Comprehensive Report 2006

Bureau of Economic Geology
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OREWORD

The Bureau of Economic Geology, established in 1909 as the successor to the Texas Geological Survey and the Texas Mineral Survey, is a research unit of The University of Texas at Austin. It also functions as the State Geological Survey, the Bureau Director representing Texas in the Association of American State Geologists.

Extensive advisory, technical, and informational services relating to the resources and geology of Texas are provided by the Bureau. In addition, the Bureau conducts basic and applied research projects in energy resources, mineral resources and statistics, coastal and environmental studies, land resources, geologic mapping, and a variety of other research programs in areas such as hydrogeology, basin analysis, and geochemistry. Some projects are conducted jointly with other units of the University, as well as with industry and with State, Federal, and local agencies.

The Bureau provides ongoing services to governmental agencies, including reviews of (1) environmental impact statements that are submitted to the Office of the Governor of Texas and (2) permit applications that are submitted to the Surface Mining and Reclamation Division of the Railroad Commission of Texas.

Major reports of the Bureau are published in The University of Texas Publication series; its own series includes Reports of Investigations, Geologic Quadrangle Maps, Geologic Atlas Sheets, Environmental Geologic Atlases, Guidebooks, Handbooks, Geological Circulars, Mineral Resource Circulars, and other publications. Publications are sold for a nominal price to recover printing costs. A complete list of publications is available on request.

The Comprehensive Report of the Bureau of Economic Geology outlines the scope and status of current research projects, publications, personnel activities, and services in the area of Texas resources and geology that are available to governmental agencies, industry, and the public.

ON THE WEB

A wealth of information regarding the Bureau of Economic Geology can be found at our Website, http://www.beg.utexas.edu. Here you can learn about every aspect of the Bureau’s mission, its research, public services, and staff. Download what you need.

When you visit our Website, you can check upcoming events, read about recent research awards and honors, learn about the Bureau’s large collection of rock cores and well cuttings, and contact any Bureau researcher or staff member by using his or her office e-mail address or telephone or fax number. You can review titles and authors of past and present Bureau publications—and then place an order.

Teachers and students can view earth science projects, print directions and then follow them in a Do-It-Yourself Aquifer Demonstration, determine whether Dirt Is Just Dirt, or study the Texas Rock Cycle. The Bureau’s Website also contains links to State, Federal, and industry organizations, as well as geologic and earth science resources. Visit us at www.beg.utexas.edu.
Cover image:

View of the Earth as seen by the Apollo 17 crew traveling toward the Moon, December 7, 1972. This translunar coast photograph extends from the Mediterranean Sea area to the Antarctica South polar ice cap. This is the first time the Apollo trajectory made it possible to photograph the South polar ice cap. Note the heavy cloud cover in the Southern Hemisphere. Almost the entire coastline of Africa is clearly visible. The Arabian Peninsula can be seen at the northeastern edge of Africa. The large island off the coast of Africa is the Malagasy Republic. The Asian mainland is on the horizon toward the Northeast.


The Comprehensive Report is a record of Bureau research projects and professional activities of Bureau staff during the calendar year. Additional information about Bureau research and researchers, news items, funding, and awards can be found in the Bureau’s Annual Report and Midyear Report. The List of Publications contains titles of all Bureau publications, brief descriptions of new publications, and information regarding placing orders. These reports are available on request.
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ENERGY

BASIC ENERGY RESEARCH

Applied Geodynamics Laboratory (AGL)
Martin P. A. Jackson and Michael R. Hudec, co-principal investigators; Timothy P. Dooley, laboratory manager, and Jozina Dirkzwager; helped by Nancy Cottington and Rong Li

AGL research on salt tectonics during 2006 included a geographically and topically broad suite of fundamental research problems, as well as further work on new modules of a digital atlas. The physical modeling laboratory continued to improve, with another custom-made deformation rig, new stepper motors, and a high-resolution laser scanner to capture evolving topography. Numerical modeling began again with the arrival of Jose Dirkzwager as a postdoc from Karlsruhe University.

Research expanded on several topics of salt tectonics begun previously. Mechanisms of advance and suturing of allochthonous salt canopies in the Gulf of Mexico were explored by seismic mapping, restoration, finite-element modeling, and physical modeling. Analysis of tectonostratigraphic and salt-tectonic data from the Sverdrup Basin of Arctic Canada continued with Christopher Harrison (Geological Survey of Canada), using restorations and isopach mapping. Physical modeling continued to focus on intrusive salt plumes and thrusting during diapiric squeezing and pinch-off.

Several new projects also began. The geometry of salt-stock canopies and canopy-stock interactions were examined using seismic data in the Gulf of Mexico. With Joe Cartwright (Cardiff University), we began studying how multilayered evaporites deform internally, using a seismic dataset from the Eastern Mediterranean and physical modeling. We reviewed the geology of salt welds using field examples and analyzed some factors driving and limiting this process.

The Salt Mine, a browser-based, interactive atlas of salt tectonics, expanded to a 3rd Edition with addition of five new atlas modules of allochthonous salt tectonics. More than 800 images and extended captions are now complete. The atlas is currently available only to AGL sponsors.

Quantitative Clastics Laboratory (QCL)
Lesli J. Wood and W. Paul Mann (The University of Texas at Austin Institute for Geophysics), co-principal investigators

QCL’s mission is quantitative analyses of deep-marine, shallow-marine, and fluvial/deltaic systems morphology and character to provide quantitative models and morphometric data on reservoir architecture and models for predicting change in the nature of reservoirs and understanding the processes involved in their deposition and preservation.

The project team acquires 3D seismic data for harvesting of depositional facies and element morphometric data. The seismic is examined using techniques that employ conventional seismic sequence framework development, quantitative seismic geomorphologic analysis, various attribute extractions, export and harvesting of morphologic information in ArcGIS and ErMapper, and export of these data into various programs for statistical analyses of temporal and spatial distribution and relationships. The team also works with a significant historical archive of outcrop data provided from previous clastic systems research at the Bureau. These outcrop results, collected mostly on shallow-marine and fluvial systems of the U.S. Western Cretaceous outcrops, consist of thousands of detailed facies sand lithology measurements, integrated with
>100 km of detailed architectural drawings from photopanoramic images. Data sets include significant subsurface logs integrated with outcrop data, as well as facies porosity, permeability, and velocity measurements. These data are being harvested for the morphologic information that they document. Both seismic-derived and outcrop-derived data form the basis for probabilistic models of reservoir occurrence, character, and evolution. 3D visualizations of these research results are conveyed to members, as are statistical data sets and vrm-based training modules, and are combined with results from published works and previous studies to form a larger, HTML-based Sedimentary ANalogs Database (SAND) Box catalog.

Current projects include
- Indonesia, West Natuna Basin—Fluvial, deltaic; 3,800 km² of 3D, 5 s of data, and 13 well penetrations; compressional tectonics.
- Trinidad 3D deep-water megasurvey—Shelf-edge to deep-marine basin; 10,000 km² 3D, 180 shallow (1-m) dropcore; plate boundary margin, strikeslip and thrust tectonics, mobile shale substrate.
- Trinidad 3D shallow-marine megasurvey—Subaerial to shelfedge (overlaps with deep-water megasurvey); 10,000 km² 3D and numerous geotechnical boreholes; plate boundary margin, dominated by extensional growth faulting and mobile shale substrate.
- Gulf of Mexico Shelf—Miocene-through Quaternary-age shallow-marine and fluvial to upper slope; 362 km², growth faulted, and 4.5 s of data. Areas proposed for study in 2007 include
  - North Slope Alaska, Western Offshore Morocco, Gulf of Mexico Distal Sigsbee Study Area, Gulf of Mexico Mad Dog Area

**Exploration Geophysics Laboratory (EGL)**

Bob A. Hardage, principal investigator; Milo M. Backus, Michael V. DeAngelo, Sergey B. Fomel, Robert J. Graebner, Paul E. Murray, Randy L. Remington, Diana C. Sava, and Donald E. Wagner

Joint studies with industry sponsors give EGL access to onshore multicomponent seismic surveys and multicomponent marine data. EGL develops multicomponent seismic field-recording techniques and data-processing and data-interpretation procedures that allow reservoirs to be imaged using all components of the seismic wavefield. The goal is to determine the value of independent compressional (P) wave and shear (S) wave images of subsurface stratigraphy. When P and S images are transformed into a depth-equivalent data space, researchers gain insight into petrophysical properties, pore structure, pore-fluid properties, sequence stratigraphic relationships, and spatial distributions of lithologies, fractures, and anisotropic properties of complex reservoirs.

In 2006, EGL concentrated on applying multicomponent seismic data to deep-water gas hydrate systems, super-deep gas targets, and the segregation of fizz-gas and commercial-gas reservoirs.

**Fracture Research and Application Consortium (FRAC)**

Stephen E. Laubach, Randall A. Marrett (Department of Geological Sciences, The University of Texas at Austin), Jon E. Olson (Department of Petroleum and Geosystems Engineering, The University of Texas at Austin), co-principal investigators; Julia F. W. Gale, Jon T. Holder (Department of Petroleum and Geosystems Engineering), Kitty L. Milliken (Department of Geological Sciences), Edgar A. Pinzon, and Robert M. Reed, assisted by John N. Hooker, Leonel A. Gomez, and Meghan E. Ward, in collaboration with Robert H. Lander and Linda M. Bonnell (Research Fellows, The University of Texas at Austin, and Geocosm)

The FRAC group conducts research to better characterize and predict fracture and fault
attributes. Selecting the best exploration or development strategy for rocks that contain fractures can have a huge impact on economic success or failure. FRAC research leads to new concepts and methods for accurate characterization and reliable prediction of fracture attributes, which in turn provide insights essential for our making well-informed exploration and development decisions. Many fractures are difficult or impossible to characterize adequately using currently available technology. Consequently, fractured reservoirs have been difficult to describe and interpret, posing serious challenges to successful exploration or development. Practical methods under development by FRAC can be used for evaluating individual wells or, using data from many wells, identifying field- or regional-scale fracture patterns and drilling fairways.

FRAC applications are based on advances in fundamental understanding of how structures develop in the subsurface. Specifically, FRAC is investigating interactions of chemical and mechanical processes. Recent results include linked geomechanical and structural-diagenetic models that make accurate predictions of fracture architecture that can be verified using limited subsurface samples. Predictions of interwell fracture patterns from these models have been used for designing drilling and stimulation programs and for input in fluid-flow simulators. Another effort is under way to use new fracture characterization methods, which overcome the sampling limitations that plague conventional methods, to calibrate seismic fracture detection methods. Currently the project is conducting studies in deep sandstone targets in Texas, the Rocky Mountain region, and Venezuela and is analyzing fractures in carbonate rocks in Texas, the eastern United States, and Mexico.

Outcrop Characterization of Clastic Reservoir Analog: Laser-Assisted Analog of Siliciclastic Reservoirs (LASR)

Renaud Bouroullec, principal investigator; Mark Tomasso and Keumsuk Lee

Launched in January 2004, the LASR IA focuses on outcrops of submarine-fan and deltaic depositional systems. Our goal is to contribute new and creative ideas to better understand complex stratigraphic problems in submarine fans and deltaic systems. We address questions about landscape evolution, stratal preservation, impact of physiography, and impact of syndepositional structuring in a variety of tectonic settings and temporal and spatial scales. Our biggest contribution has been advancing our understanding of three-dimensional shape and architectural bodies by integrating lidar (light detection and ranging) and conventional outcrop data (stratigraphic columns and correlation panels). The lidar capture of these outcrops enables an exciting and new level of precision in quantification of stratigraphy and architectural elements. The following outcrop systems were characterized during the past years: the Solitary Channel, Spain; Brushy Canyon, West Texas; the Capistrano Formation, southern California; Ross Sandstone, Ireland; Annot Sandstone, France; and Ferron Sandstone, Utah.

Reservoir Characterization Research Laboratory (RCRL)

Charles Kerans, F. Jerry Lucia, and James W. Jennings, Jr., co-principal investigators; Xavier Janson, Jerome A. Bellian, Hongliu Zeng, and Fred P. Wang; assisted by nine graduate students.

modeling is a fundamental problem in reservoir characterization. The RCRL has developed advanced methods of modeling matrix permeability suitable for filling geologic models with petrophysics properties. Modeling nonmatrix flow, flow in touching-vug pore systems that include fractures, solution-enlarged fractures, large vugs and caverns, and collapse breccias, remains a major problem in carbonate reservoir characterization. In 2006 the RCRL research activities focused on (1) modeling the development of large vugs in the Medina outcrop using fluid flow models; (2) mapping Ordovician karst in the Franklin Mountains, West Texas, mapping syndepositional fractures in the Devonian of Australia, and describing the mechanical stratigraphy effect on fractures in a carbonate fault zone; (3) describing a karsted dolostone reservoir (the San Andres Hobbs Unit); and (4) investigating seismic methods for imaging vuggy pore space, including karst features and moldic grainstones.

Outcrop Studies of Carbonate Heterogeneity Styles—Platform, Slope, and Basin. Outcrop studies have been the principal focus of the RCRL since its beginning. Past outcrop studies have resulted in methods for building a sequence stratigraphic framework in ramp and platform-top systems. Platform-slope-basin systems, however, continue to be difficult to characterize for reservoir characterization. Therefore, improving our understanding of carbonate slopes and slope-to-basin transitions is a major program in the RCRL. In 2006 the RCRL (1) completed a 3D model of the Mississippian mound complex in the Sacramento Mountains, New Mexico, using high-resolution lidar and measured sections and (2) continued to describe and characterize slope architecture using outcrop descriptions from West Texas, Australia, and Morocco.

Modeling of Facies, Petrophysical Properties, and Reservoir Performance. The RCRL continues to investigate methods of modeling geologic facies and describing links between petrophysical properties and geologic descriptions for the purpose of building realistic flow models. In 2006 the RCRL completed an outcrop model of a Khuff outcrop in conjunction with Aramco. High-resolution lidar data were the basis for constructing a 3D geologic model of the outcrop, which was ported into and Eclipse model for flow experiments. The geologic model was quantified petrophysically using rock fabrics and plug data. The resulting flow model was used to determine the effective permeability of this oomoldic-grainstone/dolostone system. In addition, the relationship between limestone diagenesis and petrophysical properties was further investigated for the purpose of improving the spatial predictions of petrophysical properties in complex diagenetic settings.

Assessing Deep-Water Gas Hydrate Systems and Seafloor Stability
Bob A. Hardage, principal investigator, and Diana C. Sava

New rock physics models have to be developed to describe deep-water gas hydrate systems. These models must allow the host sediment to have (1) porosities as high as 70 percent, (2) effective pressures as low as 0 to 0.2 MPa, and (3) a variety of hydrate-distribution geometries within the sediment matrix. The objective of this Jackson School Initiative funding is to develop rock physics models appropriate for deep-water environments and then to apply these models across selected deep-water gas hydrate systems.

Processing and Modeling Proprietary 2D4C OBC Data
Bob A. Hardage, principal investigator, Milo M. Backus, Robert J. Graebner, Paul E. Murray, Randy L. Remington, Michael V. DeAngelo, and Diana C. Sava

The Minerals Management Service (MMS) has contracted the Exploration Geophysics Laboratory (EGL) to process and inverse model approximately 800 mi of deep-water 2D4C seismic data across the northern shelf of the Gulf of Mexico. Objectives are to provide MMS improved images of deep-water, near-
seafloor geology and estimates of gas hydrate concentration across the 1,500 mi² spanned by the seismic grid. Information generated by EGL will be incorporated into MMS’s regional assessment of gas hydrate resources across the northern Gulf.

**Statoil Deep-Water Data**

*Bob A. Hardage, principal investigator; Milo M. Backus, Robert J. Graebner, Paul E. Murray, Randy L. Remington, Michael V. DeAngelo, Diana C. Sava, and Sergey Fomel*

Statoil is a sponsor of the Exploration Geophysics Laboratory (EGL). After observing the unique strategy EGL uses to image deep-water, near-seafloor geology with 4C OBC data, Statoil contracted EGL to analyze a proprietary deep-water 2D4C OBC line from far-north waters. EGL will use two suites of software to produce the products that Statoil has requested. Software system 1 will analyze and image near-seafloor data windows. Software system 2 will analyze and image deep geology.

**Assessing Deep-Water Gulf of Mexico Gas Hydrate Systems with Multicomponent and Multifrequency Seismic Data**

*Bob A. Hardage, principal investigator; Milo M. Backus, Robert J. Graebner, Paul E. Murray, Randy L. Remington, and Diana C. Sava*

The Exploration Geophysics Laboratory (EGL) is a subcontractor to Louisiana State University in this study. Research is funded by the U.S. Department of Interior, Minerals Management Service. The study will investigate several seafloor fluid-gas expulsion sites in the deep-water area of Green Canyon in the northern Gulf of Mexico. Sites will be selected that are traversed by one or more of WesternGeco’s deep-water, multiclient, 4-C OBC seismic lines. Multifrequency imaging of gas hydrate systems associated with these expulsion chimneys will be done by acquiring 2- to 10-kHz chirp-sonar data using an Autonomous Underwater Vehicle (AUV) and 500- to 2,000-Hz data using the Naval Research Laboratory Deep-Towed Acoustic/Geophysics System (DTAGS). These AUV and DTAGS images will then be compared with 4-C OBC images along each profile that is analyzed.

**Processing and Interpreting Multicomponent Seismic Data: Gulf of Mexico Seafloor Observatory**

*Bob A. Hardage, principal investigator; Paul E. Murray*

The Exploration Geophysics Laboratory (EGL) is a subcontractor to the Mississippi Mineral Resources Institute (MMRI) in this study. MMRI has received funding from a variety of sources (DOE, MMS, NOOA) to construct a seafloor observatory across a gas hydrate system in Mississippi Canyon Block 118. EGL’s responsibilities are to process and interpret seismic data acquired by the horizontal and vertical arrays of 1-C and 4-C seismic sensors that will be deployed across the observatory. Downgoing P waves from four types of sources will be used to illuminate gas hydrate strata: conventional surface-positioned air-gun arrays, noise from passing ships, wind-driven ocean-surface waves, and seafloor-deployed air-gun sleds. Data will be acquired in a continuous, round-the-clock mode when wind-driven surface waves are the imaging source. Data acquisition will be repeated at appropriate calendar-time intervals to investigate dynamic processes that occur in the gas hydrate system across Block MC118.

**Elastic-Wavefield Seismic Stratigraphy: A New Seismic Interpretation Technology**

*Bob A. Hardage, principal investigator; Milo M. Backus, Michael V. DeAngelo, Randy Remington, Khaled Fouad, Robert J. Graebner, and Diana C. Sava*

The Exploration Geophysics Laboratory (EGL) partnered with Fasken Oil and Ranch Ltd. and Vecta Technology to develop a new seismic interpretation technology, Elastic Wavefield Seismic Stratigraphy. This technology is based
on the physics that each mode of an elastic wavefield can, and often does, image a suite of stratal surfaces different from those imaged by its companion elastic modes. Shear (S) modes can image seismic sequences and facies not observed in the compressional (P) mode, which is the only elastic-wave mode used in conventional seismic stratigraphy. In a homogeneous Earth, a full-elastic (9-component) seismic wavefield yields three S-wave modes: SH-SH (horizontal shear), SV-SV (vertical shear), and P-SV (converted shear). In an anisotropic Earth, each of these S modes splits into S1 (fast-S) and S2 (slow-S) modes controlled by the principal axes of anisotropy. Thus, there is a rich source of stratigraphic information in a full-elastic wavefield that is not being utilized in conventional P-wave seismic stratigraphic studies. The objectives of this research were to create compelling examples that prove that different stratal surfaces are imaged by different elastic-wave modes, to develop systematic relationships between petrophysical properties and combinations of elastic-mode sequences and facies, and to demonstrate how this new seismic imaging technology should be applied to improve geologic understanding of oil and gas systems.

**Exploring for Subtle Mission Canyon Stratigraphic Traps with Elastic-Wavefield Seismic Technology**

*Bob A. Hardage, principal investigator; Milo M. Backus, Michael V. DeAngelo, Robert J. Graebner, Jeffrey A. Kane, Paul E. Murray, and Diana C. Sava*

This study was funded by the U.S. Department of Energy and Vecta Exploration. In its subcontract to Vecta Exploration, Inc., the Exploration Geophysics Laboratory (EGL) developed a new seismic technology to explore for subtle Mission Canyon oolitic limestone reservoirs in the Williston Basin. This technology is based on acquisition and application of full-elastic (9-component) seismic data. Mission Canyon reservoirs are elusive targets when exploration is based on conventional compressional (P) wave seismic data. The attraction of 9-component (9-C) seismic data is that three shear (S) wave modes can also be used for target imaging: SH-SH (horizontal shear), SV-SV (vertical shear), and P-SV (converted shear) modes. Work at EGL has shown that each mode of an elastic wavefield can, and often does, image stratal surfaces across a target interval differently than do other elastic modes. Thus, any of the S modes can depict seismic sequences and seismic facies that are not observed using P waves. This rich, expanded source of stratigraphic and lithofacies information in full-elastic seismic wavefields needs to be utilized in Mission Canyon exploration. The objectives of this study are to acquire, process, and interpret 9C3D seismic data across Mission Canyon plays, develop relationships between drilling objectives and elastic-wavefield attributes, drill confirmation wells, and then share research findings so that full-elastic seismic technology can be applied to improve oil exploration across other areas.

**Imaging Deep Gas Prospects Using Multicomponent Seismic Technology**

*Bob A. Hardage, principal investigator; Milo M. Backus, Michael V. DeAngelo, Sergey B. Fomel, Khaled Fouad, Robert G. Graebner, Paul E. Murray, Randy L. Remington, and Diana C. Sava*

Operators across the Gulf of Mexico (GOM) are targeting deeper and deeper drilling objectives. For deep targets to be evaluated, seismic data are required that have longer and longer source-receiver offsets. Most shallow-water operators in the GOM consider 30,000 ft (9 km) to be the greatest target depth to be drilled for the next several years. For geology at depths of 9 km to be imaged, seismic reflection data must be acquired with offsets of 9 km or more. This long-offset requirement is difficult to achieve using towed-cable seismic technology in areas that are congested by production facilities, which is the situation for many shallow-water blocks across the northern GOM shelf. Ocean-bottom-cable (OBC) and ocean-bottom-sensor (OBS) technologies are
logical options for long-offset data acquisition in congested production areas because ocean-floor sensors, once deployed, are immobile and can be positioned close to platforms, well heads, and other obstructions that interfere with towed-cable operations. An additional appeal of OBC seismic technology is that four-component (4-C) data can be acquired, allowing targeted reservoir intervals to be imaged with P-SV wavefields, as well as P-P wavefields. Once 4-C seafloor receivers are deployed, source boats can maneuver along a receiver line to generate P-P and P-SV data from long-offset distances.

This research was designed to investigate the value of long-offset, multicomponent seismic data for studying deep-gas geology across the northern shelf of the GOM. The term long offset means that 4-C OBC data were processed using uniformly sampled source-receiver offsets ranging from 0 to 10 km. The study area was a large, 3,200-mi² (8,200-km²) section of the Louisiana shelf noted for prolific gas production. Data consisted of parallel north-south and parallel east-west 2-D 4C profiles spaced at intervals of 2 mi. P-P and P-SV images produced from these long-offset reflection data were interpreted to determine the relative depth-imaging capabilities of each seismic mode. Analysis of these long-offset data showed that the P-P mode contains reflection signals from depths of 60,000 ft (18 km), which is deeper than any reported seismic reflection effort in the GOM basin. Equally important, the critical P-SV mode had a reflection signal from depths of 42,000 ft (13 km).

Devine Test Site
Bob A. Hardage, principal investigator; Milo M. Backus, Robert J. Graebner, and Paul E. Murray; George T. Bush, site manager

The Devine Test Site, managed by the Bureau’s Exploration Geophysics Laboratory, continues to gain recognition within the geophysical community. The low level of cultural noise at the site and efficient seismic transmission properties of the strata beneath the 100-acre property provide ideal conditions for testing and developing new seismic technology. Information about the Devine Test Site, including an inventory of publicly available data acquired by its previous owner, British Petroleum, and conditions for use by nonuniversity individuals, can be found on the Bureau’s Website at www.beg.utexas.edu/indassoc/egl.

Multiple Elimination Using Plane-Wave Construction
Sergey B. Fomel, principal investigator

We are developing theory, numerical algorithm, and prototype implementation for a new method of multiple noise discrimination in seismic records. The method is based on plane-wave construction and shaping regularization. It is applicable to both prestack unmigrated gathers and depth-migrated common image gathers.

Our algorithm is designed to separate primary and multiple events cleanly by identifying and discriminating local event slopes. It is able to input multiple models generated by different methods, such as surface-related (SRME) or wave-equation (WE) approaches, and to handle a situation of several multiple sets, such as different-order multiples in SRME or receiver-side and source-side multiples in WE.

Differential Azimuth II
Sergey B. Fomel, principal investigator

We are developing theory, numerical algorithm, and prototype implementation of differential azimuth moveout, a powerful new method for regularizing 3-D seismic reflection data.

In theory, differential azimuth moveout is represented by a partial differential equation, whose role with respect to integral (Kirchhoff) azimuth moveout is similar to the role of the wave equation with respect to Kirchhoff migration. In practice, we anticipate differential azimuth moveout to behave as a compact, local, accurate, and efficiently computed regularization operator. The operator is applied iteratively to produce regular output from irregular input.
Seismic Imaging by Riemannian Wavefield Extrapolation  
*Sergey B. Fomel, principal investigator*

We are developing theory, numerical algorithm, and prototype implementation of seismic imaging by Riemannian wavefield extrapolation (RWE). RWE was proposed by Sava and Fomel (2004) for imaging steeply dipping and overturning reflections in geologically complex exploration areas, such as deep subsalt structures in the Gulf of Mexico.

RWE belongs to the class of wave-equation extrapolation methods that are known to accurately handle large-velocity contrasts, multipathing, and band-limited wave propagation effects. Instead of conventional downward extrapolation, RWE employs coordinate transformation to extrapolate waves numerically in a direction close to the preferential direction of natural wave propagation. As a result, one can accurately image large propagation angles, including overturning salt-flank reflections, using inexpensive extrapolation operators.

Wave-Equation Migration Velocity Analysis  
*Sergey B. Fomel, principal investigator*

We are developing the theory, numerical algorithm, and prototype implementation of wave-equation migration velocity analysis (WEMVA). WEMVA, a powerful and robust method of velocity analysis, is applicable to complex media (for example, subsalt). It belongs to the wavefield extrapolation family of methods that are known to handle large velocity contrasts accurately, multipathing and band-limited wave propagation effects. Wavefield extrapolation is commonly used, although not currently, for migration velocity analysis, in which the state of the art is traveltime tomography based on ray tracing. Traveltime tomography fails to estimate velocity correctly in complex media (for example, subsalt) because it is inconsistent with the frequency band of the recorded data and information used for velocity analysis is confined to a few main reflectors picked on migrated images. Thus, the quality of depth imaging decreases, despite the use of accurate wave-equation migration algorithms for imaging. In contrast, WEMVA is closely related to migration by wavefield extrapolation, is formulated in the frequency band of the recorded data, and employs information from the entire images to constrain the velocity model. This method therefore inherits all the properties of wave-equation migration and leads to more accurate and robust velocity models, improving the quality of depth-migrated images.

*Sergey B. Fomel, principal investigator*

We are developing a new technology for estimating petrophysical properties of hydrocarbon reservoirs using inversion of seismic reflection data. The key idea of the new method is the use of reflection angle gathers computed from output of 3-D prestack wave equation migration. The petrophysical information contained in wave-equation angle gathers is extracted by full waveform inversion using global and hybrid optimization methods and stochastic uncertainty analysis.

“Madagascar” Open-Source Project  
*Sergey B. Fomel, principal investigator*

Researchers doing computational data-processing experiments need software tools that make conducting experiments and exchanging experimental results both convenient and efficient. “Madagascar” is a project that addresses these goals. Started by Bureau Scientist Sergey Fomel in 2003 under the name “RSF” (Regularly Sampled Format), the package was released to the public in June 2006 at the EAGE Workshop,
“Open Source E&P Software—Putting the Pieces Together” in Vienna. In August 2006, the Madagascar package was the focus of a School and Workshop in Vancouver titled “Reproducible Research in Computational Geophysics.” Fifty participants representing fifteen different companies and fifteen different universities attended the school and received certificates for completing basic Madagascar training. More schools are being planned for next year.

Although developed from scratch, Madagascar follows the tradition of geophysical data-processing packages such as SEPlib (developed at Stanford), Seismic Unix (developed at Stanford and Colorado School of Mines), and FreeUSP (developed at Amoco and BP). It reimplements some of the functionality and ideas from these other packages, while updating them to modern software design practices.

The distinguishing feature of Madagascar is its orientation toward reproducibility of computational experiments. Bringing reproducibility to the field of computational geophysics and enabling fast, convenient technology transfer were the main motivation for the package’s development. Madagascar consists of two levels: low-level main programs and high-level processing flows that combine main programs and thoroughly document data-processing histories for testing and reproducibility. Experience shows that high-level programming is easily mastered—even by beginning students that have no previous programming experience.

Madagascar follows the open-source tradition, which is responsible for now-famous products such as the Linux operating system, the Mozilla Firefox Web browser, etc. The main model for the open-source development is an open collaboration among different developers from around the world. Madagascar is hosted by Sourceforge, the main repository of open-source projects. Major contributors include Sergey Fomel and Jim Jennings from BEG; Paul Sava (now at Colorado School of Mines); and Gilles Hennenfent, Henryk Modzelewski, and Colin Russell (University of British Columbia). During the first 4 months of public existence, the package was downloaded from Sourceforge about 400 times and installed by many different organizations.

Madagascar is used primarily for processing and analyzing seismic data. However, its flexible data format makes the package applicable to many other areas that involve computational experiments involving large datasets. An example is the stochastic modeling tools developed by Jim Jennings, which are easily integrated with forward seismic modeling and imaging tools for studying seismic responses of realistic reservoir models. http://www.beg.utexas.edu/mainweb/services/madagascar.htm

JSG Structural Diagenesis

Stephen E. Laubach and Randall A. Marrett, principal investigators; Kitty L. Milliken, Jon E. Olson, and Robert H. Lander, co-principal investigators, Peter Eichhubl, John N. Hooker, Julia F. W. Gale

The Jackson School of Geosciences has funded a research initiative in the research area and discipline of structural diagenesis. Structural diagenesis is an approach that deliberately synthesizes mechanics and geochemistry in ways that have been neglected in traditional diagenesis and structural studies. This approach promises to provide solutions to long-standing geologic problems in sedimentary basins, as the iteration of mechanical and chemical processes lead to feedback and strongly nonlinear processes. The program is designed to make the Jackson School a world leader in linked structural and diagenetic issues. This effort will make previous approaches to diagenesis and mechanical studies in sedimentary basins obsolete.

The initial focus under this initiative is on fracture-opening processes from the perspective of chemical/mechanical evolution of fracture systems. Fluid flow in fractured rock is an increasingly central issue in recovering water and hydrocarbon supplies and geothermal energy in predicting flow of pollutants underground, in
engineering structures, and in understanding large-scale crustal behavior. The goal of this project is to develop an understanding of how fracture growth and diagenetic alteration interact to create and destroy fracture porosity systematically. This cross-disciplinary research will result in fundamental advances in our understanding of how diversity of natural fracture patterns evolves and better predictions of fracture-pattern attributes in the subsurface where sparse sampling is the rule. Jackson School support will help build our already strong cross-disciplinary and cross-departmental program in fundamental and applied fracture and rock-property evolution research. As an essential step in a broad study of links between mechanical and chemical processes in opening fractures, we are testing a new theory of cementation in fractures that predicts fracture porosity evolution as a function of temperature, surface area, and opening history. Results will allow us to estimate fracture-opening rates, which will be a significant contribution to understanding crustal mechanics and a constraint on intraplate tectonic processes.

**Predicting Fracture Porosity Evolution in Sandstone**

Stephen E. Laubach, Peter Eichhubl, Robert H. Lander, Linda M. Bonnell (Research Fellows, The University of Texas at Austin), Jon E. Olson (Department of Petroleum and Geosystems Engineering, The University of Texas at Austin), Julia F. W. Gale, and Randall A. Marrett (Department of Geological Sciences, The University of Texas at Austin), co-principal investigators; Jon T. Holder (Department of Petroleum and Geosystems Engineering), Kitty L. Milliken (Department of Geological Sciences), Dick Larese (consultant), John N. Hooker and Robert M. Reed; assisted by, Kira Diaz-Tushman, Makayla Hensley, Edgar Pinzon, Natalia Kalitynska, Aysen Ozkan, Leonel A. Gomez, and Meghan E. Ward

Continuity of fracture porosity is fundamental to how fractures conduct fluids. It is an increasingly central issue in recovering water and hydrocarbon supplies and geothermal energy, in predicting flow of pollutants underground, in engineering structures, and in understanding large-scale crustal behavior. Researchers at BEG, the Departments of Geological Sciences and Petroleum and Geosystems Engineering, and Geocosm L.L.C. are working to develop an understanding of how fracture growth and diagenetic alteration interact to create and destroy fracture porosity systematically. This cross-disciplinary research will fundamentally advance researchers’ understanding of how diversity of natural fracture patterns evolves and enable better predictions of fracture-pattern attributes in the subsurface, where sparse sampling is the rule.

As an essential step in a broad study of links between mechanical and chemical processes in opening fractures, researchers will test a new theory of cementation in fractures that predicts fracture-porosity evolution as a function of temperature, surface area, and opening history. The centerpiece of this effort is a study focused on the Piceance Basin of Colorado that combines fracture and diagenesis observations, mechanical and diagenetic modeling, and novel rock-property tests on specially prepared artificial rocks that have cement properties matching those of rocks at various positions along the modeled burial-history curve of a target formation in the basin. This study is supported by a grant from Chemical Sciences, Geosciences, and Biosciences Division, Office of Basic Energy Sciences, Office of Science, U.S. Department of Energy. The research is divided into characterizing fractures and cements, constraining temperature and load conditions, modeling burial history and the diagenetic–fracture pathway, and quantitatively linking diagenesis model results to geomechanical model and scaling observations. Researchers also seek to demonstrate how chemical and mechanical interactions combine to produce aperture, length, and spacing patterns—essential ingredients for understanding the role of fractures in fluid flow in the Earth. In a separate study supported by the Jackson School, these results are being extended to
estimation of fracture-opening rates, which will be a significant contribution to understanding crustal mechanics and a constraint on intraplate tectonic processes.

**Basin and Field Studies**

**Stratigraphic Architecture and Sandstone Reservoir Quality in Deep Shelf Gas Plays of Texas State Waters**

Shirley P. Dutton and Robert G. Loucks, co-principal investigators; Angela McDonnell, Romulo P. Briceno, L. Frank Brown, Jr., Ruari J. Day-Stirrat, and Jeffrey A. Kane; assisted by Younis Altobi, Mary Bezara, Hugo Castellanos, Tiffany Hedayati, Nia Nikmanesh, and Blake Walker

The deep-shelf gas play in the Gulf of Mexico (GOM) is focusing exploration attention below 15,000 ft in the shallow waters of the offshore Texas State leases. Ultradeep wells are being planned by industry operators for depths from 20,000 ft to greater than 30,000 ft to target large structures below the present-day Texas shelf that contain sandstones deposited in lowstand systems tracts. At these depths the greatest unknown and most critical risk factor is reservoir quality. The ability to predict reservoir quality (porosity and permeability) and physical characteristics of ultradeep reservoir rocks has lagged behind our understanding of other parts of the petroleum system, such as depositional facies, traps, and petroleum migration.

The Bureau’s Deep Shelf Gas project is supported by a consortium of companies. Major goals are to decrease exploration risk by (1) mapping general stratigraphic architecture and areas of deep to ultradeep depocenters from 3-D seismic data and (2) understanding the uncertainty involved in preservation or enhancement of porosity and permeability at depth. Specific goals of this multidisciplinary study are (1) mapping of deep stratigraphic architecture from seismic data, (2) isochron mapping of deep sedimentary packages, (3) seismic facies analysis of these packages, (4) petrographic and geochemical analysis of rock samples, (5) statistical analysis of porosity/permeability relationships to controlling parameters, and (6) wireline-log analysis for complete vertical data coverage in selected areas.

Data for this project include several thousand thin-section analyses, cores to depths as great as 23,500 ft, and a 3-D seismic data volume (supplied by Seismic Exchange, Inc.) of State Waters that covers 15 x 220 mi (3,300 mi² of data). Quality of the seismic data allows analysis of the complete Tertiary section down to 8-s two-way traveltime (TWT). Other data include an extensive, far-offset, deep-penetration (16-s TWT), 2-D seismic dataset (supplied by GX Technology). These 2-D data overlap with the 3-D volume.

Seismic analysis is providing a clear picture of the structural and stratigraphic architecture of the State Waters area. Both extensional and compressional structural features are being mapped and integrated with the sequence stratigraphic history of the basin. Sand depocenters are being identified, and new insights are being made into the role of salt tectonics on depocenter development in the State Waters area. Results of these studies will aid in identifying fairways of potentially deeply buried sandstones that may be reservoirs.

Regional studies in the shallower Tertiary sandstone section have shown that significant regional variation in reservoir quality is controlled by differences in detrital mineralogy, grain size and texture, depositional environments, burial history, and geothermal gradient. Previous Bureau studies resulted in publication of what are still the most complete analyses of geographic and depth trends in mineralogy, grain size, texture, porosity, and permeability in lower Tertiary sandstones from the onshore Texas Gulf coast. The Deep Shelf Gas project is now conducting a comparable analysis of regional and depth variations in deep Cenozoic sandstones (>15,000 ft), both from the onshore
Texas Gulf coast and on the inner continental shelf. A major goal is to place the sandstones that are studied into a structural and sequence-stratigraphic framework to help us understand how reservoir quality is affected by changes in structural styles and depositional setting.

During 2006 we completed study of the north half of the Texas coast and began our investigation of the south Texas coast. Additional industrial sponsors are invited to join the project.

**BEG Research in the Jackson School Royalty Area**


John A. (“Jack”) Jackson left an amazing legacy to The University of Texas at Austin, and the John A. and Katherine G. Jackson School of Geosciences (Jackson School) is a direct result of his generosity. Among his gifts were royalty interests in some 1,000 producing wells in the Fort Worth Basin, where, during the 1950’s, Jack was a pioneer in gas discoveries from Pennsylvanian Bend Conglomerate reservoirs. Those giant reservoirs still produce, but the rapidly expanding Barnett Shale exploration play has significant promise for Jackson School interests.

**Barnett Shale**

The Barnett Shale is a Mississippian shale formation that, in Newark East field, is now the largest natural-gas-producing field in Texas and is second in the nation, according to daily rate. It is the hottest play in Texas, with more than 100 drilling rigs running and with play boundaries still being defined by drilling. Favorable economics are enabling royalty owners, producers, service companies, and their shareholders to benefit—Texas-style—from the play.

The Barnett is classified as an unconventional reservoir because of its mudstone lithology and the necessity for hydraulic fracture stimulation. Unconventional reservoirs, which now account for 40 percent of the natural gas produced in the U.S. and include coals and shales, will not flow commercial amounts of gas unless the wells are stimulated to improve reservoir properties. Production from the Barnett Shale was minimal prior to 1997 because wells would not flow gas at rates sufficient to justify costs.

Today, a host of technologies, including laboratory analysis of gas yields from the shale, hydraulic fracturing, horizontal drilling, 3-D seismic, microseismic monitoring of fracture-stimulation jobs, and rock-mechanics assessment prior to fracturing, are assisting operators in expanding the play.

**Bureau Research**

Bureau research sponsored by the Jackson School has been under way for nearly 3 years on the Barnett in Wise County, where Jackson School royalty interests are concentrated. The primary objective is to provide technical analysis that could stimulate additional drilling and production in the royalty area. A secondary objective is to track expansion of the play and to update the value of Jackson School royalty interests accordingly.

This past year we have emphasized revising our forecast of Barnett potential in the western two-thirds of Wise County. The success of about a dozen recently drilled horizontal wells there suggests that Barnett development over most of the JSG royalty area will be by horizontal drilling, followed by completion involving multiple stages of carefully sized hydraulic fracture jobs. The expected gross reserves per well are on the order of 1 billion cubic feet, and we calculate that such wells will be economic under future gas price scenarios as low as $4 to $5 per thousand cubic feet. Improvements in drilling and completion operations are expected to continue, resulting in development of the Barnett across all of the JSG royalty area. The biggest remaining unknown for the current cycle of development is: what percentage of drilling locations will not be developed because of operators' concerns about intersecting faults.
with horizontal well bores? Crossing such faults with horizontal wells commonly results in the production of unwanted saltwater, sourced from the underlying Ellenburger Group. Currently, 3-D seismic surveys are used by operators to image these faults and to position horizontal wells accordingly. We are actively working with selected operators to better characterize the faults and to determine whether all faults must be avoided.

We also completed research on key aspects controlling gas production from the Pennsylvanian-age Bend Conglomerate, which lies above the Barnett Shale. Our objective was to demonstrate additional infield production potential by conducting modern reservoir characterization studies of this giant gas-producing trend, where production began in the 1950’s. A pilot study area covering the southwest quarter of Wise County, coinciding with much of the Jackson royalty area, was completed. We mapped conglomerate- and sandstone-rich, reservoir-scale genetic units. Petrophysical analyses of well logs and core samples complemented the effort. Results to date have defined (1) depositional fabric and setting of Bend reservoir units, (2) relation between producing wells and areal distribution of units, (3) fundamental petrophysical controls on production, and (4) many potential infill, step-out, and recompletion locations on the basis of geoscience and petrophysics. These results were reviewed with key operators in the area and presented as a poster session at the AAPG annual meeting. One operator had already conducted a successful step-out drilling program on the basis of its own parallel study, and several other operators requested our detailed study results to support their own infill recommendations.

BEG’s Barnett Shale research activities expanded significantly in FY2006 as STARR and Permian Basin Synthesis programs undertook joint statewide studies on basic geological aspects of the play. Results of this work were presented at well-attended workshops in Houston and Midland.

State of Texas Advanced Resource Recovery (STARR) Project

Robert G. Loucks (principal Investigator), Eric Potter (Associate Director of Energy), Ramón H. Treviño, Ursula Hammes, L. Frank Brown, Jr., Hongliu Zeng, Steve Ruppel, Julia Gale, Fred Wang, Florence Bonnaffe, Angela McDonnell, and Wayne Wright; assisted by Joseph Yeh, Dallas Dunlap, Abdelmoniem Kamal Abdelmoniem, Mary Bezara, Hugo Castellanos, Joseph Coleman, Mochamad Fachmi, Martin Handzlik, Tiffany Hedayati, Richard Kilby, Rosalba Mendes, Brian Moore, Nia Nikmanesh, Patricio Sanchez, David Soto, and Blake Walker

The State of Texas Advanced Resource Recovery program, Project STARR, has been successful in its major objective of increasing royalty income to the Permanent School Fund through technological and research projects that promote the drilling of profitable oil and gas wells on State Lands and Waters. The Bureau of Economic Geology currently receives funds from the State to analyze State Lands properties and then advise and assist operators on how to increase current production or identify new production. The State requires Project STARR to be revenue neutral—that is, Project STARR has to cause an amount of new revenue to flow into the State of Texas General Revenue Fund that equals or exceeds the amount that is appropriated to the program by the Legislature.

Project STARR concentrates on three major areas: (1) reservoir characterization of known fields to identify infill and step-out wells, deeper untapped reservoirs, and enhanced recovery methods; (2) new venture studies in which regional fairways for drilling exploration wells are emphasized; and (3) unconventional resources, such as hydrocarbons from shale, tight gas sands, and low-pressure gas. One such unconventional resources study that project STARR completed last year was of the Barnett Shale-Gas play in the Fort Worth Basin (BEG’s CD-ROM No. SW0016), which was disseminated to the public in a series of workshops in November 2006. The study provides new data and concepts on the shale-gas play, and the data will be able
to be applied to similar West Texas shale-gas plays where State Land leases are abundant.

Project STARR results have been used to recommend more than 71 infill wells, 57 recompletions, and 33 step-out wells over the project’s 11-year history. Project STARR has also identified and worked on several prospects in previously undrilled deeper strata. To date, Project STARR has completed studies or is currently working on 28 fields on State Lands, and these studies have created royalty revenue to the Texas Permanent School Fund and severance tax to the State General Revenue Fund in the amount of $35.8 million during the time period September 2004 through August 2006. Relative to total income, Project STARR is revenue positive by a factor of 17.9. The high positive revenue factor is from 27 successful wells drilled in several fields in the State Waters, a successful tertiary recovery project in Yates field in West Texas, and higher prices for oil and gas. It commonly takes several years between the delineation of prospects and the actual drilling of wells; therefore, many more millions of dollars to the Permanent School Fund may result from Project STARR’s recent recommendations and successes. Over the 11-year life of Project STARR, ~$117 million has been added to the Permanent School Fund from royalties and to the State from severance taxes on the increased production from wells drilled by STARR’s industry partners—an average of $10.6 million per year.

**Reviving Abandoned Reservoirs with High-Pressure Air Injection:**

*Application in a Fractured and Karsted Dolomite Reservoir*

Stephen C. Ruppel and Robert G. Loucks, co-principal investigators; Julia Gale.

The goals of this project, which ended in 2006, were to evaluate the applicability of high-pressure air injection (HPAI) in revitalizing a nearly abandoned carbonate reservoir in the Permian Basin of West Texas. Utilizing geoscientists and petroleum engineers from the Bureau of Economic Geology and the Department of Petroleum Engineering (both at The University of Texas at Austin), we conducted reservoir characterization and flow modeling studies of an abandoned Ellenburger dolostone reservoir to define controls on HPAI response and fluid flow.

These studies and related laboratory tests and a reservoir pilot project were successful in demonstrating the efficacy of the technology and delineating key reservoir flow controls. Unfortunately, the project ended prematurely owing to operator difficulties in obtaining continuing funding. Despite its premature end, however, the project was successful in demonstrating both the feasibility of the technology and in documenting the controls of reservoir heterogeneity in the test-case reservoir.

Successful application of high-pressure air-injection technology has tremendous potential for increasing the flow of oil from deep carbonate reservoirs in the Permian Basin, a target resource that can be conservatively estimated at more than 1.5 billion barrels. Results of these reservoir characterization studies are being documented and will be widely disseminated so that HPAI can be considered for adoption by oil operators in other reservoirs in the Permian Basin and elsewhere in the U.S.

**Integrated Geological Synthesis of the Permian Basin**

Stephen C. Ruppel, principal investigator; Rebecca H. Jones, Robert G. Loucks, Wayne R. Wright, Charles Kerans, Edgar H. Guevara, H. Seay Nance, and Caroline L. Breton; Ted E. Playton, Martin Hanzlik, and David Soto

Bureau researchers have begun integrated analysis of the depositional history and stratigraphic architecture of the Permian Basin. The goals of the program are to (1) produce a detailed, comprehensive history of the Paleozoic
depositional and reservoir systems in the Permian Basin and (2) create spatially integrated databases of depositional, stratigraphic, lithologic, and petrophysical properties for each stratigraphic horizon.

The Permian Basin is the largest producing basin in the U.S., with 30 billion barrels of mobile oil remaining in existing reservoirs and a projected 3.5 billion barrels of undiscovered oil and natural gas liquids (NGL) resources. Recovery of this vast remaining resource has become an increasing challenge as new companies unfamiliar with the basin and its geology have replaced original, data- and expertise-rich, major oil companies. A particular problem for these new companies is difficulty of access to data and knowledge of how to use the data. The project will address this problem by providing needed fundamental stratigraphic and reservoir-specific data in readily accessible and usable formats. No modern, integrated synthesis of Permian Basin geology currently exists.

An integrated synthesis of available data, concepts, and models in the Permian Basin will form a fundamental basis for providing Permian Basin operators with (1) outcrop and subsurface-reservoir-specific models to be applied to engineering- and completion-based redevelopment of existing reservoirs and (2) a detailed regional stratigraphic framework for applying such models to new exploration targets. These data will decrease the risk and increase the efficiency of exploiting remaining hydrocarbons in the Permian Basin and define new opportunities for drilling. The data will also form the basis for new engineering approaches and completion practices.

The project will involve participation and sponsorship of oil companies active in the Permian Basin. This liaison will accomplish two goals: (1) industry input will assure that goals of the project will be those that are of greatest value to industry and (2) more effective technology and data transfer will be facilitated.

Project deliverables will include (1) a comprehensive written analysis of Paleozoic depositional history, stratigraphy, facies, and structural history of the basin and (2) data syntheses of selected hydrocarbon-rich plays in the basin. Data, which will include a wide variety of geologic and reservoir data, will be spatially integrated into a geographic information system (GIS) format for ready data access and use. Data sets will be made available digitally both on CD and through direct access over the World Wide Web. Funding for the project is being shared by DOE, sponsoring industry partners, and the Bureau’s Carbonate Reservoir Characterization Research Laboratory and Starr Project.

During the first year of this 3-year project, three depositional episodes were selected for detailed study: the Carboniferous Barnett Shale, the Upper Devonian Woodford Shale, and the Lower Devonian Thirtyone Chert and Carbonate Formation. In subsequent years, detailed study is planned for carbonate systems of the Silurian Wristen Formation, the Permian Clear Fork Group, the Lower Ordovician Ellenburger Group, and other depositional intervals according to interest.

Carbonate Slope and Basin Sediment-Gravity Flow Systems: Toward Developing an Exploration Model

Xavier Janson, principal investigator

This project is a 2-year research project sponsored by Shell International E&P. The first year (2005) consisted of reviewing and synthesizing available knowledge on carbonate-slope, toe-of-slope, and basinal-carbonate-sediment-gravity-flow deposits for both modern and ancient carbonate depositional systems to produce a digital atlas of carbonate-slope deposits. The introductory part of this atlas presents an updated synthesis of carbonate-slope-basin deposits, including depositional mechanism, revised classification of slopes based on depositional process, and a stratigraphic model that attempts to link
deposit type, pore type, deposit geometry, and stacking pattern to a sequence stratigraphic model. In addition, quantification and classification of the morphology, type of deposit, and stratigraphic architecture are provided.

Year 2 (2006) of this project consisted of more detailed study of selected subsurface and outcrop datasets provided to test validity and predictability of the models developed during year 1. At the same time, forward stratigraphic modeling was used to test concepts and questions that arose during year 1. In addition, 2D and 3D synthetic seismograms for selected existing studies and synthetic stratigraphic model were built to help us identify characteristic seismic response to a spectrum of carbonate-slope reservoir settings.

3-D Modeling of Permo-Triassic Khuff Carbonate Outcrop Analogs for Advanced Reservoir Characterization
Xavier Janson, principal investigator; Jerome A. Bellian, James W. Jennings Jr., and F. Jerry Lucia

3D laser outcrop analysis was conducted on the Khuff-equivalent outcrops near Buraydah, Saudi Arabia, in December 2004 by Janson and Bellian. The error for the overall model was +/- 0.165 m absolute precision to the control established by Aramco Surveying Services. From an average distance of 40 m, 147 laser scans were acquired with more than 140,000,000 points in total at an average spacing of 1.7 cm. Stratigraphic interpretation was performed using “polyline” tools in the IMInspect module and then imported into Gocad software for final model construction. An interpolated and slightly decimated “Short GPS” point cloud (10-cm point spacing) was exported in ASCII format to display as a base map in Gocad.

The outcrop studied belongs to the Khartam Member of the Khuff Formation, which is the uppermost member of the outcropping Khuff Formation. It lies in central Saudi Arabia and is dated as latest Permian and Triassic. On the outcrop, 6 sedimentological sections were measured, and 164 plugs were taken. Bed mapping was done in the field and on photomosaics. The Triassic part of the section is characterized by several thick ooid/peloid moldic grainstones that extend across the entire outcrop. Between these grainstone intervals, deposits consist of peloid wackestone, mudstone, and brachiopod grainstone. The uppermost part of the outcrop consists mostly of dolomitized brachiopod grainstones. The grainstones are deposited as sheet or filled erosive depression. These rocks are interpreted to have been deposited on a shallow subtidal shelf influenced by tides.

Stratigraphic horizons were mapped on the lidar data and used for creating 12 3D surfaces, which in turn form the framework of a 3D geological model. The 3D stratigraphic grid is 600 x 385 m and 23 to 33 m thick. The grid cell dimensions are 3 m x 3 m x 0.3 m (on average), resulting in an approximately 4-million-cell model. On the basis of the six measured sections, facies were extrapolated using both deterministic filling between two surface and sequential Gaussian simulations. The extrapolated facies were painted back onto the lidar data for comparison with actual outcrop stratigraphy. Most of the grainstone intervals (>1 m thick) are larger than the modeled area of the outcrop and are assumed to have a lateral extension larger than 600 m.

The principal rock fabrics are class 1 oomoldic grainstone, with 22 percent porosity and 0.7 md permeability; class 3 mudstones and wackestones, with 8 percent porosity and <0.1 md permeability; and classes 1 and 2 dolostones with 18 percent porosity and 52 md permeability. In addition the outcrop contains an ooid/peloid grainstone that lacks permeability, which is confined to one layer described as a channel deposit. Interestingly calcitization of dolostones and anhydrite is considerable. Flow properties are clearly dominated by the dolostone beds.

The 3D geologic facies model was simplified into a 3D rock-fabric facies model, and stochastic simulation was used to generate grids of porosity
and permeability according to observed rock-fabric-dependent porosity and permeability relationships. Averaging calculations were used to estimate effective horizontal and vertical permeabilities of the entire model, 3.6 and 0.05 md, respectively. The resulting effective permeability anisotropy ratio of 0.013 is caused by the layering of petrophysical rock types in the model.

Support for Curation of Academic Research Cores, Samples, and Collections in the Geosciences
Scott W. Tinker, principal investigator; Shirley P. Dutton, co-principal investigator; Beverly B. DeJarnett, John M. Els, Darrell O. Haynes, David C. Jordan, and Randy E. McDonald

The National Science Foundation (NSF) Earth Science Division (EAR) acquired space within BEG’s Houston Research Center (HRC) for storage and curation of terrestrial scientific cores, rock samples, and collections procured through EAR/NSF-funded research projects. Cores and cuttings collected for the Plate Boundary Observatory (PBO) component of the EarthScope project were sent to the HRC under this program. NSF support of the HRC ended in 2006, but the HRC will curate this material and facilitate continued access to, and use of, the material by researchers in the geologic community for the foreseeable future. Laboratory space and equipment needed for examining and sampling NSF project material will be provided at the standard fees for HRC services.

Deep Burial Diagenetic Processes in Siliciclastic Strata
Shirley P. Dutton, Robert G. Loucks, and Kitty L. Milliken, co-principal investigators; Ruarri J. Day-Stirrat

This study funded by the Jackson School of Geosciences is focused on physical and chemical processes in GOM sandstones and mudstones below 4.5 km. The primary driver of the proposed research is the unresolved issue of the scale of mass transfer during burial diagenesis in sedimentary basins. The largely physical processes of compaction have important implications for understanding fluid-flow systems in the subsurface. We will focus on the progress of brittle fracture and pressure solution in samples below 4.5 km. An ability to make predictions of pore evolution with burial also hinges on a fundamental understanding of the nature of basinal chemical reactions. Chemical reaction mechanisms in diagenesis may change in a discernible way with increasing depth. Processes of precipitation and dissolution are not strongly linked in shallow diagenesis, but precipitation reactions in deep diagenesis may be increasingly localized at sites of dissolution.

Research begun this year focused on the mudstone and siltstone horizons in a deeply buried (22,000 ft) onshore Gulf of Mexico well for which high-quality core material and composite log information were available. Because of the chemical complexity of mudstones and siltstones compared with that of sandstones, they are potential sources and sinks for reactants and products in adjacent sandstone strata. Composite log and core data allowed a detailed 1-D maturity model to be built. The completed experimental work has focused on the alignment of phyllosilicate minerals, a physical property that has mechanical and chemical (diagenetic) controls that are still not entirely understood. The ongoing work focuses on electron and optical microscopy as a characterizing prelude to semiquantitative X-ray diffraction for us to better understand the chemical processes at play in deep basinal settings.

The project Stratigraphic Architecture and Sandstone Reservoir Quality in Deep-Shelf Gas Plays of Texas State Waters provides the matching funding. This matching project, which is funded by a group of companies engaged in exploring for deep gas reservoirs on the Gulf of Mexico shelf, is focused on reservoir-quality prediction. The research funded by the Jackson School emphasizes fundamental questions of
siliciclastic diagenesis and complements the other, more practically focused project.

Center for Energy Economics
Highlights
Michelle Michot Foss, Mariano Gurfinke1, Gürcan Gülen, Ruzanna V. Makaryan, Dmitry Volkov, and Miranda Ferrell Wainberg
(Natalie Silva, administrative assistant)

The Center for Energy Economics (CEE), which joined the Bureau of Economic Geology (BEG) June 1, 2005, has a number of ongoing research projects in energy economics and market developments. With its mission “to educate stakeholders on energy economics and commercial frameworks using comparative research to facilitate energy development,” the CEE applied-economics “do tank” has programs both in the U.S. and abroad. CEE also supports key BEG programs and initiatives and will undertake new initiatives as we continue to integrate with BEG and The University of Texas at Austin (UT) community.

CEE’s work spans large geography and diverse undertakings. This past year, our interactions ranged from discrete meetings with domestic and international visitors to our multinational annual capacity building program, New Era in Oil, Gas & Power Value Creation; from short thought pieces to comprehensive briefing papers; and from genesis of idea to implementation of concept. A sampling of CEE activities in FY06 follows.

CEE’s efforts to examine the role of liquefied natural gas (LNG) in the North American and global economies and reach out to public audiences on LNG safety and security continued to achieve great outcomes. Since establishing the LNG Research Consortium in 2003, we have become the leading university-based center of expertise on development of new import terminals in the U.S. and across the continent. In FY06, CEE completed a new briefing paper—“Offshore LNG Receiving Terminals.” The paper addresses a whole range of issues related to construction and operation of offshore LNG terminals, including siting, permitting, regulation, and development perspectives. Also in FY06, we launched major new research within the LNG Consortium to address the issues of community and economic benefits for large infrastructure projects. The purpose of this project is to address the need for clarity on local benefits for host communities, as well as larger market areas and national need; identify host community “costs” and strategies for transforming costs into benefits; incorporate practical considerations stemming from LNG safety and perceptions of risk; and improve the knowledge base for presenting long-term net benefits associated with international LNG trade well beyond the development project and for both new and existing facilities. Throughout the year, CEE staff participated in more than a dozen public forums on LNG, and our work is relied upon by a broad cross section of the news media. Our expertise reaches well beyond North America—we are tracking, working on, and interacting with LNG developments and developers around the globe. This interaction has given us a strong, broad, unique perspective on an array of issues ranging from LNG value chain economics to community acceptance—the focal point of our current work—to perceptions of risk to business-government linkages for risk management. CEE’s briefing papers and LNG Website (www.beg.utexas.edu/energycon/lng) provide an independent, objective, and widely accessible knowledge and education base on LNG for many stakeholders involved in industry developments.

CEE’s engagement in international energy-sector development assistance is a natural outgrowth of our queries on frameworks that best facilitate successful commercial development. In FY06 CEE’s focus remained on Africa, with the addition of more than $600,000 through CEE’s $3.5-million USAID cooperative agreement to expand previous work in Ghana to the West Africa region. The first task of the Smart Development Initiative (SDI) grant is to continue
development of the Resource Center for Energy Economics and Regulation (RCEER) in Ghana, which was established by CEE in 2005, and use RCEER as a conduit for regional public education and capacity building to support emerging natural gas market frameworks in the subregion. These frameworks are a consequence of both Nigeria’s Natural Gas Master Plan and operation of the West Africa Gas Pipeline, which carries natural gas from Nigeria to Benin, Togo, and Ghana. The Guide to Natural Gas in Ghana was published in FY06 and serves as a key source of natural gas industry information for many stakeholders in Ghana, as well as a model for other countries in the West Africa subregion. The CEE team is also evaluating the applicability of the SDI model to Latin America. Elsewhere, the CEE team continues to actively search and evaluate proposals for new energy partnership opportunities worldwide. Some under development include the University of Port Harcourt (Natural Gas Programme), Nigerian National Petroleum Corporation (NNPC, a matching supporter for the West African SDI), University of Alberta MBA in Energy and Natural Resources, Bodø School of Graduate Studies (Norway), Moscow State University for International Relations (MGIMO, Russia), and a proposed partnership with the Instituto Tecnológico Autónomo de México (ITAM).

In FY06, CEE also hosted international visitors attending programs, ranging in length from 1 day to 6 months. These included delegations of representatives of the LNG industry in Russia, two delegations on a natural gas study tour from Ghana and Nigeria, long-term visiting researchers from Ghana and South Korea, and visitors from the Universidade Federal do Rio de Janeiro and the Bank of China. CEE hosted 26 delegates to its annual New Era Program held May 8–19, 2006. The program brought together delegates from Angola, Cote D’Ivoire, Ecuador, Ghana, South Korea, Mexico, Nigeria, Turkey, and the U.S. New Era is supported by U.S. government agencies and international organizations, as well as leading multinational energy companies. Houston session participants visited Freeport LNG Import Terminal, Dow Chemical Company Fuel Cell Project, and Clean Energy LNG Refueling Center. In Austin, the group met with the Public Utilities Commission of Texas, the Railroad Commission of Texas, and the Lower Colorado River Authority, as well as researchers from BEG and other departments at UT-Austin. Following the New Era program was a 1-week customized training program organized for the Iraqi Ministry of Oil delegation. As with previous New Era sessions since 2001, this year’s program allowed us to build new partnerships and expand our reach across global energy industries. Cooperation that originated in an earlier session of New Era continues with the University of Port Harcourt in Nigeria. CEE and UNIPORT held two joint energy value chain courses in Abuja for Nigerian energy sector professionals.

CEE continues to expand and improve its Web portal. A year ago, we added a new public forum—“Think Corner”—through which CEE staff and its global network provide insights, commentaries, and research on global energy industry, market, and policy developments. Some of the latest additions to the Think Corner include articles on alternative energy in India and the world and energy sector modernization in Mexico—among others. New Era program materials, more than 30 countries’ case studies that are used as teaching materials in the program, are now available on CEE’s publications page for free access.

CEE’s portfolio of research publications expanded substantially. A key publication completed during FY06 was the Guide to Electric Power in Mexico, released in October. Modeled after CEE’s Guide to Electric Power in Texas, the Mexico power guide was produced jointly with Instituto Tecnológico y de Estudios Superiores de Monterrey, ITESM (Mexico), and was featured at the Border Energy Forum in Tampico. The guide includes facts, history, regulations, and policies, as well as major...
issues and trends in development of Mexico’s electric power industry. Other recently issued CEE publications include a new briefing paper for the online Guide to LNG in North America, Offshore LNG Receiving Terminals; excerpt of a new research report, Economics of the Alaska Gas Pipeline, in the Oil & Gas Journal, “Historical Data Provide Low-Cost Estimating Tool”; a research report and chapter for the Center for Strategic and International Studies forthcoming publication Energy Cooperation in the Western Hemisphere (“Hydrocarbon Sector Regulation and Cross-Border Trade in the Western Hemisphere”); and a research paper titled “Overview of the Alberta Oil Sands.”

In addition to its ongoing programs, CEE has been supporting core BEG initiatives. We continue to provide economics and policy research to the Gulf Coast Carbon Center to support the emerging CO2 value chain. We also support the STARR program and actively participate in BEG’s preparation of Texas’ proposal for FutureGen.

As CEE undertakes these new projects and builds upon existing ones, our focus will remain on “people development,” which we see as key to well-functioning energy sectors and energy enterprises anywhere in the world. Our goal is to continue to grow as a regional, national, and international leader in understanding economic, technological, business, and policy/regulatory dimensions of energy resources and infrastructure development; energy sector human capacity building fully integrated with BEG, JSG, and other UT initiatives; and public education and outreach on energy.

**RESOURCE ASSESSMENT**

**Texas Coal Sample Collection for Rank Determination**
*Edgar Guevara, principal investigator;*  
*Cari Breton, GIS specialist*

BEG continued its participation in a cooperative program with the USGS to preliminarily assess the coalbed methane potential of North-Central Texas bituminous coals. Fifty-seven coal and coaly shale samples were collected from drilling cuttings from the shallow subsurface (mostly <2,000 ft) penetrated at a total of five wells in Young County. The collected samples represent coal-bearing intervals in the Cisco, Canyon, and Strawn Groups (Pennsylvanian).

The samples were used in coal-rank determinations by means of vitrinite reflectance and to help document the depth and stratigraphic position of subsurface coal and coaly shale occurrences in this area. Coal rank in the sample dataset ranges from lignite (Ro=0.39), in a sample from the Cisco Group at 310 to 320 ft, to high-volatile bituminous A coal (Ro=0.91) in a sample from the lower part of the Canyon Group at 2,030 to 2,040 ft. These data, compiled in a Geographic Information System (GIS) database, will be included in USGS’s National Coal Resources Data System (NCRDS).

**ENVIRONMENT AND EARTH SYSTEMS**

**Environmental Quality**

**FutureGen Texas: The World’s First Near-Zero-Emissions Power Plant**
*Scott W. Tinker, principal investigator;*  
*Jay P. Kipper, Ian J. Duncan, William A. Ambrose, Susan D. Hovorka, Michelle Michot Foss, Gürcan Gülen, Michael Williams (Commissioner, Railroad Commission of Texas), Carol Treadway (Railroad Commission of Texas), Chuck McDonald (Consultant), R. Ellyn Perrone, UT, Gwen W. Grigsby, UT, Jerry Hill (Consultant), Steve Walden (Consultant), Rebecca C. Smyth, and Jeffrey G. Paine*

FutureGen is a U.S. Department of Energy (DOE) initiative to build a power facility that is capable of producing hydrogen and sequestering carbon dioxide (CO2), with near-zero emissions, and by doing so turn the nation’s abundant coal supply into a decarbonized fuel. The $1-billion research project is intended to
enable clean use of coal, greatly limiting negative environmental impacts of using this cheap and abundant resource.

The FutureGen project has two major components: (1) to build an energy facility that will create power and hydrogen and capture CO₂ and (2) to locate a host site that will store the CO₂ permanently. The prototype facility will be designed to allow testing of various components and fuel types in all phases of the process, as well as full measurement, monitoring, and verification of CO₂ sequestration.

DOE’s FutureGen Objectives:
1. Design, construct, and operate a nominal 275-megawatt prototype plant that produces electricity and hydrogen with near-zero emissions;
2. Sequester at least 90 percent of CO₂ emissions from the plant with future potential to sequester nearly 100 percent—1 million tons per year;
3. Prove the effectiveness, safety, and permanence of CO₂ sequestration;
4. Establish standardized technologies and protocols for CO₂ measuring, monitoring, and verification; and
5. Validate the engineering, economic, and environmental viability of advanced, coal-based, near-zero-emission technologies.

The Bureau was charged by Texas Governor Rick Perry with coordinating Texas’ site-selection process and the State’s response to the DOE Request for Proposals. A FutureGen Texas team, under the direction of State Geologist and Bureau Director Scott W. Tinker and consisting of Bureau staff and key UT staff and consultants, demonstrated that Texas is uniquely qualified for siting, construction, and operation of the FutureGen project. The FutureGen Texas team (FGTT) developed a systematic procedure for identifying the optimal location for a FutureGen plant.

In late 2005, FGTT created an internal competition among Texas Councils of Governments (COG’s) to identify the best potential sites for the FutureGen plant. After a rigorous site identification process was performed, two final sites were selected from nine sites proposed. FGTT selected two sites (one near Odessa in west Texas and one near Jewett in east Texas) to enter into the national competition. In May 2006, 7 states entered a total of 12 proposed sites in response to the FutureGen request for proposals (RFP). In August, finalists announced by the FutureGen Alliance were two of the sites put forward by Illinois and both of the sites proposed by Texas. Since then, FGTT, assisted by numerous environmental consulting organizations, has been working on supplying extensive data sets that will form the basis for Federal NEPA (National Environmental Policy Act) environmental impact assessments of both Texas sites. The team is also assembling “Best Value” packages for each site, outlining economic and other advantages offered by the Texas sites. These will be submitted to the Alliance before its final site-selection decision, which is expected in September of 2007.

**Geological and Petrophysical Characterization for CO₂ Sequestration in Enhanced Oil Recovery Floods, Permian Basin of West Texas**

*Mark H. Holtz, principal investigator; Rebecca C. Smyth and Caroline L. Breton*

The Bureau has partnered with the U.S. Department of Energy’s Southwest Regional Partnership for Carbon Sequestration to conduct geological and petrophysical characterization of enhanced oil recovery floods in the Permian Basin of West Texas. This 4-year project, conducted with operator KinderMorgan, will investigate CO₂ sequestration in carbonate oil reservoirs.

The study has two components. Researchers will begin by geologically characterizing portions of the Upper Pennsylvanian Canyon Formation in the SACROC (Scurry Area Canyon Reef Operators Committee) Unit and Claytonville oil reservoir fields. The first field, the SACROC, has
undergone CO₂ flooding for over 20 years; the second reservoir is the Claytonville, which will begin the flooding process during the project. After baseline data are collected, researchers will extensively monitor the injected CO₂—with a focus on the overlying aquifers—to determine whether CO₂ is leaking from the rock unit in which it is being sequestered.

**Getting a Picture of the Rocks**

Accurate geologic assessments and models of pilot test reservoirs are critical to analysis of the storage, and possible leakage, of CO₂. Researchers will study and integrate

1. Stratigraphic relationships to help define flow units between CO₂ injectors and oil producers,
2. Petrologic analyses (performed at the pore level), coupled with stratigraphic analyses, to define the storage potential and to provide the framework within which all other reservoir experiments are conducted,
3. Quantitative petrography to assess potential interactions between injected CO₂ and subsurface mineralogy and potential CO₂ leakage pathways, and
4. Petrophysical analyses (performed at the pore level) to produce geocellular reservoir models for simulation analyses and to establish potential long-term-CO₂-storage capacity.

**Watching for CO₂ Leakage**

The Permian Basin rock units in which researchers are conducting the pilot test are overlain by saltwater aquifers. This is an ideal situation in which to test for CO₂ that may leak out of the rock unit into which it is being injected. Researchers will collect detailed baseline water sample data before CO₂ injection and then monitor extensively for CO₂ movement after injection. Water sampling wells will be drilled into the overlying aquifer. Groundwater samples will be collected and analyzed for a year prior to CO₂ injection to determine normal seasonal or meteoric-event hydrochemical fluctuations.

Researchers will measure isotopes of dissolved inorganic carbon, trace elements, pH, and other constituents following Texas groundwater data-system sampling procedures. All data will be compiled in a GIS system so that information will be easily mapped, transferable among researchers, and transferred to the DOE.

**Impact of Land Use Change on Groundwater Resources in the Southern High Plains**

*Bridget Scanlon, principal investigator; Robert Reedy, Andrew Tachovsky*

Unsaturated-zone (UZ) chloride profiles in semiarid regions provide a decadal-scale record of past environmental changes, similar to climate-change records provided by tree rings and ice cores. Impacts of conversions from natural ecosystems to rain-fed agriculture on water resources are recorded in chloride profiles in semiarid regions, as typified by the southern High Plains (SHP), Texas, southwestern U.S. Large chloride accumulations beneath natural grassland and shrubland ecosystems (three profiles) reflect evapotranspirative enrichment of atmospherically derived chloride during the Holocene, indicating no recharge in interdrainage areas. Conversion to rainfed agriculture is recorded by downward displacement (10 profiles) or complete flushing (10 profiles) of chloride bulges, indicating increased recharge. Increased recharge associated with cultivation (median 24 mm/yr, 5% of precipitation, 19 profiles) was quantified using chloride mass balance calculations. The timing of land-use change was estimated using chloride data, and results (43 to 89 yr) are consistent with air-photo records and land-owner surveys. New equilibrium recharge rates in the SHP (0.63 km³/yr) will require decades to establish and represent 1 to 8 times recharge rates for baseline precultivated conditions that is focused beneath ephemeral lake or playa drainages (0.08 to 0.83 km³/yr). These chloride profiles generally represent decadal-scale monitoring of subsurface response to land-use change.
Sustainable Water Resources Development
Bridget Scanlon, principal investigator; Robert Reedy, Andrew Tachovsky, Dani Kurtzman, Gil Strassberg

The following review on impacts of conversions from natural to agricultural ecosystems on water resources was conducted as part of the Sustainable Water Initiative program.

Past land-use changes have greatly impacted global water resources, with often opposing effects on water quantity and quality. Increases in rain-fed cropland (460 percent) and pastureland (560 percent) during the past 300 years from forest and grasslands decreased evapotranspiration and increased recharge (two orders of magnitude) and streamflow (one order of magnitude). However, increased water quantity degraded water quality by mobilization of salts, salinization caused by shallow water tables, and fertilizer leaching into underlying aquifers that discharge to streams. Since the 1950’s, irrigated agriculture has expanded globally by 174 percent, accounting for about 90 percent of global fresh-water consumption. Irrigation based on surface water reduced streamflow and raised water tables, resulting in waterlogging in many areas (China, India, US). Marked increases in groundwater-fed irrigation in the last few decades in these areas has lowered water tables (≤1 m/yr) and reduced streamflow. Degradation of water quality in irrigated areas has resulted from processes similar to those in rain-fed agriculture: salt mobilization, salinization in waterlogged areas, and fertilizer leaching. Strategies for remediating water-resource problems related to agriculture often have opposing effects on water quantity and quality. Long time lags (decades to centuries) between land-use changes and system response (for example, recharge, streamflow, water quality), particularly in semiarid regions, mean that the full impact of land-use changes has not been realized in many areas and remediation to reverse impacts will also take a long time. Future land-use changes should consider potential impacts on water resources—particularly tradeoffs between water, salt, and nutrient balances—to develop sustainable water resources to meet human and ecosystem needs.

The impact of El Niño Southern Oscillation and Pacific Decadal Oscillation on precipitation in the southern and central U.S. was evaluated by Dani Kurtzman. Understanding and predicting regional impacts of El Niño Southern Oscillation (ENSO) and Pacific Decadal Oscillation (PDO) on winter (Oct–Mar) precipitation can provide valuable inputs to agriculture and water managers. Effects of ENSO and PDO on winter precipitation were assessed in 165 climate divisions in the southern U.S. A continuous region of significantly (P<0.05) increased (decreased) winter precipitation in response to El Niño (La Niña) conditions in the preceding summer (Jun–Sep) Southern Oscillation Index (SOI)) extends across the entire southern U.S. and as far north as South Dakota. Within this region stronger correlations (r≤-0.45) are found along the Gulf of Mexico, southern Arizona, and central Nebraska. Winter precipitation in warm- and cold-phase PDO periods is significantly different (P<0.1) only in the south-central region, with greatest significance centered in Oklahoma. Enhanced negative La Niña anomalies during PDO cold phases are dominant in the central region (Texas to South Dakota), whereas enhanced positive El Niño anomalies during PDO warm phases are dominant in the southwest (Arizona, Nevada, and California) and southeast (Louisiana to Florida). Validation tests of winter precipitation predictions based on summer SOI and/or PDO-phase show a decrease of 9 to 16 percent in the relative Mean Absolute Error (MAE) from the MAE obtained by using the mean as a predictor in areas with high correlation between SOI and precipitation. Logistic regression probability models of having above or below average winter precipitation had up to 77 percent successful predictions. The advantage of having probabilities exceeding certain precipitation thresholds at the beginning of a hydrologic year make logistic regression models attractive for decision makers.
Development of an Integrated Superconducting Gravity Meter Sensor System

Bridget Scanlon, Principal Investigator; Gil Strassberg

The ability of the Gravity Recovery and Climate Experiment (GRACE) satellite data to monitor seasonal water storages in the High Plains Aquifer was examined by Gil Strassberg.

This study presents the first direct comparison of seasonal groundwater storage changes derived from the Gravity Recovery and Climate Experiment (GRACE) satellite data in a semi-arid region. Changes in soil moisture estimated from a land surface model were subtracted from GRACE terrestrial water storage to isolate groundwater storage changes in the High Plains aquifer, U.S.A. (450,000-km² area). Good agreement was found between seasonal GRACE-derived terrestrial water storage and combined groundwater and soil moisture estimates ($R = 0.82$). A weaker agreement was observed between GRACE-soil moisture derived groundwater storage changes and those based on in situ measurements ($R = 0.58$). Uncertainty in the GRACE-soil moisture data was smaller than for seasonal variations, and all winter to summer groundwater storage changes over the analysis period (2003–2005) were detectable. Results demonstrate the potential for GRACE to monitor groundwater storage changes in semi-arid regions where irrigation pumpage results in large seasonal groundwater storage variations.

Feasibility Analysis of Water Supply for Small Public Water Systems, Phase II

Bridget Scanlon, Principal Investigator

The distribution of arsenic in the vadose zone was evaluated in the southern High Plains. The purpose of this study was to evaluate the fate of anthropogenic arsenic applications related to agriculture using arsenic applications on cotton in the southern High Plains (SHP), Texas, as a case study and examining possible linkages with contamination of the underlying Ogallala aquifer in this region, where about 30 percent of the wells exceed the new EPA 10 µg/L standard. Arsenic compounds were applied at the land surface as pesticides in agricultural areas globally. Vadose zone soil samples were collected from boreholes beneath natural ecosystems (grassland/shrubland) to provide a control (no arsenic application) (2) and cotton cropland (18) for analyses of water-extractable arsenic, vanadium, phosphate, chloride, and nitrate. Natural ecosystem profiles have arsenic concentrations at depth (maximum 7.2–63.7 µg/kg, 5.9–6.5 m depth) that are attributed to a geologic source. A profile adjacent to a cotton gin had high arsenic levels (maximum 943 µg/kg) in the upper 2.2 m that correlated with phosphate concentrations ($r = 0.82$) related to fertilizer application. Most profiles beneath cotton cropland have high arsenic concentrations within the upper meter (mean 1.7–31.6 µg/kg) that correlate with phosphate ($r = 0.72$) and reflect an arsenic application source similar to that in the cotton gin profile. High arsenic concentrations greater than or equal to 1 m depth (mean ≤36.3 µg/kg) found in cropland profiles are attributed to a geologic source because of similarity with profiles beneath natural ecosystems, lack of correlation with phosphate, and pore-water ages that predate arsenic acid application. GIS analyses showed poor correlations between groundwater arsenic and percent cultivated land ($r = -0.15$), groundwater nitrate ($r = 0.30$), and water-table depth ($r = -0.31$), further supporting that anthropogenic-derived arsenic in the shallow subsurface is not linked to groundwater arsenic contamination in this region.

Review of Documents and Dissemination of Environmental Geologic Information Related to Environmental Restoration at the U.S. Department of Energy’s Pantex, Carson County, Texas

Bridget Scanlon, principal investigator
Plume Research Group:
Integrated Regional, Site-Specific, and Theoretical Studies of Ground Water Contaminant Plumes
Bridget Scanlon, principal investigator

Fate and Transport of Contaminants Training
Bridget Scanlon, principal investigator

Evaluation of Nitrate Contamination in Selected Aquifers in Texas II
Bridget Scanlon, principal investigator

Field Validation of Geologic Assessment of Features Sensitive to Pollution in Karst and Development of Best Management Practices
Susan D. Hovorka, principal investigator; Adrien L. Lindley and Mike Barrett

This study, funded by Texas Commission on Environmental Quality, quantitatively evaluated the hydrologic function of typical, small karst features in the upland of the Edwards aquifer recharge zone and was completed in 2006. Because sinkholes may allow water or contaminants to be transported rapidly to the subsurface via fractures or conduits, they have the potential of being sensitive features if poor-quality water is introduced to the area during or after development. These small features have traditionally been described as “possibly sensitive,” leaving uncertainly as to appropriate protection or Best Management Practice (BMP) required by state law.

In this study, pairs of sinkholes and control plot sets were subjected to constant-head, single-ring infiltrometer experiments at four sites located in the Edwards aquifer recharge zone. Infiltration rates at soil-lined sinkholes were found to be similar to background rates, but because the sinkholes are small-scale topographic depressions, they pond water and focus infiltration. To further assess the function of these features, we applied blue dye to the ponded water at two representative sinkholes and ran Ground Penetrating Radar Surveys (GPR) over them. Excavation showed that the sinkhole depressions are centered on small-aperture (decimeter), solution-enlarged fractures and pits that were soil-filled as far as they could be excavated. Dye ponded around these vertical features, leaving a ring of stain before it drained. Repeat ponding tests after soil removal produced slightly higher but still soil-dominated infiltration rates. GPR surveys showed a possible void beneath one of the sinkholes; however, any conduits in the other three features are too small to be resolved using this technology.

In contrast, two features were tested that had been identified as sensitive and that accepted water at rates as much as 30 times that of the background: an excavated solution cavity and a sinkhole with a cobble-filled drain had such infiltration rates. Other large-aperture features clearly accept large volumes of water; the infiltrometer method is not suitable for quantification of these high-volume features. In addition, a test in an area of Glen Rose bedrock around an ash juniper produced high infiltration rates.

Results suggest that small soil-floored sinkholes are sites of focused recharge mostly because of topographic depressions. If degraded water may be produced as a result of development, grading the land surface might be an adequate BMP. The recharge function of these small features might be replaced by conservation of more sensitive features having coarse fills or visible aperture. Site engineers should be aware that small sinkholes are part of the active karst system and may open to larger apertures and well-connected karst features at depth.
Gulf Coast Carbon Center

Ian J. Duncan, director; Susan D. Hovorka, principal investigator; Mark H. Holtz, J.P. Nicot, Tip Meckel, Srivtsan Lakminisarihan, and Joseph Essandoh-Yeddu; assisted by Vanessa L. Núñez-López and Derek J. Woods

The Gulf Coast Carbon Center (GCCC) seeks to apply its technical and educational resources to implementing geologic storage of anthropogenic carbon dioxide on an aggressive time scale, focusing on a region where large-scale reduction of atmospheric releases is needed and short-term action is possible. Geologic sequestration—capturing, compressing, and storing unwanted carbon dioxide in subsurface environments—is one of a portfolio of approaches for reducing the negative impacts of CO₂ emissions.

GCCC was formed as an industrial-academic partnership in 2003 in recognition of the unique characteristics in the Gulf Coast as a region of concentrated CO₂ sources and a wide array of co-located, subsurface sinks. Industry partners during 2006 were BP America, KinderMorgan, Chevron, Praxair, Entergy, NRG, Marathon, and Schlumberger. The roles of the industry partners are to supply information and serve as a “reality check” from the perspectives of their industries on how carbon storage and commercialization might develop in the region and to concur on GCCC’s message to advise governmental organizations, other think tanks, and other industries that are observing this process. GCCC partners provide funding that is used to conduct research, prepare and publish results, and catalyze acquisition of additional funding from Federal, State, and industrial sources, as needed to develop the center’s mission and tasks. The Jackson School provided matching funds for new members and additional funds during academic year 2005–2006 to support addition of staff.

Products of GCCC during 2006 include a preliminary economic assessment, including capture and pipeline costs, contributed by Joseph Essandoh-Yeddu in collaboration with CEE, an assessment of the elements needed for developing a site, and an overview of seals.

GCCC served as a focus and source of expertise for numerous other carbon projects funded from diverse sources and conducted under its banner in order to widen its pool of expertise. These associated projects include Frio Brine Pilot Phase I and II: Stacked Storage—$4.9 million, duration October 2005–2009, source Southern States Energy Board, PI Hovorka; Assessment of Existing and New Injection Sites in West Texas—$1.1 million, duration October 2005–2009, PI Holtz, New Mexico Tech; Texas FutureGen—$2 million, duration August 2005–2006, PI Tinker, State of Texas; Assessment of Potential of Four Regions for Geologic Storage—$75 thousand, PI Holtz, BP America; Frio Brine Pilot II—$5.1 million, duration 2005–September 2006, PI Hovorka, NETL.

Optimal Geological Environments for Carbon Dioxide Disposal in Brine-Bearing Formations in the United States—Pilot Sequestration in Brine in the Frio Formation

Susan D. Hovorka, principal investigator; Shinichi Sakurai, Jeff Kane, Tip Meckel, and Mark Holtz

Brine formations beneath, and separated from, potable water provide a large volume of widely available resources for storage of carbon dioxide (CO₂) as an alternative to releasing byproducts of combustion into the atmosphere. To demonstrate that subsurface storage is effective in isolating CO₂ from the atmosphere over long periods of time, BEG researchers conducted an approximately $6-million field experiment funded by the Department of Energy, National Energy Technology Laboratory (DOE/NETL), and in-kind contributions from many partners. The experiment is known as the Frio Brine Pilot. BEG is leading the experiment in South Liberty oil field near Dayton, Texas, with the participation of 20 institutions from the United States, Australia, and Canada.

The Frio II Brine Pilot was conducted using the same injector/monitoring well pair developed and characterized for the 2004 Frio Brine Pilot CO₂ sequestration experiment. The CO₂
injection occurred in the “Blue Sand,” a hydrologically isolated sandstone, 120 m below the previously investigated “C” sandstone tested during the initial Frio Brine Pilot. The Frio II injection consisted of a small volume (~300 tonnes) of CO₂ over 5 days (September 26–October 1) into the lower part of a 10-m-thick flow unit in a heterogeneous fluvial sandstone. A program of wireline logging, crosswell seismic monitoring, geochemical sampling using a U-tube and Kuster sampler, and hydrologic testing using water-soluble and gas-soluble partitioning and nonpartitioning tracers was used to explain the fate of the injected CO₂.

During injection the CO₂ traveled vertically near the injection well and laterally through a thin high-permeability zone and was detected near the top of the Blue sandstone at the observation well 30 m away. Comparison between the first and second injections illustrates interactions among injection rate, injection strategy, and heterogeneity of the injection interval and their impact plume evolution. Both experiments illustrate the utility of combining several monitoring tools with modeling assessments to describe plume evolution. Monitoring will continue through summer 2007 so that the stabilization process of this small plume can be measured.

Gulf Coast Carbon Center Participation in the Southeast Regional Sequestration Partnership

Susan D. Hovorka, principal investigator; Tip Meckel, Mark H. Holtz, Rebecca C. Smyth, Ian Duncan, and Scott Tinker

To complement Gulf Coast Carbon Center activities and better integrate them with the DOE national program, the BEG research team joined the Southeast Regional Carbon Sequestration Partnership, which is led by the Southern States Energy Board. Results of the 2-year study, including assessment of storage capacity in the 15 states of the southeastern U.S., were completed in 2006.

The Gulf Coast Stacked Storage project demonstrates the concept of phased use of subsurface volumes, combining early use of CO₂ for enhanced oil recovery with later injection into deeper and larger volume brine formations. The benefits of this phased development are short-term, large-volume injection with immediate commercial benefit to support research and infrastructure development, followed by use of deeper, brine-bearing formations for large-volume, long-term storage. Technical focus areas are (1) documenting retention in the injection zone, (2) quantifying capacity, and (3) quantifying pressure response to injection. The Cranfield unit in Southwest Mississippi was selected for this test.

The Southeast Regional Carbon Sequestration Partnership (SECARB) determined that the saline formations of the Gulf Coast are extensive and of regional significance as potential sinks for carbon sequestration. The Gulf Coast Basin has the potential to become a major site, and perhaps the nation’s predominant site, for carbon sequestration.

The Gulf Coast of Alabama, Mississippi, Louisiana, and Texas is formed by the thickest sedimentary wedge in the onshore U.S. This clastic sequence is composed of tens of formations of late Mesozoic- to Cenozoic-age in six sub-basins. All the formations are composed of porous and permeable fluvial, deltaic, shoreline, and marine sandstones, separated by regionally extensive, thick, impermeable marine shales that isolate fluids. Further compartmentalization and isolation of storage volumes throughout the Gulf Coast is provided by structures, which include anticlinal four-way closures, rollover anticlines, and fault-bounded traps. The permanence of storage in these formations is well documented by oil and gas that has been trapped in long timeframes by structures and seals. Representative world-class sequestration target formations in the Gulf Coast are the Cretaceous Tuscaloosa Formation of the Mississippi salt basins and the equivalent Woodbine Formation of the East Texas Basin, as well as Cenozoic-age Wilcox, Vicksburg/Frio, and Miocene Formations of the lower Gulf Coast. The Tuscaloosa Formation lies
beneath an area of approximately 46,000 mi² in southern Alabama and Mississippi, the Florida Panhandle, and Louisiana. Using NATCARB 2006 assumptions, Massachusetts Institute of Technology (MIT) estimated a minimum storage volume for the Tuscaloosa Formation of 10,000 million metric tonnes of CO₂. The Woodbine of East Texas, a continuation of this regionally significant CO₂ sink, can hold approximately equivalent volumes. Additional storage in the Gulf Coast Cenozoic is estimated at 177,000 tonnes. Data from the Tuscaloosa trend can also help improve capacity estimates for the Cretaceous of the eastern seaboard, which provides the best target for the area, totaling an additional 134,000 million metric tonnes of CO₂.

The sequestration target selected for the Gulf Coast Stacked Storage Project is associated with Denbury’s Cranfield unit, near Natchez, Mississippi. The injection target was selected to be representative of the high-quality targets provided by the Gulf Coast, in that it lies within the thick marine-reworked to fluvial lower sandstone of the Tuscaloosa Formation in a typical Gulf Coast four-way closure. This test site was also selected at a location where large volumes of pipeline CO₂ will become available in 2007 and where existing infrastructure and substantial industry match will allow an ambitious demonstration relevant to large-volume storage to be completed within the available budget and in the near term.

The stacked-storage concept is based on the following assessment: Where large-volume oil fields in decline are in a region, market forces will determine that initial anthropogenic carbon capture will supply product for CO₂-enhanced oil recovery (CO₂-EOR). Only as the resource available to recover decreases and volumes of CO₂ captured increase, will brine storage be widely utilized. Pipeline infrastructure in place will favor continued injection in the same trend. Lack of cement behind casing in production wells will limit use of shallow horizons for brine storage; however, injection into brine-bearing formations below and adjacent to former production may prove to be attractive targets. Deeper formations in the same footprint as oil production are geologically well known, with well-defined surface and mineral ownership and high public acceptance. Key questions needed to demonstrate the validity of this model are: (1) will CO₂ used for EOR be retained in the subsurface effectively so that benefit to the atmosphere results, especially considering the performance of well penetrations; (2) how should the capacity in large volumes below and downdip of the reservoirs be calculated, for it will determine how large a footprint will be underlain by CO₂; and (3) is the pressure response in the near and far field understood quantitatively well enough to move safely to large-volume injection?

GCC has partnered with Denbury Resources of Plano, Texas, to begin to answer these questions under realistic conditions associated with large-volume (>one-half million tonnes/year CO₂). The CO₂ injection design used by Denbury is identical to one that would be used for large-volume storage in that only CO₂ is injected—the CO₂ injection volume and field pressure are high compared with those of the West Texas process of injection of water alternating with gas (WAG).

**Carolinas EPRI and Carolinas SSEB**

Rebecca C. Smyth, Researcher in charge; Susan D. Hovorka, principal investigator, Cari Breton and Tip Meckel

Saline reservoirs are one type of geologic CO₂ “sink,” which require depth sufficient to maintain CO₂ at or near supercritical phase, integrity of overlying seal, and capacity sufficient to prevent displacement of saline water into freshwater zones. Large areas of the southeastern U.S. either are unsuitable or have low potential for geologic storage of CO₂. Assessment completed for DOE-sponsored SECARB Partnership shows that the Carolinas are underlain by (1) fractured crystalline rocks that lack overlying seals or (2) sequences of sediment not thick enough to store CO₂ at sufficient density, containing freshwater aquifers in most horizons. Few options are therefore left for onshore geologic
storage of CO₂ within North and South Carolina. Alternatives include transporting CO₂ via pipeline from power plants to sinks underlying nearby states or to potential Atlantic margin subseafloor sinks. Potential onshore sinks outside the Carolinas are in Upper and Lower Cretaceous and Triassic units in the South Georgia Basin, the Upper Cretaceous in southeastern Alabama and the Florida Panhandle, Mt. Simon Formation in Tennessee, and Knox Formation in Kentucky and West Virginia. Cretaceous-age strata, 25 to 175 km offshore in the western Atlantic, show promise for subseafloor (>1-km depth) CO₂ storage. Water column height (50–1,000 m) overlying the seafloor enhances suitability of the potential subseafloor sinks because of added pressure. The CO₂ storage potential for the subseafloor Atlantic margin could be significant along the entire U.S. eastern seaboard. Costs associated with transporting CO₂ from power plants in the Carolinas to potential geologic sinks are not trivial.

**Technical Studies to Support TCEQ on Environmental Quality Review of Low-Level Radioactive Waste**

*Jean-Philippe Nicot, principal investigator*

The Bureau of Economic Geology is providing technical support to the Texas Commission on Environmental Quality in its review of a license application to dispose of low-level radioactive wastes.

**Study to Evaluate Electronic Access to Geologic Data and Surface Casing Depths Necessary to Protect Usable Groundwater in the State**

*Edward W. Collins, principal investigator; Thomas A. Tremblay, Aaron Averett*

This study is a collaboration with TCEQ surface casing staff to develop a prototype Website for electronic access to geologic data and surface casing depths necessary to protect usable groundwater in Texas. The result, the Surface Casing Information Site, provides a digital database for use by TCEQ, well operators, and the public and enables 24-hour electronic access to geologic data necessary for Texas’ oil and gas operators and TCEQ. Users can generate location maps of proposed well locations required by TCEQ, obtain estimates of probable surface casing requirements, and review well logs and other relevant information. The Website currently includes data from Brazos, Leon, Madison, Robertson, Burleson, Milam, and Lee Counties. Data for four additional counties—Bastrop, Gonzales, Fayette, and east half of Caldwell—will be added in 2006–2007. The digital database benefits oil and gas operators and the public and reduces the time and effort required for TCEQ review.

**COASTAL PROCESSES**

**Galveston Bay: Wetland Habitat Transition Due to Relative Sea Level Rise**

*James C. Gibeaut, principal investigator*

Researchers are determining the likely future distribution of estuarine wetland habitats and uplands under various relative-sea-level-rise scenarios. We are combining our research-quality lidar digital elevation models of Follets and Galveston Islands and Bolivar Peninsula with our recently completed wetland maps. This project will quantify topographic relationships of wetlands in the study area and then artificially raise the sea level (lower the topographic surface) to simulate future relative-sea-level rise. Other effects, such as differential land subsidence across the study area, erosion by waves and currents, and vertical sediment accretion, will also be incorporated into the inundation model. We are projecting distribution of wetlands 90 years into the future by repeating the historical sea-level change record from the last 90 years. Results of the wetland modeling are showing which areas are most susceptible to change and where uplands, if preserved, will allow wetlands to transgress. The distribution of coastal habitats is strongly related to elevation above or below mean sea level (msl). The style of transition of
estuarine habitats during rising sea level depends largely on the slope of the upland and sediment supply. Fringing wetlands on the barrier islands of lower Galveston Bay exist within a narrow elevation range, with shifts from barren tidal flat to marsh to upland vegetation occurring across areas, with only a 50- to 60-cm rise in elevation. This amount of topographic change may occur gradually over an extensive coastal plain or, as is the case on the bay sides of Follets, Galveston, and Bolivar Islands, on a small and complicated scale across relict geomorphic features, such as storm washover and flood-tidal delta deposits and beach ridges and swales.

Follets Island is a narrow, transgressive barrier island. Its relatively narrow and steep back-barrier slope limits upland wetlands migration, thus resulting in a wetlands loss of 41 percent, including a loss of important low marsh wetland of 52 percent. The southwestern end of Galveston Island is similar to Follets, but a wider and low back barrier allows an increase in high marsh to more than offset losses in low marsh. Farther to the east, Galveston Island has a regressive configuration, with a broad ridge and swale topography. Here the model predicts an increase in wetland area of 53 percent as the gentle banks of swales transition to high marsh. On the whole, Follets and Galveston Islands increase their wetland areas by 3 percent after 90 years, but with a 61-percent loss of low marsh and a 128-percent gain of high marsh. On Bolivar Peninsula, two large relict flood-tidal delta fans, a wide and gently sloping back barrier area, and swales allow wetlands to adjust to sea-level rise and increase by 11 percent. This increase includes a 6-percent gain in low marsh and a 17-percent gain in high marsh.

The 90-year model run is based on a historical sea-level-change record without accounting for any increase in rate of sea-level rise due to climate change. Adding a climate change effect on sea-level rates may cause net wetland losses. Furthermore, although the amount of total wetland area may stay the same, shifts from low marsh to high marsh may be of concern. Finally, future development of back-barrier areas may eliminate the space needed for wetlands to migrate landward. Results from this study can be used to draw buffer zones for migrating wetlands.

**Web-Based Geographic Information System for Sand Resources of Sabine and Heald Banks and the State of Beach Erosion in Southeast Texas**

*James C. Gibeaut, principal investigator; Thomas A. Tremblay and Rachel L. Waldinger*

Shoreline retreat along the Texas southeast coast has prompted interest in finding sources of sand for beach nourishment projects. In 2001 and continuing in 2002, BEG renewed investigation of sand resources in Federal waters of the Texas continental shelf in cooperation with the Division of International Activities and Marine Minerals (INTERMAR) of the U.S. Department of Interior’s Minerals Management Service (MMS). MMS and BEG cooperated from 1993 through 1995 in collecting and analyzing data pertaining to Sabine and Heald Banks. During 2001, earlier data were incorporated into a geographic information system (GIS). During 2002, extensive core data from the central Texas coast belonging to Rice University were added to the Web-based GIS site using ArcIMS software. Data and documentation may be viewed and downloaded from http://www.beg.utexas.edu/coastal/sand.htm. In addition to geological data, GIS layers of obstructions to potential sand-mining operations, such as oil platforms, pipelines, shipwrecks, and navigation channels, are available. Shoreline data acquired by BEG’s lidar system in 2001 and 2002 were also analyzed during 2002 and integrated with historical shoreline data sets that BEG maintains to compute short- and long-term shoreline change rates. This information is required to design and estimate the volume of sand needed for beach nourishment projects. In 2005, additional lidar data were acquired before and after Hurricane Rita, and in 2006 these data were analyzed and new shorelines were extracted.
Texas Tidal Inlets Project:
Depositional Environments and
Morphodynamics of San Luis Pass
James C. Gibeaut, principal investigator;
Tiffany L. Hepner, Rachel L. Waldinger,
William A. White, Rebecca C. Smyth,
Roberto Gutierrez, and John R. Andrews

San Luis Pass is a tidal inlet between Galveston and Follets Islands along the southeast Texas coast. It is a natural inlet in that it has never been dredged nor have jetties been constructed. This project is developing baseline data for the inlet area, including geoenvvironments, bathymetry, topography, shoreline change, and tidal prism. It is also developing a morphodynamic model that describes and explains historical variation in channel orientations and changes in ebb- and flood-tidal deltas and adjacent shorelines.

The Texas General Land Office is funding this study because tidal inlets play a variety of critical roles. They serve as passageways for commercial and recreational vessels, as well as marine life and nutrients. Tidal inlets affect water quality in coastal bays, and deposition of sediment near inlets forms foundations for intertidal habitats. Inlet processes are also fundamental controls on the littoral sediment budget and, hence, affect shoreline change. Full understanding of coastal erosion problems along the Texas coast must include examination of processes occurring at the 13 open inlets and several more that are periodically open.

The Texas Shoreline Change Project
James C. Gibeaut, principal investigator;
Roberto Gutierrez, William A. White, Thomas A. Tremblay, Rachel L. Waldinger, Tiffany L. Hepner, Rebecca C. Smyth, and John R. Andrews

Texas has a variety of shoreline types along its coastal bays and open Gulf of Mexico coast that are constantly shifting and mostly retreating landward. This retreat results in loss of private and public property and important natural habitats, such as beaches, dunes, and marshes. To address this problem, in 1999 the Texas Legislature passed the Coastal Erosion Planning and Response Act. This Act authorized the General Land Office to conduct a coastal-erosion response program. In support of the program, BEG coastal researchers are identifying and studying eroding areas along the Gulf of Mexico and coastal bay shorelines of Texas. They are quantifying data gleaned from research and creating a comprehensive, digital database of historical shoreline positions and average annual rates of shoreline change and are making them available to the public through the Internet (http://www.beg.utexas.edu/coastal/intro.htm). Funding is provided by the Texas General Land Office, Texas Coastal Management Program, and Galveston County.

The goal of the Texas Shoreline Change Project is to develop a modern shoreline-monitoring and shoreline-change analysis program that will help guide coastal-erosion and storm-hazard-mitigation projects along bay and Gulf shorelines. This goal is being met through digital rectification of historical photographs to extract past shoreline positions, airborne topographic lidar surveys for acquiring new and future shoreline data, select ground topographic transects, and establishment of Global Positioning System (GPS) reference points to support the monitoring. Previous funding from NASA has enabled BEG to develop the application of lidar and geodetic GPS surveys for tracking coastal change. BEG owns and operates an Optech Inc. lidar instrument and is continually developing new and improved coastal survey techniques.

Status and Trends of Wetlands
and Aquatic Habitats on
Padre Island National Seashore
and the Texas Chenier Plain
William A. White, principal investigator;
Thomas A. Tremblay, Rachel L. Waldinger,
and Thomas R. Calnan (Texas General Land Office)

In this project, the status and trends of wetlands on Padre Island National Seashore (PINS) along the southern Texas coast and the Chenier Plain along the upper Texas coast are being
investigated. These two coastal areas, totaling approximately 165 km in length, include two contrasting areas. The Chenier Plain contains one of the most extensive areas of salt and brackish marshes along the Texas Gulf Coast, and PINS contains a variety of habitats, including sand and shell beaches; fresh, brackish, and salt marshes; wind-tidal flats; seagrass beds; and shallow lagoons. The contrast in these two areas is exemplified and controlled largely by differences in precipitation. Average annual precipitation in the area of PINS (Kenedy and Kleberg Counties) is approximately 28 inches/yr, and in the area of the Chenier Plain (Jefferson County) approximately 57 inches/yr, or twice that of the seashore. Other differences include (1) shoreline erosion rates that range as high as 26 ft/yr along the Chenier Plain and 10 ft/yr along the seashore and (2) shoreline types that include wave-cut clay terraces vegetated with salt marsh vegetation along the Chenier Plain and sand and shell beaches backed by high fore-island dunes on Padre Island National seashore.

The net direction of long-shore currents on the upper coast are toward the southwest or lower coast, whereas along PINS, the net directions of currents converge midway along the island. Relative sea-level rise rates (which include subsidence) also differ substantially, with rates as high as 1.3 cm/yr on the upper coast near Sabine Pass and 0.4 cm/yr on the central and southern coast near the National Seashore. Substantial wetlands have been lost owing to erosion along the Gulf Shore of the Chenier Plain, whereas on PINS, where annual precipitation is low, marshes have been lost and gained by eolian processes, including deposition and deflation. Furthermore, marshes have been lost along active surface faults on the Chenier Plain, but surface faults have not been mapped on PINS. Wetland status and trends are being investigated along these coastal segments from the Gulf shoreline to the Intracoastal Waterway on the Chenier Plain and from the Gulf shoreline to Laguna Madre on PINS. Wetland losses and gains and probable causes are being documented from the 1950’s to 1979–83 to 2003–04.

Funding for this project is provided by the National Oceanic and Atmospheric Administration through the Coastal Management Program, along with the Coastal Coordination Council; funding is administered by the General Land Office of Texas. This study complements our investigations of the status and trends of wetlands and aquatic habitats on other Texas barrier islands. Wetland distribution (status) is determined by interpreting and digitizing wetlands on color infrared (CIR) photographs taken in 2003 and 2004. Historical distribution is based on photographs taken in the 1950’s and 1979, as well as on historical GIS maps obtained from the U.S. Fish and Wildlife Service.

Status and Trends of Wetlands and Aquatic Habitats on Barrier Islands, Coastal Bend
William A. White, principal investigator; Thomas A. Tremblay, Rachel L. Waldinger, and Thomas R. Calnan (Texas General Land Office)

This project was a joint project between the Texas General Land Office and the Bureau of Economic Geology (BEG). We used historical and recent aerial photographs supported by field surveys to determine spatial and temporal changes in salt-, brackish- and fresh-water marshes, mangroves, tidal flats, and water bodies on San Jose Island, Mustang Island, and North Padre Island. Coastal wetlands on barrier islands are essential natural resources that are highly productive biologically and chemically. Scientific investigations of wetland distribution and abundance through time are prerequisites to effective habitat management, thereby promoting long-term biological productivity and public use.

Wetland losses and gains and probable causes were documented from the 1950’s to 1979 through 2002–04. In general, estuarine marshes increased in total area during each period (1950’s–1979 and 1979–2002–04), with a total net gain of 2,246 ha from the 1950’s through 2002–04. Previous studies by BEG of barriers on the upper Texas coast indicate
substantial losses in wetlands due to subsidence and associated relative sea-level rise. In contrast to the upper coast, studies of wetlands on barrier islands in the Coastal Bend show that although there was a substantial decrease in the area of wind-tidal flats, there was an increase in marshes, seagrasses, and mangroves as a result of relative sea-level rise. On Mustang Island, for example, much of the area mapped as tidal flats in the 1950’s was converted to seagrass beds (~50 percent), open water (~20 percent), and marshes (~6 percent) as topographically low flats became submerged and slightly higher flats became more frequently flooded, contributing to a spread of marshes and mangroves. This conversion of tidal flats since the 1950’s to more permanently flooded habitats, such as seagrass beds, can be largely explained by a relative rise in sea level (sea-level rise + subsidence). For example, tide-gauge data at nearby Rockport indicates that from the mid-1960’s through the mid-1970’s average rise in relative sea level was almost 1.7 cm/yr. From the 1950’s through 1979, seagrasses increased by 2,159 ha.

Funded by the National Oceanic and Atmospheric Administration through the Coastal Management Program, along with the Coastal Coordination Council, with funding administered by the General Land Office of Texas, this study complements our investigations of the status and trends of wetlands and aquatic habitats on other Texas barrier islands (White and others, 2002, 2004, 2005, and 2006). These reports can be viewed at the following GLO Website: http://www.glo.state.tx.us/coastal/pubs.html.

GEOLeGIC MAPPING

Geologic Mapping for the STATEMAP Program

Edward W. Collins, principal investigator; Thomas A. Tremblay, and James C. Gibeaut

The goal of the Texas STATEMAP projects, part of the National Cooperative Geologic Mapping Program administered by the U.S. Geological Survey, is to produce geologic maps of areas of Texas where knowledge of the geologic framework is of vital importance. Study areas for the Texas program typically include areas having specific environmental and natural resource concerns, urban and rural corridors undergoing population growth, and areas of critical aquifers and their recharge areas.

Two Current Mapping Projects

Researchers are currently mapping a portion of the Brazos River Valley and the associated aquifers within Burleson, Brazos, Robertson and Milam Counties. In this study area, the Brazos River alluvial aquifer, a prolific alluvial aquifer, intersects several other significant Texas aquifers—Carrizo-Wilcox, Queen City, Sparta, and Yegua. These aquifers supply much of the water required for urban, rural, and agricultural needs in the region. This geologic map can be used to evaluate the area’s geologic framework, to aid in understanding the physical and hydrologic relationships between the aquifers, and to provide geologic information useful for managing water quality and availability. A second project is the geologic mapping of part of the Bolivar Peninsula along the upper Texas Gulf Coast to provide information that will aid in the planning of land use and management of this sensitive coastal area. Within this coastal setting, natural and man-induced processes, including erosion along the Gulf shore, subsidence caused by active surface faults, dredged channels, road construction, regional subsidence, and sea-level rise, can rapidly change island environments, such as beach, dune, wetland, and upland areas. This map, with other recent maps of nearby Galveston Island, will aid in evaluating shoreline changes, changes in geologic depositional environments, and changes in land use. Airborne lidar data are being used with aerial photography and field observations for this study.

Recently Completed Maps

The Geologic Map of the West Half of the Taylor, Texas, 30 x 60 Minute Quadrangle: Central Texas Urban Corridor, Encompassing
Round Rock, Georgetown, Salado, Briggs, Liberty Hill, and Leander (scale 1:100,000) was recently published as Miscellaneous Map No. 43. This map shows the areal distribution of bedrock and surficial geologic units and faults for this corridor within the northern segment of the Edwards aquifer, located north of Austin, that is undergoing rapid urban and suburban growth. The study area is typical of the Central Texas areas where geological characteristics are key to managing and planning the use of land and water resources and conducting responsible, cost-effective construction practices. This map is intended for, and has already been used by, a diverse audience comprising professionals in geology, hydrology, engineering, urban planning, archeology, and related fields, as well as laypersons and students. Applied uses include (a) identification of aquifer recharge areas; (b) characterization of attributes and heterogeneities within aquifer strata; (c) location and characterization of faults; (d) information for water-management decisions regarding groundwater flow and aquifer response to pumpage and recharge; (e) improved planning and permitting related to land-use activities such as construction, design of foundations, and siting of landfills and other waste-disposal sites; and (f) location of construction materials.

Five open-file maps of Texas Gulf Coast areas were also complete during spring 2006: three covering Galveston Island and two for Mustang Island. These maps display Holocene geologic units associated with the coastal depositional environments of the barrier islands and are available as color paper copies or GIS digital data sets. Also six open-file maps of the Brazos River Valley were completed during spring 2006 and are available as black and white paper products.

Delineating Salinity Sources along Segments of the Colorado River and Petronila Creek

Jeffrey G. Paine, principal investigator;
Edward W. Collins; H. S. Nance

In this major stream salinization study sponsored by the Texas Commission on Environmental Quality (TCEQ), we employed airborne and ground-based electromagnetic induction (EM) methods and complementary water sampling and analysis to identify and assess the extent, intensity, and potential source areas of salinity-impacted segments of the Colorado River in West Texas and Petronila Creek near Corpus Christi. Innovative, helicopter-based geophysical surveys were flown to acquire EM data (1) along the Colorado River axis from Lake Ivie to Lake Thomas and (2) within a corridor centered on Petronila Creek. These data revealed multiple salinized areas that contribute water high in dissolved solids that degrades stream water quality. Airborne survey results, along with water-flow measurements and chemical analyses of water samples, are being used by TCEQ, the Railroad Commission of Texas (RRC), and their subcontractors to constrain models of constituent loading in these streams and direct future mitigation efforts aimed at improving water quality. Two comprehensive reports summarizing project results were completed in January 2006. Additional investigations, sponsored by the Railroad Commission of Texas through TRC Environmental Solutions, have included detailed ground and borehole geophysical surveys to identify salinity sources in and near the Wendkirk Oil Field along the Colorado River below E. V. Spence Reservoir.

Self-Sealing Evaporation Ponds

Jean-Philippe Nicot, principal investigator

Because the Texas population is expected to grow tremendously in the coming decades, municipalities and other water-supplying entities will have to supplement or replace their current fresh-water sources. Desalination of brackish water is part of the mix and could become the sole source of water for some West Texas cities. However, concentrate disposal could impede further consideration of desalination because of legal, technical, and cost challenges. An option for small facilities (<1 million gallons a day) is to use evaporation ponds. Such ponds legally
require at least a geomembrane or clay liner on the bottom and on the sides, which can be prohibitively expensive for small communities, especially if a leak occurs. A solution that may allow less reliance on conventional liners and that would limit leaks is to use self-sealing evaporation ponds. Water chemical composition of those ponds is such that the precipitating material creates a low-permeability layer that would heal itself if punctured.

The project found no regulatory hurdle in the implementation of this feature. By design, material accumulates at the bottom of an evaporation pond, the sludge consisting primarily of less-soluble salts, such as calcite, gypsum, possibly sepiolite, a claylike mineral, and other minor minerals that are a function of the chemical composition of feed water. Actual sampling and geochemical modeling showed that flow properties of the sludge layer approached the legal requirements but did not go beyond them without engineered additives. Overall, developing self-sealing ponds is not technically challenging; doing so at a cost lower than that of present simple technology is not easy, however. Self-sealing deposition could be advantageous in settings where an additional defense-in-depth layer would be needed, such as areas with an underlying unconfined aquifer sensitive to contamination.

Panhandle Groundwater Conservation District Review, FY2007
Jean-Philippe Nicot, principal investigator

The Bureau of Economic Geology provided technical support to the Panhandle Groundwater Conservation District in its review of a groundwater pumping-permit application.

Update of Northern Trinity and Woodbine Aquifer
Jean-Philippe Nicot, principal investigator

BEG provided pumpage input to support a groundwater model of the Trinity-Woodbine aquifer in north Texas. The model is being revised, including the addition of groundwater use owing to the rapid development of the Barnett Shale play. The play, currently the most prolific onshore gas play in the country, has seen a quick growth in the past decade with the development of new “frac” (fracture stimulation) technologies needed to create pathways to produce gas in the very low permeability mudstones. This technology uses large amounts of water in a short period of time to develop a gas well (3.0 to 3.5 million gallons of fresh water for a typical horizontal well completion). There are currently over 5,600 wells producing gas from the Barnett Shale, with thousands more likely to be drilled in the next couple of decades as the play expands out of its core area. Almost 8,000 acre-feet of water (from all sources) was used in 2005, mostly in an area equivalent to a Texas county. BEG computed projections of groundwater use by the oil and gas industry through 2025. Total water use is highly uncertain, being dependent on the price of gas above all. The uncertainty was tackled by developing high, medium, and low scenarios that can be somewhat understood as cases with decreasing gas prices.

Other important factors include geologic risk factors in the Barnett (maturity of the shale, thickness of the formation, presence of features limiting or hampering well completion), technological factors (horizontal vs. vertical wells, water recycling), operational factors (number of well completions that can be done in a year, proximity of a fresh-water source), and regulatory factors. The high scenario calculates most of the high-end water use of the previous parameters, whereas the low scenario uses the low values of their range. The high scenario calls for a total water use between 2007 and 2025 of 417,000 AF of groundwater (~22,000 AF/yr on average). This figure represents, however, no more than 10% of total groundwater use and even less of total water use.
Airborne Lidar Survey for the Southern California Beach Processes Study: Point La Jolla to Dana Point
Roberto Gutierrez, principal investigator; James C. Gibeaut, Tiffany L. Hepner, Rebecca C. Smyth, and Amy Neuenschwander (The University of Texas at Austin Center for Space Research)

The goal of this joint program between the University of California, Scripps Institution of Oceanography, and BEG is to understand beach processes in Southern California, especially the relationship between seasonal storm patterns, ocean waves, and changes in beach sand level. The original objective of the collaboration was to collect topographic data along the coast from Point La Jolla to Dana Point and develop new methods of shoreline mapping using airborne lidar technology. Lidar surveys were conducted in May, September, and December of 2002 during periods of low tide. Additional surveys were conducted in March and October 2003. In 2004, the survey area was increased to include the shoreline from Long Beach south to the U.S.-Mexico border at Tijuana. Despite poor weather and serious wildfires in southern California during 2004, a comprehensive survey of this extended area was successfully completed in October. The shoreline between Long Beach and the U.S.-Mexico border was resurveyed in April and October 2005 and March and October of 2006. These data are being analyzed at Scripps and UT.

Mapping of Padre Island National Seashore and NPS Mapping Support in Texas
James C. Gibeaut, principal investigator; Thomas A. Tremblay, Tiffany L. Hepner, Rachel L. Waldinger, and William A. White

In 1980, BEG published a map titled *Geology and Natural Environments of Padre Island National Seashore*, which was based on aerial photographs taken in 1975. The geology and natural environments have changed significantly over the past 28 years, and now the National Park Service is funding a 2-year program to re-map this dynamic environment. BEG researchers are remapping Padre Island National Seashore using the 1980 map as a template for the new map. The mapping is based on color infrared digital orthophotos acquired in 2003 and other photography as needed. Photo interpretation and mapping of geoenvironmental units is being conducted at a scale of 1:8,000 or larger. The final map will be at least as accurate as 1:24,000-scale U.S. Geological Survey Topographic Quadrangle maps. The new map will provide data for evaluation of the many changes in both geology and natural environments that have occurred since 1975. This information is valuable for park management and helps meet objectives of the National Inventory and Monitoring Program. The work will also benefit from ongoing studies in the Laguna Madre area funded by other sources. In 2006, a draft map was completed and reviewed by the National Park Service. We are currently making adjustments to map units including adding more detail to wetland units.

Geohazards Map of Galveston Island
James C. Gibeaut, principal investigator; Thomas A. Tremblay, Rachel L. Waldinger, Edward W. Collins, and Tiffany L. Hepner

This work will provide the City of Galveston with a geohazards map of Galveston Island. The project is an outgrowth of a preliminary report presented to the City by an expert panel of geologists chaired by James Gibeaut. That report, titled “Living with Geohazards on Galveston Island: A Preliminary Report with Recommendations” and presented to the City Council in July 2004, includes a recommendation for creating a geohazards map. This map, now completed, considers the spatial and temporal patterns of geological processes, geomorphology, and geoenvironments (e.g., wetlands and dunes) that combine to create potentially hazardous conditions. The goal of the mapping is to provide information neces-
sary to the planning process. The map will also serve to increase public awareness of the natural physical processes acting on the island.

Over the last 5 years, BEG’s Coastal Studies Group has acquired several large data sets pertinent to delineating geohazards on Galveston Island. These data sets, which include topography, photography, wetlands, and historical shoreline positions, were combined with newly mapped features in creating the geohazards map. The approach to constructing the map was first to create digital map layers in a Geographic Information System (GIS). Each layer contained a specific type of information pertinent to delineating geohazards. We then overlaid these layers in the GIS and combined the information into a hybrid map of geohazards.

**Lidar Digital Elevation Data and Related Products, Ventura, California**

*James C. Gibeaut, principal investigator; Roberto Gutierrez; Tiffany L. Hepner; Amy L. Neuenschwander (Center for Space Research)*

This survey was funded by the U.S. Geological Survey out of the Geologic Division at Menlo Park, California. In October 2005, an approximate 210-km² area in coastal Ventura County was surveyed using BEG’s Optech lidar system with full waveform digitization. These data are being used to delineate fine-scale hill slopes and channel networks for the purpose of landslide assessment and control, as well as to aid surficial geologic mapping.

**Coast of California Storm and Tidal Wave Study, Santa Barbara and Ventura Counties—Lidar Survey**

*Roberto Gutierrez, principal investigator; Tiffany L. Hepner; Amy L. Neuenschwander (Center for Space Research)*

The lidar survey of Santa Barbara and Ventura Counties in California was a collaboration between the California Department of Boating and Waterways, the United States Geologic Survey, The University of California Santa Cruz, and the Bureau of Economic Geology, The University of Texas at Austin. The overall goal of the program is to understand beach processes along the Ventura and Santa Barbara Counties shoreline in Southern California, especially the relationship between ocean waves and changes in beach sand level. The specific objective of the BEG was to collect topographic data along the coast from Point Conception to Port Hueneme using airborne lidar mapping technology. The survey was conducted in October 2005, and data were processed in 2006. This survey was funded by the Beach Erosion Authority for Clean Oceans and Nourishment, a joint powers authority also referred to as BEACON.

**Airborne Lidar Survey in the Vicinity of Mustang Island**

*Roberto Gutierrez, principal investigator; James C. Gibeaut; Tiffany L. Hepner; Amy L. Neuenschwander (Center for Space Research)*

This research-grade lidar survey was conducted primarily for and funded by the City of Corpus Christi, Texas in August 2005. All of Mustang Island, a barrier island at the mouth of Corpus Christi Bay, was surveyed using the Bureau’s Optech scanning lidar instrument installed in a Texas Department of Transportation Cessna 206. Data-point spacing is closer than 1 m. During 2006, the data were processed, and points were classified as representing buildings, vegetation, or ground. The point data were then used to create digital terrain models. The city is using these models for creating surface-water drainage maps and designing drainage projects. Coastal researchers at the Bureau are also using the data for shoreline change detection and wetlands mapping and will use it for modeling environmental change caused by sea-level rise.
Lidar Digital Elevation for Coyote Wash and South Avatatz Fan, California

Roberto Gutierrez, principal investigator; Tiffany L. Hepner; Amy L. Neuenschwander (Center for Space Research)

This survey was funded by the U.S. Geological Survey out of the Geologic Division at Menlo Park, California. In October 2005, two project areas (South Avawatz and Coyote Lake) in the Mojave Desert, California, were surveyed using the Bureau’s Optech lidar system. These data are being used to delineate fine-scale hill slopes and channel networks for the purpose of alluvial-fan assessment and to aid surficial geologic mapping.
PUBLIC OUTREACH
AND EDUCATION

The Texas High School Coastal Monitoring Program:
A Project in Education, Public Awareness, and Coastal Management
James C. Gibeaut, principal investigator; Tiffany L. Hepner

The Texas High School Coastal Monitoring Program (THSCMP) is an ongoing Bureau project designed to help coastal residents develop a better understanding of dune and beach dynamics on the Texas coast. Bureau researchers work with high school and middle school students and teachers, showing them how to measure topography, map vegetation lines and shorelines with Global Positioning Systems (GPS), and observe weather and wave conditions. As participants in an actual research project, the students enhance their science education and provide coastal communities with valuable data on their changing shoreline.

THSCMP, in its tenth year of operation, receives funding from the Texas Coastal Management Program. Participating schools are Ball High School on Galveston Island (10 years in the program), Port Isabel High School in South Texas (8 years in the program), and Port Aransas High School on Mustang Island (8 years in the program). During the 2004–05 school year, the program expanded to include two additional schools in the Bay City region. Van Vleck Middle School and students participating in the Spanish Science Club at Tidehaven Middle School started collecting data on Matagorda Peninsula. And Palacios High School joined the program during the 2006–07 academic year. Bureau researchers and students make at least three field trips to survey sites in their coastal regions. The Bureau envisions a network of coastal schools conducting scientific beach studies and then sharing their observations with other students, schools, and the public using the Internet. For more information, visit the program’s Website at http://coastal.beg.utexas.edu/thscmp/.

Earth Science Week
Sigrid J. Clift, principal investigator

Earth Science Week (ESW), a nationwide program designed to promote interest in and knowledge about earth science and its contributions to society, is observed yearly during the second week in October. In 1998 the American Geological Institute began the ESW observance that is now celebrated annually in every state and in countries around the world. The Austin ESW Consortium, chaired by Bureau scientist Sigrid Clift, includes members from earth-science-related organizations and companies from the Central Texas area. Of the four very successful events organized for 2006, a book drive for the Austin Public Libraries raised $2,500 for much-needed earth science books in their collection. Hurricanes and groundwater resources were the themes for the 4th annual summer lecture series, which 200+ people attended, and more than 600 children and their parents attended the Summer Earth Science Festival co-sponsored by Austin ESW and Zilker Park. ESW events in Austin culminated in the 7th Annual Earth Science Career Fair for more than 300 middle school students. Financial sponsors for the events were the Jackson School of Geosciences; Texas Space Grant Consortium; the Lower Colorado River Authority; Holt, Rinehart and Winston; D. B. Stephens & Associates; the Subsurface Library; the Austin Geological Society; and the City of Austin Watershed Protection Department. More than 65 dedicated professionals donated their time and resources to provide meaningful earth science educational experiences to students and the general public. Austin ESW owes its
success to its sponsors and volunteers. For more information about Austin ESW, visit the Texas ESW Website at www.beg.utexas.edu/esw.

Petroleum Technology Transfer Council (PTTC)
Scott W. Tinker, Director; Sigrid J. Clift, Coordinator; Eric C. Potter, Advisor; and Sylvia J. Jennette, Webmaster; Alexandra N. Barrientos, Student Assistant; Bob Kiker, PTTC Permian Basin Program Manager; and Allen Gilmer, Chairman of the PTTC Texas Region Producer Advisory Committee

The mission of the PTTC program is to provide technology transfer opportunities to small independent oil and gas producers in Texas that will lead to increased production of Texas oil and natural gas through best practices and proven technology. The PTTC Texas Region, which is managed by the Bureau, sponsored or co-sponsored nearly 20 events in 2006. These events included workshops and symposiums on best-practice methods for waterfloods and CO₂ enhanced oil recovery, as well as hydraulic fracture technology, software and safety training seminars, and applications for reducing CO₂ and methane emissions.

The Petroleum Technology Transfer Council is a national not-for-profit organization established in 1994 by producers, state organizations, and the DOE. For more information, visit the PTTC Website at www.pttc.org.

Museum Outreach
The Fort Worth Museum of Science and History is well known for outstanding hands-on displays and interactive experiences for visitors. The museum is planning a significant renovation and expansion, with a completion target date in 2009. The topic of energy is one of the key themes for the expanded design. The Bureau is part of an advisory team formed to provide expert assistance in the new energy-related design efforts. In October Associate Director Eric Potter represented the Bureau in a planning meeting with museum officials and design consultants.

The Bureau of Economic Geology continued its partnership with the Petroleum Museum in Midland in 2006 by again taking part in the American Geological Institute’s annual Earth Science Week activities. Presented by Scott Rodgers and coordinated by the Museum’s educational staff, elementary and junior high school students from the Midland and Odessa school districts were treated to EarthView Texas, a unique virtual reality presentation using the Bureau’s state-of-the-art passive stereo visualization system. The program explores Bureau research into real-world issues such as resource management, energy development, and coastal erosion. Students and teachers are exposed to key geologic concepts and scientific insights into the world in which they live. The Petroleum Museum also scheduled special evening sessions that were attended by the general public and museum supporters.
The Bureau maintains formal and informal cooperative arrangements with several governmental entities. Parts of the Bureau’s research program are conducted under The University of Texas at Austin contracts and grants with Federal, State, and private organizations.

Contract-management personnel prepare proposals and budgets, negotiate contracts, and monitor expenditures. During the contract period, technical and financial reports are distributed at monthly, quarterly, and annual intervals. In 2005, the following projects, each of which had reporting requirements, were active at the Bureau:

**FEDERAL**

“Applications of VSP Technology for Evaluation of Deep-Water Gas-Hydrate Systems”: supported by the University of Mississippi.

“Assessment of the Availability of Alternative Groundwater Supplies that Meet Arsenic MCL’s for Selected Public Water Systems in New Mexico”: supported by the USPHS Indian Health Service.

“A Technology Transfer Program, Texas Region of the Petroleum Technology Transfer Council”: supported by the Petroleum Technology Transfer Council.

“CMG Research: Multi-Scale Flow and Transport Modeling of Large-Vug Cretaceous Carbonates”: supported by the National Science Foundation.

“Combining Multicomponent Seismic Attributes, New Rock-Physics Models, and In Situ Data to Estimate Gas-Hydrate Concentrations in Deep-Water, Near-Seaﬂoor Strata of the Gulf of Mexico”: supported by the U.S. Department of Energy.

“Development of an Integrated Superconducting Gravity Meter Sensor System”: supported by the NSF through the Department of Geological Sciences.

“Evolution of Releasing Stepover Arrays along the Eastern Boundary of the Sierra Nevada Micro-Plate—Implications for Geothermal Exploration and Prediction”: supported by the U.S. Department of Defense, Naval Air Warfare Center.

“Geologic and Geophysical Data Preservation Booklets”: supported by the U.S. Geological Survey.

“Geologic Mapping, Big Bend National Park, Texas”: supported by the National Park Service.

“Gulf Coast Carbon Center Participation in the Southwest Regional Sequestration Partnership”: supported by the U.S. Department of Energy through the New Mexico Institute of Mining and Technology.

“Imaging Super-Deep Gas Plays across the Gulf of Mexico Shelf with Multicomponent Seismic Technology”: supported by the U.S. Department of Energy.

“Integrated Synthesis of the Permian Basin: Data and Models for Recovering Existing and Undiscovered Oil Resources from the Largest Oil-Bearing Basin in the U.S.”: supported by the U.S. Department of Energy.

“Mapping of Padre Island National Seashore and NPS Mapping Support in Texas”: supported by the National Parks Service, U.S. Department of the Interior.


“Participation in the Southeast Regional Sequestration Partnership, Phase II”: supported by the U.S. Department of Energy through the Southern States Energy Board (two subcontracts).

“Predicting Fracture Porosity Evolution in Sandstone”: supported by the U.S. Department of Energy.

“Processing and Modeling Proprietary 2D-4C OBC Data”: 
supported by the Minerals Management Service, U.S. Department of the Interior.

“Review of Documents and Dissemination of Environmental Geologic Information Related to Environmental Restoration at the U.S. Department of Energy’s Pantex Plant, Carson County, Texas”: supported by the Energy Conservation Office.

“Reviving Abandoned Reservoirs with High Pressure Air Injection: Application in a Fractured and Karsted Dolomite Reservoir”: supported by the U.S. Department of Energy.


“Seismic Data Processing, Gas Hydrate Seafloor Observatory: Block MC 118”: supported by the U.S. Department of Energy through the University of Mississippi.

“Smart Development Initiative”: supported by the U.S. Agency for International Development.

“Startup of a Public Geological Core and Sample Repository in Houston, Texas”: supported by the U.S. Department of Energy.

“Support for Solvent Based Enhanced Oil Recovery for In-Situ Upgrading of Heavy Oil Sands”: supported by the Florida International University.

“Support for the Curation of Academic Research Cores, Samples, and Collections in the Geosciences”: supported by the National Science Foundation.

“Texas Coal Sample Collection for Rank Determination”: supported by the U.S. Geological Survey.

“Texas High Plains Land Use/Land Cover Groundwater Effects Special Study”: supported by the U.S. Bureau of Reclamation, U.S. Department of the Interior.

“Feasibility Analysis of Water Supply for Small Public Water Systems, Phase II”: supported by the Texas Commission on Environmental Quality, State of Texas.

“Fracture Opening Processes”: supported by the Jackson School of Geosciences, The University of Texas at Austin.

“FutureGen II”: supported by the Railroad Commission of Texas, State of Texas.

“Geohazards Map of Galveston Island”: supported by the City of Galveston, Texas.

“JSG Initiative Program # 6—Innovative Research to Support a Successful Carbon Sequestration Industry in Texas”: supported by the Jackson School of Geosciences, The University of Texas at Austin.

“JSG Initiative # 17—Clift Earth Science Week”: supported by the Jackson School of Geosciences, The University of Texas at Austin.

“Low Emission Diesel Fuel Peer Review Process”: supported by the Texas Commission on Environmental Quality, State of Texas.

“New Directions in Salt—l0601”: supported by the Jackson School of Geosciences, The University of Texas at Austin.

“Panhandle Groundwater Conservation District Review, FY2007”: supported by the Panhandle Groundwater Conservation District.

STATE AND LOCAL

“BEG JSG Equipment Matching Fund”: supported by the Jackson School of Geosciences, The University of Texas at Austin.

“BEG JSG SEM CL Lab Equipment Match for Laubach”: supported by the Jackson School of Geosciences, The University of Texas at Austin.

“Evaluation of Nitrate Contamination in Selected Aquifers in Texas II”: supported by the Texas Commission on Environmental Quality, State of Texas.

“Fate and Transport of Contaminants Training”: supported by the Texas Commission on Environmental Quality, State of Texas.
“Self-Sealing Evaporation Ponds”: supported by the Texas Water Development Board, State of Texas.

“Status and Trends of Barrier Wetlands, Padre Island National Seashore (Lower Coast) and the Chenier Plain (Upper Coast)”: supported by the General Land Office, State of Texas.

“Status and Trends of Dune Volume, Morphology, and Vegetative Cover along the Texas Gulf Shoreline”: supported by the Texas General Land Office and Veterans Land Board, State of Texas.

“Study to Evaluate Electronic Access to Geologic Data and Surface Casing Depths Necessary to Protect Usable Groundwater in the State, Phase II”: supported by the Texas Commission on Environmental Quality, State of Texas.

“Support of TCEQ’s Low-Emission Diesel Fuel Peer Review Process”: supported by the Texas Commission on Environmental Quality, State of Texas.

“Sustainable Water Resources Development in Texas”: supported by the Jackson School of Geosciences, The University of Texas at Austin.


“Technology Center for Oil and Gas Recovery Optimization on Texas State Lands of Texas”: State of Texas.

“Texas High School Coastal Monitoring Program”: supported by the General Land Office, State of Texas.

“Texas Tidal Inlets Project: Depositional Environments and Morphodynamics of San Luis Pass”: supported by the General Land Office, State of Texas.

“The Texas Shoreline Change Project—Gulf of Mexico Shoreline Sabine Pass to the Brazos River, Pass Cavallo to Aransas Pass, and the Padre Island National Seashore”: supported by the General Land Office, State of Texas.

“Utopia: History of Texas”: supported by UTOPIA, The University of Texas at Austin.

“Virtual Model for Exploring How Sea Level Changes Have and Will Affect Coastal Environments”: supported by the Energy Conservation Office, State of Texas.

PRIVATE

“Airborne Lidar Survey for the Southern California Beach Processes Study: Point La Jolla to Dana Point”: supported by the University of California, San Diego.


“Applied Geodynamics Laboratory”: supported by various donors.

“Aaron Technology Center for Oil and Gas Recovery Optimization on Texas State Lands of Texas”: State of Texas.

“Texas High School Coastal Monitoring Program”: supported by the General Land Office, State of Texas.

“Texas Tidal Inlets Project: Depositional Environments and Morphodynamics of San Luis Pass”: supported by the General Land Office, State of Texas.

“The Texas Shoreline Change Project—Gulf of Mexico Shoreline Sabine Pass to the Brazos River, Pass Cavallo to Aransas Pass, and the Padre Island National Seashore”: supported by the General Land Office, State of Texas.

“Utopia: History of Texas”: supported by UTOPIA, The University of Texas at Austin.

“Virtual Model for Exploring How Sea Level Changes Have and Will Affect Coastal Environments”: supported by the Energy Conservation Office, State of Texas.

“Support of TCEQ’s Low-Emission Diesel Fuel Peer Review Process”: supported by the Texas Commission on Environmental Quality, State of Texas.

“Sustainable Water Resources Development in Texas”: supported by the Jackson School of Geosciences, The University of Texas at Austin.


“Technology Center for Oil and Gas Recovery Optimization on Texas State Lands of Texas”: State of Texas.

“Texas High School Coastal Monitoring Program”: supported by the General Land Office, State of Texas.

“Texas Tidal Inlets Project: Depositional Environments and Morphodynamics of San Luis Pass”: supported by the General Land Office, State of Texas.

“The Texas Shoreline Change Project—Gulf of Mexico Shoreline Sabine Pass to the Brazos River, Pass Cavallo to Aransas Pass, and the Padre Island National Seashore”: supported by the General Land Office, State of Texas.

“Utopia: History of Texas”: supported by UTOPIA, The University of Texas at Austin.

“Virtual Model for Exploring How Sea Level Changes Have and Will Affect Coastal Environments”: supported by the Energy Conservation Office, State of Texas.

“Support of TCEQ’s Low-Emission Diesel Fuel Peer Review Process”: supported by the Texas Commission on Environmental Quality, State of Texas.
“Geologic Mapping to Support Improved Database Development and Understanding of Critical Aquifers, Urban Corridors and Special Areas of Environmental Concern in Texas”: supported by the U.S. Geological Survey.

“Geologic Storage Potential of the Southeastern U.S.: North Carolina and South Carolina”: supported by the U.S. Department of Energy through the Southern States Energy Board (two subcontracts).

“Geological Storage Potential of the Southeastern United States: North Carolina and South Carolina”: supported by the Electric Power Research Institute.

“Gulf Coast Carbon Center”: supported by various donors.

“Lidar Mapping of Devils Sinkhole State Natural Area, Edwards County, Texas”: supported by the Texas Cave Management Association.

“Lidar Survey for the Southern California Beach Processes Study: Point La Jolla to Dana Point II”: supported by the University of California, San Diego.

“Multiple Elimination Using Plane-Wave Construction” supported by the Norsk Hydro.


“Permian Basin Synthesis Project”: supported by various donors.

“Plume Research Group: Integrated Regional, Site-Specific, and Theoretical Studies of Ground-Water Contaminant Plumes”: supported by various donors.

“Quantitative Clastics Laboratory” supported by various donors.

“Regional Characterization of the Latest Pleistocene and Holocene Stratigraphy, Structure and Depositional Processes of Offshore Eastern Trinidad and Venezuela”: supported by various donors.

“Reservoir Characterization Research Laboratory”: supported by various donors.

“Seismic Vector-Wavefield Characterization of Complex Reservoirs”: supported by various donors.

“Stratigraphic Architecture and Sandstone Reservoir Quality in Deep-Shelf Gas Plays of Texas State Waters”: supported by various donors.

“Stratigraphy and Petrophysics of the Yates and Seven Rivers Formation in Andrews and Gaines County, Texas”: supported by Lynx Production Company.

“Surface and Borehole Geophysical Investigation, Wendtkirk Oil Field, Coke County, Texas”: supported by the TRC Environmental Corporation.

“Update of Northern Trinity and Woodbine Aquifer”: supported by R. W. Harden & Associates.

“West Texas Bolsons GAM”: supported by LBG-Guyton Associates.

“West Texas Ground Water Availability Model (GAM)”: supported by Intera, Inc.
**Lectures and Addresses**

**William A. Ambrose**


Depositional systems and sedimentary facies of coal-forming environments: presented as part of AAPG workshop: Application of depositional systems to coalbed methane and shale gas exploration: core workshop for sorbed gas reservoir systems, Houston, Texas, April.


CO₂ EOR plays and geologic controls on CO₂ sequestration in the Gulf Coast and Permian Basin: presented at Southwest Section AAPG Annual Meeting, Midland, Texas, May.

Update on CO₂ injection research at the Gulf Coast Carbon Center: presented at the 2006 TCEQ Environmental Trade Fair and Conference, Austin, Texas, May.

U.S. energy minerals: unconventional resources for the future: presented at Southwest Section AAPG Annual Meeting, Midland, Texas, May.

U.S. energy mineral resources and frontiers: presented to San Antonio Chapter, SIPES, San Antonio, Texas, July.

BEG–Pemex integrated basin and play assessment of the southern Laguna Madre–Tuxpan continental shelf, northeastern Mexico: presented to Quantitative Clastics Laboratory consortium members, Grand Junction, Colorado, August.


Worldwide tidal depositional systems: presented to Quantitative Clastics Laboratory consortium members, Grand Junction, Colorado, September.


**Florence Bonnaffé**

Developments in ground-based lidar data acquisition, processing, and visualization: presented at LASR Annual Meeting, Austin, Texas, January.

Preliminary results of new research program in the Capistrano Formation, California borderland: presented to Shell, Houston, Texas, January.

Preliminary results of research at the Grand Coyer subbasin, SE France: impact of preexisting topography on the early fill and late evolution of a confined deepwater basin: presented at LASR annual meeting, Austin, Texas, January.


Syndepositional faulting in the Eocene–Oligocene Annot Sandstone, Annot, SE France: high-resolution kinematic analysis and stratigraphic

**Renaud Bouroullec**


Preliminary results of new research program in the Capistrano Formation, California borderland: presented at LASR annual meeting, Austin, Texas, January.

**Shirley P. Dutton**


**Sergey Fomel**

Seismic slope as a universal attribute: presented at SEG Forum, Mathematical Problems of Seismic Imaging and Inversion, Novosibirsk, Russia, January.

Waveland continuation: presented at Institute for Geophysics, Novosibirsk, Russia, February.

Introducing “Madagascar,” a computational platform for geophysical data processing and reproducible numerical experiments: presented at EAGE Workshop, Open-Source E&P Software—Putting the Pieces Together, Vienna, Austria, June.

**Michelle M. Foss**

LNG: can we/should we/will we build it?: presented at Law of LNG Symposium, The University of Texas at Austin School of Law, Austin, Texas, January.


Forward, backward, sideways: global energy redux: presented as Fuels Keynote at the American Institute of Chemical Engineers Spring Conference, Orlando, Florida, April.


LNG update: presented at Texas CPA Oil and Gas Conference, Austin, Texas, May.


**Julia F. W. Gale**


**James C. Gibeaut**

Exploring and living with the dynamic Texas coast: presented at Clint Small Middle School, Austin, Texas, January.

Beaches and dunes: presented to Surfrider Foundation Central Texas Chapter, Austin, Texas, February.

Changes in barrier island environments during sea-level rise: presented to Sigma Xi Research Society, Texas A&M Chapter, College Station, Texas, March.

Texas shoreline change analysis and communicating the results to the public: presented at Shoreline Change Conference II: a workshop on managing shoreline change, Charleston, South Carolina, May.

Galveston geohazards map: presented to the City of Galveston City Council, Galveston, Texas, July.

Mapping geohazards on Galveston Island: presented at public meeting of the Galveston City Council, Galveston, Texas, July.

Wetland habitat transition induced by relative sea-level rise: presented to Galveston Bay Council, Clear Lake, Texas, July.

The Texas Gulf Coast: presented to Clint Small Middle School, Austin, Texas, August.

Past and future wetland change on the barrier islands of the upper Texas coast: presented to the Texas Commission on Environmental Quality, Austin, Texas, October.

Texas coast susceptibility to storms and sea-level rise: poster presented as prelecture activity as part of The University of Texas at Austin, Environmental Science Institute, Outreach Lecture Series, Austin, Texas, October.

Sand resources of Sabine and Heald Banks, Texas: presented to the Texas General Land Office CT2020 Coastal Sand Sources Workshop, Austin, Texas, November.

Virtual reality model for visualizing coastal environments and sea-level change: presented to the Middle and High School Science Teachers’ Workshop organized by the Texas State Energy Conservation Office, Dallas, Texas, November.

**Bob A. Hardage**


**Mark H. Holtz**


Geologic factors controlling CO₂ storage capacity and permanence—techniques and case studies based on experience with heterogeneity in oil and gas reservoirs applied to CO₂ storage: presented at CO₂SC Symposium, Lawrence Berkeley National Laboratory, Berkeley, California, March.

Subsurface characterization of CO₂ sequestration sites—example from a carbonate reef setting: presented at CO₂SC Symposium, Lawrence Berkeley National Laboratory, Berkeley, California, March.


Sequestration pilot sites in the U.S.: part of a panel discussion, Coal Gasification Summit, Denver, Colorado, November.

**John N. Hooker**


**Susan D. Hovorka**

Assessment of geological storage capacity of the southeastern U.S. for CO₂ in brines and economic use for EOR: presented at SECARB Industry Briefing, Atlanta, Georgia, January.

Monitoring and verification issues for carbon storage pilot experiments: presented at SECARB Industry Briefing, Atlanta, Georgia, January.

Stacked storage field project: presented at SECARB Industry Briefing, Atlanta, Georgia, January.

Update on Frio Brine Project—15 months after injection: presented at Workshop on Carbon Capture and Storage, hosted by RITE, Tokyo, Japan, February.

Downscaling capacity from a regional to a site scale—a case study for the southeastern U.S.: presented at Fifth Annual Conference on Carbon Capture & Sequestration, Alexandria, Virginia, May.


**Michael R. Hudec**

Far-traveled minibasins and the great Plio–Pleistocene salt surge, Green Canyon, Gulf of Mexico: presented at UTIG Seminar Series,
The University of Texas at Austin, Austin, Texas, March.

Advance history of the Mad Dog salt sheet, Gulf of Mexico: presented to Total E&P USA, Houston, Texas, April.

Diachronous growth of fold limbs on the Mad Dog anticline: implications for base-salt deformation in the Atwater fold belt: presented to Total E&P USA, Houston, Texas, April.

Effects of salt-sheet shape and synkinematic loading on the structure of salt-sheet sutures: presented to Total E&P USA, Houston, Texas, April.

Emplacement of allochthonous salt sheets in passive margins and orogens: presented to Total E&P USA, Houston, Texas, April.

Factors affecting the ability of welds to seal: presented to Total E&P USA, Houston, Texas, April.


Physical models of salt-sheet sutures and drop-through basins: presented to Shell International Exploration and Production, Houston, Texas, April.

Physical modeling of import and export of salt from squeezed stocks: presented to Total E&P USA, Houston, Texas, April.


Physical modeling of thrust faults and salt welds associate with squeezed stocks: presented to Total E&P USA, Houston, Texas, April.


Preliminary thoughts on the influence of advance history on the base-salt disturbed zone, Mad Dog salt sheet, Gulf of Mexico: presented to Shell International Exploration and Production, Houston, Texas, April.

Preliminary thoughts on the influence of advance history on the base-salt disturbed zone, Mad Dog salt sheet, Gulf of Mexico: presented to Total E&P USA, Houston, Texas, April.

Thrust advance along the modern Sigsbee Escarpment: consequences for base-salt structure and overpressure: presented to Shell International Exploration and Production, Houston, Texas, April.

Overview of the Applied Geodynamics Laboratory: presented to Institute of Petroleum Engineering, University of Texas at Austin, Austin, Texas, April.

Overview of the Applied Geodynamics Laboratory: presented to Petrobras management, Austin, Texas, May.

Overview of the Paradox Basin, Utah: presented to Statoil Global Exploration, Moab, Utah, May.

AGL models for deepwater Gulf of Mexico ascension zones: presented to ExxonMobil Exploration Company, Austin, Texas, June.

Mechanics of the advance of buried salt sheets: presented to BP Production, Houston, Texas, July.

AGL overview and models for salt-sheet advance: presented to Chevron Energy Technology Company, Austin, Texas, August.


Evolution of suprasalt minibasins in the deepwater Gulf of Mexico: presented at Montana State University, Bozeman, Montana, December 1.

Advance mechanisms of allochthonous salt sheets: implications for predicting subsalt port pressure: presented at University of Wyoming, Laramie, Wyoming, December 5.


Evolution of suprasalt minibasins in the deepwater Gulf of Mexico: presented at New Mexico State University, Las Cruces, New Mexico, November 29.

Advance mechanisms of allochthonous salt sheets: implications for predicting subsalt port pressure:
presented at New Mexico State University, Las Cruces, New Mexico, November 30.

Introduction and AGL overview: presented at Applied Geodynamics Laboratory Industrial Associates Meeting, Austin, Texas, November 2.


Deformation associated with strike sutures between salt sheets: presented at Applied Geodynamics Laboratory Industrial Associates Meeting, Austin, Texas, November 2.

Transported sutures, rotated roof blocks and salt breakouts in head-on and oblique salt-sheet collisions: presented at Applied Geodynamics Laboratory Industrial Associates Meeting, Austin, Texas, November 2.


Evolution of suprasalt minibasins in the deepwater Gulf of Mexico: presented at The University of Texas at El Paso, El Paso, Texas, November 30.


Influence of abyssal-plain sedimentation rates on style of salt breakouts: presented at Applied Geodynamics Laboratory Industrial Associates Meeting, Austin, Texas, November 2.

Overview of subsalt trap types in salt-canopy systems: presented at Applied Geodynamics Laboratory Industrial Associates Meeting, Austin, Texas, November 3.

Xavier Janson

Exploration concepts for deep water carbonates: presented to Shell Exploration, Houston, Texas, March.

Martin P. A. Jackson

Geodynamic modeling of salt tectonics on passive margins: presented to Maersk, Copenhagen, Denmark, December 14.

Overview of research at Applied Geodynamics Laboratory: presented to Maersk, Copenhagen, Denmark, December 14.

The Salt Mine: a digital atlas of salt tectonics: presented to Maersk, Copenhagen, Denmark, December 14.


How and where is the Sigsbee Escarpment advancing?: presented to Applied Geodynamics Laboratory Industrial Associates, Austin, Texas, November 2.

Evolution of intrusive salt plumes from squeezed salt stocks: presented to Applied Geodynamics Laboratory Industrial Associates, Austin, Texas, November 2.

Geology of salt welding: implications for hydrocarbon seals and seismic imaging: presented to Applied Geodynamics Laboratory Industrial Associates, Austin, Texas, November 2.


Gravity-driven deformation and multiple detachments in layered evaporites: presented to Applied Geodynamics Laboratory Industrial Associates, Austin, Texas, November 2.

Deepwater salt tectonics: presented to Petrobras, Rio de Janeiro, Brazil, August 30.

James W. Jennings, Jr.

Building models of deep-water channels for forward seismic modeling: presented at SEG Advanced Modeling Project Meeting, Houston, Texas, April.

Introduction to geostatistics for reservoir characterization and modeling: presented to PGE337, Department of Petroleum and Geosystems Engineering, The University of Texas at Austin, Austin, Texas, April.

Principles of carbonate matrix petrophysical data analysis and reservoir flow model construction presented at Isatis Users Group Meeting, Houston, Texas, April.


Principles of carbonate matrix petrophysical data analysis and reservoir flow model construction: presented to GEO391, Department of Geological Sciences, The University of Texas at Austin, Austin, Texas, May.

Cloud transforms, multivariable statistics, and scaleup: insight for modeling imperfectly correlated porosity and permeability: presented to Shell, Houston, Texas, August.

Geostatistics with Madagascar or variograms and random fields with FFTs: presented at Madagascar Workshop on Reproducible Research in Computational Geophysics, Vancouver, Canada, August.

Stephen E. Laubach

What are the most important types of geological data that need to be quantified to best constrain the fabrics of reservoir rocks and fracture systems for 4D reservoir modeling and production?: invited talk presented to AAPG Reservoir Deformation Group (also served as panelist), Houston, Texas, April.

Insights into reservoir heterogeneity from fracture and structural diagenesis research: presented to Petrobras, Rio de Janeiro, Brazil, July.


Robert G. Loucks
Depositional setting, lithofacies, and pore networks of the Mississippian Deepwater Barnett Shale facies in the Fort Worth Basin: presented at Southwest Section AAPG Annual Meeting, Midland, Texas, May.

F. Jerry Lucia
Why do you think wireline logs will recognize your carbonate facies: here is how it works: presented at Southwest Section AAPG Annual Meeting, Midland, Texas, May.

Reservoir model of SARCRO Northern Platform Pennsylvanian field, Scurry County, Texas: presented to Houston SPE Permian Basin Study Group, Houston, Texas, October.

Angela McDonnell
Paleocollapse megastructures (suprastratal deformation) related to Lower Ordovician Ellenburger coalesced, collapsed-paleocave systems in the northern Fort Worth Basin, Texas: presented at Southwest Section AAPG Annual Meeting, Midland, Texas, May.

Abhijit Mukherjee
Hydrologic characterization of the arsenic contaminated western Bengal basin, India: presented as part of Rast–Holbrook Lecture Series, Department of Earth and Environmental Sciences, University of Kentucky, Lexington, Kentucky, February.

Paul E. Murray
Data storage and archiving solutions for the Seafloor Observatory through UT-Austin: presented at Gulf of Mexico Hydrates Research Consortium, University of Mississippi, Mississippi Mineral Research Institute, Oxford, Mississippi, February.

Improving near-seafloor imaging with existing 2-D 4-C OBC data: presented at Gulf of Mexico Hydrates Research Consortium, University of Mississippi, Mississippi Mineral Research Institute, Oxford, Mississippi, February.

H. Seay Nance
Tracking salinity sources to Texas streams: examples from West Texas and the Texas Gulf Coastal Plain: presented at Gulf Coast Association of Geological Societies 56th Annual Convention Lafayette, Louisiana, September.

Jean-Philippe Nicot

Capillary trapping in the overburden as a defense-in-depth mechanism...
against leakage from CO$_2$ storage sites: the case of the Tertiary Texas Gulf Coast: presented at CO$_2$SC Symposium, Lawrence Berkeley National Laboratory, Berkeley, California, March.


Carbon storage: what are the potential impacts on groundwater in the Texas Gulf Coast?: presented at 2006 Ground Water Summit, San Antonio, Texas, April.

Could oil fields be good recipients of desalination concentrates?: presented at 2006 Ground Water Summit, San Antonio, Texas, April.

Overview of desalination concentrate issues in Texas: presented to Sandia National Laboratories, Geochemistry Department, Albuquerque, New Mexico, April.

Leakage pathways from potential CO$_2$ storage sites in the Texas Gulf Coast and implications for permitting: presented at Fifth Annual Conference on Carbon Capture & Sequestration, Alexandria, Virginia, May.

Overview of risk analysis and permitting issues in the Texas Gulf Coast: presented at 2nd Quarter Gulf Coast Center Partners Meeting, Austin, Texas, June.


Impact of carbon storage on shallow ground water and pressure-controlled regional capacity for brine aquifers: poster presented at American Geophysical Union Fall Meeting, San Francisco, California, December.

Vanessa Nuñez-López
Quick-look assessments to identify optimal CO$_2$ EOR strategies: presented at CO$_2$SC Symposium, Lawrence Berkeley National Laboratory, Berkeley, California, March.

Moving Permian Basin technology to the Gulf Coast: the geologic distribution of CO$_2$ EOR potential in Gulf Coast reservoirs: presented at West Texas Geological Society Symposium, Midland, Texas, October.

Jeffrey G. Paine
Applying geophysics to environmental and engineering problems: a Texas sampler: presented at Southwest Research Institute, San Antonio, Texas, April.

Streambed induction logs: an airborne approach to identifying salinity sources and quantifying salinity loads: presented at Symposium on the Application of Geophysics to Engineering and Environmental Problems, Seattle, WA, April.

Geophysical investigations of salinization along the Upper Colorado River: presented at Texas Water Conservation Association Fall Meeting, San Antonio, Texas, October.


The “I” in Business Ethics: lunch talk presented at Midland College, Midland, Texas, February.


The “I” in Business Ethics: presented to Illinois State Geological Survey and Department of Geology, University of Illinois at Urbana--
Champagne, Champagne, Illinois, February.

FutureGen and the role of Texas: lunch talk presented at Clean Coal Technology Foundation, Austin, Texas, March.
The future of energy: invited lunch talk presented to Society of Independent Professional Earth Scientists, Austin Chapter, Austin, Texas, March.
The future lies in talent and we must act now: presented at American Association of Petroleum Geologists Annual Convention, Houston, Texas, April 6.

Global energy: where will we be in 2053?: keynote lunch talk presented to Panhandle Royalty Owners Group, Amarillo, Texas, May.
The future of global energy: trends, technology, and talent: keynote lunch talk presented at AAPG Pacific Section, SPE, GSA joint meeting, Anchorage, Alaska, May.
The future of global natural gas and implications for the Gulf and Texas: presented at TGP ANR Shipper Meeting, Lake Geneva, Wisconsin, August.
The “I” in business ethics: presented to Austin Geological Society, Austin, Texas, August.
The “I” in business ethics: presented to Texas Commission on Environmental Quality, Austin, Texas, August.
The “I” in business ethics: presented as keynote luncheon talk at DPA/AAPG International Meeting, Perth, Australia, November 6.


Mark Tomasso
Outcrop versus seismic architecture of deep-water deposits: a slope to basin-floor transect of the Brushy Canyon Formation, west Texas: presented at LASR Annual Meeting, Austin, Texas, January.

Three-dimensional seismic forward modeling of a sinuous slope channel, Brushy Canyon Formation, west Texas: presented at LASR Annual Meeting, Austin, Texas, January.

LASR 2006 research plans: presented to Chevron, ConocoPhillips, ExxonMobil, Marathon, Statoil and Shell, Houston, Texas, February.
Outcrop versus seismic architecture of deep-water deposits: a slope to basin-floor transect of the Brushy Canyon Formation, west Texas: presented as part of Soft Rock Talk Series, Department of Geological Sciences, The University of Texas at Austin, Austin, Texas, February.
Seismic forward modeling of clastic outcrops: presented to Statoil, Houston, Texas, February.

3D seismic forward models of a sinuous slope channel: Beacon Channel, Brushy Canyon Formation, west Texas: presented at ExxonMobil, Marathon, ConocoPhillips, Shell, and Statoil, Houston, Texas, February.
Static and dynamic connectivity in bed-scale models of turbidites: keynote address presented at Structurally Complex Reservoirs meeting, The Geological Society, London, UK, March.

Ramón H. Treviño
Tools of a petroleum geologist: presented to Austin Area Science Fair Earth Science Experiment
students and parents at STARR work area, Austin, Texas, March.

**William A. White**


**Wayne R. Wright**

Reservoir quality control in the Arab and Asab Formations U.A.E.: Invited talk presented to Anadarko, Houston, Texas, February.

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**BEG SEMINARS**

**Ruarri Day-Stirrat**

Reorientation mechanisms of phyllosilicate minerals: Gulf of Mexico, North Sea, and Podhale Basin, Poland, October.

**Tim Dooley**

Modeling of allochthonous salt extrusion, roof dispersion, and intrusive import and export of salt in squeezed stocks, February.

**Peter Eichhubl**

Structural geology, November.

**Sergey Fomel**

Fast surface reconstruction from point sets: Bureau of Economic Geology Research Seminar, The University of Texas at Austin, Austin, Texas, November.

**Michelle M. Foss**

CEE update: U.S. natural gas—down the up staircase?: presented at Bureau of Economic Geology Research Seminar, The University of Texas at Austin, Austin, Texas, March.

**Julia F. W. Gale**

Predicting fracture and porosity evolution in dolostone: presented at Bureau of Economic Geology Research Seminar, The University of Texas at Austin, Austin, Texas, March.

Geological fieldwork in Greenland: presented at Bureau of Economic Geology Research Seminar, The University of Texas at Austin, Austin, Texas, August.

**Mark H. Holtz**

Optimizing permanent CO₂ storage in brine-bearing aquifers, February.

**John N. Hooker**

SEM–CL and fracture, or Too many microfractures!: presented at Bureau of Economic Geology Research Seminar, The University of Texas at Austin, September.

**Susan D. Hovorka**

Is there really enough space to “put it back”?: Capacity estimation for geologic storage of CO₂: presented at Bureau of Economic Geology Research Seminar, The University of Texas at Austin, Austin, Texas, September.

**Martin P. A. Jackson**

Modeling of allochthonous salt extrusion, roof dispersion, and intrusive import and export of salt in squeezed stocks, February.

**Daniel Kurtzman**

The use of fracture surveys and hydraulic tests for improving predictions of flow and transport in fractured chalk, March.

**Eric C. Potter**

The Barnett play, Fort Worth Basin, Texas—impact on the Jackson School Royalty Lands, September.

**Srivatsan Lakshminarasimhan**

Is there really enough space to “put it back”?: Capacity estimation for geologic storage of CO₂: presented at Bureau of Economic Geology Research Seminar, The University of Texas at Austin, Austin, Texas, September.

**Robert G. Loucks**

Mississippian Barnett Shale in the Fort Worth Basin: lithofacies and depositional setting of a deepwater shale-gas succession, October.

**F. Jerry Lucia**

Fractures to caves to fractures the touching-vug pore system: presented at Bureau of Economic Geology Research Seminar, The University of Texas at Austin, Austin, Texas, April.

**Abhijit Mukherjee**

Groundwater contamination studies in India, October.

**Jean-Philippe Nicot**

Is there really enough space to “put it back”?: Capacity estimation for geologic storage of CO₂: presented at Bureau of Economic Geology Research Seminar, The University of Texas at Austin, Austin, Texas, September.

Criticality issues, or can Yucca Mountain explode?: presented at Bureau of Economic Geology Research Seminar, The University of Texas at Austin, Austin, Texas, December.

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**BUREAU OF ECONOMIC GEOLOGY — 2006 Comprehensive Report**

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David R. Pyles
Stratigraphic and hydrodynamic concepts learned from a three-dimensional exposure of a sinuous channel, Brushy Canyon Formation, west Texas, January.

Robert M. Reed
Microscopy, November.

Bridget R. Scanlon
Impact of climate variability and land use/land cover change on recharge in the southwestern U.S., January.

Mark Tomasso
Three-dimensional seismic forward modeling of a sinuous slope channel, Brushy Canyon Formation, West Texas: presented at Bureau of Economic Geology Research Seminar, The University of Texas at Austin, Austin, Texas, March.

Fred P. Wang
Barnett production technology, October.

Committee Services and Offices
William A. Ambrose
Acting EMD Representative, American Association of Petroleum Geologists Distinguished Lecturer Committee Meeting, Houston (2006)

EMD President-Elect Representative, EMD Gas Hydrates Committee Meeting, Houston (2006)

EMD President-Elect Representative, EMD Unconventional Gas Resources Committee Meeting, Houston (2006)


EMD Representative, American Association of Petroleum Geologists Astrogeology Committee Meeting, Houston (2006)


Judge, 2006 Eastern Section of American Association of Petroleum Geologists Meeting, Buffalo, NY Oral Session: Black Shales—What We Know and What We Need to Know (2006)


Vice Chair, American Association of Petroleum Geologists Astrology Committee (2006–2007)

Renaud Bouroulec
Oral Session Co-Chair, American Association of Petroleum Geologists Annual Convention, Houston, Texas, Committee on Tectonics and Sedimentation of Mobile Substrates I (2006)

Oral Session Co-Chair, American Association of Petroleum Geologists Annual Convention, Houston, Texas, Committee on Tectonics and Sedimentation of Mobile Substrates II (2006)

Poster Session Co-Chair, American Association of Petroleum Geologists Annual Convention, Houston, Texas, Committee on Tectonics and Sedimentation of Mobile Substrates (2006)

Beverly B. DeJarnett
Member, National Geological and Geophysical Data Preservation Federal Advisory Committee Subcommittee (2006)

Vice-President, SEPM, Gulf Coast Section (2006–2007)

Jozina Dirkzwager
Organizer and convenor, Karlsruhe University 2-day workshop, Geodynamics of SE-Carpathians (2002–2006)

Shirley P. Dutton

Member, The University of Texas at Austin Ad Hoc Consultative

**Peter Eichhubl**
Associate Editor, Geological Society of America Bulletin (2006–2009)

**Julia F. W. Gale**

**Bob A. Hardage**
Member, Geophysics Curriculum Group, John A. and Katherine G. Jackson School of Geosciences (2005–present)
Member, John A. and Katherine G. Jackson School of Geosciences Appointments Committee (2005–2006)

**Susan D. Hovorka**
Chair, John A. and Katherine G. Jackson School of Geosciences, The University of Texas at Austin K–12 and Public Outreach Committee (2006–present)
Member, Regional Geologic Sequestration Partnerships Outreach Working Group (2005–2006)

**Michael R. Hudec**
Member, John A. and Katherine G. Jackson School of Geosciences, The University of Texas at Austin Endowment Committee (2005–2006)

**Martin P. A. Jackson**
Member, John A. and Katherine G. Jackson School of Geosciences, The University of Texas at Austin External Appointments Committee (2006)
Member, John A. and Katherine G. Jackson School of Geosciences, The University of Texas at Austin Search Committee for Dean (2006)

**Xavier Janson**
Member, SEPM (Society for Sedimentary Geology) Nominating Committee (2006–2007)
Session Chair, American Association of Petroleum Geologists Annual Convention, Houston, Texas Seismic Imaging of Carbonates (2006)

**James W. Jennings, Jr.**

**Stephen E. Laubach**
Chair, Bureau of Economic Geology Promotion Advisory Committee (2005–2006)
Member, Geological Society of America Academic & Applied Geosciences Relations Committee (2006–present)

**F. Jerry Lucia**
Member, Department of Geological Sciences, The University of Texas at Austin Graduate Studies Committee (2006–present)

**Amanda R. Masterson**
Chairman, Gulf Coast Association of Geological Societies Publications Committee (2006–present)

**Abhijit Mukherjee**
Chairman, University of Kentucky Graduate and Family Housing Resident Council (2005–2006)

Jean-Philippe Nicot
Associate Editor, Hydrogeology Journal (2006–2009)
Chair, American Geophysical Union Fall Meeting 11–15 December 2006: Surface and Shallow Subsurface Processes and Risks Related to Geological Carbon Storage II Poster Session (2006)
Member, Bureau of Economic Geology Publication Board (2004–2006)

Jeffrey G. Paine
President Elect, Environmental and Engineering Geophysical Society Board of Directors (2006)

Stephen C. Ruppel
Chair, American Association of Petroleum Geologists Annual Convention, Houston, Texas SEPM Field Trip and Short Course Committee (2006)
Member, John A. and Katherine G. Jackson School of Geosciences, The University of Texas at Austin Endowments Committee (2005–2006)

Scott W. Tinker
Board Member, Quantum Technology Services, Inc. (2006)
Member, Budget Review & Finance Committee (2006–2007)
Member, Indiana University Geologic Field Station Advisory Board (2006–present)
Member, National Petroleum Council (2006–present)
Member, Quantum Technology Services, Inc. Board of Advisors (2006)
Member, Supply Task Group of the NPC Committee on Global Oil & Gas, National Petroleum Council (2006–present)
Member, University of Michigan Department of Geosciences Advisory Board (2006)
Member, University of Michigan Department of Geological Sciences Alumni Advisory Board (2006–2011)

Mark Tomasso
Co-Chair, American Association of Petroleum Geologists/Society of Economic Paleontologists and Mineralogists Annual Meeting Poster Session on 3-D Outcrop Imaging, Reservoir Analogs, and Teaching (2006)
Co-Chair, 26th Annual GCSSEPM Foundation Bob F. Perkins Research Conference Outcrops and Modern Environments as Analogs for Characterizing Reservoirs (2006)

Ramón H. Treviño

Lesli J. Wood
Co-Convenor, 2006 Hedberg Conference on Mobile Shale Basins, Port of Spain, Trinidad (2006)
Member, Jackson School of Geosciences, The University of Texas at Austin Admissions Committee (2006–present)
Member, Jackson School of Geosciences, The University of Texas at Austin Strategic Planning Committee (2006–present)

Wayne R. Wright
Session Judge, American Association of Petroleum Geologists Annual Convention, Houston, Texas SEPM (2006)

CONGRESSIONAL, LEGISLATIVE, AND SPECIAL COMMITTEE TESTIMONY

Michelle M. Foss
California Energy Commission, LNG Access Workshop

Susan D. Hovorka
National Academy of Science Committee, Earth resources in “Overview of Carbon Storage Field Projects,” Washington, D.C., April.
Scott W. Tinker
Committee on the Whole of the Texas State Board of Education, Austin, Texas, November.

UNIVERSITY TEACHING

Peter Eichhubl
Structural Diagenesis Master Class: co-instructor of biweekly graduate seminar, Department of Geological Sciences, The University of Texas at Austin, Austin, Texas, Spring.

Introduction to Geological Field Methods, lecture and field instruction, 3 units: Texas A&M University–Corpus Christi, Corpus Christi, Texas, Fall.

Structural Geology, lecture and lab, 4 units: Texas A&M University–Corpus Christi, Corpus Christi, Texas, Fall.

Bob A. Hardage
Vertical seismic profiling: presented at Universidad Nacional Autónoma de Mexico, 3-hour-credit graduate course, Mexico City, Mexico.

Michael R. Hudec
Principles and Applications of Salt Tectonics: presented to The University of Texas at Austin AAPG Student Chapter, Austin, Texas, January.

F. Jerry Lucia
Advanced Reservoir Characterization Carbonates: Instructor, Department of Geological Sciences, The University of Texas at Austin, Austin, Texas, Spring.

Jeffrey G. Paine
Hydrogeophysical field methods: presented to Hydrogeology Field Methods class (GEO 376L), Department of Geological Sciences, The University of Texas at Austin, Austin, Texas, May.

Overview of near-surface geophysics in engineering and environmental studies: presented to Engineering Geology class (CE 387G), Department of Civil, Architectural, and Environmental Engineering, The University of Texas at Austin, Austin, Texas, July.

PUBLIC OUTREACH

Amanda R. Masterson
Panning for Gold: presented at Explore UT day, Austin, Texas, March.

Beverly B. DeJarnett

All that glitters: demonstration presented at Explore UT, Austin, Texas, March.

Making of “Tour through the Edwards Aquifer” movies: presented at Explore UT, Austin, Texas, March.

Tour through Edwards aquifer: presented at Explore UT, Austin, Texas, March.

All that glitters: demonstration presented at Zilker Geofest, Austin, Texas, August.

One-on-one mentoring of high school students Trey Ballman, Jenna Kroman, Tanner Scheneward: Bureau of Economic Geology, Austin, Texas.

Wayne R. Wright
Morrow and Atokan-age limestones at Pedernales Falls State Park: presented as co-leader of field trip with Charles Kerans for U.T. Department of Geological Sciences, Pedernales Falls State Park, Texas, April.

K–12

Beverly B. DeJarnett

Susan D. Hovorka
Host for shadowing: three “COOL Week” students from Leander and Cedar Park High Schools, Austin, Texas, February.

All that glitters: demonstration presented at Explore UT, Austin, Texas, March.

Making of “Tour through the Edwards Aquifer” movies: presented at Explore UT, Austin, Texas, March.

Tour through Edwards aquifer: presented at Explore UT, Austin, Texas, March.

All that glitters: demonstration presented at Zilker Geofest, Austin, Texas, August.

One-on-one mentoring of high school students Trey Ballman, Jenna Kroman, Tanner Scheneward: Bureau of Economic Geology, Austin, Texas.

Randy L. Remington
The rock cycle: presented to Llano Jr. High 6th grade science classes, Llano, Texas.
Papers


Hardage, B. A., DeAngelo, Michael, Sava, Diana, and Remington, Randy, 2006, Technology can avoid the fizzes: AAPG Explorer, Geophysical Corner, March, p. 28–29.


Hovorka, S. D., Doughty, Christine, Benson, S. M., Freifeld, B. M., Sakurai,


McPherson, Brian, Chidsey, Tom, Holtz, Mark, Heath, Jason, Han, Weonshik, Allis, Rick, and Benson, Richard, 2006, Initial and ongoing results of CO2 sequestration field demonstrations in the southwestern USA, in 8th International Conference on Greenhouse Gas Control Technologies, Trondheim, Norway, June 19–22, CD-ROM [5 p.].


Nance, H. S., 2006, Tracking salinity sources to Texas streams: examples from West Texas and the Texas Gulf Coastal Plain: Gulf Coast Association of Geological Societies Transactions, v. 56, p. 675–693.


Sava, Paul, and Fomel, Sergey, 2006, Generalized imaging conditions for wave-equation migration: Colorado School of Mines, Center for Wave


Abstracts


Ambrose, W. A., Holtz, M. H., and Nuñez López, Vanessa, 2006, CO$_2$ EOR plays and geologic controls on CO$_2$ sequestration in the Gulf Coast and Permian Basin (abs.), in Program with abstracts, Southwest

Ambrose, W. A., Holtz, M. H., and Nuñez, Vanessa, 2006, CO₂ EOR plays and geologic controls on CO₂ sequestration in the Gulf Coast and Permian Basin (abs.), in Southwest Section AAPG annual meeting: Permian Basin oil: good to the last drop, May 22–24, Midland, Texas, unpaginated.


Browaeys, T. J., and Chevrot, S., 2006, Decomposition of anisotropic elastic tensors by Euclidean projections on symmetry class subspaces (abs.), in 12th International Workshop on Seismic Anisotropy, Beijing, China, October 22–27, unpaginated.

Brown, L. F., Jr., 2006, Applying sequence-stratigraphic technology and depositional systems tract analysis using wireline logs and 3 D seismic data to define new subtle targets in mature producing areas, Eastern Shelf and basin margin of West Texas Basin, North-Central Texas (abs.), in New E & P opportunities—case studies, bypassed pays, unconventional resources and play openers, October 10, Houston: SITES Houston Chapter, 2006 Continuing Education Seminar, p. 8–9.


Davies, R., and Wood, L. J., 2006, Hollis Hedberg’s years in Trinidad and eastern Venezuela—retracing his steps (abs.), in Mobile shale basins—genesis evolution and hydrocarbon systems, Port of Spain, Trinidad: Hedberg Conference Proceedings, unpaginated.


Gibeauf, J. C., 2006, Texas shoreline change analysis and communicating the results to the public (abs.), in Shoreline Change Conference II: a workshop on managing shoreline change, May 3–5, Charleston, South Carolina.


Holtz, M. H., 2006, Probabilistic reserve estimation at the reservoir scale, in Reserves North America 2006, February 27, Houston (abs.): IQPC, Oil & Gas IQ, CD-ROM.


Hovorka, S. D., Smyth, R. C., and Paine, J. G., 2006, Downsampling capacity from a regional to a site scale—a case for the southeastern U.S. (abs.), in Fifth Annual Conference on Carbon Capture & Sequestration: Taking steps toward deployment utilizing the accumulated knowledge base, May
8–11, Alexandria, Virginia, unpaginated.


Manzocchi, T., Walsh, J. J., Strand, J., Tomasso, M., Childs, C., and Haughton, P., 2006, Static and dynamic connectivity in bed-scale models of turbidites (abs.), in Structurally complex


Lakshminarasimhan, Srivatsan, 2006, Leakage pathways from potential CO₂ storage sites in the Texas Gulf coast and implications for permitting (abs.), in Fifth Annual Conference on Carbon Capture & Sequestration: Taking steps toward deployment utilizing the accumulated knowledge base, May 8–11, Alexandria, Virginia, unpaginated.


Pyles, David, and Bouroullec, Renaud, 2006, Processes and facies associations in basin-margin strata of structurally confined submarine fans: example from the Carboniferous Ross Sandstone, western Ireland (abs.): American Association of Petroleum Geologists Annual Convention, v. 15, p. 87.


Soto, M. D., Mann, Paul, and Wood, L. J., 2006, Structural and stratigraphic evidence for the offshore extension of the central range fault zone of Trinidad into the eastern offshore region (abs.): American Association of Petroleum Geologists Annual Convention, v. 15, p. 100.


Tinker, S. W., 2006, The "I" in business ethics (abs.), in Program Austin Geological Society.

Tinker, S. W., 2006, The "I" in business ethics (abs.), in TCEQ program, Texas Commission on Environmental Quality.


Contract Reports


Guevara, E. H., and Breton, Caroline, 2006, Pennsylvanian coal and coaly shale samples, Young County, North-Central Texas: drill cuttings sampling for coal-rank determination: The University of Texas at Austin, Bureau of Economic Geology, annual report prepared for U.S. Geological Survey, NCRDS State Cooperation Program, under award number 05ERAG0019, 29 p. + apps.


Janson, Xavier, Bellian, J. A., Jennings, J. W., Jr., and Lucia, F. J., 2006, 3-D modeling of Permo-Triassic carbonate outcrop analogs for advanced reservoir char-
acterization: The University of Texas at Austin, Bureau of Economic Geology, Reservoir Characterization Research Laboratory, final report prepared for Saudi Aramco, 80 p. + apps.


Nicot, J. -P., and Duncan, I. J., 2006, Preliminary CO₂ storage outlook in Matagorda and surrounding counties, Texas: The University of Texas at Austin, Bureau of Economic Geology, final report prepared for Sargent & Lundy LLC, 42 p.


Paine, J. G., Collins, E. W., and Nance, H. S., 2006, Geophysical investigations of salinization along the Upper Colorado River between Lake Thomas and Ivie Reservoir, Texas: The University of Texas at Austin, Bureau of Economic Geology, final report prepared for Texas Commission on Environmental Quality, 111 p. + CD-ROM.


White, W. A., Tremblay, T. A., Waldinger, R. L., and Calnan, T. R., 2006, Status and trends of wetland and aquatic habitats on Texas barrier islands, Coastal Bend: The University of Texas at Austin, Bureau of Economic Geology, final report prepared for the Texas General Land Office and National Oceanic and Atmospheric Administration, under GLO contract no. 05-041, a report of the Coastal Coordination Council pursuant to, National Oceanic and Atmospheric Administration Award No. NA04NOS4190058, 64 p. + CD-ROM.