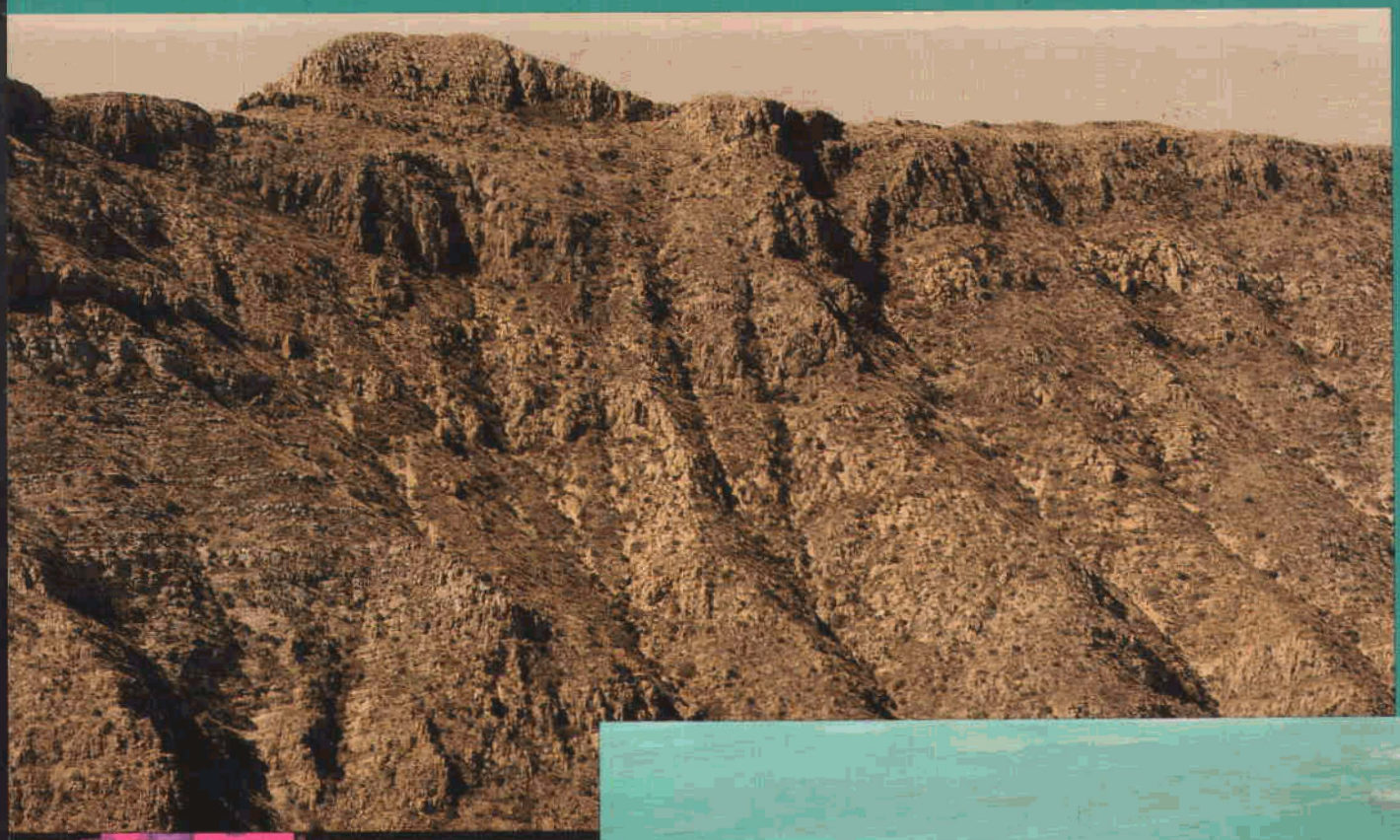
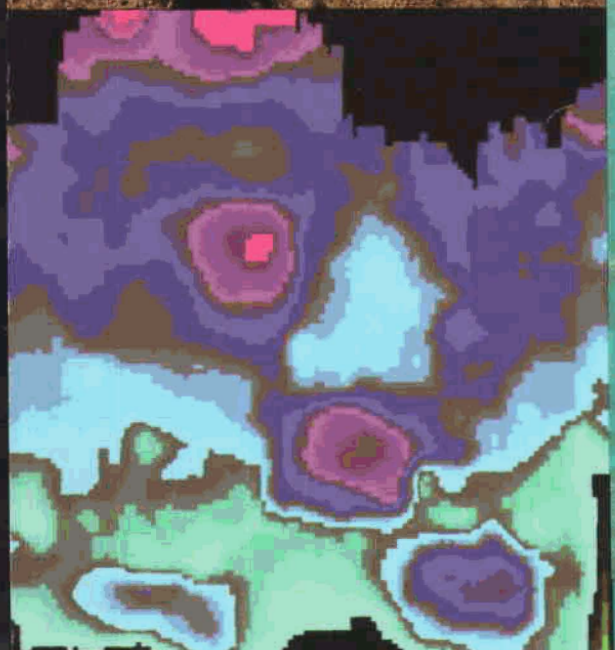
Bureau of Economic Geology

Annual Report 1995

Noel Tyler, Director

The University of Texas at Austin • Austin, Texas 78713-8924





Reservoir Analog Studies

Foreword

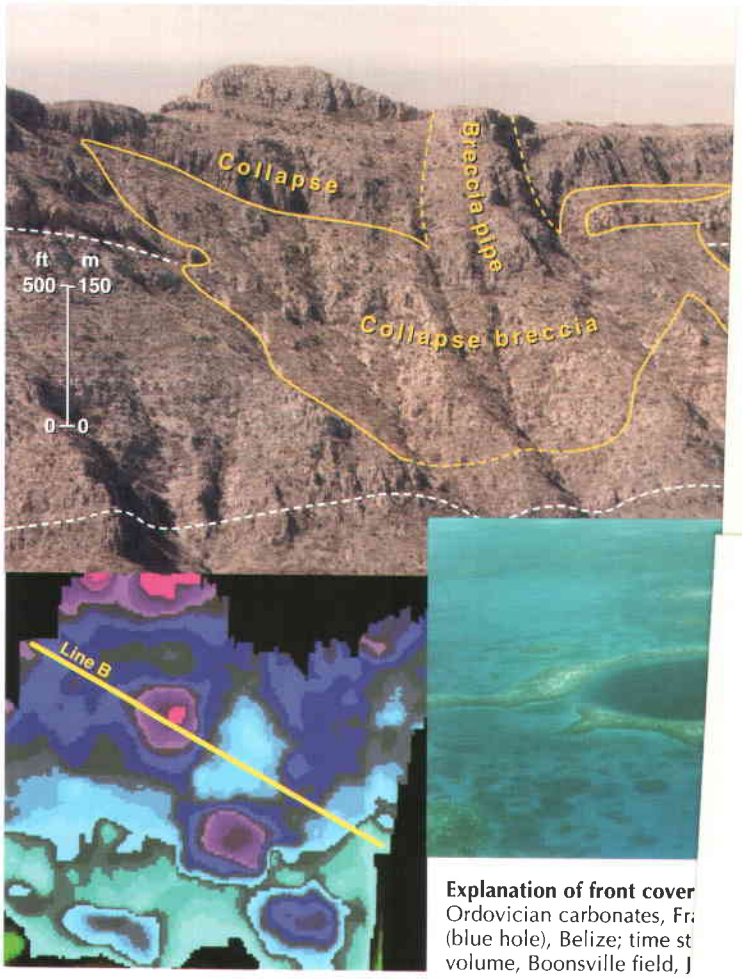
The Bureau of Economic Geology, established in 1909 as the successor to the Texas Geological Survey and the Texas Mineral Survey, is a research entity of The University of Texas at Austin. It also functions as the State Geological Survey, the Bureau Director representing Texas in the Association of American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

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

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

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

The Annual Report of the Bureau of Economic Geology ou
research projects, publications, personnel activities, and service
geology that are available to governmental agencies, industry, and



Explanation of front cover
Ordovician carbonates, Fr
(blue hole), Belize; time st
volume, Boonsville field, T

BUREAU OF ECONOMIC GEOLOGY

The University of Texas at Austin • Austin, Texas 78713-8924

ANNUAL REPORT

1995

Noel Tyler, Director

Research and Administrative Office and Laboratories

J. J. Pickle Research Campus
10100 Burnet Road
Austin, Texas 78758-4497
(512) 471-7721
(512) 471-1534
FAX 471-0140

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

Acknowledgments

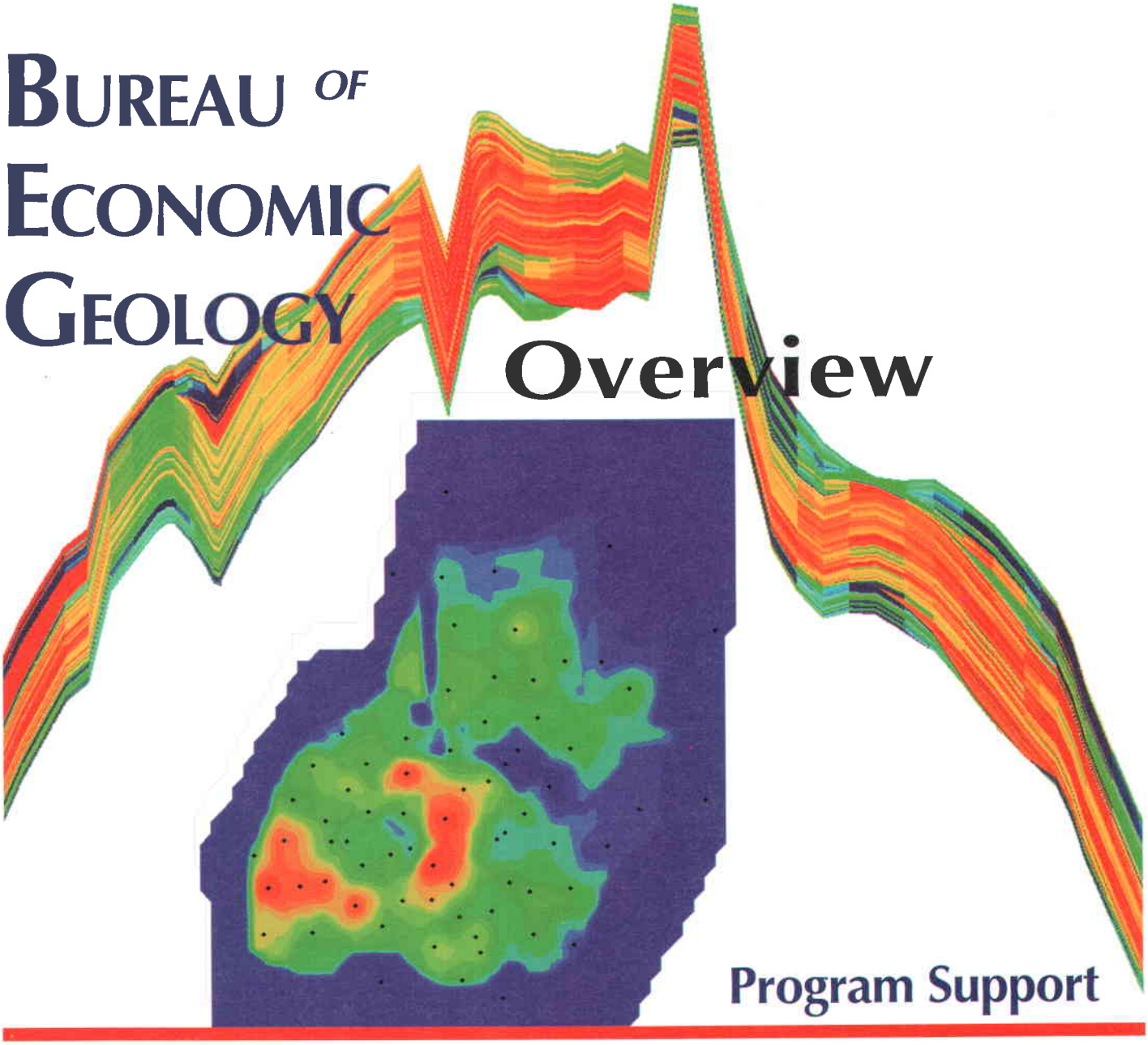
Compilation and technical editing by Tucker F. Hentz, editing and production coordination by Lana Dieterich, word processing by Susan Lloyd, proofreading by M. Alison Boyd, and design by Margaret L. Evans.

Contents

Research Staff Activities

Support Staff

BUREAU OF ECONOMIC GEOLOGY



Overview

Program Support

During its first full year under new directorship, the Bureau of Economic Geology continued to prosper from aggressive program development, particularly in the areas of energy and environmental research. International research ventures played an increasingly prominent role at the Bureau in 1995, maintaining a trend that started in 1993 and that represents one of the most substantial modifications in recent program strategy.

In 1995 the Bureau's operating budget increased by $0.5 million from the previous year, to a total of $14.9 million (in Federal equivalents) from 64 contracts and grants and line-item State appropriations. Forty-seven of these funding sources were interagency contracts with State and local governments and various agencies of the Federal government; seventeen were with the petroleum industry (foreign and domestic) and private institutions. In 1995, the Bureau conducted a total of 54 research projects, several of which are highlighted herein.

In 1995 the Bureau's operating budget increased over 1994 levels with 64 contracts, grants, and appropriations.

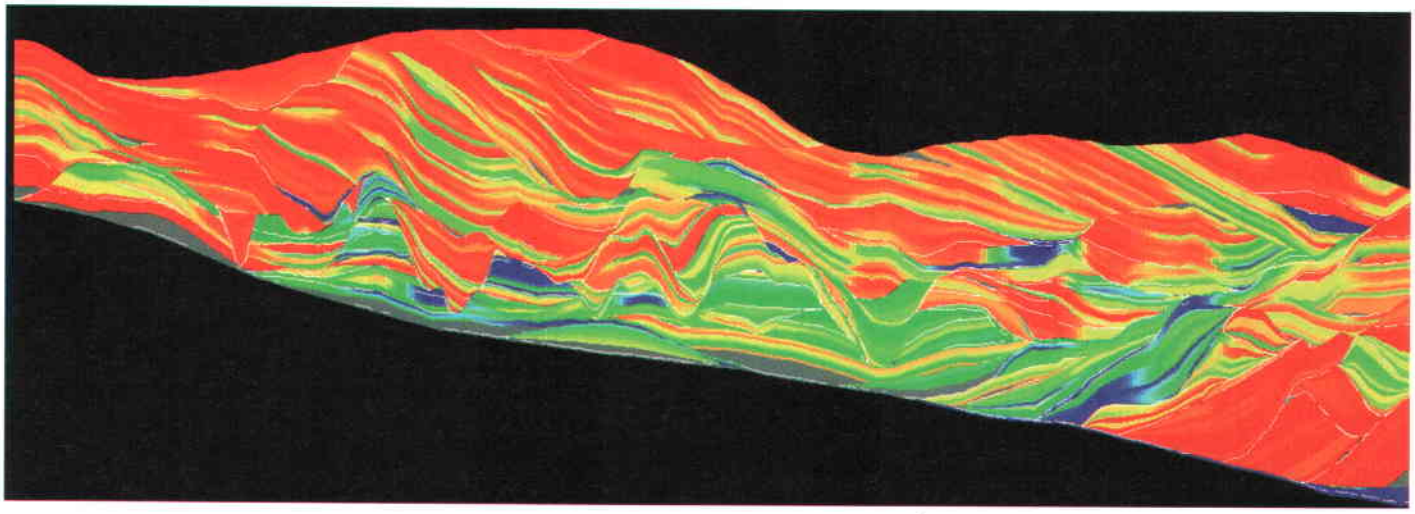
Oil Resource Investigations

In 1995 the goal of oil-resource researchers at the Bureau was to better understand approaches to maximizing recovery of oil from existing fields and to guiding strategies for resource exploitation. Because of steadily declining royalties from oil and gas production on Texas State Lands, the Bureau, using funding received in 1995 from the Texas Legislature, began aggressively to identify prospects that could increase production on State Lands. The goal of this State of Texas Advanced Resource Recovery (STARR) Project is to help producers capture a substantial part of the large volume of hydrocarbons remaining on State Lands by identifying infill-drilling and recompletion opportunities. Success in this program will benefit the state at large because the Texas Permanent School Fund receives royalties from State Lands production.

In an ongoing project funded by the U.S. Department of Energy (DOE), Bureau researchers have been scrutinizing the flow-unit heterogeneity of selected fluvial-deltaic oil reservoirs of the Frio Formation, South Texas, in an attempt to extend the economic life of these reservoirs. Many of these historically prolific reservoirs are now on the verge of abandonment despite having much remaining oil. Researchers have been evaluating reservoir architecture and compartmentalization in the Frio Rincon and T–C–B fields using sequence-stratigraphic and advanced reservoir-modeling techniques to determine controls on locations and volumes of unrecovered mobile oil.

Studies of outcrops as reservoir analogs are designed to help solve the problem of declining production.

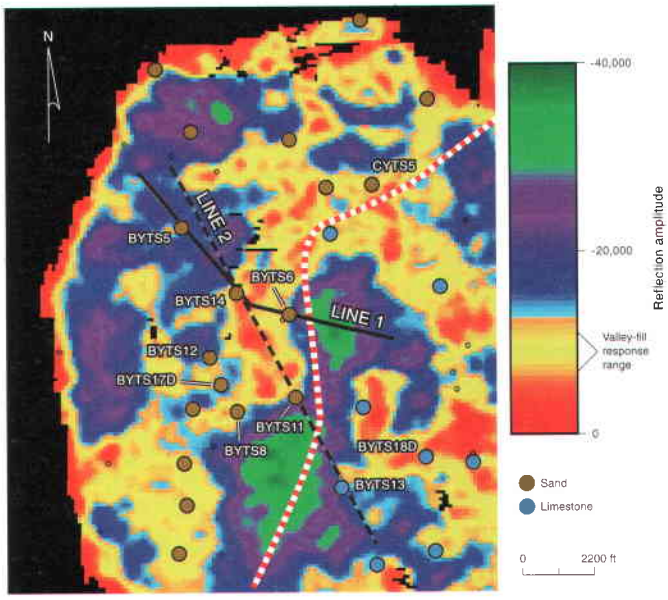
In the Delaware Basin of West Texas, many productive slope and basin sandstone reservoirs of the Delaware Mountain Group have been facing similar premature abandonment because of low recovery efficiencies. Funded by DOE, the Bureau and Conoco, Inc., have been utilizing advanced reservoir characterization strategies and designing enhanced-recovery and well-completion programs to optimize recovery from the Ford Geraldine unit and Ford West field.



Studies of outcrops as reservoir analogs (featured on the cover) have also been designed to help solve the problem of declining production from reservoirs that have remaining resources. Resource recovery requires a detailed understanding of the spatial distribution of properties that affect fluid flow. Translation of outcrop measurements of geologic heterogeneities into information useful to geologists and production engineers was therefore the primary goal of several 1995 Bureau projects. These projects focused on outcrops of the Permian San Andres and Grayburg Formations, West Texas and New Mexico; the Triassic Potrerillos Formation, Argentina; the Cretaceous Ferron Sandstone, Utah; the Cretaceous Fall River Formation, South Dakota and Wyoming; the Cretaceous Frontier Formation, Wyoming; the Cretaceous Açu Formation, Brazil; and the Cretaceous carbonate-ramp limestones of southwest Texas.

Natural Gas Resource Investigations

Gas research projects conducted during 1995 examined the geologic controls on producibility of natural gas and coalbed methane. Funded by the Gas Research Institute (GRI), Bureau investigations of the geologic influences on gas productivity from low-permeability (tight) gas sandstones expanded in 1995 to include the prolific Wilcox Lobo Formation of South Texas. Study of depositional-facies control on reservoirs in the Canyon Sandstone of the Val Verde Basin has continued with new funding from GRI. Both formations are currently among the most active gas plays in the United States. Moreover, Bureau researchers have been developing and testing potentially breakthrough methods to map natural fractures in reservoirs using cathodoluminescence examination of quartz-filled microfractures in several tight gas sandstones nationwide.



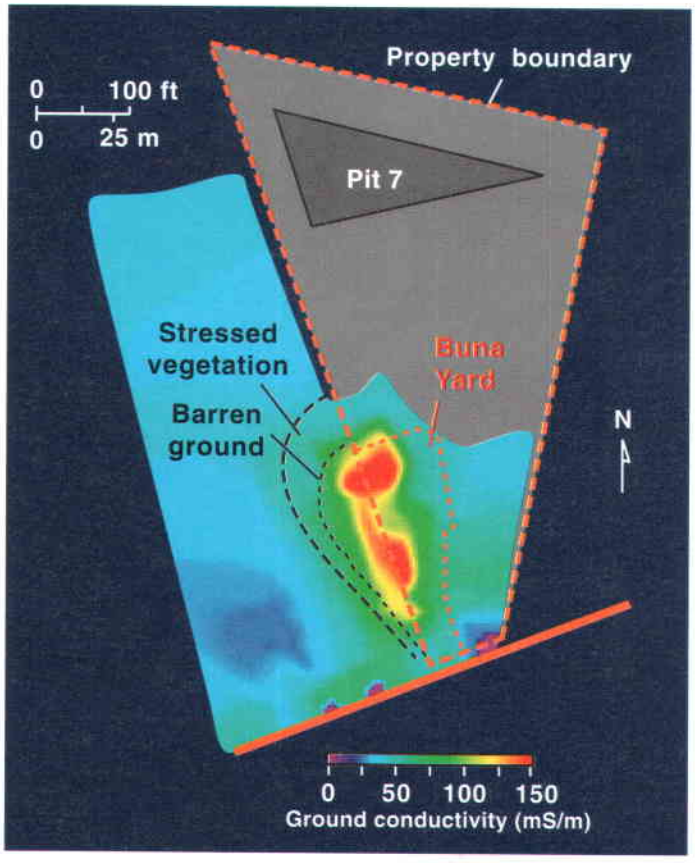
In 1995, the multiyear Secondary Natural Gas Recovery (SGR) Project completed its study of Boonsville field in North-Central Texas with the active involvement of field operators. The SGR Project has focused on documenting the impact of stratigraphic and diagenetic compartmentalization on deltaic gas reservoirs deposited in low-accommodation settings of the Midcontinent region. Bureau geoscientists have been providing operators direct guidance in production strategies, which include innovative 3-D seismic analyses. Several interpretational case histories now exist documenting that stratigraphically trapped reservoirs can be detected when selected seismic attributes are calibrated to subsurface control.

Bureau geoscientists have been providing operators direct guidance in production strategies, which include innovative 3-D seismic analyses.

Coalbed-methane research on controls of gas production in the San Juan and Piceance Basins continued. Hydrodynamics, depositional systems, coal rank, gas chemistry, and other factors critically influence producibility in these western United States coal-bearing basins, and these factors can be directly applied to worldwide coal-gas exploration and development.

Work on the offshore gas and oil reservoir atlas of the northern Gulf of Mexico continued during 1995. The first volume, containing Miocene and older fields, is scheduled to be published in 1996.

Hydrogeology and Environmental Investigations



Bureau research in 1995 also addressed several environmental issues, including aquifer characterization and contaminant containment. The extensive Edwards aquifer, a source of potable water critical to the high-growth corridor between Austin and San Antonio, has been the subject of a regional integrated study essential to its proper growth management. Bureau researchers investigated the regional three-dimensional permeability structure of the aquifer using a multidisciplinary approach that focused on the role of fractures in ground-water flow, quantification of aquifer permeability by means of aquifer tests, and calculation of matrix permeability according to well-log data and computer modeling.

Geographic information system (GIS) studies focused on the creation of highly detailed digital data bases supporting environmental analyses of the Lower Rio Grande delta of Texas, the United States–Mexico border region, and the Gulf of Mexico. Substantial investment in GIS and GPS (global positioning system) hardware, software, and personnel training in 1995 enabled the Bureau to continue to provide leadership in the application of these emerging technologies.

Researchers in ongoing site-characterization studies of the State's proposed low-level radioactive waste disposal site in the Eagle Flat region, Hudspeth County, continued to monitor the saturated and unsaturated zones and to analyze subsurface flow in detail. Moreover, investigations supporting the installation and monitoring of a prototype engineered contaminant-containment barrier were conducted. The

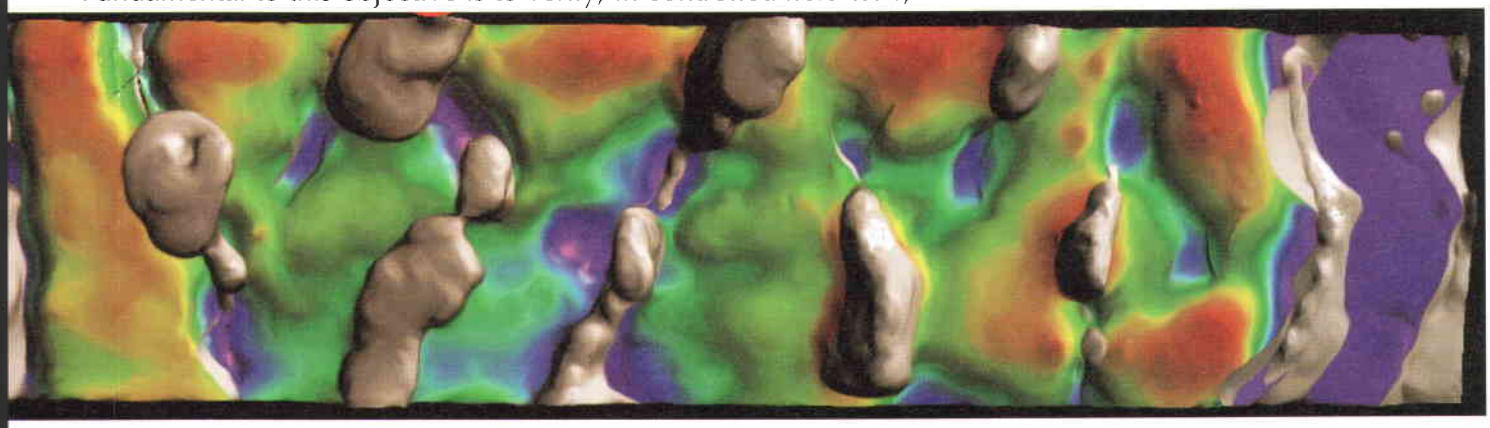
Bureau's expertise in unsaturated-zone hydrology has led to Bureau scientists' involvement in reviews of other programs in arid settings, including the low-level waste program at Hanford, Washington, and the high-level nuclear waste program at Yucca Mountain, Nevada. Additionally, the Bureau's involvement in the National Academy of Sciences panel for Ward Valley, the proposed California site, has led to guidelines for low-level waste disposal facilities of the future.

Industrial Associates Programs

In 1995, projects funded by consortia of industrial associates tackled diverse tasks related to hydrocarbon exploration and production. Workers on two separate multiyear projects have been using geologic data from outcrop analogs of deltaic and carbonate-ramp reservoirs to better explain reservoir architecture and its controls on the three-dimensional distribution of petrophysical properties. Deltaic Reservoirs Industrial Associates Project researchers have been investigating attributes of a spectrum of deltaic reservoirs represented by outcrops of the Cretaceous Fall River Formation, South Dakota and Wyoming, and the Cretaceous Frewens Castle sandstone of the Frontier Formation, central Wyoming. Carbonate-ramp outcrops of two geological systems, the Permian of West Texas and the Cretaceous of southwest Texas, are the focus of the Carbonate Reservoir Characterization Research Laboratory Project. The Permian program has currently been concentrating on prolific Grayburg Formation reservoirs, and a new program to study Clear Fork reservoirs was begun in 1995. World-class Cretaceous carbonate-ramp exposures along the Pecos River will provide data on analogous Cretaceous reservoirs, which include many giant fields from Mexico to the Middle East.

World-class Cretaceous carbonate-ramp exposures along the Pecos River will provide data on analogous Cretaceous reservoirs, which include many giant fields from Mexico to the Middle East.

Industry-funded geophysical research at the Bureau aims at developing new seismic technologies that will increase information about the internal architecture of heterogeneous hydrocarbon reservoirs. Fundamental to this objective is to verify, in controlled field tests, how



P-waves and S-waves are affected by critical reservoir rock properties. Bureau researchers will apply the basic principles of compressional and shear wavefield reflections established in these field tests to three-component seismic measurements and interpretations, which involve surface-based P and S sources and receivers, in order to detect complex reservoir systems.

The Applied Geodynamics Laboratory develops new concepts for predicting salt-related structural hydrocarbon traps.

The Applied Geodynamics Laboratory (AGL) develops new concepts for predicting the location and geometry of structural hydrocarbon traps in a wide range of tectonic settings involving salt. These settings include the Gulf of Mexico, the North Sea, the Persian Gulf, West Africa, and the Red Sea. Research emphasizes mostly physical and numerical modeling aided by seismic interpretation and fieldwork. Results are intended to be used by industry for exploration, development, and training. In 1995, AGL's program had 18 supporting oil companies, 7 of which are based overseas. Interest in the program is high partly because of the heightened focus on subsalt exploration. AGL research aims partly at deducing the little-known geometry of subsalt faults from well-imaged geometry of faults above the salt. Another major research emphasis in 1995 was investigation of the complex effects of superposing different structural regimes in sequence, such as the overprinting of compressional deformation on existing extensional structures.

International Research Programs

Geographically, Bureau programs have expanded steadily to include geoscientific research outside the United States. In 1995, the Bureau conducted six reservoir-characterization and related studies in Argentina, Australia, Brazil, Colombia, and Venezuela. The professional collaboration and cooperative interchange of research methods between Bureau researchers and their colleagues at the supporting international oil companies serve to enhance the Bureau's reputation abroad.

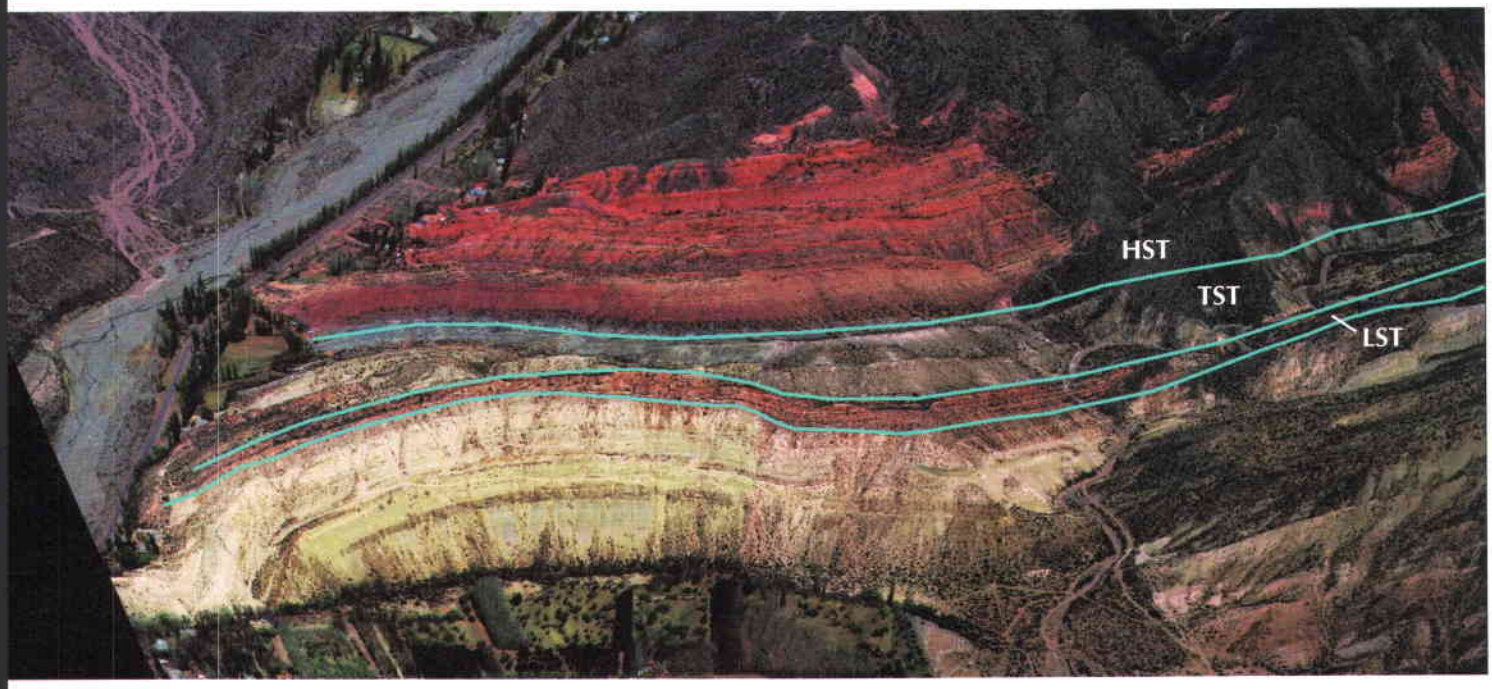
In a new project for 1995, the Bureau joined Venezuela's Corpoven, S.A., in establishing a strategy to increase oil reserves and ensure sustained production from the historically prolific Budare and Elotes Sur oil fields of the Eastern Venezuela Basin. Using 3-D seismic and other data, a team of Bureau researchers and Corpoven staff have been conducting studies of reservoir geology, petrophysics, geophysics, and petroleum engineering.

Similarly, Bureau researchers and geoscientists from Lagoven, S.A., and Maraven, S.A., of Venezuela have been teaming up to determine ways to increase recovery from complexly compartmentalized reservoirs in the Mioceno Norte area and Lagunillas field in the north part of Lake

Maracaibo, Venezuela, respectively. Bureau researchers have also been collaborating with geologists from Petrobras, S.A., of Brazil to develop a numerical data base from outcrop mapping and permeability measurements, which would provide a portable framework for simulating the complex fluvial reservoirs of the Açu Formation, Potiguar Basin, northeast Brazil. The goal of another project, funded in 1995 by Argentina's Yacimientos Petroliferas Fiscales (YPF), S.A., is to maximize oil recovery from the Triassic Potrerillos Formation in Barrancas and North Barrancas fields, Cuyo Basin, Argentina.

In the third of a series of projects funded by Santos Ltd. of Australia, Bureau and Santos personnel conducted a detailed sequence-stratigraphic analysis and reservoir characterization study of Australia's largest onshore oil field—specifically the Jurassic Hutton and Westbourne reservoirs in Jackson field, Eromanga Basin, Queensland, Australia. Among other findings, the stratigraphic framework proved to be essential for predicting reservoir-sandstone distribution and for explaining aquifer encroachment and pressure depletion, which, when combined with predicted sandstone geometries, resulted in identification of several step-out drilling locations and numerous recompletion opportunities.

In 1995, the Bureau conducted six reservoir-characterization and related studies in Argentina, Australia, Brazil, Colombia, and Venezuela.



Highlights

Kerans, Lucia, and Senger Win Prestigious Award

In a letter dated August 15, AAPG President E. F. "Bud" Reid notified Charlie Kerans that he and co-authors Jerry Lucia and Reiner Senger will receive the prestigious Wallace E. Pratt Memorial Award for best paper published in the *AAPG Bulletin* in 1994. The authors will be presented the award during the opening session of the AAPG annual meeting in San Diego in May.

The article, "Integrated Characterization of Carbonate Ramp Reservoirs Using Permian San Andres Formation Outcrop Analogs," appeared in the February 1994 issue of the *Bulletin*. It presents the results of a multiyear outcrop study of shallow-water-platform carbonates of the San Andres Formation in the Guadalupe Mountains of West Texas and southeastern New Mexico. The San Andres is the dominant hydrocarbon-producing reservoir interval in the Permian Basin, with cumulative oil production of more than 9 Bbbl. The article describes the authors' rigorously innovative methods for characterizing these oil-rich strata as a first step in planning an effective recovery of the large resource remaining in the complex San Andres reservoirs.

Charles Kerans (at left) and field-trip participants—Guadalupe Mountains, southeastern New Mexico. Photo by Laura Zahm.

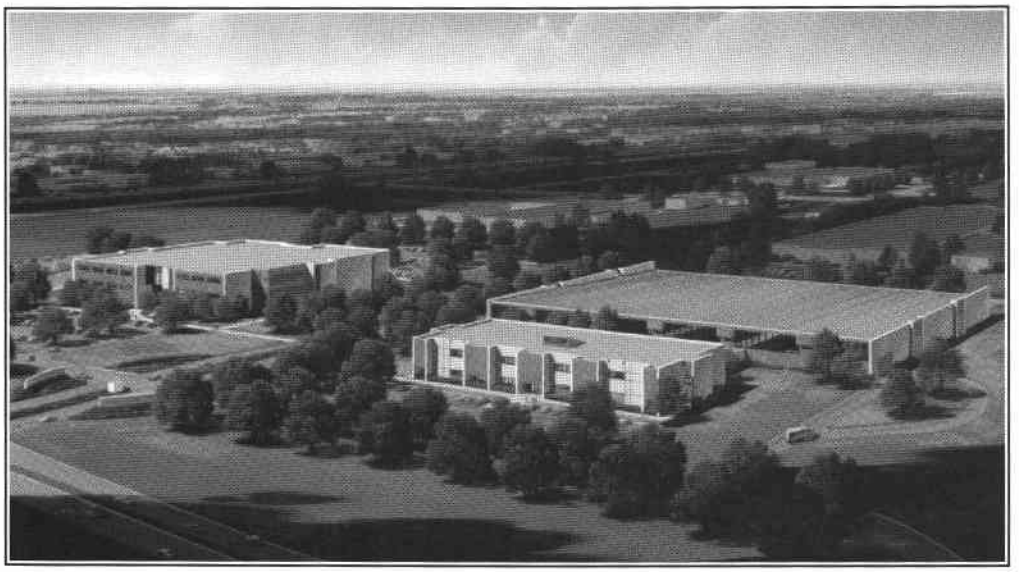
New Bureau Program to Maximize Petroleum Recovery from State Lands

In 1995 the Texas Legislature appropriated $890,000 in order for the Bureau of Economic Geology to begin a new program to maximize oil and gas recovery from State Lands reservoirs. This 2-yr program, begun September 1, 1995, has three components: (1) characterization and advanced-recovery-technology deployment in key reservoirs, (2) identification of underdeveloped reservoirs, and (3) transfer of concepts and approaches to recovery optimization to State Lands operators. This project will actively promote incremental drilling in State Lands fields when researchers identify the best infill-drilling locations and the best targets for oil and gas production.

Bureau Launches WWW Home Page

Piloted by Bureau Director Noel Tyler, the Bureau entered cyberspace on March 9, 1995, by launching its first World-Wide Web home page. Prepared by the Deputy Associate Directors, support-staff supervisors, Tucker Hentz, Jamie Coggin, Margaret Evans, Joel Lardon, Amanda Masterson, and Gerry White, the Bureau's home page features an architectural rendering of the Bureau triplex and a brief description of the Bureau that links up with individual program areas. It can also be linked to other Internet sites in Texas and around the world.

The page was revised by Amanda Masterson and Gerry White in July



What's New at BEG
Oil Research Program
Gas Research Program
Coalbed Methane
Geophysics Program
Environmental Program
Coastal Studies

Hydrogeology Program
Industrial Associates
International Programs
GIS Capabilities
Core Research Facilities
Publications and Products
Services and Staff

Welcome to the Bureau of Economic Geology

Part of the Bureau's Internet home page, located at http://www.utexas.edu/research/beg/, issued in March 1995.

and September, at which time a clickable image map, lists of Bureau publications and an on-line order form, and more links to other organizations were added. In November, members of the Internet Committee, chaired by Associate Director Tom Grimshaw, made a presentation at the 1995 Geological Society of America annual meeting in New Orleans that featured the Bureau's page. Currently the page resides at http://www.utexas.edu/research/beg/. Future additions to the Bureau's home page will include a listing of the Core Research Center holdings and more links to other geoscience organizations.

Bureau Research Featured in *AAPG Explorer*

"Cutting edge technology developed by geologists at the Bureau of Economic Geology at The University of Texas at Austin just might make [computer animation] an important link in geologic studies." So opened the lead article in the April issue of the *AAPG Explorer*. The article highlights the innovative techniques developed by Bureau researchers of the Applied Geodynamics Laboratory (AGL) to help geologists visualize the dynamics of complex structural processes, particularly those relating to salt tectonics. These techniques involve computer animation of static tectonic-model images. As Bureau researcher Giovanni Guglielmo pointed out in the article, computer animation allows geologists in 20 seconds to replay on the computer an experiment that took several days to complete in the laboratory. Furthermore, the article announces, three computer animations will be available over the Internet after the first public showing of AGL-produced animations at the annual AAPG Archie Conference in April.

Bureau Active in Technology Transfer

In 1995 the Bureau conducted three sets of workshops in its ongoing dissemination of research results to the producing community.

The Bureau's Secondary Gas Recovery (SGR) research team taught seven workshops that attracted more than 350 participants from Texas, Colorado, and Oklahoma. Local geological and engineering societies in Houston, Tyler, Graham, Oklahoma City, Tulsa, and Denver sponsored these technology transfer courses. Attendees were shown how subsurface information from more than 200 wells in Boonsville field of the Fort Worth Basin, North-Central Texas, was combined with 26 mi^2 of 3-D seismic data, vertical seismic profiles, and reservoir engineering data to characterize the fluvial-deltaic reservoir system in the highly productive Atoka (Bend) interval. Research results are the product of a 2-yr investigation funded by the Gas Research Institute, the U.S. Department of Energy, and the State of Texas.

The Bureau also presented a coalbed methane short course, sponsored by the Gas Research Institute, at the J. J. Pickle Research Campus in Austin. The course included a comprehensive summary of the geologic and hydrologic controls critical to coalbed methane producibility and resource assessment of the San Juan, Greater Green River, and Piceance Basins of western United States. The short course was attended by 30 participants from State organizations, industry, and academe.

The Bureau, in conjunction with the Texas Independent Producers and Royalty Owners Association (TIPRO), presented four workshops for the Governor's Technology Transfer project in Houston, Corpus Christi, and Midland. The workshops were designed to acquaint the petroleum industry with the latest developments in play analysis, resource assessment, and reservoir characterization of four key Texas oil and gas plays: the Frio Fluvial-Deltaic Sandstone play, the Frio Barrier/Strandplain Sandstone play, the Wilcox Deltaic Sandstone play, and the Upper Guadalupian Sandstone play. Bureau and TIPRO researchers presented reserve-growth concepts, reservoir characterization methodology, and type-study examples for each play. Also discussed were the Play-Based User Groups, permanent organizations composed of people interested in specific Texas plays that meet periodically to explore business opportunities, learn of new technical developments, and share ideas.

Major and Scott Elected to Prominent Society Offices

R. P. Major has been elected Secretary of the Gulf Coast Section of the Society of Economic Paleontologists and Mineralogists. He holds that office for 1 yr beginning in January 1996.

Andrew Scott has been elected Gulf Coast Councilor for the Energy Minerals Division (EMD) of the American Association of Petroleum Geologists. The EMD was founded in 1977 to address the needs of geologists studying energy minerals and related topics, which now include coal, coalbed methane, geothermal resources, uranium, and remote sensing. Andrew's term of office will extend through mid-1997, during which he will represent the EMD in Florida, Mississippi, Alabama, Louisiana, and parts of Texas and Arkansas.

Awards and Honors

Robert J. Finley was named a Fellow of the Geological Society of America. The Society of Exploration Geophysicists awarded **Robert J. Graebner**, Senior Research Fellow at the Bureau, an Honorary Life Membership in the society.

Stephen C. Ruppel won Honorable Mention for Excellence of Poster Presentation from SEPM (Society for Sedimentary Geology) for his paper, "Improvements in the Record of Secular Change in Sea Water $^{87}Sr/^{86}Sr$: A Stronger Basis for Dating Depositional and Diagenetic Events," which was presented at the AAPG annual meeting. The article by **Andrew R. Scott,** "Limitations and Benefits of Microbially Enhanced Coalbed Methane," was selected as the Best Paper in the Reservoir

Characterization/Coal Science category at the annual Intergas '95 Symposium. **Roger Tyler, W. R. Kaiser, Andrew R. Scott,** and **Douglas S. Hamilton** received the Energy Minerals Division Best Paper Award at the 1995 AAPG meeting in Houston, Texas. The paper is titled "Geologic and Hydrologic Controls on Coalbed Methane Resources, Greater Green River Basin, Southwestern Wyoming and Northwestern Colorado."

Barnes's Autobiography Published

On Solid Ground: Memoirs of a Texas Geologist, autobiography of Virgil E. Barnes, Senior Research Scientist at the Bureau, was published by the Bureau in the fall. In his memoirs, Barnes recounts highlights of his life and career in entertaining detail: his childhood in Washington; his worldwide travels in search of tektites, accompanied by his wife, Milla; and his geological mapping and other research at the Bureau. Barnes began his long and prolific career at the Bureau in 1935. He directed the mapping project that resulted in 38 Geologic Atlas of Texas sheets and the four-quadrant geologic map of the entire state. In recognition of his many professional accomplishments, Barnes was named Distinguished Texas Scientist for 1988 by the Texas Academy of Science. A year later he was honored by the Meteoritical Society by being presented the prestigious Barringer Award. In 1993 he received the Public Service Award from the American Association of Petroleum Geologists for his distinguished contribution to the profession and his service to the state and to the nation.

Milla and Virgil Barnes at Camly Falls, Dalat, Vietnam, during a tektite-hunting trip in 1960, which yielded several hundred tektites. Photo by Adrien Milles-Lacroix.

New Research Staff

Saleem Akhter rejoined the Bureau as Research Associate in January after 2 1/2 yr with Saudi Aramco, where he studied reservoir engineering, simulation, and development in Ghawar field, Saudi Arabia. Saleem will work on the Bureau's international projects and on developing studies related to Eastern Europe and the CIS. **Janok P. Bhattacharya**, a Research Associate, is conducting outcrop and sedimentological studies for the Deltaic Reservoirs Industrial Associates program. Janok received his Ph.D. in Geology from McMaster University and worked in the Stratigraphic Analysis Group at ARCO research lab before joining the Bureau. **Patricia W. Dickerson**, who received her Ph.D. from The University of Texas at Austin (1995), joined the Bureau as a Postdoctoral Fellow. Pat is studying the complex structure of the Wilcox Lobo trend for the Tight Gas Sands project. Her principal research interests are tectonics and structural geology, particularly of West Texas, New Mexico, and northern Mexico. **Robert K. Goldhammer**, who is working on the State Lands project, received his Ph.D. from Johns Hopkins University (1987). His dissertation focuses on cyclic platform carbonate deposits of the Alpine Triassic. From 1987 through 1995 he was employed by Exxon Production Research Company, where his work centered on carbonate cyclostratigraphy and sequence stratigraphy. **Edgar H. Guevara** rejoined the Bureau as a Research Scientist after working for Lagoven S.A. in Venezuela for 2 1/2 yr as a project manager. Edgar received his Ph.D. from The University of Texas at Austin and is currently involved in the characterization of deep-water, sandstone oil reservoirs in the Delaware Basin and in international reservoir-characterization projects. **Ursula Hammes** joined the Bureau as a Postdoctoral Fellow with the Secondary Natural Gas Recovery project in order to study secondary

natural gas recovery in the Ellenburger Group, West Texas. Ursula received her Ph.D. (1992) in Geology from the University of Colorado. Her expertise is in carbonate diagenesis, carbonate sedimentology, and stratigraphy. She has 2 yr of oil and gas exploration experience in carbonate reservoirs with ARCO Oil and Gas, Plano, Texas, Marathon Oil Company, Littleton, Colorado, and Simon Petroleum Research, North Wales, England. Since 1994, she has worked for IT Corporation as an environmental scientist on assessment and remediation projects. **L. Morgan Ives** joined the Bureau as an Operating System Specialist. Previously he worked at The University of Texas at Austin Computation Center for 17 yr. Morgan attended UT Austin and Stephen F. Austin State University, where he studied Anthropology and Computer Sciences. **James W. Jennings** joined the Bureau as a Research Associate in the Reservoir Characterization Research Laboratory. After earning his Ph.D. in Petroleum Engineering from Texas A&M University, James worked for Sohio in chemical flooding, for British Petroleum as a Reservoir Engineer, and for ARCO as a Senior Research Engineer. **Michael T. Kader** became the Bureau's Manager of Computer Resources. A mechanical engineer with more than 12 yr of computing services experience in the oil and gas industry, Mike has been assessing the Bureau's immediate and long-term computer resources needs. **Jerry W. Mullican** signed on with the Bureau as a part-time Research Fellow. Jerry, who received a Master's in Geology from Texas Tech University, retired on September 1 from the Railroad Commission of Texas (RRC), where he was Assistant Director of the Oil and Gas Division. Before joining the RRC in 1980, he was Chief of Geological Services for the Texas Water Quality Board and the Texas Department of Water Resources. Jerry currently serves as President of the Underground Injection Practices Research Foundation, the research arm of the Ground Water Protection Council, a national nonprofit organization. **Deborah A. Salazar** became the new Bureau GIS Coordinator, responsible for overseeing all GIS projects. Deborah received her Ph.D. in Geography from The University of Texas at Austin. She has 8 yr of experience in GIS applications, having completed field projects in Ecuador, Mexico, and Venezuela. **Jirapa Skolnakorn,** a Research Scientist Associate, is working on the Lagoven project conducting log-data quality control for petrophysical analysis. **Ramón H. Treviño**, who holds a Master's in Geology from The University of Texas at Arlington and a Master's of Business Administration from the University of Oklahoma, is working on the Maraven and YPF projects. Previously Ramón worked as a mud logger (1984) and as an exploration geologist (1988 through 1992) for Mobil Oil Company. **Christopher D. White**, a Research Scientist, received his Ph.D. in Petroleum Engineering from Stanford University. Chris is currently working on the Deltaic Reservoirs Industrial Associates program, where he is conducting three-dimensional reservoir-engineering modeling and reservoir simulation. Before joining the Bureau, Chris worked as a Research Engineer for Shell Oil.

Research

Energy Resources Investigations

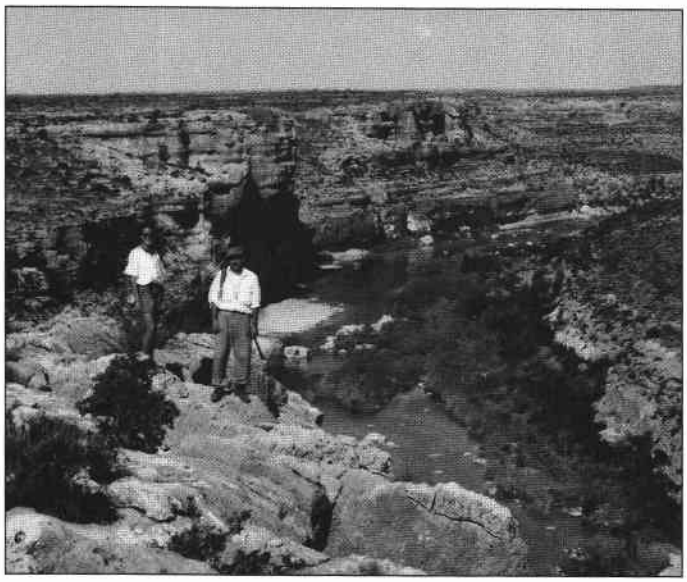
Petroleum

Reservoir Characterization Research Laboratory: Characterization of Carbonate Reservoirs

F. Jerry Lucia and Charles Kerans, principal investigators; James W. Jennings; assisted by Andrew P. Czebieniak, William M. Fitchen, Kirt A. Kempter, Qiucheng Ye, and Laura C. Zahm

The goal of the Carbonate Reservoir Characterization Research Laboratory (RCRL) is to develop new generic methods for describing the three-dimensional distribution of petrophysical properties in carbonate-ramp reservoirs. Our purpose is to (1) provide quantified geologic–petrophysical models for input into reservoir simulators to improve predictions of reservoir performance and (2) map the distribution of remaining hydrocarbons. This research is funded by the RCRL Industrial Associates sponsors, including Amoco, Aramco, ARCO, BP, Exxon, JNOC, Marathon, Meridian, Oxy, Pennzoil, Petroleum Development Oman, Phillips, Shell Canada, Shell Western, Texaco, TOTAL, and UNOCAL. In addition, the program is supported by Intera, Landmark, Terra Science, and OGCI, companies that provide state-of-the-art software.

The approach is to combine the study of outcrop analogs of major reservoir types with subsurface reservoir studies.



Bureau scientists studying the sequence framework and world-class petrophysical properties of Cretaceous (Albian) ramp limestones exposed along the Pecos River, Southwest Texas. Photo by Laura Zahm.

The outcrop is important because it provides the only opportunity to study the interwell environment directly and collect information for characterizing this environment geologically and petrophysically. Subsurface reservoir studies provide a means of developing methods for applying this information to analogous reservoirs. Outcrop studies have shown not only that rock-fabric facies compose the basic flow unit of carbonate reservoirs but also that the stacking of rock-fabric flow units is systematic within a sequence stratigraphic framework. Subsurface studies have resulted in methods for using core and log data to describe the sequence stratigraphic framework and to quantify it in terms of rock-fabric flow units, water saturation, absolute permeability, and relative permeability. Simulation studies demonstrate the importance of the stacking of flow units, reservoir barriers, and rock-fabric-specific relative permeability relationships.

Two geological systems are currently being studied—the Permian of West Texas and Cretaceous outcrops of southwest Texas. Reservoirs of the San Andres and Grayburg Formations in the Permian Basin have been selected for study because of (1) the vast hydrocarbon resource remaining in these reservoirs and (2) the world-class outcrops of these formations in the nearby Guadalupe Mountains. The research program was expanded last year to include world-class Cretaceous (Albian) outcrops along the Pecos River, southwest Texas. The goal of this project is to develop methods for characterizing the geologic framework and petrophysical properties in Cretaceous ramp limestones and to relate these scales to the vast resources in Cretaceous reservoirs in the Middle East.

In addition to the Permian program currently focused on Grayburg reservoirs, a new program to study Clear Fork reservoirs has begun. Detailed outcrop mapping and petrophysical characterization will define 3-D geometries of grainstone and grain-dominated packstone rock-fabric facies in the Brokeoff Mountains west of the Guadalupe Mountains. The subsurface study is developing reservoir models for simulation studies of the South Cowden reservoir. The Cretaceous program is developing a regional and reservoir-scale sequence stratigraphic framework to prepare for reservoir modeling studies.

Geoscience/Engineering Characterization of the Interwell Environment in Carbonate Reservoirs on the Basis of Outcrop Analogs—Permian Basin, West Texas and New Mexico

Charles Kerans and F. Jerry Lucia, principal investigators; Stephen C. Ruppel and Roger J. Barnaby; assisted by Milton H. Kwong and William B. Ward

The objective of this project, which is funded by the U.S. Department of Energy, is to investigate styles of reservoir heterogeneity in low-permeability pelleted wackestone–

packstone facies and mixed carbonate–clastic facies found in Permian Basin reservoirs, by studying similar facies exposed in the Guadalupe Mountains. Specific objectives of the outcrop study include constructing a sequence stratigraphic framework, quantifying the framework petrophysically, and using reservoir simulators to test the outcrop reservoir model for effects of reservoir heterogeneity on production performance. Specific objectives of the subsurface study include testing and developing methods of using core and wireline log data to construct a sequence stratigraphic framework, quantifying that framework in terms of petrophysical parameters, and determining the spatial distribution of remaining oil saturation by using a reservoir simulator.

The outcrop study focuses on the Grayburg Formation, which crops out in the Brokeoff Mountains just west of the Guadalupe Mountains. A series of ridges and deeply incised meandering canyons provide the opportunity to construct three-dimensional views of stratigraphic units. Mapping and construction of the sequence stratigraphic framework are completed. Current outcrop activities focus on mapping and petrophysical characterization of grainstone and grain-dominated packstone rock-fabric bodies. The geologic framework and petrophysical characterization of South Cowden Grayburg field have been completed. Current subsurface activities include using a combination of geological and geostatistical methods to construct reservoir models for input into a flow simulator.

State of Texas Advanced Resource Recovery (STARR) Project

Raymond A. Levey, principal investigator; Mark A. Chapin, Chester M. Garrett, Jr., Robert K. Goldhammer, Douglas S. Hamilton, Mark H. Holtz, Richard P. Major, H. Seay Nance, Deborah A. Salazar, and Roger Tyler; assisted by Hye Won Kim

Since 1839, when the Republic of Texas began designating public lands to be used to benefit public schools, the State of Texas has amassed more than 20.5 million acres, 12.5 million of which has been set aside to assist public education. In the 155 yr since that forward-looking decision was made, more than $6.3 billion in revenue for public schools has been generated, most derived from royalties and rentals paid from oil and gas leases.

An enormous hydrocarbon resource remains on State Lands. In fact, State Lands fields contain more oil and gas than have been recovered over the decades-long history of State Lands production. Rather than being unattainable, a large volume of this remaining oil and gas is recoverable through strategic, or targeted, deployment of advanced recovery technologies.

The Bureau of Economic Geology, with funding from the Texas Legislature, has begun Project STARR to provide critical technical support to State Lands operators. The best prospects for increased production are being identified, and with the support of allied producers, we are investigating infill drilling and recompletion opportunities in State Lands oil and gas fields. The process of maximizing oil and gas recovery from State Lands fields requires (1) characterization and advanced recovery technology deployment in key reservoirs, (2) identification of underdeveloped reservoirs, and (3) transfer of concepts and recovery-optimization approaches to State Lands operators. We are aggressively pursuing advanced recovery on State Lands, in order to capture a large part of the vast remaining unrecovered oil and gas.

A Robust Economic Technique for Crosswell Seismic Profiling

Bob A. Hardage, principal investigator; James L. Simmons, Jr.; assisted by Eric M. Matzel, Jose N. Pecina-Cruz, and Eric J. Phinney

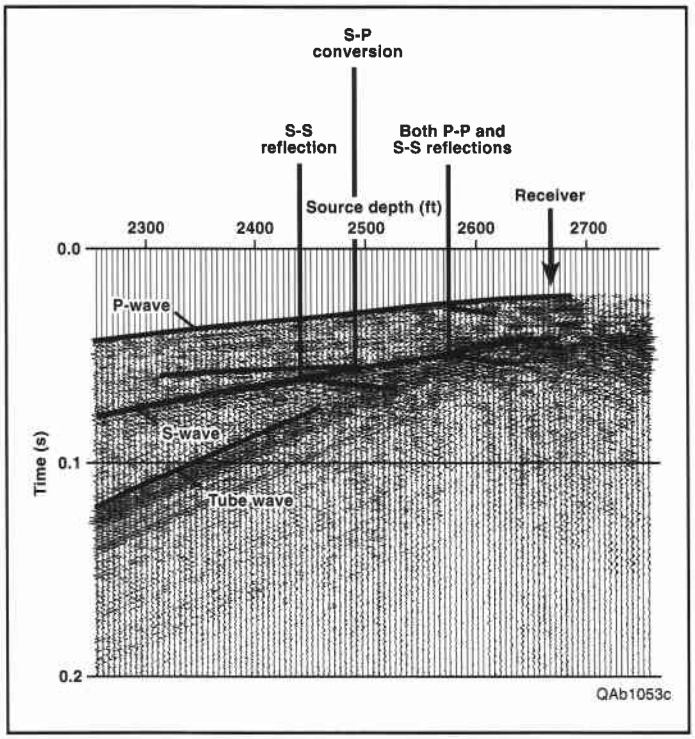
Crosswell profiling is a seismic measurement, made by means of downhole seismic sources and receivers, that images the geology between two wells at a rather high spatial resolution. Crosswell profiling, an important emerging seismic technology, is being considered by several industries as a way of mapping interwell fluid-flow paths and of monitoring the behavior of secondary recovery processes. The objective of this DOE-funded research program is to determine whether surface-based seismic sources instead of downhole sources can be used to generate crosswell tomographic data. Traditionally, crosswell data are recorded by deploying receivers in one well and a seismic source in a second well and then recording the seismic wavefield that travels across the interwell space. In the method being investigated in this study, workers deploy receiver arrays in two wells, position a seismic source on the surface at an offset location that is in line with the two wells, and then use the two downhole arrays to record the wavefield that traverses the interwell space.

The attraction of surface–source crosswell tomography is that the method allows a large vertical aperture of crosswell data to be acquired in a shorter period of time than it takes for the data aperture to be recorded using a downhole source. This reduction of field-data-acquisition time translates into low-cost crosswell surveys. The Bureau of Economic Geology has now done what is thought to be the first rigorous test and demonstration of surface–source tomography in an active oil field. In this test, a 1,020-ft vertical aperture of crosswell data, the downhole wavefields being produced at four different surface–source locations and sampled at vertical intervals of 10 ft in each receiver well, was acquired in only 10 operating hours. Acquiring the same number of crosswell data using current downhole–source technology would require approximately 60 to 100 h.

Using Seismic Vector Wavefields to Analyze Heterogeneous Reservoir Architecture

Bob A. Hardage and Robert J. Graebner, principal investigators; H. Seay Nance and James L. Simmons, Jr.; assisted by Eric M. Matzel and Jose N. Pecina-Cruz

The objective of this industry-funded research is to develop and demonstrate expanded seismic technologies that increase information about the internal architecture of het-



Crosswell seismic data that were used to study the basic physics of compressional (P) and shear (S) wave mode conversions in reservoir systems. Bureau scientists are working with industry partners to develop three-component seismic imaging technology that can provide both P and S images of reservoirs. The Bureau has focused on downhole sources and three-component receivers to record crosswell data, such as shown here, over reservoir intervals that have well log, core, and production data. Such data can be used to calibrate rock and fluid properties to specific P and S mode conversions.

erogeneous reservoirs. Fundamental to this objective is to verify, using actual field tests, how P-waves and S-waves are affected by (and, thus, provide information about) critical reservoir rock properties. A unique aspect of this geophysical research is its reliance on the geologic and reservoir engineering expertise of Bureau of Economic Geology scientists to provide a detailed anisotropic model of each reservoir system studied. At each study site, research follows a two-phase sequence: (1) study of the basic physics of P and S transmission and reflection in heterogeneous reservoirs via carefully controlled crosswell experiments and (2) extension of the findings of phase 1 to acquisition geometries involving surface-positioned sources or receivers or both.

The primary research objective is to analyze three-component crosswell wavefields in various gather formats to (1) determine depths at which one type of seismic wave mode is reflected and another mode is not or depths at which all wave modes are reflected and then (2) acquire and apply geologic and engineering control to define what changes in rock properties cause these behaviors in vector wavefields reflectivity. The ultimate objective is to apply the basic principles of vector wavefield reflection established in these controlled tests to seismic measurements and interpretations that involve surface-based P and S sources and receivers and anisotropic reservoir systems.

Quantification of Flow-Unit and Bounding Element Properties and Geometries, Ferron Sandstone, Utah: Implications for Heterogeneity in Gulf Coast Tertiary Deltaic Reservoirs

Noel Tyler, principal investigator; Mark D. Barton and Edward S. Angle

Because oil and gas reservoirs typically display a complex architecture that controls paths of fluid migration, recovery efficiency, and the volume of hydrocarbons left in a reservoir at the time of abandonment, recovery of these resources requires a detailed understanding of the spatial distribution of the properties that affect fluid flow. The goal of this project, which is sponsored by the Gas Research Institute, is to translate outcrop measurements of geologic heterogeneities into transportable information useful to development geologists, well log analysts, and production engineers. The project focuses on the Cretaceous Ferron Sandstone as an outcrop analog to heterogeneous fluvial-deltaic reservoirs, which have a large potential for reserve growth. The low hydrocarbon recovery efficiencies in Texas fluvial-deltaic reservoirs indicate that substantial reserves remain, and they highlight the need for predicting the spatial distribution of interwell heterogeneities. Exposures of the Upper Cretaceous Ferron Member of the Mancos Shale allow us to quantify the three-dimensional architecture and petrophysical attribute structure of fluvial-deltaic sandstones within a sequence stratigraphic framework and to document the expression of such relationships within a subsurface setting.

Predictable changes in facies arrangements and proportions can be related to a stratigraphic framework that is governed by two parameters: accommodation and sediment supply. Different styles of reservoir heterogeneity are represented in Ferron seaward- and landward-stepping depositional cycles. The principal sandstone repository within seaward-stepping cycles is the shallow-marine facies tract, where continuous shales compartmentalize parasequences both vertically and laterally. Valley-fill and distributary-channel sandstones are volumetrically minor components of Ferron seaward-stepping cycles. Deposits are preserved as lithologically homogeneous, ribbonlike sandstone bodies encased in and widely separated from adjacent sandstone bodies by mudstone-rich strata. These relationships are almost reversed in Ferron landward-stepping cycles, where valley-fill and distributary-channel belts are volumetrically the most important sandstones. These sandstone bodies are segmented internally by low-permeability mudstones and intraformational clay-clast conglomerates that were deposited along channel-base bounding surfaces. By contrast, within the shallow-marine facies tract, parasequences and component mouth-bar deposits are amalgamated into a single upward-coarsening, strike-elongate sandstone succession that displays a low degree of lithologic diversity. Genetically based, these conclusions are not formation specific, but they can apply to reservoirs in analogous stratigraphic, depositional, and diagenetic settings.

Geologic and Engineering Characterization of the BACH-24, A-22, LL-02, and LL-08 Reservoirs, Mioceno Norte Area, Lake Maracaibo, Venezuela

Richard P. Major, principal investigator; William A. Ambrose, Fred P. Wang, M. Saleem Akhter, and Jirapa Skolnakorn; Milton M. Mendez and Regulo A. Alvarez (Lagoven, S.A.); assisted by Nina L. Baghai, Erica M. Boghici, Herbert Haubold, and Amy K. Sapp

Since their discovery in the 1930's, Miocene reservoirs in the 30-km^2 Mioceno Norte Area in the northeast part of Lake Maracaibo have produced more than 265 MMbbl of oil. These reservoirs are, however, estimated to have a recovery efficiency of only 27 percent at the end of primary recovery operations at current 20- to 25-acre well spacing. Although production accelerated during World War II to meet wartime demands, appreciable volumes of oil remain in multiple reservoir compartments. Strategic development of these poorly drained compartments could improve ultimate recovery by as much as an additional 10 to 15 percent of the original oil in place.

The Bureau of Economic Geology, in an 18-mo study funded by Lagoven S.A., used an integrated approach to reservoir characterization of the Mioceno Norte Area, which produces from a 2,500-ft section. Combining structural, stratigraphic, seismic, palynological, petrophysical, petrographic, petroleum-engineering, and volumetric analyses, we can identify areas of remaining oil that can be produced by means of infill wells, recompletions, and secondary-recovery operations. Comparing (1) maps of porous hydrocarbon volume (SoPhiH) and net pay and (2) cumulative production, our scientists can identify numerous underproduced areas. Wells having high water production that were identified could be considered for conversion to water injection for strategic waterflooding, particularly on the flanks of structurally high areas.

By volumetrically analyzing and petrophysically evaluating 43 key wells, the Bureau will quantify volumes of remaining oil in each reservoir. Additionally, we will delineate infield-exploration fairways and devise development strategies for each reservoir in the field, targeting compartments inferred from production history and analysis of depositional architecture. The project will conclude with site-specific recommendations for infill wells and recompletions, extending the productive life of the Mioceno Norte Area into the next century.

Characterization of Oil Reservoirs in the Triassic Potrerillos Formation, North Barrancas and Barrancas Fields, Cuyo Basin, Argentina

Raymond A. Levey, principal investigator; M. Saleem Akhter, project manager; Edward S. Angle, William A. Ambrose, Luis A. Sánchez-Barreda, Mark D. Barton, Shirley P. Dutton, Steven J. Seni, Jirapa Skolnakorn, Ramón H. Treviño, Joseph S. Yeh, and Fred P. Wang; Virginia M. Pendleton (independent consultant); Marta A. Bugarini, Claudio Marcelo Fonseca, Guillermo Frati, Pedro Lafourcade, and Edgardo Ignacio Moreiras (YPF); assisted by Eugene M. Kim and Faisal Rashid

The goal of this project, funded by Yacimientos Petroliferas Fiscales (YPF) S.A., is to maximize oil recovery from the Triassic Potrerillos Formation within North Barrancas and Barrancas fields, Argentina, and to provide technical support and training to YPF personnel. To realize this goal, Bureau of Economic Geology researchers are investigating geologic controls on reservoir compartmentalization as a basis for determining future drilling locations. This reservoir characterization methodology integrates (1) outcrop studies of sandstone-body geometries, (2) high-resolution subsurface well and 3-D seismic correlations, (3) reservoir engineering, and (4) reservoir simulations. The Potrerillos Formation was deposited in lacustrine rift basins associated with the opening of the southern Atlantic Ocean and has since been folded in an asymmetric thrusted anticline at North Barrancas and Barrancas fields during Cenozoic Andean contraction.

Fieldwork on outcrops of the Potrerillos Formation in the Andean foothills has produced data on sandstone-body architecture, which will guide analysis of reservoir geometries. Permeability structure measured in the fields will be used to predict reservoir compartmentalization. At North Barrancas and Barrancas fields, subsurface correlations have identified lacustrine flooding surfaces, which will provide the framework for identifying high-resolution genetic packages. These depositional styles and facies have been identified: (1) aggradational fluvial, (2) progradational "Gilbert-type" lacustrine delta, (3) muddy lacustrine, and (4) mixed retrogradational. Perforated intervals are concentrated in the retrogradational and aggradational facies. A three-dimensional seismic survey will identify reservoir geometries and locate small faults that could compartmentalize oil reservoirs. Reservoir engineering will concentrate on petrophysical, production, and reservoir-volumetric analyses; reservoir simulations will also be performed.

An important aspect of the project is the cooperative interchange of research methodologies. Bureau and YPF personnel will work together during all phases of the project.

Characterization of Eocene Reservoirs: VLA-6/9/21 Area, Lake Maracaibo, Venezuela

Noel Tyler, principal investigator; Kenneth T. Barrow, M. Saleem Akhter, Roger J. Barnaby, Shirley P. Dutton, Fred P. Wang, Joseph S. Yeh; assisted by Alistair S. Clague, James A. Davidson, Qing Fang, Humayun Hasan, Sangram R. Kakulavaram, Nestor V. Rivera, Martha L. Romero, and Kriyanti Setiyono

This project, funded by Maraven S.A., an oil and gas exploration and production affiliate of Petróleos de Venezuela S.A., aims to increase oil recovery from tide-dominated deltaic and shelf reservoirs in the C members of the Eocene Misoa Formation in Lagunillas field in northern Lake Maracaibo. Reservoir compartmentalization, because of mul-

tiple episodes of structural deformation and complicated reservoir architecture, has led to relatively inefficient production. Average recovery efficiency has been less than 25 percent of nearly 2 billion barrels (Bbbl) of oil originally in place.

Phase 1 of this four-part, 28-mo study was completed in 1995. During phase 1, the Bureau of Economic Geology studied in detail all available data from the C4 and C5 reservoirs within a 3-mi^2 pilot area. More than 1,000 ft of core was described and matched to wireline log responses to create a depositional model of these marginal-marine sandstone reservoirs. Genetic stratigraphic sequences were correlated, and sandstone-body geometry was mapped from logs. We created an integrated structural interpretation by merging wireline log and 3-D seismic data. Analysis of production data within the context of the geologic model led to identification of flow units and a series of recommendations for infill drilling locations, recompletions, and waterflood realignment strategies.

Phase 2 of this project will incorporate all wells in Maraven's VLA-6/9/21 area into the study. More than 130 wells (about one-half of the ultimate total) have been included to date, and 32 stratigraphic units have been identified. In the months to come, more wells and stratigraphically higher units will be added as the project area expands to encompass off-structural parts of the field. When completed, this project and the Bureau's recently completed study of the Lagoven LL-652 area will form a uniquely detailed explanation of the geology and oil and gas production from the Eocene Misoa Formation of the Maracaibo Basin.

Reservoir Characterization Study, Budare Field, Guarico State, Eastern Venezuela Basin

Noel Tyler, project director; Edgar H. Guevara, project coordinator; Douglas S. Hamilton, Fred P. Wang, M. Saleem Akhter, Joseph S. Yeh, Bob A. Hardage, Richard D. Edson, Jr., R. Stephen Fisher, Amy K. Sapp, and Jirapa Skolnakorn; Ana Rojas de Salazar, Carmen Elisa de Cova, Moises Uzcategui, Alberto Rusic, and Toribio Jimenez (Corpoven, S.A.); assisted by Jianchun Dai, Muhammad Razi, and Carlos Amaya

This 6-mo project, funded by Corpoven, S.A. (an affiliate of Petróleos de Venezuela, S.A.) and begun in mid-August 1995, is a reservoir characterization study through volumetric analysis. The primary project objective is defining a development plan to increase oil reserves and ensure sustained production from Budare and Elotes Sur oil fields of the Eastern Venezuela Basin over the mid- and long term.

Oil in the study area is produced from sandstone reservoirs that are composed mostly of fluvial and deltaic facies forming part of the Oligocene Merecure Formation and the Oligocene–Miocene Oficina Formation. Oil accumulations are combination stratigraphic–structural, normal-fault-related traps.

The project data base comprises a 50-mi^2, 3-D seismic survey, digitized well logs from approximately 100 wells that include directional and horizontal boreholes, core data from 2 wells, slabbed core from 1 well, and production data spanning about 30 yr. Data are being analyzed by means of Landmark and Geographix software installed on SunSparc 20 and Pentium-based PC computer workstations.

The team carrying out the study is composed of Bureau of Economic Geology researchers and Corpoven staff that consist of reservoir geologists, petrophysicists, geophysicists, and petroleum engineers. Data were collected and core described in Venezuela. The project continues at Bureau facilities in Austin.

Characterization of Heterogeneity Style and Permeability Structure in Fluvial Reservoirs, Açu Formation, Brazil

Noel Tyler, principal investigator; Mark D. Barton, Edward S. Angle, Shirley P. Dutton, and Joseph S. Yeh; Mauro Roberto Becker and Benjamim N. Carrasco (Petrobras)

Outcrop characterization of the architecture and permeability of flow-unit and sealing components of reservoir analogs is a powerful tool for constructing geologically based reservoir models and flow simulations. The goal of this 18-mo collaborative study funded by Petroleo Brasileiro S.A. (Petrobras) was to develop a numerical data base from outcrop mapping and permeability measurements in order to provide a portable framework for simulating fluvial reservoirs as exemplified by the Açu Formation of Brazil. The Açu Formation, which produces low-gravity oil at depths of 650 to 820 ft in the Potiguar Basin, Rio Grande do Norte, northeast Brazil, is exposed in outcrop approximately 25 mi from the producing fields.

In the first phase of this project, a team of Bureau of Economic Geology and Petrobras geologists mapped sandstone-body architecture and collected more than 1,400 permeability measurements from an outcrop of the Açu Formation. In the second phase of the project, geologists incorporated flow-unit and flow-boundary architecture and permeability data assembled on outcrop into a two-dimensional model using *StrataModel*© geocellular modeling software. The resulting model recreates the two-dimensional permeability structure of the reservoir analog while preserving the geologic reality determined by the detailed outcrop characterization of facies architecture, and it will be used by Petrobras as input for flow simulation of the Açu reservoir.

The Açu outcrop exposes a sandstone body composed of multiple truncating channel storeys that display vertically stacked and sidelapping relationships. Storeys are defined by a basal erosion surface overlain by an intraformational mudclast breccia. The sandstone body is interpreted to record the superposition of a series of alternate bars within a low- to moderate-sinuosity channel by downstream migration. Grain size is the dominant control on permeability. Other influencing factors are sorting and the presence of ductile mud clasts. A visual comparison of permeability profiles and stratal architecture indicates that (1) permeabilities are reduced one to three orders of magnitude near bedset and channel-storey bounding surfaces, (2) channel-bar deposits and component bedsets are characterized by consistently upward increasing permeability trends, and (3) adjacent channel-fill deposits are characterized by reduced permeabilities that display an erratic to upward-decreasing trend.

Petroleum Technology Transfer Program

Raymond A. Levey, principal investigator; L. Edwin Garner, Mark H. Holtz, Richard P. Major, Lisa E. Remington, Deborah A. Salazar, and W. Gerald White

The Bureau of Economic Geology has been designated as the Regional Lead Organization of the Petroleum Technology Transfer Council (PTTC), Texas Region. The PTTC is a national nonprofit organization formed in 1993 to serve as a national clearinghouse for upstream technology needs of United States oil and gas operators. Its main missions are (1) to identify the technological problems of U.S. oil and gas producers and to communicate these needs to the research and development community and (2) to transfer to domestic producers new and existing upstream technologies that will help them reduce finding costs, improve operating efficiency, improve ultimate recovery, enhance environmental compliance, and add to domestic oil and gas reserves.

The technical information that the PTTC transfers to producers comes from all sectors of the research and development community and intermediary providers of technology, including government, universities, the Gas Research Institute (GRI), professional and trade societies, national laboratories, private companies, and the service industry. Although not involved directly in any research or development, the PTTC serves as a clearinghouse for improving technology transfer to domestic operators.

The PTTC was begun by the Independent Petroleum Association of America, in cooperation with State and regional oil and gas producer associations, GRI, the Interstate Oil and Gas Compact Commission, and other groups. The Department of Energy is providing start-up funds through a 5-yr cost-share program. Additional funding is being provided by GRI, State governments, the industry, and other sources.

Regional program activities conducted by PTTC include the Regional Resource Centers, which provide operators access to technical and referral assistance, and computer workstations that have data covering project histories, field and reservoir data, and analytical software.

Jackson Region Reservoir Characterization and Performance Study

Raymond A. Levey, principal investigator; Douglas S. Hamilton, Mark H. Holtz, Joseph S. Yeh, and Shirley P. Dutton; assisted by Syed A. Ali and Chun-Yen Chang

This project, funded by Santos Ltd. and completed during 1995, involved a detailed sequence stratigraphic analysis and reservoir characterization study of the Jurassic Hutton Sandstone and Westbourne Formation in the Jackson region, Eromanga Basin, Queensland, Australia. The primary objectives of the study were to (1) establish a high-resolution sequence stratigraphic framework within which the architecture of reservoir and nonreservoir facies could be determined; (2) investigate the trends in reservoir fluid flow by engineering analysis; (3) integrate fluid-flow trends with reservoir architecture to identify fundamental reservoir heterogeneities and develop three-dimensional flow-unit models of the reservoir; (4) construct a three-dimensional geocellular model to estimate original oil in place, residual oil saturation, and remaining mobile oil; and (5) identify opportunities for reserve growth by means of geologically targeted infill and step-out drilling, recompletions, and field-management strategies.

Contrary to existing perception, the Hutton Sandstone, a continental-scale bed-load fluvial system, does not behave as does a large, homogeneous tank in which pistonlike displacement of produced oil occurs unimpeded by vertical migration of the aquifer. Our sequence stratigraphic analysis identified numerous thin but widespread shale units, which had been deposited during lacustrine flooding events that periodically interrupted episodes of coarse clastic Hutton deposition. These shales represent chronostratigraphically significant surfaces or sequence boundaries. More important, the trends that we established in reservoir fluid flow by monitoring aquifer encroachment, analyzing production response to water shut-off workovers, and testing differential depletion in repeat-formation tests, indicate that these shale units act as efficient barriers to vertical fluid flow. Erosion of the upper part of the Hutton reservoir by the younger Birkhead mixed-load fluvial system caused further stratigraphic complexity and introduced additional barriers to vertical and lateral migration of mobile oil and aquifer encroachment. The study identified opportunities for infill and step-out drilling, as well as recompletion candidates, both of which had not been fully revealed in previous field development and production strategies, because the stratigraphic complexities in the Hutton reservoir were not completely known.

The Westbourne Formation is interpreted as a series of fluvial-dominated lacustrine deltas. Facies variability and sediment-dispersal pathways within the unit are very complex, if not chaotic, because of the shallow lacustrine sedimentation. Five extensive chronostratigraphic genetic units separated by widespread lacustrine flooding events were identified. The stratigraphic framework proved to be essential for unraveling sediment transport patterns and, thus, predicting reservoir sandstone distribution. The stratigraphic framework also provided the key to explaining aquifer encroachment and pressure depletion which, when combined with predicted sandstone geometries, resulted in our identifying several step-out drilling locations and numerous recompletion opportunities.

Technology Transfer Initiative

Raymond A. Levey, principal investigator; L. Edwin Garner, Chester M. Garrett, Jr., Mark H. Holtz, Richard P. Major, Lisa E. Remington, and W. Gerald White

This project, completed in the third quarter of 1995, was the second phase of the Energy Resource Optimization (ERO) program that had been implemented through the State Lands Energy Resource Optimization (SLERO) project. The goal of the technology transfer component was to transfer results of SLERO research to the producing community, emphasizing small, independent producers on State Lands who have no financial or scientific resources to develop or implement research-dependent improved recovery methods.

During the technology transfer phase of the ERO program we assembled data relating to reservoirs in the SLERO project

and readied the data for dissemination to producers by means of both workshops and electronic bulletin boards. The Bureau of Economic Geology directed the project in cooperation with the Texas Independent Producers and Royalty Owners Association (TIPRO), who assisted in disseminating information to the independent producers. The project was funded through the Governor's Office, State of Texas.

Four oil and gas plays were selected by the Bureau and TIPRO as prototypes for an electronic bulletin board: the Upper Guadalupian Platform Sandstone play in the Permian Basin and the Frio Barrier/Strandplain Sandstone, the Down-Dip Frio Barrier/Strandplain Sandstone, and the Wilcox Deltaic Sandstone plays on the Gulf Coastal Plain. Play-based user group workshops were conducted by the Bureau in Houston, Corpus Christi, and Midland.

Revitalizing a Mature Oil Play: Strategies for Finding and Producing Unrecovered Oil in Frio Fluvial-Deltaic Reservoirs of South Texas

Noel Tyler and Raymond A. Levey, principal investigators; Mark H. Holtz, Paul R. Knox, and W. Gerald White; assisted by Syed A. Ali, Radu N. Boghici, Chun-Yen Chang, and Hye Won Kim

The Bureau of Economic Geology has completed the third year of a 46-mo cooperative agreement with the U.S. Department of Energy (DOE) as part of the Oil Recovery Technology Program for Class I (fluvial-deltaic) reservoirs. The DOE program's primary goal is to forestall premature abandonment by extending the economic life of some of the nation's most endangered crude oil reservoirs. Fluvial-deltaic reservoirs, among the most stratigraphically heterogeneous of reservoir types, represent a large percentage of the fields on the verge of being abandoned despite having large amounts of remaining oil. Frio Formation reservoirs of the South Texas Gulf Coast that have produced nearly 1 Bbbl of oil and still contain more than 1.6 Bbbl of unrecovered mobile oil resources are excellent candidates for studying and characterizing stratigraphic heterogeneity inherent in fluvial-deltaic depositional systems.

An early focus of the project was evaluation of the range and statistical distribution throughout the play of various reservoir attributes, including porosity, initial water saturation, and residual oil saturation. Subsequently, reservoirs selected in two fields—Rincon field, Starr County, and T–C–B field, Jim Wells County—were evaluated in detail to characterize range of reservoir architecture and compartmentalization within the play and document potential for reserve growth. The understanding of high-frequency sequence stratigraphic controls on depositional style and reservoir architecture gained from outcrop studies of the Ferron Sandstone, Utah, has been applied to improve between-well predictability of reservoir geometries and heterogeneities and, thus, more accurately assess the potential for large volumes of unrecovered oil. Interwell-scale reservoir models that integrate geological facies variability with reservoir engineering attributes have been developed to characterize flow-unit architecture and determine controls on locations and volumes of unrecovered mobile oil. These results will lead not only to identification of specific opportunities for incremental oil recovery in these particular fields but also to creation of a model for developing strategies in heterogeneous Frio reservoir exploitation throughout this play. A microcomputer-based advisor system incorporating the approach of this multidisciplinary study is being developed to augment planned workshops for disseminating these technologies to operators in this play and other similar plays throughout the United States.

Strontium Isotopic Signatures of Subsurface Brines: Key to Identifying Interreservoir Hydraulic Connectivity

Stephen C. Ruppel, principal investigator; Roger J. Barnaby; assisted by Jubal G. Grubb and James V. White

Because strontium isotopes do not fractionate during geological processes, the $^{87}Sr/^{86}Sr$ ratio of oil-field brines provides a natural tracer for subsurface fluid studies. Heterogeneities in brine $^{87}Sr/^{86}Sr$ composition may delineate reservoir compartments, whereas uniform $^{87}Sr/^{86}Sr$ waters indicate that the reservoir brines are well mixed and imply good hydraulic interconnectivity. The strontium isotopic composition of formation brines, therefore, may be a tool useful for evaluating fluid flow and compartmentalization in oil and gas reservoirs.

This 2-yr project, funded by the Advanced Technology Program of the Texas Higher Education Coordinating Board, is examining the potential of this technique to define interreservoir and intrareservoir hydraulic connectivity. Currently we are focusing on Dagger Draw and Indian Basin fields, which produce oil and gas from Upper Pennsylvanian shelf-margin dolostones. Anomalies in production, reservoir pressure, and fluid contacts within this field make it a good candidate for evaluating this technology's potential.

Formation fluids in Indian Basin and Dagger Draw fields are Na-Cl-SO_4-type waters having 4,000 to 50,000 mg/L total dissolved solids. The $^{87}Sr/^{86}Sr$ compositions of these waters (0.7090 to 0.7101) are variably radiogenic relative to marine $^{87}Sr/^{86}Sr$ values (0.7082) in this part of the Pennsylvanian. Fluid $^{87}Sr/^{86}Sr$ compositions exhibit a systematic spatial variation across the field. Whereas radiogenic, higher salinity waters occur in the updip west and south parts of the field, progressively more radiogenic, lower salinity formation waters are encountered downdip to the east and northeast.

Heterogeneous reservoir formation water $^{87}Sr/^{86}Sr$ reflects fluid flow and the influx of ^{87}Sr-enriched formation waters along the western field margin. Elevated $^{87}Sr/^{86}Sr$ ratios and salinities along the updip parts of the field probably reflect deep circulation of fluids that derived their dissolved constituents from overlying Upper Permian evaporites. Lower $^{87}Sr/^{86}Sr$ ratios in downdip reaches of the reservoir indicate either that fluids did not penetrate this far downdip or that they have been equilibrated with the reservoir host rocks.

Areas within the field characterized by highly heterogeneous formation-fluid compositions coincide with regions identified as exhibiting anomalous production and reservoir-pressure characteristics. In the coming year we will investigate this potential relationship further to better define potential application of formation fluid composition to delineation of reservoir compartments.

Application of Advanced Reservoir Characterization, Simulation, and Production Optimization Strategies to Maximize Recovery in Slope and Basin Clastic Reservoirs, West Texas (Delaware Basin)

Shirley P. Dutton, principal investigator; Edgar H. Guevara; assisted by Carlos A. Amaya and Radu N. Boghici

The Bureau of Economic Geology began the first year of a 48-mo cooperative agreement with the U.S. Department of Energy as part of the Oil Recovery Technology Program for Class III (slope and basin clastic) reservoirs. The Bureau's partner in this project is Conoco, Inc. Funds for the project are matched by the Texas Office of State–Federal Relations through State Match Pool Funding awarded in a contract titled "Rejuvenating a Dying Oil Play: Benefits to the State, the Permanent School Fund, and the People and Economy of Far-West Texas."

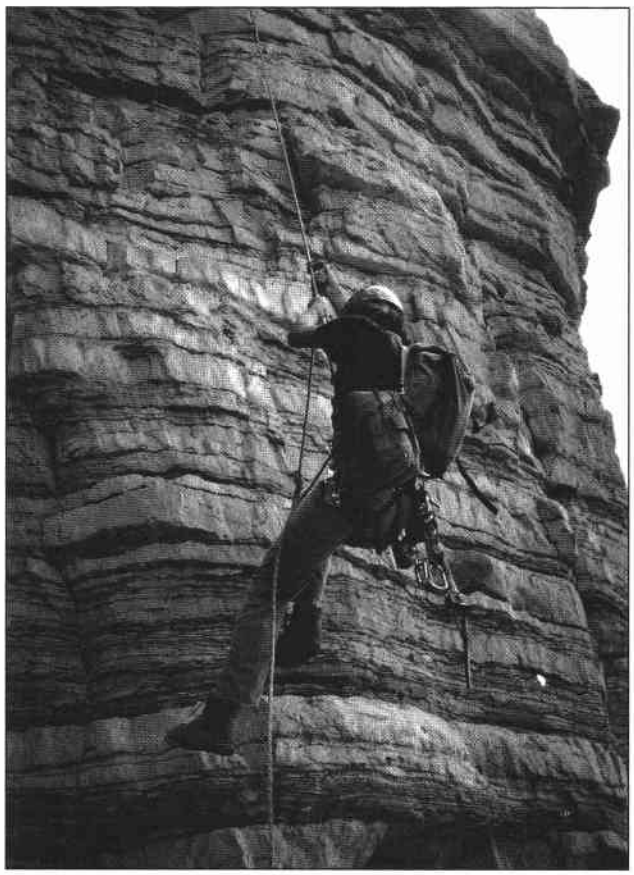
The goal of the project is to increase production and prevent premature abandonment of slope and basin clastic reservoirs in the Delaware Basin of West Texas and New Mexico. Slope and basin clastic reservoirs in sandstones of the Delaware Mountain Group in the Delaware Basin contained more than 1.8 Bbbl of original oil at discovery. Because recovery efficiencies of these reservoirs average only 14 percent, a substantial amount of the original oil in place still remains. The Bureau and Conoco, Inc., will deploy advanced reservoir characterization strategies to optimize recovery from the Ford Geraldine unit and Ford West field, which produce from the two most prolific horizons in the Bell Canyon and Cherry Canyon Formations, respectively, of the Delaware Mountain Group in Culberson and Reeves Counties, Texas.

The objective of this study is to demonstrate that reservoir characterization—utilizing 3-D seismic data, high-resolution sequence stratigraphy, and other techniques—integrated with reservoir simulation can optimize infill drilling and enhanced-oil-recovery projects. Once the reservoir characterization study of both fields is completed, a pilot area of approximately 1 mi^2 will be chosen for reservoir simulation. During phase 2, a geologically designed, enhanced-recovery program (CO_2 flood, waterflood, or polymer flood) and well-completion program will be developed and one to three infill wells will be drilled to increase recovery from the pilot area. Through technology transfer workshops and other presentations, the knowledge gained in the comparative study of these two fields that have 89 MMbbl of remaining oil in place can then be applied to increase production from the more than 100 other Delaware Mountain Group reservoirs, which together contain 1,558 MMbbl of remaining oil.

Characterization of Heterogeneity Style and Permeability Structure in a Sequence Stratigraphic Framework in Fluvial-Deltaic Reservoirs

Shirley P. Dutton, principal investigator; Janok P. Bhattacharya, Michael H. Gardner, Christopher D. White, and Brian J. Willis; assisted by Charl A. M. Broquet, Qing Fang, Sharon L. Gabel, Senira S. Kattah, Kirt A. Kempter, Xijin Liu, Brien R. Sheedy, and Matthew M. Uliana

The principal goals of this project are to develop an understanding of sandstone architecture and permeability structure in a spectrum of deltaic reservoirs deposited in high- to low-accommodation settings and to translate this understanding into realistic, geologically constrained reservoir models. Our approach uses three-dimensional outcrops as analogs to subsurface reservoirs. Because determining the spatial distribution of petrophysical properties at the interwell scale in

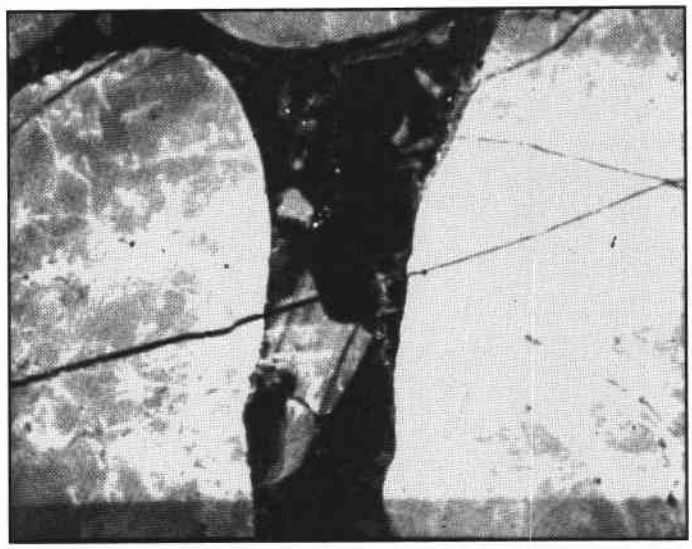


Bureau scientist scaling cliff of interbedded sandy and heterolithic facies within the Frewens Castle sandstone of the Cretaceous Frontier Formation, central Wyoming. These tide-influenced delta sandstones are the subject of a reservoir-analog outcrop study. Using climbing gear, he can sample beds every 2 dm and find fine vertical resolution of permeability. Permeability and facies-architecture data collected from outcrops are used to improve reservoir models that predict fluid-flow behavior. Photograph by Shirley P. Dutton.

the subsurface is virtually impossible, we use outcrop studies to provide data on sandstone-body architecture, stacking, and continuity; the distribution and length of internal shales; and the permeability structure of strata. Permeability and architectural data collected from outcrop drive construction of reservoir models that predict subsurface fluid-flow behavior.

Initial studies focused on the Fall River Formation, an incised-valley and associated deltaic system in a low-accommodation setting on the cratonic side of the Cretaceous Interior Seaway. The Fall River, exposed around the margins of the Black Hills Uplift in South Dakota and Wyoming, produces oil and gas in the adjacent Powder River Basin. Since the geologic study of the Fall River Formation was completed in 1995, data have been used to construct reservoir models and conduct flow simulation for optimizing recovery process as a function of geologic variability. The geologic focus of the Deltaic Reservoirs project expanded in 1995 for workers to investigate another class of prolific reservoirs, tide-influenced deltas. Few ancient examples of tide-influenced deltas have been documented, and no field-scale studies of outcrop analogs have been attempted. Consequently, we began fieldwork during the summer of 1995 on a tide-influenced delta system in the Upper Cretaceous Frontier Formation. The Frewens Castle sandstone of the Frontier Formation is well exposed in Central Wyoming, east of the Big Horn Mountains. This study will contribute to our understanding of deltaic reservoirs because the Frewens Castle sandstone provides a rare opportunity to examine in detail the reservoir attributes of a coarse-grained tide-influenced delta.

This investigation is funded by a consortium of industrial associates comprising the following companies: BP Exploration Operating Company Limited; Chevron Oil Field Research Company; Conoco, Inc.; Exxon Production Research Company; Intevep S.A.; Japan National Oil Corporation; Maxus Energy Corporation; Occidental International Exploration and Production, Inc., and OXY USA, Inc.; Oryx Energy Company; STATOIL; and Union Oil Company of California. In addition, the program is supported by Kerr-McGee Corporation and The Louisiana Land and Exploration Company, both of which provide valuable data.



Transgranular, sealed microfractures that have been exposed by scanned cathodoluminescence imaging cut across quartz grains and quartz cement in a sample from the Travis Peak Formation (a low-permeability [tight] gas formation in East Texas). This breakthrough technique not only enables detection of quartz-filled microfractures in sandstones having synkinematic quartz cement but also permits fracture strikes to be mapped in areas of the wellbore where no macrofractures are present. Photograph by Sigrid J. Clift.

Gas

Improved Resource Characterization Technology for Tight Gas Sandstones

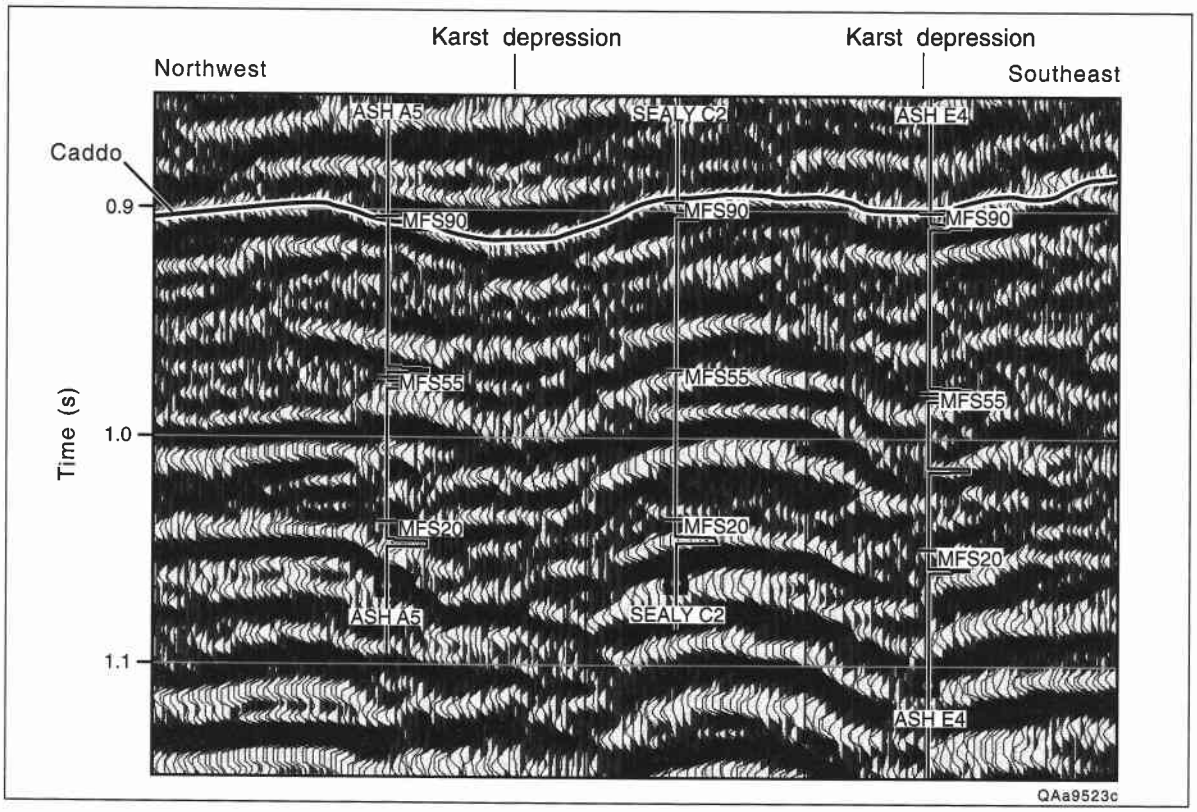
Stephen E. Laubach, principal investigator; Sigrid J. Clift, Patricia W. Dickerson, H. Scott Hamlin, Tucker F. Hentz, and Deborah A. Salazar; assisted by Sara L. Burns, Mary K. Johns, and Pamela L. Taylor

A large energy resource is known to exist in stratigraphically and diagenetically complex sandstones, including tight gas sandstones—generally defined as sandstone formations having in situ gas permeability of 0.1 md or less. In the United States (lower 48 states), the estimated gas in place in tight gas sandstones is 5,000 Tcf. Although much of this gas is distributed in a manner that will prevent it from being recovered, a significant volume is technically and economically recoverable. According to a 1992 National Petroleum Council study, the tight gas resource figures prominently in the country's total natural gas resource base, representing 27 percent (349 Tcf of 1,295 Tcf) of the technically recoverable lower-48 supply. Currently U.S. tight gas annual production is about 2.0 Tcf/yr, or about 12 percent of total nonassociated lower-48 production—production being distributed throughout the most prolific hydrocarbon-producing provinces.

Projections prepared for the Gas Research Institute (GRI) show tight gas production steadily increasing in the future. An underlying assumption of these projections is that better exploration techniques and completion practices will combine to allow economically successful development of the resource despite a movement over time of exploration and development into what appear now to be lower quality reservoirs.

The purpose of the research in this project is to help effect necessary technology improvements in geologically based exploration and development techniques. Many facets of the challenge of enhancing tight gas production have been addressed in this research project, as documented by publications available from GRI, as well as the Bureau of Economic Geology. The current study is aimed at enhancing exploration and development techniques in two steps: (1) creating innovative mapping and analysis methods to define sandstone fairways and other variables influencing high productivity in outer shelf–slope deposits and (2) developing and testing new methods for quantifying and mapping natural fracture attributes in highly cemented sandstones that contain natural fractures.

The aim is to improve methods of accessing natural gas resources in stratigraphically complex and highly cemented



Seismic profile of Boonsville field in the Fort Worth Basin, part of a 3-D seismic data volume, showing the genetic relation between the compartmentalization of siliciclastic reservoirs and karst depressions created by dissolution of deeper carbonates. The Caddo horizon is the top of the productive Bend Conglomerate section and is more than 2,000 ft above the Ellenburger carbonates, where the karsting occurred. Production data show that the structural high between the two karst depressions contains a Caddo sandstone reservoir.

sandstones and in sandstones in which natural fractures are key contributors to production. Methods that lead to efficient delineation of regional and local controls on productivity will result in more effective targeting of remaining resources, verification of advanced engineering technology benefits, and more appropriate application of these technologies.

Among the formations being studied in this project are the Canyon Sandstone, Val Verde Basin; Wilcox Lobo Formation, South Texas; Frontier Formation, Wyoming; and Davis Sandstone, Fort Worth Basin.

Secondary Natural Gas Recovery (SGR): Targeted Technology Applications for Infield Reserve Growth in Midcontinent Sandstones

Robert J. Finley and Bob A. Hardage, principal investigators; David L. Carr, Ronald A. Johns, Carol L. Ruthven, James L. Simmons, Jr., and Joseph S. Yeh; assisted by Eric J. Phinney and Bhushan K. Veerapaneni

The Bureau of Economic Geology is the lead technical contractor of this 2-yr project funded by the Gas Research Institute, the U.S. Department of Energy, and the State of Texas. The Secondary Natural Gas Recovery (SGR) project has focused on identifying and documenting the impact of stratigraphic and diagenetic compartmentalization in deltaic gas reservoirs deposited in the low-accommodation settings of the Midcontinent region, including Oklahoma and Texas, which contain 33 to 41 Tcf of reserve growth resources. Research began in 1993 and continued in 1995 in Boonsville field in North-Central Texas. SGR project subcontractors, Holditch and Associates, Inc., are conducting reservoir engineering analysis; Scientific Software Intercomp, Inc., researchers are performing petrophysical research; and Envirocorp Services and Technology workers are handling field operations for the project. Three gas operators (OXY USA, Inc., Midland; Enserch Exploration, Inc., Dallas; and Threshold Development Corp., Fort Worth) are also actively involved.

The study site in Boonsville field contains more than 200 existing wells and includes a three-dimensional seismic survey across 26 mi^2, which was designed by the Bureau and acquired by the Boonsville SGR partnership. The unique design of the seismic survey results from vertical and horizontal wave testing, minihole dynamite sources, and staggered source and receiver lines. Postacquisition processing involved testing the concept of flexible binning. The project has acquired vertical seismic profiles and detailed check-shot surveys for calibrating Pennsylvanian thin-bed seismic stratigraphy, multiple pressure test data, and more than 400 ft of conventional high-quality core data. Thirteen third-order depositional sequences and several fourth-order sequences have been identified by advanced geological correlating and mapping techniques by means of the OXY USA stacked curves program.

Landmark technology has been used in 3-D seismic interpretation, and several interpretational case histories now exist that document the fact that stratigraphically trapped reservoirs can be detected when selected seismic attributes are calibrated to subsurface control. Significantly, the 3-D seismic data show that numerous karst collapse zones begin at the deep Ellenburger level, extend vertically for as much as 2,500 ft, and influence sedimentation and reservoir compartmentalization in the younger Pennsylvanian-age rocks that compose the major producing interval at Boonsville field.

Technology Transfer for Secondary Natural Gas Recovery (SGR): Targeted Technology Applications for Infield Reserve Growth in Gulf Coast Reservoirs

Robert J. Finley and Bob A. Hardage, principal investigators; David L. Carr, Carol L. Ruthven, and James L. Simmons, Jr.

Research on gas compartmentalization in deltaic reservoirs deposited in low-accommodation Midcontinent basins was finalized and documented in technical articles, topical reports, and short courses. Seven technical summaries were prepared on 3-D seismic techniques, reservoir engineering analyses, and petrophysics. Each summary is a well-illustrated, simple discussion of 8 to 10 pages, and 5,000 copies of each booklet have been printed. Numerous requests for these technology transfer publications have been received, and several hundred copies have been distributed to industry operators.

A comprehensive, 1-day short course was prepared that detailed the research involved in the integrated study of Boonsville field in the Fort Worth Basin. This short course was taught in Houston, Tyler, and Graham, Texas, and courses are scheduled for Denver, Oklahoma City, Tulsa, Dallas, and Houston.

Development and Evaluation of a Basin-Scale Coalbed Methane Producibility Model

Roger Tyler, principal investigator; William R. Kaiser, H. Seay Nance, and Andrew R. Scott; assisted by Martha Z. Beltran, Ronald G. McMurry, and Muhammad Razi; in cooperation with the Colorado Geological Survey

Research in the Rocky Mountain Foreland basins, funded by the Gas Research Institute, shows that permeability, hydrodynamics, depositional systems and coal distribution, coal rank, gas content, and tectonic and structural setting control the producibility of coal gases. High coalbed methane productivity requires that these geologic and hydrologic controls be synergistically combined. That synergism is evident in a comparison of the prolific San Juan Basin and marginally producing Sand Wash Basin. In the San Juan Basin, ground water flows through high-rank, high-gas-content coals orthogonally toward lower rank coals at a no-flow boundary or flow barrier along a structural hingeline. At this point in the basin, flow turns upward and coalbed wells typically produce more than 1,000 Mcf/day and small volumes of water. A combination conventional–hydrodynamic trap is postulated to exist along the hingeline, implying that free, migrated, and solution gas are sources of coalbed methane. In the Sand Wash Basin, flow is through low-rank, low-gas-content coals toward areas of higher thermal maturity. Permeability contrasts and absence of seals limit the potential for conventional trapping of gas.

Out of a comparison between the San Juan and Sand Wash Basins, a basin-scale coalbed methane producibility model has evolved and is being applied to the Piceance Basin. The model essentially comprises (1) ground-water flow basinward through coals of high rank and high gas content orthogonally toward no-flow boundaries or flow barriers (regional hingelines, fault systems, facies changes and/or discharge areas) accompanied by generation of secondary biogenic gas and (2) conventional trapping of migrated and solution gases along those barriers. Gas is gathered by lateral flow, dissolved or entrained, and swept basinward ahead of an advancing flux of meteoric water for conventional trapping. When flow is orthogonal to flow boundaries, the largest possible area of flow is intercepted, thus maximizing the opportunity for resorption and conventional trapping of gas, which plays a much larger role in coal-gas production than is generally recognized. After basin uplift and cooling, additional sources of gas are needed beyond that initially sorbed on the coal surface in order to achieve a high gas content for consequent high productivity. Those additional sources of gas are migrated conventionally trapped gas, secondary biogenic gas, and solution gas.

In the Piceance Basin, the most prolific coal-bearing horizons and coalbed methane targets are found in the Upper Cretaceous Williams Fork Formation, which has been genetically defined on the basis of correlation with the Sand Wash Basin. Net coal is thickest in a north-south belt, behind west-east-prograding shoreline sequences. Depositional setting and thrust faults cause thick coals along the Grand Hogback and in the subsurface to be in modest to poor reservoir and hydraulic communication. Meteoric ground-water recharge and flow basinward is, thus, restricted. The best potential for coal-gas production may lie in conventional traps basinward of where outcrop and subsurface coals are in good hydraulic communication. Understanding the reasons for these contrasts in producibility is vital to worldwide coal-gas exploration and development.

Oil and Gas Resource Atlas Series: Offshore Northern Gulf of Mexico

Robert J. Finley and Steven J. Seni, principal investigators; Bruce A. Desselle, Deborah A. Salazar, Thomas A. Tremblay, and Chester M. Garrett, Jr.; assisted by Suhas V. Bodwadkar, Mustafa M. Erbil, and Naresh D. Sen; subcontracts to Louisiana State University Center for Coastal Energy and Environmental Resources/Basin Research Institute and to the Alabama Geological Survey

In collaboration with Louisiana State University and the Alabama Geological Survey, the Bureau of Economic Geol-

ogy is nearing completion of an atlas series of oil and gas plays in the Federal and State offshore waters of the northern Gulf of Mexico. In the fall of 1992 and the spring of 1993, the U.S. Department of Energy, Minerals Management Service, and the Gas Research Institute began funding the 4-yr program. During 1995, collection and analysis of reservoir data continued. Reservoir plays were finalized for Miocene and older reservoirs. Drafting illustrations and writing and editing play descriptions continued. A Technical Advisory Group consisting of ARCO Oil and Gas Company; CNG Producing Company; Conoco, Inc.; Marathon Oil Company; Oryx Energy Company; Shell Offshore, Inc.; Texaco USA; and UNOCAL, Inc., has provided industry liaison and technical support.

As domestic oil and gas production declines, the Gulf of Mexico plays an increasingly important role in supplying domestic energy. The Gulf of Mexico offshore region currently produces 14 and 25 percent, respectively, of the nation's annual production of oil and gas. In State and Federal waters, more than 20,000 reservoirs in more than 800 active fields have produced an estimated 10.2 Bbbl of oil and about 118 trillion cubic feet (Tcf) of gas. In addition, the Gulf region contains an estimated 17 and 26 percent, respectively, of the nation's undiscovered conventional oil and gas resources. The northern Gulf of Mexico is currently receiving much attention from the oil and gas industry for both field extension and infill drilling in mature areas of the basin, as well as for frontier exploration in deeper parts of the Gulf. The northern Gulf of Mexico is an especially attractive exploration area because of its rich hydrocarbon endowment, its modern petrochemical production and refining infrastructure, and its untapped potential. An integrated analysis of domestic oil and gas resources of the Gulf, including systematic synthesis of geologic and engineering data in oil and gas reservoir plays, can play a critical role in sustaining the region's productivity and success in exploration and development.

We have delineated 91 reservoir plays in Federal and State waters of the Gulf of Mexico, typically using depositional style or origin as the key defining attribute of a play. We identify plays by integrating regional patterns of hydrocarbon occurrence and patterns of depositional style and structure with engineering reservoir data. The combination of various elements of geological and engineering data is synthesized to determine the boundaries of plays. For example, major new petroleum discoveries in the 200- to 500-MMbbl field-size class characterize a completely new hydrocarbon play associated with horizontal salt features in deeper waters across the outer shelf and slope.

Systematic compilation of Gulf of Mexico reserves and production data within a reservoir-play-defined framework will help us assess the most promising combinations of trap types and producing facies. The data can be used to (1) identify the areas of greatest potential, which have the highest concentration of remaining unrecovered hydrocarbons in existing fields, and (2) guide frontier exploration in ultradeep water on the basis of analysis of older submarine fans and slope-apron plays encountered beneath the shallower adjacent continental shelf. Regional reservoir play analysis thus provides a logical basis for simultaneously evaluating both field reserve-growth potential and opportunities for extension exploration in mature plays.

Experimental and Applied Tectonics Investigations

Applied Geodynamics Laboratory: Physical Tectonic Modeling

Martin P. A. Jackson, principal investigator; Bruno C. Vendeville, laboratory manager; assisted by Hongxing Ge

The Applied Geodynamics Laboratory (AGL) carries out physical scale modeling to generate new concepts, test hypotheses, and duplicate specific geologic structures relevant to the location, origin, mechanics, and evolution of structural traps for oil and gas. Research is funded by the Applied Technology Program of the Texas Higher Education Coordinating Board and by a consortium of oil companies: Agip S.p.A., Amoco Production Company, Anadarko Petroleum Corporation, ARCO Oil and Gas Company and Vastar Resources, BHP Petroleum (Americas) Inc., BP Exploration, Inc., Chevron Petroleum Technology Company, Conoco, Inc., Du Pont and Company, Exxon Production Research Company and Exxon Exploration Company, The Louisiana Land and Exploration Company, Marathon Oil Company, Mobil Research and Development Corporation, Petróleo Brasileiro S.A., Phillips Petroleum Company, Société Nationale Elf Aquitaine Production, STATOIL, Texaco, Inc., and Total Minatome Corporation.

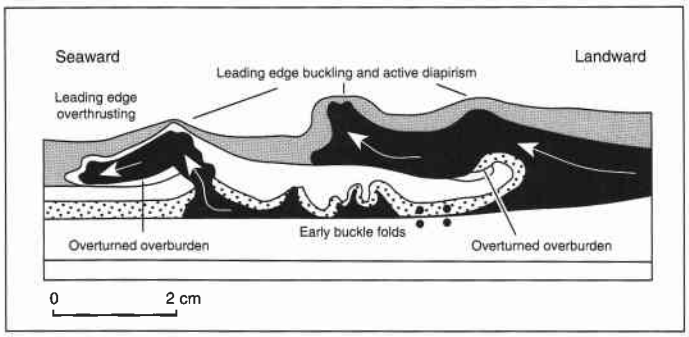
All experiments were carried out in a normal gravity field. Deformation rigs, which allow almost any structural styles to be simulated and superposed, are driven by stepper motors controlled by electronic indexers and a computer. Modeling in an accelerated gravity field uses a high-speed, high-capacity centrifuge equipped with digital speed and temperature controls.

Experimental research focused on the following main topics: (1) effects of contraction on rejuvenating dormant, preexisting diapirs; (2) effects of extension superposed on contractional folds and thrusts decoupling over salt; (3) fault geometry of hard and soft linkages between offset grabens; (4) minibasins formed by multidirectional extension above lobate, spreading allochthonous salt; (5) effects of progradation on initiating and controlling salt tectonics above a stepped subsalt basement; and (6) effects of prograding loads on elliptical allochthonous salt sheets.

Applied Geodynamics Laboratory: Mathematical Tectonic Modeling

Martin P. A. Jackson, principal investigator; Daniel D. Schultz-Ela, Giovanni Guglielmo, Jr.; assisted by Richard A. Ketcham

The Applied Geodynamics Laboratory (AGL) carries out numerical modeling and computer visualization to generate new concepts or test hypotheses relevant to the formation of structural traps for oil and gas. Research at AGL is funded by the Applied Technology Program of the Texas Higher Educa-



Cross section of a physical model showing complex deformation at the leading edge of originally extrusive salt sheets (black). Deformation is driven by gravitational loading by a prograding sedimentary wedge off section to the right. Similar structures are widespread in former slope environments in the Gulf of Mexico.

tion Coordinating Board and by the following industrial associates: Agip S.p.A., Amoco Production Company, Anadarko Petroleum Corporation, ARCO Oil and Gas Company and Vastar Resources, BP Exploration, Inc., Chevron Petroleum Technology Company, Conoco and Du Pont Corporation, Exxon Production Research Company and Exxon Exploration Company, The Louisiana Land and Exploration Company, Marathon Oil Company, Mobil Research and Development Corporation, Petróleo Brasileiro S.A., Phillips Petroleum Company, Société Nationale Elf Aquitaine Production, STATOIL, Texaco, Inc., and Total Minatome Corporation.

Mathematical modeling requires several Macintoshes and digitizers, two Silicon Graphics workstations, and a variety of software. The mathematical simulation involves finite-element modeling, by means of GEOSIM-2D®, a program that can simulate combined brittle and ductile deformation, large strains, faulting, sedimentation, and erosion. The following topics were systematically investigated: (1) fault patterns in overburden flexing by layer-parallel slip above normal, reverse, and vertical subsalt faults; (2) active diapiric piercement in regimes of superposed contraction, extension, layer-parallel slip, tilting, and variable density; and (3) allochthonous sheets loaded by synkinematic sediments, with and without regional extension.

EarthVision® is being used in full three-dimensional visualization, volumetrics, mapping, and creation of data volumes of structural traps from digitized cross sections of two physical models: (1) salt walls and associated faults produced during regional extension by gravity spreading and (2) minibasins evolving between passive diapirs. Such visualization improves understanding of three-dimensional salt tectonics and can be used to enhance design, processing, and interpretation of three-dimensional seismic surveys worldwide.

Two-dimensional animations, which were featured in a lead article of *AAPG Explorer,* increase comprehension of structural development in numerical models, physical models, and restorations. The following types of deformation were animated: (1) diapirs sagging because of regional extension, (2) monoclinal folding above a subsalt fault, (3) an allochthonous sheet stretching, and (4) flow patterns within a passive diapir.

Digital communication via the World-Wide Web allows users to access and duplicate releasable research results rapidly, including multimedia hypertext publications comprising animations, high-resolution color three-dimensional images, and searchable text. Samples of these results can be viewed at http://www.utexas.edu/research/beg/giovanni.

Environmental Resource Investigations

Environmental, Geologic, and Hydrogeologic Studies

Hydrologic and Geologic Studies of the Proposed Low-Level Radioactive Waste Disposal Site, Eagle Flat Region, Hudspeth County, Texas

Jay A. Raney and Bridget R. Scanlon, principal investigators; Edward W. Collins, Alan R. Dutton, Richard S. Goldsmith, William F. Mullican III, Jeffrey G. Paine, Steven W. Tweedy, Jiannan Xiang; assisted by Joseph D. Coker, John F. Gamble, Leipin He, Sung-Chi Hsu, Jiunnren Lai

Site characterization studies in support of the State's proposed low-level radioactive waste disposal site in northwest Eagle Flat Basin continued in 1995. In these studies, monitoring of the saturated and unsaturated zones continued and subsurface flow in Grayton Lake and fissured sediments was analyzed in detail. But besides site characterization studies, investigations supporting the installation and monitoring of a prototype engineered barrier were conducted, and interrogatories from reviewers of the license application were resolved by Bureau scientists. The work was supported by the Texas Low-Level Radioactive Waste Disposal Authority and the U.S. Department of Energy.

In 1995, investigations shifted from exclusively site characterization to design and installation of the facility's operational ground-water monitoring network. As a result, we now have a better understanding of site-specific controls, rates, and directions of ground-water flow. A new monitor well was installed in addition and is now part of the ground-water monitoring network.

The unsaturated zone was studied by means of detailed analysis of core samples collected beneath Grayton Lake. Northwest Eagle Flat Basin, which is the proposed site of the Texas facility, is a closed topographic basin that drains internally into Grayton Lake, an ephemeral lake or playa. Analysis of sediments sampled from beneath Grayton Lake for water content, water potential, and chloride indicates that subsurface water fluxes are low; however, preferential flow occurs along desiccation cracks beneath the playa, as indicated by bomb pulse tritium and above-background levels of chlorine-36.

The scope of work on fissured sediments was expanded in 1994 when 14 boreholes were drilled in and adjacent to 4 fissures near the Eagle Flat site. During 1995, we analyzed sediment samples from these boreholes for water potential and chloride and found that water potentials are high and

chloride was flushed out beneath the fissures. The data also suggest that the zone of high flux is localized and limited to the upper 10 m in the Eagle Flat fissure. The lateral extent of high flux was generally limited to 160 ft or less in all fissures and even less than 30 ft in the Eagle Flat fissure. Bomb pulse tracers such as tritium and chlorine-36 showed that preferential flow occurs throughout the profiles.

Continued monitoring of hydraulic parameters at the Hueco Bolson and Eagle Flat sites has resulted in a unique data set that evaluates the response of different geomorphic surfaces to atmospheric forcing. The monitoring program was expanded during 1995 to include monitoring of air permeability. Evaluation of air permeability is required for predicting upward movement of noxious gases such as radon, tritium, and carbon-14 by means of the engineered cover system. Retrievable thermocouple psychrometers were also installed in a borehole during 1995.

Site characterization studies focus on the ability of the natural system to contain waste reliably. However, in the short term (100 to 500 yr) the engineered-barrier system must minimize subsurface transport of contaminants. Although detailed site-characterization studies of the natural system have been conducted at many sites, data on the performance of engineered barriers are limited. To overcome this shortcoming and to evaluate the performance of the proposed design of the engineered barrier, a prototype barrier will be constructed and monitored. The goal of the engineered-barrier program will be to provide a water balance for the system that can be used to validate numerical models of the engineered system's performance and bolster confidence in predictive numerical simulations of future repository performance.

The Bureau's expertise in unsaturated-zone hydrology has led to Bureau scientists' involvement in reviewing other programs in arid settings, including the Low-Level Waste Program at Hanford, Washington, and the High-Level Nuclear Waste Program at Yucca Mountain, Nevada. The Bureau has helped the National Academy of Sciences panel for Ward Valley, the proposed California site, to provide guidelines for future work at low-level waste disposal facilities.

Studies to Optimize the Monitoring System of a Trench and Engineered Barrier in an Arid Setting

Bridget R. Scanlon, Joseph D. Coker, Richard S. Goldsmith, Susan D. Hovorka, William F. Mullican III; assisted by Sung-Chi Hsu and Ian C. Jones

Although many data have been collected to characterize the performance of natural arid settings for waste disposal, little information is available on the performance of engineered barriers. Evaluation of the performance of engineered barriers requires detailed monitoring of these systems. The objective of this study was to evaluate various monitoring devices and to determine optimal locations of monitoring equipment for the proposed low-level radioactive waste disposal facility in the Eagle Flat Basin of Hudspeth County, Texas. These monitoring devices will be installed in a prototype barrier that will be constructed in 1996, and monitoring of the disposal units will be required for a minimum of 30 yr. The study was funded by the National Low-Level Waste Disposal Program at Idaho National Engineering Laboratories through the Texas Low-Level Radioactive Waste Disposal Authority.

Unsaturated-zone monitoring technologies have evolved substantially in the last decade. Water-content monitoring was previously restricted to our using neutron probes, which, because of their radioactive source, cannot be monitored in an automated way. Time domain reflectometry (TDR) is now being used at various sites to monitor water content automatically and to avoid the hazards associated with a radioactive source. We acquired a TDR data-acquisition system and are evaluating various probe designs to optimize water-content monitoring in an arid setting. Thermocouple psychrometers, heat-dissipation probes, and fiberglass blocks are being evaluated for monitoring matric potential in soil. Because of long-term monitoring requirements and the limited lifespan of many instruments, such as thermocouple psychrometers, retrievable psychrometers were installed in a borehole to allow for their replacement and recalibration. Because upward gas movement is also a concern at the proposed low-level radioactive waste disposal facility, differential pressure transducers were installed to monitor pneumatic pressures at depth and to estimate air permeabilities of the sediments.

Horizontal neutron-probe access tubes will be used to monitor beneath the disposal facilities. A newly developed SEAMIST system is being considered for facilitating access of monitoring instruments in boreholes. The SEAMIST system consists of an impermeable membrane that lines the test hole and is everted under a pressure of 10 to 30 kpa. The system has several advantages over dedicated equipment. Although the low-level waste disposal units require a long-term monitoring period, the SEAMIST system will allow innovations in technology to be incorporated into the monitoring program as they are developed. For example, the ability of the SEAMIST system to transport a neutron probe as far as ≤100 m will be tested at the Eagle Flat site. Additionally, numerical simulations will be conducted to evaluate the ability of the system to monitor gas movement.

Ideally, detailed monitoring will be restricted to a prototype barrier, and monitoring of the individual disposal units is expected to be minimal. Noninvasive techniques, such as electromagnetic induction and plant measurements, would be particularly suitable for routine monitoring of the disposal units because using such techniques would forestall the installation of dedicated equipment whose life span has not been tested for the time periods required in this project. We are also testing these noninvasive methods under ambient and increased rainfall conditions to evaluate their suitability further.

Geologic and Hydrologic Characterization of Pantex Plant

Thomas C. Gustavson, principal investigator; Don G. Bebout, Alan E. Fryar, Richard S. Goldsmith, Susan D. Hovorka, William F. Mullican III, Jeffrey G. Paine, Bridget R. Scanlon, and Jiannan Xiang

Work began in September 1990 on this 5-yr project, which was funded by a U.S. Department of Energy (DOE) grant to the Governor's Office, to describe the hydrology and geology of the DOE's Pantex Plant near Amarillo, Texas. The

Pantex Plant is the nation's site for assembling and disassembling nuclear weapons. Previous DOE environmental surveys revealed local contamination of soil, sediment, and perched ground water to depths of approximately 300 ft beneath the plant, primarily by residues of high explosives, gasoline, industrial solvents, and chrome. Investigations at and near the Pantex Plant were conducted to enable the State to guide future remediation efforts by DOE. Research objectives were to determine (1) the rates and processes by which runoff is collected and recharged through the unsaturated zone to an extensive perched aquifer and eventually to the Ogallala aquifer, (2) the chemical evolution of contaminants as they pass through playa biota and underlying sediments, (3) the hydrology and water chemistry of the Ogallala and perched aquifers, and (4) the depositional systems of the Ogallala and Blackwater Draw Formations and playa sediments.

The Pantex project was completed in August 1995 and resulted in a series of Bureau publications, refereed journal articles, and final contract reports. Significant findings are that the Ogallala aquifer at the Pantex Plant consists of several hundred feet of heterogeneous sequences of fluvial coarse sand and gravel capped by overbank muds and clays. Several hundred feet of eolian fine sand and silt of the upper Ogallala and Blackwater Draw Formations overlie the fluvial sediments. These sediments contain numerous potential flow paths for preferential flow, such as root tubules and fractures. Playa-filling sediments, also heterogeneous, include lacustrine clay, playa-margin deltaic sediments, and thin eolian sands interbedded with eolian sands and silts of the Blackwater Draw Formation. Numerous potential preferential flow paths, such as fractures, root tubules, and well-sorted lithofacies, are also present in these sediments. Shallow reflection and refraction seismic data indicate that five of the playa basins near the Pantex Plant were affected by subsidence over areas of dissolution of Permian salt. We also used seismic data to locate buried channels within Ogallala fluvial sediments. Recharge to the Ogallala is focused through playas, and recharge to the perched aquifer on the Pantex Plant is focused through both playa 1 and a system of unlined surface-drainage ditches. Recharge, which occurs through both matrix and preferential flow paths, is rapid such that rainfall has reached depths of approximately 250 ft in the about 40 yr. Elevated levels of carbon dioxide in soil gases from sediments below playas indicate that organic carbon is being degraded by microbial activity. Natural microbial activity is probably also responsible for the reduction in nitrate in waters being recharged beneath playas.

Lower Rio Grande Valley Geographic Information System (GIS)

E. G. Wermund, Gene J. Paull (UT–Brownsville), and Eric Rieken (UT–Pan American), principal investigators; Deborah A. Salazar and Thomas A. Tremblay; assisted by Chengyan Wu

This project, funded by the Texas Higher Education Coordinating Board, involves the construction of a geographic information system (GIS) of the Rio Grande delta plain. The GIS will provide data useful for managing the demand for, and supply of, surface water in the region. The study area comprises the late Pleistocene Rio Grande delta, which includes parts of Starr, Hidalgo, Willacy, and Cameron Counties in Texas and a part of Tamaulipas, Mexico. Spatial data sets, which are almost completed, encompass not only hydrography (irrigation and drainage features) but also natural features, transportation, surficial geology, topography, land use, and cultural features, including colonia locations and census boundaries.

The Bureau of Economic Geology has gathered and digitized data sets of the hydrography, topography, and transportation GIS layers of the entire delta region. Electronic data sets acquired from the U.S. Geologic Survey (USGS) and the Texas Department of Transportation have been extended into Mexico by means of digitization of Instituto Nacional de Estadística Geografía e Informática (INEGI) maps. Surficial geology of the Rio Grande delta has been digitized from several sources, including the Environmental Geologic Atlas of the Texas Coastal Zone (EGAT), a geologic map from an incomplete University of Texas at Austin (UT) dissertation, and a geologic map contracted by the Mexican government. The remaining surficial geology in Mexico is being interpreted from aerial photography.

Project participants at UT–Pan American have upgraded USGS hydrographic data by assigning codes to distinguish irrigation from drainage features and by modifying linear hydrographic features to reflect directional flow. The UT–Brownsville group—a principal liaison with Mexican universities—has digitized a historic land-use layer from EGAT working maps. Interpretation of vintage Edgar Tobin photomosaics will provide further historic land-use data on the lower Rio Grande valley GIS.

Hydrogeologic Studies in Support of the Superconducting Super Collider

Alan R. Dutton, principal investigator; Robert E. Mace and R. Stephen Fisher; assisted by Martina U. Blüm, Erika M. Boghici, William M. Doneghy, Jordan W. Forman, Jr., Andy M. Graham, Leslie B. Kelley, Jr., and Steven M. Rooks

Since the late 1993 decision by the U.S. Department of Energy (DOE) to terminate construction of the Superconducting Super Collider (SSC) in Ellis County, Texas, Bureau of Economic Geology hydrogeologists have been working closely with personnel of the Texas National Research Laboratory Commission (TNRLC) and DOE to provide a better understanding of the ground-water environment at the time of project termination after more than 3 yr of construction. Tasks focused on continuing measurement and evaluation of ground-water levels, installing and maintaining monitoring wells, providing ground-water samples from 29 site wells to DOE quarterly for quantitative chemical analysis, and completing reports that document ground-water conditions.

Water levels were monitored in 117 old, shallow wells near the SSC ring, 23 SSC project wells, 35 test wells, 7 pneumatic piezometers installed by the Bureau, and 13 access shafts to the SSC tunnel. These wells were important for documenting the horizontal and vertical distribution of water levels. Ground-water pressure at five SSC project wells was greatly affected by SSC tunnel and shaft construction. Pneumatic piezometer data suggest that the zone of drainage has extended at least

100 ft horizontally and 75 ft vertically from the tunnel. Water levels in the overlying weathered zone remain unaffected.

Leaching of dissolved solutes from a typical Austin Chalk spoil pile at the SSC site probably will not pose a significant water-quality problem in local aquifers in weathered bedrock. This conclusion is based on hydrologic setting, average salinity, water flow rate and residence time, and present use of ground water in weathered and unweathered bedrock units.

Study of the risk of solute migration in weathered and fractured chalk at the SSC site was completed, building on previous hydrogeologic work. The purpose of the work was to evaluate short- and long-term monitoring needs by incorporating statistical descriptions of hydrogeologic properties into building and applying realistic numerical models to quantify flow and transport. We found that ground-water traveltimes in weathered and fractured chalk depend on vertical variations in hydraulic conductivity, water-table position, and point of entry into the flow system. For example, traveltimes at low water-table positions (low-recharge season) can be 10 times longer than traveltimes in high water-table positions (high-recharge season) because of differences in transmissivity and hydraulic gradient. Fracture intensity, rainfall rate, water-table elevation, and fracture coatings appear to be important controls on solute transport in weathered and fractured chalk.

Geophysical Screening of Potential Brine Leakage Sites, Runnels County, Texas

Jeffrey G. Paine, principal investigator; Thomas A. Tremblay; assisted by Erika M. Boghici and Ianthe Nelson

This 1-yr project, funded by the Railroad Commission of Texas, demonstrates an application by the Bureau of Economic Geology and its subcontractor, World Geoscience Inc., of an integrated ground-based and airborne geophysical approach to characterizing oil-field-related brine contamination in a pilot study area in Runnels County, Texas. Infiltration of oil-field brine into the subsurface from leaking well casings, evaporation ponds, and storage facilities can affect wildlife, restrict agriculture, and pollute aquifers and surface water. Concern about the environmental effects of brine pollution has increased interest in how to determine whether oil-field brines have been introduced into the subsurface, where they have migrated, and whether they cause specific problems on the land surface, in water wells, or in surface water.

Because oil-field operations cover only a part of the test area, a screening process will be used to limit the number of sites that are intensively investigated. In the first step of the screening process, a geographic data base was developed that included potential sources of contamination (wells, pipelines, and storage facilities) and other relevant features (streams, lakes, and water wells). Critical sites were chosen from this data base for reconnaissance study. Selection criteria included complaints, geophysical signature from airborne magnetic and electromagnetic surveys completed as part of this project, surface evidence of leakage, proximity to surface water or water wells, and the degree to which the site represents a type of problem that may exist elsewhere in the study area or in other oil fields in Texas. Reconnaissance geophysical and geological investigations at the critical sites will further limit the number of sites that will be intensively investigated.

Intensive geophysical and hydrological studies will be limited to those sites that are shown by airborne or ground-based reconnaissance to have potential brine contamination. At these sites, deep-exploring ground conductivity instruments will be used to establish the areal extent of potential brine contamination. Time-domain electromagnetic sounding instruments will be employed across the sites to determine vertical conductivity profiles and approximate depths and thicknesses of the highly conductive zones. Water samples will be taken from nearby streams, water bodies, and water wells to be chemically analyzed. Results of these investigations will help identify sources of salinity and the lateral and vertical extent of potential contaminants.

Remediation-Focused Hydrogeological Investigations of Abandoned Oil-Field Cleanup Sites

Alan R. Dutton, principal investigator; William R. Kaiser, Jeffrey G. Paine; assisted by Martina U. Blüm, William M. Doneghy, Jordan W. Forman, Jr., Andy M. Graham, and Leslie B. Kelley, Jr.

The Railroad Commission of Texas (RRC) has statutory responsibility under S.B. 1103 (72d Legislature, 1991) for oversight of cleanup of abandoned oil-field sites throughout Texas. Straightforward solutions to cleanup are readily apparent at many of the sites. At other sites, however, delimiting cost-effective approaches to site cleanup requires information not only on the surface, but also on the less well defined subsurface extent of the contaminant. The Bureau of Economic Geology is assisting the RRC in identifying solutions to meet RRC obligations for protecting public health and safety and the environment. Investigations by the Bureau focus on defining the extent of problems at selected sites and evaluating cost-effective remediation alternatives. The Bureau investigations are designed to limit cleanup cost to the State of Texas by applying nonintrusive and cost-effective techniques to define the extent of the problems at selected abandoned oil-field sites.

The Bureau began hydrogeologic investigations at two sites—Manvel Salt-Water Disposal (SWD) and Fox Vacuum—in RRC District 3 following Site Investigation Plans (SIPs). The Manvel SWD site near Manvel in Brazoria County consists of two large and several small earthen pits. The large pits, which contained salt water in the past, now contain crude-oil-contaminated drilling mud. Field activities at this site included geophysical surveys, setting location control points using global positioning satellite (GPS) technology, sampling drainage ditch sediments, and sampling pit sediments and pit waters. The Fox Vacuum site near Kirbyville in

Jasper County consists of a sulfuric acid plume moving at shallow depth in a perched saturated zone in water-logged soil, which is killing grasses and stressing trees in adjacent property. Also on site are several earthen pits containing crude-oil-contaminated drilling mud. Field activities at the Fox Vacuum site included surveying location control points, conducting detailed electromagnetic geophysical surveys, augering and coring boreholes, collecting pit samples for compositing and analyzing, and collecting water samples from adjacent properties.

Hydrogeologic and Biologic Survey of Texas National Guard Training Facilities

R. Stephen Fisher, principal investigator; Robert E. Mace, Conrad A. Kuharic, and Deborah A. Salazar; assisted by Erika M. Boghici

Bureau of Economic Geology scientists are assisting the Texas National Guard with its environmental stewardship of Camps Barkley (Taylor County), Bowie (Brown County), Mabry (Travis County), Maxey (Lamar County), Swift (Bastrop County), and Fort Wolters (Parker County). The goal of the project is to provide a comprehensive surface- and groundwater hydrologic characterization of each training facility, which, in conjunction with aquatic biology surveys conducted by Texas Parks and Wildlife, will increase the National Guard's ability to understand natural resource constraints and plan operational management programs to maximize the military use of facilities while minimizing environmental impact. The hydrogeologic and biologic activities of this project are being coordinated through the Nature Conservancy of Texas.

U.S.–Mexico Border Area Regional Environmental Information System

Jay A. Raney, principal investigator; W. Gerald White; assisted by Clint C. Phillips

This multiyear project, funded by the U.S. Environmental Protection Agency (EPA) Regions 6 and 9, has the Bureau of Economic Geology designated to direct a regional environmental information system (REIS) designed to catalog and disseminate data and metadata on global environmental change. The Consortium for International Earth Science Information Network (CIESIN) administers project funds. Research organizations, universities, and other data holders who perform environmental, socioeconomic, and public health research, will be both consumers and providers of the data on the REIS. The scientific community, public policymakers, and the general public will benefit from the information thus collected.

The metadata ("data about data") will be provided over the Internet by means of widely available, free software (when applicable), such as Mosaic or Netscape, in conjunction with CIESIN's Catalog Services software—the client application program which can be downloaded over the Internet at no cost to the user. During the first year, we acquired metadata on 10 regional data-holder organizations from Texas to Arizona, more than 125 data sets on that regional area, and links to World-Wide Web Internet sites in Mexico, such as INEGI. A U.S.–Mexico border home page was established at the Bureau as a repository of this metadata; the home page allows interactive searches by interested users, permitting additional data sets to be located.

Geologic Analogs of Engineered Barriers

Jay A. Raney and Bridget R. Scanlon, principal investigators; Thomas C. Gustavson, Susan D. Hovorka, and Edward W. Collins

The purpose of this project is to investigate natural geologic analogs of earthen barriers that have been constructed to isolate wastes from the accessible environment for long periods, as can be found in improved near-surface disposal facilities mostly throughout the western United States. These facilities commonly have engineered barriers constructed of primarily earthen materials principally for containment. Those wanting to dispose of low-level radioactive materials (as at the proposed Texas low-level radioactive waste disposal facility), toxic and hazardous substances, and mixed wastes rely on this kind of methodology.

The short- and intermediate-term performance (months to years) of engineered barriers can be demonstrated by careful field and laboratory experiments and by numerical models that are appropriately verified and validated. Long-term performance (centuries to millennia), however, remains an area of prediction that is based on projections from the numerical simulations. The Bureau of Economic Geology hopes to improve understanding of the long-term performance of engineered barriers by evaluating the changes that have occurred in analogous geologic deposits affected by natural processes for thousands of years. The overall objective of the study is to evaluate the physical, chemical, and mineralogical characteristics of geologic analogs of engineered barriers in order to define the long-term performance of engineered barriers better.

Quantity and quality will be observed in the outcrop analogs, both in Texas and elsewhere in the western United States, and the impact of the materials and the layering on the analog site will be documented in terms of long-term stability and hydrologic performance. More effective natural barriers will be compared with those that have failed. Geologic analog studies will complement and reinforce numerical simulations of long-term barrier performance. The results of this study will improve understanding of critical processes, increase confidence in performance assessment, and may even lead to innovations in engineering designs.

Regional Permeability Study of the Edwards Aquifer

Alan R. Dutton, principal investigator;
Susan D. Hovorka, Robert E. Mace, Edward W. Collins; assisted by Nina L. Baghai, Erika M. Boghici, Norman D. Johns, and Jun Liao

This multidisciplinary study, funded by the Edwards Underground Water District, describes the three-dimensional permeability structure of the Edwards aquifer in the Balcones Fault Zone of Kinney, Uvalde, Medina, Bexar, Comal, and Hays Counties, Texas. Three interrelated approaches were used to characterize the permeability of this complex and prolific aquifer: (1) description of the role of faults and fractures in aquifer permeability, (2) quantification of aquifer permeability by means of aquifer tests, and (3) calculation of matrix permeability by means of porosity logs and SGM StrataModel© software. Results of this study include revision of a 1:250,000-scale surface and subsurface structure map of the Edwards Group, collection and statistical analysis of about 6,000 aquifer tests, and updating of concepts interrelating Edwards depositional facies, diagenesis, structure, and aquifer development.

The structure map incorporates recently completed outcrop mapping to guide interpretation of subsurface structure. Large faults offset the aquifer so that permeable strata are discontinuous and cross-fault permeability is decreased. Relay ramps, formed between en echelon faults, are identified as areas where flow may be diverted around large faults. Comparison of structure with recent detailed mapping of the interface between the aquifer and downdip saline water shows complex relationships, faults serving as barriers in the east and as apparent sources of saline water in the west.

A numerical relationship between specific capacity and hydraulic conductivity was developed for the Edwards karst aquifer. Statistical analyses were used to characterize the observed high and variable (10^1 to 10^6 ft/d) hydraulic conductivity. High average hydraulic conductivity is found in the east part of the confined aquifer, and lower-than-average hydraulic conductivity occurs in the unconfined aquifer.

Facies-specific-porosity to matrix-permeability transforms were developed by means of plugs from core and outcrop. SGM StrataModel software was used to image and quantify matrix-permeability distribution throughout the aquifer. Matrix permeability overlaps the low end of measured hydraulic conductivity, suggesting that flow in some of the less productive wells may be matrix dominated. Higher hydraulic conductivities (averaging 100 times higher than the matrix) of most wells quantify the importance of conduit (fracture and karst) flow.

Image analysis of outcrop photomosaics and statistical analysis of fracture measurements were used to quantify the role of conduits. Fracture frequency and interconnectedness increase adjacent to faults, and the width of the highly fractured zone increases with fault throw. Caves composing 1 to 3 percent of outcrop areas are abundant in dolomitized subtidal facies, and large caves are associated with highly fractured intervals. A revised model of the permeability structure of the aquifer includes high permeability both because of stratigraphically controlled dolomite dissolution and because of fault-associated fracture dissolution.

Coastal Studies

Detecting Small-Scale Topographic Changes and Relict Geomorphic Features on Barrier Islands Using Airborne Synthetic Aperture Radar (AIRSAR)

James C. Gibeaut, principal investigator; Melba M. Crawford (UT, Center for Space Research) and Roberto Gutierrez; assisted by K. Clint Slatton

The shapes and elevations of barrier islands may change dramatically over a short period, such as during a storm. Even between storms sediment is constantly shifting to and from these islands and between different areas of the islands at varying rates and in varying amounts. Coastal scientists and engineers, however, are currently unable to measure these changes occurring over an entire barrier island at once. This 3-yr project, which is funded by the National Aeronautics and Space Administration (NASA) and jointly conducted by the Bureau of Economic Geology and the Center for Space Research at The University of Texas at Austin, aims at overcoming this problem by developing airborne synthetic aperture radar (AIRSAR) to detect changes in coastal topography. Topographic changes on Galveston Island and Bolivar Peninsula, Texas, detected by AIRSAR will be compared with changes measured by global positioning system ground surveys. Three AIRSAR images will be compared to detect changes during 1995, 1996, and 1997, and we will relate these changes to meteorological and wave conditions. In addition to topographic mapping, this project will evaluate the use of AIRSAR to detect old features such as storm scarps, storm channels, former tidal inlets, and beach ridges that have been obscured by vegetation, erosion, deposition, and artificial filling. Methods developed during this project will provide coastal geologists with a tool unprecedented for detecting and explaining sedimentological changes. This knowledge will improve overall coastal management policies and will help reduce the effects of natural and human-induced coastal hazards.

Despite the different methodologies employed, such as conventional ground surveying, kinematic GPS surveying, and mapping by means of aerial photography, scientists are currently unable to monitor small (<1 ft) topographic changes with high spatial resolution (10 × 10 ft) over large coastal areas (for example, 62 mi^2). We will attempt to obtain this topographic information by using interferometric techniques to analyze the radar data. The method is based on the concept that radar signals received by two antennas are processed at the same Doppler frequency to form images. Assuming that the two antennas are within the scattered beam of the same ground resolution cell, then the signals reflected from a scatterer on the ground will interfere with one another. The phase difference between the two paths is then used to derive ground elevation.

We successfully completed our first AIRSAR mission on April 28 and 29, 1995. During the flight, we operated 2

geodetic-quality GPS base stations on the ground and 1 on the DC-8 aircraft, and, just before the flight, we placed and surveyed 24 radar reflectors along 2 19-mi flight lines to aid in image registration and correction. Within 2 days of the mission we completed detailed GPS surveys of a 1.24-mi stretch of beach on Galveston Island, and additional GPS surveys along 10 transects over the study area. These ground surveys are required for checking AIRSAR topographic solutions. In 1996, we will analyze data collected in 1995 and fly another mission.

Analysis and Prediction of Coastal Erosion and Wetland Loss in Southeastern Texas

Robert A. Morton, principal investigator; William A. White, L. Edwin Garner, Jeffrey G. Paine, James C. Gibeaut; assisted by Radu N. Boghici and Laura B. Stewart

Coastal erosion and wetland loss in Texas are occurring at rapid rates in some areas that are undergoing rapid economic development. Erosion and submergence threaten transportation networks, a large industrial complex, ports, and high-density development, as well as a nationally based economy. Understanding and solving these problems require an extensive quantitative data base and predictive models that can forecast changes. To address these needs, the Bureau of Economic Geology and the U.S. Geological Survey have initiated a 5-yr cooperative study of the southeastern Texas coast extending from Sabine Pass to Sargent Beach.

The purpose of the study is to develop information and expertise needed to ensure that economic development of the coastal region is compatible with a dynamic system. Specific objectives of the study include (1) providing technical data on coastal erosion and land loss to government, industry, and coastal planners, (2) predicting rates of coastal erosion and land loss, (3) evaluating the impacts of recent hurricanes and predicting impacts of future hurricanes, (4) evaluating the impact of relative sea-level rise on coastal lands and communities, and (5) identifying and evaluating offshore and nearshore sand resources for possible beach restoration.

During 1995 we (1) prepared topographic and stratigraphic cross sections for selected crossings of the lower Sabine, Neches, Trinity, and San Jacinto Rivers, showing the upper Pleistocene and Holocene fluvial terraces and valley-fill deposits, (2) submitted 18 samples of organic material to The University of Texas at Austin Radiocarbon Lab for age dating (^{14}C analysis), (3) investigated recent wetlands changes associated with active faults near oil and gas fields, (4) identified and interpreted foraminiferal assemblages in 5 cores from the coastal plain and Sabine Lake, (5) recorded seismic profiles in Sabine Lake and side-scan sonar profiles over Sabine Bank, (6) collected and described 29 vibracores taken from Sabine Lake, the former incised valley of the Sabine–Neches River, and (7) tested high-resolution seismic profiling techniques at three coastal-plain sites. This multidisciplinary approach is designed to provide a better understanding of the geological evolution of the southeastern coast and to offer a basis for predicting environmental changes.

Determining Recent Sedimentation Rates of the Nueces River, Texas

Robert A. Morton and William A. White, principal investigators; assisted by Radu N. Boghici

This project has grown out of previous investigations of sedimentation and marsh loss in fluvial-deltaic areas of the Texas coast, funded by the Texas Water Development Board. More than 300 acres of marshland in the Nueces River delta has been lost since the 1930's. Most of the loss results from conversion of interior vegetated wetlands to water and barren flats, indicating that marsh sedimentation rates have not kept pace with rates of subsidence and sea-level rise. A principal objective of this study was to assist the Texas Water Development Board in defining river inflow and sediment-load parameters that are needed to sustain wetland elevations and periodically replenish wetland habitats with additional river-borne sediment.

The general methodology was to determine rates of river sedimentation that are necessary for maintaining existing wetland habitats in a setting where past rates of relative sea-level rise have locally exceeded 6.5 mm/yr. A total of 11 shallow cores were taken in brackish marshes, fresh marshes, and transitional areas of the Nueces River and delta for physical and chemical analysis. Dr. Charles Holmes of the U.S. Geological Survey in Denver conducted isotopic analyses of sediments in cores to determine excess ^{210}Pb activities, and activity profiles were used to determine sedimentation rates at each coring site. Other analyses included sediment textures, water content, organic and mineral matter, and bulk density.

Preliminary results of the distribution of excess ^{210}Pb activity with depth show that sedimentation rates vary from core to core. The Texas Water Development Board will use the sedimentation data to determine the relationship between river flooding and sediment deposition in order to define river inflow sediment-load requirements for maintaining wetlands.

Digital Compilation of Sediment Textures, Sediment Compositions, and Washover Areas of the Texas Coast

Robert A. Morton, principal investigator; William A. White, Thomas A. Tremblay, and W. Gerald White

This 1-yr project funded by the Texas General Land Office as part of the Natural Resources Inventory of Texas has two primary objectives. The first is to digitize sediment textural and geochemical data that currently exist only in published tables and maps. Sedimentological and geochemical analyses are available for more than 6,000 surface samples that were collected in the mid-1970's to establish biological and geological baseline conditions for the submerged lands of Texas. These samples represent a large synoptic data set that is unmatched in any other coastal state. The State-owned submerged lands include all the bays, estuaries and lagoons, and the inner continental shelf of the Gulf of Mexico extend-

ing about 10 mi offshore. The second objective is to identify and map washover channels and other low-lying coastal areas that are subjected to repeated flooding by storms in the Gulf of Mexico. Washovers pose some of the greatest natural hazards in the coastal environment, at the same time serving important functions in terms of barrier-island dynamics and sustenance of the back-barrier marshes and sand flats.

In 1995, the textural and geochemical analyses and washover locations were transformed into electronic data and formatted so they were compatible with the geographic information system being developed for management and protection of coastal resources by the State trustee agencies. The electronic data will provide a historical basis for detecting and monitoring changes in the coastal barriers and submerged lands. Results of the project will be used by agencies involved in oil-spill response and contingency planning, as well as coastal-zone management. For example, washover channels crossing barrier islands represent potential invasion sites of oil spilled in the Gulf of Mexico penetrating into the adjacent lagoons; they also are unsafe sites for coastal construction.

Physical and Environmental Assessment of Sand Resources—Texas Continental Shelf

Robert A. Morton, principal investigator; William A. White and James C. Gibeaut

A recent inventory of nonfuel minerals in the Gulf of Mexico demonstrated that potentially economic deposits of sand lie on the Texas continental shelf. Particularly promising for commercialization in the near term are nearshore deposits of sand that may be suitable for beach nourishment if sediment textures are compatible with beach sand. Demand for beach-nourishment sand along the northwestern Gulf of Mexico is increasing as the combined effects of rising sea level and land subsidence become manifested as rapid beach erosion. In Texas, Heald and Sabine Banks are two offshore sand deposits that have the greatest economic potential for near-term exploitation because they are (1) probably suitable for beach nourishment, (2) the largest sand deposits offshore of some of the most rapidly eroding developed shores, and (3) relatively close to potential markets in both southeastern Texas and western Louisiana.

The purpose of this study, funded by the Minerals Management Service Office of International Activities and Marine Minerals, is to evaluate the potential for leasing and mining sand from Heald and Sabine Banks. During 1995 workers (1) assessed the quality and volume of sand in Heald and Sabine Banks, (2) evaluated the potential environmental impact of offshore mining on adjacent shores, (3) analyzed oceanographic conditions that might limit or inhibit mining, and (4) provided guidance as to the economic feasibility of sand mining in the near term. To accomplish these tasks, we cored the banks, determined sediment textures and mineralogy, modeled and compared wave refraction patterns over the banks with shoreline erosion patterns on nearby beaches of the southeast Texas coast, analyzed seasonal sea-state and weather conditions to determine when offshore mining operations would be prohibited, and summarized costs associated with extracting and delivering offshore sand for beach replenishment.

Mapping Shoreline Types of the Texas Coast

Robert A. Morton, principal investigator; William A. White

This multiyear project is funded by the Texas General Land Office as part of the Natural Resources Inventory of Texas, a geographic information system program supported by the natural resource trustee agencies in Texas. The purpose of this regional comprehensive effort is to characterize and map the different shoreline types along the Gulf of Mexico, in the interior bays, and along the Gulf Intracoastal Waterway (GIWW) in Texas. Results of the study will be used by State and Federal agencies responsible for managing coastal resources and for oil-spill response and contingency planning.

In 1995, the Bureau of Economic Geology and Research Planning, Inc. (RPI), of Columbia, South Carolina, classified and ranked shorelines according to their sensitivity to oil-spill damage. For example, hard, synthetic structures (such as sea walls) exposed to high-energy waves have generally low sensitivities to oil-spill cleanup activities, whereas wetlands (marshes and swamps) have high sensitivities. The classification scheme also incorporates shore morphologies, slopes, composition, and wave exposure. Shoreline types were determined from low-altitude color video surveys and aerial photographs, delineated on 1:24,000 topographic maps, and field checked from the air and on the ground. Shoreline characterization and mapping were completed for the Gulf shores between Sabine Pass and East Matagorda Bay, as well as the adjacent interior bay shores (Sabine Lake, Galveston, Trinity, East, West, and Christmas Bays) and the GIWW. The mapped shorelines were digitized, and the data were formatted in a geographic information system (ARC/INFO) by RPI. A report was prepared that explains the procedures and techniques used, describes the classification scheme, and presents photographic examples of the different shoreline types.

Responses of Fluvial, Estuarine, and Barrier-Island Systems to Climate and Sea-Level Change—Central Texas

Michael D. Blum, University of Nebraska—Lincoln; Robert A. Morton, The University of Texas at Austin, Bureau of Economic Geology; and Robert A. Ricklis, The University of Texas at Austin, Archeological Research Laboratory, principal investigators

This 2-yr collaborative research project, which is funded by the National Science Foundation, combines expertise from several scientific disciplines, including fluvial geomorphology, coastal geology, micropaleontology, and archeology. The purpose of the project is to document how fluvial, estuarine, and barrier-island environments of the central Texas coast

have responded to climatic and eustatic changes during the last 150,000 yr. Improving our understanding of the interaction between coastal evolution and threshold values of sea-level rise will improve our predictions of changes in coastal environments and natural resources.

In 1995, the Bureau of Economic Geology conducted a field reconnaissance survey of depositional environments from Copano Bay to Nueces Bay. We also collected, described, and analyzed five hollow-stem auger cores: three cores from upper Pleistocene ("Deweyville") terrace deposits of the Nueces River near Odem, Texas, and two cores from the beach-ridge and incised valley-fill deposits near Portland, Texas. Stacking patterns of sedimentary facies observed in the cores provide clues to the changes in depositional environments during falling and rising phases of sea level.

Shallow-Water, High-Resolution Bathymetric Surveying System

James C. Gibeaut, principal investigator; Robert A. Morton and Roberto Gutierrez; assisted by John A. Kyser

Developing and testing conceptual and theoretical models of coastal sedimentation require bathymetric surveys more precise than are currently available. Precise surveys are difficult to make inside small boats in shallow water because waves and currents cause rapid, short-period boat motion and astronomical tides cause slow, long-period changes in water levels. Comparisons of repeated bathymetric surveys are commonly inconclusive because the magnitudes of potential errors are equal to or greater than the actual changes of the sea floor. The purpose of this study is to develop an electronic surveying system that will either eliminate or compensate for errors inherent in conventional bathymetric surveys. The improved surveying system will include a portable industrial computer for integrating digital records from a (1) precision depth recorder, (2) heave compensator, (3) electronic compass, and (4) global positioning system (GPS). The heave compensator, which is a motion sensor, will correct for the boat motion, whereas the GPS elevations will provide a way of correcting for water-level differences.

Bureau scientists conducting tests of high-accuracy bathymetric surveying system. Photo by David M. Stephens.

The work in 1995 focused on integrating and testing the equipment, making adaptations for field use, checking synchronization of the electronic data, and conducting preliminary surveys in a test tank and lake under rigidly controlled conditions. Plans for 1996 include several tank tests, additional open-water tests in a lake, and eventually a full-scale test in the Gulf of Mexico.

After the system is fully tested, it will be used for a variety of applications such as monitoring seasonal sediment fluctuations, as well as storm-induced erosion and deposition along beaches and around tidal inlets of the Texas coast. The system can also be used to determine sedimentation patterns near river mouths and within river channels. High-precision bathymetric surveys will greatly improve the accuracy of sediment volumes calculated from repeated bathymetric surveys. Improved volumetric calculations will lead to a better understanding of how the beach and shoreface respond to dynamic coastal processes.

Monitoring the Beach and Vegetation Line on Galveston Island

Robert A. Morton, principal investigator; James C. Gibeaut and Roberto Gutierrez

In August 1983, Hurricane Alicia crossed the Texas coast, causing substantial beach erosion and extensive damage to houses near the shoreline. Scouring action by storm waves and currents undermined many homes, destroyed bulkheads, and caused natural vegetation to retreat landward. The purpose of this study is to provide current information concerning magnitudes and rates of recovery of the beach and vegetation line after a major storm. Also under study is how human activities influence recovery processes. This information should prove useful to (1) owners of coastal property that is subject to storm damage and (2) public officials responsible for reviewing and permitting activities in the Coastal Zone. In the study, we are examining recent aerial photographs and measuring the beach profile at selected sites in underdeveloped areas of West Beach, Galveston Island, and Follets Island.

In 1995 we extended our investigation to all Gulf beaches in Galveston County. This was done to assist the Texas General Land Office in identifying the areas of critical dunes and determining the function and criticality of different dune types. A team of coastal geologists, a botanist, a biologist, and land surveyors measured beach profiles at selected sites and described dune morphologies and vegetation along the profiles. Field surveys were conducted using global positioning system receivers that were linked to tide-gauge datums in the region to provide precise vertical control. Results of the study indicate that dune conditions depend primarily on beach

stability and sand supply. Dunes are relatively large where sediment supply is adequate and the beach is relatively stable, whereas dunes are absent or small where there is a deficit in the sand budget and the beach is retreating. Dunes are also absent or small along most of the developed beach segments because the retreating beaches are narrow and the locations of beach houses prevent the natural accumulation of dune sand.

Investigating the Status and Trends of Sea Grasses in the Corpus Christi Bay System

William A. White, Principal Investigator

The Bureau of Economic Geology has been subcontracted by the Texas Parks and Wildlife Department (TPWD) to investigate the status and trends of marine grasses in the Corpus Christi Bay system, a study sponsored by the Corpus Christi Bay National Estuary Program. Principal objectives of this study are to assist TPWD in documenting historical changes in marine-grass distribution since the 1950's and in determining the natural and artificial processes that have contributed to the changes. We are working closely with Dr. Warren Pulich, TPWD's Principal Investigator. Because marine grasses are a dominant and essential ecological habitat in the Corpus Christi Bay system, understanding their spatial and temporal distribution patterns is essential to developing sound management programs for maintaining the health of the bay system. Dramatic losses in submerged aquatic vegetation in the Galveston Bay system since the 1950's, as a result of a combination of natural and human-induced processes, underscore the need to define and isolate probable causes of trends in marine grasses in the Corpus Christi Bay system. Investigative methods are patterned after those used in the Galveston Bay system. Historical aerial photographs dating from the 1950's, 1960's, 1970's and 1980's, providing more than 40 yr of records through 1994, are being used to document changes at a scale of 1:24,000.

Preproject Surveys of Beach and Nearshore Conditions, Galveston Island Beach Replenishment Project

Robert A. Morton, principal investigator; James C. Gibeaut, Roberto Gutierrez; assisted by William C. Bergquist and Daniel H. Ortuño

Coastal tourism and the economy of many coastal communities depend greatly on accessibility to beaches and related recreational facilities. Local governments worldwide, therefore, artificially replenish beaches that are degraded as a result of beach erosion. Replenishment involves mining sand at a borrow site (either onshore or offshore) and placing the mined sand on the restored beach.

The first large-scale replenishment of a Gulf beach in Texas was recently completed on Galveston Island along the sea wall from 10th to 61st Streets. The preproject surveys, which were funded by the City of Galveston, were conducted to characterize native conditions of the beach and nearshore environments at Galveston between East Beach and 61st Street before beach-nourishment dredging and pumping operations began. During preproject activities we (1) acquired and interpreted low-altitude aerial photographs; (2) surveyed the highest annual tide line; (3) made surveys to determine the width, elevations, and slope of the beach and nearshore profile at selected sites; (4) surveyed the proposed borrow area, and (5) acquired and analyzed texture of sediment samples to determine the composition and grain-size distribution of natural beach and shoreface material. We need information (1) to establish the preproject baseline conditions for comparison with postproject changes in the fill, (2) to provide data for evaluating beach-fill performance, (3) to help predict how long the beach fill will last, and (4) to evaluate depth changes at the borrow site.

We conducted fieldwork in December 1994 using standard land-surveying techniques and state-of-the-art surveying and navigation equipment in the offshore areas. Beach profiles, surveyed using an electronic total station, originated at benchmarks along the sea wall established by the U.S. Army Corps of Engineers. We conducted offshore surveys using a boat-mounted precision depth recorder (echo sounder) to survey the sea floor, global positioning system (GPS) receivers to determine precise geographic locations, and a motion sensor to correct for boat movement caused by waves. The beach profiles and offshore surveys were integrated to produce long transects extending from the sea wall approximately 3,500 ft offshore to water depths of about 18 ft. Results of the study, which were summarized in a contract report, included 22 long transects, textural analyses of sediment samples collected along the transects, and bathymetric maps of the offshore borrow site.

Characterization of Sand Bodies within Seismic Sequences—Texas Continental Margin

Robert A. Morton, principal investigator; assisted by Radu N. Boghici

This project, which was initiated in 1989, is funded by the U.S. Department of the Interior, Minerals Management Service, as part of its Continental Margins Program. The primary objective of this research is to improve the prediction of lithologies and the identification of potential reservoir facies within depositional sequences on the basis of seismic patterns and reflection terminations. Upper Quaternary depositional sequences preserved beneath the continental shelf were selected for detailed study because of the existing shallow subsurface control and the constraints on sea-level fluctuations that occurred during the past 100,000 yr. We do this work by integrating and analyzing two data sets—high-resolution seismic surveys and foundation borings.

In 1995, we extended maps portraying the physical properties (thickness, percent sand, and lithologies), depositional environments, and paleogeography of four previously identified seismic sequences onto the adjacent continental slope. We did so by interpreting a grid of high-resolution seismic profiles on the slope and by interpreting and correlating de-

scriptions of deep cores and foundation borings provided by the petroleum industry. Results of the project showed that resedimentation of sand onto the continental slope was extremely limited and that most of the sand deposited by the late Quaternary lowstand deltas was stored in the delta-front sediments. A final contract report was prepared that summarized the geologic history of the study area and emphasized the influence of sea-level fluctuations and salt mobilization on sequence development and deposition of sand bodies within each sequence.

Mapping Investigations

Geologic Atlas of Texas

Virgil E. Barnes, principal investigator

The Bureau's Geologic Atlas of Texas provides geologic map coverage of the entire state at a scale of 1:250,000. New work focuses on reprinting older maps as they go out of print. The Fort Stockton sheet was revised and reprinted in 1995.

GPS/GIS for State and Federal Regulated Facilities in the EPA Region 6 International Border Area

Jay A. Raney, principal investigator; Deborah A. Salazar, W. Gerald White, and Edward S. Angle; assisted by Allison J. Goldberg

Workers on this 2-yr project, funded by the U.S. Environmental Protection Agency (EPA) Region 6, are using real-time, differential global positioning system (GPS) technology to determine the locations of EPA-permitted facilities along the U.S.–Mexico border area from Brownsville, Texas, to Deming, New Mexico.

Approximately 5,000 permits have been issued by EPA in the border area of Texas and New Mexico, covering toxic-release sites, drinking-water facilities, wastewater outfalls, landfills, Superfund sites, underground storage tanks, and industrial-waste producers. Project workers have input permit information into a tracking data base in order to identify duplicate and out-of-date records or records having improper locational data on the basis of new locational data derived from the field surveys and a records review. Regulated facilities are being located to within a 7- to 23-ft accuracy (latitude, longitude, and elevation). These improved locational data are then used to enhance the facility-permit data bases maintained by EPA Region 6, the Texas Natural Resource Conservation Commission (TNRCC), and the New Mexico Environment Department (NMED).

The first year of the project netted approximately 800 actual sites from the 2,000 facility-permit records investigated. The number of located sites is fewer than the number of permits because (1) some facilities have relocated or gone out of business, (2) the EPA has issued multiple permits for the same site or facility, or (3) the site could not be found readily in the field on the basis of information available in the permit files. Areas visited during the first year include Cameron, Hidalgo, Willacy, Val Verde, Webb, and El Paso Counties in Texas, and Doña Ana County in New Mexico.

Facility locations are being converted to ARC/INFO GIS format and plotted against 1:24,000-scale base maps, by county, to summarize the results of the survey. Software allows direct plotting of facility locations from the real-time, differential GPS field data and requires no postprocessing. Cooperating State and Federal agencies will be given a demonstration of the GPS data collection, as well as assistance in developing similar programs themselves.

Geologic Study of Sierra del Carmen, Mexico and Big Bend, Texas

Jay A. Raney, principal investigator; Edward W. Collins

The purpose of this project, begun in 1995, is to provide geologic base maps to support mapping of biologic (vegetation) resources. This mapping is being conducted by the National Biologic Service and National Park Service in the Sierra del Carmen, Coahuila, Mexico, and adjacent areas in Big Bend National Park, Texas. The project, funded by the National Biologic Service, has as its primary goal the production of a 1:50,000- to 1:100,000-scale geologic map that synthesizes existing geologic maps and new aerial photographs and field maps. The geologic map of this region is intended to help students, interested visitors, and other scientists understand the geology of this fascinating area and to interpret the influence of the geologic framework on related sciences. The map will emphasize bedrock and surficial units that can influence the distribution of plant communities. The map will also aid management at the park and support other ongoing studies.

STATEMAP Project: New Braunfels, Texas

Jay A. Raney, principal investigator; Edward W. Collins

This multiyear project has focused on mapping the geology of the 1:100,000-scale New Braunfels, Texas, quadrangle, an area that covers a rapidly developing part of Central Texas, including Wimberley, Canyon Lake, Guadalupe River State Park, New Braunfels, northern San Antonio, Government Canyon State Natural Area, Lake Medina, Boerne, and Comfort. This project, part of the U.S. Geological Survey's (USGS) STATEMAP program, is funded jointly by the USGS and the Bureau of Economic Geology. The geology is being mapped on 1:24,000-scale 7.5-minute quadrangles; a composite color map will be published using the USGS 1:100,000-scale topographic map of the area as a base. Ten open-file geologic maps, 1:24,000 scale, completed during this project year include the Van Raub, Helotes, Waring, Ranger Creek, Jack Mountain, San Geronimo, Comfort, Turkey Knob, Pipe Creek,

and Medina Lake quadrangles. This year we completed the mapping of the 32 7.5-minute quadrangles that are within the 1:100,000-scale New Braunfels, Texas, map area.

The map area encompasses a region that is undergoing rapid urban growth. It lies within part of the recharge zone of the Edwards aquifer and covers a complex part of the Balcones Fault Zone. The geology of this region is important to geologists and other professionals involved in planning land use, designing construction projects, and studying the Edwards aquifer. Recharge of the aquifer may be locally enhanced at karst features, faults, and joints. Faulted aquifer strata influence regional ground-water flow, and faults locally juxtapose strata that have different physical properties, creating potential construction–foundation problems. The geologic maps of this area provide some of the most useful and fundamental information about this geologically critical area of Central Texas.

Cretaceous limestone, marl, and shale make up most of the outcropping strata. Quaternary sand and gravel cover older deposits along major drainageways and are most abundant southeast of the Balcones Escarpment. Large faults of the broad Balcones Fault Zone strike mostly N40° to 70°E and dip southeastward. Composite stratigraphic displacement across the fault zone is as much as 1,800 ft in the New Braunfels area.

STATEMAP Project: El Paso, Texas

Jay A. Raney, principal investigator; Edward W. Collins

The objective of this multiyear project is to map the El Paso–Rio Grande border area that includes parts of the Hueco Bolson and bounding Franklin Mountains, Hueco Mountains, and Diablo Plateau. Geologic mapping is critical in this area because development and exploitation of geologic and other resources are stressing the environment. This project, part of the U.S. Geological Survey's (USGS) STATEMAP program, is funded jointly by the USGS and the Bureau of Economic Geology. The geology is being mapped on 1:24,000-scale 7.5-minute quadrangles, and a composite color map will be published at 1:100,000 or 1:50,000 scale when the mapping of the region is completed. Twelve open-file geologic maps, 1:24,000 scale, were completed during this second project year. The Fort Bliss NE and Fort Bliss SE quadrangles are within part of the basin floor of the Hueco Bolson. The Nations East Well, Nations South Well, Hueco Tanks, Helms West Well, and Clint NE quadrangles encompass the east margin of the basin floor and the west edge and foothills of the Hueco Mountains. The Ysleta, San Elizario, Clint NW, Clint, and Clint SE quadrangles contain the basin floor, Rio Grande valley, and valley border.

The basin floor of the Hueco Bolson contains windblown sand deposits that overlie middle Pleistocene–Pliocene Camp Rice sand and gravel and lesser amounts of silt and clay. Camp Rice deposition represents a system of predominantly fluvial and alluvial-fan deposition, along with some floodplain and minor lacustrine deposition. On the basin floor, the top of the Camp Rice is capped by a well-developed stage IV–V pedogenic calcrete. Windblown sand deposits that overlie the Camp Rice Formation appear to be mostly less than 6 to 10 ft thick, although at one abandoned sand quarry, the eolian sand was more than 26 ft thick. Coppice dunes, interdune sheet deposits, and deflation areas are common. At the east margin of the Hueco Bolson, local areas of active sand dunes and areas of partly vegetated, stabilized to partially stabilized dunes are present. The basin floor contains a series of north-trending sand-covered scarps that may be fault related.

East of the Franklin Mountains, the Rio Grande valley and valley border consist of remnant terraces that have been incised into the Camp Rice Formation. Fan deposits at the mouths of arroyos and smaller drainageways that flow into the river valley also exist. Alluvium associated with the remnant terraces and fans along the valley border are thin, whereas alluvium of the Rio Grande floodplain is commonly cultivated where it is not urbanized. Windblown sand deposits also occur within the valley border. Sand–gravel quarries, where the relatively uncemented Camp Rice deposits are mined, are common along the valley border rim.

At the east edge of the Hueco Bolson, fan and drainageway alluvium composes the piedmont deposits shed from the Hueco Mountains. Bedrock hills surrounded by alluvium are common at the basin margin. Bedrock stratigraphy of the area records a long geologic record. At the west edge of the Hueco Mountains the bedrock stratigraphy consists of Upper Cambrian(?), Ordovician, Silurian, Devonian, Mississippian, Pennsylvanian, and Permian limestone, marl, shale, and sandstone. Tertiary intrusive rocks in the area are mostly syenite to monzonite of the Hueco Tanks region that were intruded about 35 mya as sills and dikes. Northwest-striking and north-striking normal faults cut bedrock. Broad northwest-trending folds are expressed within the bedrock strata. Localized folding related to sill emplacement has also occurred. Limestone is active, being quarried for crushed stone and cement along the flanks of the Hueco Mountains.

Other Geologic Investigations

Geomorphic Studies of Archeological Sites

L. E. Garner, principal investigator

The Texas Department of Highways and Public Transportation has contracted with the Bureau of Economic Geology to provide services as needed to perform geomorphic studies for archeological investigations. The required work includes field investigations and drilling programs at selected locales, analysis of soils data, and short reports of observations and conclusions.

The geomorphic studies are being conducted to determine the geomorphology of locales, its influences on past human activities, and the effects of natural processes on deposits of cultural materials. Investigations during the past year have focused on habitation sites along Culebra Creek and the Medina River near San Antonio and the Wilson–Leonard site in Williamson County, Texas.

Contract and Grant Support

The Bureau maintains formal and informal cooperative arrangements with several governmental entities. Parts of the Bureau's research program are conducted under University of Texas contracts and grants with Federal, State, and private organizations.

Contract-management personnel prepare proposals and budgets, negotiate contracts, and monitor expenditures. During the contract period, technical and financial reports are distributed at monthly, quarterly, and annual intervals. In 1995, the following 75 contracts, each of which had reporting requirements, were active at the Bureau:

Federal

"Analysis and Prediction of Coastal Erosion and Wetland Loss in Southeastern Texas": supported by the U.S. Geological Survey, U.S. Department of the Interior.

"Application of Advanced Reservoir Characterization, Simulation and Production Optimization Strategies to Maximize Recovery in Slope and Basin Clastic Reservoirs, West Texas (Delaware Basin)": supported by the U.S. Department of Energy.

"Detecting Small-Scale Topographic Changes and Relict Geomorphic Features of Barrier Islands Using SAR": supported by the National Aeronautics and Space Administration.

"El Paso STATEMAP Project": supported by the U.S. Geological Survey, U.S. Department of the Interior (two contracts).

"Geologic and Hydrologic Site Characterization of the Pantex Plant": supported by the U.S. Department of Energy through the Office of the Governor, State of Texas.

"Geologic Support of National Parks Service Survey of Sierra del Carmen, Mexico and Big Bend": supported by the National Biological Service, U.S. Department of the Interior.

"Geoscience/Engineering Characterization of the Interwell Environment in Carbonate Reservoirs Based on Outcrop Analogs, Permian Basin, West Texas and New Mexico": supported by the U.S. Department of Energy.

"GPS/GIS for Regulated Facilities in the Region 6 International Border Area": supported by the U.S. Environmental Protection Agency.

"Hydrology of Camps Barkley, Bowie, Mabry, Maxey, Swift, and Wolters in Relation to Aquatic Biology": supported by the Texas Army National Guard through the Nature Conservancy of Texas.

"Lignite Resources, Jackson and Wilcox Trends, South Texas; and Jackson–Yegua Trend, East Texas": supported by the U.S. Geological Survey, U.S. Department of the Interior.

"Midland Core Repository": supported by the U.S. Department of Energy.

"Monitoring Techniques Related to Subsurface Gas Transport": supported by the Nuclear Regulatory Commission through the University of Arizona.

"New Braunfels STATEMAP Project": supported by the U.S. Geological Survey, U.S. Department of the Interior.

"Offshore Northern Gulf of Mexico Oil and Gas Resources Atlas Series": supported by the U.S. Department of Energy, the Minerals Management Service, U.S. Department of the Interior, and the Gas Research Institute (two contracts).

"Physical and Environmental Assessment of Sand Resources—Texas Continental Shelf": supported by the Minerals Management Service, U.S. Department of the Interior.

"Responses of Fluvial, Estuarine, and Barrier Island Systems to Climate and Sea-Level Change—Central Texas": supported by the National Science Foundation.

"Revitalizing a Mature Oil Play: Strategies for Finding and Producing Unrecovered Oil in Frio Fluvial-Deltaic Reservoirs of South Texas": supported by the U.S. Department of Energy.

"A Robust Economic Technique for Crosswell Seismic Profiling": supported by the U.S. Department of Energy.

"Studies Related to Continental Margins (years 8 through 10)": supported by the Minerals Management Service, U.S. Department of the Interior (three contracts).

"A Technology Transfer Program, Texas Region of the Petroleum Technology Transfer Council": supported by BDM–Oklahoma, Inc., through the Petroleum Technology Transfer Council.

"U.S.–Mexico Regional Environmental Information System": supported by the U.S. Environmental Protection Agency through the Consortium for International Earth Science Information Network.

State and Local

"Assistance to the Natural Resource Damage-Assessment Division of the General Land Office": supported by the Texas General Land Office.

"Assistance to the Public Utility Commission of Texas": supported by the Public Utility Commission of Texas.

"Assistance to the Texas General Land Office in the Kenedy Foundation Litigation": supported by the Texas General Land Office.

"Brazos River Erosion Assessment": supported by the Texas Parks and Wildlife Department (two contracts).

"Comprehensive Hydrogeologic Investigations of Regional Ground-Water Flow and Ground-Water Resources, Ellis County Area, North Texas": supported by the Texas National Research Laboratory Commission.

"Determining Recent Sedimentation Rates of the Lower Nueces River, Texas": supported by the Texas Water Development Board.

"Digital Compilation of Sediment Textures, Sediment Compositions, Washover Areas within the NRI Priority Regions": supported by the Texas General Land Office.

"Documenting Possible Subsidence at the GSU Marsh Restoration Site": supported by the Texas Department of Parks and Wildlife.

"Geologic and Hydrologic Studies of the Eagle Flat Area": supported by the Texas Low-Level Radioactive Waste Disposal Authority (two contracts).

"Geophysical Screening of Potential Brine Leakage Sites, Runnels County, Texas": supported by the Railroad Commission of Texas (two contracts).

"Hydrogeological Reconnaissance of Selected Abandoned Oil Field Cleanup Sites": supported by the Railroad Commission of Texas (two contracts).

"Identification of Critical Dune Areas and Gulf Beach Access Points": supported by Texas General Land Office.

"Identification of Geologic Analogs for Engineered Barriers": supported by the Texas Low-Level Radioactive Waste Disposal Authority (two contracts).

"Mechanics of Active Salt Diapirism: Advanced Simulation by Finite Elements and Experiments": supported by the Texas Higher Education Coordinating Board.

"Multiple Attribute Geographic Information System Environmental Baseline, Lower Rio Grande Valley": supported by the Texas Higher Education Coordinating Board.

"Project Plan for Mapping Shoreline Types of the Texas Coast": supported by the Texas General Land Office.

"Regional Permeability Study of the Edward's Aquifer": supported by the Edwards Underground Water District.

"Rejuvenating a Dying Oil Play: Benefits to the State, the Permanent School Fund, and the People and Economy of Far West Texas": supported by the Texas Office of State–Federal Relations.

"Shallow-Water, High-Accuracy, High-Resolution Bathymetric Surveying System": supported by the Texas Higher Education Coordinating Board.

"Spoil Pile Water Quality": supported by the Texas National Research Laboratory Commission.

"Strontium Isotopic Signatures of Subsurface Brines: Key to Identifying Interreservoir Hydraulic Connectivity": supported by the Texas Higher Education Coordinating Board.

"Studies to Optimize the Monitoring System of a Trench and Engineered Barrier in an Arid Setting": supported by the Texas Low-Level Radioactive Waste Disposal Authority.

"Technology Transfer Initiative": supported by the Office of the Governor.

"Texas Highway Department—Archeological Projects": supported by the Texas Department of Highways and Public Transportation (now the Texas Department of Transportation).

Private

"Applied Geodynamics Laboratory": supported by Agip S.p.A.; Amoco Production Company; Anadarko Petroleum Corporation; ARCO Exploration and Production Technology; BHP Mineral; BP Exploration, Inc.; Chevron Petroleum Technology Company; Conoco, Inc.; E. I. DuPont de Nemours and Company; Exxon; The Louisiana Land and Exploration Company; Marathon Oil Company; Mobil Research and Development Corporation; Phillips Petroleum Company; Société Nationale Elf Aquitaine Production; Petróleo Brasileiro S. A.; STATOIL; Texaco, Inc.; and Total Minatome Corporation.

"Characterization and Quantification of Geologic and Petrophysical Heterogeneity in Fluvial-Deltaic Reservoirs": supported by the Gas Research Institute.

"Characterization of Heterogeneity Style and Permeability Structure in Fluvial Reservoirs, Açu Formation, Brazil": supported by Petróleo Brasileiro S.A.

"Characterization of Heterogeneity Style and Permeability Structure in a Sequence Stratigraphic Framework in Fluvio-Deltaic Reservoirs": supported by BP Exploration Operating Company Ltd.; Chevron Oil Field Research Company; Conoco, Inc.; Exxon Production Research Company; Intevep; Japan National Oil Corporation; Maxus Energy Corporation; Occidental International Exploration and Production, Inc., and OXY USA, Inc.; Oryx Energy Company; STATOIL; and Union Oil Company of California.

"Characterization of San Andres and Grayburg Reservoirs": supported by Amoco Production Company; ARCO Exploration and Production Technology; BP International, Ltd.; Exxon Production Research Company; Japan National Oil Corporation; Marathon Oil Company; Meridian Oil; OXY USA, Inc.; Pennzoil Petroleum Company; Petroleum Development Oman; Phillips Petroleum Company; Shell Canada, Ltd.; Shell Western E&P; Texaco Exploration and Production Technology; TOTAL Compagnie Française des Petroles; and Union Oil Company of California.

"Characterize Miocene Reservoirs that are Found in the Mioceno Norte Area of Maracaibo Lake": supported by Lagoven S.A.

"Detailed Characterization Study for the Eocene Reservoirs of the VLA-6/9/21 Area, Block I, Lake Maracaibo Field": supported by Maraven, S.A.

"Development and Evaluation of a Basin-Scale Coalbed Methane Producibility Model": supported by the Gas Research Institute.

"Development of Seismic-Imaging Applications for Optimally Characterizing Depositionally Heterogeneous Reservoirs": supported by Vastar Resources, Inc., Mitchell Energy Corporation, Phillips Petroleum Company, and Maxus.

"Feasibility Study for the Establishment of a National Geoscience Data System": supported by the American Geological Institute.

"Geologic Analysis of Primary and Secondary Tight Gas Sands Objectives": supported by the Gas Research Institute.

"Integrated Strategies for Carbonate Reserve Growth: An Example from the Ellenburger Group, Permian Basin, West Texas": supported by the Gas Research Institute and the U.S. Department of Energy (two contracts).

"Jackson Region Reservoir Characterization and Performance Study": supported by Santos, Ltd.

"Precambrian Tectonics": supported by BHP Mineral.

"Preproject Surveys of Beach and Nearshore Conditions, Galveston Island Beach Replenishment Project": supported by the City of Galveston.

"Reservoir Characterization of the Portrerillos Formation and Recovery Optimization Project Barrancas Norte Field": supported by YPF, S.A.

"Reservoir Characterization Study, Budare Field, Guarico State, Eastern Venezuela Basin": supported by Corpoven.

"Secondary Natural Gas Recovery—Infield Reserve Growth Joint Venture: Applications in Midcontinent Sandstones": supported by the Gas Research Institute and the U.S. Department of Energy (two contracts).

"Technology Transfer Field Conference for Deep-Water Development": supported by British Petroleum and STATOIL.

Publications

In its role as a public geological research unit, the Bureau of Economic Geology disseminates the results of research projects and programs primarily through its own publication series. During its 85-yr history, the Bureau has published nearly 2,300 reports, bulletins, circulars, maps, and other publications covering major aspects of the geology and natural resources of Texas. In 1995, publishing efforts expanded to include electronic publication via the Bureau's home page on the Internet (http://www.utexas.edu/research/beg/). The Bureau will continue to develop new ways to serve the needs of the geological community by making research results available in a variety of media.

Publications are sold at nominal prices to recover printing or duplication costs. To date, more than 1.7 million publications have been distributed worldwide, mostly through direct sales but also through charitable donation. In 1995, about 21,000 volumes were distributed. The Bureau issued the following publications in 1995.

Reports of Investigations

RI 226. Production Optimization of Tide-Dominated Deltaic Reservoirs of the Lower Misoa Formation (Lower Eocene), LL-652 Area, Lagunillas Field, Lake Maracaibo, Venezuela.

by W. A. Ambrose, E. R. Ferrer, S. P. Dutton, F. P. Wang, Antonio Padron, Williams Carrasquel, J. S. Yeh, and Noel Tyler. 46 p., 29 figs., $4.50

Many oil reservoirs worldwide contain substantial volumes of unrecovered mobile oil that remains trapped in compartments after primary and secondary development. For example, the C members of the Lower Misoa Formation in Lagunillas field, Maracaibo Basin, Venezuela, have tide-dominated deltaic reservoirs that are expected to have an ultimate recovery of only 22 percent after primary recovery. An estimated 923 million stock-tank barrels (MMSTB) of unrecovered mobile oil is projected to remain in the field at current levels of development at 80-acre well spacing. The complex tectonic history of Maracaibo Basin has created many structural compartments between intersecting faults of different ages. The authors of this report discuss the structural complexity and depositional heterogeneity that have resulted in great potential for reserve growth from the remaining mobile oil. They document volume and location of remaining oil in the C member so that through geologically targeted development a large part of this resource can be recovered. The integrated study entailed using 22 structural, 27 stratigraphic, and 12 seismic cross sections of major stratigraphic sequences, 76 thin sections, and 47 dipmeter logs. By comparing maps of hydrocarbon volumetrics and production with structural and stratigraphic maps, the authors delineated areas favorable for infill-well development of each reservoir. The documented original-oil-in-place resource is 2.3 billion stock-tank barrels, of which 923 MMSTB will remain in the LL-652 areas after proved and extended-development reserves have been recovered. Deploying 102 geologically optimized infill wells will result in recovery of a projected 116 MMSTB of oil. Moreover, the authors propose that horizontal and inclined wells in the C-3-X and C-4-X members can recover additional volumes of poorly contacted oil. This research was performed for and funded by Lagoven, S.A., which is part of the Petroleos de Venezuela, S. A., organization.

RI 227. Identification and Assessment of Remaining Oil Resources in the Frio Fluvial-Deltaic Sandstone Play, South Texas.

by M. H. Holtz and L. E. McRae. 46 p., 33 figs., 7 tables, $5.00

Since field development began 50 yr ago, the Frio Fluvial-Deltaic Sandstone play along the Vicksburg Fault Zone has produced nearly 1 billion barrels of oil. More than half of the reservoirs in the play are abandoned, although large volumes of oil remain. To estimate the volume of oil remaining in the play and to assess reservoirs having additional unproduced oil, the authors evaluate geologic and engineering characteristics of reservoirs in fields throughout the play area. Geologic characterization includes analyses of depositional history, reservoir facies, and styles of heterogeneity. Reservoir attributes assessed include porosity, initial water and residual oil saturation, net pay, reservoir area, and fluid characteristics. These parameters were statistically evaluated by various probability tests, and the Weibull function was found to represent the frequency distribution of reservoir volumes most accurately, including original oil in place (OOIP) and mobile oil in place. Estimated OOIP is 3.8 to 5.6 billion stock-tank barrels (BSTB), original mobile oil in place is 2.5 to 3.6 BSTB, and residual oil ranges from 1.5 to 2.3 BSTB. Untapped oil resources may amount to 380 million stock-tank barrels, or 10 percent of the OOIP. Although prior enhanced oil recovery efforts in the Frio did not include methods of producing residual oil, the authors conclude that modern reservoir characterization and management techniques could help in the recovery of additional remaining mobile oil. This research was performed for and funded by the U.S. Department of Energy.

RI 228. Geologic and Hydrologic Assessment of Natural Gas from Coal: Greater Green River, Piceance, Powder River, and Raton Basins, Western United States.

by Roger Tyler, W. R. Kaiser, A. R. Scott, D. S. Hamilton, and W. A. Ambrose. 219 p., 131 figs., 4 tables, 4 appendices, $25.00

Although domestic coalbed methane production has increased nearly fivefold since 1990, current development represents only a small part of the estimated 675 trillion cubic feet (19.1 Tm^3) of in-place coal-gas resources in United States coal basins. Researchers at the Bureau of Economic Geology, on behalf of the Gas Research Institute, are characterizing western United States coal basins to identify geologic and hydrologic conditions favorable for high coalbed methane producibility.

This report represents the first comprehensive analysis of the coalbed methane geology and resource potential within the Greater Green River, Piceance, Powder River, and Raton Basins. The analysis is based on critical geologic and production parameters established by Bureau researchers in previous publications on the San Juan Basin, the most prolific coalbed gas-producing basin in the United States. In this report, the authors present detailed evaluations of these four basins in terms of their tectonic structure, stratigraphy, deposition, coal rank, gas composition and content, hydrology, and production history. Of the basins studied, cumulative production and industry activity are highest in the Piceance and Powder River Basins; to date, the difficulty of dewatering the coal reservoirs has limited production in the Greater Green River Basin, and the absence of an interstate pipeline precludes deliverability of gas from the Raton Basin. Using extensive technical and economic criteria, the authors conclude that all four basins are attractive targets for coalbed methane exploration and development. Moreover, the Piceance Basin has the primary potential for making a significant near-term contribution to the nation's gas supply; the Greater Green River, Powder River, and Raton Basins have secondary potential. Numerous illustrations, detailed appendices, and an extensive bibliography provide further information useful to geologists, hydrologists, and industry personnel. Funding for this research was provided by the Gas Research Institute.

RI 229. Origin and Development of Playa Basins, Sources of Recharge to the Ogallala Aquifer, Southern High Plains, Texas and New Mexico.

by T. C. Gustavson, V. T. Holliday, and S. D. Hovorka. 44 p., 22 figs., 4 tables, $6.00

Playa basins are small, internally drained, roughly circular to oval depressions formed by the interaction of geomorphic, pedogenic, hydrochemical, and biologic processes. More than 20,000 playa basins have formed on and persisted within the Southern High Plains of Texas and New Mexico. Development of playa basins and their long-term stability in the landscape of the area result partly from the difference in rates of sediment accumulation in upland areas versus playas. A stable landscape prevailed on the High Plains uplands throughout much of the Quaternary and late Tertiary, preserving both eolian sediments and large volumes of soil carbonate ($CaCO_3$) in interplaya areas. During the same period, although playas accumulated lacustrine, eolian, and deltaic sediment and small amounts of pedogenic $CaCO_3$, they were also subject to deflation. As a result, playa basins were enlarged (deepened) relative to surrounding uplands partly by more rapid vertical accretion of sediment and soil carbonate on uplands.

Playa basins in Texas and New Mexico are economically important because they collect runoff and focus recharge to the Ogallala aquifer, which is the primary source of water on the Southern High Plains. In this report, the authors present new and significant data on playa basin morphology and developmental processes, critically review current hypotheses of playa basin origin and development, and describe an integrated model of the genesis of playa basins. This work was supported by the U.S. Department of Energy and the National Science Foundation.

RI 230. Chert Reservoir Development in the Devonian Thirtyone Formation: Three Bar Field, West Texas.

by S. C. Ruppel and S. D. Hovorka. 50 p., 40 figs., 3 tables, $7.50

Chert reservoirs of the Lower Devonian Thirtyone Formation represent a substantial part of the hydrocarbon resource in the Permian Basin. More than 700 million barrels of oil has been produced from these rocks, and an equivalent amount of mobile oil remains. Effective exploitation of this sizable remaining resource, however, demands a comprehensive understanding of the complex factors that have contributed to reservoir development.

The authors' analysis of Thirtyone Formation chert deposits in Three Bar field and elsewhere in the Permian Basin reveals that reservoirs display substantial heterogeneity that results from an interplay of depositional, diagenetic, and structural processes. Large-scale reservoir geometries and finer scale, intrareservoir heterogeneity are attributable primarily to original depositional processes. These cherts, which were deposited by relatively deep water sediment gravity processes along a north-trending depocenter, exhibit relatively continuous stratal geometries, especially in the area of Three Bar field, which contains one of the largest of these reservoirs. Porosity development in these rocks is due principally to variations in rates and end products of early silica diagenesis. Because this diagenesis was partly a function of depositional facies architecture, porosity development follows original depositional patterns.

In reservoirs such as Three Bar field, where the Thirtyone Formation has been unroofed by Pennsylvanian deformation, meteoric diagenesis has added heterogeneity by causing dissolution of chert and carbonate, especially in areas of higher density fracturing and faulting and along truncated reservoir margins. Structural deformation has also controlled heterogeneity directly, particularly in reservoirs under waterflood. High-density fracture zones create preferred flow paths that result

in nonuniform sweep through the reservoir. Faulting locally creates fault compartments by offsetting reservoir flow units.

Three Bar field exhibits many of the major styles of heterogeneity that contribute to inefficient recovery in the Thirtyone Formation. The processes and models that the authors have defined here help explain causes of heterogeneity in all Thirtyone chert reservoirs in the Permian Basin and facilitate recovery of the sizable hydrocarbon resource remaining in these rocks. Funding for this research was provided by The University of Texas System.

RI 231. Flow-Unit Characterization and Recovery Optimization of a Braid-Delta Sandstone Reservoir, Tirrawarra Oil Field, South Australia.

by H. S. Hamlin, S. P. Dutton, R. J. Seggie, Noel Tyler, and J. S. Yeh. 44 p., 49 figs., 6 tables, $10.00

The Tirrawarra Sandstone is the primary producing zone at Tirrawarra field in the Cooper Basin of South Australia, where it contains 146 million barrels (MMbbl) of unrecovered oil. Because previous reservoir models had failed to predict reservoir performance accurately and development drilling had yielded poor results, the authors undertook this study in order to construct a three-dimensional descriptive model of the Tirrawarra Sandstone reservoir. In their model, they calculated the volumes and residency of original and remaining oil in place. This depositional-facies-based flow-unit model resulted in the identification of an additional 36 MMbbl of oil in place. It also advanced current understanding of past reservoir behavior and the identification of opportunities for incremental development. A comprehensive subsurface data base, including 3,000 ft of core from 31 wells, was used to develop the flow-unit model.

The Carboniferous–Permian Tirrawarra Sandstone reservoir, which was deposited in a proglacial intracratonic setting, is 90 to 180 ft thick. It comprises four main depositional facies that record progradation of several fluvial-deltaic systems across a lacustrine basin. A braid-delta system, the core of the reservoir, is dominated by bed-load fluvial channel-fill sandstone and is bounded by more lithologically heterogeneous facies. Prodelta, delta-front, distributary-channel, and channel-mouth-bar facies underlie the braid-delta facies, which are truncated and overlain by braid-plain facies. The Tirrawarra Sandstone is primarily a fine- to medium-grained sublitharenite, although each facies has distinct petrographic characteristics. Texture and detrital composition, both inherited from the depositional environment, determined the magnitude of porosity loss during diagenesis.

Depositional environment is the primary control on reservoir properties and productivity at Tirrawarra field. Each facies has distinctive petrophysical properties and displays characteristic geometries and internal stratification patterns. In this report, the authors defined reservoir flow units within each facies on the basis of stratigraphic position and petrophysical properties. Stratigraphic analysis, by means of well log and core data, established flow-unit architecture and delineated flow barriers. Petrographic and petrophysical analyses quantified flow-unit-specific properties such as porosity, permeability, and hydrocarbon saturation. Geological and petrophysical data were then used to construct the three-dimensional model, which enhanced visualization of reservoir heterogeneities, performed volumetric calculations, and served as a basis for developing strategies to optimize recovery. The model identified undeveloped pay in all major flow units and revealed untapped reservoir compartments in the north part of the field. Geologically targeted infill wells and recompletions will improve recovery efficiency in existing enhanced-oil-recovery (EOR) patterns, and the northern reservoir compartments will be accessed by new EOR patterns. Funding for this research was provided by Santos Ltd.

RI 232. Canyon Sandstones—A Geologically Complex Natural Gas Play in Slope and Basin Facies, Val Verde Basin, Southwest Texas.

by H. S. Hamlin, S. J. Clift, S. P. Dutton, T. F. Hentz, and S. E. Laubach. 74 p., 68 figs., 7 tables, 3 appendices, $6.50

Canyon sandstones form a prolific low-permeability gas play in the Val Verde Basin of southwest Texas. Exploration and development activity is at a high level, but little published information on Canyon geology is available. Although several geographically and stratigraphically distinct "Canyon" intervals (Upper Pennsylvanian–Lower Permian) are productive, the authors of this report focused on characterizing the stratigraphy, diagenesis, and natural fractures of Sonora Canyon sandstones in Sutton County and Ozona Canyon sandstones in Crockett County. These Canyon intervals are composed of hundreds to thousands of feet of thinly interbedded sandstone and mudstone, which formed in slope and basin depositional systems.

Because outcrops are nonexistent in the Sonora and Ozona intervals and seismic data were unavailable, well logs and cores formed the data base for this study. Sandstone distribution was mapped regionally and locally in Sutton County, where dense well control and core allowed field-scale facies characterization. Sonora sandstones lie in a wedge-shaped interval along the southwest margin of the Eastern Shelf, whereas the more tabular Ozona interval occupies a basin-floor position adjacent to the south margins of the Ozona Arch and the Central Basin Platform. Other Canyon or "Wolfcamp" sandstone intervals lie adjacent to the Ouachita orogenic belt in the south and west parts of the Val Verde Basin.

Sonora and Ozona sandstones were deposited in deep-water, turbidite systems. Several depositional facies were identified in core: conglomeratic sandstone, thick- and thin-bedded turbidites, chaotic facies, and hemipelagic mudstone. These facies recur in characteristic associations to form the elements of submarine fans: slope channel, proximal channelized fan lobe, distal lobe, and lobe fringe. Individual fan lobes are a few hundred feet thick and a few miles wide, and fan channels are less than 100 ft (< 30 m) thick and less than 1 mi (< 1.6 km) wide. Channel and lobe depositional elements are complexly interbedded and laterally coalesced. Regionally Canyon fans form multiple-sourced, strike-elongate submarine ramps and slope aprons.

Most Sonora and Ozona sandstones are fine- to medium-grained litharenites. Chert and sedimentary and low-rank-

metamorphic rock fragments are the predominant lithic grains. Original porosity and permeability were largely destroyed by compaction and by cementation by quartz and carbonate minerals. Pervasive diagenetic modification masked the expected relationship between depositional facies and reservoir quality. In Sonora sandstones, however, early siderite cementation preserved some intergranular porosity by inhibiting mechanical compaction and precipitation of quartz cement. Although siderite-cemented layers developed preferentially in Bouma T_a turbidite divisions, predicting siderite-enhanced porosity will require more comprehensive investigations.

Natural fractures in Canyon core were mapped and described to determine their attributes and orientations. Ozona and Sonora fractures are typically subvertical extension fractures that terminate at the boundaries of beds or cementation zones. Clay-filled fractures in siderite-cemented zones form the most common fracture class in Sonora sandstones but may be flow barriers. Although quartz- and carbonate-cemented fractures are less common in core, fracture porosity is preserved locally along their traces. Although spacing between larger, more permeable fractures could not be observed directly, it is likely comparable to the thickness of the quartz-cemented intervals that contain the fractures—several feet to tens of feet. A wide range in fracture strike was observed in oriented Sonora core, but subsurface fractures trending generally northeastward are most prone to be open because of in situ stress conditions. Funding for this research was provided by the Gas Research Institute.

RI 233. Shallow-Seismic Evidence for Playa Basin Development by Dissolution-Induced Subsidence on the Southern High Plains, Texas.

by J. G. Paine. 47 p., 37 figs., 6 tables, $7.00

The origin of thousands of playa basins on the Southern High Plains of Texas and New Mexico has been attributed to eolian deflation, evaporite or carbonate dissolution and subsidence, piping, or animal activity. Shallow seismic data from three ephemeral lake (playa) basins in the Texas Panhandle, collected as part of a hydrogeological study of High Plains playa and interplaya environments, demonstrate that subsidence has figured prominently in the formation of these three basins. Sevenmile Basin, Pantex Playa 3, and Pantex Lake, playas that occupy basins varying from 1.2 to 5.5 km in diameter, have 4 to 9 m of surface relief and contain lacustrine and eolian sediments that interfinger with the Quaternary Blackwater Draw Formation. Below these sediments lies the upper Tertiary Ogallala Formation, which overlies Permian or Triassic bedrock. The authors collected seismic reflection and refraction data across these basins to investigate their geological history and hydrogeological framework and to help explain the mechanism by which they recharge the regionally important Ogallala aquifer.

Sevenmile Basin, 25 km east of Amarillo, Texas, is the largest of the three playa basins studied. The reflection section shows a middle Ogallala reflector, another reflector produced by an erosional unconformity at the top of Permian or Triassic bedrock, and reflectors within bedrock that indicate a structural low beneath Sevenmile Basin. Relief increases with depth, ranging from 9 m at the surface to 70 m on the middle Ogallala reflector to 110 m at the unconformity at the base of the Ogallala. Reflection data at Pantex Playa 3, a small playa about 25 km northeast of Amarillo, reveal the presence of four major reflecting horizons. Each horizon mimics surface topography, and relief increases with depth: the playa floor lies 4 m below the upland; the Ogallala caprock, absent directly under the playa, has 16 m of relief; an upper Ogallala fine-grained zone has 30 m of relief; a stratigraphic boundary between lower Ogallala coarse fluvial deposits and finer middle Ogallala lacustrine and fluvial deposits has 35 m of relief; and the erosional Permian or Triassic bedrock surface has 75 m of relief. At Pantex Lake, which is situated in a large, irregularly shaped basin 34 km northeast of Amarillo, five strong reflecting horizons can be correlated to recurring geophysical log patterns in nearby water wells. The shallowest reflector, not visible directly beneath Pantex Lake, is thought to be from the Ogallala caprock. Deeper reflectors are interpreted to be (1) the top of a conductive, fine-grained (dominantly clay to sandy clay) section in the middle of the Ogallala Formation; (2) the boundary between a lower Ogallala resistive and coarse-grained (clayey sand to gravelly sand) zone and the conductive, fine-grained zone composing the middle Ogallala section; (3) a stratigraphic boundary within the lower Ogallala coarse-grained zone; and (4) the top of eroded Permian or Triassic bedrock. Relief on each surface increases with depth: the playa floor lies 6 m below the upland, the top of the middle Ogallala fine-grained zone has 28 m of relief, the boundary between lower Ogallala resistive and middle Ogallala conductive zones has 31 m of relief, and the lower Ogallala and Permian or Triassic bedrock reflectors have 45 to 50 m of relief.

Relief increasing with age indicates that subsidence, probably caused by dissolution of underlying Permian evaporites, has played a role in the formation of each basin. A combined Ogallala Formation and Blackwater Draw Formation thickness greater than bedrock relief suggests that subsidence began before or during Ogallala deposition and may continue to this day. Pedogenic carbonate is less abundant directly beneath the playas than it is beneath uplands adjacent to the playas. Either pedogenic carbonate formed beneath these playas and was subsequently removed by erosion or dissolution, or it never formed beneath perennially wet basins that have probably existed since Ogallala deposition. This project was funded by grant DE-FG04-90AL65847 from the U.S. Department of Energy through the Office of the Governor, State of Texas.

RI 234. Geologic Controls on Reservoir Properties of Low-Permeability Sandstone, Frontier Formation, Moxa Arch, Southwestern Wyoming.

by S. P. Dutton, H. S. Hamlin, and S. E. Laubach. 89 p., 72 figs., 8 tables, $9.50

The Upper Cretaceous Frontier Formation in Wyoming accounts for a large part of domestic tight gas production, reserves, and new completions. Geologic studies of the Frontier Formation have demonstrated that geological controls

play a critical role in gas producibility. Tight reservoirs in the Frontier have produced more than 1 Tcf of gas, the most prolific production being from the Moxa Arch in the western Green River Basin. Advanced technology will be needed to maximize gas recovery from the Frontier, and geologic characterization can contribute to understanding and efficiently developing these complex gas reservoirs. This report summarizes the results of integrated geologic characterization of the Frontier Formation along the Moxa Arch in southwestern Wyoming in four major areas of study: (1) stratigraphic and depositional systems, (2) diagenesis of reservoir sandstones, (3) distribution of natural fractures, and (4) horizontal stress orientation.

Along the Moxa Arch, the Frontier Formation was deposited in fluvial and wave-dominated deltaic systems. Within these systems, strike-aligned shoreface sandstone and dip-oriented fluvial channel-fill sandstone form the most prolific reservoirs. The Frontier is divided into several sandstone-bearing intervals, of which the Second Frontier Sandstone contains the most prolific gas reservoirs. In turn, the Second Frontier is composed of several sandstone benches, the First and Second of which are most widespread. The First Bench comprises laterally discontinuous fluvial channel-fill sandstones, whereas the Second Bench is a single progradational shoreface sandstone having good lateral continuity. The main depositional and stratigraphic controls on distribution and quality of Frontier reservoirs are sandstone continuity and detrital clay content.

Diagenesis has overprinted depositional reservoir quality in these fine- to medium-grained litharenites and sublitharenites. Clean sandstones from all intervals contain an average of 1.6 percent primary intergranular porosity and 4.2 percent secondary porosity; microporosity averages 6.5 percent. Calcite, quartz, mixed-layer illite–smectite (MLIS), and illite are the most abundant cements. Authigenic MLIS clays consist of about 80 percent illite layers, suggesting that clays may be only moderately sensitive to fresh water. Low permeability in Frontier sandstones results from loss of porosity because of compaction, occlusion of pores by cements (particularly calcite and quartz), and lining of primary pores by fibrous illite and MLIS.

Natural fractures, although sparse in Frontier Formation core, are important reservoir elements in the Frontier. Fracture networks in outcrops have wide spacing and great lateral extent, both of which would tend to make them effective fluid conduits but difficult to intersect and detect by means of vertical wells. The direction of fracture strike can shift by 90° between adjacent beds. Moreover, fractures are commonly in discrete, irregularly spaced swarms separated laterally by domains that have few fractures, rather than in regularly spaced, orthogonal fracture sets. Strikes of some fracture sets can be explained as resulting from regional tectonic extension directions. More challenging to predict is fracture orientation in a specific bed and the probability of encountering a dense cluster of fractures by means of hydraulic fractures or horizontal wells.

Under typical reservoir conditions, the growth direction of hydraulic fractures parallels maximum horizontal stress (SH_{max}). The Green River Basin is in the Cordilleran east-west extension stress province but near the boundary shared with the east-northeast compressional midplate stress province. Young north-striking normal faults along the west margin of the basin and borehole breakout data suggest east-west extension and approximately north-south-trending SH_{max}. In contrast, stress directions from some tests in the basin suggest an azimuth of 95° to 115° for the growth directions of hydraulic fractures in the Frontier Formation near the Moxa Arch. These directions are consistent with the east-northeast SH_{max} direction of the nearby midplate stress province, or growth of hydraulic fractures parallel to natural fractures. Funding for this research was provided by the Gas Research Institute.

RI 235. Sequence Hierarchy and Facies Architecture of a Carbonate-Ramp System: San Andres Formation of Algerita Escarpment and Western Guadalupe Mountains, West Texas and New Mexico.

by Charles Kerans and W. M. Fitchen. 86 p., 55 figs., 2 tables, 2 color plates in pocket, $9.50

The San Andres Formation, as exposed along the Algerita Escarpment and in Cutoff Mountain, the Brokeoff Mountains, and the Western Escarpment of the Guadalupe Mountains, provides one of the world's most complete platform-to-basin transects of a carbonate-ramp system. More than 25,000 ft of measured sections and extensive bed tracing using oblique aerial photomosaics allowed construction of a detailed stratigraphic framework for the 22-mi dip-parallel exposures along this northwest margin of the Delaware Basin. The hierarchy of stratigraphic cyclicity includes 2 composite sequences (long-term), 15 high-frequency sequences (HFS) (intermediate-term), and at least 100 high-frequency cycles (short-term) on the platform alone. This new high-resolution chronostratigraphic framework documents changes in the stratal architecture of a 2-m.y. period of carbonate-ramp evolution. The report demonstrates the utility of a high-resolution chronostratigraphic framework in addressing hydrocarbon exploration-scale problems and, equally important, places changing styles of reservoir-scale facies architecture in a more inclusive and, therefore, more predictive stratigraphic framework.

Facies, vertical facies associations, and facies tracts are described within the context of this chronostratigraphic hierarchy, allowing detailed assessment of changing styles of depositional models through time. Nineteen facies are arranged in eleven vertical facies associations, along with several less repetitive facies associations. These facies associations are in turn grouped into facies tracts, which are strike-parallel belts of common depth- and energy-dependent sedimentation. Linkage of multiple facies tracts from a shelf-to-basin transect within highstand and transgressive systems tracts of individual high-frequency sequences allows development of depositional models specific to each high-frequency sequence.

Funding for this research was provided by industry sponsors Agip, Amoco, ARCO, British Petroleum, Chevron, Conoco, Exxon USA and Exxon Production Research, Fina, JNOC, Marathon, Mobil, Phillips, Shell, Texaco, Total, and Unocal. The U.S. Department of Energy supplied matching funds for portions of this research.

RI 236. Quaternary Evolution of Playa Lakes on the Southern High Plains—A Case Study from the Amarillo Area, Texas.

by S. D. Hovorka. 52 p., 40 figs., 3 tables, $7.50

Playa lakes are abundant small ephemeral lakes (generally <0.5 km in area) that occur in shallow depressions (generally <11 m deep) on the surface of the Southern High Plains. This study, based on analysis of excavations and 63 hollow-stem auger cores taken from 10 lake basins in the study area around the Pantex Plant northeast of Amarillo, Texas, resolves long-standing controversies regarding origin, evolution, and recharge behavior of playa lakes.

Origin of playa lakes has been debated for decades because the lakes are abundant and the processes that form them obscure. All of the lake basins studied have had a long history, originating as topographic lows before or during the early phases of Blackwater Draw deposition. The origin of some topographic lows can be related to dissolution of underlying Permian salt beds. Other basins appear to have been formed by other geomorphic processes. Stacked depositional cycles identified in lake sediments record repeated phases of (1) initial highstand, (2) ephemeral lake conditions, and (3) lake shrinkage and prolonged subaerial exposure. Although sedimentary structures show that the lakes were ephemeral during all phases, duration and frequency of flooding varied, thus changing relative amounts of sediment accumulation, deflation, and soil formation.

Playa lake basins in the study area contain 5 to 18 m of Quaternary lake sediments, including gray clays, oxidized red-brown clays, heterogeneous lacustrine delta deposits, fine lacustrine–eolian sand and silt beds and laminae, and admixed sand and clay. Lake sediments interfinger with calcic soils and red-brown loam of the Blackwater Draw Formation near the edges of the playas. As many as 12 calcic soil horizons are identified in the Blackwater Draw Formation in the upland. A sand unit underlies both playas and uplands at depths of 10 to 20 m.

Although the ephemerally ponded playa lakes are floored by clay soils, ground-water and unsaturated-zone investigations show that playa lakes serve as sites of focused recharge. Description of a spectrum of playa basins of various sizes and recharge behaviors documents the long-term maintenance of the seasonally ephemeral lakes and their responses to past climatic changes. All of the lakes are underlain by thick but laterally and vertically heterogeneous clay sections. However, evidence of preferential pathways controlling flow is abundant beneath playas, including shrink–swell cracks and roots in clay soils and gleying, illuviated clay, leached carbonate, or mineralized fractures in older sediments. Sand interbeds within the lacustrine deposits may also influence flow rates. Vertical fractures served as conduits for both oxidizing and reducing fluids in high-permeability, well-sorted sands, as well as in low-permeability sediments. These observations can be used to constrain assumptions that will be made about subsurface stratigraphy and recharge from the playas at the Pantex Plant. This work was supported by a U.S. Department of Energy grant to the Office of the Governor of Texas.

Geological Circulars

GC 95-1. A 3-D Seismic Case History Evaluating Fluvially Deposited Thin-Bed Reservoirs in a Gas-Producing Property.

by B. A. Hardage, R. A. Levey, Virginia Pendleton, James Simmons, and Rick Edson. 16 p., 22 figs. Reprinted from Geophysics, v. 59, no. 11, p. 1650–1665, $5.50

At Stratton field, a large Frio gas-producing property in Kleberg and Nueces Counties in South Texas, the authors of this circular conducted a study to determine how to best integrate geophysics, geology, and reservoir engineering technologies to detect thin-bed compartmented reservoirs in a fluvially deposited reservoir system. Their work documents that narrow, meandering, channel-fill reservoirs as thin as 10 ft and as narrow as 200 ft can be detected by means of 3-D seismic imaging at depths exceeding 6,000 ft if the 3-D data are carefully calibrated using vertical seismic profile control. Although the 3-D seismic images show considerable stratigraphic detail in the interwell spaces and indicate where numerous thin-bed compartment boundaries could exist, the seismic images cannot by themselves specify which stratigraphic features are the flow barriers that create the reservoir compartmentalization. However, when well production histories, reservoir pressure histories, and pressure interference tests are incorporated into the 3-D seismic interpretation, a compartmentalized model of the reservoir system can be constructed that improves development drilling and reservoir management. This case history illustrates how realistic, thin-bed, compartmented reservoir models result when geologists, engineers, and geophysicists work together to develop a unified model of a stratigraphically complex reservoir system. Funding for this research was provided by a joint venture of the Gas Research Institute, the U.S. Department of Energy, and the State of Texas.

GC 95-2. Controls on Reservoir Heterogeneity in Permian Shallow-Water-Platform Carbonate Reservoirs, Permian Basin: Implications for Improved Recovery.

by S. C. Ruppel, Charles Kerans, R. P. Major, and M. H. Holtz. 30 p., 25 figs., $4.50

Shallow-water-platform carbonate reservoirs of Permian age have accounted for more than half of the oil production in the Permian Basin. Despite a long history of primary and secondary oil production, these reservoirs have a low recovery efficiency and still contain as much as two-thirds of the original oil in place. The low recovery efficiency results from geological and petrophysical heterogeneities of the reservoirs and their controls on subsurface fluid flow. In this circular, the authors describe the styles and causes of heterogeneity in Permian Basin reservoirs and how they affect reservoir pro-

ductivity. Using reservoir and outcrop data sets from the Leonardian and Guadalupian, the authors develop a model of shallow-water platforms that can be applied to all middle Permian reservoirs. Typical facies tracts include inner ramp, ramp crest, outer ramp, and slope basin. Integrated study of outcrops and subsurface reservoirs reveals that both major controls on heterogeneity in Permian Basin platform carbonates—depositional facies distribution and diagenesis—are a function of high-frequency rise and fall of relative sea level. The authors conclude that maximum recovery of the original oil resource depends on applying integrated studies and models early in the process of reservoir exploitation, ideally before beginning secondary recovery operations. Funding for this study was provided by The University of Texas System, the State of Texas Energy Research in Applications Program, the State Lands Energy Resource Optimization Program, and members of the Reservoir Characterization Research Laboratory.

GC 95-3. Naturally Occurring Radioactive Materials (NORM) in Produced Water and Scale from Texas Oil, Gas, and Geothermal Wells: Geographic, Geologic, and Geochemical Controls.

by R. S. Fisher. 43 p., 12 figs., 7 tables, 1 appendix, $6.00

Water produced from oil, gas, and geothermal reservoirs contains natural radioactivity that ranges from background levels to levels found in uranium mill tailings. Radioactivity in fluids and in the scale that forms in oil-producing and gas-processing equipment increases concerns for worker and public safety as well as costs of handling and disposing of naturally occurring radioactive materials (NORM), which include water, sludge, scale, and affected equipment. This study explored natural controls on such radioactivity to identify screening criteria by which high NORM activity can be anticipated on the basis of geologic or geochemical information. Such criteria can help State and Federal agencies target disposal regulations for situations likely to incur high radioactivity levels and can also prevent operators from making costly measurements if the likelihood of encountering elevated NORM activity is low.

To explore natural controls on radioactivity, the authors considered (1) geographic distribution of NORM in oil-producing and gas-processing equipment; (2) geologic controls on uranium, thorium, and radium in sedimentary basins and reservoirs; (3) mineralogy of NORM scale; (4) potential of Texas formation waters to precipitate barite scale; (5) radium activity in Texas formation waters; and (6) geochemical controls on radium isotope activity in barite scale. This approach combined compilations of published data, collection and analyses of new water and scale samples, and geochemical modeling of scale precipitation and radium incorporation in barite. Results suggest that multivariate analysis of geologic and geochemical parameters may be useful in predicting NORM activity in produced water and scale in individual basins, plays, or reservoirs. Funding for this research was provided by the U.S. Department of Energy under contract no. DE-AC22-92MT92011.

GC 95-4. Seismic Analysis of the Duval County Ranch Area, South Texas: Assessment of Exploration Potential in the Wilcox, Queen City, and Jackson–Yegua Plays.

by J. C. Fiduk and D. S. Hamilton. 42 p., 29 figs., $8.00

Potential for commercial hydrocarbon accumulations in Eocene and older strata of the Duval County Ranch was assessed by means of seismic data, and three seismic facies are recognized and tied to well control. Seismic facies 1 has low-amplitude, continuous seismic reflections; seismic facies 2 has short, discontinuous, high-amplitude reflections; and seismic facies 3 has long, continuous, intermediate- to high-amplitude reflections. In the upper Wilcox Group (lower Eocene) and Queen City Formation (middle Eocene), seismic facies 1 and 2 are thought to be sandstone-rich coastal/delta-plain and delta-front/distributary-mouth-bar deposits, respectively, and they both rank high in exploration potential. Seismic facies 3 is thought to be a mudstone-rich, deeper water basinal deposit having lower exploration potential. The Duval County Ranch area was a locus of clastic deposition during the early Eocene because of subsidence and growth faulting along the underlying Wilcox Fault Zone. Sandstone-rich seismic facies 1 and 2 of the upper Wilcox Group are thus widespread in the Duval County Ranch area. Shelf-margin progradation followed upper Wilcox deposition, and by Queen City time, coastal/delta-plain deposits of seismic facies 1 dominated the Duval County Ranch area. Seismic facies 2 and 3 of the Queen City Formation are restricted to the southeasternmost part of the study area.

Seismic character of the Yegua (upper middle Eocene) and Jackson (upper Eocene) stratigraphic intervals resembles that of the underlying upper Wilcox Group and Queen City Formation. Seismic facies 1, 2, and 3 are recognized within the Yegua and Jackson over the Duval County Ranch area, but only seismic facies 1 is widespread within the boundaries of the Duval County Ranch. Although seismic facies 1 is associated with sandstone-rich barrier-island and strandplain deposits in the Jackson–Yegua interval, prospectivity of this seismic facies is more difficult to assess than that of the underlying units because, within this interval, hydrocarbon accumulation depends heavily on trapping mechanisms provided by stratigraphic pinch-out and facies variability. Unlike the upper Wilcox, effects of the Wilcox Fault Zone on Jackson–Yegua strata were minor, now represented only as small-scale faults and gentle flexures.

In all stratigraphic units, seismic facies 1 and 2 are more prospective if they contain specific horizons having very high amplitude "bright spot" reflections. A bright spot anomaly in Queen City sandstones produces oil and gas in Lundell field, and untested bright spot anomalies detected in this study appear elsewhere in the Queen City Formation and Jackson Group. High-amplitude seismic reflections of Jackson sandstones to the southeast of Seventy-Six West field suggest potential for a field extension or new field discovery. In the Duval County Ranch area, upper Wilcox seismic facies 2 exhibits numerous untested zones that are expressed as discontinuous, very high amplitude reflections. These random bright spot anomalies are associated with a zone of expanded upper Wilcox section in which sand deposition was focused

on the downthrown side of the growth faults where rollover structures provide closure. A trend of greatly expanded upper Wilcox section, known as the Deep Wilcox Trend, occurs principally downdip of the Duval County Ranch, and potential for discovery of fields such as Seven Sisters East or Rosita Northwest is restricted to the southeasternmost corner. Because the authors also observed that the lower Wilcox appears to be sandstone poor in the Duval County Ranch area, they assigned it a low exploration potential. Below the lower Wilcox, a high-risk deep gas exploration play, comprising large structures associated with salt withdrawal, lies in the Lower Cretaceous. Funding for this study was provided by the State Lands Energy Resource Optimization (SLERO) program under a program administered by the Office of the Governor of Texas.

Other

On Solid Ground: Memoirs of a Texas Geologist.

by V. E. Barnes. 332 p., 17 photos, 1 appendix, $10.00

The geologic career of Virgil Everett Barnes is long and distinguished, spanning more than 40 years at the Bureau of Economic Geology and many years of research on several continents. A well-known authority on tektites, Dr. Barnes traveled extensively to remote localities around the world, accompanied by his wife, Milla, and also pursued his research and mapping activitites in Texas. In this intriguing autobiography, Dr. Barnes chronicles his personal life, multifaceted career, and worldwide travels. Dr. Barnes's numerous publications are listed in a comprehensive bibliography.

Reprinted Publications

Geological Circular 91-4. A Glossary of Salt Tectonics.

by M. P. A. Jackson and C. J. Talbot. 44 p., 19 figs., 1 table, 3 appendices. Reprinted May 1995, $2.50

Fort Stockton Sheet, Geologic Atlas of Texas.

by J. E. Anderson, Jr., J. B. Brown, J. C. Gries, E. M. P. Lovejoy, D. McKalips, and V. E. Barnes. Scale 1:250,000. Revised and reprinted May 1995. $6.00

Mineral Resource Circular No. 56. Gold and Silver in Texas.

by T. J. Evans. 35 p., 14 figs., 5 tables, 1 appendix. Reprinted December 1995, $4.00

Papers and Abstracts by Bureau Staff in Outside (Non-BEG) Publications

Papers

Barnaby, R. J., and **Ward, W. B.,** 1995, Sequence stratigraphic framework, high-frequency cyclicity, and three-dimensional heterogeneity: Grayburg Formation, Brokeoff Mountains, New Mexico, *in* Pausé, P. H., and Candelaria, M. P., eds., Carbonate facies and sequence stratigraphy: practical applications of carbonate models: Permian Basin Section–SEPM (Society for Sedimentary Geology), Publication 95-36, p. 37–49.

Blum, M. D., **Morton, R. A.,** and Durbin, J. M., 1995, "Deweyville" terraces and deposits of the Texas Gulf Coastal Plain: Gulf Coast Association of Geological Societies Transactions, v. 45, p. 53–60.

Collins, E. W., 1995, Structural framework of the Edwards aquifer, Balcones Fault Zone, Central Texas: Gulf Coast Association of Geological Societies Transactions, v. 45, p. 135–142.

Darling, B. K., **Hibbs, B. J., Dutton, A. R.,** and Sharp, J. M., 1995, Isotope hydrology of the Eagle Mountains area, Hudspeth County, Texas: implications for development of ground-water resources, *in* Water resources at risk: Denver, American Institute of Hydrology, p. SL-12–SL-23.

Dutton, A. R., 1995, Groundwater isotopic evidence for paleorecharge in U.S. High Plains aquifers: Quaternary Research, v. 43, p. 221–231.

Eisenstadt, Gloria, **Vendeville, B. C.,** and Withjack, M. O., 1995, Introduction to experimental modeling of tectonic processes: New Orleans, Annual Meeting of the Geological Society of America, Continuing Education Manual, variously paginated.

Finley, R. J., 1995, Appendix D: More natural gas from old fields: the issue of natural gas reserve growth, *in* Electric Power Research Institute, final report, EPRI TR-105405, Project 3201-05, p. D-1–D-18.

Finley, R. J., 1995, Secondary natural gas recovery—infield reserve growth joint venture: applications in Midcontinent sandstones, *in* Malone, R. D., ed., Proceedings, Natural Gas RD&D Contractors Review Meeting, Volume I: U.S. Department of Energy, Office of Fossil Energy, DOE/METC-95/1017, v. 1, p. 20–44.

Fisher, R. S., 1995, Geologic, geochemical, and geographic controls on NORM in produced water from Texas oil, gas, and geothermal reservoirs, *in* Proceedings, SPE/EPA Exploration & Production Environmental Conference: Society of Petroleum Engineers and U.S. Environmental Protection Agency, Paper No. SPE 29709, p. 195–205.

Fisher, W. L., 1995, The geosciences: adapting to a world of change: Geotimes, v. 40, no. 4, p. 4.

Fryar, A. E., Macko, S. A., Romanak, K. D., Bennett, P. C., and **Mullican, W. F., III,** 1995, Evidence of limited denitrification beneath playas recharging the Ogallala aquifer, *in* Jensen, Ric, ed., Water for Texas: research leads the way: Proceedings, 24th Water for Texas Conference: sponsored by Texas Water Development Board, Texas Water Resources Institute, and Texas Water Conservation Association, p. 443–452.

Fryar, A. E., Macko, S. A., Romanak, K. D., Bennett, P. C., and **Mullican, W. F., III,** 1995, Evidence of partial denitrification during ground-water recharge, Southern High Plains, Texas, *in* Charbeneau, R. J., ed., Proceedings, International Symposium in conjunction with the First International Conference on Water Resources Engineering: groundwater management: San Antonio, Texas, American Society of Civil Engineers, p. 115–120.

Galloway, W. E., and McGilvery, T. A., 1995, Facies of a submarine canyon fill reservoir complex, Lower Wilcox Group (Paleocene), Central Texas coastal plain, *in* Winn, R. D., and Armentrout, J. M., eds., Turbidites and associated deep-water facies: SEPM (Society for Sedimentary Geology), Core Workshop No. 20, p. 1–23.

Ge, Hongxing, Jackson, M. P. A., and **Vendeville, B. C.,** 1995, Rejuvenation and subsidence of salt diapirs by regional extension: Gulf Coast Association of Geological Societies Transactions, v. 45, p. 211–218.

Hardage, B. A., 1995, This month in Geophysics: Geophysics, v. 60, no. 1–6, p. 1–2, 315–316, 627–628, 937–938, 1281–1282, 1625–1626.

Hardage, B. A., Carr, D. L., and **Simmons, J. L., Jr.,** 1995, 3-D seismic impact on integrated team study of Midcontinent gas reservoirs, *in* MESA Technology Conference: Boulder, Green Mountain Geophysics, Inc., p. 1–4.

Hardage, B. A., and **Finley, R. J.,** 1995, 3-D identifies uncontacted reservoirs: The American Oil & Gas Reporter, v. 38, no. 4, p. 90–94.

Hardage, B. A., Levey, R. A., Pendleton, Virginia, **Simmons, James,** and **Edson, Rick,** 1995, A 3-D seismic case history evaluating fluvially deposited thin-bed reservoirs in a gas-producing property: South Texas Geological Society Bulletin, v. 35, no. 7, p. 17–29.

Hardage, B. A., Levey, R. A., Pendleton, Virginia, **Simmons, James,** and **Edsen, Rick,** 1995, *Discussion on:* A 3-D seismic case history evaluating fluvially deposited thin-bed reservoirs in a gas-producing property: Geophysics, v. 60, p. 1585–1592.

Hentz, T. F., 1995, Diagenesis of Ozona Canyon fracture fills: implications for potential fractured reservoirs in the Ozona gas play, Val Verde Basin, West Texas, in Martin, R. L., ed., In search of new Permian Basin oil and gas fields: using today's technologies and tomorrow's ideas for exploration, development, and 3-D seismic in a mature basin: West Texas Geological Society, Publication 95-98, p. 69–81.

Hovorka, S. D., Mace, R. E., and **Collins, E. W.,** 1995, Regional distribution of permeability in the Edwards aquifer: Gulf Coast Association of Geological Societies Transactions, v. 45, p. 259–265.

Kaiser, W. R., 1995, Texas—Texas coal geology, in Keystone coal industry manual: Chicago, Maclean Hunter, p. G-148–G-154.

Kaiser, W. R., Hamilton, D. S., Scott, A. R., Tyler, Roger, and **Finley, R. J.,** 1994, Geological and hydrological controls on the producibility of coalbed methane: Geological Society of London Journal, v. 151, p. 417–420.

Kaiser, W. R., Scott, A. R., and **Tyler, Roger,** 1995, Geology and hydrology of coalbed methane producibility in the United States: analogs for the world: Tuscaloosa, The University of Alabama, Intergas '95 Short Course, 516 p.

Kerans, Charles, 1995, Stratigraphic framework of the San Andres Formation, Algerita Escarpment, Guadalupe Mountains, New Mexico, *in* The San Andres in outcrop and subsurface: guidebook to the Permian Basin–SEPM 1995 Annual Field Conference: SEPM (Society for Sedimentary Geology)–Permian Basin Section, Publication 95-37, p. 7–30.

Kerans, Charles, Lucia, F. J., and Senger, R. K., 1995, Integrated characterization of carbonate ramp reservoirs using Permian San Andres Formation outcrop analogs: American Association of Petroleum Geologists Bulletin, v. 78, no. 2, p. 181–216.

Kerans, Charles, Lucia, F. J., and **Wang, F. P.,** 1994, Integration of rock-fabric facies and geostatistical models within a sequence stratigraphic framework: implications of the West Texas experience for recovery in Middle Eastern carbonate ramp reservoirs, *in* Al-Husseini, M. I., ed., GEO '94: the Middle East petroleum geosciences: volume II: selected Middle East papers from The Middle East Geoscience Conference: Manama, Bahrain, Gulf PetroLink, p. 579–590.

Laubach, S. E., Mace, R. E., and **Nance, H. S.,** 1995, Fault and joint swarms in a normal fault zone, *in* Rossmanith, H.-P., ed., Mechanics of jointed and faulted rock: Rotterdam, Balkema, p. 305–309.

Lucia, F. J., 1995, Chapter 14, Lower Paleozoic cavern development, collapse, and dolomitization, Franklin Mountains, El Paso, Texas, *in* Budd, D. A., Saller, A. H., and Harris, P. M., eds., Unconformities and porosity in carbonate strata: American Association of Petroleum Geologists, AAPG Memoir 63, p. 279–300.

Lucia, F. J., Kerans, Charles, and **Wang, F. P.,** 1995, Fluid-flow characterization of dolomitized carbonate-ramp reservoirs: San Andres Formation (Permian) of Seminole field and Algerita Escarpment, Permian Basin, Texas and New Mexico, *in* Stoudt, E. L., and Harris, P. M., eds., Hydrocarbon reservoir characterization: geologic framework and flow unit modeling: SEPM (Society for Sedimentary Geology), SEPM Short Course No. 34, p. 129–153.

Mace, R. E., 1995, Geostatistical description of hydraulic properties in karst aquifers: a case study in the Edwards aquifer, *in* Charbeneau, R. J., ed., Proceedings, International Symposium in conjunction with the First International Conference on Water Resources Engineering: groundwater management: San Antonio, Texas, American Society of Civil Engineers, p. 193–198.

Major, R. P., and Johnstone, R. D., 1995, Distinguishing unconformities from faults in Tertiary sandstone reservoirs of the Gulf Coast—potential sources of error in subsurface mapping (with figures): South Texas Geological Society Bulletin, v. 35, no. 6, p. 29–34.

Merle, Olivier, and **Vendeville, Bruno,** 1995, Experimental modelling of thin-skinned shortening around magmatic intrusions: Bulletin of Volcanology, v. 57, p. 33–43.

Morton, R. A., 1995, *Review of* Coastal Evolution—Late Quaternary Shoreline Morphodynamics, R. W. G. Carter and C. D. Woodroffe, eds., Cambridge University Press, 1994: Journal of Sedimentary Research, v. A65, no. 4, p. 724.

Morton, R. A., Gibeaut, J. C., and **Paine, J. G.,** 1995, Meso-scale transfer of sand during and after storms: implications for prediction of shoreline movement: Marine Geology, v. 126, p. 161–179.

Mullican, W. F., III, 1995, ed., Suitability of solution-mined caverns for oil and gas waste disposal: Railroad Commission of Texas, Oil and Gas Division, and The University of Texas at Austin, Bureau of Economic Geology, 48 p.

Ruppel, S. C., and **Hovorka, S. D.,** 1995, Controls on reservoir development in Devonian chert: Permian Basin, Texas: American Association of Petroleum Geologists Bulletin, v. 79, no. 12, p. 1757–1785.

Scanlon, B. R., and other members of the Committee to Review Specific Scientific and Technical Safety Issues Related to the Ward Valley, California, Low-Level Radioactive Waste Site, 1995, Ward Valley: an examination of seven issues in Earth sciences and ecology: Washington, D.C., National Academy Press, 212 p.

Scott, A. R., 1995, Limitations and benefits of microbially enhanced coalbed methane, *in* Proceedings, Intergas '95: International Unconventional Gas Symposium: Tuscaloosa, The University of Alabama, Paper 9509, p. 423–432.

Scott, A. R., and **Kaiser, W. R.,** 1995, Hydrogeologic factors affecting dynamic open-hole cavity completions in the San Juan Basin, USA, *in* Proceedings, Intergas '95: International Unconventional Gas Symposium: Tuscaloosa, The University of Alabama, Paper 9510, p. 247–257.

Scott, A. R., Kaiser, W. R., Hamilton, D. S., Tyler, Roger, and **Finley, R. J.,** 1995, Geologic and hydrologic factors affecting coalbed methane producibility and resource assessment in the western U.S.A., *in* Proceedings, International Conference on Coalbed Methane Development and Utilization: Beijing, China, B204, p. 1–17.

Scott, A. R., Tyler, Roger, Hamilton, D. S., and Zhou, Naijiang, 1995, Summary of coal and coal gas resources for the Mesaverde Group and Fort Union Formation in the Greater Green River Basin, *in* Forty-Sixth Annual Field Conference: Wyoming Geological Association, Guidebook, p. 185–190.

Scott, A. R., Zhou, Naijiang, and Levine, J. R., 1995, A modified approach to estimating coal and coal gas resources: example from the Sand Wash Basin, Colorado: American Association of Petroleum Geologists Bulletin, v. 79, no. 9, p. 1320–1336.

Seni, S. J., 1995, Technical aspects of the occurrence of salt in Texas, *in* Mullican, W. F., III, ed., Suitability of solution-mined caverns for oil and gas waste disposal: Railroad Commission of Texas, Oil and Gas Division, and The University of Texas at Austin, Bureau of Economic Geology, p. 1–18.

Travis, C. J., **Vendeville, B. C.,** Harrison, H., Peel, F. J., Hudec, M. R., and Perkins, B. E., eds., 1995, Salt, sediment, and hydrocarbons: Gulf Coast Section, Society of Economic Paleontologists and Mineralogists Foundation, Sixteenth Annual Research Conference, 308 p.

Tyler, Roger, Kaiser, W. R., Hamilton, D. S., Scott, A. R., and **Finley, R. J.,** 1995, Geologic and hydrologic controls critical to coalbed gas producibility and resource assessment: the Rocky Mountain Foreland experience, *in* Coal bed methane exploration trends and potential for southern Africa: South African Institute of Mining and Metallurgy and The Geological Society of South Africa, Seminar, variously paginated [20 p.]

Tyler, Roger, and **McMurry, R. G.,** 1995, Genetic stratigraphy, coal occurrence, and regional cross section of the Williams Fork Formation, Mesaverde Group, Piceance Basin, northwestern Colorado: Colorado Geological Survey, Division of Minerals and Geology, Department of Natural Resources, Open File Report 95-2, 42 p. + 1 pl.

Tyler, Roger, Scott, A. R., and **Hamilton, D. S.,** 1995, Coalbed gas potential of the Greater Green River Basin, southwest Wyoming and northwest Colorado, *in* Proceedings, International Unconventional Gas Symposium: Intergas '95: Tuscaloosa, The University of Alabama, Paper No. 9502, p. 23–38.

Vendeville, B. C., Ge, Hongxing, and **Jackson, M. P. A.,** 1995, Scale models of salt tectonics during basement-involved extension: Petroleum Geoscience, v. 1, p. 179–183.

Vendeville, B. C., and Nilsen, K. T., 1995, Episodic growth of salt diapirs driven by horizontal shortening, *in* Travis, C. J., Vendeville, B. C., Harrison, H., Peel, F. J., Hudec, M. R., and Perkins, B. E., eds., Salt, sediment, and hydrocarbons: Gulf Coast Section, Society of Economic Paleontologists and Mineralogists Foundation, Sixteenth Annual Research Conference, p. 285–295.

Wang, H. F., Myer, L. R., Witherspoon, P. A., Nelson, P. P., Logan, J. M., **Dutton, A. R.,** and Younker, L. W., 1994, Abandoned SSC site can provide underground facility for geoscience research: Eos, v. 75, no. 48, p. 561–564.

Wermund, E. G., Tremblay, T. A., Paull, G. J., and Rieken, Eric, 1995, GIS base data for water management on the Rio Grande delta plain, *in* Jensen, Ric, ed., Water for Texas: research leads the way: Proceedings, 24th Water for Texas Conference: sponsored by Texas Water Development Board, Texas Water Resources Institute, and Texas Water Conservation Association, p. 605–613.

White, W. A., and **Tremblay, T. A.,** 1995, Submergence of wetlands as a result of human-induced subsidence and faulting along the upper Texas Gulf Coast: Journal of Coastal Research, v. 11, no. 3, p. 788–807.

Xiang, Jiannan, 1995, The evaluation of the flowmeter test in three-layer aquifers and the influence of disturbed zones: Journal of Hydrology, v. 166, p. 127–145.

Xue, Lianqing, and **Galloway, W. E.,** 1995, High-resolution depositional framework of the Paleocene middle Wilcox strata, Texas Coastal Plain: American Association of Petroleum Geologists Bulletin, v. 79, no. 2, p. 205–230.

Abstracts

Barnaby, R. J., Ruppel, S. C., and **Fitchen, W. M.,** 1995, Strontium isotopes in oil field brines: potential fingerprints of reservoir heterogeneity (abs.), *in* AAPG 1995 annual convention official program: petroleum technology of the world: American Association of Petroleum Geologists, p. 6A.

BeMent, W. O., **Levey, R. A.,** and Mango, F. D., 1995, The temperature of oil generation as defined with C7 chemistry maturity parameter (2,4-DMP/2,3-DMP RATIO) (exp. abs.), *in* Grimalt, J. O., and Dorronsoro, Carmen, eds., Organic geochemistry: developments and applications to energy, climate, environment and human history: selected papers from the 17th International Meeting on Organic Geochemistry, Donostia–San Sebastián, The Basque Country. Spain. p. 505–507.

Collins, E. W., 1995, Structural framework of the Edwards aquifer, Balcones Fault Zone, Central Texas (abs.): American Association of Petroleum Geologists Bulletin, v. 79, no. 10, p. 1556.

Couzens, B. A., **Vendeville, B. C.,** and Wiltschko, D. V., 1995, Control of stratigraphy on thrust vergence and formation of triangle zones within thrustbelts (abs.), *in* The 1995 AAPG International Conference and Exhibition program: American Association of Petroleum Geologists, p. 15A.

Dutton, S. P., 1995, Interpretation of compaction and quartz cementation processes from integrated petrographic and burial-history analyses, Lower Cretaceous Fall River Formation, Wyoming and South Dakota (abs.), *in* AAPG 1995 annual convention official program: petroleum technology of the world: American Association of Petroleum Geologists, p. 24A.

Dutton, S. P., Gardner, M. H., and **Willis, B. J.,** 1995, Characterization of heterogeneity style and permeability structure in fluvial-deltaic reservoirs deposited in a low-accommodation setting (abs.): American Association of Petroleum Geologists Bulletin, v. 79, no. 8, p. 1209.

Fisher, W. L., 1995, Rethinking resources (abs.): American Association of Petroleum Geologists Bulletin, v. 78, no. 9, p. 1457.

Galloway, W. E., 1994, Reservoirs of the northern Gulf of Mexico Cenozoic petroleum megasystem (ext. abs.), *in* Schneidermann, Nahum, Cruz, Pablo, and Sanchez, Rafael, eds., First Joint AAPG/AMGP Hedberg Research Conference: geologic aspects of petroleum systems: American Association of Petroleum Geologists, unpaginated (5 p.).

Gardner, M. H., Barton, M. D., Willis, B. J., Tyler, Noel, and **Dutton, S. P.,** 1995, Outcrop characterization of stratal architecture and permeability structure in deltaic-reservoir analogs (abs.), *in* Quantification and modelling of spatial patterns in permeable rocks: IMA conference program: Scarborough, England, The Institute of Mathematics and Its Applications, unpaginated.

Gibeaut, J. C., Kyser, J. A., Gutierrez, Roberto, and **Morton, R. A.**, 1995, High-accuracy bathymetric surveys for coastal research (abs.), *in* Linked Earth systems: Congress program and abstracts, vol. 1: St. Pete Beach, Florida, SEPM (Society for Sedimentary Geology), p. 58.

Gibeaut, J. C., and Piper, Ernest, 1995, Shoreline oil from Exxon *Valdez:* change from 1991 to 1993 (abs.), *in* Proceedings, 1995 International Oil Spill Conference (Achieving and Maintaining Preparedness): sponsored by U.S. Coast Guard, American Petroleum Institute, U.S. Environmental Protection Agency, International Maritime Organization, and International Petroleum Industry Environmental Conservation Association, p. 972–973.

Guglielmo, Giovanni, Jackson, M. P. A., Schultz-Ela, D. D., and **Vendeville, B. C.,** 1995, Computer animations of salt tectonics to visualize potential traps for hydrocarbons (abs.), *in* Fifth Archie Conference, visualization technologies to find more oil and gas: Houston, May 14–18, unpaginated.

Gustavson, T. C., 1995, The Tertiary Ogallala Formation beneath the Southern High Plains of Texas and New Mexico is not composed of coalesced alluvial fans (abs.), *in* Blair, T. C., and McPherson, J. G., eds., Proceedings and Abstracts, International Research Conference: Alluvial fans: processes, forms, controls, facies models, and use in basin analysis: SEPM (Society for Sedimentary Geology), p. 47.

Hallmark, Julie, **Guglielmo, Giovanni, Jr., Masterson, A. R.,** and **White, W. G.,** 1995, Internet (WWW) home page design to improve dissemination of geoscience information (abs.): Geological Society of America Abstracts with Programs, v. 27, no. 6, p. A-197. Also in GIS Newsletter, no. 155, p. 6–7.

Hardage, B. A., 1995, Editor's report, *in* 1995 Annual Report of the Society of Exploration Geophysicists: Society of Exploration Geophysicists, p. 11–12.

Hardage, B. A., 1995, Using modern technology to understand reservoir compartmentalization: demonstration and technology transfer to industry (exp. abs.), *in* Technical program: expanded abstracts with authors' biographies: Houston, Society of Exploration Geophysicists, International Exposition & 65th Annual Meeting p. 1553.

Hardage, B. A., Carr, D. L., and **Simmons, J. L., Jr.,** 1995, Combining sequence stratigraphy with 3-D seismic imaging in low-accommodation basins (exp. abs.), *in* Technical program: expanded abstracts with authors' biographies: Houston, Society of Exploration Geophysicists, International Exposition & 65th Annual Meeting, p. 1524–1527.

Hovorka, S. D., 1995, Bedded gypsum in the Edwards Group, Texas: its role in reducing porosity and enhancing permeability (abs.), *in* AAPG 1995 annual convention official program: petroleum technology of the world: American Association of Petroleum Geologists, p. 44A.

Hovorka, S. D., 1995, Permeability structure of the Edwards aquifer—implications for aquifer management (abs.): South Texas Geological Society Bulletin, v. 36, no. 3, p. 4.

Hovorka, S. D., 1995, Porosity and permeability structure of the San Antonio segment of the Edwards aquifer (abs.): Austin Geological Society Newsletter, v. 30, no. 4, p. 1.

Hovorka, S. D., 1995, Quaternary playa lake evolution on the Southern High Plains of Texas: cyclic variation in lake level recorded in sediments (abs.): Geological Society of America, North-Central–South-Central Sections, Abstracts with Programs, v. 27, no. 3, p. 60.

Hovorka, S. D., Mace, R. E., and **Collins, E. W.,** 1995, Regional distribution of permeability in the Edwards aquifer (abs.): American Association of Petroleum Geologists Bulletin, v. 79, no. 10, p. 1559.

Jackson, M. P. A., and **Vendeville, B. C.,** 1995, Origin of minibasins by multidirectional extension above a spreading lobe of allochthonous salt (abs.), *in* The 1995 AAPG International Conference and Exhibition program: American Association of Petroleum Geologists, p. 33A.

Jackson, M. P. A., and **Vendeville, B. C.,** 1995, Origin of minibasins by multidirectional extension above a spreading lobe of allochthonous salt (abs.), *in* Travis, C. J., Vendeville, B. C., Harrison, H., Peel, F. J., Hudec, M. R., and Perkins, B. E., eds., Salt, sediment, and hydrocarbons: Gulf Coast Section, Society of Economic Paleontologists and Mineralogists Foundation, Sixteenth Annual Research Conference, p. 135.

Johns, M. K., Laubach, S. E., and Milliken, K. L., 1995, New microtextural evidence of syncementation fracturing in sandstone (abs.): Geological Society of America, Abstracts with Programs, v. 27, no. 6, p. A-216.

Kerans, Charles, 1995, Carbonate stratigraphic research: evolution and future directions (abs.), *in* Pausé, P. H., and Candelaria, M. P., eds., Carbonate facies and sequence stratigraphy: practical applications of carbonate models: a joint Permian Basin Section–SEPM/Permian Basin Graduate Center Symposium in honor of Dr. James Lee Wilson: SEPM (Society for Sedimentary Geology)–Permian Basin Section, Publication 95-36, p. 201–202.

Knox, P. R., 1995, Sequence-stratigraphic controls on subsurface fluid movement: an example of selective charging of stacked hydrocarbon reservoirs, West Fulton Beach field, Texas (abs.), *in* AAPG 1995 annual convention official program: petroleum technology of the world: American Association of Petroleum Geologists, p. 51A.

Knox, P. R., and **McRae, L. E.,** 1995, High-resolution sequence stratigraphy: the key to identifying compartment styles in Frio Formation fluvial-deltaic reservoirs, T-C-B field, Jim Wells County, Texas (abs.), *in* AAPG 1995 annual convention official program: petroleum technology of the world: American Association of Petroleum Geologists, p. 51A.

Levey, R. A., 1995, Hydrocarbon recovery optimization in conventional reservoirs through application of advanced technology and improved reservoir characterization (abs.), *in* Professional division luncheon meeting flyer: Indonesian Petroleum Association, 1 p.

Levey, R. A., and **Hardage, B. A.,** 1995, Hydrocarbon recovery optimization in stacked thin-bed reservoirs: application of advanced technology and improved reservoir characterization (abs.), *in* Programas y resumenes de conferencias: 33rd Congreso Nacional: Veracruz, AIPM Fraternidad y Superacion, unpaginated.

Levey, R. A., Tyler, Noel, Dutton, S. P., Kerans, Charles, and **Lucia, F. J.,** 1995, Merging basic science and applied reservoir characterization research: an effective approach for assisting industry in field optimization for incremental recovery of oil and gas (abs.), *in* The 1995 AAPG International Conference and Exhibition program: American Association of Petroleum Geologists, p. 40A–41A.

Mace, R. E., and Fang, Guo, 1995, Determination of the location and properties of subsurface fractures using surface resistivity and telluric current methods—an example from the United States: Scientia Geologica Sinica, v. 4, no. 1, p. 89–96.

Mace, R. E., Nance, H. S., and **Laubach, S. E.,** 1995, Geostatistical analysis of fault and joint measurements in Austin Chalk, Superconducting Super Collider site, Texas (abs.): American Association of Petroleum Geologists Bulletin, v. 79, no. 6, p. 910.

Mace, R. E., and Sharp, J. M., Jr., 1995, Diffusion of contaminants through fracture skins (abs.), *in* The 1995 Annual Spring Meeting of the Texas Section of AEG: hazardous waste management: Texas A&M University, Association of Engineering Geologists, Lone Star Student Chapter, p. 9.

Major, R. P., Bebout, D. G., and Harris, P. M., 1995, Recent evolution of a Bahamian ooid shoal: effects of Hurricane

Andrew (abs.), *in* Linked Earth systems: 1st SEPM Congress on Sedimentary Geology: St. Petersburg, SEPM (Society for Sedimentary Geology), p. 86–87.

Major, R. P., and **Holtz, M. H.,** 1995, Development strategy in a fractured dolomite reservoir, Permian Basin, southwestern USA (abs.): American Association of Petroleum Geologists Bulletin, v. 79, no. 6, p. 910–911.

Morris, W. R., Posamentier, H. W., **Bhattacharya, J. P.,** Kupecz, J. A., Loomis, K. B., Lopez-Blanco, M., Wu, C., Kendall, B., Landis, C. R., Spear, D. B., and Thompson, P. R., 1995, Cretaceous Panther Tongue Sandstone outcrop case study I: regional sequence stratigraphic analysis (abs.), *in* AAPG 1995 annual convention official program: petroleum technology of the world: American Association of Petroleum Geologists, p. 77A.

Morris, W. R., Posamentier, H. W., **Bhattacharya, J. P.,** Loomis, K. B., Kupecz, J. A., Wu, C., Lopez-Blanco, M., Thompson, P. R., Spear, D. B., and Kendall, B., 1995, Panther Tongue Sandstone outcrop case study II: evolution of delta types within a forced regression (abs.), *in* AAPG 1995 annual convention official program: petroleum technology of the world: American Association of Petroleum Geologists, p. 68A.

Morton, R. A., and **White, W. A.,** 1995, Evolution of incised coastal plain rivers, southeast Texas coast (abs.), *in* Linked Earth systems: Congress program and abstracts, vol. 1: St. Pete Beach, Florida, SEPM (Society for Sedimentary Geology), p. 93.

O'Connell, Shaun, **Bhattacharya, Janok,** and Braman, Denis, 1995, Sequence stratigraphy and regional correlation of the Upper Cretaceous Milk River and Lea Park Formations, southern Alberta (abs.), *in* Swift, D. J. P., Snedden, J. W., and Plint, A. G., eds., Tongues, ridges, and wedges: highstand versus lowstand architecture in marine basins: SEPM Research Conference program: SEPM (Society for Sedimentary Geology), unpaginated [4 p.]

Paine, J. G., 1995, Subsidence beneath a playa basin on the Southern High Plains, U.S.A.: evidence from shallow seismic data (abs.): Oklahoma Geology Notes, v. 55, no. 1, p. 37–38.

Posamentier, H. W., Morris, W. M., and **Bhattacharya, J. P.,** 1995, The Panther Tongue Sandstone, Utah—an example of a forced regression deposit (abs.), *in* Swift, D. J. P., Snedden, J. W., and Plint, A. G., eds., Tongues, ridges, and wedges: highstand versus lowstand architecture in marine basins: SEPM Research Conference program: SEPM (Society for Sedimentary Geology), unpaginated [3 p.]

Posamentier, H. W., Morris, W. R., **Bhattacharya, J. P.,** Kupecz, J. A., Loomis, K. B., Lopez-Blanco, M., Wu, C., Kendall, B., Landis, C. R., Spear, D. B., and Thompson, P. R., 1995, Cretaceous Panther Tongue Sandstone outcrop case study I: regional sequence stratigraphic analysis (abs.), *in* AAPG 1995 annual convention official program: petroleum technology of the world: American Association of Petroleum Geologists, p. 77A.

Pulich, W., Jr., and **White, W. A.,** 1995, Remote sensing and GIS analysis of seagrass landscape dynamics in a midcoastal Texas estuary (abs.), *in* Estuaries: bridges from watersheds to coastal seas: Estuarine Research Federation 13th Biennial International Conference, p. 106.

Ruppel, S. C., and James, E. W., 1995, Strontium isotope chemostratigraphy: a tool for refining the stratigraphic framework of the Permian Basin (abs.), *in* In search of new Permian Basin oil and gas fields: using today's technologies and tomorrow's ideas for exploration, development, and 3D seismic in a mature basin: West Texas Geological Society Fall Symposium, Publication 95-98, p. 51.

Ruppel, S. C., James, E. W., and Barrick, J. E., 1995, Improvements in the record of secular change in sea water $^{87}Sr/^{86}Sr$: a stronger basis for dating Paleozoic diagenetic and depositional events (abs.), *in* AAPG 1995 annual convention official program: petroleum technology of the world: American Association of Petroleum Geologists, p. 84A.

Salazar, D. A., 1995, Environmental diversity and medicinal plant supplies among the Pemon Indians of Venezuela (abs.), *in* Abstracts: Association of American Geographers 91st Annual Meeting, p. 268.

Salazar, D. A., 1995, Internet and geographic information system technology: bridging the U.S.–Mexico information frontier (abs.), *in* Health without boundaries: the U.S.–Mexico Border Conference on Women's Health: The University of Texas System and Texas–Mexico Border Health Coordination Office, unpaginated.

Scanlon, B. R., Langford, R. P., and **Paine, J. G.,** 1995, Geomorphic controls on subsurface flow in an arid setting (abs.): Eos (Supplement), v. 76, no. 46, p. F235.

Schultz-Ela, D. D., 1995, Inferring subsalt structures from suprasalt structures: results from numerical modeling of extension around salt sheets (abs.), *in* AAPG 1995 annual convention official program: petroleum technology of the world: American Association of Petroleum Geologists, p. 86A.

Scott, A. R., and Ayers, W. B., Jr., 1995, Compositional variability, origins, and migration of Pictured Cliffs Sandstone gases, San Juan Basin, New Mexico (abs.), *in* AAPG 1995 annual convention official program: petroleum technology of the world: American Association of Petroleum Geologists, p. 86A.

Scott, A. R., and **Kaiser, W. R.,** 1995, Microbially enhanced coalbed methane: limitations and possible benefits (abs.), *in* AAPG 1995 annual convention official program: petroleum technology of the world: American Association of Petroleum Geologists, p. 86A.

Tyler, Roger, and **Hamilton, D. S.,** 1995, Genetic sequence stratigraphy of the intermontane Paleocene Fort Union Formation, Greater Green River Basin, southwest Wyoming and northwest Colorado (abs.), *in* AAPG 1995 annual convention official program: petroleum technology of the world: American Association of Petroleum Geologists, p. 98A.

Tyler, Roger, Kaiser, W. R., Scott, A. R., and **Hamilton, D. S.,** 1995, Geologic and hydrologic controls on coalbed methane resources, Greater Green River Basin, southwestern Wyoming and northwestern Colorado (abs.), *in* AAPG 1995 annual convention official program: petroleum technology of the world: American Association of Petroleum Geologists, p. 98A–99A.

Vendeville, B. C., and **Dickerson, P. W.,** 1995, Integrated field and experimental investigation of an extensional strike-slip duplex: Tascotal Mesa fault zone, Big Bend (W. Texas) segment of Rio Grande rift (abs.): Geological Society of America, Abstracts with Programs, v. 27, no. 6, p. A-384.

Vendeville, B. C., and Le Calvez, Joël, 1995, Physical models of normal-fault relays between variable offset grabens (abs.), *in* The 1995 AAPG International Conference and Exhibition program: American Association of Petroleum Geologists, p. 63A–64A.

Vendeville, B. C., Nilsen, K. T., and Johansen, J. T., 1995, Experimental and geologic evidence for rejuvenation of salt diapirs by horizontal contraction (abs.), *in* The 1995 AAPG International Conference and Exhibition program: American Association of Petroleum Geologists, p. 63A.

White, W. A., and **Morton, R. A.,** 1995, Active faults and their effect on wetlands (abs.), *in* Wetland understanding/wetland education: 16th annual meeting: Boston, Society of Wetland Scientists, p. 42–43.

Williams, L. B., Hervig, R. L., and **Dutton, S. P.,** 1995, Interpreting paleofluid compositions by microanalysis of oxygen isotopes in diagenetic quartz (abs.), *in* V. M. Goldschmidt Conference: an international conference for the advancement of geochemistry: program and abstracts: The Geochemical Society, p. 97.

Willis, Brian, Gardner, M. H., and **Dutton, S. P.,** 1995, Architecture of fluvial-dominated valley-fill deposits in the Cretaceous Fall River Formation (abs.): Geological Society of America, Abstracts with Programs, v. 27, no. 6, p. A-277.

Zeng, Hongliu, **Tyler, Noel,** and Backus, M. M., 1995, Three-dimensional seismic modeling and seismic facies imaging: Gulf Coast Association of Geological Societies Transactions, v. 45, p. 622–627.

Contract and Grant Reports

Barton, Mark, Angle, Edward, and **Yeh, Joseph,** 1995, Characterization of heterogeneity style and permeability structure in fluvial reservoirs: The University of Texas at Austin, Bureau of Economic Geology, final report prepared for Petrobras under contract no. 6502032931, 42 p.

Bureau of Economic Geology, The University of Texas at Austin, 1995, A computer program for interpreting IES wireline logs: The University of Texas at Austin, Bureau of Economic Geology, technical summary of research conducted for the Gas Research Institute, U.S. Department of Energy, and State of Texas, Technical Summary GRI-95/0312, 10 p.

Bureau of Economic Geology, The University of Texas at Austin, 1995, Identification of linear flow geometries and implications for natural gas reservoir development: The University of Texas at Austin, Bureau of Economic Geology, technical summary of research conducted for the Gas Research Institute, U.S. Department of Energy, and State of Texas, Technical Summary GRI-95/0162, 10 p.

Bureau of Economic Geology, The University of Texas at Austin, 1995, Staggered-line 3-D seismic recording: The University of Texas at Austin, Bureau of Economic Geology, technical summary of research conducted for the Gas Research Institute, U.S. Department of Energy, and State of Texas, Technical Summary GRI-94/0446, 10 p.

Bureau of Economic Geology, The University of Texas at Austin, 1995, Tools for identification of compartmentalization in moderate-permeability gas reservoirs: The University of Texas at Austin, Bureau of Economic Geology, technical summary of research conducted for the Gas Research Institute, U.S. Department of Energy, and State of Texas, Technical Summary GRI-95/0104, 10 p.

Bureau of Economic Geology, The University of Texas at Austin, 1995, The use of small, directionally focused charges as a 3-D seismic energy source: The University of Texas at Austin, Bureau of Economic Geology, technical summary of research conducted for the Gas Research Institute, U.S. Department of Energy, and State of Texas, Technical Summary GRI-94/0448, 9 p.

Bureau of Economic Geology, The University of Texas at Austin, 1995, 3-D seismic thin-bed imaging: The University of Texas at Austin, Bureau of Economic Geology, technical summary of research conducted for the Gas Research Institute, U.S. Department of Energy, and State of Texas, Technical Summary GRI-95/0188, 13 p.

Bureau of Economic Geology, The University of Texas at Austin, 1995, Vertical wavetesting: The University of Texas at Austin, Bureau of Economic Geology, technical summary of research conducted for the Gas Research Institute, U.S. Department of Energy, and State of Texas, Technical Summary GRI-94/0447, 10 p.

Collins, E. W., and **Raney, J. A.,** 1995, Summary report for the El Paso, Texas, STATEMAP project, 1995: The University of Texas at Austin, Bureau of Economic Geology, report prepared for the U.S. Geological Survey under cooperative agreement no. 1434-94-A-1254, 22 p.

Collins, E. W., and **Raney, J. A.,** 1995, Summary report for the New Braunfels, Texas, STATEMAP project, 1995: The University of Texas at Austin, Bureau of Economic Geology, report prepared for the U.S. Geological Survey under cooperative agreement no. 1434-94-A-1255, 20 p.

Fryar, A. E., and **Mullican, W. F., III,** 1995, Delineating controls on the composition of ground water in the vicinity of the Pantex Plant, Southern High Plains, Texas: The University of Texas at Austin, Bureau of Economic Geology, final report prepared for the U.S. Department of Energy under grant no. DE-FG04-90AL65847, 88 p.

Fryar, A. E., and **Mullican, W. F., III,** 1995, Geochemical modeling of ground water in the vicinity of the Pantex Plant, Southern High Plains, Texas: The University of Texas at Austin, Bureau of Economic Geology, report prepared for the U.S. Department of Energy under grant no. DE-FG04-90AL65847, 24 p.

Gustavson, T. C., 1995, Fluvial and eolian depositional systems, paleosols, and paleoclimate: late Cenozoic Ogallala and Blackwater Draw Formations, Southern High Plains, Texas and New Mexico: The University of Texas at Austin, Bureau of Economic Geology, final report prepared for the U.S. Department of Energy under grant no. DE-FG04-90AL65847, 120 p.

Gustavson, T. C., Bebout, D. G., Bennett, P. C., Fish, E. B., **Fryar, A. E., Hovorka, S. D.,** Hua, H.-P., Kirschenmann, Kyle, Laun, Scot, Minehardt, T. J., **Mullican, W. F., III,** Nicot, J.-P., **Paine, J. G.,** Pezzolesi, T. P., Rainwater, Ken, Ramsey, Heyward, Reedüer, Alan, Romanak, K. D., **Scanlon, B. R.,** Thompson, David, **Xiang, Jiannan,** and Zartman, R. E., 1995, Summary hydrogeologic assessment, U.S. Department of Energy Pantex Plant, Carson County, Texas: The University of Texas at Austin, Bureau of Economic Geology, milestone report prepared for U.S. Department of Energy, 98 p.

Holtz, M. H., Hamilton, D. S., Ambrose, W. A., Yeh, J. S., Dutton, S. P., Tyler, Noel, Asquith, George, Tadiar, Ed, Anthony, Dave, and Chamalaun, Michelle, 1995, High-resolution sequence stratigraphic and systems tract analysis and resource and play assessment of the Toolachee/Nappacoongee–Murteree blocks: The University of Texas at Austin, Bureau of Economic Geology, final report prepared for Santos, Ltd., 194 p.

Hovorka, S. D., 1995, Quaternary evolution of playa lakes on the Southern High Plains—a case study from the Amarillo area: The University of Texas at Austin, Bureau of Economic Geology, contract report funded by the Office of the Governor of Texas using funds provided by the U.S. Department of Energy under grant no. DE-FG04-90AL65847, 102 p.

Hovorka, S. D., 1995, Stratigraphy of playas in the Pantex area—Playa 5 and Pantex Lake: The University of Texas at Austin, Bureau of Economic Geology, milestone report activity 1, annual supplement to scope of work 1993–1994, U.S. Department of Energy through the Office of the Governor of Texas, 22 p.

Hovorka, S. D., Mace, R. E., and **Collins, E. W.,** 1995, Regional distribution of permeability in the Edwards aquifer: The University of Texas at Austin, Bureau of Economic Geology, final report prepared for Edwards Underground Water District under contract no. 93-17-FO, 128 p.

Laubach, S. E., Hentz, T. F., Johns, M. K., Baek, Hwanjo, and **Clift, S. J.,** 1995, Using diagenesis information to augment fracture analysis: The University of Texas at Austin, Bureau of Economic Geology, topical report prepared for Gas

Research Institute under contract no. 5082-211-0708 (GRI-94/0455), 189 p.

Mace, R. E., 1995, Solute transport through the Austin Chalk weathered zone at the SSC site: The University of Texas at Austin, Bureau of Economic Geology, final report prepared for the Texas National Research Laboratory Commission under contract no. IAC 94-0108, 43 p.

McRae, L. E., Holtz, M. H., Hentz, T. F., Chang, C.-Y., and **Knox, P. R.,** 1995, Strategies for reservoir characterization and identification of incremental recovery opportunities in mature reservoirs in Frio fluvial-deltaic sandstones, South Texas: an example from Rincon field, Starr County: The University of Texas at Austin, Bureau of Economic Geology, topical report prepared for the U.S. Department of Energy, under contract no. DE-FC22-93BC14959, 111 p.

McRae, L. E., Holtz, M. H., and **Knox, P. R.,** 1995, Revitalizing a mature oil play: strategies for finding and producing unrecovered oil in Frio fluvial-deltaic sandstone reservoirs of South Texas: The University of Texas at Austin, Bureau of Economic Geology, annual report prepared for U.S. Department of Energy, Assistant Secretary of Fossil Energy, under contract no. DE-FC22-93BC14959 (DE95000160), 155 p.

Morton, R. A., 1995, Deep-water deposition of sand bodies within late Quaternary seismic sequences, Texas continental margin: The University of Texas at Austin, Bureau of Economic Geology, final report prepared for the U.S. Department of the Interior, Minerals Management Service, under cooperative agreement no. 14-35-0001-30731, 27 p.

Morton, R. A., and **Gibeaut, J. C.,** 1995, Physical and environmental assessment of sand resources, Sabine and Heald Banks: second phase 1994–1995: The University of Texas at Austin, Bureau of Economic Geology, final report prepared for the U.S. Department of the Interior, Minerals Management Service, Office of International Activities and Marine Minerals, under cooperative agreement no. 14-35-0001-30635, variously paginated [246 p.]

Morton, R. A., Gibeaut, J. C., and **Gutierrez, Roberto,** 1995, Pre-project surveys of beach and nearshore conditions, Galveston Island beach nourishment project: The University of Texas at Austin, Bureau of Economic Geology, contract report prepared for the City of Galveston, Texas, 45 p.

Morton, R. A., Gutierrez, Roberto, and **Gibeaut, J. C.,** 1995, Field identification and classification of coastal dunes, Galveston County, Texas: The University of Texas at Austin, Bureau of Economic Geology, report prepared for the Texas General Land Office, Texas Natural Resources Inventory, under interagency contract no. 95-026, 101 p.

Morton, R. A., Tremblay, T. A., White, W. A., and **White, W. G.,** 1995, Digital compilation of submerged lands, sediment textures, sediment geochemistry, and washover areas of the Texas coast: The University of Texas at Austin, Bureau of Economic Geology, final report prepared for the Texas Natural Resources Inventory Program, Texas General Land Office, Texas Natural Resource Conservation Commission, and Texas Parks and Wildlife Department under interagency contract no. IAC 94-276, 35 p.

Morton, R. A., and **White, W. A.,** 1995, Shoreline types of the upper Texas coast: Sabine–Galveston–Freeport–Sargent areas: The University of Texas at Austin, Bureau of Economic Geology, final report prepared for the Texas Natural Resources Inventory Program, Texas General Land Office, Texas Natural Resource Conservation Commission, and Texas Parks and Wildlife Department under GLO contract no. 94-177R and Minerals Management Service Gulfwide Information Systems at Louisiana State University, CMI-30660-19901, 42 p.

Morton, R. A., White, W. A., Gibeaut, J. C., Gutierrez, Roberto, and **Paine, J. G.,** 1995, East Texas and western Louisiana coastal erosion study: year 4: The University of Texas at Austin, Bureau of Economic Geology, annual report prepared for the U.S. Geological Survey, U.S. Department of the Interior, under cooperative agreement no. 14-08-0001-A0912, unpaginated [474 p.].

Mullican, W. F., III, Johns, N. D., and **Fryar, A. E.,** 1995, Development and sensitivity analysis of steady-state and transient Ogallala aquifer ground-water flow and particle tracking models: The University of Texas at Austin, Bureau of Economic Geology, final report prepared for the U.S. Department of Energy under grant no. DE-FG04-90AL65847, 115 p.

Paine, J. G., 1995, Shallow seismic data acquisition, processing, and interpretation at Playa 5, Carson County, Texas: The University of Texas at Austin, Bureau of Economic Geology, report prepared for the U.S. Department of Energy through the Office of the Governor of Texas, 26 p.

Paine, J. G., Goldsmith, R. S., and **Scanlon, B. R.,** 1995, Electrical conductivity and gamma ray response to clay, water, and chloride content in fissured sediments, Trans-Pecos Texas: The University of Texas at Austin, Bureau of Economic Geology, final report prepared for the U.S. Department of Energy, National Low-Level Radioactive Waste Management Program, Assistant Secretary for Environmental Management, under DOE Idaho Operations Office Contract No. DE-AC07-95ID 13223 and Interagency Contract No. 94-0304, 52 p., variously paginated.

Scanlon, B. R., and **Goldsmith, R. S.,** 1995, Evaluation of subsurface flow in fissured sediments in the Chihuahuan Desert, Texas: The University of Texas at Austin, Bureau of Economic Geology, final report prepared for the U.S. Department of Energy, National Low-Level Radioactive Waste Management Program, Assistant Secretary for Environmental Management, under DOE Idaho Operations Office Contract No. DE-AC07-95ID 13223 and Interagency Contract No. 94-0304, 60 p., variously paginated.

Tyler, Roger, Kaiser, W. R., McMurry, R. G., Nance, H. S., Scott, A. R., and Zhou, Naijiang, 1995, Geologic characterization and coalbed methane occurrence: Williams Fork Formation, Piceance Basin, northwest Colorado: The University of Texas at Austin, Bureau of Economic Geology, annual report prepared for Gas Research Institute under contract no. 5091-214-2261, GRI-94/0456, 218 p.

Services

Core Research Centers

The Bureau of Economic Geology manages two core research facilities, the Core Research Center (CRC) and the Midland Core Research Center (MCRC). The CRC, located adjacent to the Bureau of Economic Geology Research and Administration Office, houses the largest public collection of subsurface geological materials in the United States and is open Monday through Friday from 7:00 a.m. to 5:00 p.m. (CST). The Curator is George Bush. The repository, approximately 103,000^2 ft, houses nearly 50 linear miles of shelving. Roughly 10 percent of the repository is isolated and climate controlled for storing unstable core materials.

Other CRC services include gamma-scan facilities, photography lab, sawroom, and general core processing. Facilities for holding core seminars are also available. Advance notice is requested for CRC services.

A brochure describing the CRC, its policies, procedures, and price list is available upon request. Customized printouts of CRC holdings are available for purchase. Printouts can be generated on the basis of county, operator, lease name, or sample range. The entire CRC data base, listing all CRC holdings, may also be purchased by contacting John Boldovici, Data-Base Manager.

Visitors may view cores or cuttings in the Main Viewing Room, which is large enough to display as much as 1,800 ft of conventional core. Approximately 12,770 core samples and 60,300 drill cuttings from wells are available for study at the CRC. Geologic specimens housed at the CRC represent 35 countries and 1,100 counties or parishes within 43 states. Patrons are asked to provide results of analyses of sampled materials within 1 yr of completion of their studies, which then become part of the CRC's reference material.

During (fiscal) 1995, the CRC received more than 250 visitors, who made transactions involving CRC inventory that included materials from more than 1,380 wells and required the transfer of more than 22,000 boxes of core to and from viewing and shipping areas.

New acquisitions in 1995 totaled 370 new core samples, in excess of 1,500 boxes and nonconventional (cuttings, sidewall, unwashed cuttings, outcrop) core samples from 2,684 wells, totaling 3,110 boxes. Donations were received from Ashtolla Drilling; Amerada Hess; American Petrofina; T. S. Brown; the Bureau of Economic Geology; Coastal Management Corp.; Department of Energy/Superconducting Super Collider; Jack Colle and Associates; Core Labs–Carrollton; Lindholm Oil; Mobil; Nueces Oil; Reservoirs, Inc.; Threshold Development; Terratek, Inc.; and TexasGulf, Inc..

The MCRC, which was donated to The University of Texas System by Shell Oil Company and Shell Western E&P, Inc., in 1994, is also administered by the Bureau. The facility, a 32,700-ft^2 building on 3.7 acres in Midland, Texas, has a core examination room, a processing room for slabbing core, and office space. The MCRC's collection contains about 259,000 boxes of samples and core, the majority of which come from wells drilled in Texas, although it also contains material from several other states. The Curator is Robert (Rick) Richardson, who can be reached at (915) 686-9902.

The MCRC is open between 8 a.m. and 5 p.m. (CST), Monday through Friday. Materials are being organized according to protocols followed by the CRC in Austin. The MCRC collection's data are currently being incorporated into the Bureau's existing data base, which will allow patrons of the new facility to access these data, as well as those of the CRC in Austin.

Mineral Studies Laboratory

The Mineral Studies Laboratory (MSL), headed by Chief Chemist Steven W. Tweedy, serves as the Bureau's analytical geochemistry facility. Located in approximately 18,000 ft^2 of laboratory space adjacent to the Bureau's Research and Administrative Office, the MSL can provide nearly complete geochemical, mineralogical, and textural characterization of most geological materials. The facility contains several major instrumental systems capable of performing a variety of analyses, including inductively coupled plasma optical and mass spectrometry (ICP-OES, ICP-MS) for major, minor, and trace element measurements; stable isotope mass spectrometry (hydrogen and oxygen in waters, carbon and oxygen in carbonate minerals, and nitrogen in waters and ammonium compounds); electron microprobe analysis (four automated wavelength dispersive X-ray spectrometers); scanning electron microscopy (SEM) examination and photography; X-ray diffractometry (XRD) for mineral identification; thermal analysis (thermo-gravimetric analyzer); ion chromatography (IC); and gas chromatography (GC). Complete wet-chemical analysis, coal-fuel analysis, and sample comminution have also been performed at the MSL.

The MSL provided analytical services to many Bureau researchers during 1995, whose projects included Characterization of the Pantex Plant, Texas Low-Level Radioactive Waste Disposal Authority—Eagle Flat (LLEF), Superconducting Super Collider—Hydrology (SSC), Texas Advanced Research Programs—Hydraulics (ATP–Hydraulics), Lagoven, Corpoven, and RRC Abandoned Lands projects. In addition to supporting Bureau projects, the MSL provided services to The University of Texas Material Sciences and Engineering (UT–MS&E), Construction Material Research (UT–CMR), Texas Archeological Research Laboratory (UT–TARL), and The University of Texas at San Antonio (UT–SA) Geosciences departments as well as to the general public.

Public Information

Requests for information about the mineral, geological, energy, and land resources of Texas come to the Bureau from geologists, engineers, educators, students, landowners, and other interested individuals, as well as from industry, governmental agencies, and other organizations.

Extensive data and information are available at the Bureau's Reading Room/Data Center, and members of the Bureau's research staff provide advisory and technical services in their areas of expertise. The Bureau's Public Information Geologist

maintains files on mineral resources (both energy and nonenergy minerals) and general geology of specific areas of the state and assists patrons in locating answers to questions. During 1995, approximately 1,500 such requests were handled by L. Edwin Garner, the Public Information Geologist. In addition to direct inquiries, Bureau staff members have contributed to educational programs by making presentations at public schools in the Austin area.

Reading Room/Data Center

The Bureau's Reading Room/Data Center provides a wide range of geological data and information to staff members, students, and visitors interested in Texas geology. The facility, supervised by L. Edwin Garner, is open to the public for reference use from 8:00 a.m. to 5:00 p.m. Monday through Friday.

The Reading Room houses a collection of more than 5,000 monographs and serials and about 50 periodicals. Included in the collection are extensive reports and open-file materials received from the U.S. Geological Survey, the U.S. Bureau of Mines, and the U.S. Department of Energy.

The Data Center houses an extensive collection of surface and subsurface geological data pertaining to Texas and adjacent states. Research Document Inventory data consisting of original maps, cross sections, and other data used in preparing Bureau publications are available, as are topographic and geologic maps, aerial photographs, and Landsat images. Subsurface data files include well logs for more than 50,000 wells in Texas and 8,000 wells in adjacent states; microfiche copies of well logs for more than 40,000 wells in West Texas, New Mexico, and Oklahoma; scout tickets and well records for more than 200,000 Texas wells and 30,000 New Mexico wells; drillers' logs for about 400,000 Texas wells; and completion cards for more than 300,000 Texas wells and more than 150,000 wells in adjacent states.

The Reading Room staff cataloged, indexed, shelved, and entered into a computer data base more than 1,800 items. More than 1,200 items were received from other states and countries through the Bureau's publication-exchange program. Most of the exchange volumes were transferred to The University of Texas at Austin, Department of Geological Sciences library.

Geophysical Log Facility

The Geophysical Log Facility (GLF), managed by L. Edwin Garner, is housed in the Bureau's Reading Room/Data Center. The facility was established by State legislation, effective September 1, 1985, that requires that all operators of oil, gas, and geothermal wells provide the Railroad Commission of Texas with at least one copy of a well log for each new, deepened, or plugged well. A subsequent agreement with the Railroad Commission designated the Bureau as the entity responsible for providing public access to these logs. The Railroad Commission supplies paper or microfiche copies of the well logs and three different cumulative indexes to the logs. They are then filed at the GLF by district number and API number. Users of the facility include commercial companies, independent researchers, and Bureau scientists. Patrons may examine well logs using the GLF's microfiche readers. Requests for log copies can be made in person or by mail or telephone.

By the end of 1995, the facility had accumulated approximately 150,000 well logs of various types, at a rate of 800 logs per month, which are being entered into the GLF's computer data base.

Research Staff Activities

Lectures and Public Addresses

M. Saleem Akhter

"An overview of exploration and production in selected CIS countries and potential for production growth with Western technology": presented to the Petroconsultants Scout Group for East Europe/CIS, Houston, Texas.

William A. Ambrose

"Geologic and engineering characterization of the BACH-24, A-22, LL-02, and LL-08 reservoirs, Mioceno Norte Area, Lake Maracaibo": presented to Lagoven, S.A., Maracaibo, Venezuela.

Edward S. Angle

"Demonstration of GPS/GIS technology used in EPA U.S.–Mexico border study": presented to representatives of TNRCC, GLO, and others, Austin, Texas (with W. Gerald White and Allison Goldberg).

Mark D. Barton

"Stratigraphic controls on facies architecture and permeability structure, Cretaceous Ferron Sandstone, central Utah": presented to the Deltaic Reservoirs Industrial Associates project review meeting, Austin, Texas.

Janok P. Bhattacharya

"Stratigraphic framework of the Frewens Castle sandstone": presented to the Deltaic Reservoirs Industrial Associates project review meeting, Austin, Texas.

David L. Carr

"Sequence stratigraphy, structure, and reservoir distribution in the Boonsville 'Bend Conglomerate' gas field, Fort Worth Basin, Texas": presented to the West Texas Geological Society, Midland, Texas.

"Stratigraphy, structure, and reservoir distribution in the Boonsville 'Bend Conglomerate' gas field, Fort Worth Basin, Texas": presented to the Oklahoma Geological Conference and Convention, Oklahoma City, Oklahoma.

"Sandstone reservoir distribution and compartmentalization in the Boonsville 'Bend Conglomerate' gas field, Fort Worth Basin, Texas: general lessons": presented to the Society of Petroleum Engineers, Dallas, Texas.

"Sandstone reservoir distribution and compartmentalization in the Boonsville 'Bend Conglomerate' gas field, Fort Worth Basin, Texas: case history examples": presented to the Society of Petroleum Engineers, Dallas, Texas.

"Using new sequence stratigraphy concepts and 3-D seismic imaging to evaluate Bend Conglomerate reservoirs": presented to the Houston Geological Society, Houston, Texas.

Patricia W. Dickerson

"Ordovician lithostratigraphy, structural geology, and igneous activity of the southern margin of Laurentia—West Texas and adjacent Mexico": presented to the Geological Society of America Penrose Conference, San Juan, Argentina.

Richard L. Dillon

"Maps and map production methods over the last 30 years": presented to 150 Leander Junior High students, Austin, Texas.

Alan R. Dutton

"Hydrogeology of fractured Austin Chalk at the SSC site": presented to the Dallas Geological Society and the Department of Geological Sciences, Southern Methodist University, Dallas, Texas.

Shirley P. Dutton

"Petrographic analysis and reservoir quality": presented to Maxus Energy, Austin, Texas.

"Diagenesis of deeply buried incised-valley sandstones, Buck Draw field, Wyoming": presented to B.P. Exploration, Houston, Texas.

"Recovering remaining Texas oil resources": presented to Westminster Manor Men's Club, Austin, Texas.

"Reservoir quality of Misoa sandstones, LVA-765 well, Lagunillas field": presented to Maraven, Austin, Texas.

"Depositional versus diagenetic controls on permeability, Fall River sandstone in outcrop and subsurface": presented at the Deltaic Reservoirs Industrial Associates Midyear Project Review Meeting, Austin, Texas.

"Interpreting the timing of compaction and quartz cementation in the Lower Cretaceous Fall River Formation, Wyoming and South Dakota": presented to The University of Texas at Austin, Department of Geological Sciences, Soft Rock Seminar, Austin, Texas.

"Composition and diagenesis of Frewens Castle sandstone in outcrop": presented to the Deltaic Reservoirs Industrial Associates project review meeting, Austin, Texas.

Robert J. Finley

"Geology and engineering characteristics of Oligocene fluvial systems of South Texas": presented to The University of Texas at Austin, Department of Geological Sciences (Geology 391), Austin, Texas.

"Natural gas resources today": presented to the National Energy Education Development Project's Leadership Training Conference, Lago Vista, Texas.

"University research in oil and gas exploration": presented at the Corporate Council on Africa—Trade and Development Agency–sponsored Orientation Visit for the African Petroleum Ministers and Executives, Houston, Texas.

"Secondary natural gas recovery—infield reserve growth joint venture: applications in Mid-Continent sandstones": presented to the U.S. Department of Energy, Natural Gas RD&D Contractors Review Meeting, Baton Rouge, Louisiana.

"Natural gas reserves and resources: a snapshot of U.S. and Texas supply developments": presented to the Austin Geological Society, Austin, Texas.

"Now that we know the gas resource is there, are we developing the reserves?": presented to the Fourth Annual U.S. Department of Energy–NARUC Natural Gas Conference, Orlando, Florida.

"Application of 3-D seismic for development of compartmented thin-bed gas reservoirs: an example from the Midcontinent" and "Technology transfer and cost-benefit analysis

in natural gas reservoir research for reserve growth": presented to the Interstate Oil and Gas Compact Commission, annual meeting, Houston, Texas.

"U.S. experience in oil and gas reserve growth," "Reserve growth in fluvial-deltaic natural gas reservoirs in Texas," and "Oil production optimization in Eocene deltaic reservoirs, Lake Maracaibo, Venezuela": presented to OMV Energie, Vienna, Austria.

R. Stephen Fisher

"Physical and chemical controls on NORM (Naturally Occurring Radioactive Materials) in Texas oil and gas fields": presented to the Railroad Commission of Texas, Austin, Texas.

William L. Fisher

"The earth science enterprise: coping in a changing world": presented to the All Convention Luncheon, American Association of Petroleum Geologists, Pacific Section, San Francisco, California.

"Supply factors in natural gas prices": presented to the Energy Information Administration Workshop on Natural Gas Prices, Washington, D.C.

"The future of state geological surveys": presented to the Forum on Geology's Future: Perspectives from the USGS, State Surveys, Academic Institutions, and the Private Sector, Geology and Public Policy Committee, Geological Society of America Annual Meeting, New Orleans, Louisiana.

"Natural gas plays": presented to the Gas Daily Conference on Where the Best Plays Are, Houston, Texas.

"The changing character of U.S. oil and gas activity": presented to the Dutch Treat Wildcatters, Dallas, Texas.

"Dynamics in the natural gas business": presented to the East Texas Gas Association, Tyler, Texas.

Robert L. Folk

"Precipitation of carbonates and clay minerals by nannobacteria (dwarf bacteria)": presented to Georgia Technical Institute, Department of Geosciences, Atlanta, Georgia.

"Carbonate minerals and nannobacteria": presented to The University of Texas at Dallas, Department of Geology, Arlington, Texas.

"Nannobacteria and mineral precipitation": presented to California State University, Department of Geology, Sacramento, California, and California State University, Department of Geology, Northridge, California.

"Pyramids of Egypt: concrete or real limestone?": presented to California State University, Department of Geology, Sacramento and Northridge, California.

Alan E. Fryar

"Evidence of limited denitrification beneath playas recharging the Ogallala aquifer": presented to the Idaho National Engineering Laboratory, Idaho Falls, Idaho.

"Nitrogen isotopes": presented to The University of Texas at Austin, Department of Geological Sciences (Geology 391), Austin, Texas.

William E. Galloway

"Reservoirs of the northern Gulf of Mexico Cenozoic petroleum megasystem": presented to the First Joint American Association of Petroleum Geologists/AMGP Research Conference, Mexico City, Mexico.

James C. Gibeaut

"Shallow-water, high-accuracy, high-resolution bathymetric surveying system": presented at Water for Texas Conference, College Station, Texas.

Douglas S. Hamilton

"Jackson region reservoir characterization and performance study": presented to Santos Ltd., Brisbane, Queensland, Australia.

"Integrated geologic and engineering reservoir characterization": presented to Santos Ltd., Brisbane, Queensland, Australia.

"Application of nonmarine sequence stratigraphic concepts to reservoir characterization: examples from oil and gas fields of Australia": presented to The University of Texas at Austin, Department of Geological Sciences, Soft Rock Seminar, Austin, Texas.

H. Scott Hamlin

"Geologically complex gas reservoirs in slope and basin facies, Canyon sandstones, Val Verde Basin, southwest Texas": presented to the American Institute of Professional Geologists and the Oklahoma Geological Survey, Norman, Oklahoma.

"Wolfcamp sandstones in Pakenham field, Terrell County: resource technologies": presented to Chevron U.S.A. Production Company, Midland, Texas.

"Lobo sandstone study: challenges and goals": presented to Wilcox Lobo operators, Houston, Texas.

"Review of previous Canyon sandstone research and presentation of new research plan": presented to Canyon and Wolfcamp sandstones operators, Midland, Texas.

"Flow-unit characterization and recovery optimization of a braid-delta sandstone reservoir, Tirrawarra oil field, South Australia": presented to STATOIL, Austin, Texas.

Bob A. Hardage

"Technology transfer in the DOE/GRI/Texas secondary gas recovery project": presented at the Society of Exploration Geophysicists Development and Production Forum, Snowmass, Colorado.

"3-D seismic technology demonstrated in Midcontinent basins": presented to the Gas Research Institute program advisory group, Houston, Texas.

"3-D seismic imaging of karsted reservoirs": presented to SEPM (Society for Sedimentary Geology), Midland, Texas.

"3-D seismic field techniques": presented to the Shreveport Geological Society, Shreveport, Louisiana.

"3-D seismic imaging and interpretation of thin-bed gas reservoirs in South Texas": presented to the Houston Geological Society, Houston, Texas.

"Using modern technology to understand reservoir compartmentalization: demonstration and technology transfer to industry": presented to the Society of Exploration Geophysicists Annual International Meeting, Houston, Texas.

"Combining sequence stratigraphy with 3-D seismic imaging in low-accommodation basins": presented to the Society of Exploration Geophysicists Annual International Meeting, Houston, Texas.

"The influence of 3-D seismic technology on independent operator strategies": presented to the Interstate Oil and Gas Compact Commission, Houston, Texas.

"3-D seismic case histories": presented to The University of Texas at Austin, Department of Geological Sciences (Geology 391), Austin, Texas.

Tucker F. Hentz

"Key-well concept and other aspects of stratigraphic analysis of the Wilcox Lobo play": presented to Wilcox Lobo operators, Houston, Texas.

"Regional overview of the structure and depositional facies of the Cleveland Formation": presented to the Cleveland Development Forum, Amarillo, Texas.

Mark H. Holtz

"Reservoir characterization and reserve growth potential of the Jackson field area, Cooper Basin, Australia": presented to Santos Ltd., Brisbane, Queensland, Australia.

"Risk assessing reserves in Frio Fluvial/Deltaic Sandstone reservoirs": presented to Pennzoil South Texas Production Team, Houston, Texas.

Susan D. Hovorka

"Results of BEG study of regional distribution of permeability in the Edwards aquifer": presented to the Edwards Underground Water District Board, San Antonio, Texas.

"Update on BEG study of regional distribution of permeability in the Edwards aquifer": presented to the TNRCC Groundwater Protection Committee, Austin, Texas.

Martin P. A. Jackson

"Research in salt tectonics at the Applied Geodynamics Laboratory": presented to Agip Petroleum, Austin, Texas.

"Plate tectonic and salt tectonic evolution of northeastern Mexico": presented to BHP Minerals, San Francisco, California.

"Salt tectonics in the northern Gulf of Mexico: conceptual advances through modeling": presented to Pemex, Austin, Texas.

"Multidirectional extension of minibasins" and "Three-dimensional kinematics of prograding sedimentary wedges": presented to Phillips Petroleum Salt Forum, Houston, Texas.

"Salt tectonics driven by progradation," "Raft tectonics on the West African margin," and "Subtle effects on contraction or salt diapirs": presented to B. P. Exploration, London.

William R. Kaiser

"Hydrology of the Fruitland Formation": presented to the Northern San Juan Basin Industry Group, Durango, Colorado.

Charles Kerans

"San Andres reservoirs of the Permian Basin": presented to Pogo Exploration, Austin, Texas.

"Risk assessment in carbonate reservoir development and exploration": presented to Unocal, Houston, Texas.

"Sequence stratigraphy and reservoir analog setting of Cretaceous (Albian) carbonate ramp, Pecos River, West Texas: implications for Cretaceous reservoirs of Oman": presented to Oman Petroleum Development, Muscat, Oman.

"Carbonate stratigraphic research: evolution and future directions": presented to the Wilson Symposium, Midland, Texas.

"Outcrop and subsurface sequence stratigraphy of Guadalupian-age carbonate reservoirs, Permian Basin": presented to TOTAL and Shell Canada, Austin, Texas.

"Application of high-frequency sequence stratigraphy to exploration and exploitation of carbonate reservoirs": presented to Amoco, Houston, Texas.

"Insights for understanding architecture of Cretaceous ramp reservoirs: the Albian of the Pecos River Canyon": presented to Saudi Aramco, Dhahran, Saudi Arabia.

"Future directions in the application of high-frequency sequence stratigraphy of carbonate reservoirs": presented to ARCO International, Austin, Texas.

"Example of greenhouse carbonate platform, Albian of Pecos River Canyon": presented to The University of Texas at Austin, Department of Geological Sciences, Soft Rock Seminar, Austin, Texas.

"Carbonate depositional systems": presented to The University of Texas at Austin, Department of Geological Sciences (Geology 391), Austin, Texas.

"Carbonate sequence stratigraphy": presented to The University of Texas at Austin, Department of Geological Sciences (Geology 391), Austin, Texas.

"High-frequency stratigraphic analysis of mixed siliciclastic/carbonate platform, Queen Formation, Guadalupe Mountains": presented to The University of Texas at Austin, Department of Geological Sciences (Geology 391), Austin, Texas.

Paul R. Knox

"Orders of flooding surfaces and their effects on reservoir charging, an example from West Fulton Beach field, Texas": presented to the Society of International Professional Earth Scientists, Austin, Texas.

"T–C–B reservoir characterization": presented to U.S. Department of Energy representatives at the Bureau of Economic Geology, Austin, Texas.

"Progress report: T–C–B field reservoir characterization": presented to Mobil Exploration and Producing, U.S., Houston, Texas.

"Predicting reservoir architecture and internal heterogeneity in fluvial upper delta plain settings: implications for reserve-growth potential and development strategies": presented to Pennzoil Corporation, Houston, Texas.

"A relationship between flooding surfaces and reservoir charge: why some sands are filled and some are not": presented to Pennzoil Corporation, Houston, Texas.

"The application of outcrop observations to subsurface reservoir characterization: architecture and heterogeneity of Frio Formation upper delta plain fluvial reservoirs, South Texas": presented to participants of GRI-sponsored field trip, Ferron Sandstone, central Utah.

Stephen E. Laubach

"Improved resource characterization technology using new structural methods": presented to the Gas Research Institute Project Advisors Group meeting, Grand Junction, Colorado.

"Improved resource characterization technology: overview of project": presented to the Gas Research Institute Project Advisors Group meeting, Chicago, Illinois.

"Fracture and diagenesis analyses applicable to Canyon Sandstone": presented to Canyon and Wolfcamp sandstone operators, Midland, Texas.

"Introduction to new research project in Wilcox Lobo play": presented to Wilcox Lobo operators, Houston, Texas.

"Introduction and concept for new fracture analysis approach" and "Using a new classification of diagenesis to predict fracture conductivity": presented at Fracture Quantification Working Group meeting, Fort Worth, Texas.

"Geology of the Wilcox Lobo natural gas trend, South Texas": presented to the Railroad Commission of Texas, Austin, Texas.

"Fault and joint swarms in a normal fault zone": presented at the Second International Conference on Mechanics of Jointed and Faulted Rock, Vienna, Austria.

"Analyses of slopes in jointed weak rock masses using distinct element method": presented at the Second International Conference on Mechanics of Jointed and Faulted Rock, Vienna, Austria.

"Using diagenesis information to improve interpretation of natural fractures": presented to The University of Texas at Austin, Department of Geological Sciences Soft Rock Seminar, Austin, Texas.

"Natural fracture detection using cathodoluminescence": presented at the Gas Research Institute Geology Technical Advisory Group meeting, Austin, Texas.

"Gas research program overview": presented at the Siberian oil and gas managers' training program, Austin, Texas.

Raymond A. Levey

"Energy resources programs at the Bureau of Economic Geology": presented to Pogo Producing Company, Austin, Texas.

"Overview of Bureau research programs": presented to ARCO International, Inc., and Sita Oil Exploration House, Inc., Austin, Texas.

"Advanced hydrocarbon recovery strategies in sandstone and carbonate reservoir systems": presented to Pemex Production, Mexico City, Mexico.

"Advanced recovery optimization using new technologies": presented to Institute of Mexican Petroleum, Mexico City, Mexico.

"Bureau energy research programs in hydrocarbon recovery optimization": presented to Edge Petroleum, Austin, Texas.

"Bureau energy research programs in oil recovery optimization": presented to Western Atlas and Landmark/Zycor, Inc., Austin, Texas.

"Advanced technology for identification and optimization of production from fractured reservoirs": presented to Pemex Production, Austin, Texas.

"Advanced recovery strategies for energy resource optimization": presented to Petronas, Kuala Lumpur, Malaysia, and Pertamina, Jakarta, Indonesia.

"Hydrocarbon recovery optimization in conventional reservoirs through application of advanced technology and improved reservoir characterization": presented to the Indonesian Petroleum Association, Jakarta, Indonesia.

"Hydrocarbon production characteristics of Granite Wash reservoirs in the Midcontinent, U.S.A.": presented to Asmera Oil Corporation, Jakarta, Indonesia.

"Statistical evaluation of compartmented gas reservoirs": presented to ARCO Indonesia Corporation, Jakarta, Indonesia.

"Advanced recovery optimization using new technologies": presented to Institute of Mexican Petroleum, Austin, Texas.

"Petrophysical evaluation of sandstone reservoir systems: examples from the Gulf Coast": presented to the Railroad Commission of Texas, Austin, Texas.

"Regional lead organization activities and year-2 plan for the Petroleum Technology Transfer Council": presented to the Texas Petroleum Technology Transfer Council, Producer Advisory Group, Houston, Texas.

"Field optimization studies for increased production": presented to YPF Reservoir Engineering Division, Buenos Aires, Argentina.

"Let's talk energy: issues facing the nation": presented to the National Energy Education Development Project, Lago Vista, Texas.

"Maximizing conventional recovery in mature oil and gas fields": presented at RIPED, Beijing, China.

"Methodology and strategies in modern reservoir characterization for identifying reserve growth potential": presented at RIPED, Beijing, China.

"Application of sequence stratigraphy to the prioritization of incremental reserve growth opportunities in mature reservoirs: an example from Frio fluvial-deltaic sandstones, T–C–B field, South Texas": presented at RIPED, Beijing, China.

"Strategies for optimizing incremental recovery from mature reservoirs in Frio fluvial-deltaic sandstones, Rincon field, South Texas": presented at RIPED, Beijing, China.

"Flow unit characterization and recovery optimization of a braid-delta sandstone reservoir, Tirrawarra oil field, South Australia": presented at RIPED, Beijing, China.

"Production optimization of tide-dominated deltaic reservoirs of the Lower Misoa Formation (lower Eocene), LL-652 area, Lagunillas field, Lake Maracaibo, Venezuela": presented at RIPED, Beijing, China.

"Rock fabric approach to characterizing carbonate ramp reservoirs for fluid flow simulation": presented at RIPED, Beijing, China.

"Geologic and hydrologic factors affecting coalbed methane producibility: United States analogs useful for China coalbed methane exploration and development": presented at RIPED, Beijing, China.

"Approaches for estimating coal and coalbed methane resources and delineating potential exploration sweet spots": presented at RIPED, Beijing, China.

"Design and application of 3-D seismic to finding reserves in mature fields": presented at RIPED, Beijing, China.

F. Jerry Lucia

"Acoustic log methods of identifying vuggy pore types": presented to Petroleum Engineering Seminar, The University of Texas at Austin.

"The origin of fractured and brecciated lower Paleozoic carbonate reservoirs": presented at the Tulsa Geological Society.

"Rock fabric approach to characterizing carbonate ramp reservoirs": presented to Saudi Aramco, Dhahran, Saudi Arabia.

"Rock fabric approach to characterizing carbonate ramp reservoirs": presented to Oman Production Development, Muscat, Oman.

"Rock fabric approach to characterizing carbonate ramp reservoirs": presented to TOTAL Oil Company, Paris, France.

"Defining petrophysical/geological flow units in the Seminole San Andres reservoir": presented at Society of Professional Well Log Analysts luncheon meeting, Midland, Texas.

"Dolomitization, a porosity-destroying process": presented at the Carbonate Research Committee meeting, American Association of Petroleum Geologists Annual Meeting, Houston, Texas.

"Rock fabric/petrophysical relationships in South Cowden Grayburg field": presented to the annual fall meeting of the San Andres/Grayburg Reservoir Characterization Research Laboratory Industrial Associates, Carlsbad, New Mexico.

Robert E. Mace

"History and hydrogeologic use of hand-dug wells": presented to The University of Texas at Austin, Department of Geological Sciences, Austin, Texas.

"Results of BEG study of regional distribution of permeability in the Edwards aquifer": presented to the Edwards Underground Water District Board, San Antonio, Texas.

Richard P. Major

"Play analysis, resource assessment, methods of reservoir characterization, and reservoir characterization type studies": presented to the Petroleum Technology Transfer Council Workshop on the Upper Guadalupian Sandstone and Carbonate Play, Midland, Texas.

"Open forum discussion of technology transfer needs": presented to the Petroleum Technology Transfer Council Workshop on the Upper Guadalupian Platform Sandstone and Carbonate Play, Midland, Texas.

"Open forum discussion of technology transfer needs": presented to the Petroleum Technology Transfer Council Workshop on the Frio Barrier/Strandplain Sandstone Play, San Marcos Arch, Corpus Christi, Texas.

"Open forum discussion of technology transfer needs": presented to the Petroleum Technology Transfer Council Workshop on the Wilcox Deltaic Sandstone Play, Rio Grande Embayment, Corpus Christi, Texas.

"Open forum discussion of technology transfer needs": presented to the Petroleum Technology Transfer Council Workshop on the Frio Fluvial/Deltaic Sandstone Play, Vicksburg Fault Zone, Houston, Texas.

"Oil resources: reservoir characterization as a tool for maximum recovery efficiency": presented to the Leadership Training Conference, National Energy Education Development Project, Lago Vista, Texas.

"Midland Core Research Center, Bureau of Economic Geology, The University of Texas at Austin": presented to the U.S. Department of Energy Contractors Meeting, Fountainhead, Oklahoma.

"Review of carbonate reservoir systems and reservoir characterization research": presented to Sita Oil Exploration House, Inc., Austin, Texas.

"Review of oil resources research programs": presented to the Texas General Land Office, Austin, Texas.

"Petroleum Technology Transfer Council": presented to the Drilling Engineering Association Panel, Houston, Texas.

"Review and summary of petroleum exploration and production research by the Bureau of Economic Geology, The University of Texas at Austin": presented to the China National Petroleum Company, Austin, Texas.

"Diagenesis of metastable carbonate marine cements under conditions of rapid burial and low water:rock ratio": presented to The University of Texas at Austin, Department of Geological Sciences, Soft Rock Seminar, Austin, Texas.

Robert A. Morton

"Beach erosion in Aransas Bay and alternative responses": presented to the Key Allegro Property Owners Board, Rockport, Texas.

"Global impact of mining and urbanization on earth surface processes and geomorphology in the coastal zone": presented at technical meeting sponsored by the Scientific Committee on Problems of the Environment and the International Union of Geological Sciences, Madrid, Spain.

"Shoreline changes in Texas": presented at the Coastal Erosion Response Plan, Technical Transfer Meeting, Texas General Land Office, Galveston, Texas.

"Geology and sediment history of Laguna Madre": presented at the Interagency Coordination Team Meeting, U.S. Army Corps of Engineers, Austin, Texas.

William F. Mullican III

"Design, construction, and completion of monitor wells at hazardous waste sites": presented to The University of Texas at Austin, Department of Geological Sciences (Geology 382), Austin, Texas.

"Groundwater data on the Internet": presented at the Groundwater Management Districts Association Annual Conference.

H. Seay Nance

"Fault and joint measurements in Austin Chalk, Superconducting Super Collider site, Texas": presented to the Austin Geological Society, Austin, Texas.

Jeffrey G. Paine

"Pantex geophysics program summary": presented to the Pantex project quarterly meeting, Amarillo, Texas.

"Shallow seismic reflection and refraction methods in hydrogeological investigations": presented to The University of Texas at Austin, Department of Geological Sciences (Geology 376L), Austin, Texas.

"Electromagnetic induction methods": presented to The University of Texas at Austin, Department of Geological Sciences (Geology 391), Austin, Texas.

Jay A. Raney

"Public education and the role of the Bureau of Economic Geology": presented to the American Association of Petroleum Geologists Annual Meeting, Houston, Texas.

"Environmental programs at the Bureau of Economic Geology with comments on the recent Alpine earthquake": presented to UT LAMP, Austin, Texas.

"Geologic effects of the Alpine earthquake": presented to the Texas Low-Level Radioactive Waste Disposal Authority, Sierra Blanca, Texas.

"Faulting in the vicinity of the proposed Texas low-level radioactive waste disposal facility, Hudspeth County, Texas": presented at a public meeting in Sierra Blanca, Texas.

"Structural setting and earthquake potential in the vicinity of the proposed Texas low-level radioactive waste disposal facility, Hudspeth County, Texas": presented to Dames and Moore, Inc., Los Angeles, California.

Lisa E. Remington

"Texas rocks and minerals": presented to students at the Spicewood Country Preschool, Austin, Texas.

Stephen C. Ruppel

"Summary of geological characterization studies of the Monahans Clear Fork reservoir": presented to Shell Western Exploration and Production, Inc., Houston, Texas.

Deborah A. Salazar

"Through sickness and in health: a tropical ethnoecology of traditional medicine in southeastern Venezuela": presented to the Austin Geological Society, Austin, Texas.

"Environmental diversity and medicinal plant supplies": presented to the Department of Geography (Geography 11), St. Edward's University, Austin, Texas.

"GIS in research centers: Bureau of Economic Geology": presented to GIS Texas: Expanding Frontiers, Austin, Texas.

"Multiple attribute GIS environmental baseline, lower Rio Grande valley": presented to the U.S. Environmental Protection Agency Workshop for Baseline Indicators for the U.S.–Mexico Border, San Diego, California.

"United States–Mexico cooperative transborder GIS projects: Is there a formula for success?": presented to the Urban and Regional Information Systems Association Annual Conference and Exposition, San Antonio, Texas.

"Border projects in GIS at the Bureau of Economic Geology": presented to the LBJ School of Public Affairs (Public Affairs 882A), The University of Texas at Austin.

Bridget R. Scanlon

"Issues related to Ward Valley, the proposed low-level radioactive waste disposal facility in California": presented to the Low Level Radioactive Waste Disposal Board, Austin, Texas.

"Review of unsaturated zone studies in arid sites and implications for contaminant transport": presented to the Nuclear Waste Technical Review Board, San Francisco, California.

"Review of unsaturated zone studies in arid sites and implications for contaminant transport": presented to The University of Texas at Austin, Department of Geological Sciences, Brown Bag Seminar, Austin, Texas.

"Controls on subsurface flow in an arid setting including evaluation of preferred pathways": presented at the VII Evans Workshop, "Flow and transport through unsaturated fractured rock," Phoenix, Arizona.

Andrew R. Scott

"Exploration strategies for secondary biogenic gases": presented to B.P. Exploration Company Ltd., London, England.

"Coal gas composition and reservoir heterogeneity in the northern San Juan Basin": presented to the Northern San Juan Basin Industrial Group, Durango, Colorado.

"A modified approach to estimating coal and coal gas resources": presented to Santos Ltd., Austin, Texas.

"Geologic and hydrologic controls critical to coalbed methane producibility and resource assessment": presented to the University of Petroleum, China.

Daniel D. Schultz-Ela

"Inferring subsalt structures from suprasalt structures: results from numerical modeling of extension around salt sheets": presented to the Tulsa Geological Society, Bartlesville, Oklahoma.

"Do laboratory flow laws for salt describe its flow in the Earth?": presented to the Gordon Research Conference on Rock Deformation, Tilton, New Hampshire.

"Effect of salt budget on overburden deformation," "Salt tectonics above basement faults," and "Inferring subsalt structures from suprasalt structures": presented to the Industrial Associates of the Applied Geodynamics Laboratory, Austin, Texas.

"Sedimentary loading of salt sheets with and without extension": presented to Phillips Salt Forum, Houston, Texas.

Steven J. Seni

"Northern Gulf of Mexico gas and oil atlas seminar": presented to the U.S. Department of Energy Office of Fossil Energy, Contractor Review Meeting, Baton Rouge, Louisiana.

"The northern Gulf of Mexico gas and oil atlas series": presented to Western Atlas, Austin, Texas.

"Review of the northern Gulf of Mexico gas and oil atlas series": presented to the Gas Research Institute Technical Advisors Group, Houston, Texas, and to the Gas Research Institute, Chicago, Illinois.

"GIS capabilities of the northern Gulf of Mexico gas and oil atlas series": presented to Pemex, Austin, Texas.

"Can technology expand a shrinking lower-48 resource base": presented to the National Association of Petroleum Investment Analysts, San Antonio, Texas.

James L. Simmons

"Field techniques and data-processing procedures for broadband 3-D seismic imaging in the Boonsville Bend Conglomerate field": presented to the Permian Basin Geophysical Society, Midland, Texas.

"AVO inversion and direct hydrocarbon detection": presented to the Society of Exploration Geophysicists, Gulf Coast Section Annual Meeting, Houston, Texas.

"Amplitude versus offset: modeling and inversion": presented at Amoco Research Company, Tulsa, Oklahoma.

Thomas A. Tremblay

"GIS base data for water management on the Rio Grande delta plain": presented at the 7th Conference of the U.S.–Mexico Border States on Recreation, Parks and Wildlife, Brownsville, Texas.

"Water management for the Rio Grande delta": presented at the Camp Mabry Environmental Speakers Series, Austin, Texas.

"Border projects of the Bureau of Economic Geology": presented to GIS Texas: Expanding Frontiers, Austin, Texas.

Noel Tyler

"Current status and future directions of the Bureau of Economic Geology": presented to the Geology Foundation Advisory Council, Austin, Texas.

"Maximizing recovery from heterogeneous reservoirs": presented to the Geological Institute, University of Bergen, Bergen, Norway.

"Contrasting architectures and recovery response in deltaic reservoirs": presented at Nörsk Hydro, Bergen, Norway.

"Recovery optimization from mature fields": presented to Pemex, Mexico City, Pozo Rica, and Villahermosa, Mexico.

Roger Tyler

"Geologic and hydrologic controls critical to coalbed methane producibility and resource assessment: presented to the University of Petroleum, China.

"Basin-scale exploration for coalbed methane: an example from the Greater Green River Basin": presented to engineers and geologists of the Chinese National Petroleum Company, Austin, Texas.

"Geologic and hydrologic controls critical to coalbed methane resources, Greater Green River Basin, Wyoming and Colorado": presented to Chevron Natural Gas Team, Austin, Texas.

"Geologic and hydrologic controls critical to coalbed gas producibility and resource assessment, the Rocky Mountain Foreland experience": presented to the South African Institute of Mining and Metallurgy and the Geological Society of South Africa, Johannesburg, South Africa.

"Geologic and hydrologic controls critical to coalbed gas producibility and resource assessment": presented to Anglovaal Limited, Johannesburg, South Africa.

"Coalbed gas potential and resource calculations in the Rocky Mountain Foreland: analogs useful to Sub-Saharan coalfield gas

exploration and development": presented to the University of the Witwatersrand, Department of Geology, Johannesburg, South Africa.

"Genetic sequence stratigraphy, coal occurrence, and depositional systems of coal-bearing foreland basins; controls critical to coalbed methane producibility": presented to the University of the Witwatersrand, Department of Geology, Johannesburg, South Africa.

Bruno C. Vendeville

"Experimental and geologic evidence for rejuvenation of salt diapirs by horizontal contraction": presented to Mobil Research and Development Corporation, Dallas, Texas.

"Introduction to salt tectonics": presented to Occidental International Exploration and Production Company, Bakersfield, California.

"Do turtle structures need to stretch?": presented at the Applied Geodynamics Laboratory Industrial Associates meeting, The University of Texas at Austin.

"Late extension superposed on salt-based contraction": presented at the Applied Geodynamics Laboratory Industrial Associates meeting, The University of Texas at Austin.

"3-D differential loading of a salt tongue": presented at the Applied Geodynamics Laboratory Industrial Associates meeting, The University of Texas at Austin.

"Regional extension of an elliptical salt tongue": presented at the Applied Geodynamics Laboratory Industrial Associates meeting, The University of Texas at Austin.

"Rejuvenation of salt diapirs by lateral shortening": presented at Phillips Petroleum Salt Forum, Houston, Texas.

"Late extension superposed onto older compressional structures above salt": presented at Phillips Petroleum Salt Forum, Houston, Texas.

Fred P. Wang

"Petrophysical characterization of Miocene sandstones in Bacha-24, A-22 and LL-02-08 areas in Lake Maracaibo, Venezuela": presented to Lagoven, S.A., Maracaibo, Venezuela.

Christopher D. White

"Quantification of outcrop data for flow-model construction": presented to the Deltaic Reservoirs Industrial Associates project review meeting, Austin, Texas.

W. Gerald White

"Demonstration of GPS/GIS technology used in EPA U.S.–Mexico border study": presented to representatives of TNRCC, GLO, and others, Austin, Texas (with Edward Angle and Allison Goldberg).

"Border studies of the Bureau of Economic Geology," Austin, Texas (with Thomas Tremblay): presented at the TNRIS-sponsored GIS Forum, Austin, Texas.

Brian J. Willis

"Characterization of fluvial-deltaic reservoirs in a low-accommodation setting: outcrop analogs to valley-fill reservoirs in the Fall River Formation of Wyoming": presented to The University of Texas at Austin, Department of Geological Sciences (Geology 391), Austin, Texas.

"Reservoir characterization of Buck Draw field": presented to B.P. Exploration Co., Houston, Texas.

"Outcrop characterization of a low-accommodation fluvial-deltaic reservoir, Black Hills of South Dakota and Wyoming": presented to B.P. Exploration Co., Houston, Texas.

"Miocene river systems in the Himalayan Foredeep of Pakistan": presented to The University of Texas at Austin, Department of Geological Sciences, Soft Rock Seminar, Austin, Texas.

"Architecture and permeability structure of fluvial-dominated valley-fill deposits in the Cretaceous Fall River Formation": presented to B.P. Exploration Co., London, England.

"Interwell-scale facies architecture and permeability structure, Fall River Formation": presented to the Delta Industrial Associates Midyear Project Review Meeting, Austin, Texas.

"Facies architecture and permeability structure, Frewens Castle sandstone": presented to the Deltaic Reservoirs Industrial Associates project review meeting, Austin, Texas.

Jiannan Xiang

"A vertical sweep–surfactant washing method for speeding aquifer restorations": presented to the Department of Civil and Environmental Engineering, Tulane University, New Orleans, Louisiana.

Bureau of Economic Geology Seminars

Alan E. Fryar

"Evidence of limited denitrification beneath playas recharging the Ogallala aquifer"

Douglas S. Hamilton

(and Mark H. Holtz) "Application of sequence stratigraphic concepts to reservoir characterization in an intracratonic basin setting: Toolachee field, Cooper Basin, Australia"

Bob A. Hardage

"Seismic concepts that support modern research programs"

"Applying seismic vector wavefield principles in Bureau programs"

Mark H. Holtz

(and Douglas S. Hamilton) "Application of sequence stratigraphic concepts to reservoir characterization in an intracratonic basin setting: Toolachee field, Cooper Basin, Australia"

Susan D. Hovorka

"Regional distribution of permeability in the Edwards aquifer"

Paul R. Knox

"A model for upper delta-plain fluvial response to base-level change: implications for mature reservoir prioritization and characterization"

Robert E. Mace

"Determination and geostatistical description of hydraulic properties in the Edwards aquifer"

Andrew R. Scott

"Microbially enhanced coalbed methane"

Steven J. Seni

"Atlas of northern Gulf of Mexico gas and oil reservoirs"

Roger Tyler

"Cretaceous and Tertiary coal-fracture patterns, Rocky Mountain Foreland, western United States; permeability indicators for coalbed methane producibility"

Jiannan Xiang

"A new method for speeding aquifer restorations—vertical sweep–surfactant washing"

Congressional, Legislative, and Special Testimony

William L. Fisher

"Statement on oil and gas resource estimates of the Arctic National Wildlife Refuge (ANWR)": presented to the Committee on Energy and Natural Resources, U.S. Senate, Washington, D.C.

"Statement on reservoir class programs of the U.S. Department of Energy": presented to the Committee on Reservoir Classes, Board on Earth Sciences and Resources, National Research Council, Dallas, Texas.

Committee Services, Offices, and Other Professional Responsibilities

Mark D. Barton

Leader of field trip, "Sequence stratigraphy, facies architecture, and permeability structure of fluvial-deltaic reservoir analogs: Cretaceous Ferron Sandstone, central Utah," Gas Research Institute, Emery County, Utah.

Janok P. Bhattacharya

Co-chair, Sequence Stratigraphy Research Group, SEPM (Society for Sedimentary Geology).

Member, Research Group in Quantitative Stratigraphy, SEPM (Society for Sedimentary Geology).

Edward W. Collins

Leader of field trip, "Geology of the proposed Faskin Ranch low-level radioactive waste site and surrounding areas of West Texas": presented to Sul Ross State University, Environmental Geology and Subsurface Geology classes, Sierra Blanca and Faskin Ranch, Texas.

Patricia W. Dickerson

Co-chair, Before the gulf—Paleozoic tectonics of the southern margin of Laurentia, theme session, Geological Society of America Annual Meeting.

Member, International Geological Correlation Programme Project 376—Laurentian–Gondwanan Connections before Pangea.

Compiler, Chihuahua and Coahuila, Mexico, portions of Map of Active Faults of North America, U.S. Geological Survey.

Alan R. Dutton

Editor, *The Hydrogeologist,* Geological Society of America, Hydrogeology Division.

Member, Ground-Water Protection Committee, Texas Natural Resources Conservation Commission.

Shirley P. Dutton

Associate Editor, *Journal of Sedimentary Research,* SEPM (Society for Sedimentary Geology).

Robert J. Finley

Member, Committee on Publications, American Association of Petroleum Geologists.

Member, Committee on Development Geology, American Association of Petroleum Geologists.

Member, Interstate Oil and Gas Compact Commission, Texas delegation.

Member, Program Committee, Second SPE/EPA Exploration and Production Environmental Conference.

Candidate, Vice-President, American Association of Petroleum Geologists.

R. Stephen Fisher

Member, Committee on Hydrogeology and Environmental Geology, SEPM (Society for Sedimentary Geology).

William L. Fisher

Director, Geology Foundation, The University of Texas at Austin.

Chair, Committee for Strategic Planning, American Geological Institute.

Chair, Faculty Review Committee, Department of Geological Sciences, The University of Texas at Austin.

Vice Chair, Board of Directors, Texas Low-Level Radioactive Waste Disposal Authority.

Board of Advisors, Jefferson Energy Foundation Project on Man, Energy, and the Environment.

Foundation Trustee, American Geological Institute.

Trustee Associate, American Association of Petroleum Geologists Foundation.

Member, Board of Directors, Gulf Coast Association of Geological Societies.

Member, Faculty Senate, The University of Texas at Austin.

Member, University Council, The University of Texas at Austin.

Member, Council on Data Needs, Railroad Commission of Texas.

Member, Research and Development Needs Committee, National Petroleum Council.

Member, Committee on Governmental Relations, Natural Sciences Foundation, The University of Texas at Austin.

Member, Research Committee, Interstate Mining Compact Commission.

Member, Research Committee, Interstate Oil and Gas Compact Commission.

Member, Advisory Council, Gas Research Institute.

Member, University Advisory Board, Center for Legislative Energy and Environmental Research, South/West Energy Council.

Trustee, Southwest Research Institute.

Member, Advisory Board, World Energy Update.

Member, Advisory Board, Treatise on Petroleum Geology, American Association of Petroleum Geologists.

Member, Committee on Resources, American Association of Petroleum Geologists.

Member, Steering Committee, National Geoscience Data Repository System.

Member, National Petroleum Council.

Member, Commission on Geosciences, Environment, and Resources, National Research Council.

Member, National Academy of Engineering.

Member, Technical Planning Committee, World Energy Conference.

Bob A. Hardage

Member, Executive Committee, Society of Exploration Geophysicists.

Editor, *Geophysics,* Society of Exploration Geophysicists.

Member, Publications Committee, Society of Exploration Geophysicists.

Member, Organizing Committee, Society of Exploration Geophysicists Research Forum.

Member, Organizing Committee, Society of Exploration Geophysicists Development and Production Forum.

Member, Development and Production Committee, Society of Exploration Geophysicists.

Member, Editorial Board, *Journal of Seismic Exploration.*

Mark H. Holtz

Chair, Registration Committee, Gulf Coast Association of Geological Societies.

Technical Editor, *Reservoir Engineering,* Society of Petroleum Engineers.

Susan D. Hovorka

Co-convenor, "Carbonates and evaporites," technical session, American Association of Petroleum Geologists Annual Meeting.

Martin P. A. Jackson

Co-convenor, "World of salt tectonics international," technical session, American Association of Petroleum Geologists Annual Meeting.

Co-convenor, "Salt tectonics—new models for hydrocarbon exploration," technical session, American Association of Petroleum Geologists International Meeting.

Member, International Union of Geological Sciences Commission on Tectonics.

William R. Kaiser

Member, Steering Committee on Coal Reserves Assessment, U.S. Department of Energy.

Charles Kerans

Co-convenor, "High-frequency eustatic cycles, control on depositional processes," technical session, American Association of Petroleum Geologists Annual Meeting.

Leader of field trip, "Permian Reef Geology Trail, McKittrick Canyon, Guadalupe Mountains: facies, depositional models, and sequence stratigraphy," American Association of Petroleum Geologists Annual Meeting.

Co-leader of field trip, "Sequence stratigraphy and reservoir geology of the San Andres Formation, Sacramento and Guadalupe Mountains," Permian Basin Section, SEPM (Society for Sedimentary Geology) Annual Meeting.

Paul R. Knox

Chair, Membership Committee, Austin Geological Society.

Stephen E. Laubach

Member, Technical Editor Board, Society of Petroleum Engineers.

Convenor, "Geology and structural geology," special session, Second International Conference on Mechanics of Jointed and Faulted Rock.

Raymond A. Levey

Member, Data Needs 1995 Project, Railroad Commission of Texas.

Member, Texas Oil and Gas Forum.

Member, Research Committee, American Association of Petroleum Geologists.

F. Jerry Lucia

Review Chair, SPE Formation Evaluation, Society of Petroleum Engineers.

Member, Production Geology and Geophysics Committee, Society of Petroleum Engineers.

Robert E. Mace

Member, Barton Springs/Edwards Aquifer Conservation District Technical Advisory Committee.

Richard P. Major

Associate Editor, American Association of Petroleum Geologists *Bulletin.*

Associate Editor for Book Reviews, *Journal of Sedimentary Research,* SEPM (Society for Sedimentary Geology).

Delegate, House of Delegates, American Association of Petroleum Geologists, representing the Austin Geological Society.

Member, Admissions and Support Committee, Department of Geological Sciences, The University of Texas at Austin.

Lee E. McRae

Member, Student Grants-in-Aid Evaluation Committee, Gulf Coast Association of Geological Societies.

Robert A. Morton

Member, Editorial Board, *Journal of Coastal Research,* Coastal Education and Research Foundation.

Associate Editor, *Journal of Sedimentary Research,* SEPM (Society for Sedimentary Geology).

Moderator, panel on "Structural and nonstructural approaches to barrier restoration in Louisiana," Barrier Restoration Workshop, New Orleans, Louisiana.

William F. Mullican III

Co-chair, Technical Program Committee, 1996 South-Central Geological Society of America Annual Meeting.

Member, Advisory Panel, Texas Rehabilitation Commission Supported Employment Systems Change Grant.

Conference Chair, "Suitability of solution-mined caverns for oil and gas waste disposal," Railroad Commission of Texas and Bureau of Economic Geology.

Jeffrey G. Paine

Associate Editor for Geophysics, *Environmental and Engineering Geoscience,* Geological Society of America and the Association of Engineering Geologists.

Jay A. Raney

Member, Interagency GIS Coordination Committee, GIS Planning Council, Department of Information Resources.

Member, U.S. Environmental Protection Agency, U.S.–Mexico Border, Ground-Water Protection Subgroup.

Lisa E. Remington

Member, Texas Environmental Awareness Network.

Member, Membership Committee, Austin Geological Society.

Member, Registration Committee, Gulf Coast Association of Geological Societies Annual Convention.

Stephen C. Ruppel

Chair, Publications Committee, Austin Geological Society.

Deborah A. Salazar

Board Member, Latin American Studies Specialty Group, Association of American Geographers.

Member, Advisory Board, Texas–Mexico Borderlands Data and Information Center, Texas Natural Resources Information System, Texas Water Development Board.

Member, Texas State Geographic Information Systems (GIS), Planning Council and Subcommittees.

Member, Texas Department of Information Resources, The Transboundary Resource Inventory Project (TRIP), Texas General Land Office.

Bridget R. Scanlon

Editor, *Ground Water,* Association of Ground Water Scientists and Engineers.

Member, Committee to Evaluate Flow Processes at the Proposed California Low-Level Radioactive Waste Disposal Facility, National Academy of Sciences.

Andrew R. Scott

Councilor, Gulf Coast Section, Energy Minerals Division, American Association of Petroleum Geologists.

James L. Simmons

Associate Editor of Amplitude-Versus-Offset (AVO), *Geophysics,* Society of Exploration Geophysicists.

Convenor, "Seismic acquisition and processing," technical session, Society of Exploration Geophysicists, Gulf Coast Section Annual Meeting, Houston, Texas.

Thomas A. Tremblay

Member, Managers Committee, Texas Department of Information Resources, Geographic Information Systems.

Noel Tyler

Chair, Continental Margins Committee, Association of American State Geologists.

Member, Coastal Processes Committee, Association of American State Geologists.

Member, Environmental Affairs Committee, Association of American State Geologists.

Member, Texas Data Project 1995, Railroad Commission of Texas.

Member, Board on Earth Sciences and Resources, National Research Council, National Academy of Sciences.

Member, Producer Advisory Group, Texas Independent Producers and Royalty Owners Association (TIPRO).

Member, Texas STATEMAP Advisory Panel, USGS.

Member, Energy and Minerals Policy Committee, Association of American State Geologists.

Member, Radioactive Waste Committee, Association of American State Geologists.

Roger Tyler

Member, South African Council for Natural Scientists.

Bruno C. Vendeville

Member, Editorial Board, *Tectonophysics.*

Chair, Geometry and Evolution of Salt Bodies and the Sediments Surrounding Them session, Annual Gulf Coast Section, Society of Economic Paleontologists and Mineralogists Foundation Research Conference.

Co-chair, Program Advisory Committee, Annual Gulf Coast Section, Society of Economic Paleontologists and Mineralogists Foundation Research Conference.

Judge, Petroleum Geology of West Africa session, American Association of Petroleum Geologists International Meeting.

E. G. Wermund

Chair, Awards Committee, Austin Geological Society.

Member, Environmental Geology Issues Committee, Division of Environmental Geosciences, American Association of Petroleum Geologists.

Member, Membership Committee, Geological Society of America.

Member, Texas Mapping Advisory Committee.

Member, Texas Natural Resources Information System Task Force.

Member, Scientific and Technical Advisory Committee, Galveston Bay National Estuary Program.

Member, Scientific and Technical Advisory Committee, Corpus Christi Bays National Estuary Program.

Member, H.O.S.T.S. Program, Ortega Elementary School.

Judge of Science Fair, Ortega Elementary School.

Brian Willis

Co-chair, Sedimentology, Clastic II: Sedimentary Process and Lithofacies technical session, Geological Society of America Annual Meeting.

Jiannan Xiang

Convenor, "Environmental engineering," special session, Society of Engineering Science Annual Technical Meeting.

Member, National Engineering Design Challenge Committee, National Society of Professional Engineers.

University Teaching/ Continuing Education

David L. Carr

"Using new concepts and modern technologies to evaluate Midcontinent reservoirs": co-lecturer of short course presented to the American Association of Petroleum Geologists Annual Meeting, Houston, Texas.

"Using new concepts and modern technologies to evaluate Bend Conglomerate reservoirs": co-lecturer of short course presented to independent operators, Tyler and Graham, Texas.

Alan R. Dutton

"Unsaturated zone hydrology": presented to The University of Texas at Austin, Department of Geological Sciences (Geology 391D), Austin, Texas.

Robert J. Finley

"Characterization of heterogeneous reservoirs": co-lecturer of short course presented to CEPET, Petróleos de Venezuela, Maracaibo and Caracas, Venezuela.

William L. Fisher

"Petroleum basin analysis": presented to The University of Texas at Austin, Department of Geological Sciences (Geology 391), Austin, Texas.

"Reservoir geology and advanced recovery": presented to The University of Texas at Austin, Department of Geological Sciences (Geology 391), Austin, Texas (with Noel Tyler).

William E. Galloway

"Depositional systems and sequences in exploration for sandstone reservoirs": continuing education short course presented to the American Association of Petroleum Geologists, Dallas, Texas.

Bob A. Hardage

"Reservoir geophysics": short course presented on behalf of the Society of Exploration Geophysicists, Lafayette, Louisiana, and Bartlesville, Oklahoma.

"Using new concepts and modern technologies to evaluate Bend Conglomerate reservoirs": co-lecturer of short course presented to independent operators, Tyler and Graham, Texas.

"Using new concepts and modern technologies to evaluate Midcontinent reservoirs": co-lecturer of short course presented at the American Association of Petroleum Geologists Annual Meeting, Houston, Texas.

"3-D seismic technology": short course presented to independent producers at Roswell and Farmington, New Mexico.

"Demonstrations of new concepts and modern technologies for evaluating heterogeneous reservoirs in low-accommodation settings": short course presented to independent operators, Denver, Colorado; Oklahoma City and Tulsa, Oklahoma; and Dallas and Houston, Texas.

"Examples of 3-D seismic technology in the Fort Worth Basin": presented to Texas Tech University, Department of Geosciences, Lubbock, Texas.

Mark H. Holtz

"Characteristics of the Frio Fluvial/Deltaic Sandstone play, Vicksburg Fault Zone": co-lecturer of Joint Bureau of Economic Geology–TIPRO Technology Transfer Workshop, Houston, Texas.

"Characteristics of the Wilcox Deltaic Sandstone, Rio Grande Embayment play": co-lecturer of Joint Bureau of Economic Geology–TIPRO Technology Transfer Workshop, Corpus Christi, Texas.

"Characteristics of the Frio Barrier/Strandplain, San Marcos Arch, play": co-lecturer of Joint Bureau of Economic Geology–TIPRO Technology Transfer Workshop, Corpus Christi, Texas.

"Characteristics of the Upper Guadalupian Platform Sandstone and Carbonate play": co-lecturer of Joint Bureau of Economic Geology–TIPRO Technology Transfer Workshop, Midland, Texas.

"Geological and petrophysical approaches to characterization of restricted platform carbonate reservoirs: examples from the Leonardian of the Permian Basin": co-lecturer of workshop presented to the Permian Basin Graduate Center, Midland, Texas.

William R. Kaiser

"Geology and hydrology of coalbed methane producibility in the United States: analogs for the world": co-lecturer of short course presented to the Intergas Unconventional Gas Symposium, Tuscaloosa, Alabama.

Charles Kerans

"Milankovitch sea-level changes, cycles, and reservoirs on carbonate platforms in greenhouse and icehouse worlds": co-lecturer of short course presented to SEPM (Society for Sedimentary Geology) Annual Meeting.

Stephen E. Laubach

Co-organizer, industry working group discussion meetings on natural fracture quantification, Lobo Wilcox play, and Canyon play, Fort Worth, Houston, and Midland, Texas.

Stephen C. Ruppel

"Geological and petrophysical approaches to characterization of restricted platform carbonate reservoirs: examples from the Leonardian of the Permian Basin": short course presented to the Permian Basin Graduate Center, Midland, Texas.

Bridget R. Scanlon

"Unsaturated zone hydrology": presented to The University of Texas at Austin, Department of Geological Sciences (Geology 391D), Austin, Texas.

Andrew R. Scott

"Geology and hydrology of coalbed methane producibility in the United States: analogs for the world": co-lecturer of short course presented to the Intergas Unconventional Gas Symposium, Tuscaloosa, Alabama.

Noel Tyler

"Reservoir geology and advanced recovery": presented to The University of Texas at Austin, Department of Geological Sciences (Geology 391), Austin, Texas (with William L. Fisher).

Roger Tyler

"Geology and hydrology of coalbed methane producibility in the United States: analogs for the world": co-lecturer of short course presented to the Intergas Unconventional Gas Symposium, Tuscaloosa, Alabama.

Bruno C. Vendeville

"Introduction to experimental modeling of tectonic processes": co-lecturer of workshop presented to the Geological Society of America Annual Meeting, New Orleans, Louisiana.

Support Staff

Administrative/Secretarial

Members of the administrative staff, under the supervision of Wanda L. LaPlante, Executive Assistant, handle general administration of the Bureau, which includes payroll and personnel, accounts payable and receivable, purchasing, travel arrangements and reimbursement, receptionist duties, correspondence, and meeting coordination. Ninety-five percent of all documents handled by this section are processed electronically. The Bureau's involvement in numerous contracts and research projects requires that the Administrative staff process more than 3,000 appointment forms each year in order to properly allocate staff time among funding sources. This section also controls more than $5 million in purchases and subcontracts and handles publication sales in excess of $155,000 per year.

Computer Resources

The Computer Resources group supports a complex computing environment consisting of multiple hardware platforms as well as various scientific and business software applications. A newly installed high-speed Local Area Network (LAN) integrates the more than 200 workstations and desktop computers installed at the Bureau. The Bureau's LAN is connected to The University of Texas at Austin's (UT) broadband Ethernet system, which allows high-speed communication with computer systems on the UT campus, at the Center for High Performance Computing, and other Internet sites worldwide.

Hardware platforms in the Bureau include a Local Area VAX Cluster, UNIX workstations, Macintosh and IBM-compatible desktop workstations, and terminals. Software tools include various data-base, word-processing, spreadsheet, and statistical packages. Seismic data analysis, ground-water modeling, reservoir modeling and simulation, well log analysis, and various integrated geological software packages are also supported.

In order to maintain its leading edge in technology, the Bureau hired Michael T. Kader, an engineer with extensive computer systems experience, to manage and direct the Computer Resources group. We are currently emphasizing Geographic Information Systems (GIS) and graphics. The Bureau will continue to research and implement new technology to integrate efficiency, reliability, performance, and information.

Publications

The Publications section of the Bureau comprises the computer-graphics, editing, design, and word-processing–typesetting staff, who produce Bureau publications and contract reports. They are also responsible for slides, posters, brochures, and other media for public distribution and for presentation at professional society meetings. Staff members use desktop publishing software and Macintosh computers to prepare digital files of text and illustrations.

Susann Doenges, Assistant Director for Publications, supervises a staff of 18 with the assistance of Richard L. Dillon, Chief Cartographer, Margaret L. Evans, Chief Designer, and Amanda R. Masterson, Editor in Chief.

In 1995, the computer graphics section's 14-person full-time staff, under the direction of Chief Cartographer Richard L. Dillon, produced 18 black-and-white plates, 8 full-color maps, 1,922 text figures, and 2,595 photographic slides, posters, and overhead transparencies. High cartographic standards are practiced to maintain the Bureau's reputation for quality.

All text figures, photographic slides, posters, and overhead transparencies are produced entirely on computers. Maps and plates, both in color and black and white, are being completed on computers as well. The computer graphics section has a 600-dpi black-and-white laser printer, a 300-dpi color printer (11 × 17 inches), a dye-sublimation color printer, a 36-inch-wide color ink-jet plotter, a monochrome scanner, a high-resolution color scanner, and a film recorder for production of 35-mm slides—all of which support the Macintosh

computers. All computers and equipment are networked through an Ethernet system.

Results of research projects are disseminated through various products developed by the entire Publications staff. During 1995, the staff prepared 16 Bureau publications and 34 contract reports (including 7 Technical Summaries for the Gas Research Institute). In addition, 55 papers and 61 abstracts by Bureau authors were published by professional journals and publishers. The staff also provided support to scientists attending regional and international professional meetings.

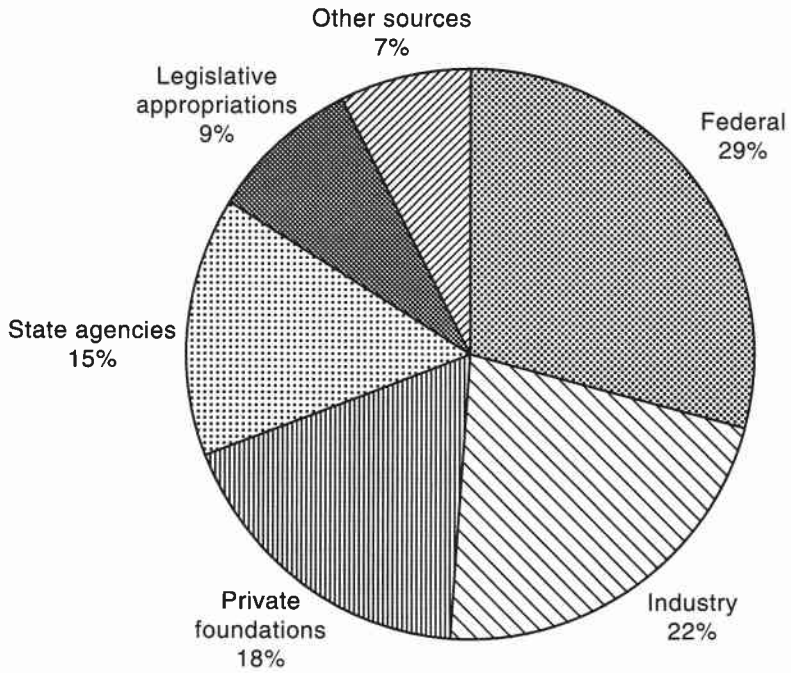
Quality Assurance

The Bureau of Economic Geology has maintained a formal quality-assurance program since 1979. The program is documented in written instructions that address research activities, analytical procedures, and methods for verifying and documenting the achievement of quality. The Bureau's quality assurance program conforms to requirements and standards contained in the Texas Constitution, Article XVI, Section 59(a); 10 CFR Part 50, Appendix B; 10 CFR Part 61; ANSI/ASME NQA-1; NUREG-0856; NUREG-1199; NUREG-1293; and NUREG-1383. The program also meets the requirements promulgated by the U.S. Department of Energy and U.S. Environmental Protection Agency.

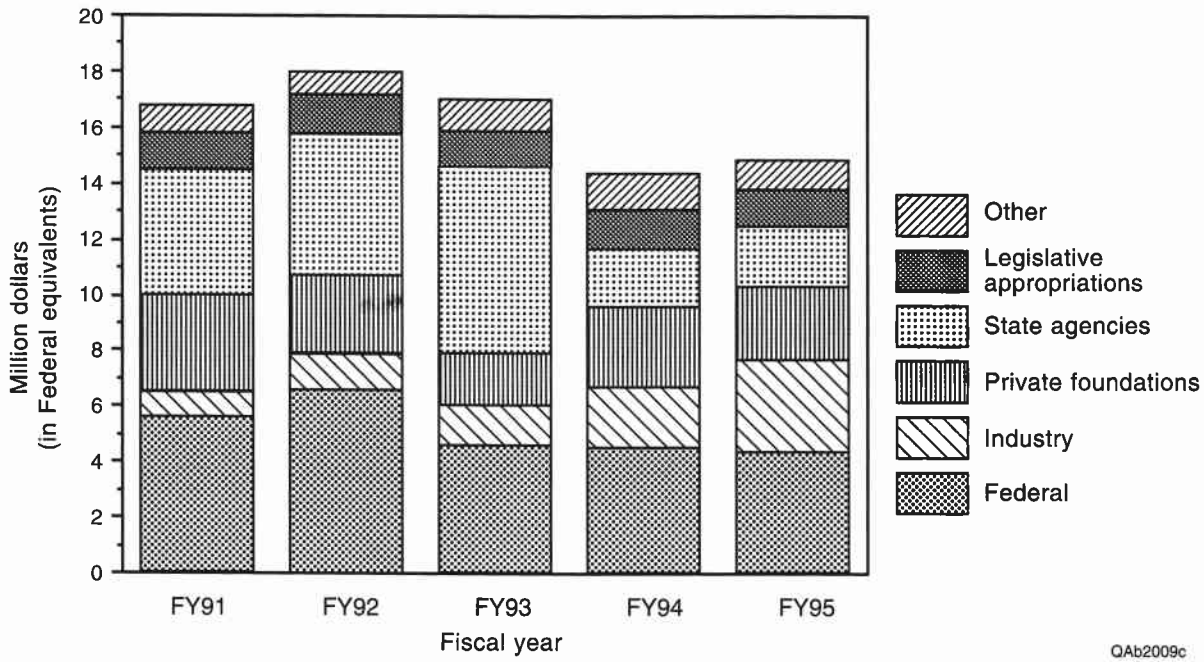
During 1995, quality-assurance personnel participated in six Bureau research projects. In addition to providing guidance to researchers on quality-assurance issues, quality-assurance personnel continued to update and revise the Bureau's Quality Assurance Program and Procedures. James Donnelly, Quality Assurance Specialist, organized a 40-h Basic Health and Safety Course that was taught by the U.S. Environmental Protection Agency at the Bureau. Participants in this course included 13 Bureau researchers and 14 others from a variety of State agencies.

Sources of Funding and Budget Trends

FY 95 SOURCES OF FUNDING



FIVE-YEAR BUDGET TRENDS



QAb2009c

Bureau of Economic Geology

Dr. Noel Tyler, Director

Dr. Robert J. Finley, Associate Director • Dr. Raymond A. Levey, Associate Director
Dr. Thomas W. Grimshaw, Associate Director • Susann V. Doenges, Assistant Director for Publications
Douglas C. Ratcliff, Associate Director • Wanda L. LaPlante, Executive Assistant

Deputy Associate Directors
Dr. Alan R. Dutton
Dr. Richard P. Major
Dr. Jay A. Raney

Program Coordinator
Lynda A. Miller

Senior Research Scientists
Dr. Virgil E. Barnes
Dr. William L. Fisher
Dr. Robert L. Folk
Dr. William E. Galloway
Dr. Thomas C. Gustavson
Dr. Claude R. Hocott
Dr. Martin P. A. Jackson
Dr. Charles Kerans
Dr. Robert A. Morton

Research Scientists
Dr. Mark A. Chapin
Dr. R. Stephen Fisher
Dr. Robert K. Goldhammer
Dr. Edgar H. Guevara
Dr. Bob A. Hardage
Dr. William R. Kaiser
Dr. Larry Lake*
Dr. Stephen E. Laubach
Dr. Stephen C. Ruppel
Dr. Bridget R. Scanlon
Dr. Daniel D. Schultz-Ela
Dr. Steven J. Seni
Dr. Bruno C. Vendeville
Dr. E. G. Wermund
Dr. Christopher D. White

Research Associates
M. Saleem Akhter
William A. Ambrose
Kenneth T. Barrow
Dr. Mark D. Barton
Edward W. Collins
Dr. Alan E. Fryar
Dr. Michael H. Gardner
L. Edwin Garner
Dr. James C. Gibeaut
Roberto Gutierrez
Dr. Douglas S. Hamilton
H. Scott Hamlin
Tucker F. Hentz
Dr. Susan D. Hovorka
Dr. James W. Jennings
Paul R. Knox
Dr. Lee E. McRae
William F. Mullican III
Dr. Jeffrey G. Paine
Dr. Carol L. Ruthven
Dr. Deborah A. Salazar
Steven W. Tweedy
Dr. Fred P. Wang
William A. White
Dr. Brian J. Willis
Dr. Jiannan Xiang

Research Scientist Associates
Edward S. Angle
Janok P. Bhattacharya
David L. Carr
Sigrid J. Clift
Bruce A. Desselle
Chester M. Garrett, Jr.
Richard S. Goldsmith
Mark H. Holtz
Ronald A. Johns
Conrad A. Kuharic
Robert E. Mace
H. Seay Nance
Thomas A. Perreault
Lisa E. Remington
Andrew R. Scott
Jirapa Skolnakorn
Thomas A. Tremblay
Ramón H. Treviño
Roger Tyler
W. Bruce Ward
Joseph S. Yeh

Senior Research Fellows
Robert J. Graebner
F. Jerry Lucia

Research Fellows
Dr. Roger J. Barnaby
Sharon L. Gabel*
Dr. Giovanni Guglielmo, Jr.
Dr. Ursula Hammes
Jerry Mullican
Dr. Luis A. Sánchez-Barreda
Dr. James L. Simmons

Administrative Staff
Jean L. Abernathy
Cordelia Barclay
Robert H. Brinkman
Margaret R. Brinson
Kelly K. Campbell
Donna Cole
Cecil E. Dishman
James A. Doss, Jr.
Patricia O. Downs
Linda N. Ford
Lucille C. Harrell
Vicki A. Heydron
Dana L. Hutto
Mary E. Koch
Sharon G. Lowe
Anne M. Maxim
Glynis G. Morse
Christine A. Mueller
Diane C. Ruetz
Marcia G. Sievert

Computer Resources
Michael T. Kader
Manager
Sharon A. Bierschenk
Dixon E. Coulbourn
Richard D. Edson, Jr.
Rodney I. Heathcott
L. Morgan Ives
W. Gerald White

Publications
Richard L. Dillon
Chief Cartographer
John T. Ames
Michele L. Bailey
William C. Bergquist
Nancy A. Cottington
Barbara M. Hartmann
Randy H. Hitt
Susan N. Krepps
Joel L. Lardon
Patrice A. Porter
Kerza A. Prewitt
Jana S. Robinson
Maria E. Saenz
Scott R. Schulz
David M. Stephens
Teresa L. Weaver

Amanda R. Masterson
Editor-in-Charge
M. Alison Boyd
Lana S. Dieterich
Bobby S. Duncan
Susan S. Hobson
Susan J. Lloyd
K. Jeannette Miether

Margaret L. Evans
Chief Designer
Jamie H. Coggin

Mineral Studies Laboratory
Steven W. Tweedy
Chemist-in-Charge
Richard S. Goldsmith

Core Research Center
Austin Facility
George T. Bush
Curator
Jon D. Boldovici
Joseph D. Coker
Alex Y. Colunga
William H. Doneghy
Mark J. Donnelly
Jordan W. Forman, Jr.
Andy M. Graham
Anselmo S. Jacobo
Leslie B. Kelley, Jr.
Robert G. Richardson
Steven M. Rooks
Robert A. Sanchez
Kenley C. Schroeder

Midland Facility
Andrew Faigle
Robert G. Richardson

Quality Assurance/ Geophysical Log Facility
Douglas C. Ratcliff
Quality Assurance Officer
Mark J. Donnelly
Daniel H. Ortuño

Student Research Assistants
Salah U. Ahmad
Adnan Ahmed
Syed A. Ali
Carlos Amaya
Kazi S. Anwar
Ali F. Azam
Nina L. Baghai
Martha Z. Beltran
Martina U. Blüm
Suhas V. Bodwadkar
Erika M. Boghici
Radu Boghici
Charl A. Broquet
Sarah L. Burns
Chun-Yen Chang
Alistair S. Clague
Andrew P. Czebieniak
Jianchun Dai
James A. Davidson
Dr. Patricia W. Dickerson
Ying Dong
Mustafa M. Erbil
Qing Fang
William M. Fitchen
John F. Gamble
Yugong Gao
Hongxing Ge
Allison J. Goldberg
Silvian Goldenberg
Jubal Grubb
Humayun Hasan
Herbert Haubold
Leipin He
Sung-Chi Hsu
Qi Jiang
Mary K. Johns
Brandy L. Jones
Ian C. Jones
David C. Jordan
M. Raza R. Kakar
Sangram R. Kakulavaram
Senira S. Kattah
Kirt A. Kempter
Hamad A. Khan
Eugene M. Kim
Hye Won Kim
Milton H. Kwong
John A. Kyser
Jiunnren Lai
Chia Nan Liu
Qunling Liu
Khaled H. Matin
Eric M. Matzel
Ronald G. McMurry
Ianthe Nelson
Ravi V. Nigudkar
Kami M. Norlin
Gregg C. Oetting
Jose N. Pecina-Cruz
Clint C. Phillips
Eric J. Phinney
Faisal Rashid
Muhammad Razi
Robert M. Reed
Susan B. Rhode
Nestor V. Rivera
Martha L. Romero
Robert S. Ruetz
Amy K. Sapp
Asad M. Sattar
Naresh D. Sen
Debarshi Sengupta
Kriyanti Setiyono
Kenneth C. Slatton
Laura B. Stewart
Li Sun
Afifa S. Tawfeeq
Pamela L. Taylor
Quoc M. Tran
Matthew M. Uliana
Bhushan K. Veerapaneni
William B. Ward
Christianne Weismantel
James V. White
Chengyan Wu
Huade Yang
Qiucheng Ye
Laura Zahm

*Temporary staff

THE UNIVERSITY OF TEXAS AT AUSTIN
Bureau of Economic Geology
University Station, Box X
Austin, Texas 78713-8924

Address correction requested

NON-PROFIT ORGANIZATION
U.S. POSTAGE
PAID
Austin, Texas
Permit 391