Annual Report 2003

Bureau of Economic Geology
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Contents

Cover image: Stationary point sources of CO_2. Data from Hendriks, Chris, van der Waart, A. S., Byers, Claire, Phylipsen, Dian, Voogt, Monique, and Hofman, Yvonne, *Building the cost curves for CO_2 storage, part 1, sources of CO_2:* IEA Greenhouse Gas R&D Programme, report and data on CD, 2002. Bathymetry from ETOPO2 data set, a 2-minute-resolution digital elevation model (DEM) of the world. Land elevation derived from GTOPO30 DEM, a 30-arc-seconds DEM.

Director's Message

I am completing my fourth year at the BEG. Hardly seems possible.

The BEG gross budget grew this year just over 20 percent to almost $15 million, and it has grown 40 percent since 2000, when I came onboard. Quite a feat considering the somewhat depressed state of the Federal and State economies the past year or two. Tribute that to the hard work and world-class reputation of our staff. We strive to maintain a balance across Federal, State, and private funding sources.

We added several bright, creative, and energetic minds to the research and support staff. Our presence in Mexico continues to expand and now includes basin analysis, reservoir characterization, and environmental research. The Industrial Associates program is healthy and growing. The Energy and Environment theme is proving to be a major area for long-term research. We are implementing several significant research initiatives, two of which—CO_2 Sequestration and Fluid-Rock-Seismic Technology—are highlighted in this report. We have automated almost all of our financial, accounting, reporting, and review systems, are the national leader in subsurface data curation with three major facilities across Texas, and continue to impact kids and adults alike through our broad array of outreach activities.

The next year represents one of major transition for the BEG. Doug Ratcliff, Associate Director for Administration, is going to the Geology Foundation full time, and Jay Kipper has joined us in that role from a very successful career in the private sector. I welcome Jay while recognizing how much I will miss the energy, vision, and counsel of Doug. Jay Raney, who has served the Bureau very well as Associate Director for Environmental Research, is transitioning back into a scientific role, and we are searching for an Associate Director of what we will call Earth Systems Research. Our Media Technologies Department has formed from a combination of several internal groups. I thank Joel Lardon for the significant role he is playing as Interim Manager. The BEG is now a member of the Jackson School of Geosciences and all that that will entail. A time of transition indeed.

Four years. For the most part, the easy stuff is done, and it's time to roll up our sleeves and get after it. As we begin the 95th year in the life of the Bureau of Economic Geology, we will strive for excellence. We will seek to define the fundamental questions and societal issues in geoscience, to design and implement major programs and attract and retain top talent, to publish the results in peer-reviewed scientific literature, and to become recognized as a world leader in geoscience research. That should be enough for the coming year . . .

ORGANIZATIONAL HIGHLIGHTS

Jackson School Charts Course

The John A. and Katherine G. Jackson School of Geosciences, under the strong leadership of its first Director, William L. Fisher, has begun to establish and fund programs that promise to realize the dream of the Jacksons to make it one of the top geoscience schools in the country. The three components of the School—the Bureau, the Department of Geological Sciences, and the Institute for Geophysics—have begun to collaborate on committees and projects. Doug Ratcliff, Associate Director of Administration at the Bureau, has moved over to the School part time as an Associate Director and will eventually serve the School full time in that capacity, handling finances and other administrative responsibilities. President Faulkner appointed a committee of internationally recognized scientists from academia, industry, and government, chaired by President Emeritus Dr. Peter T. Flawn to help the School formulate its vision. This committee visited the School and met with its Steering Committee and School members and will be making a report to the President as early as December 1.

The School now occupies its new quarters in the John A. and Katherine G. Jackson Geological Sciences Building, which was dedicated in April. Although Jack Jackson died in March, just a month before the dedication, the legacy he and his wife, Katie, left behind in their investment in the University and the people of Texas is keenly felt within the walls of the fully appointed new building and beyond this structure in the vast potential the School holds for broad-reaching research and public education and outreach.

The University announced in September that the value of the Jackson estate being transferred to the University was set at $232 million. Previous gifts of $40 million from the Jacksons—$15 million for the building renovation and $25 million for the establishment of the School—bring the total value of their gift to $272 million.

Left to right: **Dr. Scott Tinker, Dr. William Fisher, President Emeritus Peter Flawn, Dean of the College of Natural Sciences Mary Ann Rankin, Anna Louise Graeter, Jim Langham, and President Larry Faulkner pictured at the dedication of the John A. and Katherine G. Jackson Geological Sciences Building, April 25, 2003.**

"To my way of thinking, our vision should be to define fundamental questions and societal issues in geoscience, to design and implement major programs and attract and nurture top talent to address these questions and issues, to publish the results in top-tier scientific literature, and to become recognized as a world leader in geoscience research," said Bureau Director Scott W. Tinker, who sits on the School's Steering and Executive Committees. Even in its infancy, the School has ambitious goals. A Gulf Coast Carbon Center has been established combining industry support with Jackson School Foundation investment. The Center will match anthropogenic sources of carbon dioxide with geologic sinks in order to capture carbon dioxide before it is released into the atmosphere and sequester it into existing oil fields or deep saline brines. Other major initiatives being considered by the School are in the areas of fluid-rock-seismic technology (FRST) and hydrology, and members of the School are exploring ways to enhance outreach and educational opportunities for students and teachers alike. The School has also established a new program to provide matching funds for graduate assistants and postdoctoral fellows.

The show is on the road . . .

Houston Research Center Expands Collection and Services

Just a year after the Bureau took over management of the Houston Research Center (HRC), which was donated to the University by BP, it has increased its holdings and brought in new staff to maintain this expansive library of geologic cores and samples. The climate-controlled warehouse, modern core layout rooms, and well-equipped conference rooms provide visitors a rare opportunity to view materials and conduct research. Beverly Blakeney DeJarnett and Laura Zahm, onsite geologists who joined the HRC staff in February, serve as curators of the collection and help the public with technical information and logistics at the center. DeJarnett, whose background is in siliciclastic sedimentology and stratigraphy, and Zahm, whose interests lie in carbonate sedimentology and stratigraphy, bring a passion to their work to integrate core into the petroleum industry, geologic research, and community education at all levels.

Why study core? "Rocks don't lie!" says Zahm, explaining, "Cores and cuttings provide geoscientists with their only direct in situ glimpse of the reservoirs, source rocks, and seals beneath our feet." When used in combination with the latest modeling techniques, cores become a powerful tool for testing research results. DeJarnett agrees, "Cores provide the ground truth for geophysical models (including synthetics), 3-D reservoir models, and geophysical log calibration." And the collection continues to grow.

On its 12-acre campus in west Houston, the HRC houses more than 600,000 boxes of core and cuttings. Most of the cores are from onshore sites across the United States, but a recent donation of more than 50,000 boxes by Occidental Petroleum Corporation (Oxy) added cores from all over the world to the collection. Many of these cores are from world-class reservoirs that can now be studied at the facility.

In addition to the core, Oxy donated funds to the Bureau Research Fund to help maintain the collection. The HRC also received support from the National Science Foundation to curate and archive important terrestrial rock material, as well as a major grant from the U.S. Department of Energy to cover operational expenses for the year.

Besides its value as a public repository of core and other geologic samples, the HRC is fast becoming a hub for Bureau activities in Houston. The Bureau, industry, academia, and professional societies use the facility for workshops, seminars, research, and joint research planning. The Petroleum Technology Transfer Council held several seminars at the HRC this year, and Charlotte Sullivan, an Assistant Research Professor at the University of Houston, has held several classes at the facility.

In other outreach activities, the HRC hosted a field trip to the facility for Houston Geological Society members and their families during Earth Science Week in October. DeJarnett and Zahm have also assisted numerous patrons in locating cores of specific lithologies or geologic basin for applied research and short courses. Future outreach activities are already in the works for elementary through junior college teacher programs and demonstrations for students.

A portion of the HRC collection will be showcased at the 2004 American Association of Petroleum Geologists Annual Meeting in Dallas, where the first cores in the Bureau's teaching collection will be introduced to the public. Cores in the teaching collection will eventually be searchable by depositional setting, geologic age, and geologic province through an online database. Efforts are also under way to add more detailed geologic information to the current online database, as well as a map-based search tool.

The Houston Research Center provides an ideal setting for viewing cores and cuttings from all over the world. The center also has facilities for workshops and collaborative research.

Media Technologies Department

In June, the Bureau established a **Media Technologies Department** (MTD) to further its goals of creatively disseminating research results. This department brings together editing, digital imaging, graphics design and illustration, Web content and multimedia development, and publication sales to better provide services to Bureau scientists and others. Using the latest technology, the MTD is developing new products intended to inform and educate both technical and nontechnical readers. Joel L. Lardon was named the Interim Manager of the new section.

In addition to promoting research produced at the Bureau, the MTD will also seek opportunities to offer services to other departments at the University, with the goal of becoming one of the premier media groups at The University of Texas at Austin. The Bureau will continue to publish using traditional means while expanding the list of digital materials, including publishing through the Internet and on CD. In all phases of publishing, the MTD is working with the Bureau's research staff to identify the best means for disseminating their results.

Top left to right: **Joel L. Lardon, Pat A. Alfano, John T. Ames, Paula Beard, Jamie S. H. Coggin, Lana S. Dieterich, Susann V. Doenges, Sylvia J. Jennette, Amanda R. Masterson, Kerza A. Prewitt, Jana S. Robinson, Scott D. Rodgers, and David M. Stephens.**

Research through Partnerships

The Bureau has established broad, long-term research alliances with several organizations through contracts known as "framework agreements." These agreements contain the general legal and business requirements—such as liability, confidentiality, publication of results, and jurisdiction—that are needed for the Bureau to conduct research for the sponsor. Reaching agreement on terms and conditions before projects are conceived makes it easier to initiate new research projects. Framework agreements usually cover several years and allow for specific work orders to be added to original documents, thereby decreasing contract approval time.

The Bureau currently has framework agreements with ExxonMobil, Saudi Aramco, and the Texas Commission on Environmental Quality (TCEQ) and is negotiating with Pemex to secure an agreement by the end of the year.

- **ExxonMobil**, under their Master Agreement with the University, provided funds for research conducted by two of the Bureau's Industrial Associates groups—the Applied Geodynamics Laboratory and the Reservoir Characterization Research Laboratory.

- Research teams working with **Pemex** under individually sponsored projects completed several projects and started new ones. The stratigraphic and structural framework of the Laguna Madre–Tuxpan area was defined, and exploration plays were identified and ranked. Plans are under way for a similar project in the Salina Basin. Work continues on constructing the structural and stratigraphic framework of the Burgos Basin. Another project is focused on reservoir characterization of the Poza Rica field using core and seismic data to determine the distribution of facies and petrophysical properties. Future work will include a regional fracture study from the Chiapas fold belt to the giant Tabasco producing field. A Gulf Basin–wide synthesis of Neogene stratigraphy, structure, and play potential is also planned.

  In addition to energy-related research conducted on behalf of Pemex, the Bureau has proposed several environmental studies and is pursuing opportunities to collaborate with other units at The University of Texas at Austin on joint projects.

- Under a Master Agreement with **Saudi Aramco**, F. Jerry Lucia and Charles Kerans conducted a 2-week workshop on petrophysical characterization of carbonate reservoirs for two Aramco geologists. The focus of the workshop was geological and petrophysical data provided by Aramco from the Khuff Formation in Saudi Arabia.

  Kerans and Robert Loucks were invited to review Saudi Aramco's existing sequence stratigraphic framework of the giant Ghawar oil reservoir and recommend additional work that would lead to an improved reservoir model of this world-class carbonate reservoir. Partly as a result of this review, Kerans and Jerome Bellian were invited to demonstrate the use of recently developed techniques for imaging outcrops using ILRIS technology on outcrops of the Arab D Formation west of Riyadh, Saudi Arabia.

- As the Geological Survey of Texas, the Bureau shares similar concerns with its sister State agency **TCEQ** in protecting the environment and is providing expertise to analyze and solve problems related to water resources, contaminants, and other environmental concerns. Bureau hydrologists have presented workshops to the TCEQ and are developing opportunities for joint projects.

Publications

Bureau scientists publish the results of their research in Bureau publications and professional journals. In addition to publishing a large number of abstracts, contract reports, and papers during the year, researchers published the following articles in peer-reviewed publications:

Ambrose, W. A., Wawrzyniec, T. F., Fouad, Khaled, Talukdar, S., Jones, R., Jennette, David, Holtz, M. H., Sakurai, Shinichi, Dutton, S. P., Dunlap, D. B., Guevara, E. H., Meneses-Rocha, J., Lugo-Rivera, J. E., Aguilera, L., Berlanga, J., Miranda, L., Ruiz Morales, José, Rojas, R., and Solis, H., 2003, Geologic framework of upper Miocene and Pliocene gas plays of the Macuspana Basin, southeastern Mexico: American Association of Petroleum Geologists Bulletin, v. 87, no. 9, p. 1411–1435.

Aslan, Andres, White, W. A., Warne, A. G., and Guevara, E. H., 2003, Holocene evolution of the western Orinoco Delta, Venezuela: Geological Society of America Bulletin, v. 115, no. 4, p. 479–498.

Couzens-Schultz, B. A., Vendeville, B. C., and Wiltschko, D. V., 2003, Duplex style and triangle zone formation: insights from physical modeling: Journal of Structural Geology, v. 25, p. 1623–1644.

Dutton, Shirley, 2003, New paradigms in industry: corporate donations of geophysical data, *in* Esanu, J. M., and Uhlir, P. F., eds., The role of scientific and technical data and information in the public domain: proceedings of a symposium: Washington, D.C., The National Academies Press, p. 191–193.

Dutton, S. P., Flanders, W. A., and Barton, M. D., 2003, Reservoir characterization of a Permian deep-water sandstone, East Ford field, Delaware basin, Texas: American Association of Petroleum Geologists Bulletin, v. 87, no. 4, p. 609–627.

Fomel, S. B., 2003, Time-migration velocity analysis by velocity continuation: Geophysics, v. 68, no. 5, p. 1662–1672.

Fomel, S. B., 2003, Velocity continuation and the anatomy of residual prestack time migration: Geophysics, v. 68, no. 5, p. 1650–1661.

Fomel, Sergey, 2003, Asymptotic pseudounitary stacking operators: Geophysics, v. 68, no. 3, p. 1032–1042.

Fomel, Sergey, 2003, Seismic reflection data interpolation with differential offset and shot continuation: Geophysics, v. 68, no. 2, p. 733–744.

Fomel, Sergey, 2003, Theory of differential offset continuation: Geophysics, v. 68, no. 2, p. 718–732.

Fomel, Sergey, and Claerbout, J. F., 2003, Multidimensional recursive filter preconditioning in geophysical estimation problems: Geophysics, v. 68, no. 2, p. 577–588.

Fomel, S. B., Sava, Paul, Rickett, J., and Claerbout, J. F., 2003, The Wilson–Burg method of spectral factorization with application to helical filtering: Geophysical Prospecting, v. 51, p. 409–420.

Guillocheau, François, Robin, Cécile, Bouroullec, Renaud, Raillard, S., Castelltort, C., and Nalpas, T., 2003, Rates of deformation of an extensional growth fault/raft system (offshore Congo, West African Margin) from combined accommodation measurements and 3-D restoration: Basin Research, v. 15, p. 183–200.

Hentz, T. F., and Zeng, Hongliu, 2003, High-frequency Miocene sequence stratigraphy, offshore Louisiana: cycle framework and influence on production distribution in a mature shelf province: American Association of Petroleum Geologists Bulletin, v. 87, no. 2, p. 197–230.

Jackson, M. P. A., Warin, O. N., Woad, G. M., and Hudec, M. R., 2003, Neoproterozoic allochthonous salt tectonics during the Lufilian orogeny in the Katangan Copperbelt, central Africa: Geological Society of America Bulletin, v. 115, no. 3, p. 314–330.

Jennette, David, Wawrzyniec, Tim, Fouad, Khaled, Dunlap, D. B., Meneses-Rocha, Javier, Grimaldo, Francisco, Munoz, Rafael, Barrera, David, Williams-Rojas, C. T., Escamilla-Herrera, Arturo, 2003, Traps and turbidite reservoir characteristics from a complex and evolving tectonic setting, Veracruz Basin, southeastern Mexico: American Association of Petroleum Geologists Bulletin, v. 87, no. 10, p. 1599–1622.

Koyi, H. A., and Vendeville, B. C., 2003, The effect of décollement dip on geometry and kinematics of model accretionary wedges: Journal of Structural Geology, v. 25, p. 1445–1450.

Laubach, S. E., 2003, Practical approaches to identifying sealed and open fractures: American Association of Petroleum Geologists Bulletin, v. 87, no. 4, p. 561–579.

Lucia, F. J., Kerans, Charles, and Jennings, J. W., Jr., 2003, Carbonate reservoir characterization: Journal of Petroleum Technology, v. 55, no. 6, p. 70–72.

Maillard, Agnès, Gaullier, Virginie, Vendeville, B. C., and Odonne, Francis, 2003, Influence of differential compaction above basement steps on salt tectonics in the Ligurian-Provençal Basin, northwest Mediterranean: Marine and Petroleum Geology, v. 20, p. 13–27.

Paine, J. G., 2003, Determining salinization extent, identifying salinity sources, and estimating chloride mass using surface, borehole, and airborne electromagnetic induction methods: Water Resources Research, v. 39, no. 3, p. 3-1–3-10.

Reed, R. M., and Milliken, K. L., 2003, How to overcome imaging problems associated with carbonate minerals on SEM-based cathodoluminescence systems: Journal of Sedimentary Research, v. 73, no. 2, p. 328–332.

Reedy, R. C., and Scanlon, B. R., 2003, Soil water content monitoring using electromagnetic induction: Journal of Geotechnical and Geoenvironmental Engineering, November, p. 1028–1039.

Sakurai, Shinichi, Ambrose, W. A., Jennette, D. C., Holtz, M. H., Dutton, S. P., Fouad, Khaled, Wawrzyniec, T. F., Dunlap, D. B., Guevara, E. H., Grimaldo-Suárez, F. M., Aguilera-Gómez, L. E., and Rodríguez-Larios, J. A., 2003, Petrophysical evaluation of Miocene-Pliocene gas reservoirs: Veracruz and Macuspana Basins, Mexico: Petrophysics, v. 44, no. 2, p. 116–125.

Sava, P. C., and Fomel, Sergey, 2003, Angle-domain common-image gathers by wavefield continuation methods: Geophysics, v. 68, no. 3, p. 1065–1074.

Scanlon, B. R., Mace, R. E., Barrett, M. E., and Smith, Brian, 2003, Can we simulate regional groundwater flow in a karst system using equivalent porous media models? Case study, Barton Springs Edwards aquifer, USA: Journal of Hydrology, v. 276, p. 137–158.

Tinker, S. W., chair, 2003, Summary of a workshop on U.S. natural gas demand, supply, and technology: looking toward the future: The National Academy of Sciences, Committee on U.S. Natural Gas Demand and Supply Projections: A Workshop, 111 p.

Walsh, P., and Schultz-Ela, D. D., 2003, Mechanics of graben evolution in Canyonlands National Park, Utah: Geological Society of America Bulletin, v. 115, no. 3, p. 259–270.

White, C. D., Novakovic, Djuro, Dutton, S. P., and Willis, B. J., 2003, A geostatistical model for calcite concretions in sandstone: Mathematical Geology, v. 35, no. 5, p. 549–575.

Zeng, Hongliu, and Kerans, Charles, 2003, Seismic frequency control on carbonate seismic stratigraphy: a case study of the Kingdom Abo sequence, West Texas: American Association of Petroleum Geologists Bulletin, v. 87, no. 2, p. 273–293.

Awards and Honors

Bureau staff are recognized throughout the professional community for their many contributions to various organizations. During the year, the following staff received awards or were honored for their service to professional societies:

Linda Bonnell was named an American Association of Petroleum Geologists Distinguished Lecturer for 2003–2004. The title of her talk is "Diagenetic Effects on Fracture Development."

Bill Fisher was honored by the American Geological Institute Foundation through the establishment of the William L. Fisher Congressional Geoscience Fellowship Endowment, which will enable selected geoscientists to work as congressional staffers. Chairman of the Foundation, Russell G. Slayback, said the endowment was named in Fisher's honor "to commemorate his important geoscience contributions and the key role he has played in development of geo-policy decisions at the national level." Himself no stranger to Capitol Hill, Fisher served as Assistant Secretary of the Interior for Energy and Minerals under President Ford and has chaired many committees and served on many boards and councils at the national level.

Bill Galloway, Morgan J. Davis Chair Emeritus in the Department of Geological Sciences, was the first recipient of the Bureau of Economic Geology Alumnus of the Year Award, which was presented at the Jackson School Reception at the American Association of Petroleum Geologists annual convention in Salt Lake City. Galloway was a Research Scientist at the Bureau from 1975 through 1987, during which he was involved in a wide range of studies, including the geologic framework of the Gulf Coast Frio Formation and uranium and hydrogeology in South Texas. He is senior author of 17 Bureau publications, including the classic 1983 *Atlas of Major Texas Oil Reservoirs*. Galloway is one of the lead scientists on the industry-funded Gulf Basin Depositional Synthesis Project, a collaborative effort between the Department of Geological Sciences and the Institute for Geophysics. Although he is retiring from teaching this year, he will continue to conduct research.

James Gibeaut, Roberto Gutierrez, and **Tiffany Hepner** received the Third-Place Grover E. Murray Best Published Paper Award from the Gulf Coast Association of Geological Societies for their paper presented at the 2002 annual convention, "Threshold Conditions for Episodic Beach Erosion along the Southeast Texas Coast."

Bob Hardage was awarded Life Membership in the Society of Exploration Geophysicists for his exceptional service to the society throughout his career. Hardage presented "Lithology and Fluid Prediction in Exploration: Think Vectors!" as the invited keynote speaker at the Lithology and Fluid Prediction Workshop at the European Association of Geoscientists and Engineers (EAGE) convention in Stavanger, Norway.

Mark Holtz received the Distinguished Service Award from the West Texas Geological Society.

Charles Kerans received the First-Place, Grover E. Murray Best Published Paper Award from the Gulf Coast Association of Geological Societies for his paper "Styles of Rudist Buildup Development along the Northern Margin of the Maverick Basin, Pecos River Canyon, Southwest Texas," presented at the 2002 annual convention. **Kerans** and **Bob Loucks** received the Third-Place, Gordon I. Atwater Best Poster Award from the Gulf Coast Association of Geological Societies for their presentation at the 2002 annual convention, "Stratigraphic Setting and Controls on Occurrence of High-Energy Carbonate Beach Deposits: Lower Cretaceous of the Gulf of Mexico."

Steve Laubach was named a Society of Petroleum Engineers Distinguished Lecturer for 2003–2004. The title of his talk is "Fractures in Reservoirs: Prediction, Characterization, and Incorporation in Fluid-Flow Simulation." Laubach gave a keynote address on "Fracture Characterization" at the final colloquium in the series on naturally fractured rock formations sponsored by the International Francqui Chair in Exact Sciences at the Université de Liège, Belgium.

Jeff Paine was recognized for Best Paper, "Applying Airborne Electromagnetic Induction in Groundwater Salinization and Resource Studies, West Texas," at the Symposium on the Application of Geophysics to Engineering and Environmental Problems.

Ted Playton and **Charles Kerans** received the Second-Place Gordon I. Atwater Best Poster Award from the Gulf Coast Association of Geological Societies for their presentation at the 2002 annual convention, "Slope and Toe-of-Slope Deposits Shed from a Late Wolfcampian Tectonically Active Carbonate Ramp Margin."

Steven Ruppel received the Dedicated Service Award from the Permian Basin Section of SEPM (Society for Sedimentary Geology).

Shinichi Sakurai was elected the North America Regional Director of the Society of Petrophysicists and Well Log Analysts.

Scott Tinker served as Chairman of a workshop titled "U.S. Natural Gas Demand and Supply Projections," which was sponsored by the National Research Council of the National Academies. Tinker presented a Best of AAPG talk, "Upstream Technology for the Coming Natural Gas Economy," at the European Association of Geoscientists and Engineers (EAGE) convention in Stavanger, Norway. Tinker also delivered the kickoff address at the Rocky Mountain Association of Geologists meeting in Denver, "Lasers Light the Way: 3-D Outcrops Will Revolutionize Subsurface Modeling."

Changes in Bureau Staff

The Bureau said good-bye to several staff who retired this year and others who left to pursue other interests and opportunities. Some staff moved into different positions within the Bureau, and the Bureau welcomed several new staff to its family.

Robert "Rick" Richardson, Technical Staff Assistant, retired in January after 16 years of service at the Bureau's Core Research Center (CRC). Richardson, who recently returned to Austin, managed the Midland CRC for many years. He was responsible for cataloging core and cuttings donated to the University by Shell and also oversaw the construction of a new building to house 85,000 boxes of core donated by Altura.

After a long career with the Railroad Commission of Texas, **Jerry Mullican** worked part-time for the Bureau for several years, retiring in February from his position as Research Fellow. Drawing on his previous experience in environmental studies related to water, deep-well injection, and contaminated sites and his many contacts in Texas and adjacent states, Mullican helped the Bureau to acquire access to data and to formulate new projects within the environmental program.

James A. Doss, Jr., retired from the Bureau in August after 21 years of service. Doss was the Building Services Supervisor responsible for handling all the day-to-day details of keeping the Bureau's facilities running smoothly, including maintaining the vehicle fleet, running errands and delivering mail, setting up meeting rooms, and conducting an annual inventory of equipment and property.

Jay P. Kipper joined the Bureau as an Associate Director for Administration, initially working closely with longtime Associate Director Doug Ratcliff, who is moving to the Geology Foundation. Kipper brings 20 years of business experience to the Bureau. Most recently he was vice president of sales for Aspen Technology in Houston, Texas, where he was responsible for technical sales and new business development. Kipper has managed business units having annual revenues of more than $80 million and has conducted business in North and South America, in Europe, and throughout Asia, Africa, and Australia. He earned a bachelor's degree in engineering at Trinity University.

Ursula Hammes and **Robert M. "Rob" Reed** joined the staff as Research Engineering/Scientist Associates. Hammes, who earned a doctorate at the University of Colorado, specializes in carbonate sedimentology and diagenesis, as well as sequence and seismic stratigraphic interpretation. She is working on a sequence stratigraphic exploration model for the Oligocene Frio Formation in South Texas for the State Lands project, where she applies sequence stratigraphic, seismic, and sedimentologic concepts. Reed is part of the FRAC Industrial Associates team and runs the scanning electron microscope (SEM), which can magnify objects more than 100,000 times their original size. Using this powerful tool, Reed studies small-scale structures in rocks—the key, he believes, to understanding rock deformation as a whole. Reed earned his doctorate at The University of Texas at Austin. **George Bush** became the Facilities Maintenance Manager, in addition to continuing his duties as the lead curator of the Bureau's Core Research Center in Austin and its satellite facilities in Midland and Houston. After completing her bachelor's degree in English at The University of Texas at Austin, **Melanie McCammon** moved from student and temporary positions in Publication Sales to a regular staff position as Administrative Assistant. She will handle payroll and time sheets.

Other staff moved into new titles after their positions were reclassified. **Cari Breton** is now working as a Research Engineering/Scientist Associate I. She is conducting geographic information system mapping for Bureau projects on offshore Trinidad and the Permian Basin. **Sylvia Jennette** is a Technical Writer/Editor III. Her job duties include writing Web content and writing and coordinating promotional publications. **Paula Beard** is a Computer Illustration Technician. She prepares graphics for the Web as well as for presentations and publications. **Daniel Ortuño** is an Administrative Associate. He manages the Bureau's Geophysical Log Facility.

James W. Jennings, Jr., has returned to the Bureau's Reservoir Characterization Research Laboratory (RCRL) after spending a year as a Visiting Professor for Shell International Exploration and Production Company in Rijswijk, The Netherlands. Jennings taught Shell's Carbonate Development Team techniques for modeling carbonate reservoirs that were developed at RCRL.

Renaud Bouroullec joined the staff as a Research Associate. Bouroullec completed a postdoctorate at the Energy and Mineral Applied Research Center, University of Colorado at Boulder, after earning his doctorate at Imperial College of Science in London. He is a structural geologist, and his research interests lie in basin analysis, salt tectonics, stratigraphy, and fault analysis.

Timothy P. Dooley, who earned his doctorate at the University of London, Royal Holloway and Bedford New College, will conduct postdoctoral research in the Bureau's Applied Geodynamics Laboratory. Dooley's research focus has been on the dynamics and kinematics of fault systems using scaled analog modeling, field studies, remote sensing, and seismic data. He has conducted field-specific studies for sponsors and developed graphic-rich techniques for transferring research results to industry and academia.

After working as a programming consultant for the Bureau for several months, **John Els** joined the IT group as a Senior Systems Analyst. He has more than 10 years of experience in the computer industry and more than 5 years' experience in software development. Els has broad experience in Web-based development and database design. **Nancy Ewert** joined the Bureau as an Administrative Assistant. She will provide support to the Associate Directors. **Claudia Gerardo** joined the staff as an Administrative Associate. She will handle purchasing and provide administrative support to the research staff.

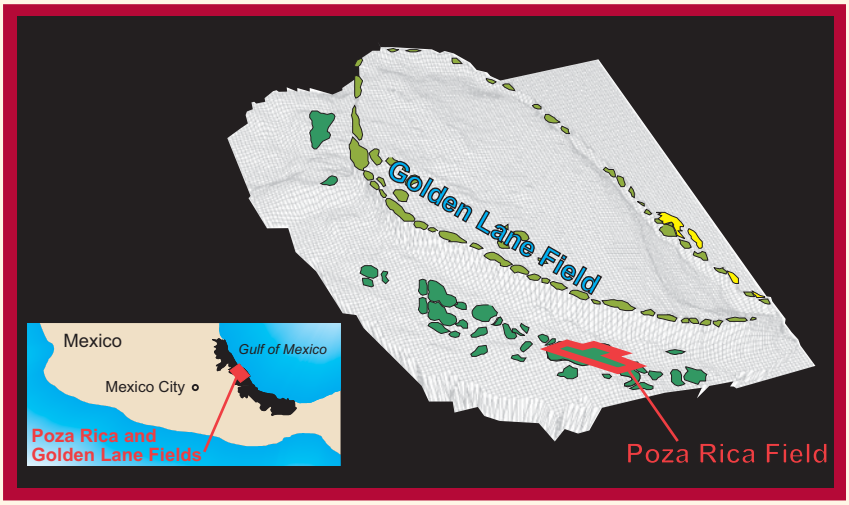
RESEARCH

ENERGY

Integrated Reservoir Characterization

Integrated Reservoir Characterization of the Cretaceous Poza Rica Field in Mexico

The onshore Poza Rica field in eastern Mexico, the world's largest deepwater carbonate hydrocarbon accumulation, served as the backbone of Mexican oil production from shortly after its discovery in 1930 until the 1970's. Bureau researchers are in the midst of a two-part collaboration with Pemex Exploración y Producción researchers to develop a state-of-the-art 3-D reservoir characterization model for this field. This field has 106 million barrels of remaining proven oil and 521 Bcf of remaining proven gas reserves and by 1999 had produced 1.354 billion barrels of oil.



Geomorphic location of the deepwater Poza Rica field relative to the shallow-water Tuxpan Platform (black).

The giant, 30,000-acre Poza Rica field produces from Cretaceous carbonate turbidites and debris flows shed from the adjacent shallow-water Tuxpan Platform (Golden Lane field). Sedimentological and petrophysical studies have been carried out on the field, but an integrated study using 3-D property modeling and upscaling had not been undertaken until this study.

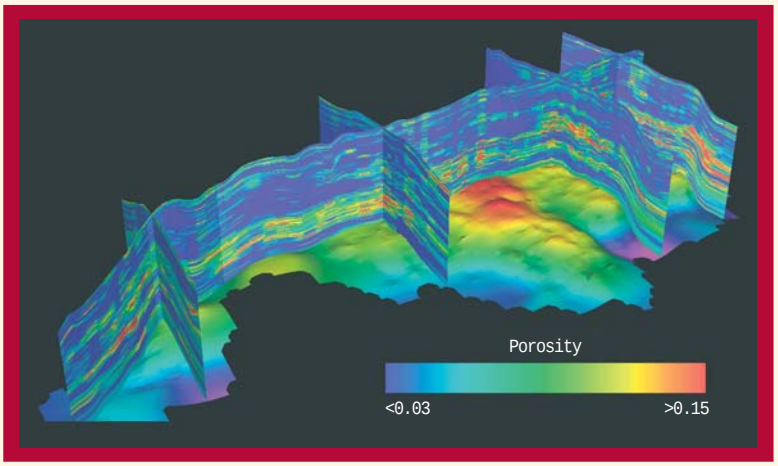
The goal of this comprehensive study is to incorporate available geologic, geophysical, petrophysical, and engineering data; construct a 3-D reservoir model that defines the flow-unit and flow-barrier architecture; and help Pemex improve recovery efficiency. Phase 1 was completed in 2002 and involved data preparation, stratigraphic framework analysis, and initial petrophysical analysis. The current Phase 2 study includes in-field stratigraphic and structural analysis. Researchers Charles Kerans and Robert G. Loucks serve as co-principal investigators for the project. Their research team includes Xavier Janson, Shinichi Sakurai, Fred P. Wang, Mark H. Holtz, and Dallas B. Dunlap.

This study is the fourth Bureau–Pemex collaborative project in Mexico and the western Gulf of Mexico. The first study, completed in 2001, was an evaluation of Tertiary plays of the Macuspana and Veracruz Basins in Eastern Mexico that included defining and assessing the gas plays in the Miocene-Pliocene section of the basins. A second study, completed in September, was an evaluation of basin-scale oil and gas systems in the Laguna Madre–Tuxpan area located north of the Veracruz Basin, Mexico. The third study is establishing the Burgos Basin Miocene structural and stratigraphic framework and identifying and ranking the exploration plays. It will be completed in February 2004.

Multidisciplinary Imaging of Rock Properties in Carbonate Reservoirs for Flow-Unit Targeting

The Leonardian-age Clear Fork represents a major oil system in the Permian Basin of West Texas. Fullerton field is one of the largest fields in this play, with estimated original oil in place of 1.3 billion barrels and 310 million barrels of oil recovered (as of 2000). A multidisciplinary team of Bureau geologists, petrophysicists, geophysicists, and petroleum engineers has been working to characterize this reservoir and create a reservoir model to simulate flow and model permeability. This study will serve as a basis for designing advanced recovery programs in Leonardian reservoirs throughout the Permian Basin—a target resource containing more than 5 billion barrels of oil.

The Fullerton field, discovered in 1942, comprises nearly 30,000 acres. Detailed geological, petrophysical, and engineering investigations are currently under way in two study areas. This work is broadly divided into three components: (1) interpretation and modeling of 3-D seismic attributes within a high-resolution, cycle-stratigraphic reservoir framework on the basis of outcrop analogs; (2) characterization, correlation, and modeling of reservoir rock fabrics; and (3) construction of a 3-D reservoir model that incorporates, as critical constraints, the sequence stratigraphic architecture of the field and petrophysical relationships defined by rock-fabric studies. With pilot area results in hand, researchers will then extend geological investigations to the remainder of the field and develop a full-field reservoir model.



Porosity distribution in Fullerton Clear Fork Unit, Andrews County, West Texas. The model, created using reservoir modeling software, lies atop the structure base map.

This model will serve as a foundation for renewed field exploitation and recovery of more of the large volumes of oil remaining in the reservoir. Early results of the study are already being used to define infill drilling targets. New drilling based on the study is expected to commence in early 2004. The ultimate goal of the project is to find new, more cost effective ways to locate and recover the oil remaining in existing carbonate reservoirs in the Permian Basin and in the United States.

The project, funded by ExxonMobil, The University of Texas System, and the U.S. Department of Energy, is led by principal investigator Stephen C. Ruppel. Other Bureau researchers involved in the project are Fred P. Wang, Jeffrey A. Kane, Hongliu Zeng, F. Jerry Lucia, James W. Jennings, Jr., Rebecca H. Jones, Charles Kerans, Mark H. Holtz, Dallas B. Dunlap, and Joseph S. Yeh.

Diapirism/Salt Tectonics

Salt Tectonics Around the Globe

When most people think of salt tectonics, they think of salt domes in the Gulf of Mexico. Researchers at the Bureau's Applied Geodynamics Laboratory (AGL) are significantly enlarging this perspective in their worldwide search for new insights into diapirism and salt tectonics. Since 1988, this industry-funded consortium has focused its research on producing innovative concepts in salt tectonics in the world's most spectacular salt basins.

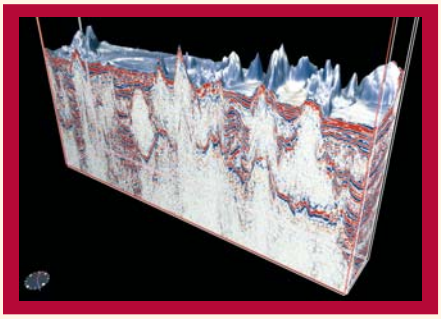
Within the past 2 years, the AGL has participated in research in Gabon, Angola, Mauritania, Democratic Republic of Congo, Zambia, Eastern Mediterranean, Gulf of Lyons (France), the Pyrenees of France and Spain, Pakistan, Germany, Brazil, Mexico, Gulf of Mexico, and Utah. The age of the investigated evaporites ranges from Precambrian (Roan Supergroup) to Miocene (Messinian). This research is cumulative: insights gleaned from one basin are applied to the investigation and understanding of salt tectonics in other basins.

One recent example of the benefits of this integrated approach can be seen in the quest to understand deepwater fold belts, currently one of the hottest exploration plays in the Gulf of Mexico. Most Gulf of Mexico folds are poorly imaged because of overlying allochthonous salt or thick overburden. AGL researchers combined results and insights from their studies of analogous fold-belt structures in the Kwanza Basin (Angola), Lower Congo Basin (Gabon), Aquitaine Basin (France), and Katanga Basin (Central Africa), plus literature

searches on structures in Pakistan, Tunisia, Iran, and Arctic Canada, with their physical and mathematical modeling of the physical parameters controlling fold-belt development. This integrated approach has dramatically clarified understanding of the factors that influence fold-belt timing, position, structural style, and sedimentation patterns—results that can now be exported back to the Gulf of Mexico.

Current AGL research efforts are directed toward understanding the emplacement and evacuation of allochthonous salt sheets, which are also of primary interest to Gulf of Mexico geologists. This work draws heavily on AGL's extensive database of models but has also involved study of analogs from the Kwanza Basin, Angola; Lower Congo Basin, Gabon; Rif Basin, Morocco; Zagros fold belt, Iran; Salt Range, Pakistan; and the Red Sea. Once again, AGL researchers—Martin P. A. Jackson, Michael R. Hudec, Daniel D. Schultz-Ela, and Bruno C. Vendeville—are taking a worldwide approach to solving specific problems in the most actively explored and petroleum-rich domestic basin.

Westward view from the space shuttle of the Persian Gulf area from above the Hormuz Straits. In the arcuate Zagros Ranges on the right, more than 160 salt diapirs are exposed in the richest display of diapirism anywhere on the Earth's surface. Image STS040-75-D courtesy of Earth Sciences and Image Analysis Laboratory, NASA Johnson Space Center (http://eol.jsc.nasa.gov).



Large mobile shale masses at depth host walls of mud volcanoes and diapirs in offshore deepwater Trinidad. At the seafloor large deep-marine leveed channels cut in and around these features and transport coarse-grained sediments eastward to the deep Orinoco fan.

Mobile Shale Systems in Offshore Trinidad and Eastern Venezuela

Although mobile shale basins occur in many types of structural settings, our understanding of the form and process of these systems is in its infancy. Some of the better known mobile shale areas of the world include Trinidad and Eastern Venezuela, the MacKenzie Delta in Canada, the Niger Delta in offshore Nigeria, Indonesia, and regions around the Caspian Sea. Researchers in the joint Bureau–Institute for Geophysics Deep-Marine Depositional Margins Industrial Alliance (DM2) are studying mobile shales as part of their larger effort to understand the structural and stratigraphic nature of the tectonically active margin in offshore Trinidad and eastern Venezuela. Research includes a quantitative morphometric analysis of deep-marine reservoir architecture, the study of mobile shale processes in tectonically active margins, gas hydrate distribution and its impact on margin processes, and the regional nature of active accretionary margin structures. The density of 3-D seismic data (about 10,000 contiguous square kilometers), shallow drop core (about 300 locations), samples for geochemistry, micropaleontology, and sedimentology in the region make this an ideal study area.

Halokinesis (movement of salt) and argillokinesis (movement of mud) exhibit similar geometries but evolve and change through very different processes. Salt is a passive body being acted on to form structures; shale is an active component of basin evolution. It enhances fluid migration, causes structural uplift, provides decollements for gravity sliding, acts as a thermal blanket in the maturation of deep source rock, and, in some cases, is the hydrocarbon source rock itself.

Subsurface mobile shale features in the offshore Trinidad area include shale walls, welds, and rollers, mud-wall complexes, pyramidal cones, "christmas tree" and "inverted christmas tree" structures, and strawlike diapiric features. Mud volcanoes as high as 250 m form "trains" along the seafloor. These "trains" show multiple episodes of extrusive activity, similar to ones on the island of Trinidad itself. The volcanoes and diapirs are evidence of their role as "pressure-release valves" for the deeper overpressured shale systems, and samples taken from these features show active hydrocarbon migration. Enormous frozen gas hydrate resources found near the seafloor in the offshore area are closely associated with the diapirs and ridges.

DM2 research is being sponsored by companies who have regional or general interests in these systems and the deepwater reservoir architectures that develop in these mobile shale settings. Principal investigators are Lesli J. Wood of the Bureau and Paul Mann of the Institute for Geophysics. Bureau researcher Caroline Breton is the database manager. Future research includes a look at the causal mechanisms of argillokinetic activity, including sediment loading, regional extension or compression through plate convergence, and the effect that episodes of extrusive shales have on the evolution of deep-marine architecture.

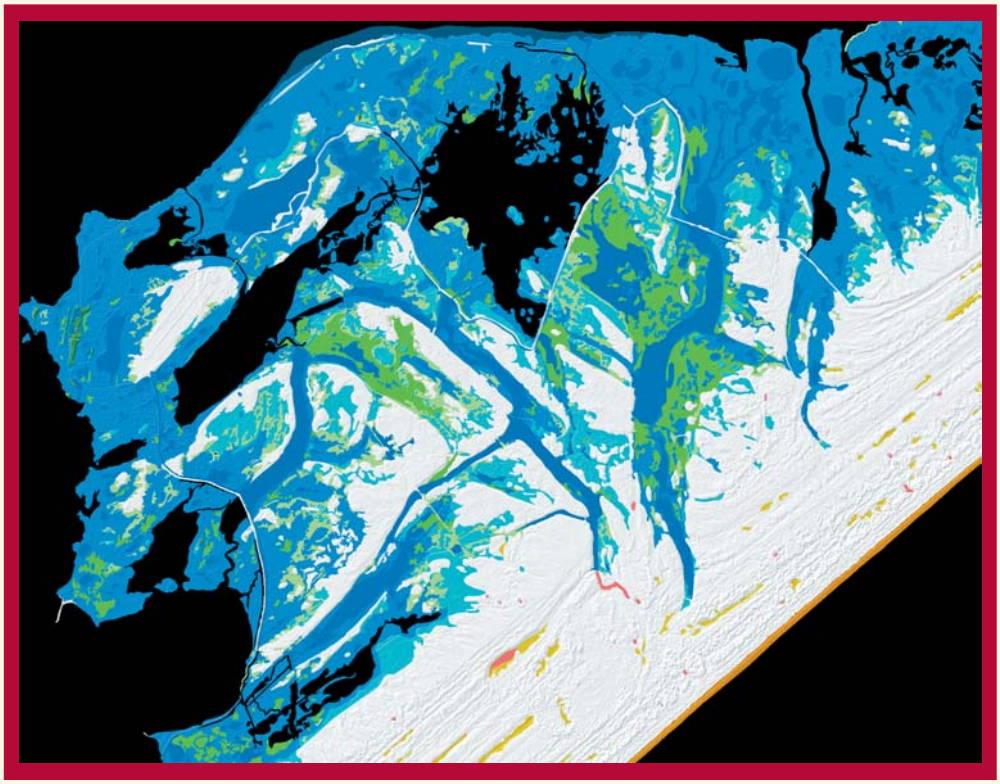
EARTH SYSTEMS

Mapping Texas

Mapping the Earth's surface has been a fundamental part of geology since the early days of geology and the pioneering work of William Smith in Great Britain in 1815. Modern mapping includes traditional field studies that are now augmented by advanced imagery and technologies such as global positioning systems (GPS), geographic information systems (GIS), and detailed 3-D laser mapping. These digital technologies add greater precision and accuracy to our maps, allow us to integrate and analyze a variety of related data sets, and provide geospatial data to an expanding array of users. Maps have also become multiattribute: geology is reflected in the soils and plants of the land's surface. As geology influences how people interact with the surface, our maps reflect these environmental parameters.

The STATEMAP program, funded in part by the U.S. Geological Survey, is perhaps the most "traditional" of our mapping programs. This program develops geologic quadrangle maps, mostly at a scale of 1:24,000, that provide the level of detail and accuracy needed to address a variety of issues. More than 120 Texas quadrangles have been mapped under this program, half of which have been captured in GIS format, which can be digitally compiled to create large regional maps.

In Texas, much of the quadrangle mapping is focused on areas of rapid urban growth. This includes parts of Central Texas, where protection of the Edwards aquifer recharge zones is essential. Aquifer managers use the maps to identify recharge zones and to develop improved aquifer models. Maps in GIS format can be readily processed into the aquifer models. Land use managers and developers use the maps to locate potential resources of limestone and sand and gravel and to identify zones where the engineering properties of the geologic units are important to the design of buildings or infrastructure.



This map combines colored areas of wetland types mapped using color-infrared digital photography draped on a high-resolution digital elevation model derived from a lidar survey. The combination readily shows the topographic relationships of the various environments on this portion of Matagorda Island, a sandy barrier island along the Texas coast.

Coastal mapping is another significant area of Bureau research. The Bureau's coastal program addresses such issues as shoreline change, status and trends of wetlands, sand resources, engineered barriers, and impacts of tropical storms. One important example is the mapping of shoreline change along the Texas coast. Historical aerial photographs are digitally rectified and interpreted to determine historical shoreline positions. Shoreline positions over several decades are entered into a GIS model that calculates the amount and location of shoreline change through time. The model then uses the calculated shoreline change information to predict the location of the future shoreline. Another shoreline mapping activity involves preparing for oil spills along the coast. The "sensitivity index" rates shorelines on the basis of the relative environmental

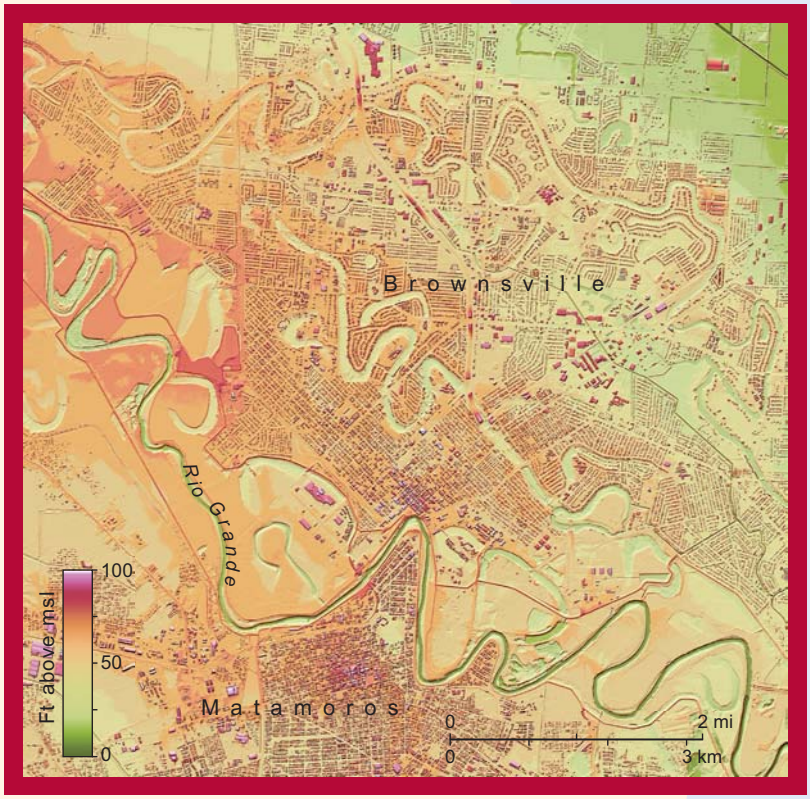
importance of the habitat and the difficulty of mitigating damage to the shoreline should an oil spill occur. These maps assist the General Land Office and other agencies that must allocate resources to protect shorelines in response to a spill. In wetland status and trends studies, the Bureau uses rectified digital aerial photographs in a GIS to map and analyze coastal wetlands to determine wetland changes through time and the causes for changes. Among the causes identified for extensive marsh losses along the upper Texas coast since the 1950's are subsidence and active surface faulting.

The Coastal Group relies heavily on advanced information technologies to facilitate access to the large amount of digital data compiled by the Bureau. Critical information is processed into the GIS and distributed to the public through Internet map servers. Users having access to the Internet can view and query GIS maps through their Web browser. Simple GIS functionality and Web-based data delivery provide an important resource to the research community and the general public.

To keep up with constant change in the coastal zone, the Coastal Research Group purchased an airborne laser topographic mapping system (ALTM) in 2000, which generates detailed 3-D maps called digital elevation models (DEM's). Lidar (light detection and ranging) mapping adds the dimension of topography to traditional photography and imaging. (See related story on lidar mapping on page 13.)

Airborne lidar mapping is a wide-ranging and increasingly well-known research tool used by the Bureau that enables researchers to push mapping to a higher level. In January 2003, Brownsville, Texas, was surveyed to produce a digital elevation model to enable authorities to develop plans for restoration of the Brownsville resaca system (meander channel cutoffs of the Rio Grande) and associated habitats. Because of its incredible detail, the map is now used by a variety of Brownsville city officials. The Bureau is reaching outside of Texas as well, providing exquisitely detailed maps for a coalbed methane operator in the Powder River Basin of Wyoming, and collaborating with the University of California Scripps Institution of Oceanography in a study of beach processes in Southern California. The potential uses for lidar-generated maps are enormous.

Mapping will continue to be a significant part of our program, as well as developing and applying advances in airborne techniques. We envision combining these maps with satellite data and surface methods to produce a new generation of maps. Digital technologies will allow us to present these data in ways that enhance our analysis, application, and understanding. Researchers at the Bureau involved in mapping include Edward W. Collins, James C. Gibeaut, Roberto Gutierrez, Tiffany L. Hepner, Jay A. Raney, Rebecca C. Smyth, Thomas A. Tremblay, Rachel Waldinger, and William A. White.



Digital elevation model of Brownsville, Texas, generated from a lidar survey on January 8–10, 2003, by researchers at the Bureau and the Center for Space Research. More than 350 million lidar points were collected over an area of approximately 100 square miles.

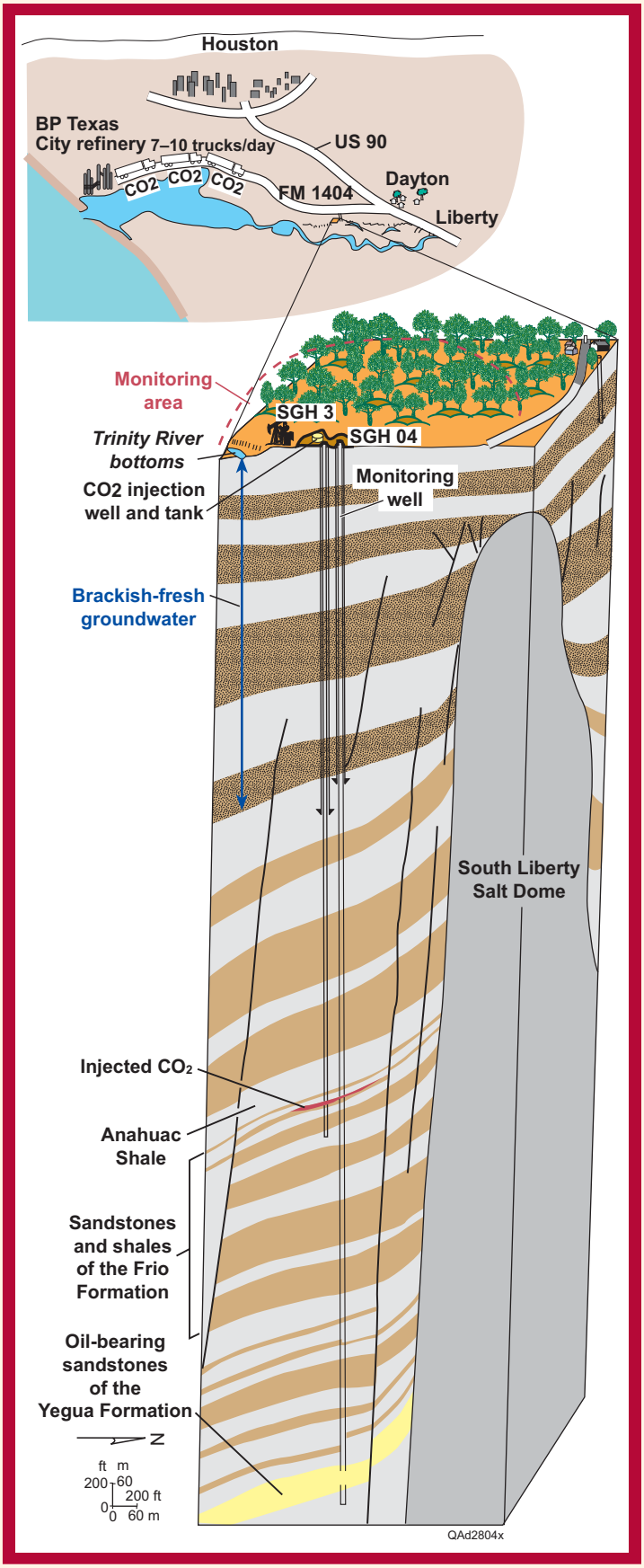
Optimal Geological Environments for CO_2 Disposal in Brine-Bearing Formations, Phase III, Pilot Sequestration in the Frio Formation

Carbon dioxide (CO_2) is an inevitable by-product of the combustion of carbon fuels. It is also a normal product of respiration that, within limits, is well tolerated by most living organisms. Increased rates of fossil fuel combustion since the industrial revolution, however, have resulted in the release of CO_2 into the atmosphere at rates exceeding the rate of CO_2 fixation of the atmosphere-ocean-terrestrial system. Geologic sequestration is the process of injecting CO_2 into the subsurface below potable water; this process has great potential to provide an alternative to releasing CO_2 into the atmosphere. This study is the first CO_2 sequestration demonstration in brine in the United States and is designed specifically to measure environmental effectiveness of geologic sequestration for greenhouse gas reduction.

This is a three-part study. Phase I was the identification of the Gulf Coast as a region of the United States having optimal conditions for geologic sequestration (sinks). Phase II was the selection of the location and formation in which to conduct sequestration experimentation. In the Gulf Coast region, sources of CO_2 include refinery and industrial sources that can supply concentrated CO_2, and coal-, oil-, and gas-fired power plants that provide electricity. Sinks include many oil and (potentially) gas reservoirs that can use CO_2 for enhanced oil recovery (EOR) and the brine formations that can store very large volumes of CO_2.

Phase III is a short-term, small-scale injection of CO_2 into a brine aquifer to collect data to test the validity of conceptual models of this sequestration method. Our target and test site are the brine-bearing sandstone of the upper Frio Formation in Liberty County, Texas. State and Federal permitting is under way with plans to conduct the experiment in the winter of 2003. About 3,000 tons of CO_2 will be trucked to the site and injected into a small, fault-bounded compartment at a depth of 5,000 ft over a period of weeks. Because the purpose of geologic sequestration is to preserve environmental quality, Bureau scientists and project partners will rigorously monitor the subsurface and surface for expected and unexpected outcomes. The experiment will emphasize intensive preinjection modeling and risk assessment, extensive monitoring before, during, and after injection, and a proactive approach to identifying the environmental risks that may be encountered during a CO_2 injection experiment.

Susan D. Hovorka is the principal investigator for the test pilot. Other Bureau researchers involved in the study are Paul R. Knox, Mark H. Holtz, Khaled Fouad, Shinichi Sakurai, Jeffrey G. Paine, and Joseph S. Yeh. Partners in this pilot project include researchers from Lawrence Berkeley National Labs, Lawrence Livermore National Labs, Oak Ridge National Labs, and Alberta Research Council (GEOSEQ Project members); Sandia Technologies, LLC; Transpetco Engineering of the Southwest, Inc.; and American Resources Company.



True-scale diagram of CO_2 injection into a brine-bearing sandstone of the upper Frio Formation.

The Powder River Basin: Hydrogeology of Coalbed Natural Gas Production and Airborne Lidar Terrain Mapping

Production of natural gas from coal beds (CBNG) has proved to be a significant addition to U.S. natural gas resources, accounting for about 8 percent of the 2002 production of dry gas. A large percentage of this production comes from the Powder River Basin in Wyoming and Montana. Bureau researchers are now working with one of the basin's technology leaders, Marathon Oil Company, to apply their skills in lidar high-resolution topographic mapping and hydrogeology to achieve the greatest production having the least surface and environmental impact on the basin.

Lidar Mapping—In May 2002, the Bureau transported its ALTM 1225 lidar mapping system to the Powder River Basin and conducted hundreds of miles of airborne lidar and ground Global Positioning System (GPS) surveys. Data generated from the surveys were used to construct high-resolution, detailed 3-D maps called digital elevation models (DEM's) that are currently being used to evaluate and plan a multitude of CBNG operations. Project hydrologists are using the DEM's to delineate surface drainage features, design reservoirs and containment ponds, and model water retention and ground recharge to manage produced groundwater. These DEM's have become an excellent tool for project engineers as they plan drill locations and design roads, surface facilities, and pipelines with minimal environmental impact. The planning results and maps are also used by landmen to communicate with landowners and by surface hydrologists to communicate with government permitting agencies. The value and wide usability of lidar-generated DEM's have made them an indispensable tool for the development of CBNG reserves.

What is Lidar?—Lidar is an acronym for Light Detection and Ranging. Lidar measures distance and reflectance characteristics of a remote target where the target can be a clearly defined object, such as a vehicle, or a diffuse object, such as a smoke plume or clouds. The Bureau, the first U.S. research institution to own both ground-based (ILRIS) and airborne (ALTM) lidar systems, is applying these technologies to a variety of investigations, including near-surface geophysics, coastal mapping, hydrology, and 3-D modeling of outcrop data.

During a lidar survey, a powerful laser pulses 25,000 times per second. A rapidly moving mirror deflects the laser beam, causing it to scan across the Earth beneath the survey aircraft. The range to a target is determined from the time interval between the laser pulse transmission by the lidar instrument and the return of the reflected pulse. Data points are then used to compute a series of DEM's having 5 × 5 ft horizontal resolution. Terrain-only DEM's show the topography with the trees and buildings removed. All-points DEM's include the surface of the trees and buildings. Ground GPS survey data indicate that the lidar elevations are accurate to within ±0.3 ft. Hundreds of square miles can be surveyed in a day.

Hydrogeological Study—Bureau researchers are also providing expertise on the subsurface flow of water for the Powder River Basin. During the production of CBNG, large volumes of groundwater are produced from the coal seams to lower reservoir pressure and enable the production of the adsorbed gas within the coal. Produced water in the Powder River Basin typically has low salinity and is disposed of through surface discharge in drainages and containment ponds. Marathon is working with both lidar and groundwater hydrology to provide mutually beneficial residential, agricultural, and wildlife uses for the surface water.

Photo of northwest part of the study area near the Montana/Wyoming border.

The critical subsurface hydrologic issues being investigated are the volume of produced water and its relation to drawdown. The Bureau is providing numerical modeling, the standard method for hydrogeologic analysis of groundwater flow in sedimentary basins, for the Power River Basin aquifers. The regional aquifer flow model is being used to investigate hydrogeologic controls on the production of CBNG, estimate boundary conditions for local-scale reservoir models, predict pressure changes that affect production, and project the volume of produced water for disposal.

This research is funded by Marathon Oil Company. The principal investigator is Bureau researcher Roberto Gutierrez. Other Bureau researchers are John R. Andrews, Alan R. Dutton, Tiffany L. Hepner, and Rebecca C. Smyth. Researchers also include Amy Neuenschwander and John Schutz from The University of Texas at Austin Center for Space Research.

NEW INITIATIVES

Changing the Role of Carbon in the Gulf Coast

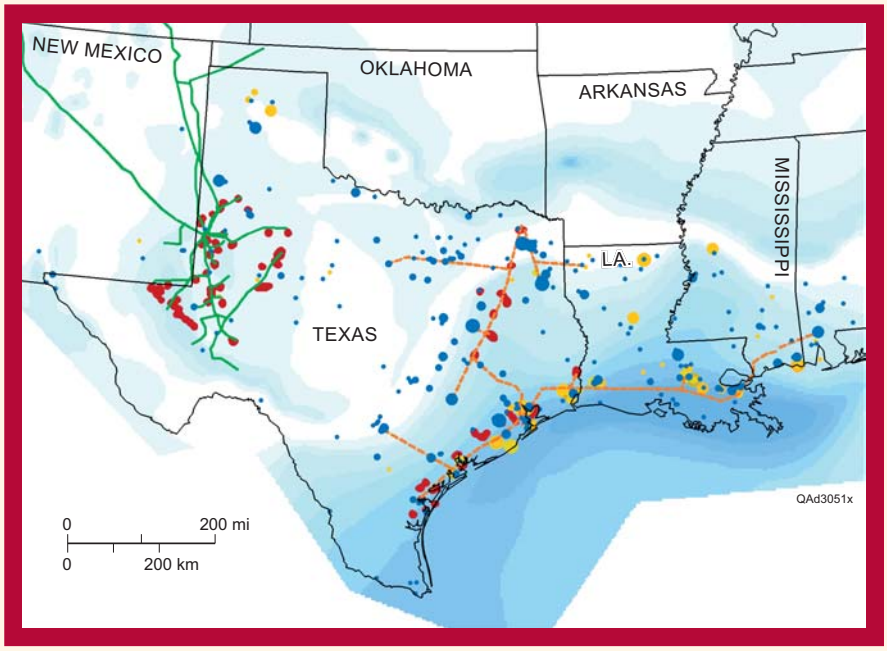
The Bureau is leading an effort to develop a Gulf Coast Carbon Center (GCCC) for carbon sequestration with the support of industry partners BP and Kinder Morgan and the John A. and Katherine G. Jackson School of Geosciences. The Jackson School has adopted this initiative to lead CO_2 sequestration research and application in the Gulf of Mexico region. The GCCC will also receive funding from the U.S. Department of Energy to support related efforts by the Southeast and Southwest Regional Partnerships. Additional Federal and State funds will be sought later to support field documentation of the effectiveness of geologic settings for carbon storage in the Gulf Coast.

The initial focus area will be Texas, Louisiana, and Mississippi. This area has a high concentration of hydrocarbon production and refining, as well as hydrocarbon-dependent manufacturing and power generation. The Gulf Coast area is also at high risk of negative environmental, economic, and health impacts resulting from climate changes and sea-level rise, which may be related to increased worldwide emissions of greenhouse gases such as CO_2. The area is already experiencing air quality degradation related to present combustion and manufacturing practices.

Conventional burning of fossil fuels emits waste gases such as CO_2 into the atmosphere. Changing atmospheric concentrations of greenhouse gases can cause climate changes by trapping heat at the Earth's surface. Because of associated risks, alternatives to atmospheric release of combustion wastes are needed. Bureau studies suggest that a viable option for large-scale reduction of atmospheric release of CO_2 in the U.S. Gulf Coast region is to capture the CO_2, concentrate it, compress it, and inject it into the subsurface in settings where it will be isolated (sequestered) from the atmosphere and from potable water. This process is known as geologic sequestration of CO_2.

The GCCC will serve as a resource for regional industries, governmental agencies, and the public to acquire needed information on CO_2 sequestration. A major objective of the program is to develop one or more pilot field demonstrations at geologic sequestration sites near sources of CO_2. The principal beneficial use is enhanced oil or gas recovery through CO_2 injection.

The Bureau is also conducting a demonstration project to inject CO_2 into the Frio Formation in an oil field near Houston. (See related story on p. 11–12.)



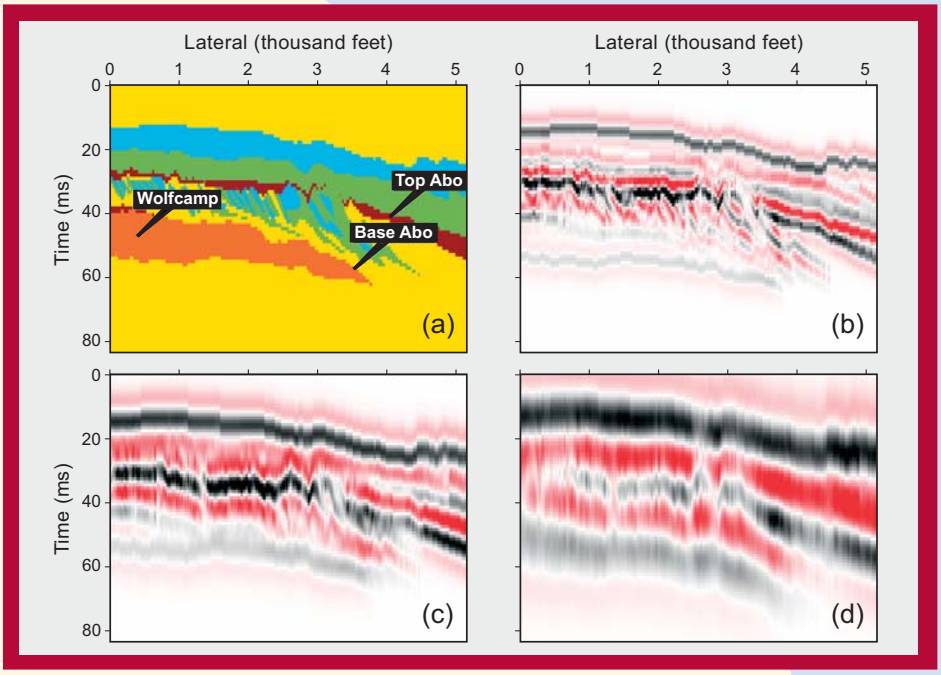
Conceptualization of how CO_2 might be sequestered in the Gulf Coast region. Near-term sources such as refineries and industrial sources (orange) and eventual sources such as power plants (blue) have been linked by a hypothetical network of pipelines to the reservoirs that have been shown to benefit from enhanced oil recovery. Blue areas show the regions having significant capacity to sequester CO_2 in the subsurface (greater than 6,000 ft of sedimentary rocks). The existing CO_2 distribution pipeline in West Texas (green) is compared with a hypothetical Gulf Coast pipeline (orange).

FRST: Breakthrough Geophysical Research Starting with the Ground Truth—World-Class Outcrop Exposures

Geophysical research involving the analysis, quantification, and improvement of seismic resolution has suffered in the past from several limitations. Truly integrated approaches and multidisciplinary teams are rare. That is, a team composed of geologists, geophysicists, rock-property modelers, and engineers has rarely had the long-term organizational commitment needed to design, implement, and evaluate the results of such a sweeping multidisciplinary problem. Commonly numerical and theoretical geophysicists are organizationally or physically separated from interpreting geoscientists. Such separation commonly gives rise to a "hand-off" workflow: a slab of geologic data is handed over to the geophysical modelers with minimal feedback. In other cases, geophysicists, in the absence of geologist-generated

data, are left to create synthetic profiles of the Earth by themselves. Consequently, many of the resultant models lack much of the critical reality and complexity that interpreters know to exist in subsurface reservoirs.

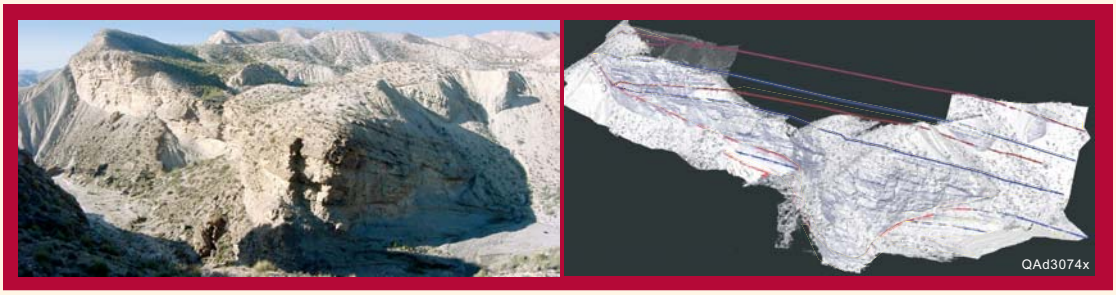
Important advances have been made in the synthetic geophysical realm, and we are now positioned to forge a research path that attempts new approaches and creates new workflows that will take our understanding of seismic data and the limits of seismic resolution to a new level. The Fluid-Rock-Seismic Technologies (FRST) research program aims to (1) establish and maintain a truly integrated team of geologists, geophysicists, and engineers; (2) develop and test an evolving workflow that has fundamental feedback loops between geology, geophysics, and reservoir modeling; and (3) construct outcrop-calibrated, real-world 3-D rock-property volumes for geophysical modeling.



Forward P-wave seismic models of the Permian Abo clinoformal complex, Apache Canyon of West Texas. (a) Acoustic impedance (AI) model showing clinoforms composed of alternating intervals of high-impedance mudstone/packstone and low-impedance reservoir grainstones. (b) Synthetic convolutional model based on the AI model using a 100-Hz Ricker wavelet. Clinoforms are clearly evident, but this bandwidth is unreasonably high. (c) Model using a 60-Hz Ricker wavelet showing loss of resolution, particularly the alternating lithologies of the clinoforms. (d) Model using a 30-Hz Ricker wavelet. High-frequency clinoforms are completely unresolved, and the Abo reservoir package appears as a simple onlapping wedge. Much of the seismic data that subsurface geoscientists use is at or near this 30-Hz bandwidth. Figure modified from AAPG Bulletin article by Zeng and Kerans (2003; see full citation on page 4). Copyright ©2003. The American Association of Petroleum Geologists. All rights reserved. Reprinted by permission of the AAPG, whose permission is required for further use.

This third point provides the foundation of the research program. Such ground-truthed volumes of reservoir and seal geology are not widely available in industry and are not reliably created by academic programs. They are not cheap; nor are they easy. However, these real, quantifiable rock systems offer geophysical modelers the best controlled laboratory to conduct seismic characterization studies of this kind. Moreover, a new suite of tools and approaches is available to outcrop geologists, reservoir modelers, and geophysicists that allows the rapid and accurate capture and analysis of true 3-D outcrop volumes. These tools include ground-based lidar (light detection and ranging) scanning devices for recording precise *x, y, z* and intensity information from outcrop faces. For the first time true spatial 2-D and 3-D outcrop information is captured.

The time is right, the tools are available, and the technologies and skills are in place to make material improvements in our assessment and ability to resolve and address the seismic detection of fine-scale reservoir and seal elements common in our subsurface reservoir settings. Moreover, a collaboration between the John A. and Katherine G. Jackson School of Geosciences (JSG) and partner companies is under way. Through the combined practical and theoretical expertise of the JSG and partner companies, we aim to surmount the existing barriers in our current understanding of the complicated roles that fluid and rock properties have on seismic resolution.



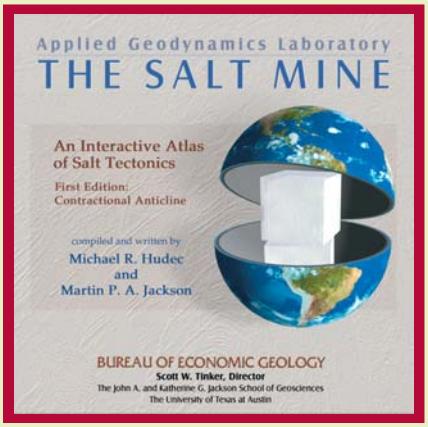
Photograph and laser-generated pointcloud of a Miocene-age deepwater canyon from the Tabernas Basin, southern Spain. The paleoflow direction is toward the observer. The canyon is 400 m wide and 60 m deep. Reservoir-grade sandstones and conglomerates occur within the erosional axis of the system and pass laterally into thin-bedded sandstones and shales toward the margins. Several high-frequency sequences defined by basal erosional surfaces (red horizons) and abandonment surfaces (blue) are mapped along the extent of the outcrop on the 3-D pointcloud data, producing a 3-D horizon and lithofacies interpretation similar to 3-D seismic data. The FRST research study uses outcrops like this as a basis for sophisticated 3-D geophysical modeling.

TECHNOLOGY EXCHANGE AND OUTREACH

With the absence of earth science in the required curriculum in Texas schools, with shortages of qualified science teachers throughout the state, with enrollments down in geoscience departments across the nation, the outlook for developing an informed public able to make good decisions for community development and policy is not encouraging. Energy resources, environmental issues, earth science education, coastal monitoring . . . They're not just important subjects, they're our future. That's why Bureau scientists spend hundreds of hours in the field and behind computer screens compiling data that can be analyzed to determine how geologic phenomena have worked in the past and how they are most likely to work in the future. That's why we host several hundred middle schoolers for a day of science activities to give students a glimpse of career opportunities and allow them to discover the secrets of how their planet works and what they can do to make it work better. That's why Bureau teams hold workshops, produce newsletters, give lectures, and travel to remote spots to measure water flow and chemical infiltration. Every Bureau project carries with it a need to convey the results. Here are a few examples of how we get the information out to the public, to students, and to our technical peers.

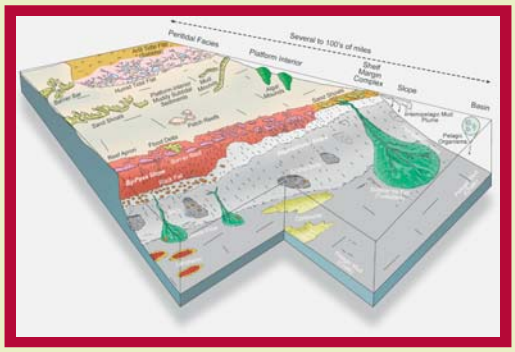
Salt Mine

Scientists at the Bureau's Applied Geodynamics Laboratory (AGL) for the last 3 years have been compiling what they expect to be the most comprehensive collection of salt-tectonic images and animations ever assembled. Known as "The Salt Mine," this interactive, HTML-based atlas of salt structures contains images of salt structures from around the world. Field exposures (outcrop views, geologic maps, aerial photographs, satellite images), seismic sections, geologic cross sections, conceptual sketches, and animations, as well as hundreds of the best examples from AGL's library of physical and numerical models, make up the collection. Images are searchable by several criteria, including keyword, geographic location, and structural style, making the atlas accessible to both beginners and experienced users. The final version of the atlas is expected to be published in 2006, and AGL sponsors will receive annual updates.

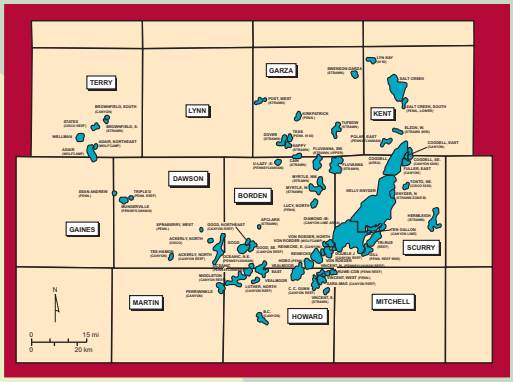


Interactive Online Learning

As part of an educational outreach effort funded by the American Geological Institute (AGI) and the American Association of Petroleum Geologists (AAPG), the Bureau has created six online learning modules on carbonate reservoir characterization. These Web-based "lectures" give students the opportunity to learn by doing, as they walk through the material and complete exercises online, with the aid of help screens and immediate feedback on their responses to questions. The modules will teach students the basic concepts of depositional systems and environments, covering topics such as carbonate platform types, sequence stratigraphy, and rock fabrics. These modules complement the 15 modules already developed that are available online at http://infosystems.aapg.org/iolcourse.



Digital Portfolio of Permian Basin Oil Reservoirs



Focusing on the more than 1,300 Permian Basin reservoirs that have attained cumulative production of at least 1 million barrels of oil through 2000, the Bureau and the New Mexico Bureau of Geology and Mineral Resources are producing a digital portfolio of this oil-rich section of West Texas and Southeast New Mexico. Play maps developed in a geographic information system are linked to a database containing production figures and other reservoir information. The portfolio includes a description of each play and information about key reservoir characteristics and successful development strategies that may be applied to analogous reservoirs in the same play. The project is funded by the U.S. Department of Energy as part of its Preferred Upstream Management Practices (PUMP) Program. A CD containing the results of the project will be available next year upon completion of the research.

DOE's Pantex Plant

The Bureau is one of the State agencies that supports the efforts of the State Energy Conservation Office to oversee environmental safety at the U.S. Department of Energy's (DOE) Pantex Plant near Amarillo, Texas. DOE uses the facility to assemble and maintain nuclear weapons. Because the plant lies over part of the Ogallala aquifer, monitoring of groundwater quality is essential to ensuring safe domestic and municipal water supplies. Bureau hydrologists review groundwater-monitoring techniques and recommend improvements in the program. They also provide information from computer simulations of rates of liquid and vapor flow through unsaturated zones below the surface to determine rates of infiltration and evaporation that could affect groundwater supplies. In a study funded by DOE and BWXT Pantex, Bureau researchers are using airborne geophysical methods to investigate the potential for lateral and vertical migration of groundwater in the perched aquifer and assess the integrity of the Ogallala fine-grained zone that perches groundwater above the Ogallala aquifer at the Pantex Plant.

Petroleum Technology Transfer Council

Bureau Director Scott W. Tinker and researcher Sigrid Clift partner to direct the Texas Region of the Petroleum Technology Transfer Council (PTTC), which coordinates the region's efforts to reach independent oil and natural gas producers throughout the state. The Bureau provides information to the exploration and production industry by maintaining a resource center for PTTC, producing a quarterly newsletter, and organizing and running workshops to promote the transfer of technology that will result in greater and more efficient oil and gas production in Texas.

State of Texas Advanced Resource Recovery

Researchers on the Bureau's State of Texas Advanced Resource Recovery (STARR) project focus their efforts on increasing production from oil and gas reservoirs on State Lands for the benefit of the Permanent School Fund. The Bureau partners with operators to provide technical analysis of oil and gas fields on State-owned lands. STARR researchers look for opportunities for new production from mature fields using the latest reservoir characterization and geophysical exploration techniques. The program has examined 16 fields to date, and current work is focused on the Oligocene Frio Formation of the Red Fish Bay field, where deep targets and new compartments are being delineated for exploitation.

Coastal Monitoring

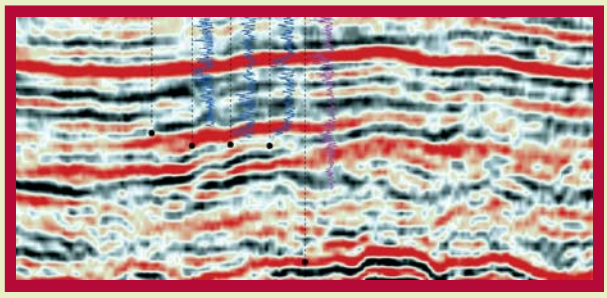
Bureau coastal geologists work with local high school teachers and students along the Texas coast to engage them in a program that gives the students a better understanding of this dynamic resource and enables them to give their community valuable information on the changing shoreline. Under the guidance of the scientists, students and teachers learn to measure beach profiles along the coast, map the vegetation line and shoreline, and observe weather and wave conditions. The students make field trips to the beach to collect data that they bring back to their classroom and share with other students over the Internet. While taking part in research and learning the scientific method of inquiry, students help educate their communities about coastal processes and hazards. The students also gain an understanding of the importance of technical information in making policy decisions to manage and protect the coastal environment.

Earth Science Week

Begun 6 years ago by the American Geological Institute to promote a better understanding of Earth science careers and the natural resources that are important in our everyday lives, Earth Science Week was celebrated this year October 12–18. As part of this year's celebration, the Bureau helped organize a career fair for 300 middle school students in Austin, held a field trip for Houston Geological Society members and their families, and staged a visualization laboratory for students in Midland.

University Lands Advanced Resource Recovery Initiative

The University Lands program was developed in the mid-1980's to characterize oil and gas fields on leases owned by The University of Texas System to gain a better understanding of the reservoir geology, thereby improving production and increasing revenue to the University. The program ran for 5 years in the 1980's and then began again in 1995. In its last year, the program included (1) a collaborative study of the giant Fullerton field in West Texas, cofunded by ExxonMobil and the U.S. Department of Energy (DOE), designed to develop new ways to increase recovery from low-efficiency Permian carbonate reservoirs, (2) a multidisciplinary analysis, also cofunded by DOE, of the application of a cutting-edge technology to obtain oil from a pressure-depleted and abandoned Ellenburger (Ordovician) carbonate reservoir, and (3) an examination of the potential for nonconventional gas resources in the Permian Yates Formation. At Fullerton field, the emphasis is on developing a more accurate 3-D reservoir model using integrated study of rock, wireline log, and geophysical data sets to guide the drilling of new production and water-injection wells and to develop a basis for evaluating the potential of enhancing recovery using CO_2 in Clear Fork Group carbonate reservoirs. (See p. 8 for more details). The Ellenburger project is focused on developing geological and engineering models to guide the application of a potentially revolutionary approach to recovering oil from a nearly abandoned reservoir at Barnhart field—high-pressure air injection.



PUBLIC INFORMATION RESOURCES

In addition to being a research unit of The University of Texas at Austin, the Bureau serves as the Texas Geological Survey. In this 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 storage facilities in Austin, Houston, and Midland that house core and rock material donated to the University. With 634,000 boxes of core and 668,500 boxes of cuttings, the Bureau is the largest curator of rock samples in the United States. 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 located at http://begdb1.beg.utexas.edu/Igor/. For more information, please call the Austin CRC manager at 512-471-0402, or visit the Bureau Web site.

The Data Center

The Data Center, comprising a Reading Room and Geophysical Log Facility managed by Sigrid J. 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) stores downhole log data received from private donations, Bureau research projects, and the Railroad Commission of Texas, which by law receives a copy of geophysical logs from every new, deepened, or plugged well in Texas. Data available for public research include wireline electric logs, well records, and scout tickets from hundreds of thousands of Texas wells. A searchable integrated database (IGOR) is available online at http://begdb1.beg.utexas.edu/Igor. Copies of logs can be requested either in person or by mail, telephone, fax, or e-mail. For information, please call the GLF manager 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 at 512-475-9513. Free copies of the current year's List of Publications, Annual Report, and Midyear Report are available upon request.

Support Staff

Administrative

Wanda LaPlante is the Executive Assistant who supports the Director's administrative needs by maintaining appointment schedules, travel arrangements, and communication at all levels. Glynis Morse supervises the administrative staff who are responsible for handling payroll, personnel, accounts payable and receivable, purchasing, travel and reimbursement, and many other tasks and services for the Bureau's nearly 150 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 T. 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.

Information Technology Services

Ron Russell manages the Information Technology Services (ITS) team who provide vital computer technology assistance to Bureau researchers and staff, including systems support, 3-D modeling, visualization, computer mapping, programming, database applications, statistical and graphical analysis of data, and PC and workstation platforms.

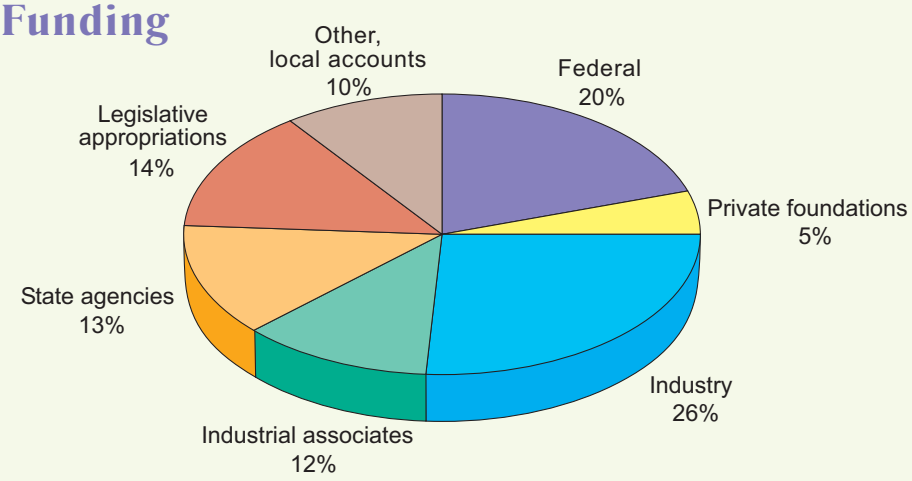
Geoscience software support comes from ABAQUS, Austin GeoModeling Inc., Computer Modeling Group Inc., DrillingInfo.com, Dynamic Graphics, Earth Decision Sciences, ER Mapper, ESRI, Geo-Logic Systems, Geovariances America Inc., Green Mountain Geophysics, GX Technology, Hampson & Russell, Innovmetric, Landmark Graphics Corporation via the Landmark University Grant Program, Midland Valley, Neuralog, Paradigm Geotechnology, PETCOM, Rose and Associates, Roxar, Schlumberger, Seismic MicroTechnology, and Terra Science.

Media Technology Services

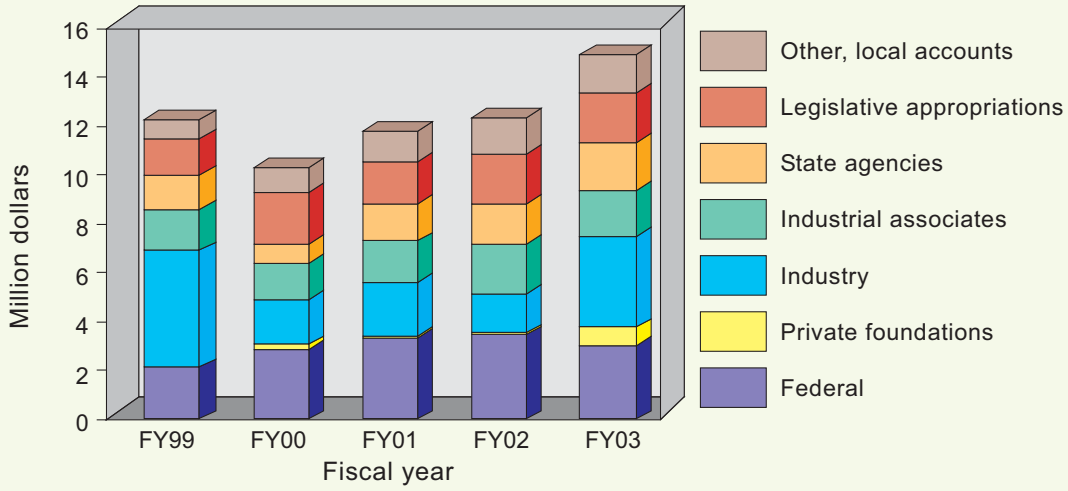
The new Media Technologies Department, under Interim Manager Joel L. Lardon, merges the Bureau's Graphics, Editing, Web, Virtual Reality Laboratory, and Publication Sales Departments into one area to support the Bureau's traditional and innovative publishing efforts.

BUREAU FINANCES AND STAFF

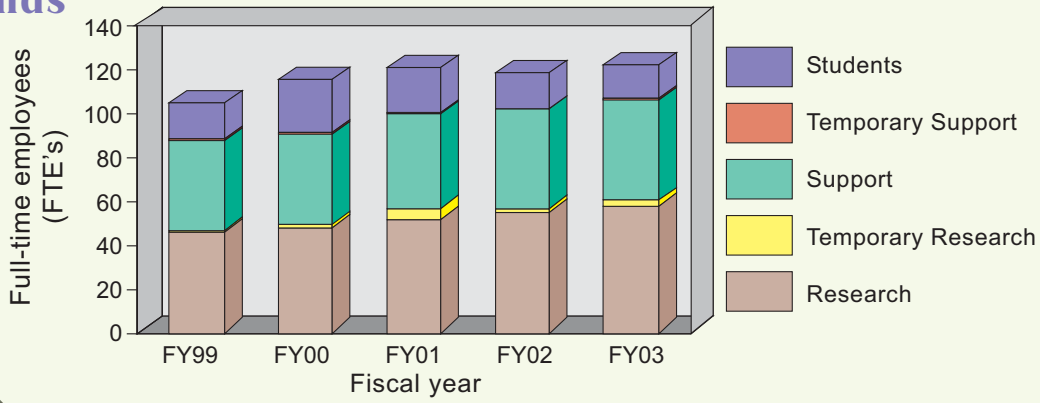
Sources of Funding

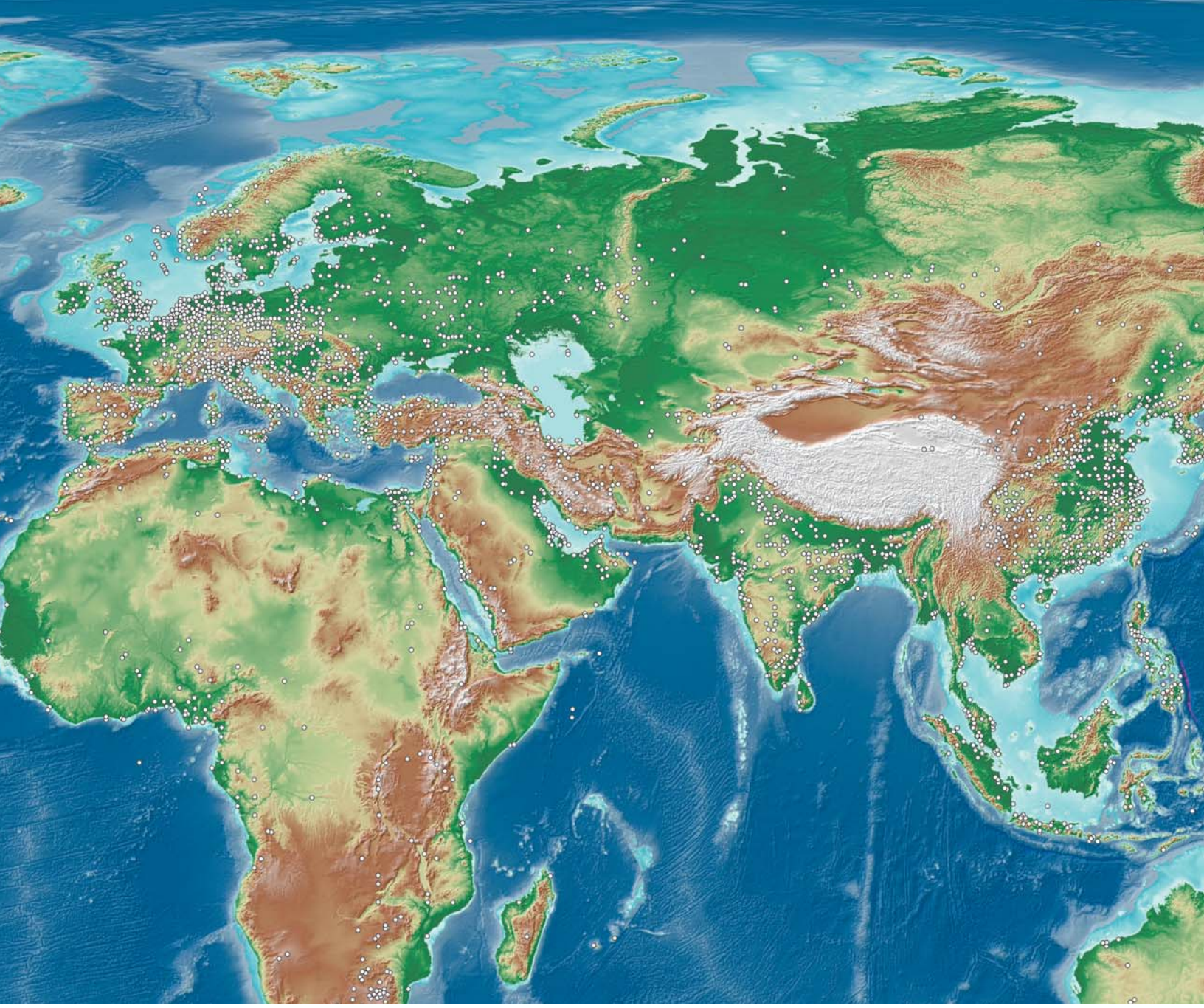


Five-year Budget Trends



Staff Trends





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