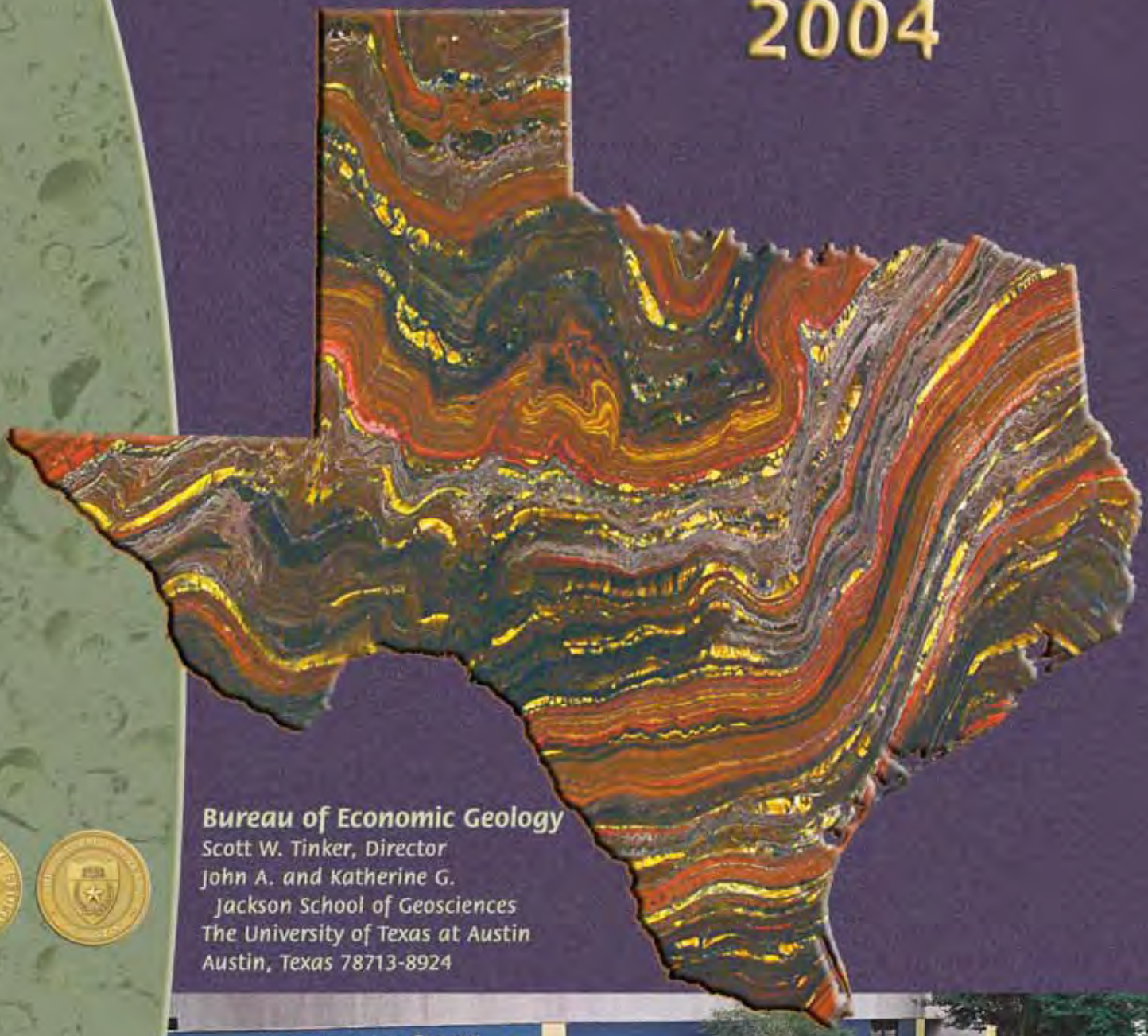
# Annual Report 2004



**Bureau of Economic Geology**
Scott W. Tinker, Director
John A. and Katherine G.
Jackson School of Geosciences
The University of Texas at Austin
Austin, Texas 78713-8924

# Bureau of Economic Geology

## Director's Message

I am reading Bill Bryson's *A Short History of Nearly Everything*. Woven into the text are insights into the minds of several centuries' worth of leading scientific thinkers. One of the more fascinating figures was 18th century Englishman Henry Cavendish: highly privileged, intellectually gifted, and perhaps one of the most withdrawn human beings in the history of science. Apparently without telling anyone, Cavendish "discovered or anticipated the law of conservation of energy, Ohm's law, Dalton's Law of Partial Pressures, Richter's Law of Reciprocal Proportions, Charles's Law of Gases, and the principles of electrical conductivity . . . foreshadowed . . . the effect of tidal friction on slowing the rotation of the earth . . . and left clues that led directly to the discovery of . . . the noble gases." Unfortunately what Cavendish discovered did not impact society until Ohm, Dalton, Richter, Charles, and others rediscovered these breakthrough concepts and then risked personal reputations to bring them into the public eye.

As I read through the pages of this Annual Report, and consider as well the myriad of other projects and programs going on at the Bureau, the words "risk" and "impact" again come to mind. The science and engineering studies conducted by Bureau researchers and supported by our great staff have an impact on our lives and on our planet. From leading the country to develop a viable carbon capture and storage industry in the Gulf Coast, to studying the precious resource we call water, to mapping the wetlands along our unique Texas coast, to conducting high-tech studies related to fossil energy, the Bureau is engaged in research that makes an impact.

Impact research takes fundamental knowledge one step further and risks testing the results in real-world applications. It can be a humbling experience when theory and application do not align, but there is little in life more exhilarating than bringing science to bear on societal issues and improving the world a little along the way.

That is what we do at the Bureau—take risks in order to make an impact—and every day I am proud of those who do it.


### Director
Scott W. Tinker

### Associate Directors
Eric C. Potter, Energy
Jay A. Raney (Jan.–Aug.), Ian Duncan (since July), Environment and Earth Systems
Jay P. Kipper, Administration

### Research and Administrative Office and Laboratories
J. J. Pickle Research Campus
10100 Burnet Road
Austin, Texas 78758-4445
(512) 471-1534, Switchboard
(512) 471-0320, Public Information
(512) 471-0140, Fax
(512) 471-7144, Publication Sales
1-888-839-4365, Toll-free phone (USA)
1-888-839-6277, Toll-free fax (USA)

### Mailing address
The University of Texas at Austin
University Station, Box X
Austin, Texas 78713-8924

### Web site
www.beg.utexas.edu

### Technical editing
Sylvia J. Jennette

### Photography
David M. Stephens

### Editing and production coordination
Susann Doenges

### Design, layout, and cover
Jamie H. Coggin

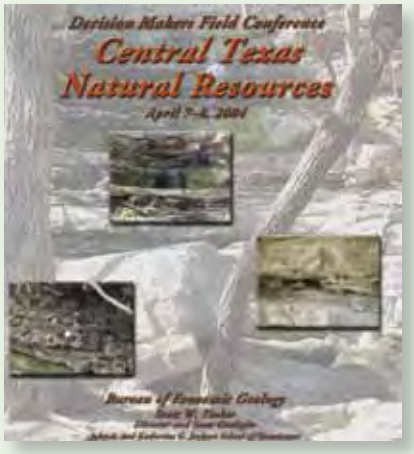
*Cover image:* The Houston Research Center grand opening.

*Page 1 image:* Fractures in folds were the focus of the 2004 Fracture Research and Application Consortium field trip and research meeting in Utah. Satellite image shows Split Mountain Anticline (center of image), Dinosaur National Monument, Utah, one of the field-trip stops.


### Contents

# Organizational Highlights

The first **Decision Makers Field Conference: "Central Texas Natural Resources"** was hosted by the Bureau April 7–8. More than 30 State legislators, key legislative staff, and leaders of State agencies attended. Participants were given a unique opportunity to explore the natural resources of Central Texas, including groundwater resources, fossil fuels, and nonfuel mineral resources, and to discuss these issues with the experts.




**Ian Duncan** became the Bureau's **Associate Director for Environment and Earth Systems** on July 1, replacing **Jay Raney,** who served in this role for nearly 10 years. Ian came to the Bureau after 10 years as a Scientist Manager at the Virginia Department of Mines, Minerals and Energy Division of Mineral Resources, and prior to that he was a geology professor at SMU in Dallas and Washington University in St. Louis.

The official **grand opening** of the **Houston Research Center** (HRC) was held June 4 at the facility located at 11611 West Little York Road. In this year alone, the HRC received donations and grants from Occidental Petroleum Corporation, U.S. Department of Energy, National Science Foundation, XTO Energy, and Anadarko Petroleum Corporation. In April Unocal donated its technical library to the HRC. This donation, valued at nearly $5 million, includes books, journals, monographs,

maps, and State and Federal geological reports primarily in the areas of geology, geochemistry, geophysics, and petroleum engineering. The library is available to the public, benefiting professionals throughout the Houston area.

Researchers and media staff are completing an animation of the **geologic history of the Texas Gulf Coastal Plain** that will be installed as the **centerpiece animation** for the soon-to-be-unveiled renovated Weiss Energy Hall exhibit at the **Houston Museum of Natural Science.** The 7-minute film takes us from the onset of the Triassic rifting to the present day and is being constructed with detailed 3-D models and 2-D animations and graphics. Presenting the scientific information in a clear and entertaining way, this animation will offer the nearly 2 million visitors a year an appreciation of the varied and complex geology that lies beneath the coastal plain.

The Bureau has hired **students** from a variety of UT departments to help with research and administrative work for more than 30 years. In the fall of 2004, 23 graduate and 3 undergraduate students worked part-time at the Bureau. Most of these students work alongside senior researchers, and 15 have chosen Bureau researchers as their primary supervisor. The students gain experience working in an applied geoscience environment while developing their theses and dissertations from current research concepts and goals. Researchers, in turn, are rewarded with exciting new talent and enthusiasm—and **significant contributions** to their research.

## Awards and Honors

**William Ambrose** was awarded the A. I. Levorsen Memorial Award for Best Paper by the American Association of Petroleum Geologists for his paper titled "Miocene Valley-Fill, Slope, and Submarine-Canyon Systems in the Laguna Madre–Tuxpan Area, Mexico" presented at the 2003 Gulf Coast Association of Geological Societies Annual Convention in Baton Rouge, Louisiana. Bill also received the Best Paper Award from the Houston Geological Society for his presentation titled "Upper Miocene and Pliocene Gas and Oil Plays in the Macuspana Basin, Southeastern Mexico."

**L. F. Brown, Jr., Bob Loucks,** and **Ramón Treviño** received the Third Place 2004 Gulf Coast Association of Geological Societies/Gulf Coast Section SEPM Gordon I. Atwater Best Poster Award for their poster "Isochronous Correlation of Sandstone Facies within and between Growth-Faulted Frio Intraslope Sub-basins: Common Correlation Pitfalls."

**Sergey Fomel** received Honorable Mention, Best Paper Award in Geophysics from the Society of Exploration Geophysicists for his paper titled "Angle-Domain Common-Image Gathers by Wavefield Continuation Methods."

**Bob Loucks** and **Charles Kerans** received the Second Place 2003 Gulf Coast Association of Geological Societies/Gulf Coast Section SEPM Gordon I. Atwater Best Poster Award for their poster titled "Lower Cretaceous Glen Rose 'Patch Reef' Reservoir in the Chittim Field, Maverick County, Texas."

**F. Jerry Lucia** was named a "50-Year Fellow" by the Geological Society of America in recognition of his 50 years of support and commitment to the Society.

A poster produced by UT graduate student **Kristine L. Mize** and coauthors **Lesli J. Wood** and Paul Mann received the SEPM Best Poster Award at the 2004 American Association of Petroleum Geologists/SEPM annual meeting. The poster is titled "Controls on the Morphology and Development of Deep-Marine Channels, Offshore Trinidad and Eastern Venezuela." This major award is rarely given to a graduate student.

**Doug Ratcliff** received the Second Annual Bureau of Economic Geology Alumnus of the Year award. Now Associate Director of the Geology Foundation and the Jackson School, Doug was the Associate Director for Administration at the Bureau for more than 20 years.

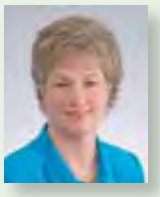
**Stephen C. Ruppel** received the Luncheon Speaker Best Paper Award for 2003–2004 from the Permian Basin Section SEPM (Society for Sedimentary Geology) for the talk he gave in October 2003: "Reservoir Architecture of the Giant Fullerton Clear Fork Field; Insights for Reservoir Characterization in the Permian Basin."

Computing Services Manager **Ron Russell** was awarded the Jackson School Staff Excellence Award for exemplary performance at the Bureau. This first-ever Jackson School Staff Excellence Award was presented to one member of each unit of the Jackson School.

**Bridget Scanlon** was awarded the Conservation Award from Barton Springs Edwards Aquifer Conservation District.

**Scott Tinker** was asked to serve as the American Association of Petroleum Geologists Distinguished Ethics Lecturer for 2005 and 2006, which will involve lectures at various conferences and venues worldwide. Scott also earned a listing in Who's Who in Sciences Higher Education, published by AcademicKeys.

**Jenny Turner** was awarded one of 30 Staff Excellence and Outstanding Supervisor Awards at the University's 43rd Annual Staff Recognition Program and President's Reception. The award recognizes non-teaching UT Austin employees who have made outstanding contributions to the continuing success of the University.



**Hongliu Zeng** and **Charles Kerans** were chosen to receive the Wallace E. Pratt Memorial Award for the best paper published in the American Association of Petroleum Geologists Bulletin in 2003 for their paper "Seismic Frequency Control on Carbonate Seismic Stratigraphy: a Case Study of the Kingdom Abo Sequence, West Texas."

## Changes in Bureau Staff

Two long-time Bureau researchers were promoted to the title Senior Research Scientist, which is equivalent to the position of full Professor in the University. **Stephen C. Ruppel,** who was promoted in April and has been with the Bureau since 1981, is a specialist in carbonate reservoir characterization. **F. Jerry Lucia** was promoted in May. Jerry joined the Bureau in 1985 and specializes in carbonate geology and petroleum geological engineering. He is the first Bureau employee without a Ph.D. to be promoted to the position of Senior Research Scientist.

New Research Associate **Alan Lee Brown** has joined the Bureau after 5 years as Product Development Manager at Landmark Graphics. Prior to his stint at Landmark, he was a geologist for 18 years at Amoco Production Company in New Orleans and Houston. Alan has a Ph.D. from Louisiana State University (2002), an M.S. degree from West Virginia University (1982), and a B.S. degree from James Madison (1977). His interests include reservoir characterization and integrating petrophysics and geophysical analyses.

**Ian Duncan** became the Bureau's Associate Director for Environment and Earth Systems on July 1, replacing **Jay Raney**, who served in this role for nearly 10 years and continues to work at the Bureau in a technical capacity. Ian joined the Bureau after 10 years as a Scientist Manager at the Virginia Department of Mines, Minerals and Energy Division of Mineral Resources. Ian's interests lie in environmental geology, remote sensing, carbon sequestration, and geoinformatics.

Postdoctoral Fellow **David Pyles** joined the Bureau after receiving his Ph.D. in geology from the University of Colorado at Boulder (2004). David has an M.S. degree in geology from the Colorado School of Mines (2000) and a B.S. degree in geology from California State University, Chico (1997). His research interests include stratigraphy, sedimentology, clastic facies analysis, and seismic data interpretation.

**Diana Sava** is a new Research Associate at the Bureau. She holds a B.S. (1995) in engineering geophysics from the University of Bucharest, Romania, and an M.S. (2001) and Ph.D. (2004) in geophysics from Stanford University. Diana's interests include statistical rock physics for reservoir characterization, quantitative integration of geological and seismic data, seismic fracture characterization, and gas hydrates.

**Paul Sava,** a new Research Associate at the Bureau, holds an engineering degree in geophysics (1995) from the University of Bucharest, as well as M.S. (1998) and Ph.D. (2004) degrees in geophysics from Stanford University. His main research interests are in seismic imaging and velocity analysis using wavefield extrapolation techniques, computational methods for wave propagation, optimization, and high-performance computing.

**Mark Tomasso** is a new Research Associate from the University College in Dublin, where he was working on a postdoctoral study with the Fault Analysis Group. Mark earned a Ph.D. in geology from the University of Birmingham (2001) and a B.Sc. in geology from Royal Holloway, University of London (1997). His research interests are deep-water clastic sedimentology, stratigraphy, reservoir modeling, and seismic interpretation.

**Sharon Campos** joined the Bureau in November as a Senior Administrative Associate, replacing **Glynis Morse**, who left to work at the Geology Foundation. Sharon comes to us from UT's College of Engineering, where she worked for nearly 13 years. She holds a BLS (Bachelor of Liberal Studies) in Business Administration from St. Edward's University and has more than 20 years' experience in government and industry.

**Nancy Cottington** rejoined the Bureau support staff as a Computer Illustrator. A former member of the graphics staff, Nancy has drafted illustrations for the Applied Geodynamics Laboratory's Salt Mine Atlas for several years as a consultant and has returned to the Bureau full-time to support that project.

**Nathan Ivicic** is a Technical Staff Assistant at the Bureau's Core Research Center in Austin. Nathan earned an Associate of Arts degree from Temple College (2001) and a B.S. degree in Government from The University of Texas at Austin (2003).

**David Jordan** joined the Media and Information Technologies group as a GIS programmer. David holds a B.S. degree in geological sciences from The University of Texas at Austin and a Master's in applied geography (M.A.G.) from Texas State University, San Marcos.

**Tom Markowski** is a part-time member of the Geophysical Log Facility staff. Tom scans well logs and updates the well-log database, which serves the Bureau's online Integrated Log and Core Database (IGOR).

**Joseph (Jiandong) Su** joined the Media and Information Technologies group as a database programmer and software systems developer. He holds a B.S. degree in computer science and engineering from Beijing Polytechnic University and has been professionally certified by Microsoft, Sun, and Oracle.

Two long-time researchers and founding members of the Applied Geodynamics Laboratory (AGL) left the Bureau this year. **Dan Schultz-Ela** returned to his roots in western Colorado and continues his ties to AGL as a consultant. **Bruno Vendeville** left the Bureau in February to join the faculty of the Université des Sciences et Technologies de Lille in Lille, France.

**Alan Dutton**, a Bureau researcher since 1982, accepted a position as Associate Professor in the Department of Earth and Environmental Science at The University of Texas at San Antonio. Alan will be continuing his research on groundwater and teaching courses in hydrogeology and groundwater modeling.

# Publications

Bureau scientists publish the results of their research in Bureau publications and professional journals. In addition to publishing more than 100 abstracts, as well as many reports to sponsors, during the year, researchers published the following manuscripts in major journals, books, and memoirs:


Ambrose, W. A., Jones, R. H., Fouad, Khaled, Wawrzyniec, T. F., Jennette, D. C., Sakurai, Shinichi, Dutton, S. P., Dunlap, D. B., Holtz, M. H., Sánchez-Barreda, Luis, Guevara, E. H., Meneses-Rocha, Javier, Lugo, Jorge, Aguilera, Leonardo, Berlanga, José, Miranda, Lino, Morales, J. R., and Rojas, Roberto, 2004, Sandstone architecture of upper Miocene and Pliocene shoreface, deltaic, and valley-fill complexes, Macuspana Basin, southeastern Mexico: The University of Texas at Austin, Bureau of Economic Geology Report of Investigations No. 270, 37 p.

Bouroullec, Renaud, Cartwright, J. A., Johnson, H. D., Lansigu, Christophe, Quemener, J.-M., and Savanier, Dominique, 2004, Syndepositional faulting in the Grès d'Annot Formation, SE France: high-resolution kinematic analysis and stratigraphic response to growth faulting, *in* Joseph, P., and Lomas, S. A., eds., Deep-water sedimentation in the Alpine Basin of SE France: new perspectives on the Grès d'Annot and related systems: Geological Society, London, Special Publications, v. 221, p. 241–265.

Brown, L. F., Jr., Loucks, R. G., Treviño, R. H., and Hammes, Ursula, 2004, Understanding growth-faulted, intraslope subbasins by applying sequence-stratigraphic principles: examples from the south Texas Oligocene Frio Formation: American Association of Petroleum Geologists Bulletin, v. 88, no. 1, p. 1501–1522.

Dooley, Tim, McClay, Ken, Hempton, Mark, and Smit, Dirk, 2004, Basement controls on salt tectonics: results from analog modeling, *in* Post, P. J., Olson, D. L., Lyons, K. T., Palmes, S. L., Harrison, P. F., and Rosen, N. C., eds., Salt-sediment interactions and hydrocarbon prospectivity: concepts, applications, and case studies for the 21st century: 24th Annual GCSSEPM Foundation Bob F. Perkins Research Conference, p. 1138–1174.

Dutton, S. P., and Flanders, W. A., 2004, Evidence of reservoir compartmentalization by calcite cement layers in deep-water sandstones, Bell Canyon Formation, Delaware Basin, Texas, *in* Cubitt, J. M., England, W. A., and Larter, S., eds., Understanding petroleum reservoirs: towards an integrated reservoir engineering and geochemical approach: Geological Society, London, Special Publications, v. 237, p. 279–282.

Fomel, Sergey, 2004, On anelliptic approximations for qP velocities in VTI media: Geophysical Prospecting, v. 52, p. 247–259.

French, V. L., and Kerans, Charles, 2004, Chapter 9. Accommodation-controlled systems-tract-specific facies partitioning and resulting geometric development of reservoir grainstone ramp-crest shoal bodies, *in* Grammer, G. M., Harris, P. M., and Eberli, G. P., eds., Integration of outcrop and modern analogs in reservoir modeling: American Association of Petroleum Geologists Memoir 80, p. 171–190.

Gale, J. F. W., Laubach, S. E., Marrett, R. A., Olson, J. E., Holder, Jon, and Reed, R. M., 2004, Predicting and characterizing fractures in dolostone reservoirs: using the link between diagenesis and fracturing, *in* Braithwaite, C. J. R., Rizzi, G., and Darke, G., eds., The geometry and petrogenesis of dolomite hydrocarbon reservoirs: Geological Society, London, Special Publications, v. 235, p. 177–192.

Hepner, T. L., and Gibeaut, J. C., 2004, Tracking post-storm beach recovery using data collected by Texas high school students: Shore & Beach, v. 72, no. 4, p. 5–9.

Hepner, Tiffany, and Davis, R. A., Jr., 2004, Effect of El Niño (1997–98) on beaches of the peninsular Gulf Coast of Florida: Journal of Coastal Research, v. 20, no. 3, p. 776–791.

Hogan, J. F., Phillips, F. M., and Scanlon, B. R., eds., 2004, Groundwater recharge in a desert environment: the southwestern United States: Washington, D.C., American Geophysical Union, Water Science and Application Series, v. 9, 294 p.

Holtz, M. H., and Major, R. P., 2004, Integrated geological and petrophysical characterization of Permian shallow-water dolostone: Society of Petroleum Engineers Reservoir Evaluation & Engineering, Paper No. SPE 87595, p. 47–58.

Hovorka, S. D., Doughty, Christine, Benson, S. M., Pruess, Karsten, and Knox, P. R., 2004, The impact of geological heterogeneity on $CO_2$ storage in brine formations: a case study from the Texas Gulf Coast, *in* Baines, S. J., and Worden, R. H., eds., Geological storage of carbon dioxide: Geological Society, London, Special Publications, v. 233, p. 147–163.

Hudec, M. R., 2004, Salt intrusion: time for a comeback? *in* Post, P. J., Olson, D. L., Lyons, K. T., Palmes, S. L., Harrison, P. F., and Rosen, N. C., eds., Salt-sediment interactions and hydrocarbon prospectivity: concepts, applications, and case studies for the 21st century: 24th Annual GCSSEPM Foundation Bob F. Perkins Research Conference, p. 119–132.

Hudec, M. R., and Jackson, M. P. A., 2004, Regional restoration across the Kwanza Basin, Angola: salt tectonics triggered by repeated uplift of a metastable passive margin: American Association of Petroleum Geologists Bulletin, v. 88, no. 7, p. 971–990.

Hudec, M. R., and Jackson, M. P. A., 2004, Salt tectonics in the new millennium: navigating the information flood, *in* Post, P. J., Olson, D. L., Lyons, K. T., Palmes, S. L., Harrison, P. F., and Rosen, N. C., eds., Salt-sediment interactions and hydrocarbon prospectivity: concepts, applications, and case studies for the 21st century: 24th Annual GCSSEPM Foundation Bob F. Perkins Research Conference, p. 1–13.

Jackson, M. P. A., and Hudec, M. R., 2004, A new mechanism for advance of allochthonous salt sheets, *in* Post, P. J., Olson, D. L., Lyons, K. T., Palmes, S. L., Harrison, P. F., and Rosen, N. C., eds., Salt-sediment interactions and hydrocarbon prospectivity: concepts, applications, and case studies for the 21st century: 24th Annual GCSSEPM Foundation Bob F. Perkins Research Conference, p. 220–242.

Jackson, M. P. A., Hudec, M. R., and Jennette, D. C., 2004, Insights from a gravity-driven linked system in deep-water lower Congo Basin, Gabon *in* Post, P. J., Olson, D. L., Lyons, K. T., Palmes, S. L., Harrison, P. F., and Rosen, N. C., eds., Salt-sediment interactions and hydrocarbon prospectivity: concepts, applications, and case studies for the 21st century: 24th Annual GCSSEPM Foundation Bob F. Perkins Research Conference, p. 735–752.

Johnson, K. S., Collins, E. W., and Seni, S. J., 2004, Sinkholes and land subsidence owing to salt dissolution near Wink, West Texas, and other sites in western Texas and New Mexico, *in* Johnson, K. S., and Neal, J. T., eds., Evaporite karst and engineering/environmental problems in the United States: Oklahoma Geological Survey Circular 109, p. 183–195.

Lansigu, C., and Bouroullec, R., 2004, Staircase normal fault geometry in the Grès d'Annot (SE France), *in* Joseph, P., and Lomas, S. A., eds., Deep-water sedimentation in the Alpine Basin of SE France: new perspectives on the Grès d'Annot and related systems: Geological Society, London, Special Publications, v. 221, p. 241–265.

Laubach, S. E., Lander, R. H., Bonnell, L. M., Olson, J. E., and Reed, R. M., 2004, Opening histories of fractures in sandstones, *in* Cosgrove, J. W., and Engelder, T., eds., The initiation, propagation, and arrest of joints and other fractures: Geological Society, London, Special Publications, v. 231, p. 1–9.

Laubach, S. E., Olson, J. E., and Gale, J. F. W., 2004, Are open fractures necessarily aligned with maximum horizontal stress?: Earth and Planetary Science Letters, v. 222, no. 1, p. 191–195.

Laubach, S. E., Reed, R. M., Olson, J. E., Lander, R. H., and Bonnell, L. M., 2004, Coevolution of crack-seal texture and fracture porosity in sedimentary rocks: cathodoluminescence observations of regional fractures: Journal of Structural Geology, v. 26, no. 5, p. 967–982.

Loucks, R. G., Mescher, P. K., and McMechan, G. A., 2004, Three-dimensional architecture of a coalesced, collapsed-paleocave system in the Lower Ordovician Ellenburger Group, central Texas: American Association of Petroleum Geologists Bulletin, v. 88, no. 5, p. 545–564.

Lucia, F. J., 2004, Origin and petrophysics of dolostone pore space, *in* Braithwaite, C. J. R., Rizzi, G., and Darke, G., eds., The geometry and petrogenesis of dolomite hydrocarbon reservoirs: Geological Society, London, Special Publications, v. 235, p. 141–155.

McClay, K. R., Dooley, T., Whitehouse, P., Fullarton, L., and Chantraprasert, S., 2004, 3D analogue models of rift systems: templates for 3D seismic interpretation, *in* Davies, R. J., Cartwright, J. A., Stewart, S. A., Lappin, M., and Underhill, J. R., eds., 3D seismic technology: application to the exploration of sedimentary basins: Geological Society, London, Memoirs, v. 29, p. 101–115.

McClay, K. R., Whitehouse, P. S., Dooley, Tim, and Richards, M., 2004, 3D evolution of fold and thrust belts formed by oblique convergence: Marine and Petroleum Geology, v. 21, p. 857–877.

National Research Council (Scanlon, B. R.), 2004, Groundwater fluxes across interfaces: Washington, D.C., The National Academy Press, 85 p.

Osleger, D. A., Barnaby, Roger, and Kerans, Charles, 2004, Chapter 5. A laterally accreting grainstone margin from the Albian of northern Mexico: outcrop model for Cretaceous carbonate reservoirs, *in* Grammer, G. M., Harris, P. M., and Eberli, G. P., eds., Integration of outcrop and modern analogs in reservoir modeling: American Association of Petroleum Geologists Memoir 80, p. 93–108.

Scanlon, B. R., 2004, Evaluation of methods of estimating recharge in semiarid and arid regions in the southwestern U.S., *in* Hogan, J. F., Phillips, F. M., and Scanlon, B. R., eds., Groundwater recharge in a desert environment: the southwestern United States: Washington, D.C., American Geophysical Union, Water Science and Applications Series, v. 9, p. 235–254.

Scott, R. W., and Kerans, Charles, 2004, Late Albian carbonate platform chronostratigraphy, Devils River Formation cycles, West Texas: Courier Forschungsinstitut Senckenberg, v. 247, p. 129–148.

Sullivan, M. D., Foreman, J. L., Jennette, D. C., Stern, David, Jensen, G. N., and Goulding, F. J., 2004, Chapter 11. An integrated approach to characterization and modeling of deep-water reservoirs, Diana field, western Gulf of Mexico, *in* Grammer, G. M., Harris, P. M., and Eberli, G. P., eds., Integration of outcrop and modern analogs in reservoir modeling: American Association of Petroleum Geologists Memoir 80, p. 215–234.

Sullivan, Sean, Wood, L. J., and Mann, Paul, 2004, Distribution, nature and origin of mobile mud features offshore Trinidad, *in* Post, P. J., Olson, D. L., Lyons, K. T., Palmes, S. L., Harrison, P. F., and Rosen, N. C., eds., Salt-sediment interactions and hydrocarbon prospectivity: concepts, applications, and case studies for the 21st century: 24th Annual GCSSEPM Foundation Bob F. Perkins Research Conference, p. 840–867.

Tinker, S. W., Caldwell, D. H., Cox, D. M., Zahm, L. C., and Brinton, Lisë, 2004, Integrated reservoir characterization of a carbonate ramp reservoir, South Dagger Draw field, New Mexico: seismic data are only part of the story, *in* Seismic imaging of carbonate reservoirs and systems: American Association of Petroleum Geologists Memoir 81, p. 91–105.

Tomasso, M., and Sinclair, H. D., 2004, Deep-water sedimentation on an evolving fault-block: the Braux and St. Benoit outcrops of the Grès d'Annot, *in* Joseph, P., and Lomas, S. A., eds., Deep-water sedimentation in the Alpine Foreland Basin of SE France: new perspectives on the Grès d'Annot and related systems: Geological Society, London, Special Publications, v. 221, p. 267–283.

Walvoord, M. A., and Scanlon, B. R., 2004, Hydrologic processes in deep vadose zones in interdrainage arid environments, *in* Hogan, J. F., Phillips, F. M., and Scanlon, B. R., eds., Groundwater recharge in a desert environment: the southwestern United States: Washington, D.C., American Geophysical Union, Water Science and Applications Series, v. 9, p. 15–28.

White, C. D., Willis, B. J., Dutton, S. P., Bhattacharya, J. P., and Narayanan, Keshav, 2004, Chapter 7. Sedimentology, statistics, and flow behavior for a tide-influenced deltaic sandstone, Frontier Formation, Wyoming, United States, *in* Grammer, G. M., Harris, P. M., and Eberli, G. P., eds., Integration of outcrop and modern analogs in reservoir modeling: American Association of Petroleum Geologists Memoir 80, p. 129–152.

Wood, L. J., 2004, Chapter 3. Predicting tidal sand reservoir architecture using data from modern and ancient depositional systems, *in* Grammer, G. M., Harris, P. M., and Eberli, G. P., eds., Integration of outcrop and modern analogs in reservoir modeling: American Association of Petroleum Geologists Memoir 80, p. 45–66.

Wood, L. J., Sullivan, Sean, and Mann, Paul, 2004, Influence of mobile shales in the creation of successful hydrocarbon basins, *in* Post, P. J., Olson, D. L., Lyons, K. T., Palmes, S. L., Harrison, P. F., and Rosen, N. C., eds., Salt-sediment interactions and hydrocarbon prospectivity: concepts, applications, and case studies for the 21st century: 24th Annual GCSSEPM Foundation Bob F. Perkins Research Conference, p. 892–930.

Zeng, Hongliu, and Hentz, T. F., 2004, High-frequency sequence stratigraphy from seismic sedimentology: applied to Miocene, Vermilion Block 50, Tiger Shoal area, offshore Louisiana: American Association of Petroleum Geologists Bulletin, v. 88, no. 2, p. 153–174.

# Research

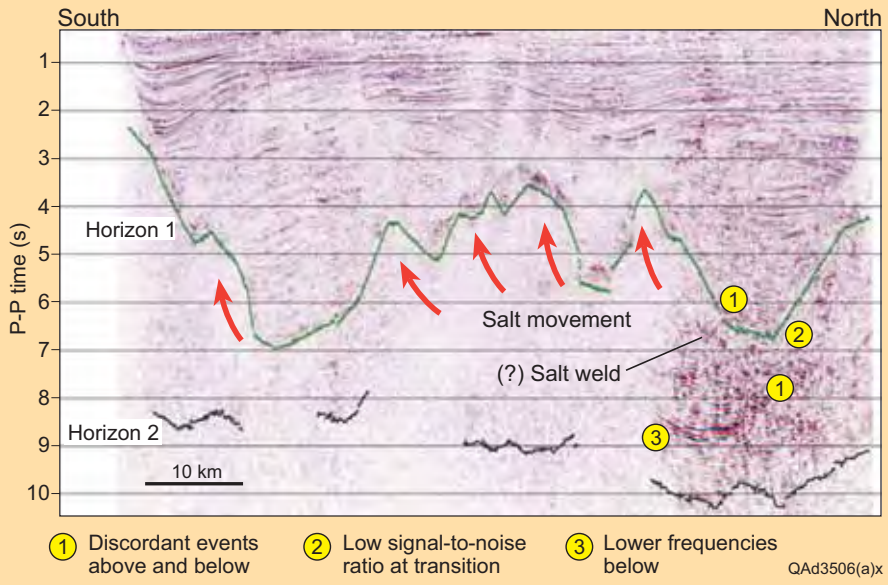
## Energy

### Imaging Deep Gas Prospects Using Multicomponent Seismic Technology

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 deepest target depth that will 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 with 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 quite 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.

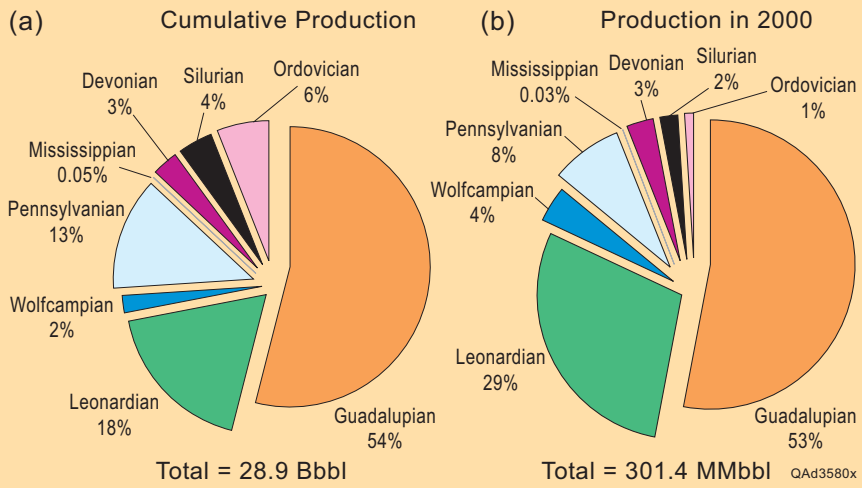
This research was designed to investigate the value of long-offset multicomponent seismic data for studying deep-gas geology across the northern shelf of the GOM. The term *long offset* means that 4-C OBC data were processed using uniformly sampled source-receiver offsets ranging from 0 to 10 km. The study area was a large, 3,200-mi$^2$ (8,200-km$^2$) section of the Louisiana shelf noted for prolific gas production. Data consisted of parallel north-south and parallel east-west 2-D profiles spaced at intervals of 2 mi. The 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 shows 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 has reflection signal from depths of 42,000 ft (13 km).




P-P image from the east portion of the Shelf-B spec survey.

Funding for the study was provided by the Research Partnership to Secure Energy for America (RPSEA), and long-offset 4-C OBC seismic spec data came from WesternGeco's Shelf-B spec survey, which extends across the West Cameron South, East Cameron South, and Vermilion South areas of the GOM and portions of the West Cameron, East Cameron, and Vermilion areas. Research

investigators were Bob A. Hardage (principal investigator), Milo Backus, Michael DeAngelo, Sergey Fomel, Khaled Fouad, Robert Graebner, Paul Murray, and Randy Remington. The research partner was WesternGeco.



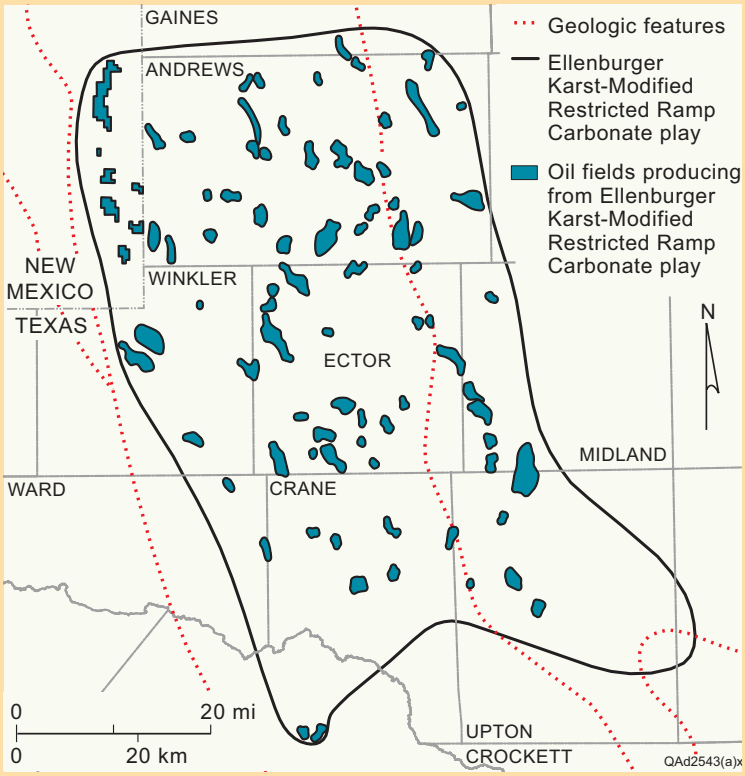

## Play Analysis and Digital Portfolio—Major Oil Reservoirs in the Permian Basin

Researchers at the BEG and the New Mexico Bureau of Geology and Mineral Resources have completed a new digital oil-play portfolio of the prolific Permian Basin of west Texas and southeast New Mexico. This portfolio was developed as part of the U.S. Department of Energy's (DOE) Preferred Upstream Management Practices (PUMP) program and is titled *Play Analysis and Digital Portfolio of Major Oil Reservoirs in the Permian Basin: Application and Transfer of Advanced Geological and Engineering Technologies for Incremental Production Opportunities.*

Project staff include BEG researchers Shirley P. Dutton, Eugene M. Kim, Caroline L. Breton, Stephen C. Ruppel, and Charles Kerans and New Mexico Bureau of Geology and Mineral Resources researchers Ronald F. Broadhead and William D. Raatz. The entire portfolio, including text, large-scale maps of plays, digital reservoir-data files, and the complete GIS project, will be available soon as a Bureau of Economic Geology Report of Investigations CD-ROM.

The Permian Basin of west Texas and southeast New Mexico has produced >30 Bbbl of oil through 2000, and it remains one of the largest petroleum-producing basins in the United States. In 2002, it accounted for 17 percent of the total U.S. oil production, and it contains an estimated 22 percent of the U.S. proved oil reserves. This region also has the biggest potential for additional oil production in the country, containing 29 percent of estimated future oil reserve growth.

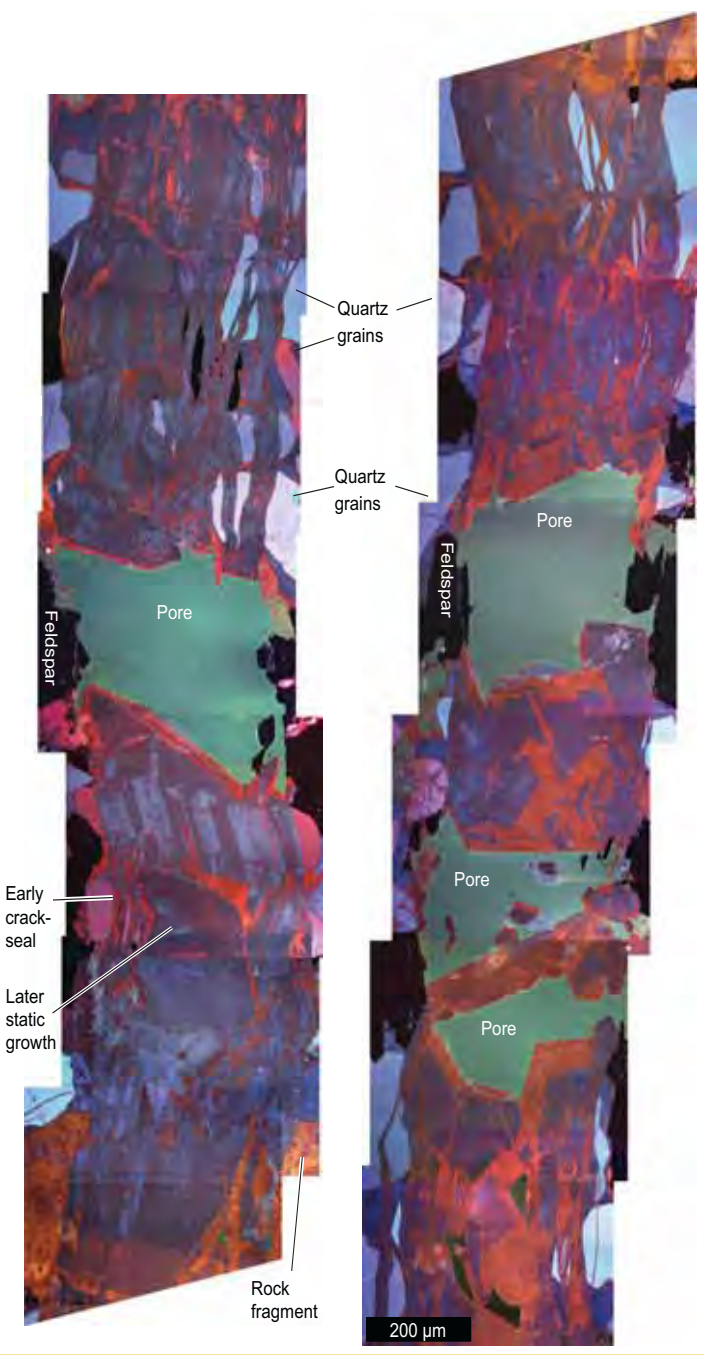
The portfolio was designed to help increase reserves and improve recovery of oil from existing reservoirs in the Permian Basin. It defines 32 oil plays in the Basin and assigns all significant-sized reservoirs that had cumulative production of >1 million barrels (MMbbl) through 2000 to a play. Each of the 1,339 significant-sized reservoirs was mapped in a Geographic Information System (GIS). The portfolio contains a summary description of each play, including illustrations of key reservoir characteristics and reservoir data tables. Summaries of successful reservoir-development practices used in these plays will aid in future production in this mature basin, which will most likely come from improved recovery from existing fields.




Map of the Ellenburger Karst-Modified Restricted Ramp Carbonate play, showing location of reservoirs having >1 MMbbl cumulative production.

# Predicting Fracture Porosity Evolution in Sandstone

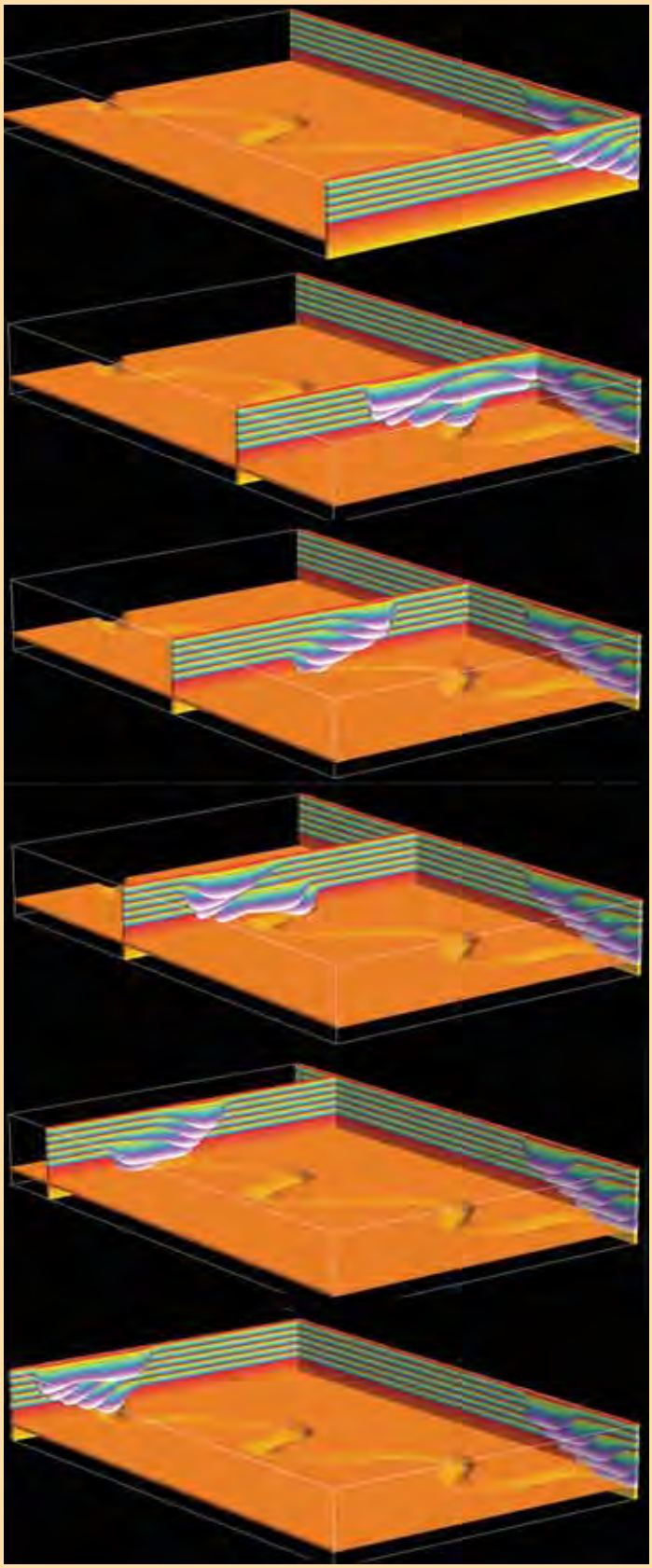
The continuity of fracture-porosity is fundamental to how fractures conduct fluids. It is an increasingly central issue in recovering water and hydrocarbon supplies and geothermal energy, in predicting flow of pollutants underground, in engineering structures, and in understanding large-scale crustal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




Color, scanning electron microscope–based, cathodoluminescence image mosaic along a partly open, quartz-lined macrofracture showing variation of crack-seal texture in the quartz bridges. Bright-green luminescent, epoxy-filled porosity is associated with nonluminescent feldspar grains.

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 rock property tests on specially prepared artificial rocks that have cement and burial history properties of a target formation in the basin. This study is supported by a grant from the U.S. Department of Energy. Recent funding from the Jackson School will permit researchers to extend this study to include the estimation of fracture opening rates, which will be a significant contribution to understanding crustal mechanics and a constraint on intraplate tectonic processes.

Although the project only got under way in 2003, initial results are exciting. In addition to four published papers, research from this project has been recognized in an American Association of Petroleum Geologists (AAPG) Distinguished Lecture tour (by L. M. Bonnell), a Society of Petroleum Engineers Distinguished Lecture tour (by S. E. Laubach), and three invited keynote lectures at international symposia (two by J. E. Olson and one by Laubach/K. L. Milliken). In February 2004, project leaders organized an AAPG Hedberg Research Conference on the interaction of chemical and mechanical processes in the Earth that featured presentations on many aspects of the research program. The project also won the award for the best university presentation at the



Preliminary 3-D model of a stacked series of deep-water clastic channels based upon an outcrop at San Clemente, California, and high-resolution seismic imaging from the Kutei Basin, offshore Borneo.

U.S. Department of Energy Symposium "Flow and Transport: from Pore to Reservoir Scales."

Principal investigators for this research are Stephen E. Laubach (BEG), Robert H. Lander (Geocosm L.L.C.), Jon E. Olson (Department of Petroleum and Geosystems Engineering), Julia F. W. Gale, (BEG), Linda M. Bonnell (Geocosm L.L.C.), and Randall Marrett (Department of Geological Sciences). Collaborating scientists are Kitty L. Milliken (Department of Geological Sciences), Dick Larese (consultant), Jon Holder (Department of Petroleum and Geosystems Engineering), and Rob Reed (BEG). Four graduate students are conducting thesis research on aspects of this study.

## Fluid-Rock-Seismic Technologies (FRST)

The Fluid-Rock-Seismic Technologies (FRST) research program is a new Bureau initiative designed to make improvements in the ability to assess the seismic detection of fine-scale reservoir and seal elements in subsurface reservoir settings. Research is focused on seismic modeling of highly detailed outcrop case studies and will serve to establish and maintain an integrated team of geologists, geophysicists, and engineers committed to cross-disciplinary research and application.

Researchers will integrate research in sedimentology, stratigraphy, rock physics, geophysics, and reservoir engineering to construct high-resolution, outcrop-based models for advanced forward seismic modeling and resolution analysis. Models are currently being developed, tested, and validated. The impact of this research on subsurface geological interpretation and reservoir property quantification will be particularly valuable in settings where drilling costs are high and well data are sparse.

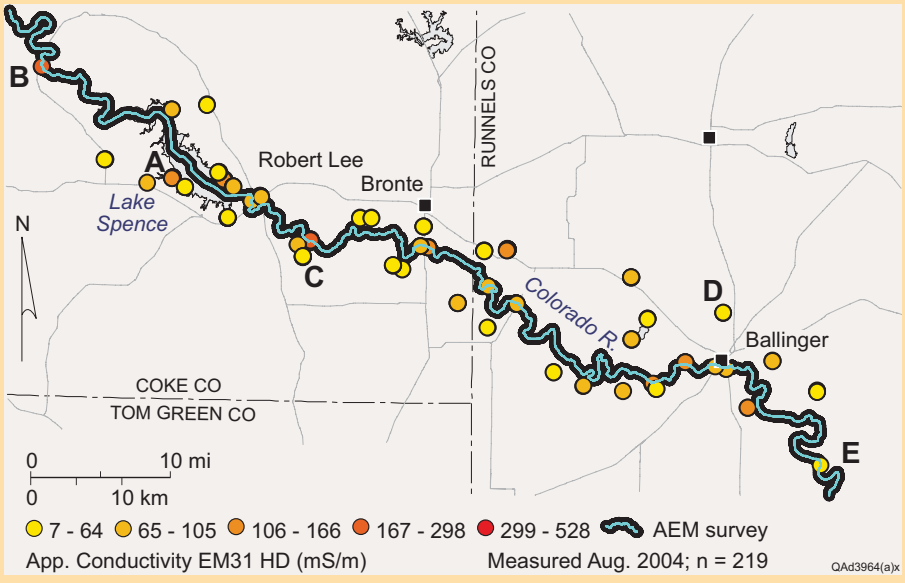
The FRST team comprises BEG researchers James W. Jennings, Jr., Sergey B. Fomel, Diana C. Sava, Paul C. Sava, Mark Tomasso, and David C. Jennette, and UT Institute for Geophysics researcher Mrinal K. Sen. First-year support for research came from ChevronTexaco and the Jackson School of Geosciences. New industrial sponsors are being sought for 2005.

# Environment and Earth Systems

## Project Portfolio with the Texas Commission on Environmental Quality

The BEG has developed a contractual relationship with the Texas Commission on Environmental Quality (TCEQ) that facilitates the BEG's providing research and technical support to the TCEQ. Steve Walden, who retired after many years at TCEQ, has played a key role in establishing this relationship and is working with the BEG on these and other projects.

Four new research projects are under way: (1) Delineating Salinity Sources along Segments of the Colorado River and Petronila Creek, (2) Feasibility Analysis of Water Supply for Small Public Water Systems, (3) Study to Evaluate Electronic Access to Geologic Data and Surface Casing Depths Necessary to Protect Usable Groundwater in the State, and (4) Field Validation of Geologic Assessment of Features Sensitive to Pollution in Karst and Development of Best Management Practices.




August 2004 apparent ground conductivity measurements superimposed on part of the airborne geophysical survey route. Total dissolved solid concentrations in the river and its tributaries were also measured.

**Delineating Salinity Sources along Segments of the Colorado River and Petronila Creek** is led by principal investigator Jeffrey Paine. This study is using ground-based electromagnetic induction (EM) methods to (1) identify and assess the extent, intensity, and potential source areas of salinity-impacted segments of the Colorado River below E. V. Spence Reservoir and Petronila Creek above Baffin Bay and (2) evaluate whether these methods, together with supplemental sampling and chemical analyses of groundwater and surface water, are a viable approach for further characterization studies along these stream segments. New and modified Geographic Information System (GIS) data sets developed during this project will aid in the selection of key stream segments for airborne EM surveys and water sampling in 2005, and enable rapid comparison of data developed during this project with existing spatial data.

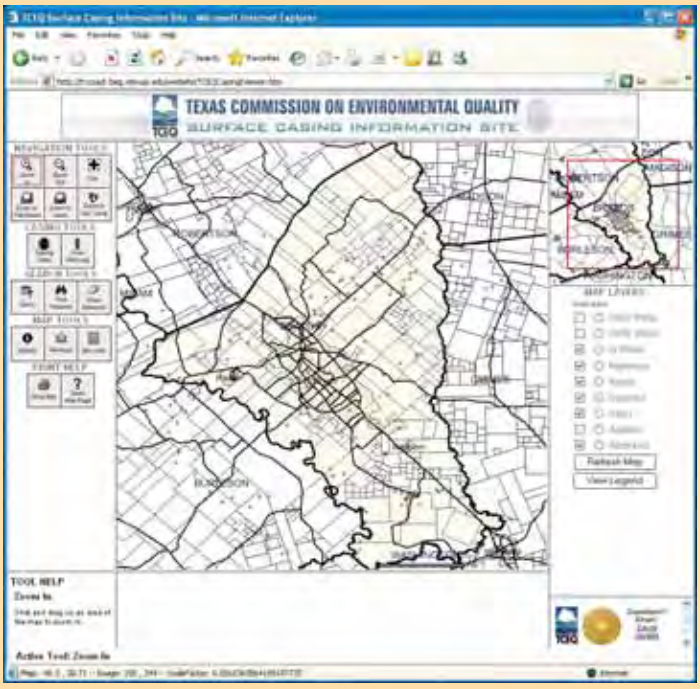
Bridget Scanlon is the principal investigator for the project titled **Feasibility Analysis of Water Supply for Small Public Water Systems**. The purpose of this study is to assist TCEQ with identifying, evaluating, and ranking U.S. Environmental Protection Agency compliance options for selected public water systems (PWS) for the Water Supply Division. Researchers will develop a feasibility report outlining compliance options for each of three PWS's in the Wichita Falls area that exceed nitrate levels and develop general methodology for assisting TCEQ and PWS's that will enable them to reach compliance using sound engineering and financial methods.

The study includes developing an inventory of available sources for groundwater and surface-water quality and water availability data, including data and information from TCEQ, Texas Water Development Board (TWDB), U.S. Geological Survey (USGS), regional planning groups, groundwater districts, groundwater and surface-water availability models, and well driller's logs. The inventory

will first identify all regional data sources, and then further refine data sources to the area within approximately 60 mi of the city of Wichita Falls, which is the pilot study area.

**Study to Evaluate Electronic Access to Geologic Data and Surface Casing Depths Necessary to Protect Usable Groundwater in the State** is led by principal investigator Jay Raney and developed by new Bureau researcher David Jordan. This is a collaboration with TCEQ surface casing staff to develop a prototype Web site 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 the 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 maps of proposed well locations required by TCEQ, obtain estimates of probable surface casing requirements, and review well logs and other relevant information. Although the pilot Web site includes only data from Brazos County, if extended to a larger region of Texas, and eventually statewide, the digital database would be of great benefit to oil and gas operators and the public and would reduce the time and effort required for the TCEQ surface casing review.

**Field Validation of Geologic Assessment of Features Sensitive to Pollution in Karst and Development of Best Management Practices** is led by principal investigator Susan Hovorka. This study will use hydrologic methods to quantify a geomorphic method for assessing sensitive karst features and provide research input that will be useful in improving future methodology. It differs from previous work in that it focuses on water and contaminant flux through typical karst features in upland areas. Initial assessment will include investigating key issues: How much retardation of flow and contaminant does a typical soil in a sinkhole or small cave produce? What area drains into a typical Edwards sinkhole and cave? What percentage of features ranked as significant on geomorphic criteria provide conduit flow into the subsurface? Surface geophysical methods such as ground-penetrating radar, shallow seismic, and conductivity mapping will be used to image the subsurface below the study features. A second goal of the project is to provide up-to-date guidance for control of runoff from new development and



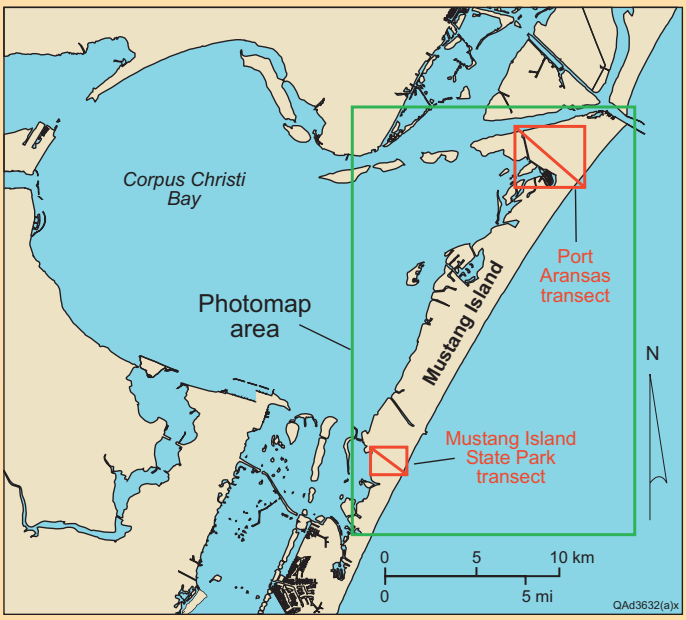

Shown in this figure is the starting page for the TCEQ Surface Casing Information Site, a map-based Web site that provides depth estimates of various subsurface water horizons that must be protected during drilling operations.

for protection of sensitive geologic features. This effort includes a literature review and survey of current practices used nationally and internationally to mitigate the impact of urban runoff. This information will be used to revise and expand TCEQ Document RG-348: Complying with the Edwards Aquifer Rules: Technical Guidance on Best Management Practices.

## High-Tech Wetland Mapping on Mustang Island

A team of Bureau researchers have been investigating whether airborne lidar (light detection and ranging) and EM (electromagnetic induction) can improve the accuracy and resolution of wetland mapping that has historically been conducted using aerial photographs.

Two representative transects across Mustang Island on the central Texas coast were chosen for investigation. Along these transects, researchers surveyed vegetation type, measured the electrical conductivity of the ground (which is closely correlated to salinity), and studied aerial photograph signatures to classify the coastal environments.



Study area on Mustang Island.

Detailed topographic data were collected during an airborne lidar survey and were used to construct Gulf-to-bay elevation profiles. This data set was then compared with traditional wetland maps developed by the U.S. Fish and Wildlife Service in the National Wetlands Inventory (NWI).

Correlations among wetland habitat, coastal environment, elevation, and conductivity suggest that lidar and EM data could be used to improve the accuracy of coastal habitat classification. The topographic detail achieved with lidar allows better discrimination of these environments and complements aerial photographic analysis by helping to distinguish areas having ambiguous photographic signatures, such as upland, palustrine, estuarine, and marine habitats. Conductivity proved to be highly inversely correlated to lidar-derived elevations and correlated well with NWI habitat and coastal environments. Conductivities closely track changes in coastal environment, suggesting that EM data could be used to classify coastal environments to the same level achievable with field-based vegetation surveys.

Bureau researchers involved in these studies on Mustang Island are Jeffrey Paine, James Gibeaut, John Andrews, Tiffany Hepner, Rebecca Smyth, Thomas Tremblay, Rachel Waldinger, and William White.

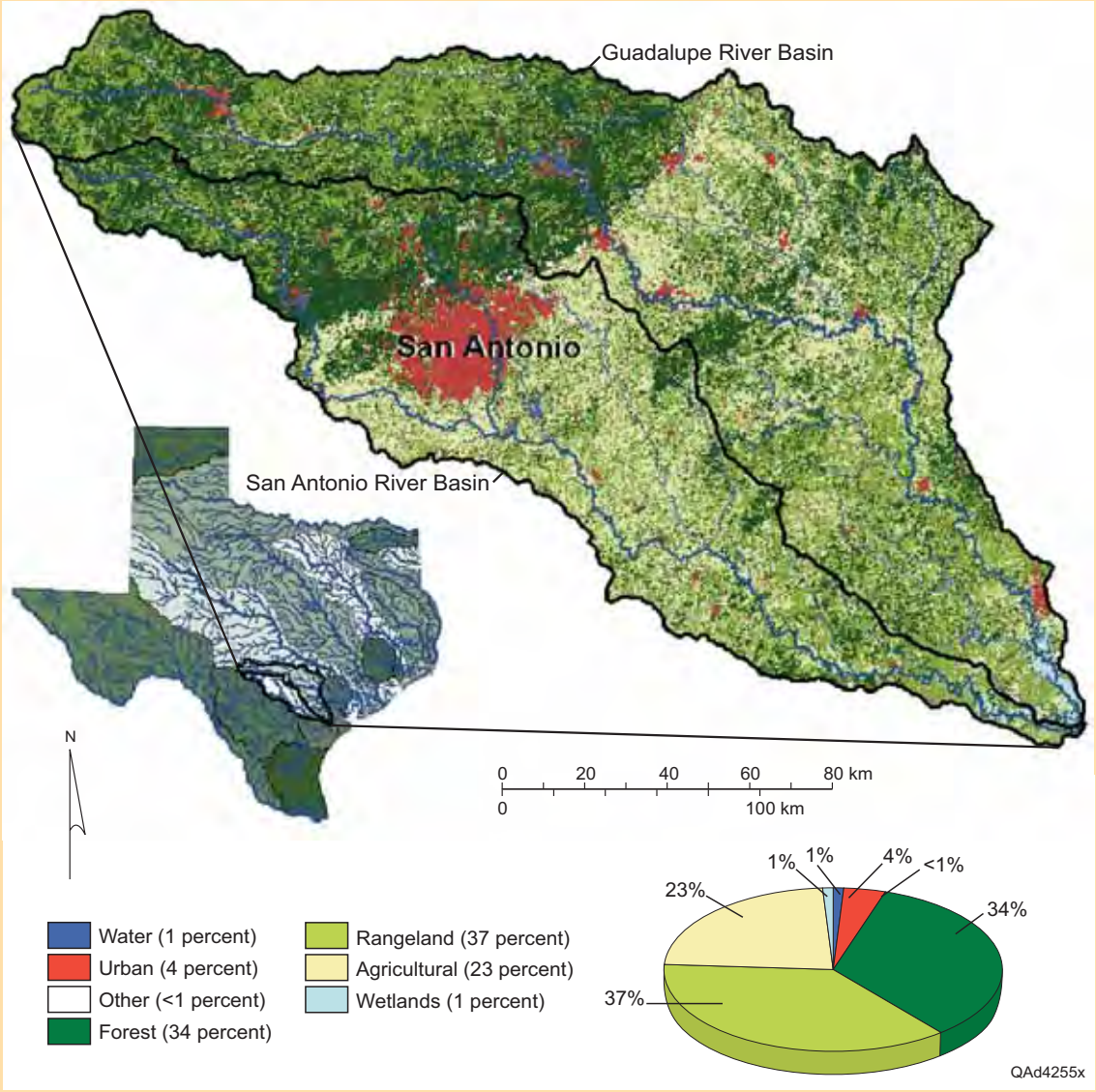
## Water for the Future: Proposed Hydrologic Observatory in Texas

Senior Research Scientist Bridget R. Scanlon and colleagues at other universities and organizations can visualize an ideal field site for answering basic questions about future water supplies in Texas. An area where climates vary, where rainfall is great enough to produce frequent floods and slight enough to cause droughts, where land use and land cover reflect extensive urban development and sparsely populated rural settings, where surface water and groundwater interact, where diverse ecosystems depend on prudent management of resources—all these conditions are met in the adjacent Guadalupe and San Antonio watersheds, which stretch from Central Texas to the Gulf of Mexico.

The proposed Texas Hydrologic Observatory (HO) would give hydrogeologists an opportunity to compare not only diverse watersheds but also different underlying aquifer systems. The Edwards aquifer is a dynamic karst system that responds quickly to changes in climate and land use. In contrast, the Carrizo-Wilcox aquifer is a porous-medium system that responds more slowly to climate and land-use change.

The Guadalupe and San Antonio watersheds and their associated aquifer systems make up an ideal site for observing scientific issues posed by the Consortium of Universities for Advancement of Hydrologic Science, Incorporated (CUAHSI), which was created in 2001 to promote research and education in hydrology. CUAHSI proposed to establish long-term observatories throughout the United States that would develop and maintain hydrogeological data that could be shared by researchers throughout the country. Two sites will be awarded funding by the National Science Foundation (NSF) in 2005. Each site will receive $10 million to cover capital expenses and $3 million annually for 5 years to cover operating expenses, for a total of $25 million. The Bureau is leading the effort to submit a winning proposal for Texas to the NSF. The proposed Texas site would bring together CUAHSI colleagues from many universities in Texas such as Rice University, Texas A&M University, Texas State University, The University of Texas at Austin, and The University of Texas at San Antonio, as well as

individuals from other universities throughout the United States, along with staff at other organizations responsible for data collection and analysis such as the U.S. Geological Survey. River basin authorities, aquifer conservation districts, cities, and Federal, State, and local agencies would also contribute to the research effort to develop a common data infrastructure.




Location map of proposed Texas Hydrologic Observatory, consisting of parallel basins of the Guadalupe and San Antonio Rivers.

Why are these data important? The information the data can yield is key to the future sustainability of water resources. Water quantity and quality are essential to thriving communities and ecosystems. By measuring rainfall, stream flow, and groundwater discharge and recharge, climate patterns over long and short periods, chemical and biological changes in the environment, among other parameters, scientists can develop plans for optimal water use and protection to sustain human and ecosystem needs well into the future.

## Desalination and Deep-Well Injection of Wastes

The demand for fresh water in Texas is increasing as a result of population growth and insufficient surface-water and groundwater supplies. Desalination of brackish water and seawater by reverse osmosis is one viable option to produce fresh water. This technology, which is being investigated by State and local communities, requires a cost-effective and safe solution for disposing of the concentrated waste products that result from the process.

Several alternatives for disposing of these wastes are emerging, including deep-well injection in depleted oil fields. The oil and gas industry in Texas has been reinjecting saline produced waters into the subsurface for years. A combination of deep-well injection and reinjection is attractive for Texas, where oil and gas fields are plentiful and formation pressures have been lowered because of past oil and gas production.

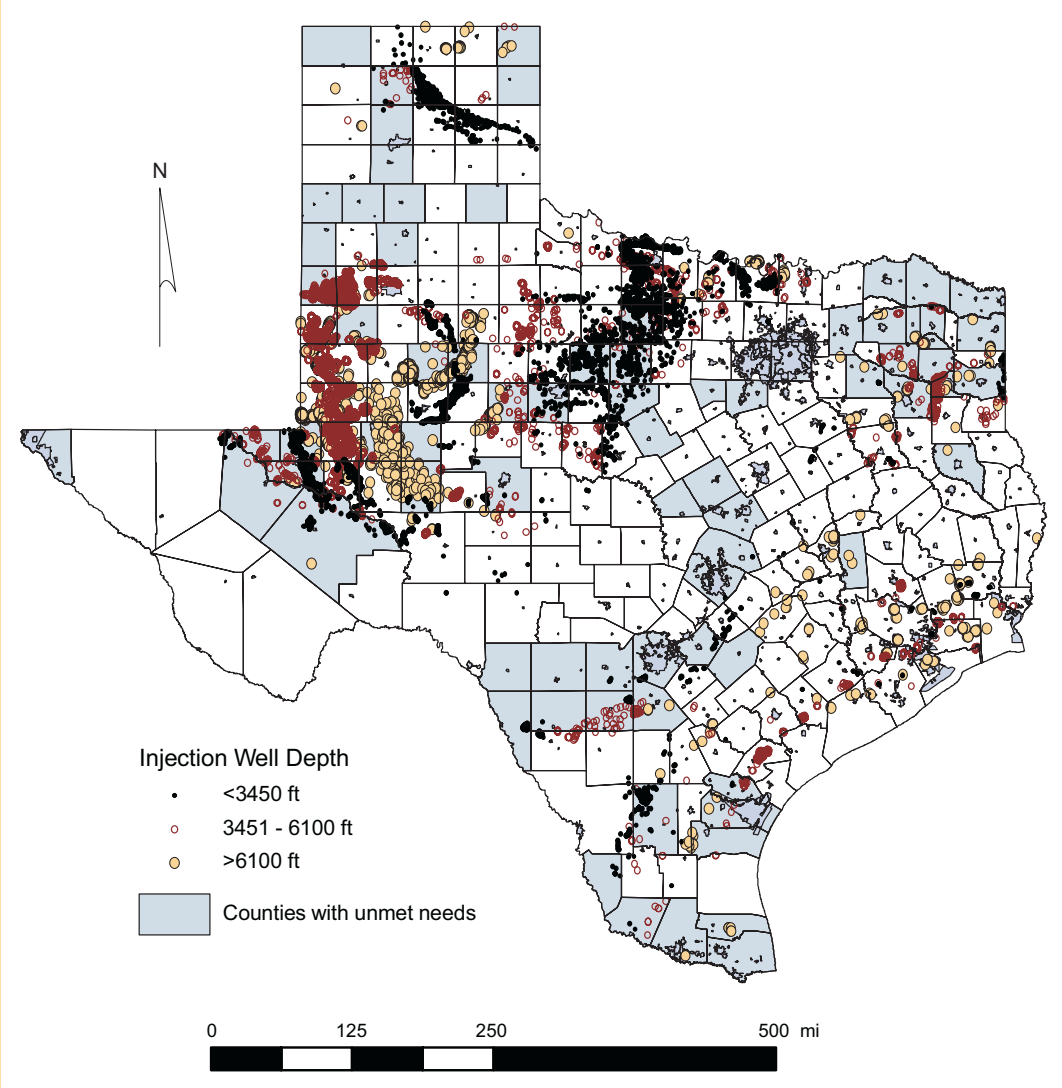
An investigation of this alternative has been under way by a team of researchers at the Texas Water Development Board (TWDB) and the BEG. "Please Pass the Salt: Using Oil Fields for the Disposal of Concentrate from Desalination Plants" is the title of this project, the primary goal of which is to develop a scientific foundation upon which to support recommended policy changes that will enable a faster and more efficient approval process for obtaining permits for injection wells from the Railroad Commission of Texas.

The technical approach for this project (1) identified potential oil fields across the state, (2) demonstrated via physical and geochemical modeling that oil fields can accept concentrate, and (3) proposed recommendations on how to streamline the permitting process. Researchers also communicated with regional and local stakeholders interested in desalination and evaluated the current process for permitting concentrate injection wells. Final recommendations contained in the study—if implemented in the future—could result in a tremendous savings of money and time spent in obtaining a permit for reinjection of saline water.

## Statewide Database

Creating a database for existing and proposed water desalination facilities and projects in Texas is another effort underway by BEG researchers and the TWDB. The project includes a comprehensive survey of all desalination facilities in the state and will contain relevant technical information for communities and organizations that might be interested in developing desalination facilities in the future.

Staff working on desalination issues are Jean-Phillippe Nicot (BEG) and Alan R. Dutton (now at UTSA), with the help of Steve Walden. Research is in collaboration with Robert E. Mace of the TWDB and funded by the U.S. Bureau of Reclamation.




Map of Texas showing counties having projected unmet water needs (before 2050 if no action is taken) and location of active injection wells related to oil and gas production operations.

# Serving the Environment by Turning a Waste Stream into a Profit Stream

by Ian Duncan, Associate Director for Environment and Earth Systems

The Bureau's Gulf Coast Carbon Center finds economic opportunities for Texas and other Gulf Coast states in the fight against $CO_2$ buildup in the atmosphere.

## Why sequester $CO_2$?

The increasing $CO_2$ concentration in the atmosphere is of global concern because many scientists think it contributes to climate change. The United States produces one-quarter of the world's $CO_2$ emissions from combustion of fossil fuel; therefore, it has a critical role to play in changing this trend. U.S. Senator John McCain recently encouraged action: "The time has come for us to accept what is known and start to solve this highly complex problem. As many of the top scientists throughout the world have stated, the sooner we start to reduce these emissions, the better off we will be in the future." A global consensus is emerging that continued burning of fossil fuels is sustainable only if the resultant $CO_2$ is captured and prevented from entering the atmosphere.

Current global levels of anthropogenic, or human-produced, $CO_2$ emissions are 25.6 billion tons of $CO_2$ per year. Approximately 1 billion metric tons of these emissions comes from the Gulf Coast region of Texas, Louisiana, and Mississippi, representing 16 percent of the U.S. annual $CO_2$ emissions from fossil fuels. The Gulf Coast region produces fossil fuels that ultimately result in 25 percent of the $CO_2$ emissions in the country. However, the Gulf Coast region also provides a good opportunity for addressing the problem.

There is a wide range of approaches to remediating $CO_2$ levels in the atmosphere, including conservation, biomass creation, and alternative power sources. Geologic sequestration is one approach that is particularly applicable to the Gulf Coast. Geologic sequestration reduces the impact of burning fossil fuel by capturing $CO_2$ from fossil fuel sources and injecting the compressed gas into the subsurface for long-term storage. This approach could help reduce the rate of increase of $CO_2$ during a transition period of a few decades while society effects a change to a hydrogen-based or some other energy future. The most useful sites are those that would assure storage for thousands of years, well past the expected age of fossil fuel dominance. The costs for capture and storage are significant in the context of energy generation, and these costs may not be distributed evenly across economies globally. Given the long-term nature of the problem, it is important to seek ways to stimulate action soon.

## Why store $CO_2$ in the subsurface of the Gulf Coast?

Four key factors suggest a leading role for the Gulf Coast in the United States' $CO_2$ sequestration efforts over the next few decades:

(1) The abundance and diversity of $CO_2$ sources in the Gulf Coast region related to the high concentration of electric power plants, refineries, and chemical plants.

(2) The presence of a variety of potential large-volume $CO_2$ sequestration sinks, both terrestrial (storage of $CO_2$ as biomass, for example, by reforestation and no-till farming methods) and geological (subsurface storage of $CO_2$ in oil fields, gas fields, the associated permeable but nonproductive brine-bearing formation, and coal seams).

(3) The large potential for $CO_2$ enhanced oil recovery (EOR), in which $CO_2$ injected at pressure into oil fields leads to the production of additional oil from fields in decline, serving to enhance energy production for Texas and the nation while increasing the tax revenue stream to help offset the costs of $CO_2$ capture.

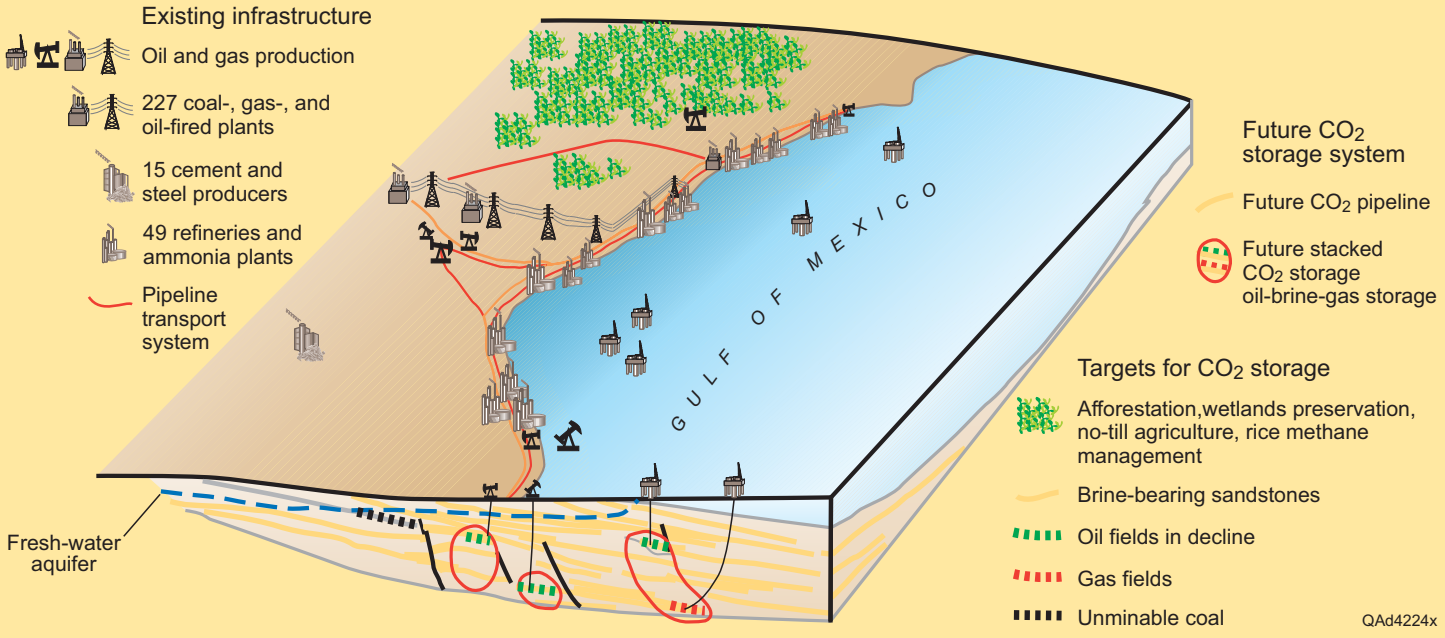
(4) The wealth of geological knowledge of the subsurface in the region and the existing experience, for example, in permitting injection wells and pipeline construction.

## What is the Bureau doing to move toward implementing geologic storage of $CO_2$?

To take on the challenge of reducing emissions at the very large scale needed to reduce impacts on the atmosphere, the Bureau of Economic Geology created the Gulf Coast Carbon Center (GCCC) to provide needed scientific, engineering, and public policy analysis. The GCCC is working with its industrial and research partners to forge the path toward geologic storage of $CO_2$ in the Gulf Coast region.

Storing enough $CO_2$ to significantly reduce atmospheric emissions will require subsurface injection at an unprecedented scale. The effort will also require finding different areas for potential storage sites. Ensuring safe and verifiable injection and storage over the long term poses a significant scientific and engineering challenge. First, researchers must demonstrate that geologic storage is effective in reducing carbon emissions at a reasonable cost. Once the value of long-term storage, or sequestration, is established, support will grow for capturing anthropogenic $CO_2$, creating incentive for large-scale expansion of EOR applications. The GCCC envisions the Gulf Coast region becoming a major site, perhaps the nation's predominant site, for a new carbon sequestration industry. Creating economic incentive for companies to invest in $CO_2$ sequestration technology will stimulate growth of the industry and provide opportunities for companies to become pioneers in this environmental/energy-related partnership.

Over the last year the GCCC has completed an assessment of geologic storage options in the Gulf Coast region. We inventoried 0.4 billion tons of $CO_2$ produced annually from 316 stationary sources in the region. Capture of $CO_2$ from these sources alone could supply a 680-mile pipeline



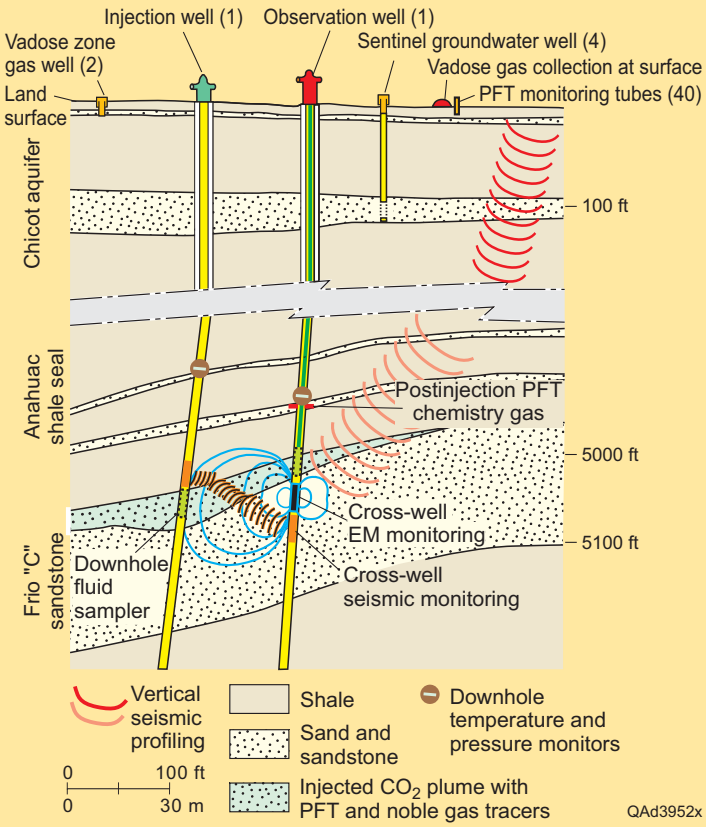

Convergence of multiple sources and multiple sinks, beneficial use for enhanced oil recovery, and a well-understood geology with existing infrastructure make the Gulf Coast an optimal location in which to undertake large-volume $CO_2$ storage.

infrastructure that links the Gulf Coast region in a network possibly extending to East Texas and into Mexico. This area comprises 767 oil and natural gas reservoirs that could be used first for EOR and then for large-volume, long-term storage of $CO_2$ in nonproductive formations below the reservoir interval. Economic assessments show that modest investment of resources would provide economic incentives for the oil and gas industry to support expanded EOR programs that would yield potential storage sites. Assessment has also identified viable initial projects that link sources and nearby sinks. Research and stakeholder dialogs are under way to further study and develop these opportunities.

We estimate that outside the traditional area of $CO_2$ EOR in the Permian Basin an additional 5.7 billion barrels of oil could be produced in Texas by using $CO_2$ EOR. By way of comparison, annual U.S. oil production is currently 3.2 billion barrels. At $30 per barrel, the 5.7 billion barrels of incremental production is estimated to have a wellhead value of $171 billion, generate $26 billion in taxes, and result in $498 billion of economic activity (these estimates for economic impact were computed using the Texas Comptroller's economic model).

This EOR activity could also lead to the storage of more than 700 million tons (0.7 gigaton) of $CO_2$. This is only a small part of the positive impact. The true prize would be that EOR would enable the construction of a $CO_2$ pipeline infrastructure that would allow cost-effective storage of Gulf Coast power plant, refinery, and chemical plant emissions from fossil fuel combustion for the next 50 years or more.

To demonstrate that subsurface storage is effective in isolating $CO_2$ from the atmosphere over long periods of time, Bureau researchers, led by Susan Hovorka, are completing an approximately $6 million field experiment supported by funds from the Department of Energy and National Energy Technology Laboratory (DOE/NETL) and in-kind contributions from many participating partners. The experiment is known as the Frio Brine pilot and is designed to measure and document how $CO_2$ is stored in subsurface environments. The Bureau is leading the experiment in the South Liberty oil field near Dayton, Texas, with the participation of




Monitoring techniques tested at Frio Brine pilot.

18 institutions from the United States, Australia, and Canada.

In previous research the GCCC characterized and compared 21 regionally extensive subsurface environments across the United States and identified the Gulf Coast as a high-priority area for investigation because it has both high emissions and a high-capacity geologic storage environment. Extensive numerical modeling was done to select an optimal site. The experiment was designed to apply scientific information gained from short-term, small-volume injection to estimate performance on a large scale. Sue Hovorka and her research team chose to work in a non-oil-bearing 20-ft-thick interval in the Oligocene upper Frio Formation. Working in a two-phase (rock-brine) system reduced the variables to allow more rigorous matching of prediction to observation, and allowed clearer quantification of $CO_2$ during injection than would have been possible in a three-phase (rock-brine-oil) system.

Permitting, preinjection site development, and characterization were completed in the fall of

Bureau researcher Seay Nance collects high-quality reservoir fluid samples at the LBNL U-tube sampler for real-time geochemical analysis to measure rock-brine-$CO_2$ interaction in the injection zone.

2003 and spring of 2004, culminating in the drilling of a new injection well and the retrofitting of an existing oil production well to serve as an observation well.

Before any $CO_2$ was injected, baseline observations were made from all of the monitoring instruments in the field during the summer of 2004. In the fall of 2004 subcontractors Sandia Technologies, Praxair, Air Liquide, and Trimeric injected 1,600 tons of $CO_2$ from commercial refineries and fertilizer plants into the fluvial-marine reworked Frio "C" sandstone 5,053 ft below the surface. The injected $CO_2$ was closely monitored by key collaborators Lawrence Berkeley National Laboratory (LBNL), Australian CO2CRC Schlumberger, and Paulsson Geophysics using downhole geophysical tools to measure pressure, temperature, and saturation of brine and $CO_2$ within the rock. The geochemical evolution of the fluid at depth was measured directly by sampling and indirectly through down-the-hole logging involving additional researchers from the U.S. Geological Survey and Lawrence Livermore National Laboratory. Fluid movement and fluid-rock interaction were measured by using noble gases, SF6, perfluorocarbons, stable isotopic analysis, and fluorescent dye tracers in an effort led by Oak Ridge National Laboratory and LBNL. These measurements are being compared with the predictions of computer models to help understand the details of movement of supercritical $CO_2$ in the subsurface. Surface monitoring using direct measurement of $CO_2$ and chemical indicators and analysis for introduced tracers in groundwater and soil gas involves researchers from NETL and LBNL. Postinjection monitoring will extend through spring 2005, when the team will evaluate the need for further experiments.

Tools appear to have been successful in measuring changing concentrations of $CO_2$ and monitoring the evolution of the plume. The U-tube designed and operated by LBNL to recover near-real-time, high-quality, minimally perturbed brine and gas samples from the injection intervals to analyze in laboratory facilities at the surface was one example of a successful instrument. Saturation logs using a neutron-sourced Schlumberger reservoir saturation tool (RST) were another. Initial results indicate that observed saturation history and geochemical evolution of fluids are similar to model predictions, increasing confidence in the ability to predict the impact and success of a larger scale injection.

Scott Klara, manager of the Carbon Sequestration Program at DOE/NETL recently praised the Frio Project for its groundbreaking efforts: "The Frio Project represents a first-time injection of anthropogenic (manmade) $CO_2$ into a saline formation in the United States to study sequestration. The Frio Project is critical to the development of the scientific tools necessary to ensure that $CO_2$ sequestration is safe and permanent, should wide scale deployment of sequestration technologies become necessary. The Frio Project is a 'showcase' within the Department of Energy's Sequestration R&D Program and has been designated as a key international project in the Carbon Sequestration Leadership Forum."

The GCCC is taking on a set of challenges that may prove critical for the ongoing sustainable development of the planet. Texas and the entire Gulf Coast region have a unique potential to create a new industry that is based on societal benefit and financed by increased oil recovery.

In addition to the author, other key members of the GCCC team are

**Sue Hovorka**, the GCCC's lead scientist and principal investigator for the Frio project, who has an international reputation as an expert in the injection of $CO_2$ into subsurface brines.

**Alan Brown**, newly appointed Director of the GCCC, who joined the Bureau after a career as a rock physicist and reservoir geologist with Amoco and more recently as a manager with Landmark.

**Mark Holtz**, petroleum engineer, who, among other tasks, has been screening oil fields for their EOR potential and working on the nature of deep brine aquifers for $CO_2$ storage.

**Eugene Kim**, former Bureau employee, who was responsible for generating statistical compilations, economic modeling, and an array of other tasks.

**Seay Nance**, hydrologist, who is a key field person in monitoring and verification for the Frio project.

**J. P. Nicot**, hydrological engineer, who has received a DOE grant to assess risks associated with $CO_2$ sequestration.

**Shinichi Sakurai**, log analyst and petrophysicist, who specializes in integrating core and log data.

**Scott Tinker**, Director of the BEG, who began this effort with Sue Hovorka in 2000. Scott speaks on the topic at certain key meetings and is working on the Federal and State roles and economic and policy aspects of the program.

**Laura Zahm**, reservoir geologist, who is working on a myriad of outreach and other issues.

## About the Author

Since joining the Bureau in July Ian has taken the lead in developing the membership and the science program for the GCCC, during which time membership has doubled. Ian's background in rock mechanics and fluid rock interactions will help shape the Center's future research directions.

# Public Information Resources

As part of its Texas Geological Survey role, the Bureau maintains the following public resources and facilities: Core Research Centers, Data Center (composed of the Geophysical Log Facility and the Reading Room), and Publication Sales. These facilities are open to the public Monday through Friday from 8:00 a.m. to 5:00 p.m. Comprehensive information about these resources can be found on the Bureau's Web site at www.beg.utexas.edu under the menu Public Resources.

## Core Research Centers

The Core Research Centers (CRC's) are the Bureau's research and curation facilities in Austin, Houston, and Midland that house core and rock material donated to the University. Public facilities include core examination rooms, processing rooms for slabbing core, and office space. Internet users can now search for geologic materials and geophysical well logs online using IGOR, a searchable integrated log and core database. For more information, please call the Austin CRC manager at 512-471-0402, or visit the Bureau's Web site.

## Data Center

The Data Center, comprising a Reading Room and Geophysical Log Facility managed by Sigrid Clift, is located on the first floor of the Bureau's headquarters in Austin. The Reading Room maintains a collection of geological reference materials, including periodicals, maps, well logs, publications, and reports from various governmental and nongovernmental earth science entities. For information, please call the Public Information Geologist at 512-471-0320.

The Geophysical Log Facility (GLF) is the official well-log repository for the Railroad Commission of Texas (RRC), which by law receives a copy of geophysical logs from every new, deepened, or plugged well drilled in Texas since September 1985. An estimated 800,000 logs are archived at the GLF, including the RRC collection and donated logs from industry and Bureau research projects. Other data sets available at the GLF include well records and scout tickets from hundreds of thousands of Texas wells. GLF is converting logs into electronic images, and logs are also available as paper copies by contacting the GLF Manager, Daniel Ortuño, at 512-471-7139.

## Publication Sales

The Bureau publishes and sells maps and reports of research conducted by Bureau staff from 1915 to the present. In 2001 we also began handling the sales of select Gulf Coast Association of Geological Societies (GCAGS) publications. The Publication Sales office is located on the first floor of Bureau headquarters in Austin. Orders for publications can be made either in person or by mail, telephone, fax, or e-mail, or through our Web site at www.beg.utexas.edu. For information, please call the Publication Sales manager, Amanda Masterson, at 512-475-9513. Free copies of the current year's List of Publications, Annual Report, and Midyear Report are available upon request.

## Support

### Administrative

Wanda LaPlante is the Assistant to the Director. Sharon Campos supervises the administrative staff that are responsible for general administration of the Bureau. Sharon and her employees handle payroll, personnel, accounts payable and receivable, purchasing, travel and reimbursement, and countless other tasks for the Bureau's 140+ employees.

### Contract Management

Contract Manager Lynda Miller and her staff help researchers prepare budgets and proposals and serve as liaisons for funding agencies. Contract management includes financial reporting, database and records management, and the documentation of progress and submission of deliverables.

### Facilities Management

The day-to-day management of the building is the responsibility of Facilities Manager George Bush. His team provides behind-the-scene support for inhouse meetings, conventions, daily mail service, maintenance of Bureau vehicles, office moves, and inventories of basic equipment.

### Media and Information Technologies

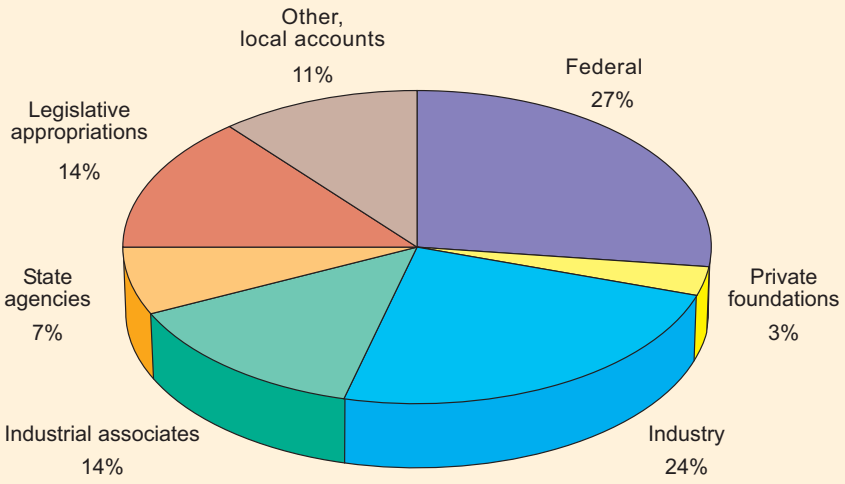
The Media Information Technologies (MIT) department is led by John Els, Joel Lardon, and Scott Rodgers. MIT combines the Bureau's Graphics, Editing, Web, Virtual Reality Laboratory, Publication Sales, and Information Technology (IT) services into one area to support the Bureau's traditional and innovative publishing and IT efforts.

### Software Support

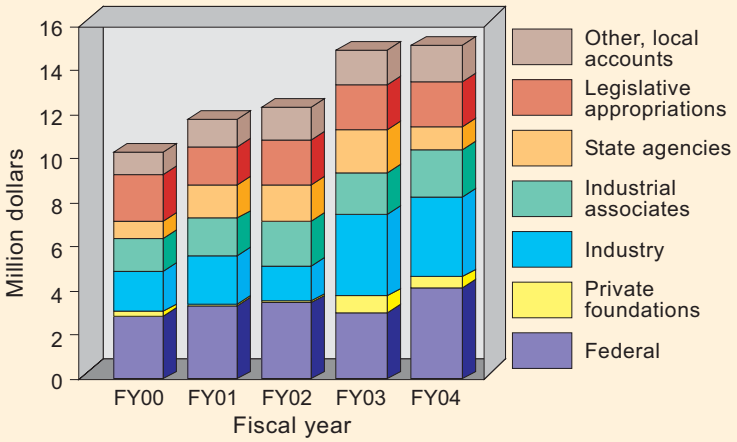
Geoscience software support comes from Landmark Graphics Corporation via the Landmark University Grant Program, Austin GeoModeling (Recon), Drilling Info Inc., Dynamic Graphics, GeoGraphix, GeoPlus (Petra), GeoQuest, GMA, Green Mountain Geophysics, GX Technology, Hampson & Russell, Lexco Offshore Well & Lease Databases (OWL), Midland Valley, Neuralog, Paradigm, Roxar (RMS), Seismic MicroTechnology, TGS Inc. (Amira), and Terra Science.

# Bureau Finances and Staff

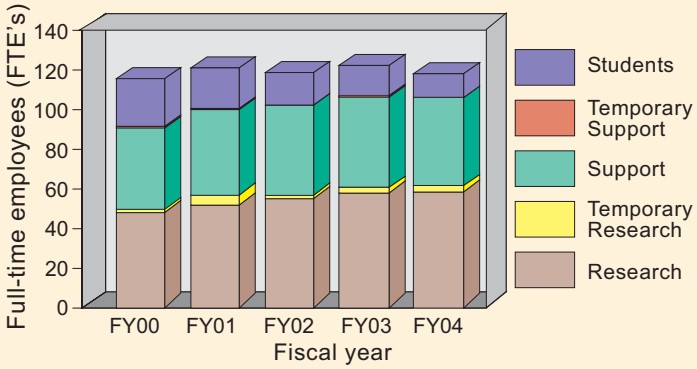
## Sources of Funding




## Five-year Budget Trends




## Staff Trends

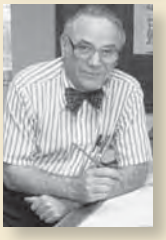


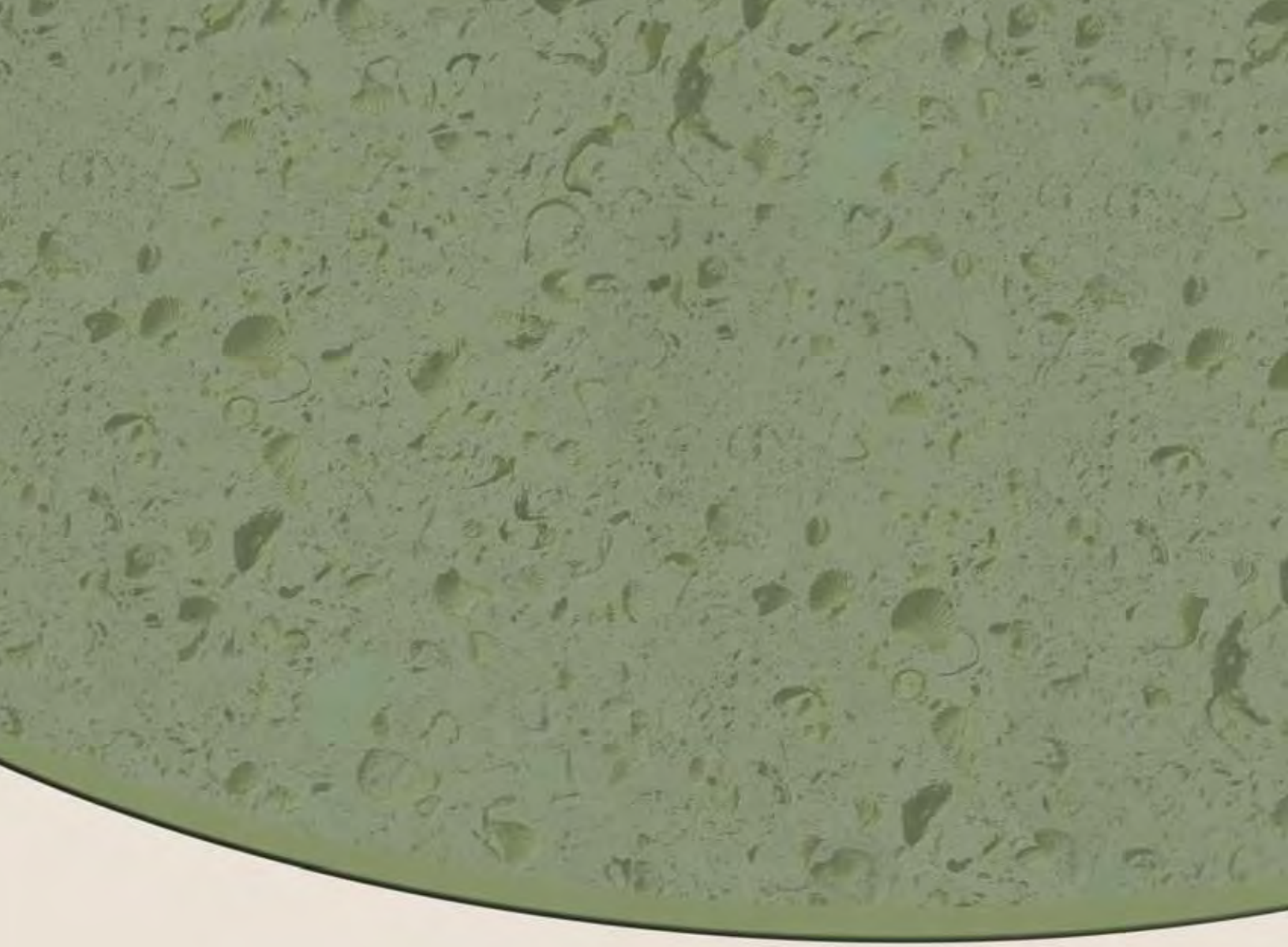

QAd4235x

# In Memoriam

**Josephine Casey** (1907–2004), longtime secretary and editor at the Bureau, died on November 23 in Austin at the age of 97. She retired from the Bureau in 1972, after serving nearly 46 years under several directors. Known as "Miss Casey" at the Bureau, she provided administrative support to the staff and edited and oversaw the publication of many manuscripts. A native Austinite, Miss Casey lived most of her life in the Hyde Park area and was active in the neighborhood association and the University United Methodist Church.

**Keith Young** (1918–2004), Professor Emeritus who taught in the Department of Geological Sciences from 1949 to 1988, died August 20 in Austin. He was the author of many publications, including Bureau publications on Cretaceous ammonites, one of his areas of expertise, and the environmental geology of the Austin area.





The University of Texas at Austin
Bureau of Economic Geology
John A. and Katherine G. Jackson School of Geosciences
1 University Sta Stop EO600
Austin, Texas 78712-0398

Address service requested

NONPROFIT ORG.
U.S. POSTAGE
PAID
PERMIT 391
AUSTIN, TEXAS