today are partly Jack's words and the vision he had for science, integration, and what he wanted to invest in," said Tinker. "I think that's an important piece. He's not just someone who gave money; he actually had a vision for how it would play out."

When Jackson, who made his fortune in the gas fields of Wise County and later in Dallas real estate, left his and wife Katie's estate to The University of Texas at Austin, it was then conservatively estimated to be worth $150 to $200 million; today, the endowment is valued at more than $300 million.

The Jackson Five (from left): Scott W. Tinker, director of the Bureau of Economic Geology; Bill Fisher, professor and the Jackson School's inaugural dean; Larry Faulkner, former president of UT-Austin; Peter Flawn, former president of UT-Austin; and James Langham, Jackson's longtime financial advisor and executor of his estate.

Educational Workshops and Training

In 2016, Bureau staff reached 275 Texas educators and students with educational workshops, training, and field experiences focusing on the geology of the state.

■ On June 17, Bureau researcher **Charles Woodruff** and Information Geologist **Linda Ruiz McCall** led an Austin-area field trip for 50 high school students in the UT San Antonio TRIO Upward Bound program. On June 21, McCall presented to 50 educators at the Groundwater to the Gulf Summer Institute in Austin about Balcones Faulting and the Edwards Aquifer. The Bureau partnered with the Texas Mining and Reclamation Association to train 25 educators at the Industrial Minerals Educator workshop held at the Bureau's administrative offices on June 29. Teachers listened to expert presentations and toured the core repository and Texas Advanced Computing Center. **Brent Elliott, Nathan Ivicic, Dallas Dunlap, John Andrews**, and McCall presented to the group.

■ **Linda Ruiz McCall** gave a distance learning presentation on August 2 for the **STEM Expo** held at the Education Service Center in San Angelo. The presentation compared the Oso, Washington, landslide of 2014 to the prehistoric landslides on Chilicotal Mountain of the Big Bend National Park, which were mapped by Bureau researcher **Eddie W. Collins**, William R. Muehlberger, and Patricia W. Dickerson and published by the Bureau in 2008 (Miscellaneous Map No. 46: Geologic Map of the Glenn Springs Quadrangle, Big Bend National Park, Texas). Rather than travel from Austin to San Angelo, McCall used the Nepris cloud-based social platform to connect 20 San Angelo area educators.

■ **Linda Ruiz McCall** and Bureau project manager **Scott Rodgers** presented to K–12 science teachers at the 2016 Conference for the Advancement of Science Teaching (CAST) in November. Over 5,500 science educators from across Texas attended the event, which was held in San Antonio. CAST includes exhibits and workshops that allow teachers to earn professional development credit and share their knowledge of the sciences with others in their field.

■ As part of the Texas Earth Science Teachers Association (TESTA) strand at the conference, McCall and Rodgers gave two workshops reaching 130 teachers on the Bureau's new book about the history of Texas geology, *Texas Through Time*. They also interacted with educators at an exhibit booth and shared hundreds of maps, rock kits, and American Geoscience Institute Earth Science Week toolkits at the TESTA Share-A-Thon.

Teachers attend the *Texas Through Time* CAST workshop.

Bureau researcher Chock Woodruff (wearing hat; top row, right) with high school students at Mount Bonnell.

Bureau director Scott W. Tinker gives keynote presentation at Career Day.

Geologist Laura Zahm of Statoil presents backpacks to students.

Austin Earth Science Week Career Day

In October, the Bureau hosted its 17th Annual **Austin Earth Science Week Career Day**, welcoming 200 middle-school students from the Austin area to the J. J. Pickle Research Campus (PRC) for a day of engaging presentations, exhibits, and face-to-face interaction with 65 geoscience professionals. Statoil supported the day as the underwriting sponsor and provided backpacks and supplies for the students. Other financial sponsors included Parsley Energy, Austin Geological Society, Schlumberger, and The Subsurface Library. In addition to Bureau staff, volunteers from the USGS Texas Water Science Center, City of Austin Watershed Protection, Texas Water Development Board, NASA Texas Space Grant, UT Center for Space Research, and the Jackson School of Geosciences Vertebrate and Non-Vertebrate Paleontology Labs also participated.

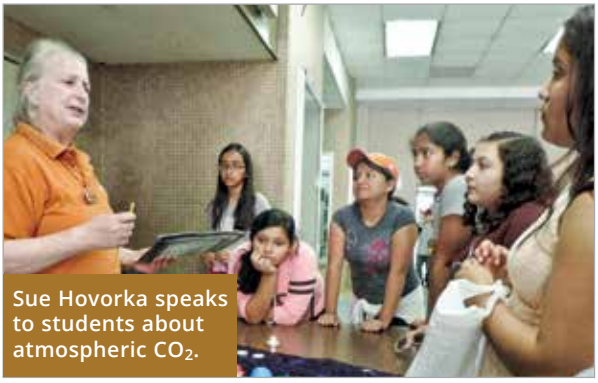
UT Forum Tour: Osher Lifelong Learning Institute

In February, the Bureau hosted 56 members of the UT Forum's Osher Lifelong Learning Institute. The group spent a day exploring the Pickle Research Campus and touring the Bureau's Austin Core Research Center (CRC), the Texas Advanced Computing Center, and the Center for Electromechanics. Bureau staff members **James Donnelly, Nathan Ivicic,** and **Linda Ruiz McCall** guided attendees around the CRC core repository, viewing rooms, and rock-cutting lab, where the group learned how core samples are collected and analyzed, and how valuable the collection is to geoscience research.

UT Forum members and Dakota Batch (front row, second from left), coordinator for the Osher Lifelong Learning Institute, tour the Austin Core Research Center.

Explore UT: Discover What's Next

Bureau staff participated in **Explore UT: Discover What's Next**, a day-long celebration in March that brings together students, teachers, parents, and community members from across the state to experience hands-on research and scholarship in a campus-wide open house. The Bureau team of 17 volunteers engaged visitors with three activities: "Potpourri of 3-D Geology Visualization," led by Research Scientist Associate **John Andrews**, "What to Do with CO_2: Cures for the Feverish Earth," led by Senior Research Scientist **Sue Hovorka**, and "Find Gold," led by Information Geologist **Linda Ruiz McCall**. Said Hovorka, "It is very valuable for UT to show the public and the next generation of scientists where our current state of knowledge and key questions lie."



Sue Hovorka speaks to students about atmospheric CO_2.

4th Annual Bureau Research Symposium

There are few better opportunities to understand the breadth and diversity of the Bureau's research enterprise, or for researchers to interact with one another and learn more about the fascinating work of their colleagues, than at the annual **Bureau Research Symposium**. Organized for the fourth year by Information Geologist **Linda Ruiz McCall**, and implemented by a team that included **David Stephens**, **Kenneth Edwards**, **Jennifer Edwards**, **Dennis Campa**, and **Kim LaValley**, the September event showcased posters illustrating research efforts ranging from the western chicken turtle's loss of wetland habitat to the question of whether ion milling might actually cause composition changes to rock samples being prepared for a scanning electron microscope.

Best Poster awards were presented to **Behzad Ghanbarian** for "Permeability in Disordered Porous Rocks: Upscaling Techniques from Statistical Physics"; **Reza Ganjdanesh** and **Seyyed Hosseini** for "EASiTool: An Enhanced Analytical Simulation Tool for Storage Capacity Estimation"; and **Luca Trevisan**, **Tip Meckel**, and **Prasanna Krishnamurthy** for "Developing a Predictive Method for Local Capillary Trapping Capacity Estimation of CO_2 Using Invasion Percolation Simulations in Realistic 3D Numerical Lithofacies Models."

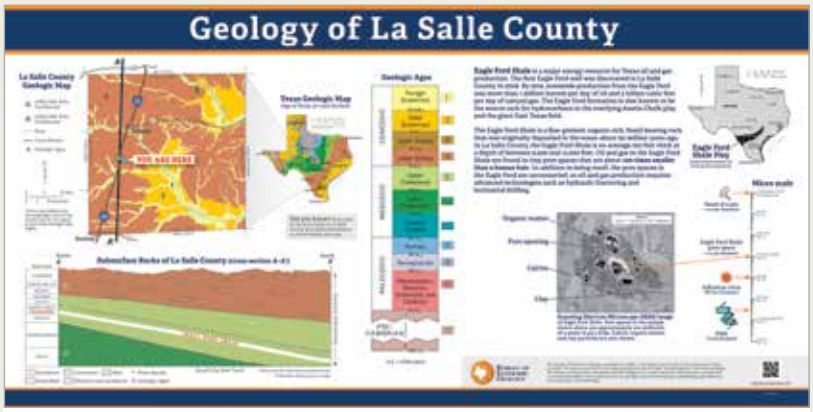
(Left) Bureau researcher Katherine Romanak and Bureau associate director Michael Young. (Right) Symposium organizer Linda Ruiz McCall discusses her poster with Mark Blount, in charge of Bureau External Affairs.

Community Service at Great Hills Park

In March, 25 hardworking Bureau volunteers restored a wildflower area and improved trails during a **Day of Service at Great Hills Park** in Austin. Work included clearing and hauling brush and small saplings to open space for wildflowers, while avoiding the many poison-oak vines. Organizers of the event (**Eric Potter**, **Linda Ruiz McCall**, **Jan Braboy**, **Donnie Brooks**, and **Melissa Garcia**) identified two main areas in the park that required special attention, but areas of care also included cutting overgrowth on several trails and litter removal.

Bureau park service group.

Bureau information geologist Linda Ruiz McCall.



An example of a GeoSign from La Salle County, showing regional geology and examples of typical rock types.

Texas GeoSign Project

The Bureau has partnered with the Texas Department of Transportation (TxDOT) to post geologic information signs at TxDot Safety Rest Areas (SRA's). This work is part of the **Texas GeoSign Project**, a new initiative whose goal is to engage the public and promote the understanding of geologic information. Currently, signs are posted in Eastland and La Salle County SRA facilities.

The long-term plan for the Texas GeoSign Project is to develop and post two signs a year with TxDOT and other partners across the state. In addition, a web-based platform will feature sign images and allow the public to explore geoscience information and learn about the geology of Texas.

Information Geologist **Linda Ruiz McCall** leads the Texas GeoSign Project, with team members **Charles Woodruff, Caroline Breton, Cathy Brown**, and **Jamie Coggin**. **Heather Christensen**, **Ursula Hammes**, and **Robert M. Reed** have also contributed to the project.

Texas Master Naturalists

In June, the Bureau's associate director **Eric Potter** and information geologist **Linda Ruiz McCall** spoke in Marble Falls at the monthly meeting of the Highland Lakes Chapter of the Texas Master Naturalists. Approximately 80 members of the group heard Potter's presentation, "Oil and Gas Energy Development in Texas." McCall shared maps and educational resources offered through The Bureau Store. The Master Naturalist certification requires many hours of training about various aspects of natural resources. Members make a commitment to volunteer and serve the community outreach efforts after they are trained.

Eric Potter speaks to the Highland Lakes Master Naturalists.

Texas HS Coastal Monitoring Program

In 2016, the **Texas High School Coastal Monitoring Program** (THSCMP) marked its 19th year of outreach. Led by Bureau scientist and program coordinator **Tiffany Caudle**, students and teachers from participating schools collect beach-monitoring data along the Texas coast three times during the academic year. The field studies teach practical scientific methods by measuring topography, mapping the shoreline and vegetation lines, and observing weather and wave conditions. Data collected is also entered into a database at the Bureau's Coastal Studies group in Austin.

Corpus Christi Cunningham Middle School students collect beach data.

THSCMP has eight participating schools—Galveston Ball, High Island, Palacios, Port Aransas, Port Isabel, and Van Vleck High Schools; and Cunningham and Tidehaven Middle Schools. The program is sponsored by the Texas General Land Office Coastal Management Program, the Trull Foundation, and the Jackson School of Geosciences.

A Gift That Keeps On Giving

Editor's Note: For each home game during football season, the Bureau rewards a deserving staff member with a pair of tickets to see the Horns in action. Here, one winner, Research Scientist Associate Robert Reedy (pictured with wife Andrea), describes the thrill of victory at the September 3 season opener against Notre Dame.

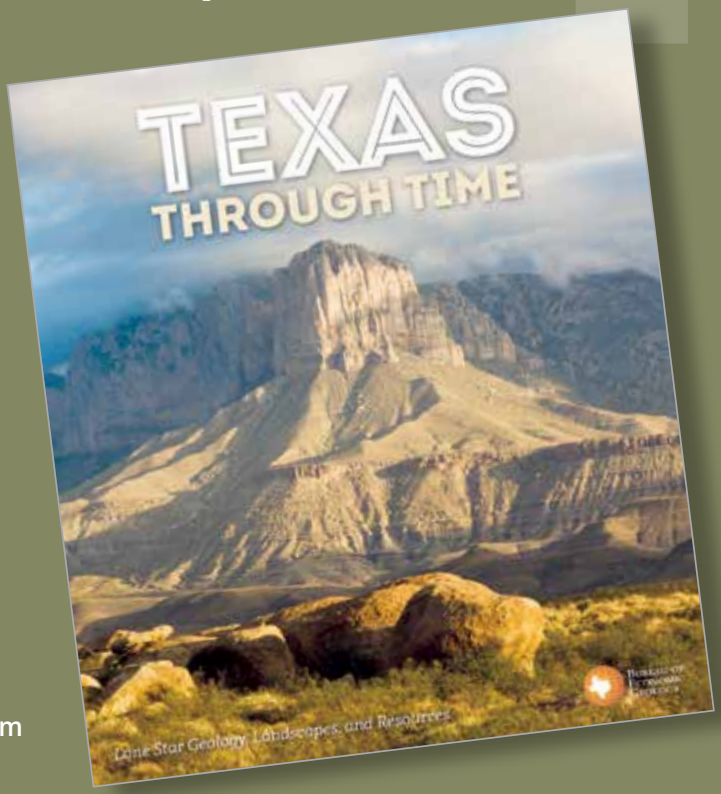
What can I say? The game was amazing? The seats were amazing? That hardly begins to describe the experience. I can't thank you enough for the gift of being there to see my daughter on the field with the UT Marching Band becoming a part of the UT tradition. It was one of the most memorable and proud moments of my life. The game set an all-time record for attendance at DKR Texas Memorial Stadium (102,315) and TV viewership is estimated at between 12 and 13 million. It was crazy exciting. The stadium was on their feet most of the time.

Afterward, my brother-in-law, the often smug Notre Dame alum, was gratifyingly morose and remained so until he departed for the airport on Monday morning. I would also note, as I did to him at least twice right after the game and once again before he left the next morning, that the last time UT beat Notre Dame was in 1970, which coincidentally was also the year he graduated from Notre Dame. So, as he has just recently retired, his long and brilliant professional career was bracketed by losses to UT. This is yet another gift that will keep on giving for years to come.

Hook 'em Horns!
Bob Reedy

The Bureau is excited to announce the publication of **Texas Through Time,** an in-depth and accessible new book by Thomas Ewing that brings the geology of Texas to life.

Texas Through Time:
Lone Star Geology, Landscapes, and Resources



Explore the landscapes, rocks, and resources of Texas and 1.7 billion years of Earth history in **Texas Through Time** by noted geoscientist Thomas E. Ewing. Visit the ancient rocks of the Llano and Van Horn areas, the legacy of now-eroded Himalaya-type ranges that initially rose over 1 billion years ago. Marvel at the giant West Texas Basin, so prolific in oil and gas, and the enigmatic Marathon and Ouachita Mountains. Watch North America separate from the supercontinent Pangea and create the enclosed, salt-rich Gulf of Mexico in its wake. Discover the vast carbonate platform that today makes up the Edwards Plateau and Texas Hill Country. And witness the complex story of mountain building, uplift, and delta building that formed today's Texas landscapes. Special chapters consider Texas resources and geologic hazards, as well as the impact of geology on human settlement over the last 15,000 years. **Texas Through Time** contains over 500 full-color photos, illustrations, and maps, all showing the state's development through geologic "deep time."

Thomas E. Ewing, Ph.D., has been an earth scientist in Texas for 35 years, first with the Bureau of Economic Geology and later as owner of Frontera Exploration Consultants and occasional lecturer at the University of Texas at San Antonio. He has given talks and led field trips across Texas for geologists and others, and his extensive publications include the Tectonic Map of Texas (BEG, 1990) and *Landscapes, Water, and Man: Geology and History in the San Antonio Area of Texas* (South Texas Geological Society, 2008). Dr. Ewing has held offices in the American Association of Petroleum Geologists, as well as in local and regional geology groups, and has received several awards for his service to the field.

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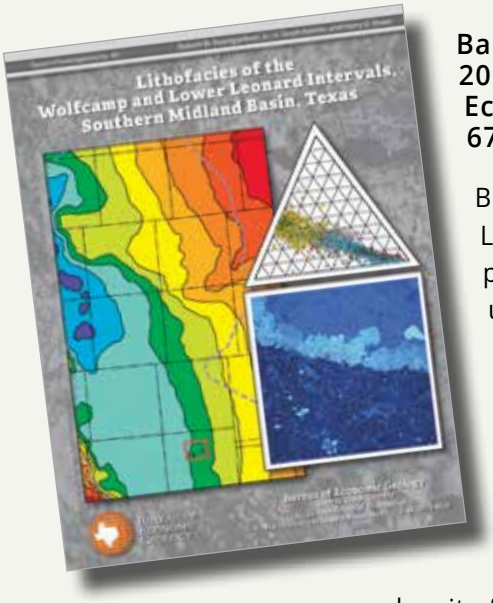
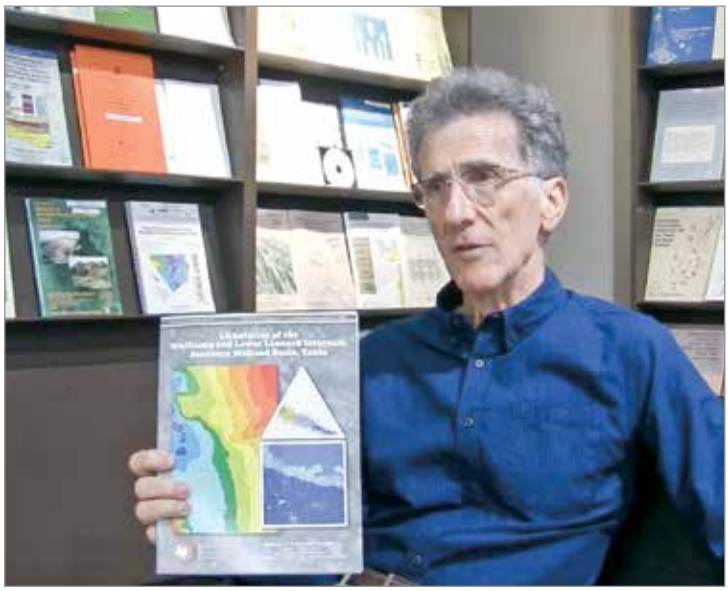
Report of Investigations:

Lithofacies of the Wolfcamp and Lower Leonard Intervals, Southern Midland Basin, Texas



Baumgardner, R. W., Jr., Hamlin, H. S., and Rowe, H. D., 2016, The University of Texas at Austin, Bureau of Economic Geology, Report of Investigations No. 281, 67 p., 4 tables, 40 illustrations/photos.

Basinal facies assigned to the Wolfcamp and lower Leonard lithostratigraphic units in the Midland Basin are prolific producers of oil and gas. Four facies in these units are recognized in core: (1) siliceous mudrock, (2) calcareous mudrock, (3) muddy bioclast–lithoclast floatstone, and (4) skeletal wackestone/packstone. Mudrocks are largely hemipelagic deposits of fine-grained sediment delivered by suspension settling. Floatstones were deposited by debris flows that originated on carbonate shelves around the basin. Wackestones/packstones are finer-grained, sediment-density-flow deposits, probably turbidites, reworked by local bottom currents. These sediments were deposited below storm wave base in a basin having limited connection to the open ocean. During deposition, low-oxygen conditions prevailed in bottom waters and sediments. Total organic carbon (TOC) content reaches 6.8 percent. TOC is facies-dependent (highest in siliceous mudrock) and varies widely within small vertical distances. Cyclicity is evident in individual meter-thick, upward-fining cycles of floatstone or wackestone/packstone, overlain by calcareous and siliceous mudrock. Rock strength increases as calcite content increases, likely as a result of diagenetic cementation. Most kerogen in the lower Leonard/Wolfcamp interval is in the oil-production window and has matured to Type II–III ("oil–gas-prone"). Based on their TOC and hydrogen content, the siliceous mudrocks have the highest potential for hydrocarbon generation.



Author Robert Baumgardner, Jr., talks about his new Report of Investigations.

Bureau researcher John Hupp aboard a specially fitted survey craft.

BEG Maps Colorado River Basin with Lidar

In early January 2016, BEG airborne-imaging researchers conducted a field mission to survey the lower basin of the Colorado River, an area that borders the states of Arizona and California. The project was sponsored by the Bureau of Reclamation to understand and map the overall geomorphology of the river basin, including the water-bottom surface. The survey area consisted of 120 mi of the river, with varying terrain altitude, water clarity, depth, and flow conditions. Bureau researchers **Kutalmis Saylam**, **John Hupp**, and **Aaron Averett** conducted the field trip with ground-truthing assistance from Surveying and Mapping, Inc., of Austin; airborne flights were contracted out to Aspen Helicopters of Oxnard, California. The team acquired approximately 5 terabytes of topographic and bathymetric lidar data, complemented with high-resolution imagery and sonar data.

The field trip was scheduled in conjunction with lower water-release rates from the Parker Dam in the upper survey area for shallower and less-turbid water conditions. Researchers completed real-time in situ measurements to understand water clarity (turbidity) on the site and captured dual-beam sonar data to complement and verify lidar data measurements in the deeper parts of the riverbed. Preliminary processing results revealed a seamless coverage of riverbed mapped by the Bureau's airborne lidar system, even in deeper areas of the river, where sonar readings indicated depths up to 11 to 12 m.

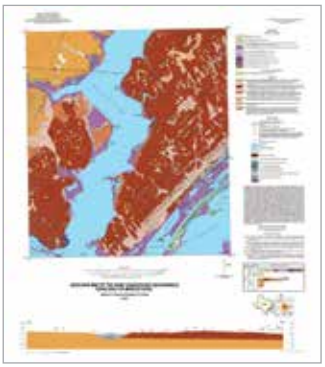
Maps

Geologic Map of the Port O'Connor Quadrangle, Texas

Paine, J. G., and Collins, E. W., 2016, The University of Texas at Austin, Bureau of Economic Geology, Open-File Map, OFM0224, scale 1:24,000.

This map illustrates the geology at the western margin of Matagorda Bay and the recently established Texas Parks and Wildlife Powderhorn Ranch conservation area. The area's geology consists of sediments deposited within a Pleistocene barrier system and Holocene bay-estuary and barrier systems. The map illustrates Pleistocene units that represent four phases of Ingleside barrier deposition and compose much of the map area. The map also displays Holocene bay margin–beach, tidal-flat, and spit deposits. Man-made features identified include selected channels, pits, dredged-material disposal areas, selected areas artificially elevated by fill material, and jetties. Subsurface data are displayed in Sheet 2: Geophysical logs and time-domain electromagnetic induction soundings.

Geologic Map of the Saint Charles Bay Quadrangle, Texas Gulf of Mexico Coast



Paine, J. G., and Collins, E. W., 2016, The University of Texas at Austin, Bureau of Economic Geology, Open-File Map, OFM0225, scale 1:24,000.

This map illustrates the geology at the eastern margin of Copano Bay and includes part of the Aransas National Wildlife Refuge and Goose Island State Park. The area also includes the 1.5-mi-wide Saint Charles Bay. Geology of the quadrangle consists of sediments deposited within a Pleistocene barrier system and a Holocene bay-estuary system. Pleistocene Beaumont fluvial–deltaic clay-rich facies occur at the northwest part of the map. Surface expression of the Pleistocene barrier sediments indicates closed basins, drainageways, and southwest–northeast-trending ridges and swales. Holocene tidal-flat and bay-margin deposits—including spit, beach, washover-fan, and clay-dune deposits—occur along Saint Charles Bay, Carlos Bay, and the Intracoastal Waterway. Man-made features mapped include pits and excavations, selected canals and channels dug for navigation or drainage, land artificially elevated by fill, dredged material, and a protective rock structure.

Geologic Map of the Bee Cave Quadrangle, Texas

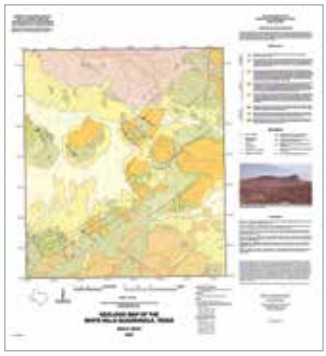
Collins, E. W., 2016, The University of Texas at Austin, Bureau of Economic Geology, Open-File Map, OFM0226, scale 1:24,000.

This map illustrates the geology for an area at the dissected eastern margin of the Edwards Plateau that has been experiencing rapid development and population increases for a number of years. Topographic relief is about 650 ft. Geology of the area consists of about 600 ft of Lower Cretaceous shelf and shore-zone deposits of the Glen Rose, Walnut, and Edwards units. Terrace deposits of the Colorado River (upper reaches of Lake Austin in this area) and Barton and Little Barton Creeks are also displayed.

Geologic Map of the Fredonia Quadrangle

Elliott, B. A., 2016, The University of Texas at Austin, Bureau of Economic Geology, Open-File Map, OFM0227, scale 1:24,000.

This map illustrates the geology for an area at the northern margin of the Llano Uplift that has been experiencing increased development in industrial sand resources. The geologic map of the Fredonia Quadrangle shows Quaternary fluvial terrace deposits of predominantly granite, gneiss, and mica schist grus in low-lying areas, especially where more-recent alluvium is deposited in the southern and western parts of the map (predominantly on Packsaddle Schist, Lost Creek Gneiss, and Valley Spring Gneiss) in streambeds, creeks, and river channels. The southern part of the map is dominated by the Cambrian-age Hickory Sandstone Member of the Riley Formation and Precambrian, pink to gray, well-foliated, alkali-feldspar augen Valley Spring Gneiss, occasionally containing pegmatitic lenses and local biotite and/or amphibole schist. The eastern border of the map is Hickory Sandstone unconformably overlying quartz biotite Packsaddle Schist and Lost Creek Gneiss.



Geologic Map of the White Hills Quadrangle

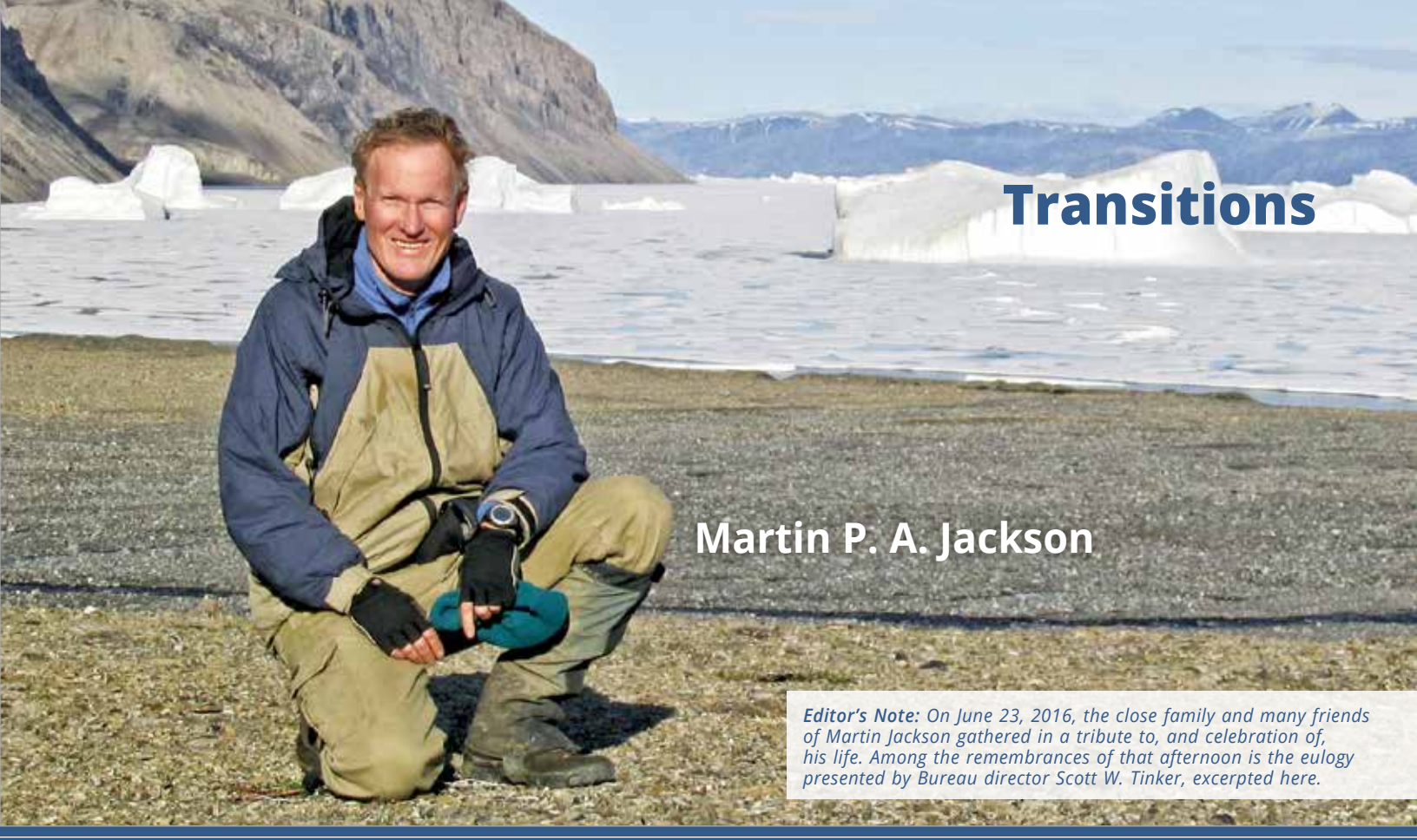
Elliott, B. A., 2016, The University of Texas at Austin, Bureau of Economic Geology, Open-File Map, OFM0228, scale: 1:24,000.

This map illustrates the geology for an area north of the Big Bend National Park in the Christmas Mountains of West Texas. The west-central part of the map is predominantly quaternary alluvium and terrace gravels, with a couple of small exposures of trachytic to rhyolitic plugs, sills, or volcanic necks intruding chalky limestone. The northern part of the map is dominated by intrusive rocks and volcanics that make up the Nine Point Mesa quartz syenite and, more northeast, chalky limestone of the Boquillas Formation. The south-central portion of the map is predominantly a transgressive shallow marine sequence of exposed Cretaceous argillaceous limestone, chalk, and chalky clay in the Boquillas Formation, with thin, nearshore, interbedded siltstone and flaggy brown to gray micrite and biomicrite. The Pen and Aguja Formations overlie the Boquillas Formation in the east-central, west-central, and southwest portions of the map and consist of predominantly calcareous marine clay, with interbeds of flaggy limestone, sandstone, and siltstone.

Geologic Map of the Upper Lake Travis Area, Central Texas

Woodruff, C. M., Jr., and Collins, E. W., 2016, The University of Texas at Austin, Bureau of Economic Geology, Oversize Color Map, MM0052, scale 1:50,000.

This map and its cross sections and related text illustrate and describe the geology of a Central Texas area (Pace Bend, Smithwick, Spicewood, and Travis Peak 7.5-min quadrangles) having diverse substrates and landforms. The area, cut by the impounded Colorado and Pedernales Rivers, is undergoing transformation from ranch land to various types of economic development, including residential, commercial, recreational, and rock–mineral resource extraction. Strata of the area—consisting of Cambrian, Ordovician, Devonian, Mississippian, Pennsylvanian, and Lower Cretaceous rocks and Quaternary sediments—record a long geologic history.



Transitions

Martin P. A. Jackson

Editor's Note: *On June 23, 2016, the close family and many friends of Martin Jackson gathered in a tribute to, and celebration of, his life. Among the remembrances of that afternoon is the eulogy presented by Bureau director Scott W. Tinker, excerpted here.*

...For 36 years Martin made his professional home at the Bureau of Economic Geology, serving under three directors and one interim director. For someone who had previously changed jobs in Africa every 4 years, I asked Martin why he chose to stay so long at the Bureau. After all, there were a myriad of other opportunities. Martin said there were two primary reasons.

First, he felt the way the Bureau operated was ideal. Although he led the raising of external funds for all his projects, he was given almost complete freedom to use those funds sensibly for any research direction. He was also given full support of equipment and facilities. In other words, he had the freedom and independence to build a world-class team of researchers, including students, in salt tectonics. Martin did this in part by establishing a research consortium in 1988 called the Applied Geodynamics Laboratory, or AGL.

Along with the RCRL (Reservoir Characterization Research Laboratory), AGL was the first Industrial Associates program established at the Bureau, and one of the first in geosciences nationally. AGL has been running continuously since 1988 and is still supported by 30 companies. Mike Hudec, a close friend and colleague of Martin's, serves as principal investigator of the AGL today. Last year, over 300 people from around the globe attended the annual meeting of AGL at the Bureau. It is the leading salt conference in the world.

The second big reason for staying was that Martin regarded the Bureau as a home in the broadest sense. Martin and his wife Jo found the strong outpouring of love and support when he was diagnosed with cancer unbelievable. According to Martin, and again I quote, "it was a revelation to see my colleagues really care about one other; they are not just showing up for a paycheck."

I hope this has provided some insight into why Martin flourished in science, and why, according to him, he was "happily astonished to be paid so generously for doing something he was passionate about."

I am in my 17th year as Director of the Bureau. Contrary to how wonderful this role might appear, it is mostly a lonely one. Several months ago, out of great respect for Martin and his perspectives, I asked if he would evaluate me, critically. It was a selfish request, to be sure, but Martin understood my motivation immediately. We both want the best for an organization that we love. I am indebted to Martin for taking on this task.

When Martin passed, I spoke with and received many notes from colleagues and friends. I am sure Mike Hudec received many more, and the family, more still. The response was consistent and clear:

> *A good man. A great man. A kind man. One of the smartest people I have known. One of the more modest people I have worked with. A mentor to me in time of need. A patient teacher. I learned more from him in a year than [in] the rest of my career.*

You get the picture.

The professional community of global geoscientists is improved immeasurably because of Dr. Martin P. A. Jackson. He is most surely one of the finest the Bureau has ever produced: both as a scientist and as a man.

Scott W. Tinker
Director, Bureau of Economic Geology
June 23, 2016

In Memoriam

Martin P. A. Jackson

Martin Jackson, world-renowned geoscientist and esteemed Bureau researcher, passed away May 31, 2016.

Martin was recognized globally for his groundbreaking work in the field of salt tectonics, with over 100 papers and 3 books on the subject. Said Bureau colleague **Michael Hudec** in 2013: "He's the number one person in the world by a goodly margin. His papers are universally regarded as the most authoritative on salt tectonics. And his name is associated with most of the major concepts in salt tectonics….You cannot work effectively in salt tectonics without reading Martin's work." In recent years, Jackson had been exploring signs of salt-tectonic activity on other planetary bodies, including Mars and Neptune's moon Triton.

Born in Rhodesia (today, Zimbabwe), Jackson initially studied old, hard Precambrian gneisses before moving to Texas and eventually becoming immersed in, as he called it, "a sub-surface world of very young, soft rocks." He came to the Bureau in 1980 and in 1988 was instrumental in the creation of the Bureau's first Industrial Associates program, the **Applied Geodynamics Laboratory** (AGL), founded to investigate the then-poorly-understood world of salt tectonics. With seed money from UT-Austin and the member support of 13 oil and gas companies, Jackson's new consortium became a model for those to follow. Over 25 years after its founding, the AGL now maintains over 30 participating companies and is widely considered the world's preeminent salt-tectonics research laboratory. Today, it is almost impossible to talk about salt tectonics without using terms and concepts developed at the AGL, including *salt canopy, salt weld, reactive diapir, squeezed diapir, extrusive salt sheet,* and *multidirectional extension*.

Jackson's numerous major career honors include the American Association of Petroleum Geologists' Robert R. Berg Outstanding Research Award (2010) in recognition of outstanding innovation in petroleum geoscience research and the Geological Society of London's William Smith Medal (2013) for outstanding research in applied geology. According to AAPG records, no one has won more AAPG technical awards, nor has anyone won in as many technical categories. Jackson's notable publications include the AAPG Memoir *Salt Tectonics: A Global Perspective* (2008, with David Roberts and Sig Snelson), a definitive book on the subject, and the major 2012 atlas *The Salt Mine* (with Bureau colleague Hudec), an interactive resource on salt tectonics. Jackson's final publication, also as co-author with Hudec, is *Salt Tectonics: Principles and Practice*, published in early 2017 by Cambridge University Press.

In addition to his preeminence as a research scientist, Jackson is equally regarded for his strength of character, gracious demeanor, and unfailing humor. His friends and peers recall his kindness, humility, insightfulness, and remarkable equanimity.

Bureau director **Scott W. Tinker** said, in conveying the loss of his friend to the Bureau family, that "Martin was one of the finest people I have known. Practical. Brilliant. Creative. Dedicated to his family and his science until the end. He will be missed but always remembered."

Salt glaciers spreading from the summit of Kuh-e-Namak, Zagros Mountains, Bushehr Province, Iran. Photo by Martin Jackson.

Patricia (Pat) Alfano

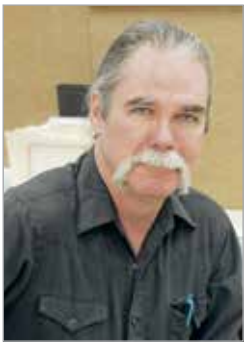
Patricia (Pat) Alfano, a computer illustrator at the Bureau from 1997 to 2004, passed away on February 11, 2016. Proud of her Italian and Philadelphia roots, Pat always had an Italian quip on the tip of her tongue and looked back fondly at her years in the '60's performing as a Philadelphia Eagles cheerleader. Before joining the Bureau, Pat worked as a graphic artist and in the video gaming industry, eventually owning and operating an art studio. At the Bureau, she quickly learned the basics of geologic maps and cross sections; as she became adept at text illustrations, her responsibilities widened to producing slide presentations and poster sessions (one award-winning) for the research staff. Upon her retirement, Pat returned to her favorite locale, Southern California and the Pacific Ocean, along with her devoted husband, Ben Turner, and their son, Monk. There, she concentrated on her writing and art, eventually producing a blog, Bohemian Opus. We celebrate Pat's individuality and remember her as a joyful woman with a zest for life.

Retirements

Sharon Campos

See "A Warm Welcome Back and Honor for Campos" on p. 26.

James Donnelly



James Donnelly, Database and Patron Services Manager at the Bureau's Austin Core Research Center (CRC), retired in February after 30 years with the Bureau. James was friend to many at the CRC, a list including researchers as well as external industry patrons. He was quick with a joke and could always find time in his schedule to lend a friend a listening ear. In his personal life, James makes time to give back to the community with service in Bikers Against Child Abuse (BACA). A soft voice backed up by a tough-guy persona, James will be missed by all those who spent time with him either on the phone or in person at the CRC.

Patricia (Pat) Downs

Patricia (Pat) Downs retired in January after 33 years at the Bureau. Pat served in many capacities, working full-time in the Geophysical Log Facility, Library, and Map Room, and part-time at the reception desk. Pat excelled at linking visitors with researchers by their areas of expertise, and she was unrivalled at identifying gemstones.

Pat's diligence in collecting the memoirs of Dr. Virgil Barnes facilitated the Bureau's publication in 1995 of Dr. Barnes's book, *On Solid Ground: Memoirs of a Texas Geologist*. In that work, Dr. Barnes wrote, "Pat processed all of the manuscript, did preliminary editing, and seemed to take pleasure in locating places on maps and confirming all geographic names mentioned, as well as confirming all proper names."

In her spare time, Pat travels to see wildflowers in spring, and in summer stays at a cabin on the Frio River in Leakey ("that's 'lake-ee,' ya'll"). We wish Pat all the best in pursuing her many interests in her retirement.

Continued on page 42

Continued from page 41

Sharan Happel

Sharan Happel, an accountant with the Bureau for 5 years, retired in August after 23 years with The University of Texas at Austin. Sharan's primary responsibilities at the Bureau included payables, utilities, payments, and reimbursements, but she considers the most rewarding parts of her job to have been the sense of trust she developed with vendors, as well as being able to help new researchers get situated financially; she says her interactions with international clients and the chance to "have friends from unexpected places" were also highlights of her time here. Sharan's plans for retirement, after deprogramming her alarm clock, include gardening in her grassless yard and listening to her husband's band, Slowly Grace, play around Austin.

Eric Potter

Eric Potter retired in September after 15 years as the Bureau's associate director (Energy Division). Said Bureau director Scott W. Tinker of his colleague: "Eric provided candid, wise, and trusted counsel, which has been integral to the Bureau's success. Please join me in thanking Eric for his tremendous contribution to the Bureau, congratulating him on a job well done, and wishing him and his wife Phyllis the very best in retirement."

In 2015, Eric received the Jackson School of Geosciences Outstanding Service Award for his "outstanding service to a unit, the School, the University, or the profession." JSG dean Sharon Mosher said: "Eric has served the Bureau and the School selflessly, consistently deflecting credit from himself to others, and being quick to recognize the best in others. He embodies the idea of service."

Eric received his B.A. in earth science from Dartmouth in 1972 and his M.S. in geology from Oregon State in 1975. Prior to joining the Bureau, he worked for over 25 years in exploration and technology positions at Marathon Oil Company, primarily on projects in the Rocky Mountains, Gulf of Mexico, and the Permian Basin. While at the Bureau, his energy research group conducted significant research in Mexico, including several major basin and reservoir-characterization studies.

David M. Stephens

David M. Stephens, Bureau photographer and computer illustrator, retired in December after a 42-year career at The University of Texas at Austin. After earning a B.F.A. in studio art/photography, David began his career working part-time at the Bureau, later moving to UT's Department of Geological Sciences as a photographer and darkroom specialist. David returned to the Bureau's Media Group full-time from 1990 to 2005, then worked part-time until his retirement. During his time at the Bureau, David developed and applied skills in conventional photography, large-format color-separated map-proof production, high-end scanning, digital photography, and digital image processing. David's work endures in the thousands of photos and other images he captured and processed for Bureau books, posters, articles, Web pages, and various presentations. His exceptional attention to detail and quality made him an invaluable contributor to the Bureau. Said Bureau director Scott W. Tinker: "David is a professional in every sense of the word: efficient, prepared, artistic, and humble. The 'shot' was never about him—always about the subject. His body of work speaks for itself. I will miss him greatly."

Director Scott W. Tinker (left) with David Stephens.

2016 Peer-Reviewed Publications
by Bureau Researchers

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Buckles, J., and Rowe, H. D., 2016, Development and optimization of microbeam X-ray fluorescence analysis of Sr in speleothems: Chemical Geology, v. 426, p. 28–32, http://doi.org/10.1016/j.chemgeo.2016.02.003.

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Carr, D. L., Wallace, K. J., Yang, C., and Nicholson, A. J., 2016, CO_2 capacity sectors in Miocene strata of the offshore Texas State Waters: GCAGS Journal, v. 5, p. 130–140.

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Chen, J. L., Wilson, C. R., Tapley, B. D., Scanlon, B. R., and Guntner, A., 2016, Long-term groundwater storage change in Victoria, Australia from satellite gravity and *in situ* observations: Global and Planetary Change, v. 139, p. 56–65, http://doi.org/10.1016/j.gloplacha.2016.01.002.

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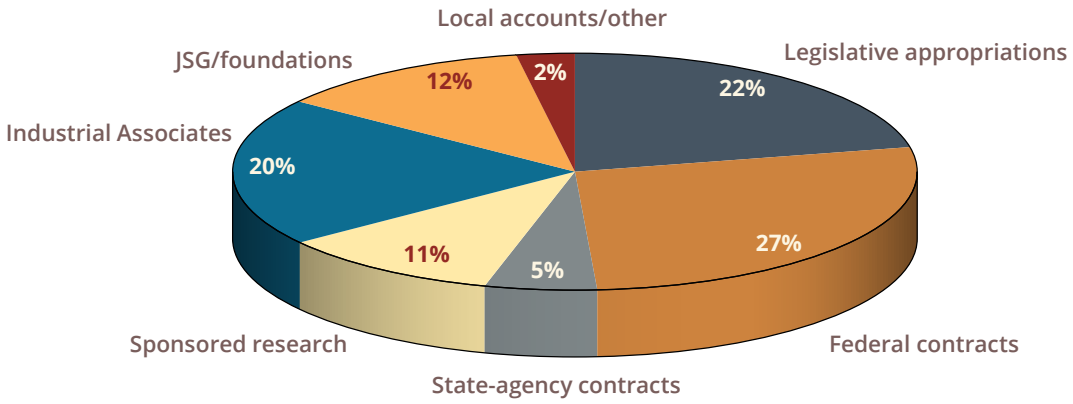
Finances


Local accounts/other
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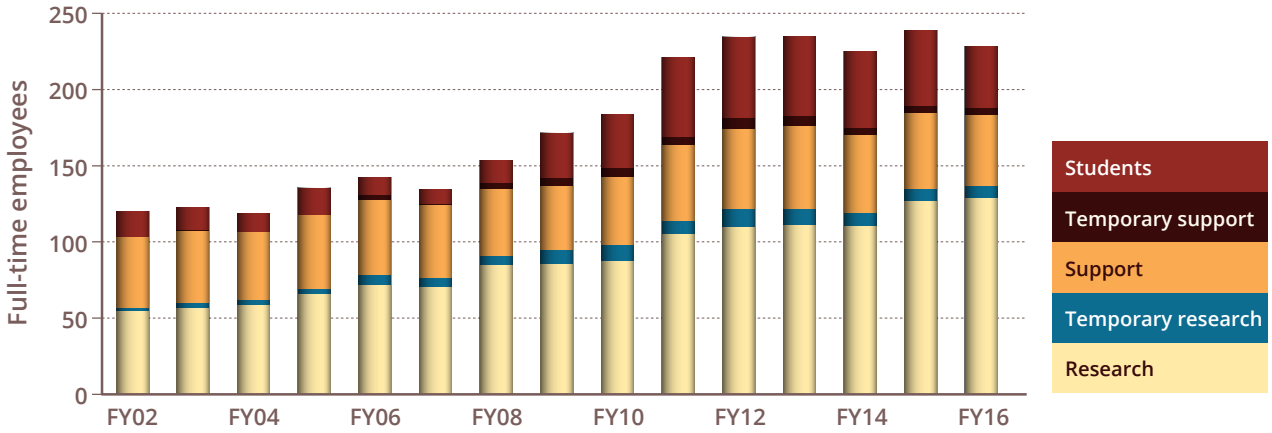
Full-time employees
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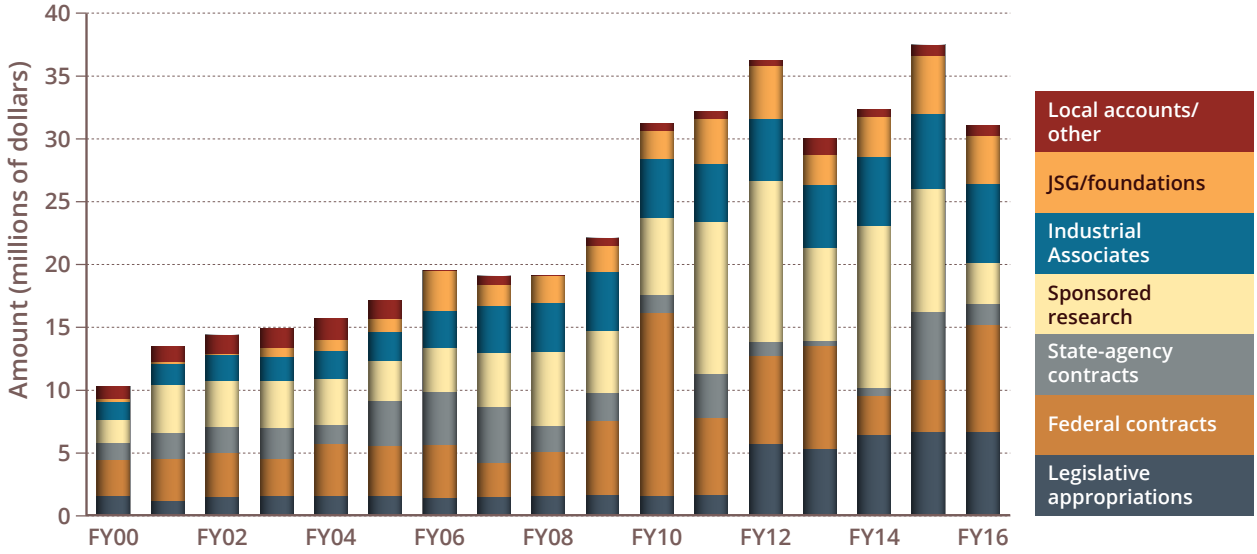
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