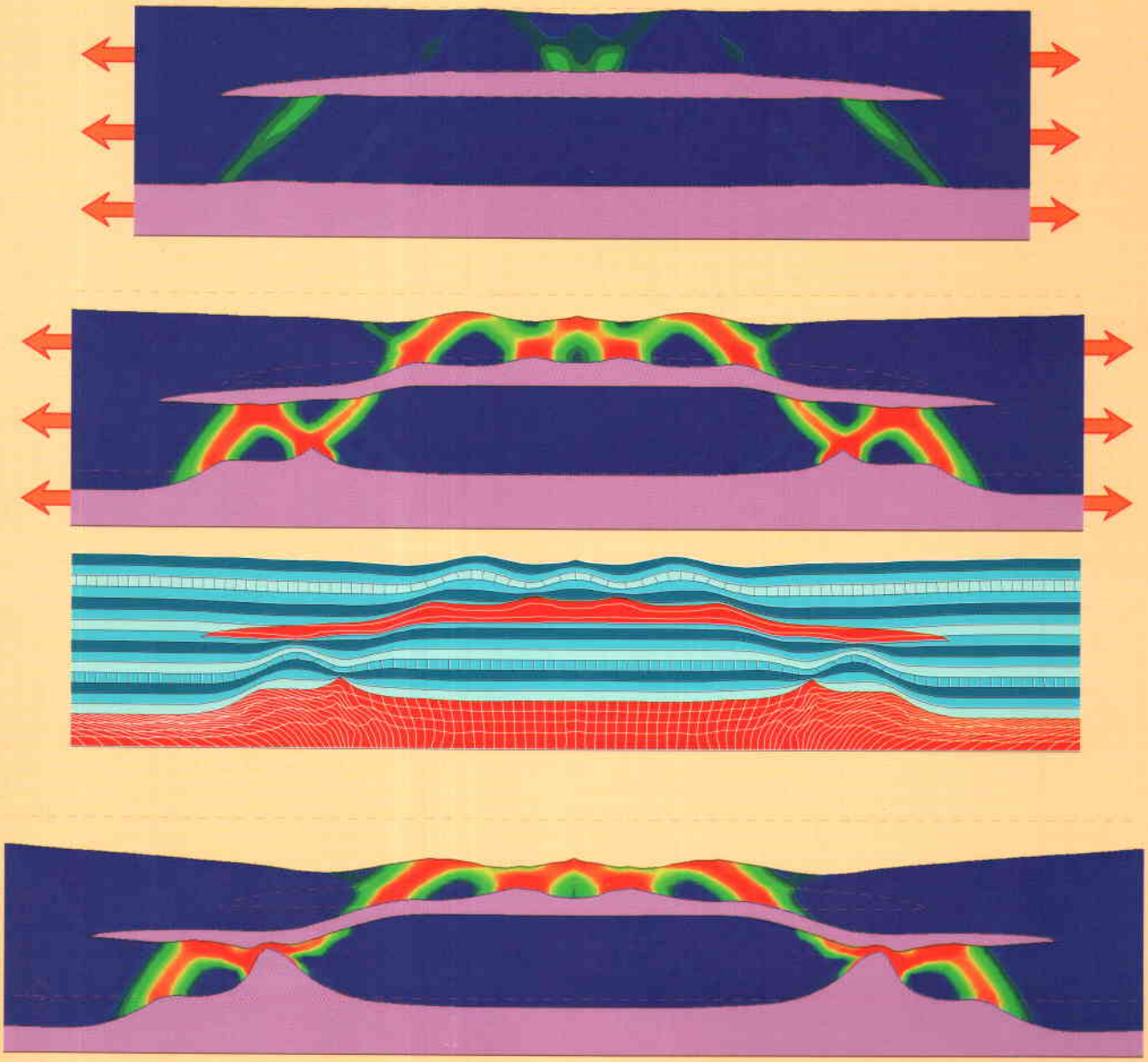
ANNUAL REPORT 1994



MODELING SUBSALT STRUCTURE

BUREAU OF ECONOMIC GEOLOGY

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

Noel Tyler, Director

Foreword

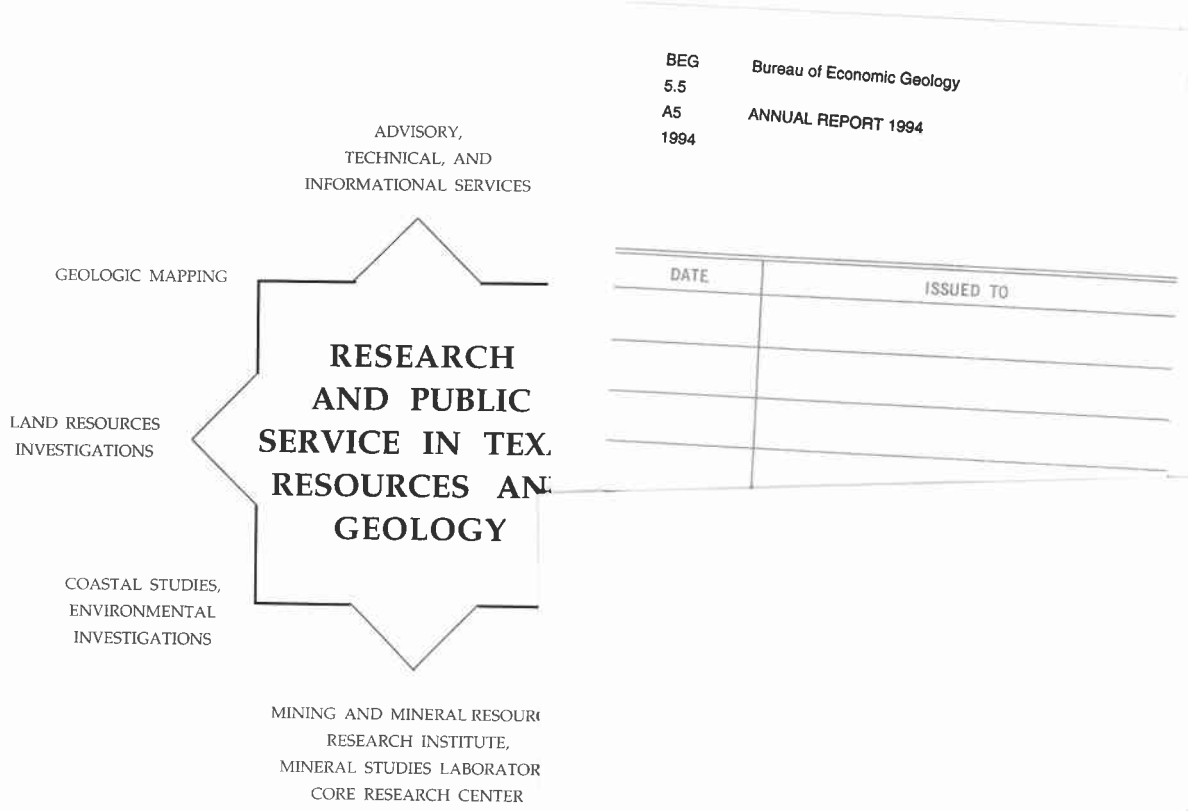
The Bureau of Economic Geology, established in 1909 as the successor to the Texas Geological Survey and the Texas Mineral Survey, is a research entity of The University of Texas at Austin. It also functions as the State Geological Survey, a quasi-State agency, and the Bureau Director represents Texas 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 Texas Mining and Mineral Resources Research Institute is an administrative unit of the Bureau.

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
Geology
research
ties, and
and geo
agencie



BUREAU OF ECONOMIC GEOLOGY

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

ANNUAL REPORT

1994

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

CONTENTS

OVERVIEW

HIGHLIGHTS

RESEARCH

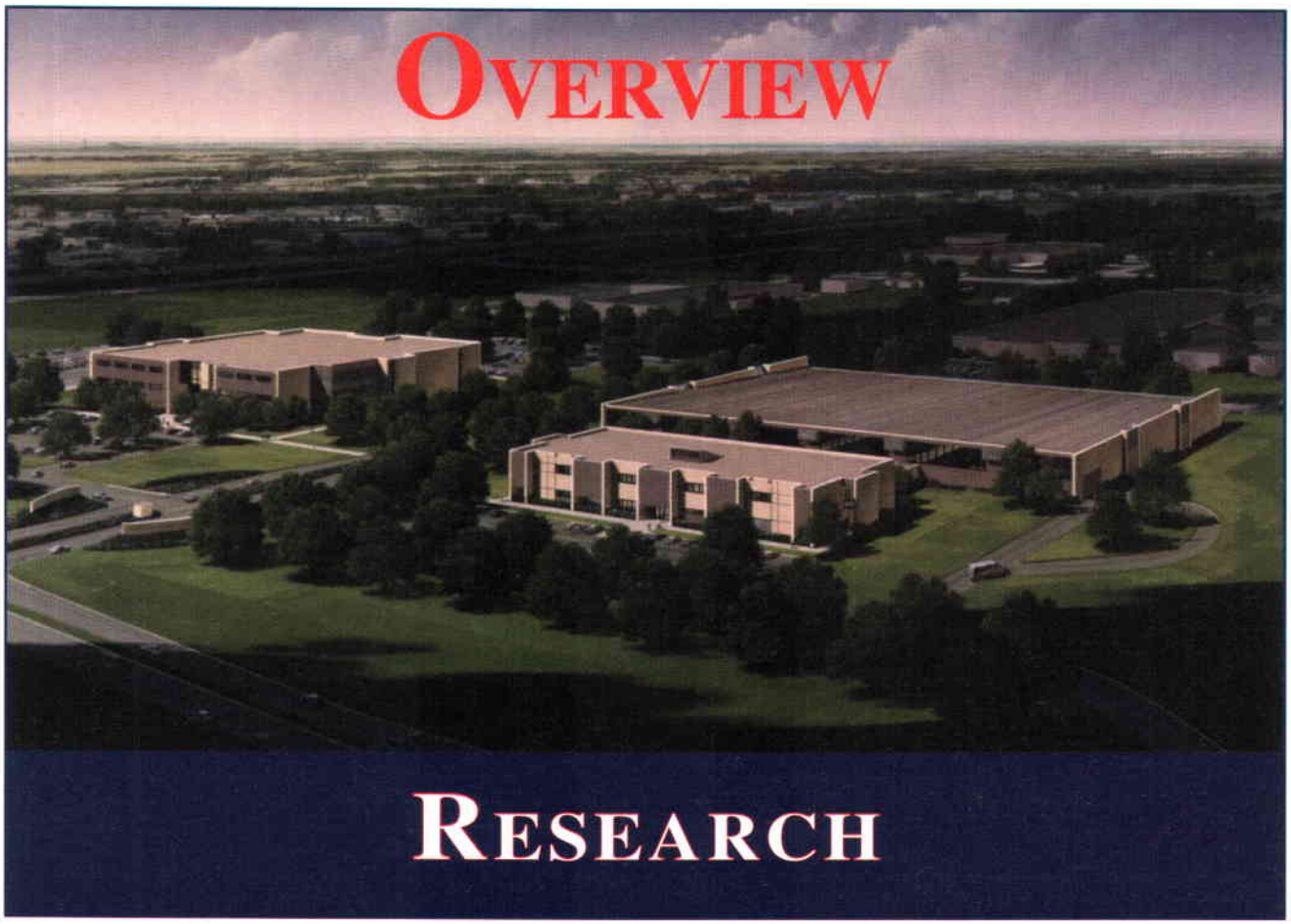
PUBLICATIONS

SERVICES

RESEARCH STAFF ACTIVITIES

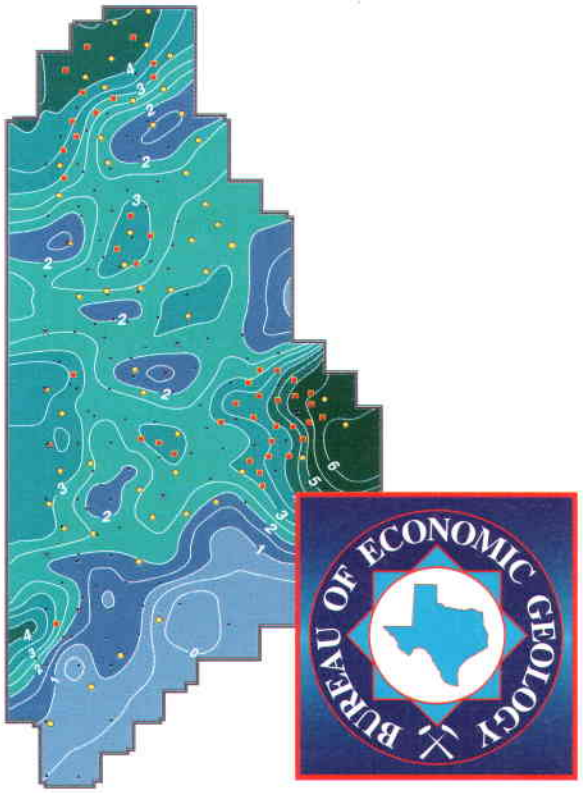
SUPPORT STAFF

BUREAU OF ECONOMIC GEOLOGY



PROGRAM SUPPORT

It has been another challenging year for the U.S. petroleum industry and for funding of related geologic investigations, the traditional realm of much research conducted at the Bureau of Economic Geology. The Bureau's program support remained firm during 1994, however, because the Bureau aggressively expanded its energy-resource and environmental–hydrogeologic investigations. Several new projects were initiated during the year, and others continued from last year. In 1994 the Bureau had an operating budget of $12.2 million from line-item State appropriations and from 56 outside contracts and grants. Of these 56 funding sources, 20 were from interagency contracts with State and local governments and 14 were with the petroleum industry (foreign and domestic) and private institutions. The rest came from various agencies of the Federal government. During the year, the Bureau conducted a total of 48 research projects. Prominent projects active during 1994 are herein described.

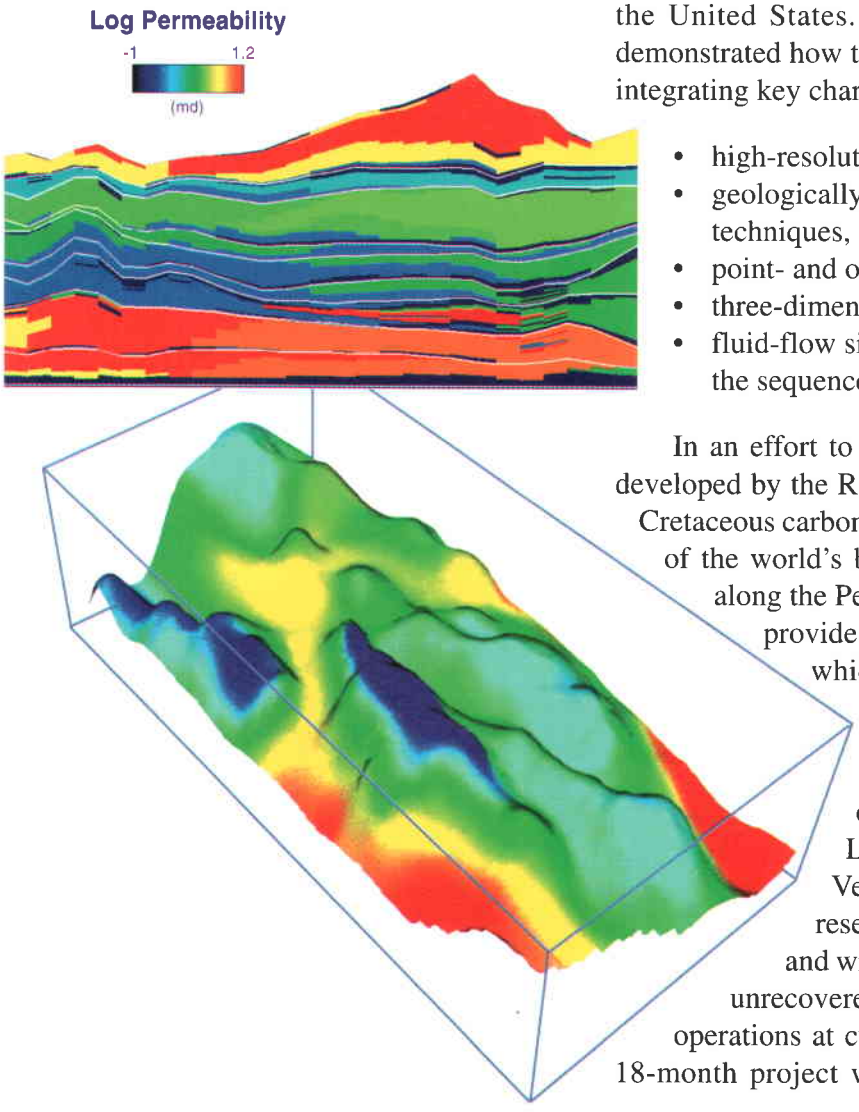


Oil Resource Investigations

One of the major challenges of both the domestic and international hydrocarbon industries in the 1990's has been optimizing recovery from existing oil and gas fields. The Bureau's Reservoir Characterization Research Laboratory (RCRL) investigating carbonate reservoirs was developed specifically to work in partnership with industry to maximize recovery of significant resources remaining in carbonate reservoirs in the Permian Basin. The RCRL, one of the world's leading carbonate reservoir characterization research groups since 1988, has a multidisciplinary team of geologists, petrophysicists, geostatisticians, and petroleum engineers. Financial support comes from an industrial consortium of 20 domestic and international companies and from the U.S. Department of Energy.

For the past 5 years the RCRL has focused on dolomitized shallow-shelf reservoirs of the Permian Basin, which contains a substantial volume of the remaining mobile oil resource in the United States. During this period, the laboratory has demonstrated how to locate remaining oil in existing fields by integrating key characterization technologies such as

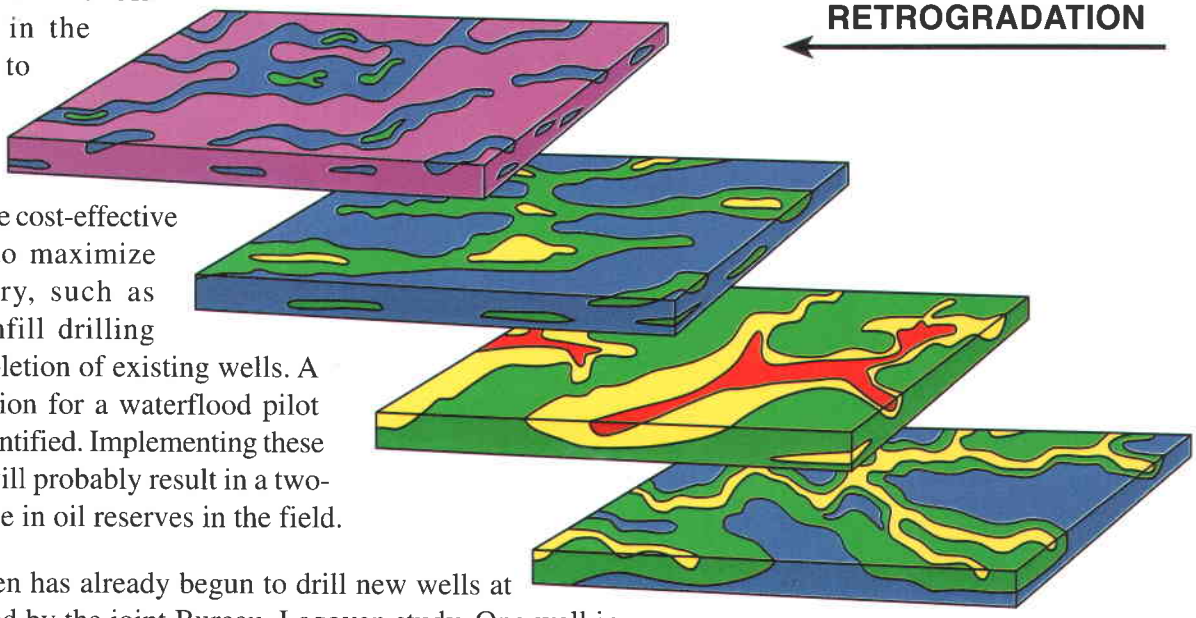
- high-resolution sequence stratigraphy,
- geologically optimized (rock-fabric) petrophysical techniques,
- point- and object-based geostatistics,
- three-dimensional geological modeling, and
- fluid-flow simulation using grids designed to preserve the sequence framework.



In an effort to test the wider applicability of techniques developed by the RCRL, the team has begun new research in Cretaceous carbonate reservoir strata. The availability of one of the world's best Cretaceous reservoir-analog outcrops along the Pecos River Canyon in southwest Texas will provide unique insights into Cretaceous reservoirs, which include many giant fields worldwide from Mexico to the Middle East.

Joining Lagoven, S.A., the Bureau characterized oil reservoirs in a part of Lagunillas field at Lake Maracaibo, Venezuela. These tide-dominated deltaic reservoirs have a complex internal geometry and will contain more than 900 million barrels of unrecovered mobile oil at the end of primary recovery operations at current technology levels. The goal of this 18-month project was to identify the geologic controls on

residency of the oil remaining in the reservoirs, to quantify the oil remaining, and to devise cost-effective strategies to maximize oil recovery, such as strategic infill drilling and recompletion of existing wells. A prime location for a waterflood pilot was also identified. Implementing these strategies will probably result in a two-fold increase in oil reserves in the field.



Lagoven has already begun to drill new wells at sites targeted by the joint Bureau–Lagoven study. One well in the north part of Lagunillas field, completed in the summer of 1994, produced approximately 450 barrels of oil per day. This BEG–Lagoven study can serve as a model for improving oil recovery in other mature, petroleum-producing provinces of Venezuela, where many fields are nearing the first stages of primary depletion. Other countries in which the Bureau is currently conducting energy-resource investigations include Brazil, Colombia, and Australia (where a new-field wildcat well testing thick channel sands identified by the Bureau made a new discovery that produced 5.5 million cubic feet of gas and 220 barrels of condensate per day).

Natural Gas Resource Investigations

Research from the Bureau's Secondary Natural Gas Recovery (SGR) project continues to influence economic strategies of Texas natural gas operators directly. Bureau research into infield natural gas reserve growth has proven that reexploration in fields more than 50 years old can economically recover natural gas. The McFaddin "A" No. 62 infield well, strategically targeted by SGR research and drilled in North McFaddin field by an independent producer in Corpus Christi, continues to produce at rates exceeding 1 million cubic feet of gas per day from two reservoir zones. Recompletions targeted by SGR research in Agua Dulce field also continue to produce at economic rates from previously bypassed, incompletely drained, and new infield reservoirs. Operators in adjacent

properties in the Texas Gulf Coast are starting to pursue these additional resources aggressively by acquiring three-dimensional seismic data, performing recompletions, and drilling new infield wells.

The goal of the Bureau's Tight Gas Sands project, funded by the Gas Research Institute, is to increase development efficiency of low-permeability sandstone gas reservoirs. Such reservoirs result from facies variations produced by different modes of deposition and subsequent histories of burial, physical compaction, cementation, and deformation.

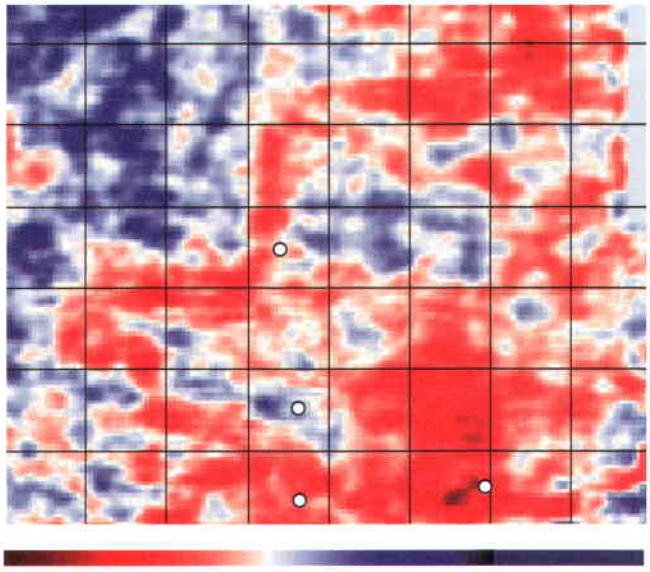
A highly acclaimed technical seminar on geological characteristics and production of a challenging gas play in West Texas epitomized the project. The Midland seminar on the Canyon Sandstone play documented, on a regional scale, stratigraphic, diagenetic, and structural variability and showed how these factors govern production and successful play development and detailed new geological mapping tailored to the slope and basin depositional setting of the formation. A survey of more than 350 registrants showed that operators will use this information and these approaches to aid in well placement and completion decision making and to reduce development risk.

The focal points of 1994 project research were the Paleozoic Canyon Sandstone of West Texas and the Tertiary Wilcox Lobo sandstone of South Texas and Mexico, two of the most active and potentially important low-permeability (tight) sandstone reservoirs in the United States. Canyon research ended with the Midland technical seminar and the publication of a Gas Research Institute topical report. Another element of project research in 1994 was a generic natural-fracture study that focused on developing and verifying new methods for predicting fracture attributes. Such information is critical for profitably targeting fracture-controlled, high-deliverability zones in many sandstone reservoirs.

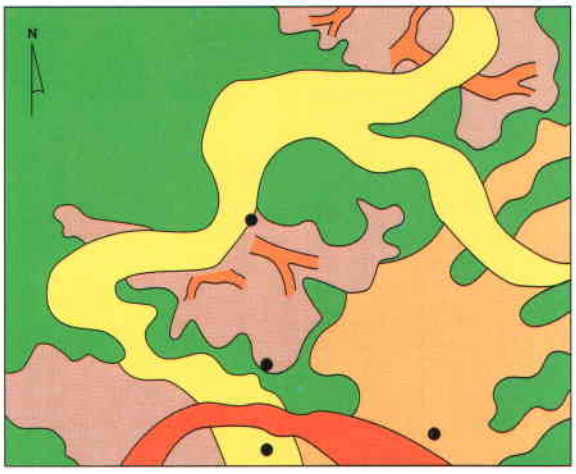
Geophysics: Three-Dimensional Seismic Applications

The Bureau continues to expand its three-dimensional seismic research and technology transfer. Previous (1992–93) fieldwork to gather three-dimensional seismic data concentrated on South Texas, where vibroseis energy sources were used to generate images of reservoir architecture in survey areas ranging in size from 1.5 to 7.5 square miles (mi^2). Currently the Bureau is active in the Fort Worth Basin, where shallow, 10-oz explosive shots have been used to produce broadband reflection data for imaging thin Pennsylvanian reservoirs over a 26-mi^2 study area.

In all of these field activities, the Bureau (1) performs wavetests to determine which seismic source and what type of receiver array geometry is optimal for the area, (2) records vertical seismic profile (VSP) data that calibrate stratigraphic depth to seismic travel time, (3) specifies and monitors the data recording and processing done by contractors, and (4) uses geologic and engineering control to interpret three-dimensional images of the targeted reservoir systems. Interpretation is done in-house.



This research has demonstrated how using VSP data can guide the interpretation of three-dimensional data in producing high-resolution images of individual thin-bed reservoirs in closely stacked thin-bed sequences. Integrating seismic data within the geologic and engineering framework helps the Bureau accurately identify reservoir compartment boundaries. On the basis of successful imaging detail produced in South Texas, operators duplicated the Bureau's three-dimensional field procedures and extended one of the Bureau's surveys to cover an additional 45-mi^2 area. To date, three wells have been drilled on the basis of this Bureau-developed technology, and additional wells are planned. In the Fort Worth Basin, operators that have leases inside the Bureau's 26-mi^2 study area will begin drilling once the three-dimensional images and accompanying geologic and engineering control have been integrated into a final interpretation by Bureau researchers.

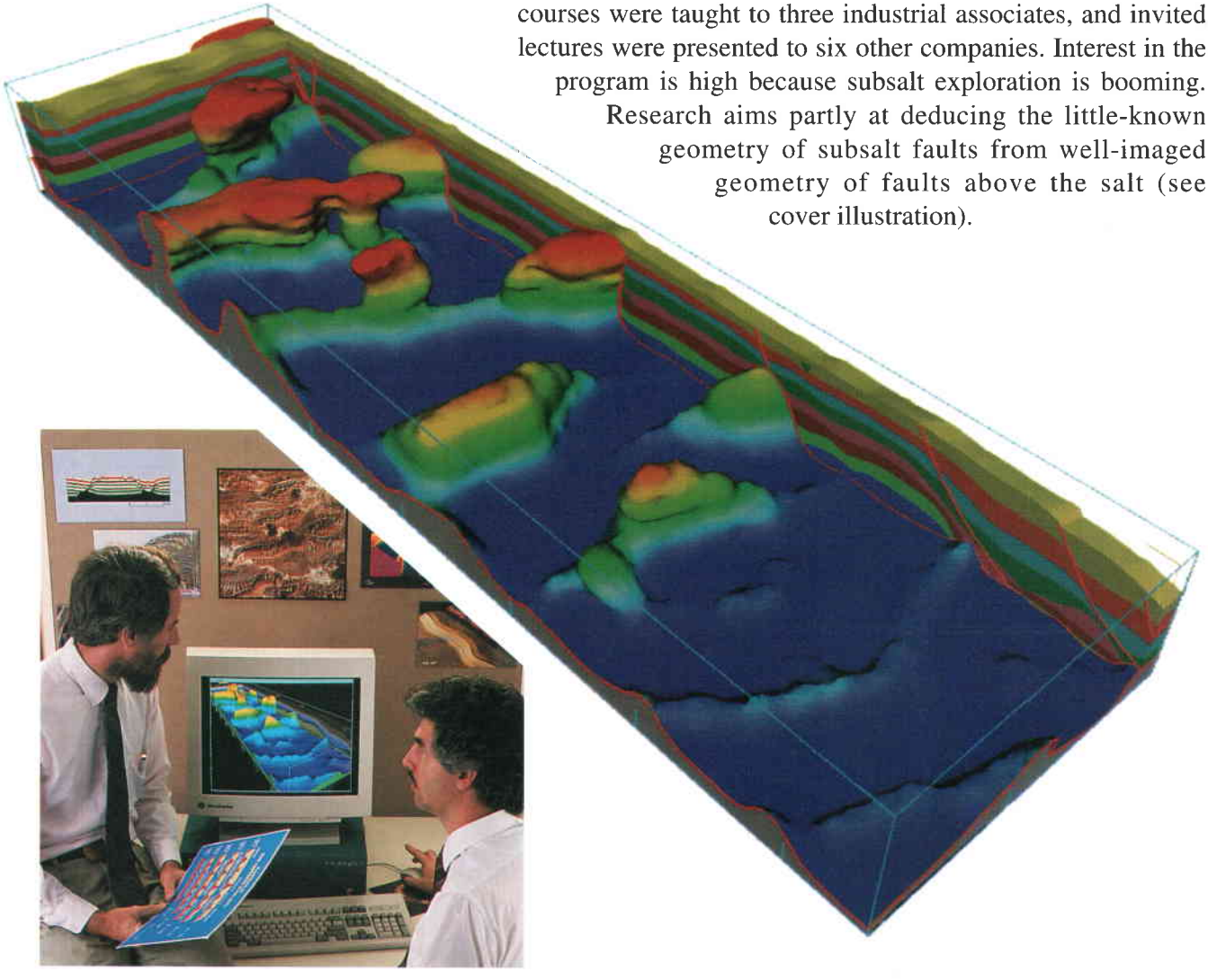


During the year, the Bureau presented three-dimensional seismic technology short courses and workshops in Dallas, Houston, and San Antonio, Texas; Oklahoma City, Oklahoma; and Wichita, Kansas. More than 700 people from large and small independent oil and gas companies attended these technology transfer sessions.

TECTONIC MODELING

The Applied Geodynamics Laboratory not only investigates the evolution of structural hydrocarbon traps but also develops new concepts to predict where, how, and why such traps are formed 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 focuses mostly on physical and numerical modeling aided by seismic interpretation and fieldwork. Results are intended to be used by oil companies for exploring, developing, and training.

Over its 6-year life, the project has received five grants from the Texas Advanced Research Program and Advanced Technology Program. Main support, however, comes from a consortium of industrial associates. The program added 2 new members this year, bringing the total to 17 oil companies, 6 of which are based overseas. During the year, two slide sets were distributed to the industrial associates, presentations were given to all industrial associates at the annual meeting, short courses were taught to three industrial associates, and invited lectures were presented to six other companies. Interest in the program is high because subsalt exploration is booming. Research aims partly at deducing the little-known geometry of subsalt faults from well-imaged geometry of faults above the salt (see cover illustration).



Hydrogeology and Environmental Investigations

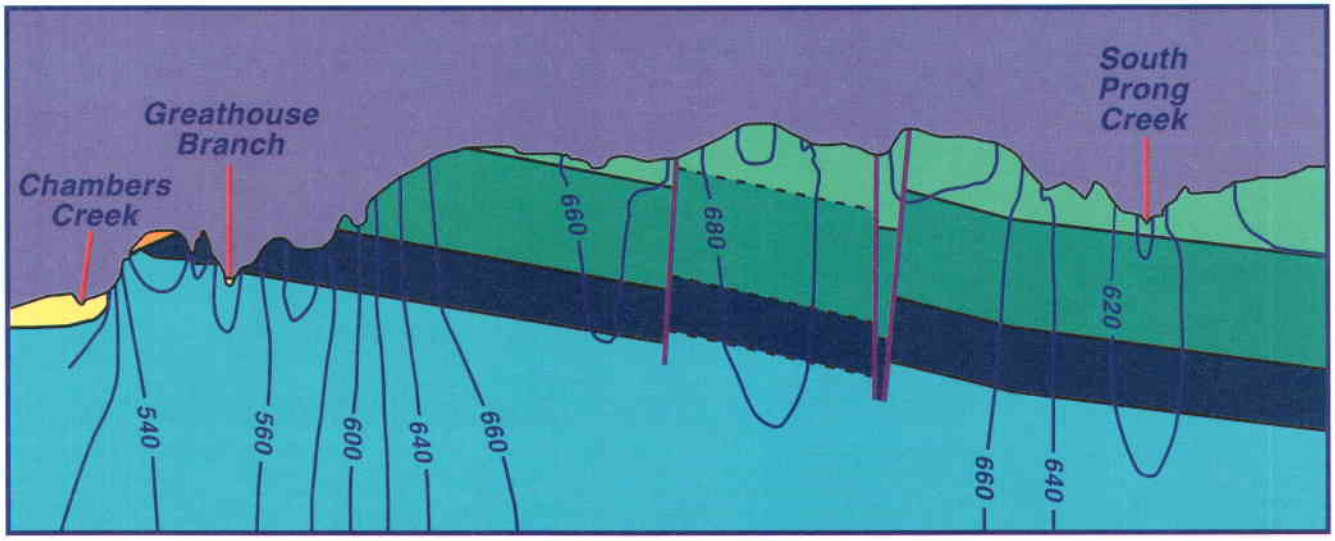
Ground-water and contaminant-containment projects compose a large and ever-growing part of Bureau research. Major investigations are currently under way at the U.S. Department of Energy Pantex Plant near Amarillo on the Southern High Plains, the Texas low-level radioactive waste repository in West Texas, and the Superconducting Super Collider (SSC) site south of Dallas. These projects make use of field and laboratory measurements, interpreted and tested by advanced numerical modeling, to document hydrogeologic and geochemical controls on three-dimensional movement of subsurface water and contaminants. They also employ other advanced analytical techniques, such as shallow subsurface geophysical surveys (seismic reflection and refraction); electromagnetic conductivity surveys; ground-penetrating radar; resistivity surveys; and telluric-current analyses, which enable nonintrusive study of subsurface geologic and ground-water properties needed in aquifer modeling and contaminant plume detection.

Numerical models supported by field measurements use state-of-the-art geologic concepts, such as aquifer heterogeneity and long-term flow evolution on local and basin scales. Insights from a regional model of ground-water resources in Lower Cretaceous sandstones beneath the SSC site are valuable to the many small rural water-supply corporations that obtain their ground water from wells in the region. Other models are used to evaluate the effectiveness of the low-level radioactive waste repository.

The Pantex Plant is the national site for assembling, maintaining, and disassembling nuclear weapons. Bureau scientists' interdisciplinary and collaborative studies of the geology, hydrology, and geochemistry of subsurface water of the High Plains at the Pantex Plant have shown that recharge occurs beneath playa basins through the porous matrix and through preferential flow paths in heterogeneous unsaturated deposits. Seismic reflection surveys show that subsidence beneath playa basins was probably related to dissolution of Permian evaporites and collapse of overlying strata.

According to the U.S. Environmental Protection Agency, nonpoint source pollution is the largest single category of contamination affecting the Nation's waters. Bureau research targets improving land management methods to control agricultural nonpoint source pollution, which requires understanding the geology and hydrology of soils, bedrock, and aquifers, as well as social and economic impacts of waste-management practices. Field studies this year focused on the Upper North Bosque River watershed in Erath County. Nitrate and ammonium in soils and surface waters were found to have distinctly different $\delta^{15}N$ compositions, which allowed workers to discriminate between sources of animal waste and fertilizer. Having established and tested laboratory and field procedures, the Bureau is now prepared to begin watershed-scale investigations of nonpoint source contamination of surface- and ground-water systems.

In 1994, Bureau scientists completed comprehensive reports on faults and joints in the Austin Chalk and on the occurrence and movement of ground water near the SSC site in Ellis County. Maps of the Austin Chalk exposed in a 9.4-mi-long section of SSC tunnel have an unmatched resolution of normal-fault and joint populations within the north end of the Balcones Fault Zone. Statistical delineation of fracture-swarm frequencies and detailed illustration of fault and joint terminations provide important insights into spacing and size distribution of faults and joints. These data can be used for improving structural models and guiding interpretation of conventional borehole and outcrop data. They have applications in (1) modeling of ground-water flow and contaminant transport through fractured rock and (2) horizontal drilling of oil and gas wells.



Highlights

Noel Tyler Assumes Bureau Directorship

After 34 years' service at the Bureau, William L. Fisher stepped down as Director to assume full-time teaching and research duties in the Department of Geological Sciences at The University of Texas at Austin, where he holds the Leonidas T. Barrow Centennial Chair in Mineral Resources. Bill Fisher ably held the position of Director since 1970, and under his guidance the Bureau became one of the largest and most accomplished state geological surveys. During his tenure, the Bureau greatly expanded its scope of research and related geological services. Noel Tyler succeeded Fisher as Bureau Director in September 1994. Noel, a Bureau researcher since 1981, was most recently active in managing and developing the Bureau's multi-project oil resources program and in developing new sources of related funding in his capacity as Associate Director overseeing the Bureau's Oil Resources Program. He has published extensively in the fields of reservoir development geology and basin and facies analysis, and he has considerable international experience in geologic research.

Bureau Wins Major Award for Its Ongoing Research in Oil Recovery in the Permian Basin

In the fall of 1994, the Bureau of Economic Geology was named one of the Hart's Best of the Southwest winners by the annual award's sponsor, Hart Publications, publisher of *Oil and Gas World Magazine*. The Bureau won in the Best Advanced Recovery Project category in recognition of its past and present studies of oil recovery on University and State lands in the Permian Basin of West Texas. The Bureau's body of research includes 127 articles and reports, 55 lectures, and numerous short courses on Permian Basin geology. The award was presented by Don Lyle, Editor of *Oil and Gas World Magazine*, at the annual Kick-Off and Awards meeting of the Permian Basin Petroleum Association held in Midland, Texas.

Bureau representatives accepting the Best of the Southwest Award presented by Hart Publications, publisher of Oil and Gas World Magazine. Pictured from left to right are William L. Fisher and Douglas C. Ratcliff, Bureau of Economic Geology; Don Lyle, Oil and Gas World Magazine (Editor); and Larry Combest, U.S. House of Representatives. Photograph by David M. Stephens.

Bureau Convenes Global Gas Workshop

The Bureau, on behalf of the Gas Research Institute and Gas Technology Information, Inc., convened a global gas resources workshop in Vail, Colorado, September 19–21, 1994. The workshop was sponsored by the International Centre for Gas Technology Information (ICGTI), a new research entity affiliated with the International Energy Agency (IEA). ICGTI was established in September 1993 by 11 member countries of the IEA to support the growth and internationalization of the gas market by promoting the exchange of gas technology and market information.

The purpose of the workshop was to assess estimates of the worldwide gas resource base and the magnitude of reserves that could be added by applying advanced technology. Senior officials from international operating companies, state-owned energy companies, governmental organizations, universities, and research institutions from 20 countries and 6 continents participated. It was the first time in 15 years that a group of international resource experts gathered to address the issue of the impact of new technology on natural gas resources.

Workshop participants concluded that the global natural gas resource base could increase by as much as 25 percent by the year 2015 with a full deployment of advanced technology. In some areas of the world, the increase in gas resources as a result of advanced technology could be as much as 80 percent.

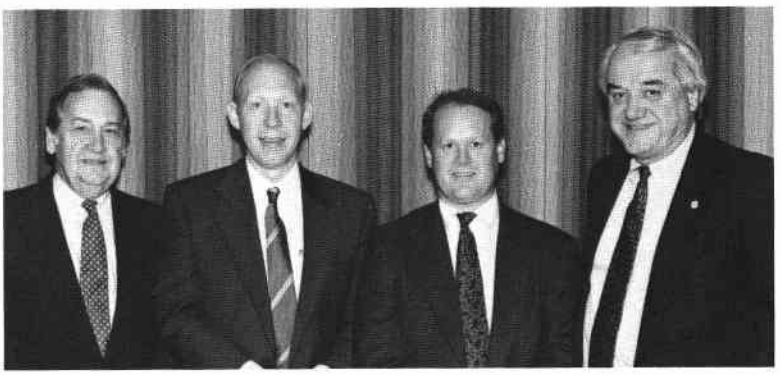
A proceedings volume, which includes a summary of the findings and implications of the workshop, was published in late 1994. Results of the workshop are being used by sponsoring members of the ICGTI to guide discussions by government officials, policy makers, and senior management on the role of natural gas in national energy policies and energy strategies. The results of the workshop will also guide the ICGTI in accelerating the future transfer of gas technology on a global basis.

Bureau Establishes Midland Core Research Center

Shell Oil Company and Shell Western E&P, Inc., have donated a 32,700-ft^2 building on 3.7 acres in Midland, Texas, to The University of Texas System. The building has a core examination room, a processing room for slabbing core, almost 259,000 boxes of samples and core, as well as office space. Shell has also donated geological materials from the Holmes Road warehouse in Houston, Texas, which includes whole core, slabbed core, sidewall samples, and drill-bit cuttings.

After the Board of University of Texas System accepted this gift, Shell Oil Company and Shell Western E&P, Inc., established the Hubert Collins Endowment for the Bureau of Economic Geology. The endowment was made in recognition of the dedication and years of service Mr. Collins gave to Shell as the General Manager of the Midland Core Warehouse; it will be used to maintain the facility in the future.

The facility will be open for operation between the hours of 8 a.m. and 5 p.m., Monday through Friday. Materials will be organized according to protocols followed by the Bureau's Core Research Center in Austin. This collection's data will be incorporated into the Bureau's existing data base, allowing patrons of the new facility to access these data, as well as those at the Core Research Center in Austin.



Executives attending the official presentation of the Midland Core Warehouse to The University of Texas System. Pictured from left to right are William L. Fisher, former Director, Bureau of Economic Geology; William White, Deputy Secretary, U.S. Department of Energy; William K. Dirks, New Field Exploration Manager, Shell, U.S.A.; and Marcus E. Milling, Executive Director, American Geological Institute.
Photograph by David M. Stephens.

Bureau Workshop on the Canyon Sandstone Play Attracts Record Audience

A workshop on the Canyon Sandstone natural gas play of the Val Verde Basin of West Texas attracted more than 350 participants, more than seven times the expected turnout, from throughout Texas and the U.S. to the Midland Convention Center in Midland, Texas. The workshop was co-sponsored by the Gas Research Institute, the West Texas Geological Society, and the Bureau of Economic Geology. Officials of the West Texas Geological Society, which hosted the workshop, stated that it was the best attended seminar of their seminar series in several years. The large turnout reflects the high interest, not only in the play itself but also in the Bureau's ongoing research of the formation.

The workshop covered Bureau research on the complex stratigraphy and highly variable formation of the reservoirs, which present the biggest challenges to finding and producing Canyon Sandstone gas. Among the topics discussed were geological exploration and development mapping tailored to the submarine-fan depositional setting of the Canyon. According to an audience survey, operators will be able to apply these approaches to identify areas favorable for development. Survey respondents also said that the workshop provided a comprehensive review that will aid in making decisions and reducing risks during the development of Canyon gas resources.

Bureau workshops on technology transfer to industry are an ongoing part of many Bureau projects, including Secondary Gas Recovery, a project focused on reserve growth in conventional-permeability natural gas reservoirs.

Bureau Co-Hosts First North American Rock Mechanics Symposium

The North American Rock Mechanics Symposium, established by the International Society for Rock Mechanics, the U.S. National Committee for Rock Mechanics, la Sociedad Mexicana de Mecanica de Rocas, and the Canadian Rock Mechanics Association, was held in Austin from May 30 through June 4, 1994. This biennial conference, hosted by the Bureau of Economic Geology and the Department of Civil Engineering, The University of Texas at Austin, is a principal forum at which attendees critically review research in progress and engineering achievements of the North American rock mechanics community. Priscilla P. Nelson of the Department of Civil Engineering and Stephen E. Laubach of the Bureau co-chaired the symposium. Because a mutual dependence of Canadian, Mexican, and United States economies has now been formally recognized by the North American Free Trade Agreement, the basic economic role of rock mechanics in resource recovery and construction industries in the three countries takes on new relevance. The Austin symposium focused on the challenges facing the petroleum, civil, and mining industries and the research that can meet these challenges. The symposium was enormously successful, drawing a large and enthusiastic audience from around the world.

Bureau Personnel Play Prominent Role in 1994 Gulf Coast Association of Geological Societies Convention

The 1994 annual joint convention of the Gulf Coast Association of Geological Societies (GCAGS) and the Gulf Coast Section of the Society of Economic Paleontologists and Mineralogists was held in Austin and was hosted by the Austin Geological Society. Bill Fisher, as current president of GCAGS, heads a list of Bureau scientists who were an integral part of the successful 1994 convention. Non-Bureau members of the Austin Geological Society also had many key responsibilities in organizing and operating the convention. Prominent among Bureau contributors, Shirley Dutton was Program

Chairman of the convention, which had the largest program in the event's 44-yr history. Additionally, R. P. Major and Susann V. Doenges were Editor and Managing Editor, respectively, of the 792-page GCAGS *Transactions* volume, which comprises 85 technical papers and 43 abstracts, one of the largest collections of study descriptions ever presented at a GCAGS convention. Other Bureau scientists acted in various capacities—9 as chairpeople, 18 as members of organizing committees, and 7 as associate editors of the *Transactions* volume.

Bureau researchers E. G. Wermund, recipient of the 1993 GCAGS Distinguished Service Award, and William L. Fisher, 1994 GCAGS President, banter at the 1994 annual GCAGS conference, hosted by the Austin Geological Society. Photograph by David M. Stephens.

Public Education Highlights

For many years the Bureau has been a resource for Texas Earth Science teachers. This year, however, Bureau staff attempted to reach out to public school teachers more directly by participating in teachers' conferences and workshops.

Bureau personnel conducted a 1-day educational seminar for secondary school Earth Science teachers as part of the GCAGS 1994 convention that convened in Austin in October. Fifty-two Earth Science teachers from Central Texas attended the seminar. The seminar's goal was to establish an informal association between the GCAGS and Earth Science teachers to help enhance geological science teaching in Texas. Guest lecturers spoke on a wide range of topics, from planetary geology to classroom funding to curricula instruction. The seminar was designed to be educational as well as entertaining, and each teacher received a comprehensive informational packet that will be useful in locating educational resources. Educational literature was collected from many Federal and State agencies, as well as from the private sector. The Bureau provided packets with maps and an abbreviated list of Bureau publications that might interest elementary and secondary school teachers.

The Bureau displayed materials in a booth at the Annual Conference for the Advancement of Science Teaching (CAST) held in October in Beaumont, Texas, that was attended by more than 3,000 science teachers. The booth featured selected Bureau publications that would be useful to teachers in designing their curricula. Free page-size geologic maps were distributed with the abbreviated publications list.

Senior Researcher Don Bebout Retires

Don Gray Bebout retired in December after 21 years of dedicated service to the Bureau. Don first joined the Bureau in 1972 after 13 years with Exxon Production Research Company, where he first utilized his career-long interest and expertise in carbonate facies and diagenesis. In 1979, Don temporarily left the Bureau to accept the joint positions of Professor in the Department of Geology at Louisiana State University and Director of Research of the Louisiana Geological Survey. Don returned to the Bureau in 1982, where he remained until his retirement.

While with the Bureau, Don conducted and supervised various projects in subsurface geology, particularly of the Texas Gulf Coast and Permian Basin. Don published prolifically, authoring or co-authoring 67 books, articles, and maps. Moreover, he served on the thesis and dissertation committees of 39 graduate students at The University of Texas at Austin and Louisiana State University. Notable among his numerous professional society activities are presidency of the Society of Economic Paleontologists and Mineralogists, Gulf Coast Section (1983–84), and American Association of Petroleum Geologists Distinguished Lecturer (1979–80). Don attained the position of Senior Research Scientist at the Bureau, prominent testimony of his respected international reputation among specialists in Gulf Coast and carbonate geology.

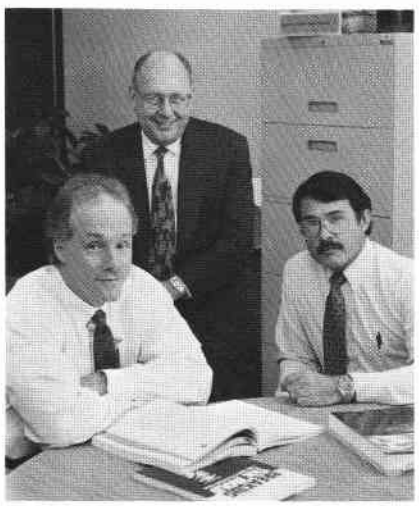
Awards and Honors

Shirley P. Dutton and **Noel Tyler** have been elected Fellows of the Geological Society of America. The National Academy of Engineering recognized the lifetime professional achievements of **William L. Fisher** by electing him as a member. He also received the 1994 Sidney Powers Memorial Medal, the highest annual award presented by the American Association of Petroleum Geologists, and was made an honorary member of the Association of American State Geologists. The Distinguished Service Award of the Association of American State Geologists went to **Dr. Fisher** as well. Finally, he served as the National Research Council Distinguished Lecturer in Geoscience Policy during 1994.

Martin P. A. Jackson and **Bruno C. Vendeville** won Honorable Mention for Excellence in Oral Presentation from the SEPM (Society for Sedimentary Geology) for their paper titled "Extreme Overthrusting and Extension above Allochthonous Salt Sheets Emplaced during Experimental Progradation" presented at the 1993 SEPM/AAPG Annual Convention. **Andrew R. Scott, Roger Tyler, Douglas S. Hamilton,** and **Naijiang Zhou** also received Honorable Mention for the Energy Minerals Division Best Poster Award at the 1994 American Association of Petroleum Geologists Annual Meeting in Denver, Colorado. Their paper was titled "Coal and In-Place Gas Resources of the Greater Green River Basin, Wyoming and Colorado." The 1993 Second-Place Best Paper award of the Gulf Coast Association of Geological Societies went to **William A. Ambrose, Raymond A. Levey**, José M. Vidal, Mark A. Sippel, James R. Ballard, David M. Coover, Jr., and Walter E. Bloxsom for their paper "Secondary Natural Gas Recovery in Mature Fluvial Sandstone Reservoirs, Frio Formation, Agua Dulce Field, South Texas." The paper was presented at the 1993 Gulf Coast Association of Geological Societies (GCAGS) convention.

Roger Barnaby's presentation, "Resource Optimization through Characterization of Downdip Frio Shoreface/Shelf Sandstone Reservoirs: Red Fish Bay Field, South Texas," coauthored by Raghu Ramamoorthy and Mark Holtz, won the third-place award among oral presentations at the 1994 GCAGS Convention. The West Texas Geological Society and the Permian Basin Section of the Society of Economic Paleontologists and Mineralogists have awarded **Charles Kerans** their annual Distinguished Service Award. **Joel L. Lardon**, a Bureau Computer Illustrator, received the prestigious 1994 University of Texas Employee Excellence Award, which recognizes consistent, high-level performance. The award is presented annually to a select group of University employees chosen by a special committee from hundreds of nominees. **Noel Tyler** received the 1994 Honor Alumnus Award from the College of Natural Resources at Colorado State University.

New Research Staff



Research staff who joined the Bureau during 1994 (left to right): James L. Simmons, Jr., Thomas W. Grimshaw, and Luis A. Sánchez-Barreda. Photograph by David M. Stephens.

As an Associate Director, **Thomas W. Grimshaw** will be overseeing new program development at the Bureau. Initially, most of Tom's efforts will be to expand the Bureau's environmental research. Formerly with Radian Corporation and most recently with IT Corporation, Tom brings to the Bureau more than 20 years of experience in environmental study and management of environmental programs. He received his Ph.D. at The University of Texas at Austin. **Luis A. Sánchez-Barreda** joined the Bureau to coordinate and assist the projects of the Latin American program. Luis received his Ph.D. in geology from The University of Texas at Austin and worked for Pecten International (Shell Oil Co.) for more than 8 years, where his area of responsibility was Latin America New Ventures. After leaving Pecten, he formed a consulting company, where he is the senior consultant. **James L. Simmons, Jr.**, a Post-Doctoral Fellow at the Bureau, received his Ph.D. in geophysics from The University of Texas at Austin. Jim is currently involved with the Secondary Gas Recovery Project, where he is conducting 3-D seismic interpretation and other aspects of exploration geophysics.

Research

Energy Resources Investigations

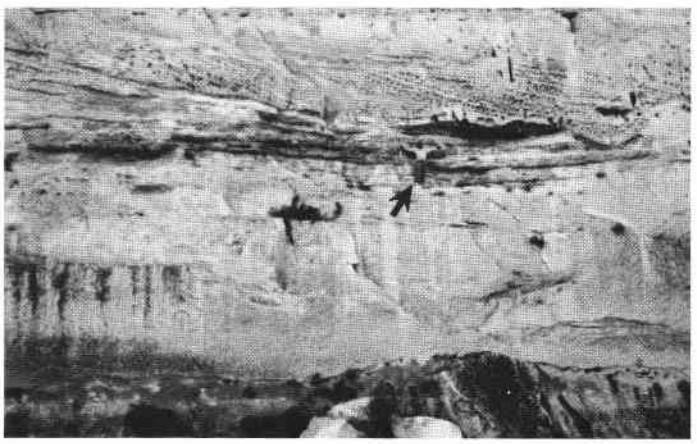
Petroleum

Reservoir Characterization Research Laboratory: Characterization of Carbonate Reservoirs

F. Jerry Lucia and Charles Kerans, principal investigators; Fred P. Wang; assisted by Andrew P. Czebieniak, Kirt A. Kempter, Gena B. Yun, Lisa E. Remington, Huade Yang, and Qiucheng Ye

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 for the purpose of (1) providing quantified geologic–petrophysical models for input into reservoir simulators to improve predictions of reservoir performance and (2) mapping the distribution of remaining hydrocarbons. This research is funded by the RCRL Industrial Associates sponsors, including Amoco, ARCO, BP, Chevron, Elf Aquitaine, Exxon, Fina, JNOC, Oxy, Pennzoil, Phillips, Production Development Oman, Shell, Texaco, TOTAL, and UNOCAL. In addition, the program is supported by StrataModel, Western Atlas, Terra Science, and OGCI, companies that provide state-of-the-art software.

The approach is to combine study of outcrop analogs of major reservoir types with subsurface reservoir studies. The outcrop is important because it provides the only opportunity to study the interwell environment both petrophysically and stratigraphically. Detailed stratigraphic and petrophysical models of the interwell environment can be developed from outcrop studies, and subsurface reservoir studies provide a means for developing methods for applying this information to analogous reservoirs.



Large-scale cross-stratification within platform-margin skeletal shoal complex from the Cretaceous (upper Albian) Devils River trend. These grainstone shoals and associated rudist mound facies are the subject of a reservoir-analog outcrop study along the Pecos River, southwest Texas, being carried out by the Carbonate Reservoir Characterization Research Laboratory. Use figure at arrow for scale. Photograph by Charles Kerans.

Initial studies have focused on San Andres and Grayburg reservoirs of the Permian Basin because of (1) the vast hydrocarbon resource remaining in these reservoirs and (2) the world-class outcrop of these formations in the nearby Guadalupe Mountains. Outcrop studies of the San Andres Formation have shown that the basic flow unit is a rock-fabric facies and that rock-fabric flow units can be predicted within the 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.

The research program has been expanded to include world-class Cretaceous outcrops along the Pecos River, southwest Texas. The goal of this project is to develop methods for determining the important scales of variability for characterizing the distribution of petrophysical parameters and to relate these scales to sequence stratigraphy in a geologic setting different from that of the Permian San Andres and Grayburg Formations.

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 William B. Ward, Milton H. Kwong, and Joseph C. Fiduk

The objective of this project, which is funded by the U.S. Department of Energy, is to investigate styles of reservoir heterogeneity found 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, to quantify that framework in terms of petrophysical parameters, and to determine the spatial distribution of remaining oil saturation by using a reservoir simulator.

The outcrop study focuses on the Grayburg Formation, which is exposed in the Brokeoff Mountains just west of the Guadalupe Mountains. A series of ridges and canyons provide the opportunity to construct three-dimensional views of stratigraphic units. Mapping and construction of the sequence stratigraphic framework are under way, and preliminary petrophysical data have been collected. South Cowden Grayburg field has been selected as the subsurface analog of this study. This field, typical of low-permeability mixed carbonate–clastic Grayburg reservoirs found on the Central Basin Platform, Permian Basin, has 28 cores available for description. Using facies descriptions from cores, we have defined four high-frequency sequences within an overall composite sequence that composes the Grayburg Formation.

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, Edward S. Angle, Raymond A. Levey, and Joseph S. Yeh; assisted by Amy K. Sapp

The goals of this project are to (1) translate geological models of Ferron Sandstone reservoir architecture into transportable information useful to well log analysts, development geologists, and production engineers, (2) develop methodology for predicting lateral heterogeneity style from vertical core or well data, and (3) delineate remaining gas resources in targeted reservoirs and develop effective strategies for recovering this resource. The research is sponsored by the Gas Research Institute.

The project focuses on the fluvial-deltaic Ferron Sandstone as an outcrop analog to a heterogeneous group of reservoirs having potential significance for gas reserve growth. The low hydrocarbon recovery efficiencies in 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 Sandstone Member of the Mancos Shale provide the opportunity 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.

The Ferron Sandstone consists of eight stratigraphic cycles, each of which represents a discrete depositional episode of basin filling. Cycles are arranged in seaward-stepping, vertically stacked, and landward-stepping configurations. In turn, each stratigraphic cycle is composed of a set of progradational to aggradational parasequences. Architectural elements and component facies associations that compose stratigraphic cycles and parasequences change as a function of stacking pattern and position within the facies tract.

In addition to characterizing reservoirs from outcrop analysis, the Ferron project provides support to another GRI project evaluating interwell seismic logging using guided waves to determine gas reservoir continuity. We created three-dimensional cubes in depth and time using a robust well log and seismic data set across a 2-mi^2 area from the central part of Stratton field in the Texas Gulf Coast. These three-dimensional cubes were used to evaluate the continuity of high-frequency depositional sequences defined by low-resistivity shales that separate fluvial-deltaic reservoirs having high and low connectedness.

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; Lee E. McRae, Shirley P. Dutton, Mark H. Holtz, and Paul R. Knox; assisted by Chun-Yen Chang, Douglas C. Dawson, and Syed A. Ali

The Bureau of Economic Geology has completed the second year of a 46-month cooperative agreement with the U.S. Department of Energy as part of the Oil Recovery Technology Program for Class I (fluvial-deltaic) reservoirs. This 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 represent a large percentage of 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 billion barrels (Bbbl) of oil yet 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.

Two fields in South Texas are being studied in detail: Rincon field, Starr County, and western T-C-B field, Jim Wells County. Reservoir mapping and stratigraphic log correlations were used to describe general depositional styles of the reservoir sequence in each field and assess the potential for compartmentalization of significant volumes of unrecovered oil. Large fluvial and distributary-channel complexes provide ideal conditions for isolating oil accumulations in multiple laterally coalescing sandstone lobes. Additional oil resources in selected reservoirs are currently being pursued by evaluating oil production trends, mapping facies, and analyzing petrophysical data. Interwell-scale reservoir models of selected zones that integrate geological facies variability with reservoir engineering attributes will be developed to characterize flow-unit architecture and determine controls on locations and volumes of unrecovered mobile oil. These results not only will lead to identification of specific opportunities for incremental oil recovery in these particular fields but also may be used as a model to aid in developing strategies for exploiting heterogeneous Frio reservoirs further in other fields throughout this mature play.

High-Resolution Sequence Stratigraphic and Systems Tract Analysis and Resource and Play Assessment of the Toolachee/Nappacoongee-Murteree Blocks, South Australia

Noel Tyler, principal investigator; Mark H. Holtz, Douglas S. Hamilton, William A. Ambrose, Shirley P. Dutton, and Joseph S. Yeh; assisted by Naresh D. Sen and Syed A. Ali

The Bureau of Economic Geology, in collaboration with and funded by Santos, Ltd., conducted a detailed sequence stratigraphic, depositional-systems, play-assessment, and reservoir-characterization analysis of the Patchawarra, Epsilon, and Toolachee Formations of the Toolachee/Nappacoongee-Murteree (TNM) blocks in southern Australia. This investigation consisted of a regional study of remaining hydrocarbon exploration potential and two detailed reservoir-characterization studies.

The regional investigation, involving stratigraphic correlation and lithofacies mapping, defined new concepts in sedimentation and basin evolution during deposition of the Patchawarra, Epsilon, Darlingie, and Toolachee Formations. The Patchawarra Formation was deposited as a series of continental bed-load fluvial and lacustrine systems. We identified at least six discrete depositional episodes named VGU1 through VGU6. Lithofacies maps illustrate the evolution of sediment-dispersal patterns and sediment source regions during each of these episodes. A mid-Patchawarra tectonic event occurred after deposition of VGU4 and resulted in erosion of Patchawarra-aged strata along local uplifts, including erosion of VGU4 through 6, from structures associated with two oil fields, Strzelecki and Marabooka fields.

The Epsilon Formation, which was deposited as a fluvial-dominated lacustrine delta system, had four discrete depositional episodes. The Darlingie Formation underwent one depositional episode and became separated from the overlying Toolachee

Formation by an unconformity. The Toolachee Formation was deposited as a fluvial- to lacustrine-delta depositional system that underwent six separate depositional events, which are preserved as discrete genetic units.

Two gas fields in the TNM blocks, the Toolachee and Dullingari field complexes, were studied and integrated with the regional study. Toolachee field produces from the Patchawarra Formation, and Dullingari field produces primarily from the Toolachee Formation. These field studies involved (1) establishing the geologic framework and (2) analyzing petrophysics and engineering data. These analyses demonstrated that the principal productive facies are bed-load and coarse-grained meanderbelt deposits. Field studies were illustrated by three-dimensional geocellular models that described the distribution of petrophysical attributes and calculated original gas in place. The first two wells, designed to test the exploration and extended-development concepts arising from this study, were successfully drilled in late 1994.

Internal Geometry of a Modern Carbonate Grainstone Shoal: Joulters Cays Ooid Shoal, Bahamas

Don G. Bebout, principal investigator; R. P. Major and Paul M. Harris (Chevron Petroleum Technology Company)

Bureau of Economic Geology researchers chose the ooid sand shoals of the Joulters Cays area of Great Bahama Bank for detailed sedimentological study in order to investigate the patterns of internal heterogeneity within a modern carbonate sand belt and to develop criteria for predicting the lateral extent of carbonate sand facies. Studying modern analogs of ancient grainstone facies can be critical to hydrocarbon reservoir development because (1) the style of internal geometry of a reservoir must be understood to deploy production technology efficiently, (2) the levels of description and quantification required to redesign recovery strategies in low-efficiency reservoirs can be realized, and (3) potential for extending trends from known reservoirs can be determined.

Major facies identified from the Joulters Cays cores are (1) crossbedded, well-sorted ooids, (2) burrowed, poorly sorted ooids, and (3) poorly sorted ooids and mud containing *Thalassia*. Clast-rich zones and mud layers were also encountered. Upon burial and compaction, the poorly sorted ooids and mud containing *Thalassia* will likely retain negligible porosity and permeability, whereas both the crossbedded, well-sorted ooids and burrowed, poorly sorted ooids will likely maintain their high initial porosity and permeability. Study of many ancient subsurface reservoirs, however, indicates that the crossbedded, well-sorted ooids can undergo considerable cementation and have low resultant porosity and permeability. In many settings, the burrowed, poorly sorted ooids could thus retain the highest porosity and permeability. Additional cementation within the clast-rich zones, which occur in both the crossbedded, well-sorted ooids and burrowed, poorly sorted ooids, will result in thin, low-porosity barriers within a reservoir.

Locally the surface configuration of the modern shoal complex at Joulters Cays was altered significantly by the passing of Hurricane Andrew in August 1992. Prominent washover bars were planed off, and well-sorted ooids were deposited in low areas of the shoal where poorly sorted and mud-rich deposits of ooids had previously accumulated. The posthurricane configuration of the shoal demonstrates how a single, short-term depositional event contributed significantly to the internal heterogeneity of the shoal complex.

Evolution of Earth's Early Atmosphere: Evidence from Earliest Proterozoic Platform Carbonates

Noel Tyler, principal investigator; R. P. Major and Roger Tyler; assisted by Norman G. Van Broekhoven

The early Proterozoic witnessed a remarkable change in the composition of Earth's primitive atmosphere. Ancient (Archean) Earth history was dominated by magmatic activity that produced an atmosphere of mostly carbon dioxide, methane, ammonia, and sulfur dioxide. During the early Proterozoic, oxygen released by cyanobacterial photosynthesis profoundly changed the atmospheric composition from anoxygenic to oxygenic, altering mineral stabilities and creating conditions optimal for evolving complex life forms.

The Bureau of Economic Geology, under funding from the Texas Higher Education Coordinating Board, conducted a petrographic and geochemical study of Proterozoic carbonate rocks from the eastern Transvaal of South Africa. The purpose of this study was to investigate the chemical effects of dolomitization in this primitive ocean–atmosphere system and to evaluate this chemistry in the context of a depositional-sequence framework. Because these rocks are among the oldest examples of marine carbonate sedimentary rocks that have not been structurally deformed or subjected to hydrothermal alteration, they provide an ideal sample set for investigation.

Sequence stratigraphic analysis of these texturally well preserved dolomites indicates that these rocks were deposited as a laterally extensive shallow-water marine carbonate platform sequence in depositional settings that ranged from subtidal shelf edge to peritidal. Carbon and oxygen isotope compositions document exposure to meteoric fresh-water input during periods of relative sea-level fall in those sequences deposited closest to the shoreline. Depositional sequences that were deposited in the deeper water marine environments retain a marine isotope composition. These data suggest that these rocks were deposited as dolomitic sediments in a marine environment, presumably because the chemically reducing primitive atmosphere favored dolomite precipitation, in contrast to the dominantly aragonitic and magnesian calcite precipitation favored in younger ocean–atmosphere systems.

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

Stephen C. Ruppel, principal investigator; Roger J. Barnaby; assisted by William M. Fitchen and Gregg C. Oetting

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. The strontium isotopic composition of formation waters may be a useful tool for evaluating reservoir interconnectivity and compartmentalization and monitoring water injection programs. Regional investigations of subsurface fluids have used strontium isotopes to delineate hydrologic flow regimes, identify fluid sources, and assess geochemical and fluid migration history. The utility of strontium isotopes to resolve more detailed hydrodynamic issues within a producing oil field or reservoir, however, has not been demonstrated.

This 2-year project, funded by the Advanced Technology Program of the Texas Higher Education Coordinating Board, will test the potential of this technique to define reservoir compartmentalization in West Texas oil fields that are producing from Permian-age carbonate reservoirs. Geological characterization of these

reservoirs using well log, core, and production data provides a framework for geochemical investigations. Water samples are being collected from multiple wells producing from each reservoir to evaluate intrareservoir geochemical variation and the influence of reservoir heterogeneity on $^{87}Sr/^{86}Sr$ ratios.

In Martin field of West Texas, six reservoirs were sampled: the Ellenburger, Wichita, Lower and Upper Clear Fork, Tubb, and San Andres. The formation waters are Na-Cl-type brines containing total dissolved solids of 40,000 to 210,000 mg/L. Strontium content ranges from 40 to 250 mg/L, and $^{87}Sr/^{86}Sr$ ratios are 0.70753 to 0.71468. Brines from each reservoir occupy discrete nonoverlapping areas on plots of $^{87}Sr/^{86}Sr$ versus total strontium, indicating that each reservoir is hydrologically isolated from the others. The brines are enriched in ^{87}Sr relative to their host carbonates, and this radiogenic strontium was acquired from extraformational siliciclastic rocks, probably during hydrocarbon migration from basinal source rocks. Ongoing studies are evaluating more subtle intrareservoir $^{87}Sr/^{86}Sr$ variations and their relationship to reservoir heterogeneity and compartmentalization.

Advanced Exploration and Development Research for Revitalizing Hydrocarbon Recovery in the Permian Basin, West Texas

Noel Tyler, principal investigator; R. P. Major, Kenneth T. Barrow, and Douglas B. Swift; assisted by Joseph C. Fiduk and Alexander P. Schoellkopf

The Permian Basin of West Texas and New Mexico is a mature exploration province typical of many onshore basins in the United States. After 70 years of production, however, an estimated 5.4 Bbbl of oil equivalent still awaits discovery in more than 1,600 large (>1 MMbbl of oil equivalent) oil and gas fields. This 3-year research project, funded by the Advanced Technology Program of the Texas Higher Education Coordinating Board, has identified 13 exploration plays in and around the Delaware Basin that can serve to stimulate new exploration in this important hydrocarbon province.

The 13 plays target reservoirs that span the Cambrian to Upper Permian basin fill. Infrequently targeted Cambro-Ordovician sandstone has high per-well production and local potential on the flanks of the Central Basin Platform. Traps are present on pre-Mississippian fault-block highs and at pre-Woodford Shale truncations. Mississippian carbonate is a major producer north of the Permian Basin, and hydrocarbon has accumulated in the Mississippian in several fields in the Delaware Basin, indicating that the Mississippian is also prospective in the Delaware Basin. Lower Pennsylvanian stratigraphic traps are present in shallow-water, high-energy carbonate and clastic rocks on the north and east sides of the basin. We project that these prospective facies bound the west basin margin and occur along the flank of the Central Basin Platform.

Permian-age sediments have produced most of the oil and gas in West Texas, and several plays are still to be pursued in these familiar reservoirs, especially along the west margin of the Delaware Basin. Among these are crinoidal bioherms in the Bone Spring Formation, channel sandstones and updip pinch-outs in the Delaware Mountain Group, and carbonate debris flows and deep-water clastic rocks in the Wolfcamp. We also predict small, shallow (<1,000 ft) accumulations in the Upper Permian (Ochoan) section. Several structural plays that have multiple reservoir targets have also been identified along the Diablo Platform and the west Delaware Basin margin.

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

Noel Tyler and Shirley P. Dutton, principal investigators; Mark D. Barton, Edward S. Angle, Mauro Roberto Becker, and Benjamin Novais Carrasco

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-month collaborative study funded by Petroleo Brasileiro S.A. (Petrobras) is to develop a numerical data base from outcrop mapping and permeability measurements that will provide a portable framework for simulating fluvial reservoirs in 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.

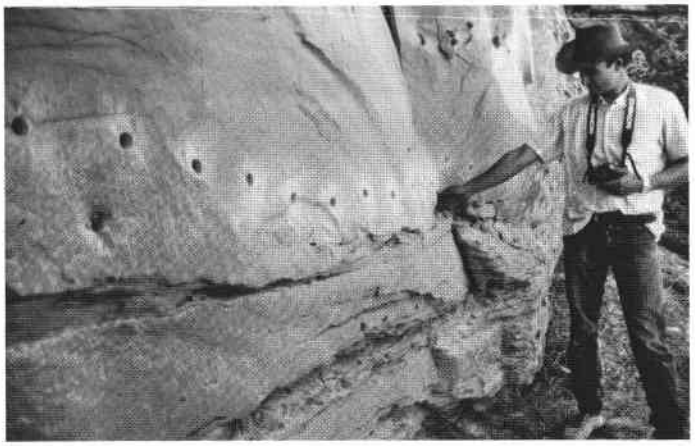
In the first phase of this project, a team of Bureau of Economic Geology and Petrobras geologists mapped sandstone-body architecture and collected more than 1,400 permeability measurements from an outcrop of the Açu Formation. At each sample site, the data that were recorded included location information, permeability, and a description of geologic attributes—grain size, fabric, lithofacies, and facies association. This information forms the basis for establishing discrete permeability groups unique to a specific depositional and diagenetic setting. Data collection was designed to investigate both lateral and vertical permeability structure at a variety of scales and within different rock types. Permeability measurements were collected at 0.3-ft intervals along a series of vertical transects and at 3.3-ft intervals along a 1,050-ft horizontal transect. Nested within the horizontal transect, data were collected every 0.3 ft within three distinct lithofacies.

In the second phase of the project, Bureau and Petrobras geologists and engineers worked together in Austin to incorporate the flow-unit and flow-boundary architecture and permeability data assembled on outcrop into a two-dimensional model using Strata-Model 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 will become the input for flow simulation of the Açu reservoir.

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

Shirley P. Dutton, principal investigator; Michael H. Gardner and Brian J. Willis; assisted by Charl A. M. Broquet, Mary C. Crabaugh, Widya Dharmasamadhi, Milagro L. Elneser, Samuel H. Epstein, Sharon L. Gabel, Richard C. Geesaman, Senira S. Kattah, Kirt A. Kempter, Mani Nachiappan, and Ali S. Sikandar

The principal goals of this project, now in its second year, are to develop an understanding of sandstone architecture and permeability structure in a spectrum of fluvial-deltaic reservoirs deposited in high- to low-accommodation settings and to translate this understanding into more realistic, geologically constrained reservoir



Bureau scientist examines a distributary channel capping an upward-coarsening marine succession in the Cretaceous Fall River Formation, western South Dakota. Rock plugs collected from the base of this channel body were used to quantify petrophysical rock properties such as permeability. The outcrop data are used to model reservoir structure in the nearby Powder River Basin. Photograph by Brian J. Willis.

models. Our approach is to quantify the interrelationships among sequence stratigraphy, depositional architecture, diagenetic history, and permeability structure through detailed outcrop characterization. The Lower Cretaceous Fall River Formation in the Black Hills of eastern Wyoming and western South Dakota, a delta and incised-valley system that was deposited in a low-accommodation setting, is the current focus of the project. The Fall River has excellent outcrops for permeability mapping, and the project has access to an outstanding set of cores and reservoir production data from Buck Draw field, which produces from the Fall River in the nearby Powder River Basin.

Sequence stratigraphic correlations indicate that the Fall River Formation is composed of shallow-marine and valley-fill facies tracts arranged in unconformity-bounded depositional sequences. Detailed work in Red and Clifton Canyons, areas of good three-dimensional exposures of the Fall River, has characterized the facies, permeability, and architecture of valley-fill sandstone successions. The interpretations of the Fall River that were developed by studying the formation in outcrop are being used to guide characterization of Buck Draw field. Diagenetic studies are investigating differences in diagenetic history between the Fall River in outcrop and in the subsurface in order to test the portability of outcrop permeability structure to the subsurface.

This investigation is funded by a consortium of industrial associates comprising the following companies: Amoco Production Company, BP Exploration Operating Company Limited, Chevron Oil Field Research Company, Conoco, Inc., Exxon Production Research Company, Intevep S.A., Japan National Oil Company, Kerr-McGee Corporation, The Louisiana Land and Exploration Company, Mobil Research and Development Corporation, Occidental International Exploration and Production, Inc., OXY USA, Inc., Oryx Energy Company, STATOIL, and Union Oil Company of California.

Characterization of Eocene Reservoirs: LL-652 Area, Lake Maracaibo, Venezuela

Noel Tyler, principal investigator; William A. Ambrose, Eulise R. Ferrer, Shirley P. Dutton, Joseph S. Yeh, and Fred P. Wang; assisted by Douglas C. Dawson and Senira S. Kattah

The goal of this project, funded by Lagoven, S.A., an affiliate of Petroleos de Venezuela, S.A., is to maximize oil recovery from lower Eocene tide-dominated deltaic and shelf reservoirs in the C Members of the Misoa Formation in Lagunillas field, northeastern Lake Maracaibo. These structurally and stratigraphically complex reservoirs have produced approximately 140 MMbbl of oil; however, at a recovery efficiency of only 22 percent, more than 900 MMbbl of oil is estimated to remain at the end of primary operations at the current 80-acre well spacing.

Primary results of the project, concluded in 1994, were the identification of geologic controls on reservoir compartmentalization, quantification of the remaining oil resource, and designation of cost-effective strategies for oil recovery by strategically targeted infill wells, recompletions, and waterflood programs. The volume of oil remaining in each reservoir was determined by volumetrically analyzing and petrophysically evaluating several key wells. Incompletely drained areas targeted for infill development occur where narrow, dip-elongate distributary-channel and tidal-ridge sandstones are compartmentalized by faults. As a result of volumetric analysis, the existing reserves have increased by more than 110 percent, from 120 MMbbl to 247 MMbbl, and approximately 30 geologically targeted infill wells and field-extension locations have been identified.

Testing of the recognized potential is under way; one well in the north part of Lagunillas field, completed in the summer of 1994, began producing approximately 450 bbl of oil per day. This Bureau of Economic Geology–Lagoven study is serving as a model for improving oil-recovery operations in other mature, petroleum-producing provinces of Venezuela, where many fields are nearing the first stages of primary depletion.

Characterization of Miocene BA-24, A-22, LL-02, and LL-08 Reservoirs: Lake Maracaibo, Venezuela

Noel Tyler, principal investigator; William A. Ambrose, Shirley P. Dutton, Joseph S. Yeh, and Fred P. Wang

This project, also funded by Lagoven, S.A., will characterize Miocene reservoirs in northeastern Lake Maracaibo. Although these reservoirs are structurally simple, they are expected to contain appreciable volumes of remaining mobile oil in compartments defined by complex fluvial and deltaic depositional architecture. The initial goal of the project, begun in September 1994, is to document facies variability and depositional systems of the reservoirs by describing more than 4,000 ft of whole core in Venezuela. Additional tasks include identifying and correlating main depositional sequences, determining sandstone-body geometry, and paleogeographically reconstructing Miocene oil-producing strata in the study area.

A reservoir-characterization program will integrate seismic-stratigraphic, petrographic, petrophysical, engineering-production, and reservoir-volumetric analyses. We will reevaluate reservoir limits by reviewing production data and fluid contacts. The study will conclude with updated reserve estimates and recommendations for future development. Specifically maps of hydrocarbon pore volume, original oil in place, and remaining oil will help target sites for strategic infill development, as well as recompletions and strategic waterfloods.

An important aspect of the project is technical training of research personnel by exchanging study techniques. Bureau of Economic Geology and Lagoven geologists and engineers will work together in all phases of the research, culminating in a 2- to 3-day workshop that will demonstrate techniques and principles used in the reservoir-characterization study. Results of the study will be applied to analyzing other important hydrocarbon-producing areas in Lake Maracaibo.

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

Raymond A. Levey and Richard P. Major, principal investigators; Roger J. Barnaby, Kenneth T. Barrow, Shirley P. Dutton, Mark H. Holtz, and Fred P. Wang; assisted by Syed A. Ali, Alistair S. Clague, Douglas C. Dawson, Hae Won Kim, and Martha Romero

This project, funded by Maraven S.A., an oil and gas exploration and production affiliate of Petroleos de Venezuela S.A., aims to forestall premature abandonment of the C-4 and C-5 reservoirs of the Misoa Formation in Lagunillas field in northern Lake Maracaibo. The project area, VLA-6/9/21, lies within a horst block that contains the structurally highest and most productive part of this field. Reservoir compartmentalization, due to multiple episodes of structural deformation and complicated reservoir architecture in this tidally dominated delta system, has led to relatively inefficient production. Recovery from the C-4 reservoir, for example, has been only 24 percent of the original 958 million barrels of oil in place. Maraven estimates that at current decline rates, only 20 million barrels of additional oil will be produced from this unit, although 80 million barrels are listed as in-place reserves. The Bureau of Economic Geology and Maraven are collaborating on a multidisciplinary study that integrates 3-D seismic data, wireline logs, core description, petrophysical data, petrographic data, and production engineering data.

Work began in September on the first part of this three-phase project. Phase 1 is a pilot study of a 3-mi^2 area incorporating more than 50 wells. Most of these wells have been drilled on 80-acre spacing and are producing light oil from Eocene C sandstone reservoirs at depths of 5,600 to 7,000 ft. The pilot study is designed to provide a thorough understanding of the depositional environments, structure, and stratigraphy of the producing units. Reservoir flow units will be determined by mapping sandstone units and bounding faults and comparing well-production history with calculated original oil in place. Recommendations to improve reservoir performance may include drilling infill-production and injection wells, deepening or recompleting existing wells, converting producing wells to water injectors, improving reservoir management practices, and acquiring additional rock, log, seismic, and engineering data.

Phase 1 is scheduled to last for 6 months, after which Maraven will implement the recommendations for drilling, recompletion, conversion to injection, and collecting additional data in a 6-month phase 2. This will include monitoring and analyzing pressure, production, and injection performance. Phase 3 will be a 12-month study that will expand the results obtained during the pilot study to a reservoir characterization of the entire VLA-6/9/21 area.

Conodont Chemostratigraphy: Improvements in the Geologic Time Scale

Stephen C. Ruppel, principal investigator; Eric W. James; assisted by Nikolas A. Hazel and Treavor A. Kendall

This research, which was completed this year, proposed to develop and implement techniques to improve age dating of Paleozoic sedimentary rock successions using conodont microfossils. Funded by the Texas Higher Education Coordinating Board through the Advanced Research Program, this study was directed at developing a more precise record of changes in $^{87}Sr/^{86}Sr$ in the world's oceans during the Paleozoic. Existing $^{87}Sr/^{86}Sr$ curves are widely used for dating depositional and diagenetic events in sedimentary rock successions, although the current record is poor for most of the Paleozoic. Conodonts are uniquely appropriate for improving the $^{87}Sr/^{86}Sr$ record because (1) biozonations based on conodonts constitute perhaps the best basis for correlation in the Paleozoic, thus facilitating temporal placement of samples from disparate geographic localities, (2) more chemically inert than other materials, being composed of less reactive apatite, they are thus more likely to retain original sea-water chemistries, and (3) they are relatively common in Paleozoic sedimentary successions.

During the course of the project, more than 160 samples were prepared and analyzed for $^{87}Sr/^{86}Sr$ in rocks of Silurian, Devonian, and Permian age from three continents. Newly developed techniques and modern instrumentation permitted high-precision analysis of individual conodont elements as small as 20 mg. Instrumental precision is better than ± 0.000015.

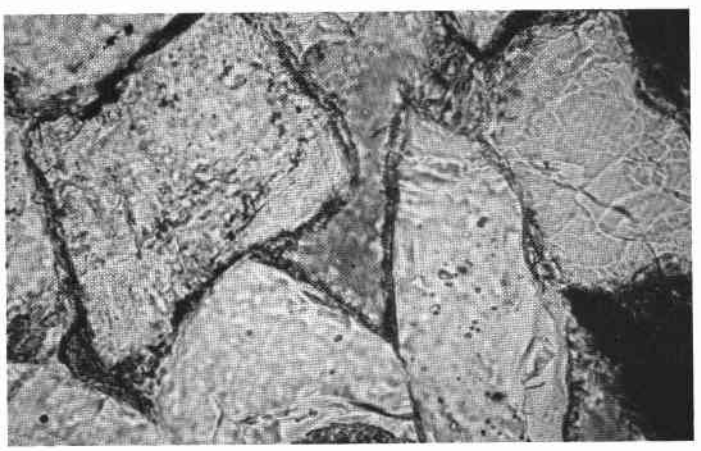
These new data define a much higher precision record of secular changes in $^{87}Sr/^{86}Sr$ for the systems studied and suggest that the most accurate depiction of secular changes in $^{87}Sr/^{86}Sr$ sea-water chemistry during the Paleozoic must be based on conodonts. Because reported sea-water $^{87}Sr/^{86}Sr$ values from other materials are inaccurate in detail, they should be used with caution when attempting to date depositional and diagenetic events in the Paleozoic.

Gas

Geological Investigations of Low-Permeability Gas Sandstone Reservoirs

Stephen E. Laubach, principal investigator; Sigrid J. Clift, H. Scott Hamlin, and Tucker F. Hentz; assisted by Hwanjo Baek, Patricia W. Dickerson, Mary Johns, and Eugene M. Kim

Because low-permeability formations contain an estimated minimum 900 Tcf of gas in place in the lower 48 states, increased production from these reservoirs would contribute significantly to



Quartz and feldspar (left) framework grains coated by fibrous chlorite grain-rimming cement in the low-permeability ("tight"), gas-bearing Lower Permian Ozona Canyon Sandstone of the Val Verde Basin, West Texas. Chlorite in tight sandstones can adversely affect well completion by forming pore-clogging, gelatinous ferric hydroxide when exposed to hydrochloric acid and oxygenated water. Rare primary intergranular porosity visible in center of photograph. Long dimension of photo 0.3 mm. Photomicrograph by Tucker F. Hentz.

the nation's supply of natural gas. The Gas Research Institute has supported investigations by the Bureau of Economic Geology of low-permeability sandstone reservoirs because geologic properties exert a fundamental influence on reservoir performance and gas production. This effort by the Bureau is part of a broader program designed to increase the understanding and utilization of gas resources in low-permeability formations by coordinating studies of geology, formation evaluation, and reservoir engineering.

In 1994, Bureau research had three major components: regional and reservoir geological studies of the Upper Pennsylvanian Canyon Sandstone, Val Verde Basin, Texas, regional reservoir geological studies of the Paleocene Wilcox Lobo trend of Webb and Zapata Counties in South Texas, and a generic study of diagenetic controls on fracture occurrence and attributes based on data from GRI research wells in the Upper Cretaceous Frontier Formation of Wyoming, the Lower Cretaceous Travis Peak Formation of East Texas, and the Pennsylvanian Canyon Sandstone. The Wilcox Lobo and Canyon are geologically complex reservoirs that contain substantial amounts of gas that could be more efficiently produced if understanding of reservoir attributes were improved. To develop low-permeability reservoirs fully and efficiently, the orientation, distribution, and character of natural fractures must be better understood.

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

Raymond A. Levey, Robert J. Finley, and Bob A. Hardage, principal investigators; Carol L. Ruthven, David L. Carr, James L. Simmons, Ronald A. Johns, and Joseph S. Yeh; assisted by Asad M. Sattar, Amy K. Sapp, and Liangqing Xue

The Bureau of Economic Geology is the lead technical contractor of this 2-year project funded by the Gas Research Institute, the U.S. Department of Energy, and the State of Texas. The 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 1994 in Boonsville field in North-Central Texas. SGR project subcontractors, Holditch and Associates, Inc., are conducting reservoir engineering analyses; Scientific Software Intercomp, Inc., are performing petrophysical research; and Envirocorp Services and Technology are handling field operations for the project. Three gas operators (OXY USA, Inc., in Midland, Enserch Exploration, Inc., in Dallas, and Threshold Development Corp. in 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 and mini-hole dynamite sources. Postacquisition processing involved testing the concept of flexible binning. The project has acquired a vertical seismic profile and detailed check-shot survey for calibrating Pennsylvanian thin-bed seismic stratigraphy, multiple pressure test data, and more than 400 ft of conventional high-quality core data. Thirteen depositional sequences have been identified by advanced geological correlating and mapping techniques using the OXY USA stacked curves program.

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

Raymond A. Levey, Robert J. Finley, and Bob A. Hardage, principal investigators; Carol L. Ruthven, W. Gerald White, Clint Phillips (independent consultant), and Peter H. Dana (independent consultant)

Research on gas compartmentalization in fluvial and deltaic reservoirs of the Gulf Coast Basin was finalized and documented in technical articles, topical reports, and short courses. In 1994 a seven-stage technology transfer program was used to assist the gas industry interested in reserve growth. In stage 1, a color flyer was sent to more than 24,500 geoscientists in Texas, Oklahoma, and Louisiana to inform them about Bureau of Economic Geology research conducted on behalf of the Gas Research Institute and the U.S. Department of Energy. In stage 2, the Bureau responded to more than 2,400 requests for additional information with a full-color brochure and SGR project order form. Stages 3 through 7 included a three-dimensional seismic and well log data set from a gas field in South Texas, a CD-ROM containing seven topical reports and abstracts from technical presentations from the Gulf Coast research, a 14-minute videotape about the SGR project, and a short course mailing list. A how-to manual is under development. SGR short courses focusing on applying 3-D seismic for increased gas recovery were conducted in San Antonio, Oklahoma City, Dallas, and Tulsa. They were co-sponsored by the Dallas Geological and Geophysical Societies and the South Texas, Oklahoma City, and Tulsa Geological Societies.

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

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

The objective of this project, funded by the Gas Research Institute (GRI), is to integrate geologic and hydrologic controls on the production of coalbed methane as a basin-scale producibility model. The Bureau of Economic Geology, after characterizing coalbed methane in western United States coal basins, completed a GRI Topical Report (GRI-93/0320) on the Greater Green River Basin. To evaluate the interplay of controls on coalbed methane production further, the Bureau and the Colorado Geological Survey, which has been subcontracted for data collection and logistical support, have begun a study of the Piceance Basin to (1) test the producibility model that has evolved out of a comparison of the San Juan and Sand Wash Basins and (2) build a robust model for global application.

In the Greater Green River Basin, despite huge coal gas resources of 314 Tcf, coalbed wells drilled to date have yielded little or no gas and large volumes of water. Drilling below 6,000 ft will be required to penetrate higher gas content coals (>350 scf/ton). Deeper drilling to test Upper Cretaceous coals in particular is justified at the northwest end of the Cedar Mountain fault system in the Sand Wash Basin, along the east margin of the Washakie Basin, and around the northeast flank of the Rock Springs Uplift. In the Fort Union Formation, the Sandy Bend Arch and the Big Piney area are thought to be prospective where structural and/or stratigraphic

trapping of migrated gases may enhance gas contents in low-rank coals.

In the Piceance Basin, we have initially focused on establishing a basinwide stratigraphic and structural framework in preparation for hydrologic and production analysis and subsequent model building. An operational Williams Fork Formation, the basin's major coal-bearing unit, has been defined and correlated throughout the Piceance Basin. Detailed studies in the Grand Valley area provide additional detail on the stratigraphy, as well as information on coal–sandstone trends, facies relations, continuity, stacking patterns, and structural style. Typically uplifts and anticlines are underlain by west- and southwest-vergent thrust faults. Williams Fork face-cleat strikes, orthogonal to a Laramide-age blind thrust fault beneath the Grand Hogback, form a radiating pattern to account for three regional cleat domains. Finally, preliminary results indicate that lineaments are unreliable indicators of subsurface structure or predictors of production in the Williams Fork Formation.

Assessment of the Impacts of Technology on the Global Gas Resource Base

Noel Tyler, principal investigator; William L. Fisher and Carol L. Ruthven

The Bureau of Economic Geology, on behalf of the Gas Research Institute and Gas Technology Information, Inc., convened a workshop on global gas resources in Vail, Colorado, September 19 through 21, 1994. The workshop was sponsored by the new International Centre for Gas Technology Information, which was established in September 1993 by 11 member countries of the International Energy Agency. The purpose of the workshop was to assess estimates of the worldwide gas resource base and the magnitude of reserves that could be added through increased detection and production efficiencies. Senior officials from international operating companies, state-owned energy companies, governmental organizations, and research institutions from 20 countries participated.

Papers from 32 resource experts representing 15 countries were presented. Resource estimates from the World Energy Resources Program of the U.S. Geological Survey and other sources were compiled and summarized by Bureau staff. These estimates were reviewed by workshop participants in light of current and prospective trends that influence the efficiency and economics of gas exploration and production. Gas resources were assessed in breakout sessions for six regions: North America, South America, Asia and Australasia, Europe and Africa, the Middle East, and the former Soviet Union. For each region, gas resources were assessed under two scenarios: existing technology in 1994 and advanced technology in 2015.

A technical report summarizing the findings and implications of the workshop was published, as well as a proceedings volume. The workshop participants concluded that the global natural gas resource base could increase by as much as 25 percent by the year 2015 if advanced technology is fully deployed. In some areas of the world, the gas-resource increase due to the use of advanced technology could be as much as 80 percent.

Histogram of producible gas in place of chronozones in the Federal Outer Continental Shelf, Gulf of Mexico. Most gas is sequestered by progradational depositional styles in middle Miocene to Pleistocene chronozones. Submarine-fan deposits are important gas reservoirs in the lower Miocene, upper Pliocene, and lower Pleistocene chronozones. Aggradational depositional styles host significant gas in Jurassic, upper Miocene, and Pleistocene chronozones, and most gas in retrogradational depositional styles is in middle Miocene deposits.

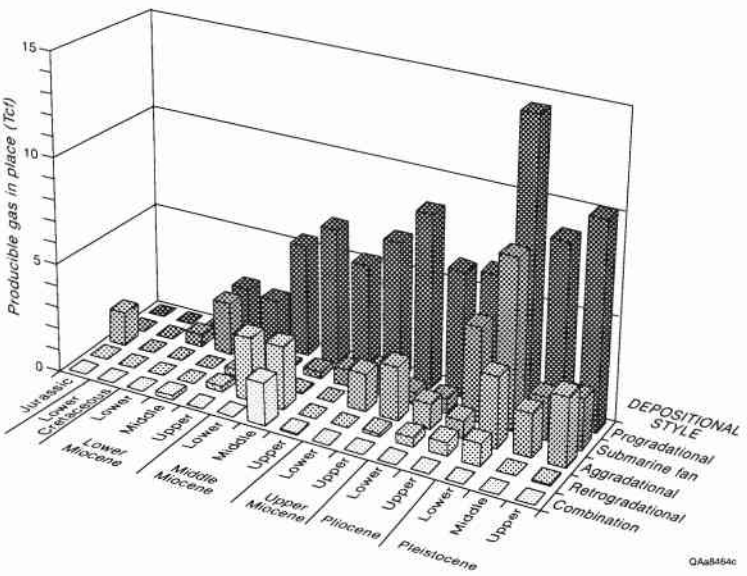
Oil and Gas Resource Atlas Series: Offshore Northern Gulf of Mexico

Robert J. Finley and Steven J. Seni, co-principal investigators; Don G. Bebout and Bruce A. Desselle; assisted by Suhas V. Bodwadkar, Suk-Joo Choh, and Ning Li; subcontracts to Louisiana State University Center for Coastal, Energy, and Environmental Resources and to Alabama Geological Survey

In collaboration with Louisiana State University and the Alabama Geological Survey, the Bureau of Economic Geology is currently developing an atlas series of oil and gas plays in the Federal and State offshore waters of the northern Gulf of Mexico. Beginning in the fall of 1992, the U.S. Department of Energy, Minerals Management Service, and the Gas Research Institute began funding the 4-year program. During 1994, collection and analysis of reservoir data continued, although reservoir play analysis had largely been completed. 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.

The decline in domestic oil and gas production and the increase in dependence on imports of foreign crude oil highlight the need for an integrated analysis of domestic oil and gas resources. The northern Gulf of Mexico is currently receiving much attention by 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 region is an especially attractive exploration area because of its rich hydrocarbon endowment, its modern petrochemical production and refining infrastructure, and its untapped potential. Systematic synthesis of geologic and engineering data with oil and gas resources, reservoir by reservoir in each play, is required for successful exploration and development of the offshore northern Gulf area to continue. The Gulf of Mexico offshore region contains an estimated 17 and 26 percent, respectively, of the nation's undiscovered conventional oil and gas resources. 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 Tcf of gas.

We have defined approximately 110 plays in Federal waters and identified 27 plays in Texas State waters, typically using depositional origin or style as the key defining attribute of a play.



Plays are identified by integrating regional patterns of hydrocarbon occurrence, patterns of depositional style, and structure with engineering reservoir data. The combination of various elements of geologic and engineering data is synthesized to determine the boundaries of plays. For example, major new petroleum discoveries in the 200- to 500-million-barrel (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 important combinations of trap types and producing facies. The data can be used to (1) identify areas of greatest potential that have the highest concentration of remaining unrecovered hydrocarbons in existing fields and (2) guide frontier exploration in ultra-deep water on the basis of analysis of older submarine fans and slope-apron plays encountered beneath the shallower adjacent continental shelf. Regional play analysis thus provides a logical basis for simultaneously evaluating both field reserve growth potential and opportunities for extension exploration in mature plays.

Coal

Computerized Calculation of Lignite Resources in Texas

William R. Kaiser, principal investigator;
assisted by Scott C. Goode

This long-term project, funded by the U.S. Geological Survey (USGS), provides estimates of remaining near-surface lignite resources in Texas. The computerized data base and graphics software of the National Coal Resources Data System (NCRDS) are used to calculate resources according to criteria in USGS Circular 891 (Coal Resource Classification System of the U.S. Geological Survey) and criteria consistent with current mining practice in Texas.

In order to simplify resource calculation, we have grouped data files for contiguous 7.5-minute quadrangles into nine raster-based resource regions (five in South Texas and four in East Texas) for more efficient gridding and resource calculation. In a five-quadrangle test area in South Texas, the NCRDS resource calculation code is being modified consistent with Texas mining practice. For example, commands dealing with underground pillars, deep coal, and tonnage factors were eliminated or modified. When completely modified, the code will be used to calculate Jackson and Wilcox resources throughout South Texas. Because data files for East Texas Jackson–Yegua thickness data have been inaccessible from NCRDS, Jackson–Yegua resources remain unrevised.

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 and Asad M. Sattar

The Applied Geodynamics Laboratory 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 following industrial associates: Agip S.p.A., Amoco Production Company, Anadarko Petroleum Corporation, ARCO Oil and Gas Company, BP Exploration, Inc., Conoco, Inc., Du Pont Corporation, Exxon Production Research 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.

Most 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) growth and lateral intrusion–extrusion mechanisms of salt tongues induced by progradation, (2) role of prograding linear and lobate depocenters in driving parallel and radial flow of salt by differential loading and gravity spreading, (3) extensional minibasins forming over allochthonous salt sheets, (4) contraction superposed on diapirs formed by extension or downbuilding (contraction ranged from subtle inversion to severe overthrusting and pinching of diapiric stems), (5) soft and hard linkage of normal fault relays connecting offset grabens, (6) structural style of fold-and-thrust belts on multiple detachments, and (7) transtensional fault relays and pull-apart basins.

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 mathematical scale modeling 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 following industrial associates: Agip S.p.A., Amoco Production Company, Anadarko Petroleum Corporation, ARCO Oil and Gas Company, BP Exploration, Inc., Conoco, Inc., Du Pont Corporation, Exxon Production Research 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 uses several Macintoshes and digitizers, two Silicon Graphics workstations, and a variety of software. Most of the mathematical modeling involves finite-element modeling using *GEOSIM-2D*®, a program that can simulate combined brittle and ductile deformation, large strains, faulting, sedimentation, and erosion. The first three of the topics following are being systematically investigated: (1) how the geometry of subsalt faults can be predicted by the geometry of faults above a stretching, allochthonous salt sheet, (2) how the salt budget within an isolated salt sheet constrains the interaction of extensional faults above and below the salt, (3) deformation of cover above arrays of extensional basement faults, (4) deformation in the clastic roof of an extruding salt glacier, and (5) buckling of alternate brittle and ductile layers.

Various software solutions for visualizing salt and other structures in three dimensions are being tested at the development stage. *Earthvision*® is being used for full three-dimensional

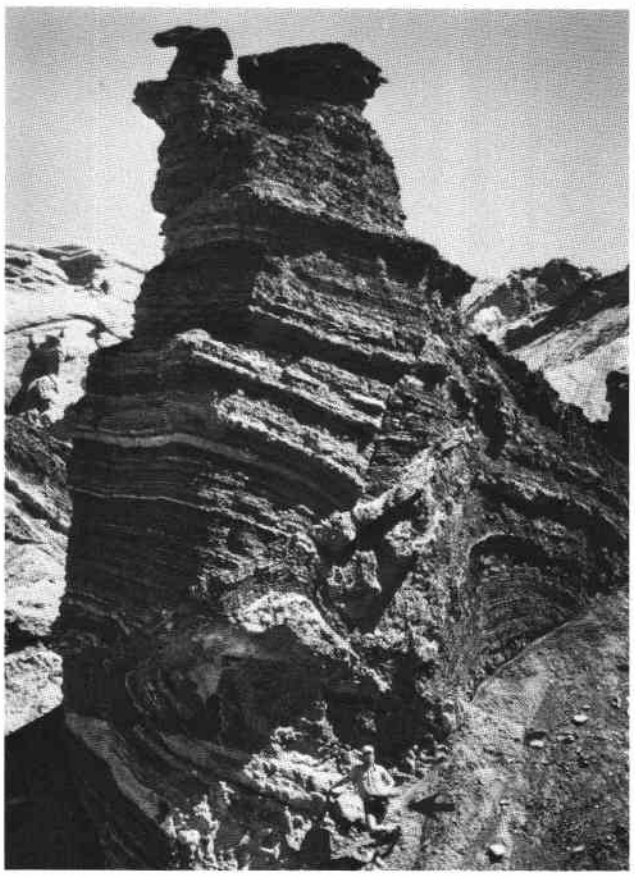
visualization, volumetrics, mapping, and creation of data volumes from digitized cross sections of physical models. *3D-Move®* palinspastically restores structures in three dimensions. Two-dimensional animation increases comprehension of structural development in large data sets from numerical models, physical models, and restorations.

Applied Geodynamics Laboratory: Structure of Upheaval Dome, Utah

Martin P. A. Jackson, principal investigator; Daniel D. Schultz-Ela; assisted by Hongxing Ge

Field mapping of Upheaval Dome was funded by Exxon Production Research Company. Other funds were supplied by the Applied Geodynamics Laboratory Industrial Associates listed for the two previous projects.

Upheaval Dome is a breached, subcircular Mesozoic dome underlain by Permian Paradox evaporites. Three-dimensional exposures suggest that Upheaval Dome may represent the pinched-off stem of a salt dome. The overhanging diapiric bulb or salt extrusion postulated to have overlain the stem would have been removed by erosion during elevation of the Colorado Plateau. Pinched-off, pancake-shaped allochthonous diapirs are common in the subsurface Gulf of Mexico. And yet necking of viscous salt in a brittle overburden, which is highly relevant to salt tectonics and to the subsalt play, has never been previously investigated. Upheaval Dome presents a unique potential opportunity to directly examine in three dimensions the brittle response to diapiric pinch-off.



Outcrop from the central zone of Upheaval Dome, Canyonlands National Park, Utah. Complex structures show combined radial and circumferential contraction. The structures and sedimentation history suggest that the dome originated when the stem of a diapir was pinched off. Use figure at arrow for scale. Photograph by Daniel D. Schultz-Ela.

Structural and stratigraphic mapping around Upheaval Dome focused on (1) gathering evidence for a protracted growth history, which would support its origin as a salt dome, and (2) determining the mode of emplacement of this structure by linked fault systems in the overburden. Two cross sections were prepared from field data: a linear section of the entire structure and a circular section of the core of the diapir through a complex pattern of imbricate thrust faults arranged roughly radially about a hub invaded by contorted clastic dikes. All the fold and fault systems are consistent with protracted necking of a diapiric stem. Analytical and numerical modeling (in collaboration with Dr. R. C. Fletcher of EPR) indicates, however, that gravity-driven diapiric pinch-off is impossible in an isotropic overburden having a realistic range of thicknesses and material properties. Further work is needed to investigate the behavior of layered or faulted overburdens.

Land, Water, and Environmental Resources Investigations

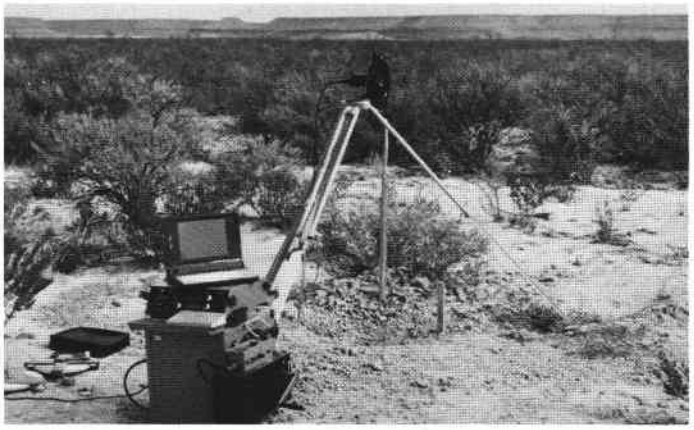
Environmental, Geologic, and Hydrogeologic Studies

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

Jay A. Raney, principal investigator; Edward W. Collins, Bruce K. Darling, Alan R. Dutton, Richard S. Goldsmith, Barry J. Hibbs, Mary L. W. Jackson, Richard P. Langford, William F. Mullican III, Jeffrey G. Paine, Bridget R. Scanlon, Steven J. Seni, Allan R. Standen, G. Stephen Stubbs, Steven W. Tweedy, E. G. Wermund, and Jiannan Xiang; assisted by Liang Chen, Joseph D. Coker, Sung-Chi Hsu, and Jun Liao

The unsaturated zone in Eagle Flat Basin within the Chihuahuan Desert of Texas is being considered as a potential repository of low-level radioactive waste. The Bureau of Economic Geology continues its involvement in geologic and hydrologic studies of the proposed site. In 1994 hydrologic studies were added, including drilling, monitoring, and numerical modeling and development of a report on vadose zone hydrologic methods. Bureau scientists also provided support on resolving geologic and hydrologic issues on a license application that is being reviewed by the regulators. This work is funded by the Texas Low-Level Radioactive Waste Disposal Authority. The Bureau also conducted work evaluating preferential flow in fissured sediments that was funded by the U.S. Department of Energy.

The proposed site of the Texas repository is located in northwest Eagle Flat Basin, which is a closed topographic basin. Additional drilling was conducted in 1994 to evaluate potential recharge beneath Grayton Lake. This work included installing neutron probe access tubes to monitor water content and collecting soil samples for various hydraulic and hydrochemical parameters to quantify recharge. Surface electromagnetism was studied in various geomorphic settings within Eagle Flat Basin to provide information on spatial variability in subsurface water fluxes; such information was previously restricted to information from sampled boreholes. The electromagnetic studies greatly increased our understanding



Logging a shallow borehole near Fort Hancock, Texas, using portable gamma-ray and electrical conductivity probes. Resulting logs are used to study changes in soil texture, moisture content, and soil-water chemistry with depth. Photograph by Jeffrey G. Paine.

of spatial variability in subsurface water movement. The program included monitoring water content using a neutron probe and water potential using thermocouple psychrometers in both the Eagle Flat and Hueco Basins and sampling ground water quarterly in Eagle Flat Basin. The monitoring program in the Hueco Basin was established in 1988 when this site was initially being considered for low-level waste disposal, and this lengthy record provides a unique data set for evaluating temporal variations in infiltration in an arid setting. Numerical simulations of liquid and vapor flow were conducted on a newly acquired Sun SPARCserver 1000 computer station to evaluate unsaturated zone processes on the basis of field data collected at Eagle Flat. Some numerical simulation work was conducted in collaboration with scientists at Los Alamos National Laboratory.

Although arid sites are increasingly being considered for waste disposal because thick unsaturated zones are thought favorable, fissured sediments typical of many arid basins in the western U.S. reduce the effectiveness of thick desert soils in attenuating contaminants by short-circuiting flow through the unsaturated zone. Subsurface flow and transport in fissured sediments were investigated in detail in 1994. These studies included surface and downhole electromagnetic surveys, soil sampling to 30 m for analyzing hydraulic and hydrochemical parameters, and monitoring water content using neutron probe and time domain reflectometry. Fissures studied included the Hoover fissure in the Eagle Flat Basin and those in Red Light Draw, Ryan Flat, and Hueco Basin. This work will greatly increase our understanding of preferential flow related to these features.

Bureau scientists also studied instrumentation of a surrogate cap for the proposed waste disposal trenches. Instrumentation included heat dissipation probes and thermocouple psychrometers to monitor water potential, time domain reflectometry to monitor water content, and surface electromagnetic surveys to monitor infiltration and plant-water potentials. Both electromagnetic surveys and monitoring of plant-water potentials provide noninvasive monitoring techniques that cover a large area and complement point monitoring devices such as time domain reflectometry probes.

Our work in arid zone systems has significantly contributed to the current understanding of flow and transport processes in these regions. Relating geomorphic, geologic, and hydrologic results has provided a comprehensive understanding of processes in arid sites. The multidiscipline and comprehensiveness of our studies will be invaluable to members of the Low-Level Radioactive Waste Disposal Authority when they respond to questions about the suitability of the site for waste disposal.

Geologic and Hydrologic Characterization of Pantex Plant

Thomas C. Gustavson, principal investigator; Alan E. Fryar, Richard S. Goldsmith, Susan D. Hovorka, Richard P. Langford, William F. Mullican III, Jeffrey G. Paine, Bridget R. Scanlon, Allan R. Standen, G. Stephen Stubbs, Steven W. Tweedy, and Jiannan Xiang; assisted by Martina U. Blüm, Stephen R. Allen, George T. Bush, Yao-Chang Chang, Min-Yuan Cheng, Alex Y. Colunga, Jordan W. Forman, Jr., Randall K. Hill, Anselmo S. Jacobo, Leslie B. Kelley, Jr., Steven M. Rooks, and Claude R. Stricklin

Work began in September 1990 on this 5-year 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, maintaining, 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, industrial solvents, and chrome. Investigations at and near the Pantex Plant are being conducted to enable the State to guide future remediation efforts by DOE. Research objectives are to determine (1) the rates and processes by which runoff is collected in playa basins 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.

Highlights of work completed to date show that the Ogallala Formation near the Pantex Plant consists of several hundred feet of fluvial sand and gravel overlain by several hundred feet of lacustrine clay and fine sand and eolian silt and fine sand. The Ogallala aquifer occupies the lower 400 ft of the Ogallala section, and the perched aquifer consists of a series of thin water-saturated interbedded clays and laminated sands at a depth of 250 to 300 ft. Recharge to the Ogallala aquifer and the overlying perched aquifer is focused through playa basins, which collect runoff from rainfall. Recharge, which flows both through matrix and preferential flow paths, is rapid—rainfall that fell during the late 1950's and early 1960's has reached depths of approximately 250 ft. Preferential flowpaths include deltas at the margins of lacustrine sequences that fill playa lake basins, soil fractures, root tubules, and burrows. Seismic reflection data collected within and near the Pantex Plant indicate that subsidence beneath playa basins is probably related to dissolution of Permian evaporites and collapse of overlying strata. Preliminary analyses of soil gases suggest that the source of elevated carbon dioxide in the sediments below playas is microbial degradation of organic carbon.

Regional Permeability Study of the Edwards Aquifer

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

Management of the Edwards aquifer as the source of water for Central Texas communities, agriculture, and preserving springs that serve as habitats for endangered species has been a recent

topic of public concern. The Edwards permeability study, funded by the Edwards Underground Water District (EUWD) analyzed permeability distribution in the Edwards aquifer using a multidisciplinary approach. We combined surface geologic mapping from the Bureau of Economic Geology's New Braunfels State Map project with subsurface mapping, using well logs to produce an updated structural interpretation of the faulting, attitude, and thickness of the aquifer. Transmissivity data were derived from pump-test and specific-capacity-test analyses. We examined outcrop transects to quantify the structural and stratigraphic distribution of fractures, faults, and caves that provide conduit permeability in the aquifer. We sampled matrix porosity and permeability in outcrops using a portable core plugger and in subsurface cores using plugs. We also developed and applied porosity-permeability transforms to porosity calculated from logs during the Bureau's 1993 Edwards Porosity Study, and we analyzed regional matrix permeability structure using SGM StrataModel.

Structural and transmissivity data developed during this study are designed to serve as inputs to a regional hydrologic model. Such a model, integrated with water level, recharge, discharge, water use, and rainfall data collected by the EUWD, will aid the district in aquifer management. Maps presented in an ARC/INFO geographic information system can be used by EUWD to advise the public of the depth to water, thickness of the aquifer, and average yields in areas of interest. In addition, the distribution of permeability in the recharge area, a variable in land-use planning and aquifer protection, is better understood using new concepts developed by this study. Concepts of stratigraphic and structural controls on permeability will also be of use in future, detailed modeling.

Environmental Atlas of the Rio Grande—Rio Bravo Border Area

Jay A. Raney, principal investigator; L. Edwin Garner

This project, funded by the U.S. Environmental Protection Agency, Region 6 Office, is reviewing available geologic, hydrogeologic, and natural resource information along the 100-km-wide corridor on each side of the Border Area between Texas and Mexico that may eventually be included in an environmental atlas of this region. The atlas would be based on geographic information system (GIS) digital maps and related environmental data. In the data and map review, we are assessing the adequacy of existing data, most of which are unavailable in a digital format.

Other agencies working in the region have determined that data at scales on the order of 1:24,000 are desirable. Although regional syntheses of geologic, hydrogeologic, and natural resource data on the Border Area exist, most are inadequate for presentation at 1:24,000 scale except for limited areas. Inconsistencies among the various sources of data abound because many of the older maps were compiled on inaccurate base maps. Although much previous work has been done in the Border Area, a concerted effort will be required to verify existing information, enter reliable data into a GIS, fill numerous gaps in the existing data base, and conduct the necessary analysis and interpretation.

Lower Rio Grande Valley Geographic Information System (GIS)

E. G. Wermund, Gene J. Paull (UT–Brownsville), and Robert W. Rodgers (UT–Pan American), principal investigators; Thomas A. Tremblay; assisted by Chengyan Wu

The purpose of this project, funded by the Texas Higher Education Coordinating Board, is to construct a geographic information system (GIS) of the lower Rio Grande area. The GIS will provide spatial, graphic, and textual data useful for managing the demand for and supply of surface and ground water in this region. The geographic boundaries of the study area are the surface limits of the latest Pleistocene Rio Grande delta, which includes parts of Cameron, Hidalgo, Starr, and Willacy Counties, Texas, and Tamaulipas, Mexico. Corners of the triangular delta are located at (1) the junction of the Rio San Juan and the Rio Grande near Ciudad Camargo, Tamaulipas, and Rio Grande City, Texas; (2) Mullet Island, 3 mi south of Port Mansfield, Texas; and (3) Mezquital on the Padre Island of Mexico. Spatial data sets at a 1:100,000 scale will include transportation, geology, soils, land use (emphasizing colonias in Texas), populations, waste disposal, surface hydrology—including irrigation canals and floodways—and potentiometric surfaces from ground-water wells.

The Bureau of Economic Geology has completed seamless data sets of the location of colonias, surface hydrography having major and minor attributes, and the road network having major and minor attributes using Bureau digitizing and data sets of the Texas Water Development Board, the U.S. Geological Survey, and the Texas Department of Transportation. The Bureau has digitized Mexico hydrography and transportation from 1:50,000-scale Instituto Nacional de Estadística Geografía e Informática maps and geology from the Environmental Geologic Atlas of the Texas Coastal Zone. We are now interpreting surficial geology in Mexico from aerial photographs.

The University of Texas (UT)–Pan American has identified flows in irrigation canals, drainage ditches, and natural streams. Researchers are currently collecting data on water availability and water delivery. UT–Brownsville—a principal liaison for acquiring data from Mexico—is identifying land use using satellite imagery.

Hydrogeologic Studies in Support of the Superconducting Super Collider

Alan R. Dutton, principal investigator; Robert E. Mace, H. Seay Nance, and Jiannan Xiang; assisted by Martina U. Blüm, Joseph D. Coker, and Steven M. Rooks

The purpose of this study, supported by the Texas National Research Laboratory Commission (TNRLC), is to develop a comprehensive account of the occurrence and movement of ground water at the Superconducting Super Collider (SSC) site. The SSC, a state-of-the-art particle accelerator, was designed to explore the basic structure of matter at energies 20 times greater than can be done by existing particle accelerators. Although the U.S. Department of Energy (DOE) had been constructing the SSC in Ellis County, Texas, since 1988, in August 1993, the DOE terminated construction. Since then, the Bureau of Economic Geology has focused on supporting the informational needs of the DOE and TNRLC on environmental issues related to project termination. Ongoing tasks include ground-water monitoring and hydrologic testing in the Austin Chalk. The Bureau drilling rig installed 33 additional monitoring piezometers in tunnel-rock spoil piles, fracture zones near the linear accelerator facility, and depressurized bedrock around and above the tunnel. Continued monitoring helps us better define ground-water flow in fractured bedrock near the linear accelerator facility, in and near spoil piles of rock excavated from the SSC tunnel, and around the dewatered tunnel sections. Water levels have been monitored since 1990 in more than 150 wells near the SSC site.

In 1994 a 393-page final contract report on the occurrence and movement of ground water in the Austin Chalk and the Eagle Ford and Ozan Formations was completed. An additional report presented

results of detailed mapping of joints and faults in about 10 mi of surface and underground exposures of Austin Chalk. Results suggest that interpretation of fracture frequency and style solely on the basis of surface-exposure study might be inaccurate because of the effects of weathering and unloading on the development of joints near ground surface. Information on the frequency and distribution of fractures mapped in the SSC tunnels will help improve models of the development of the Balcones Fault Zone in Texas and can be applied to improving the design of horizontal drilling for recovering oil from Austin Chalk oil fields in South Texas. A computer model simulating ground-water flow in the Woodbine, Paluxy, and Twin Mountains Formations was developed as an interpretive and planning tool for municipalities and rural water-supply corporations in North-Central Texas to evaluate future use of these ground-water resources.

Environmental Surveys of Texas National Guard Training Sites

E. G. Wermund, principal investigator; Arten J. Avakian

The Bureau of Economic Geology concluded a multiyear project by completing final reports that summarize the geomorphology, climate, geology, soils, and surface and ground waters of Fort Wolters and Camp Mabry. In previous years reports were completed on Camp Bowie, Camp Swift, and King Ranch training sites. These reports were accompanied by computer disks of digitized maps.

Hydrogeologic and Aqueous Biology Assessment of Texas National Guard Training Sites

E. G. Wermund and Alan R. Dutton, principal investigators

In October 1994 we began a new 2-year study for the Texas National Guard to define comprehensively the surface-water and ground-water hydrology of several training camps and to describe the aquatic ecosystems. These aquatic biology surveys are being carried out by the Texas Parks and Wildlife Department and are coordinated by The Nature Conservancy of Texas. Objectives of the new study include improving understanding of the interaction between ground water and surface water, identifying recharge areas and flood-prone areas, and providing baseline hydrology and water chemistry data for analyzing aquatic ecosystems.

Hydrogeochemical and Production Controls on Naturally Occurring Radioactive Materials in Oil- and Gas-Field Operations

R. Stephen Fisher, principal investigator; Eric W. James; assisted by Nina L. Baghai

Naturally occurring radioactive materials (NORM), chiefly radium isotopes, commonly occur at low levels in water produced along with oil and natural gas, and they can accumulate to high activities in production-equipment scale. Expenses incurred by operators trying to protect workers and dispose of NORM scale, sludge, and brine could be anticipated and reduced if conditions leading to NORM accumulations could be better understood. This research is designed to identify geologic and geochemical controls on NORM.

Our approach is to combine data on (1) the chemical and radio-isotope composition of produced water; (2) the geology of uranium, thorium, and radium in sedimentary basins; (3) the chemical and mineralogical composition of production-equipment scales; (4) the mineralogical composition, burial depth, and temperature of the reservoir; and (5) thermodynamic modeling to quantify radium coprecipitated in scale minerals in reservoirs of the Texas Panhandle, Central Basin Platform, and east, south-central, and Gulf Coast Texas. Results of this work will be used to develop screening criteria that operators can use to determine whether reservoir characteristics and production techniques at their fields and wells favor the formation of NORM precipitates.

U.S.–Mexico Regional Environmental Information System

Jay A. Raney, principal investigator; W. Gerald White, systems analyst, and Thomas A. Tremblay, GIS coordinator

The Consortium for International Earth Science Information Network (CIESIN) has a cooperative agreement with the U.S. Environmental Protection Agency (EPA) to establish regional, computer-based information systems that will afford researchers the ability to assimilate socioeconomic, public health, and environmental data. The mission of CIESIN is to advance the understanding of human interactions with the environment. The consortium will, through its regional information systems, provide a data base of global change to serve the needs of science and public and private policy making. The Bureau of Economic Geology will serve as the hub of the CIESIN/EPA Environmental Information System for the U.S.–Mexico Border Area, a zone situated 60 mi on either side of the U.S.–Mexico border from the Pacific Ocean to the Gulf of Mexico. The Bureau's border-related studies and contacts with the General Land Office, the Texas Natural Resources Information System, and other components of The University of Texas System provide a strong basis for support of this project.

The Environmental Information System will reside on a Sun SPARCserver 1000 departmental server. The software for the system, developed by CIESIN, provides interactive query capabilities for organizational and data-set information and a guide component in the form of hypertext documents. A long-term goal is the delivery of a decision support component that would aid in correlating data-set attributes.

Year 1 tasks include collecting environmental, socioeconomic, and public health data sets; installing the CIESIN Catalog System software on the SUN computer; developing the guide component; prototyping access to other data centers; and developing a draft users' manual. Year 2 tasks will expand on the work done in year 1, adding data sets from other regions bordering Mexico, installing sites at other data centers, and completing the users' manual.

Coastal Studies

Determining Recent Sedimentation Rates of the Lavaca River, Texas

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

This project has grown out of a previous investigation of sedimentation and marsh loss in fluvial-deltaic areas of the Texas coast, funded by the Texas Water Development Board. More than 15 percent of the marsh system in the lower reaches of the alluvial valley and delta of the Lavaca River has been lost since the 1930's.

Most of the loss has resulted from natural conversion of interior vegetated wetlands to water and flats, indicating that marsh sedimentation rates have not kept pace with rates of subsidence and sea-level rise. A principal objective of this study is 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 is 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 0.4 inch per year. A total of 10 shallow cores were taken in brackish and fresh marshes and transitional areas of the Lavaca–Navidad River fluvial-deltaic system for physical and chemical analyses. Dr. Charles Holmes of the U.S. Geological Survey in Denver determined sedimentation rates by isotopic analyses of excess ^{210}Pb and ^{137}Cs activities. Other analyses included total organic carbon, sediment textures, total aluminum, water content, organic and mineral matter, and bulk density.

Preliminary results of the distribution of excess ^{210}Pb activity with depth in most cores suggest at least two rates of sedimentation for different time periods. 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 to maintain wetlands.

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 1994 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 were 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.

Characterization of Sand Bodies within Seismic Sequences—Texas Continental Margin

Robert A. Morton, principal investigator; assisted by Radu 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 years. This work is being accomplished by integrating and analyzing two data sets—high-resolution seismic surveys and foundation borings.

In 1994, maps portraying the physical properties (thickness, percent sand, and lithologies), depositional environments, and paleogeography of four previously identified seismic sequences were extended onto the adjacent continental slope. We accomplished this by interpreting a grid of high-resolution seismic profiles on the slope and by interpreting and correlating descriptions 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.

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

Robert A. Morton, principal investigator; James C. Gibeaut and William A. White; assisted by Kevin T. Lyons and Radu Boghici

Coastal erosion and wetland loss in Texas are occurring at rapid rates in some areas that are undergoing rapid economic development. Erosion and submergence threatens 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-year 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 this 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 1994 we (1) prepared stratigraphic cross sections of the Sabine, Neches, Trinity, and San Jacinto Rivers, showing the upper Pleistocene and Holocene fluvial-deltaic deposits and valley-fill facies, (2) mapped shoreline types, (3) investigated wetlands changes, (4) developed computer programs for statistically analyzing shoreline movement, (5) recorded seismic profiles in Sabine Lake, and (6) described a series of cores taken from the coastal marshes, beach ridges, and former incised valley of the Sabine–Neches River. 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 that might occur in the future.

Physical and Environmental Assessment of Sand Resources—Texas Continental Shelf

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

A recent inventory of nonfuel minerals in the Gulf of Mexico demonstrated that potentially economic deposits of sand occur 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) likely to be suitable for beach nourishment, (2) the largest sand deposits located 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. Efforts during 1994 were directed toward (1) assessing the quality and volume of sand in Sabine and Heald Banks, (2) evaluating the potential environmental impact of offshore mining on adjacent shores, (3) analyzing oceanographic conditions that might limit or inhibit mining, and (4) providing 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.

Shallow-Water, High-Resolution Bathymetric Surveying System

James C. Gibeaut, principal investigator; Robert A. Morton; 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 achieve from 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 the errors inherent in conventional bathymetric surveys. The improved surveying system will include a portable industrial computer to integrate digital records from a (1) precision depth recorder, (2) heave compensator, and (3) 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.

The work in 1994 focused on acquiring and testing the equipment, making adaptations for field use, checking the synchronization of the electronic data, designing and building a test tank, and conducting preliminary surveys in the test tank under rigidly controlled conditions. Plans for 1995 include several tank tests, an open-water test in a lake, and eventually a full-scale test in the Gulf of Mexico near Galveston.

After the system is fully tested, it will be used in 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.

Mapping Shoreline Types of the Texas Coast

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

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 1994, 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 seawalls) exposed to high-energy waves generally have low sensitivities to oil-spill cleanup, 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 on 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 by RPI. A report was prepared that explains the procedures and techniques used, describes the classification scheme, and presents photographic examples of different shoreline types.

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, W. Gerald White, and Diane M. Spinney

This 1-year project funded by the Texas General Land Office as part of the Natural Resources Inventory of Texas has two primary objectives. The first objective 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 extending 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 backbarrier marshes and sand flats.

The textural and geochemical analyses and washover locations will be transformed into electronic data and formatted so that they are 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 are also unsafe sites for coastal construction.

Mapping Investigations

Geologic Atlas of Texas

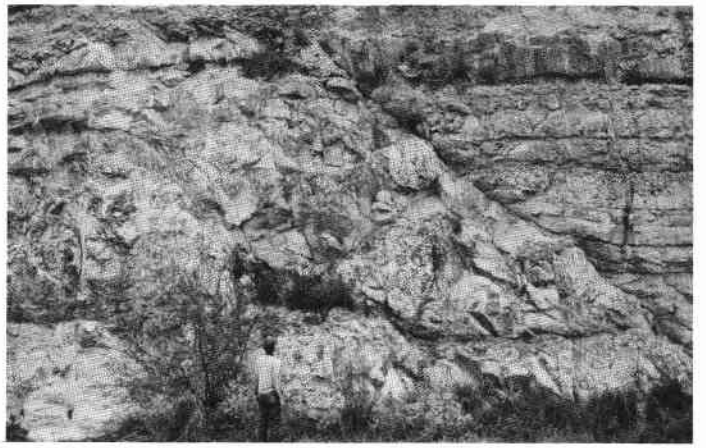
Virgil E. Barnes, principal investigator

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 revising and reprinting older maps as they go out of print. The Big Spring and Perryton sheets were revised and reprinted in 1994; the Fort Stockton sheet is currently being revised.

STATEMAP Project: New Braunfels, Texas, 1:100,000-Scale Quadrangle

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

The objective of this multiyear project is to map 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, Lake Medina, Boerne, and Comfort. This area lies within part of the recharge zone of the Edwards aquifer and covers a complex part of the Balcones Fault Zone. Although 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°–70°E and dip southeastward. Composite stratigraphic displacement across the fault zone is as much as 1,800 ft in the New Braunfels area.



Outcrop showing highly fractured Lower Cretaceous Glen Rose Limestone at a fault strand of the Balcones Fault Zone, Comal County, Texas. Faults of the Balcones Fault Zone were studied during mapping of the 1:100,000-scale New Braunfels quadrangle and during investigations of the Edwards aquifer. Photograph by David M. Stephens.

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. Open-file geologic maps, scale 1:24,000, completed during 1994 include the Castle Hills, Camp Bullis, Bergheim, Kendalia, Longhorn, Sisterdale, and Boerne quadrangles.

STATEMAP Project: El Paso, Texas, 1:100,000-Scale Quadrangle

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

This multiyear project is focused on mapping the El Paso–Rio Grande border area of far West Texas. The area 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. Open-file geologic maps, scale 1:24,000, completed during this first project year include the El Paso, North Franklin Mountain, Campo Grande Mountain, Cavett Lake, Diablo Canyon West, and Fort Hancock quadrangles.

The El Paso and North Franklin Mountain quadrangles encompass the east margin of the Franklin Mountains and west edge of the northwest Hueco Bolson, an area that includes much of urbanized El Paso and a growth corridor of the city. The Franklin Mountain range is a west-dipping, tilted fault block that trends northward. A relatively continuous stratigraphic section of Precambrian through Permian rocks that are locally intruded by

Tertiary igneous rocks is present in the Franklin Mountains. Quaternary alluvial-fan deposits have built off the edge of the mountains into the basin. The range is bound on the east by a north-striking Quaternary fault, the East Franklin Mountains fault, which cuts middle Pleistocene and upper Pleistocene deposits and may displace Holocene deposits.

The Campo Grande Mountain, Cavett Lake, Diablo Canyon West, and Fort Hancock quadrangles are near Fort Hancock, Texas. They encompass a part of the southeast Hueco Bolson that extends from the Rio Grande northward to the Diablo Plateau and southwest edge of the Finlay Mountains. The stratigraphy of this area consists mostly of piedmont and valley-border alluvium and windblown sand, which covers most of the older Cretaceous bedrock and the northeast edge of Laramide thrust faults, south of the plateau. The southeast part of the Campo Grande fault, a major northwest-striking Quaternary fault, crosses the area. This Quaternary fault cuts middle and lower upper Pleistocene deposits, although younger upper Pleistocene deposits are not displaced. A gentle monocline strikes northwestward along the plateau rim and basin margin. The monocline may have initially developed during the Late Cretaceous—early Tertiary Laramide deformation that deformed strata of this region; the monocline was possibly reactivated during the younger Cenozoic extensional deformation, which resulted in the development of the Hueco Bolson.

Other Geologic Investigations

Geomorphic Studies of Archeological Sites

L. Edwin 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.

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 1994, the following 56 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.

"Computerized Calculation of Lignite Resources, Jackson and Wilcox Trends, South Texas (Completion) and Jackson–Yegua Trend, East Texas (Revision)": supported by the U.S. Geological Survey, U.S. Department of the Interior.

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

"Environmental Atlas of the Rio Grande/Rio Bravo Border Area": supported by the U.S. Environmental Protection Agency.

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

"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.

"Hydrogeochemical and Production Controls on NORM in Oil- and Gas-Field Operations": supported by the U.S. Department of Energy.

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

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

"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).

"Produce a Generic Slide Show": supported by the U.S. Army Corps of Engineers.

"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.

"Secondary Natural Gas Recovery: Targeted Technology Applications for Infield Reserve Growth": supported by the U.S. Department of Energy and the Gas Research Institute (two contracts).

"Studies Related to Continental Margins (years 7 through 10)": supported by the Minerals Management Service, U.S. Department of the Interior (four contracts).

"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

"Advanced Exploration and Development Research for Revitalizing Hydrocarbon Recovery in the Permian Basin, West Texas": supported by the Texas Higher Education Coordinating Board.

"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.

"Conodont Chemostratigraphy: Improvements in the Geologic Time Scale through Strontium and Uranium–Thorium–Lead Isotopic Dating": supported by the Texas Higher Education Coordinating Board.

"Determining Recent Sedimentation Rates of the Lower Lavaca 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.

"Evolution of the Earth's Early Atmosphere: Evidence from Earliest Proterozoic Platform Carbonates": supported by the Texas Higher Education Coordinating Board.

"Franklin Mountains Mineral Evaluation": supported by the Texas General Land Office.

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

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

"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.

"Quality Assurance Assistance for a Low-Level Radioactive Waste Disposal Facility, Hudspeth County, Texas": supported by the Texas Low-Level Radioactive Waste Disposal Authority.

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

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

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

"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).

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

Private

"Advisory Services to Ecopetrol": supported by Empresa Colombiana de Petróleos (Ecopetrol).

"Applied Geodynamics Laboratory": supported by Agip S.p.A., Amoco Production Company, Anadarko Petroleum Corporation, ARCO Exploration and Production Technology, BP International, Ltd., Chevron Petroleum Technology Company, Conoco, Inc., E. I. DuPont de Nemours and Company, The Louisiana Land and Exploration Company, Marathon Oil Company, Mobil Research and Development Corporation, Phillips Petroleum Company, Société Nationale Elf Aquitaine Production, STATOIL, 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 Brasiliero S.A.

"Characterization of Heterogeneity Style and Permeability Structure in a Sequence Stratigraphic Framework in Fluvio-Deltaic Reservoirs": supported by Amoco Production Company, BP Exploration Operating Company, Limited, Chevron Oil Field Research Company, Conoco, Inc., Exxon Production Research Company, Intevep, Japan National Oil Corporation, Mobil Exploration and Production, 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., Chevron Petroleum Technology Company, Elf Aquitaine Production, Exxon Production Research Company, Fina Oil and Chemical Company, Japan National Oil Corporation, Marathon Oil Company, OXY USA, Inc., Pennzoil Petroleum Company, Petroleum Development Oman, Phillips Petroleum Company, Saudi Aramco Oil Company, Shell Western E&P, Texaco Houston Research Center, Texaco Services, Inc., TOTAL Compagnie Française des Petroles, and Union Oil Company of California.

"Characterize Miocene Reservoirs That Are Found in the Miocene–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.

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

"High-Resolution Sequence Stratigraphic and Systems Tract Analysis and Reservoir Characterization of the Toolachee/ Nappacoongee Murteree Blocks": supported by Santos, Ltd.

"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.

"Support of the North American Rock Mechanics Symposium": supported by the Gas Research Institute.

"Workshop: Impacts of Technology on Global Gas Resource Estimates": supported by Gas Technology Information, Inc.

Publications

In its role as a public geological research unit, the Bureau disseminates the results of research projects and programs primarily through its own publication series. During its 84-year history, the Bureau has published nearly 2,250 reports, bulletins, circulars, special publications, and maps covering major aspects of the geology and natural resources of Texas. In 1994 the Bureau's publication efforts expanded to include new media as a videocassette, CD-ROM, and data set were issued as part of the technology transfer program of the Secondary Gas Recovery project. The videocassette features recent, promising efforts to increase recovery of natural gas in known fields through advanced technology. The CD-ROM and 3-D seismic data set, described in more detail on page 37, are also technology transfer products of the Secondary Gas Recovery project. 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 formats.

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. During 1994, about 21,000 volumes were distributed. The Bureau issued the following publications in 1994.

Reports of Investigations

RI 212. Salt Tectonics on the Continental Slope, Northeast Green Canyon Area, Northern Gulf of Mexico: Evolution of Stocks and Massifs from Reactivation of Salt Sheets.

by S. J. Seni. 102 p., 59 figs., 4 tables, $6.50

In the eastern Green Canyon Area, northern Gulf of Mexico, the continental slope contains a complex assemblage of faults, basins, and salt structures that are interrelated as a result of salt-sheet burial by differential loading. The author of this report mapped the distribution and morphology of salt structures, quantified the rate and history of salt structural evolution, and developed a model of the evolution of salt structures on the slope. As an area of active salt tectonics, the modern slope is ideal for studying the ongoing evolution of salt structures. Models of salt evolution on the slope can help us understand early evolution of salt in the older sedimentary wedges in the Gulf Coast Basin and Gulf Interior basins. The practicality of such models lies in predicting the location and evolution of subtle hydrocarbon traps. This study utilizes data from both two- and three-dimensional seismic surveys and sparse wells to analyze the evolution of salt structures on the slope of the northern Gulf of Mexico, eastern Green Canyon Area. An exploration 3-D seismic data grid provides the principal means of analyzing salt structures within an 800-mi^2 region of the eastern Green Canyon Area. Funding was provided by the Texas Advanced Technology Program of the Office of the Governor of Texas.

RI 213. Depositional, Structural, and Sequence Framework of the Gas-Bearing Cleveland Formation (Upper Pennsylvanian), Western Anadarko Basin, Texas Panhandle.

by T. F. Hentz. 73 p., 34 figs., 9 tables, $6.00

Low-permeability (generally <0.10 md), "tight" sandstones of the Upper Pennsylvanian (lower Missourian) Cleveland formation compose major gas-producing reservoirs in the western Anadarko Basin of the northeastern Texas Panhandle. Although large-scale gas production began in 1956, the regional stratigraphic, depositional, and structural setting of the Cleveland is poorly known, and exploration for other possible Cleveland pay zones has been hampered by lack of information. Existing Cleveland gas fields are restricted to areas of reservoir-facies pinch-out and to folded and minor faulted zones that have deformed the northern occurrences of Cleveland sandstones in Ochiltree and Lipscomb Counties. This report summarizes findings of a study the author conducted in a 5,100-mi^2, 7-county area in the western Anadarko Basin using log suites from more than 860 evenly spaced wells, 4 cores from 4 wells, and many lithologic sample logs.

The Cleveland formation, an informal subsurface unit in the study area, is well defined by regionally continuous, thin, radioactive, black shale marker beds that bound the unit. The Cleveland section contains mostly siliciclastics between the Amarillo Uplift and the north part of the study area, where the sandstones thin and grade into thin shale intervals between much thicker, massive limestone facies of the Kansas Shelf. To the south, Cleveland strata interfinger with wedges of granite wash along the north flank of the Amarillo Uplift. Eastward toward the deep Anadarko Basin, the thickening formation becomes shalier.

The author also examined the Desmoinesian Marmaton Group, including the Oswego limestone, and the Missourian Cleveland and Kansas City Formation, in the context of their sequence stratigraphic framework. Regionally distinctive facies stacking patterns in the study interval compose a sequence stratigraphic framework of several westerly sourced systems tracts and three depositional sequences. New reservoirs should be targeted at the updip termination of systems tracts, at lap-out positions of individual sand-rich highstand systems and transgressive systems tracts, and along lowstand valley-margin stratal terminations. Funding for this research was provided by the Gas Research Institute under contract no. 5082-211-0708.

RI 214. Water-Level Controls on Halite Sedimentation: Permian Cyclic Evaporites of the Palo Duro Basin.

by S. D. Hovorka. 51 p., 29 figs., 1 table, 2 plates, $7.00

Cyclic evaporites of the San Andres Formation (Guadalupian) of the Texas Panhandle preserve sensitive indicators of water-level fluctuation in the Permian depositional environment. Sedimentary structures in halite document depth and stratification in brine pools. Evaporite dissolution documents episodes of relative sea-level rise, flooding of the evaporite environment with marine water, and sea-

level fall, when evaporites were exposed to meteoric water. Sea-level rise and marine flooding dissolved tens of feet of halite and created dark, wavy-laminated insoluble residues in areas of maximum dissolution. Exposure created karst pits and concentrations of siliciclastic silt and clay. The relative timing of dissolution is shown by facies relationships and by diagenetic phases incorporated in residues. Synsedimentary diagenesis occurred in vadose and phreatic zones during exposures of the evaporites. The amount of brine pool fabric preserved is a measure of water-level stability, in which the most altered fabrics correspond to high-frequency water-level changes. The water-depth criteria developed by the author demonstrate that halite can preserve a good record of depositional facies. Cyclic changes in water depth are analyzed, and paleoenvironmental conditions are mapped on the basis of depositional facies. Two oversize cross sections depicting San Andres units 4 and 5 accompany the text. Funding for this work was partly provided by the U.S. Department of Energy under contract no. DE-AC97-83WM46651.

RI 215. Initiation of Salt Diapirism by Regional Extension: Global Setting, Structural Style, and Mechanical Models.

by M. P. A. Jackson and B. C. Vendeville. 39 p., 21 figs., 1 appendix, $4.50

One of the least understood aspects of salt tectonics is how salt structures are initiated. For example, why should some buried evaporites be transformed into salt diapirs, whereas others remain undeformed? Initiation of salt structures controls the form of early structures—including hydrocarbon traps—in the overburden above primary salt layers or secondary salt sheets. Although both sedimentary and erosional differential loading can initiate diapirs, the most important trigger appears to be stretching of the overburden. Stretching occurs by regional extension associated with rifting, gravity gliding, or gravity spreading.

The report is in two parts. Part 1 examines some facets of initiation, then reviews the global setting and structural style of 18 salt diapir provinces around the world. It documents a close relation in time and space between regional extension and the onset of salt upwelling. Part 2 explains why extension and diapirism should be linked in time and space. The results of physical modeling and analytical modeling are used to examine the interplay of viscous forces and pressure forces, the effects of density contrast, mechanical anisotropy, and critical thickness. Finally, various structural styles involving extensional salt tectonics are compared to illustrate that overburden stretching appears to localize salt structures more effectively than does basement stretching. Funding for this research was provided by the Texas Advanced Research Program, the Texas Advanced Technology Program, and 16 member companies of the Bureau's Industrial Associates program.

RI 216. Depositional and Diagenetic Facies Patterns and Reservoir Development in Silurian and Devonian Rocks of the Permian Basin.

by S. C. Ruppel and M. H. Holtz. 89 p., 80 figs., 2 tables, 1 appendix, $6.00

Silurian and Devonian rocks in the Permian Basin constitute an important hydrocarbon-bearing succession in West Texas and New Mexico. Production from nearly 650 reservoirs developed in these rocks totals almost 2 billion barrels of oil, and the authors of this study conclude that a similar amount of mobile oil remains in existing reservoirs. Despite the economic significance of this thick succession of carbonate and chert deposits, no comprehensive study of the deposits has been published. This report presents the results of a detailed analysis of the facies, depositional and diagenetic history, and causes of reservoir development in these deposits based on an integrated study of core, wireline logs, and reservoir data. The authors clarify long-standing stratigraphic uncertainties by subdividing the succession into three genetic units—the Fusselman Formation, the Wristen Group, and the Thirtyone Formation—each of which documents a distinct stage in the evolution of the middle Paleozoic carbonate platform in West Texas. For each of these units, they describe characteristic facies, styles of reservoir development, and causes of reservoir heterogeneity. Oil reservoirs developed in these rocks are grouped into four plays on the basis of similarities in geologic character. Reservoir properties are described for each play and used in calculating resource distribution and the potential for reserve growth. Because these rocks are equivalent to hydrocarbon-bearing successions in the U.S. Midcontinent (Oklahoma and the Illinois Basin, for example), the findings of this study can be applied beyond the Permian Basin. Funding was provided by the University of Texas System as part of a comprehensive study of University Lands reservoirs in West Texas.

RI 217. Increased Oil Recovery Potential from Barrier/Strandplain Reservoirs, Jackson–Yegua Trend, by Geologically Targeted Infill Drilling: Examples from Seventy-Six West and Colmena–Cedro Hill Fields, South Texas.

by D. S. Hamilton. 52 p., 45 figs., $3.00

The Jackson–Yegua Barrier/Strandplain Sandstone play, which encompasses Zapata, Jim Hogg, Webb, Duval, and Bee Counties, comprises 300 fields having common depositional, structural, and production characteristics. Despite a cumulative oil production (1921–1989) of 625 million barrels and high average porosity and permeability, recovery efficiencies playwide are only 38 percent of original oil in place. Low recovery efficiency and lower than typical average residual oil saturation indicate that a large mobile oil resource remains in these reservoirs, apart from proved reserves. In this study, the author presents a detailed geologic and reservoir architecture characterization of Jackson Group reservoirs at Seventy-Six West and Colmena–Cedro Hill fields. At Seventy-Six West field, eight compartments were identified that are incompletely contacted by current well spacing and where zones are inefficiently swept by waterflood. Four prospects were identified, two were drilled and completed as oil producers, and a third well was drilled as a site for water injection as part of a geologically optimized waterflood. At Colmena–Cedro Hill field, where structural control and an extensive gas cap dominate production trends, two of three identified prospects were drilled and successfully completed as oil producers. Because these two fields typify all the oil fields in the play, the results of this report can be extended to include all fields, thus promoting development of these already mature Jackson–Yegua fields, prolonging field life, and ultimately increasing oil recovery. This project was partly funded by the State Lands Energy Resource Optimization program, administered by the Office of the Governor of Texas, and by grants from the U.S. Department of Energy and the Energy Laboratory of the University of Houston Allied Geophysical Laboratories.

RI 218. Coalbed Methane in the Upper Cretaceous Fruitland Formation, San Juan Basin, New Mexico and Colorado.

edited by W. B. Ayers, Jr., and W. R. Kaiser, with contributions by W. A. Ambrose, S. E. Laubach, A. R. Scott, and J. S. Yeh. (copublished by the New Mexico Bureau of Mines and Mineral Resources and the Colorado Geological Survey.) 216 p., 168 figs., 14 tables, $15.00

The San Juan Basin is the most active area of coalbed methane development and production in the United States. Within the San Juan Basin, Fruitland Formation coal beds contain an estimated 43 to 49 trillion cubic feet of methane. In 1992, nearly 2,100 Fruitland coalbed wells produced approximately 447 billion cubic feet of coalbed methane, accounting for 81 percent of total U.S. production. In this report, the authors discuss five topics that relate to controls on the occurrence and producibility of coalbed methane.

First, the chapter on tectonic setting of the San Juan Basin reviews regional tectonic controls on depositional systems and coalbed attitude, such as depositional setting. The topic of depositional setting is covered in the second half of the report. The depositional setting of Fruitland coalbed methane is followed by two chapters describing local studies. Fracture patterns in Fruitland and adjacent strata are discussed in three chapters, which also address cleat trends and lineaments. Next follow summaries of studies on hydrology, thermal maturity, and gas composition. Finally, a concluding section on integrating geologic and hydrologic studies presents data on gas and water production from Fruitland coal beds and delineates the regions of the San Juan Basin in which Fruitland coal beds have similar reservoir characteristics. Funding was provided by the Gas Research Institute under contract no. 5087-214-1544.

RI 219. Depositional Environments of Unstable Shelf-Margin Deltas of the Oligocene Vicksburg Formation, McAllen Ranch Field, South Texas.

by R. P. Langford and J. M. Combes. 60 p., 27 figs., 3 tables, $5.00

Located 50 mi north of the Rio Grande in the southern Gulf Coastal Plain, McAllen Ranch field contains natural gas reservoirs at depths of 9,000 to 15,000 ft in lower Vicksburg sandstone. At McAllen Ranch field, the Vicksburg comprises a shaly upper part and a sandy lower interval, the latter, in turn, being composed of 13 packages of upward-coarsening sandstone successions. In this study, the authors use a variety of data sources to examine the depositional environments of the lower Vicksburg at McAllen Ranch field within the context of its unstable shelf-margin setting. Nearly 360 ft of whole core was recovered from two wells (the Shell A. A. McAllen B-17 and B-18) along with log suites, high-resolution dipmeter surveys, and offset vertical seismic profiles. Additional core data from 10 wells and several Vicksburg reservoirs completed the data base used in interpreting depositional facies. Stratigraphy and structure were determined using 140 electric logs, which were correlated with vertical seismic profiles to create several structure-contour maps of key reservoirs. Using the seismic and well log data, the authors defined four seismic structural–depositional facies: wedges, continuous reflectors, basin fills, and progradational sets. Funding for this project was provided by a joint venture of the Gas Research Institute under contract no. 5088-212-1718, the U.S. Department of Energy under contract no. DE-GF21-88MC25031, and the State of Texas.

RI 220. Geologic and Hydrologic Controls on Coalbed Methane: Sand Wash Basin, Colorado and Wyoming.

by W. R. Kaiser, A. R. Scott, D. S. Hamilton, Roger Tyler, R. G. McMurry, Naijiang Zhou, and C. M. Tremain. (copublished by the Colorado Geological Survey.) 151 p., 85 figs., 9 tables, $8.00

The Sand Wash Basin, in the southeast part of the Greater Green Basin in Colorado and Wyoming, contains coal resources in the Upper Cretaceous Williams Fork Formation and the Paleocene Fort Union Formation. Coal rank is mainly subbituminous to high-volatile B bituminous, and average gas contents are less than 200 cubic feet per ton. Low gas content and high water production have limited the exploitation of coalbed methane in the basin; high productivity requires ground-water flow through coals of high gas content orthogonally toward no-flow boundaries and conventional trapping of gas along these boundaries. In this study, the authors examine the geology and hydrology of the area and present a basin-scale coalbed methane producibility model to enhance exploration and production in the Sand Wash Basin and other coal basins nationwide. The text consists of eight chapters divided into four sections: the structural and stratigraphic setting, the Upper Cretaceous Mesaverde Group, the Paleocene Fort Union Formation, and the resources and producibility of coalbed methane in the Sand Wash Basin. The authors used more than 160 geophysical logs and 115 mi of seismic data from the Williams and Fort Union and more than 135 water analyses from more than 65 Mesaverde and Fort Union wells to delineate the major coal-bearing stratigraphic units and to evaluate ground-water flow. Coal and gas resources were calculated from digitized structure, topographic, and net-coal-thickness maps on a 3.5-mi^2 grid. Funding was provided by the Gas Research Institute under contract no. 5091-214-2261.

RI 221. Quantifying Secondary Gas Resources in Fluvial/Deltaic Reservoirs: A Case History from Stratton Field, South Texas.

by R. A. Levey, R. J. Finley, and M. A. Sippel. 38 p., 41 figs., 3 tables, 2 appendices, $4.00

Using historical analysis to quantify natural gas reserve growth, the authors of this report document the effects of depositionally controlled reservoir heterogeneity on production of natural gas from a mature South Texas field. Located in Nueces, Kleberg, and Jim Wells Counties, Stratton field is an excellent candidate for detailed study because of its long development and production history, its prior infield drilling and recompletion program, and its status, unusual among Frio fluvial/deltaic systems, as a densely drilled natural laboratory. The authors of this report conducted a detailed analysis of the Wardner lease area, in the south part of Stratton field, a study area of approximately 7,400 acres. On the basis of the area's structure and stratigraphy, the authors identify five sources of reserve additions in the Wardner lease: (1) new infield reservoirs, (2) untapped reservoir compartments encountered by drilling wells and completed in the same reservoir interval that is producing in adjacent wells, (3) incompletely drained reservoir compartments encountered by drilling and completed in reservoirs that are abandoned in adjacent wells, (4) bypassed reservoirs, and (5) new wells that are drilled and completed in pool reservoirs deeper than those of the current production. Gas reserve growth was assessed to determine the effects of infield development on

the size of the secondary gas resource and to show the geologic and engineering characteristics that identify reserve growth. In their gas reserve growth assessment, the authors compare reserve growth from 1979 through 1990 using a hindcast approach, assess the impact of infield drilling in Stratton field from 1986 through 1990, and forecast reserve growth for 1990 through 2009. The authors conclude by presenting three reservoir case studies that show that reserve additions come from new infield reservoirs, untapped reservoir compartments, and incompletely drained reservoir compartments. Funding for this research was provided by a joint venture of the Gas Research Institute under contract no. 5088-212-1718, the U.S. Department of Energy under contract no. DE-FG21-88MC25031, and the State of Texas.

RI 222. Reservoir Heterogeneity and Permeability Barriers in the Vicksburg S Reservoir, McAllen Ranch Gas Field, Hidalgo County, Texas.

by R. P. Langford, J. D. Grigsby, R. E. Collins, M. A. Sippel, and E. G. Wermund. 64 p., 37 figs., 4 tables, $7.00

In this publication, the authors' purpose was (1) to describe heterogeneities, particularly those within fault blocks, within the Vicksburg S reservoir throughout McAllen Ranch field and (2) to show that these heterogeneities contribute to compartmentalization, which in turn creates opportunities for reserve addition by infield development. The area of study is the north part of the Vicksburg S reservoir, the B area. By correlating 140 publicly available electric logs and 27 logs donated by the operator, the authors first determined the stratigraphy and structure within McAllen Ranch field. Seismic reflection lines of the field were also used in this phase of the project. Numerous cores from 9 wells throughout the field were used in interpreting depositional facies and environments, and 510 thin sections were analyzed in assessing diagenesis and diagenetic facies. To assess the area's permeability barriers, the authors analyzed part of the B area using a numerical simulation, which revealed that some reservoir compartmentalization affected the production and pressure histories of the field. From this finite-element model, the authors were able to identify several recompletion opportunities in the B area, three of which were subsequently targeted by the field operator. These recompletions may reveal significant natural gas reserve additions. Understanding the distribution of reservoir heterogeneities and permeability barriers may help in the search for incremental reserves in other Vicksburg deltaic natural gas reservoirs. This project was funded by the Gas Research Institute under contract no. 5088-212-1718, the U.S. Department of Energy under contract no. DE-FG21-88MC25031, and the State of Texas.

RI 223. Impacts of Technology on the Global Gas Resource Base: Proceedings of the Global Gas Resources Workshop.

edited by C. L. Ruthven. 271 p., 118 figs., 32 tables, 1 appendix, $18.00

Organized under the auspices of the International Energy Agency's International Centre for Gas Technology Information, a global gas resources workshop cosponsored by the Gas Research Institute, Gas Technology Information, Inc., and the Bureau was held in Vail, Colorado, in September. The purpose of the workshop was to assess estimates of the global gas resource base and the magnitude of resources that could be added with the strategic deployment of advanced technology. Papers presented by 32 leading resource experts from 20 countries provide a comprehensive analysis of global gas resources and identify key technology requirements in specific countries as well as major regions.

This report documents conclusions of the resource assessment and recommendations made by the experts attending the workshop. Workshop participants concluded that strategic application of advanced technology over the next 20 years will increase total remaining resources of natural gas by 25 percent, from 11,560 to 14,489 Tcf. In some parts of the world, Asia and Australasia, for example, the impact of technology was estimated to increase the resource base by as much as 80 percent. Cost-effective and efficient exploration and production technologies, international cooperation among petroleum companies and governments, and in some areas further development of transportation infrastructure will be required to expand natural gas reserves to meet the steadily rising demand for natural gas throughout the world. Results presented in this volume will be valuable to planners and policymakers in government and industry, both in the United States and worldwide, who are interested in long-term natural gas supply and international cooperation in natural gas technology transfer.

RI 224. Mechanics of Active Salt Diapirism.

by D. D. Schultz-Ela, M. P. A. Jackson, and B. C. Vendeville. 56 p., 40 figs., $11.50

In this report, the authors first review historical assumptions concerning the formation and evolution of active diapirs. They discuss the geology of active diapirs, describe the conditions that allow initiation of active diapirism with a force balance, and then outline the evolution of active diapirs on the basis of physical and numerical modeling. The authors' physical modeling simulates the deforming system of salt and sedimentary overburden in the laboratory by using silicone polymer and dry sand. The numerical modeling uses finite-element software that can simulate both brittle failure in the overburden and the buoyant flow of viscous salt. The numerical models show that overburden flexure contributes to the early formation of active diapir structures, but piercement does not continue to emergence unless the diapir is wide or tall relative to overburden thickness. Active diapirism is easiest in rectangular diapir crests and most difficult in triangles that have pointed crests. Numerous illustrations in black and white and in color illustrate these structural and evolutionary changes. Results of these experiments will be useful to those studying active diapirs throughout the world. Funding for this research was provided by the Texas Advanced Research Program, the Texas Advanced Technology Program, and 16 member companies of the Bureau's Industrial Associates program.

RI 225. Geophysical and Geochemical Delineation of Sites of Saline-Water Inflow to the Canadian River, New Mexico and Texas.

by J. G. Paine, A. J. Avakian, T. C. Gustavson, S. D. Hovorka, and B. C. Richter. 73 p., 58 figs., 4 tables, 1 appendix, $4.50

Located in the Texas Panhandle, Lake Meredith supplies water to all major cities on the Southern High Plains. Since the construction of Sanford Dam in 1964, however, the salinity of Lake Meredith has risen and now exceeds standards set by the Texas Natural Resource Conservation Commission. Communities must now dilute Lake Meredith water with large amounts of low-salinity water pumped from the Ogallala aquifer. Before remediation of Lake Meredith salinity, the authors of this report investigated the geology, surveyed water and ground conductivity, and analyzed

the hydrochemistry of ground-water discharge sites at which the Canadian River and Lake Meredith are naturally polluted by highly saline waters. They also examined distribution of joints in local (Dockum Group) strata because the joints may be preferred pathways for ground-water flow. The discharge points located in this study can be monitored to measure the effectiveness of any remediation program designed to reduce saline ground-water flow into the Canadian River and Lake Meredith. Funding was provided by the Canadian River Municipal Water Authority and by the Texas Water Development Board.

Geological Circulars

GC 94-1. Use of Dipmeters in Stratigraphic and Depositional Interpretation of Natural Gas Reservoirs of the Oligocene Vicksburg Formation: An Example from McAllen Ranch Field, Hidalgo County, Texas.

by R. P. Langford, J. D. Hall, and W. E. Howard. 39 p., 23 figs., 3 tables, $5.50

Dipmeter techniques can be used to infer locations of areas of maximum reservoir sandstone thickness, locations of faults between wells, and stratigraphic correlation of reservoirs. In this circular, the authors describe several dipmeter log techniques used to help interpret stratigraphy and structure of the Vicksburg S reservoir in the McAllen Ranch field area of South Texas. The study area, referred to as the B area, comprises a 5-mi^2 part of McAllen Ranch field, from which 15 dipmeter logs and a three-dimensional seismic survey were available. In the B area, 14 wells had already been drilled into the Vicksburg S reservoir, and 3 step-out wells were drilled during the project; 15 wells provided a total of 58,610 ft of dipmeter and other log data for this study. Results showed that dipmeters can allow areas of greatest subsidence and deposition, and therefore the thickest reservoir sandstone locations, to be determined. Rotation azimuths can be used to infer the direction of offset areas of maximum sandstone thickness, as was used in the S_1 and S_2 intervals of the Vicksburg S. Dipmeters can also locate growth faults by identifying wells that are tilted or folded in directions different from those of offset wells. Finally, dipmeter measurement of hole eccentricity can be used to estimate horizontal stress vectors, which is particularly important in deeper Vicksburg reservoirs, where hydraulic fracture treatment is necessary. These results illustrate that dipmeter data can be useful for recovering additional reserves in fields similar to McAllen Ranch. Funding was provided by the Gas Research Institute under contract no. 5088-212-1718, the U.S. Department of Energy under contract no. DE-FG21-88MC25031, and the State of Texas.

GC 94-2. Targeted Secondary Recovery of Hydrocarbons from Barrier/Strandplain–Tidal-Plain Facies, Jackson Group, Prado Field, South Texas.

by S. J. Seni and S.-J. Choh. 47 p., 21 figs., 1 table, 2 appendices, $5.00

Prado field in Jim Hogg County has produced more than 23 million barrels of oil and more than 32 billion cubic feet of gas from structural-stratigraphic traps in barrier/strandplain sandstones of the Eocene lower Jackson Group. Recovery efficiency is 34 percent from the primary oil reservoir and 72 percent from the primary gas reservoir. The authors of this report analyzed well logs, scout cards, and reservoir engineering data to evaluate the controls on hydrocarbon accumulation and to determine the field's potential for geologically targeted reexploration. In addition, they incorporated their data into a geographic information system, which they used to construct net- and percentage-sandstone maps and structural, stratigraphic, and facies cross sections. From these data, the authors conclude that prospects for future hydrocarbon production are good and that reexploration should focus on the heterogeneous reservoir compartments of the Prado and Middle Loma Novia reservoirs, which typify the tidal-inlet-fill reservoir model. These heterogeneities should be investigated before Prado field operators implement secondary or tertiary recovery operations. In a larger context, these findings can be applied directly to further reservoir exploration in similar settings within the Jackson–Yegua and Frio Barrier/Strandplain Sandstone plays. This research was conducted for the U.S. Department of Energy, Advanced Technologies Division, under Cooperative Agreement No. DE-FC07-85NV1041.

Mineral Resource Circulars

MRC 84. Limestone Resources of Texas.

by L. E. Garner. 16 p., 1 fig., 3 tables, $3.00

Geologic formations that contain limestone deposits can be found in more than 93 Texas counties. Paleozoic, Mesozoic, and Cenozoic limestones in these areas provide commercial sources for crushed stone, cement, lime, or dimension stone. Although these abundant Texas limestones are in demand, transportation costs limit production in some areas. Formerly located near metropolitan areas, resources used by crushed stone producers are being depleted, so that producers have had to move farther from their markets. Distance from resource to production and use areas results in higher final costs to consumers. Many suitable limestone deposits lie in Central and North-Central Texas, where transportation costs to markets are minimal because railroads are near. Reduction in long-haul transportation rates could thus make production of locally produced materials more competitive. Funding was partly provided by the U.S. Bureau of Mines to the Texas Mining and Mineral Research Institute under grant nos. G119148 and G1104148.

MRC 85. The Barite Industry and Resources of Texas.

by J. R. Kyle. 86 p., 51 figs., 10 tables, 2 appendices, $6.50

Barite, a useful industrial mineral, is a weighting agent in well-drilling fluids and a source of barium in chemicals used in industry. Although most barite deposits known in Texas are too small and too low in grade to compete with other sources, they do have an economic advantage in being near processing and consuming areas. In addition, the relative purity of Texas barite deposits suggests that they provide chemical- and glass-grade barites, which are more valuable than drilling-mud-grade barite. Barite deposits, reported in at least 27 counties, lie in sedimentary terranes ranging in age from Precambrian to Recent, on the Gulf Coast, in the Llano Uplift area, and in the Trans-Pecos magmatic province. In this circular, the author summarizes the economic status of the worldwide and national barite industry, the barite processing industry in Texas, the geology of commercial deposits, and the locations and potential resources of Texas barite. Funding for this research was provided by the U.S. Department of the Interior under grants to the Texas Mining and

Mineral Resources Research Institute. Research on mineralization in the salt dome environment was supported by the National Science Foundation.

Cross Sections

Reference High-Resolution Correlation Cross Sections, Paleogene Section, Texas Coastal Plain.

by W. E. Galloway, Xijn Liu, Deborah Travis-Neuberger, and Liangqing Xue. 19-p. text, 6 figs., 1 appendix, 5 high-resolution correlation cross sections, $6.00

This cross section set traverses four Cenozoic depositional subprovinces, the Rio Grande Embayment, San Marcos Arch, Houston Embayment, and Sabine Arch. For each of these areas, the authors used closely spaced well logs to outline stratigraphic surfaces, parasequences, and marker beds to delineate regional sequence boundaries, internal stratal architectures, erosional truncation surfaces, and depositional facies associations. Also included are depth ranges of reservoirs in fields adjacent to each line of section. This synthesis of stratigraphic, lithofacies, paleogeographic, and structural features having known petroleum resources provides an overview of a major petroleum province. An important reference tool, this cross section set provides the reader with a framework for detailed analyses of the stratigraphic units, their buried slope-system equivalents, and their hydrocarbon plays.

Map

Tectonic Map of Texas.

scale: 1 inch = 100 mi, $0.25

The *Tectonic Map of Texas* depicts the major episodes of plate tectonic motion in Texas and highlights structure and relationships among segments of the Earth's crust. It delineates three main tectonic cycles, the Llano cycle, the Ouachitan cycle, and the Gulf Coast cycle. Color coding shows depths to various formations relative to various reference horizons; for example, one reference horizon in West Texas is the Paleozoic Ellenburger Formation, which is correlated to the West Texas and Anadarko Basins by dark-blue shading. Areas shaded in green and brown were deposited during formation of the Gulf of Mexico and Atlantic Ocean. This map complements another page-size sheet, the *Geology of Texas* map. Larger, more detailed versions of the *Tectonic Map* (scale 1:750,000, $15) and the *Geology of Texas Map* (scale 1:500,000, $22.50) are also available.

Other New Releases

In addition to these publications, the Bureau issued two computer-related items and upgraded the *Restore*© data base.

3-D Seismic and Well Log Data Set: Fluvial Reservoir Systems—Stratton Field, South Texas.

compiled by R. A. Levey, B. A. Hardage, R. D. Edson, Jr., and V. M. Pendleton. 8-mm cassette, 3.5-inch disk, and 30-p. text, $40.00

As part of the Bureau's technology transfer program for the Gas Research Institute and the U.S. Department of Energy, this product provides versatile data sets that can be used for testing hardware and software, training others in the use of 3-D and seismic data, and illustrating the complex structure and stratigraphy of natural gas reservoirs. This seismic and well log data set will assist gas operators and contractors in deploying new technologies to ensure adequate natural gas resources at competitive prices. The focus of the data set is on gas reservoirs in the Vicksburg and Frio Formations in Stratton and Agua Dulce fields in Nueces and Kleberg Counties in South Texas. The DOS-formatted diskette contains 21 digitized logs from 21 wells and depths, and the 8-mm tape contains seismic two-way travel times of 10 middle Frio reservoir horizons. The 3-D data set is in SEGY format; complete data-loading instructions are included in the text. Funding was provided by the Gas Research Institute under contract no. 5088-212-1718, the U.S. Department of Energy under contract no. DE-F621-88MC25031, and the State of Texas.

CD-ROM: Target Technology Applications for Infield Reserve Growth.

compiled by R. A. Levey, C. L. Ruthven, W. G. White, D. M. Spinney, and Clint Phillips. $20.00

This CD-ROM was developed by the Bureau on behalf of the Gas Research Institute and the U.S. Department of Energy to present research results from the joint venture "Secondary Natural Gas Recovery: Targeted Technology Applications for Infield Reserve Growth" in a multimedia format. The purpose of this CD-ROM is to assist gas operators interested in natural gas reserve growth. Research results and benefits analysis from geologic, engineering, petrophysical, and geophysical project analyses conducted on Frio, Vicksburg, and Wilcox gas fields in the Texas Gulf Coast are captured on the CD-ROM. It presents seven technical topical reports, a video describing a compartmented natural gas reservoir simulator that was a product of the research, and technical abstracts, as well as a master bibliography of all project-related articles published in a wide array of technical journals and presented at national and regional meetings. This CD-ROM application is user-friendly and interactive, allowing users to browse, search the text for keywords, read abstracts, view graphical figures, equations, charts, and tables, and watch the video. The application runs on an IBM-compatible PC. System requirements to run this application are as follows: personal computer, 80286 or higher; Microsoft Windows, version 3.0 or higher; DOS, version 3.1 or higher; 1.5 MB RAM; Windows-compatible graphics card; CD-ROM drive and driver software; and a mouse or other pointing device. Usage notes and a Help screen are included. Funding was provided by the Gas Research Institute under contract no. 5088-212-1718, the U.S. Department of Energy under contract no. DE-F621-88MC25031, and the State of Texas.

Restore© *Upgrade*

Restore©, a balancing-cross-section program designed by Bureau researchers in 1991, has been upgraded. Three major changes and several enhancements have been made, making it easier to use. Registered users may request the upgrade only ($50 [commercial or individual users] and $10 [nonprofit]) or purchase additional full copies at the regular price and receive the upgrade disk and documentation at no additional charge.

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

Papers

Baek, Hwanjo, Laubach, S. E., and Nelson, P. P., 1994, Fracture toughness and crack morphology of a variably cemented sandstone, *in* SEM (Society for Experimental Mechanics) Spring Conference and Exhibits: Baltimore, Society for Experimental Mechanics, p. 153–158.

Barnaby, R. J., Ramamoorthy, R., and **Holtz, M. H.,** 1994, Resource optimization through characterization of downdip Frio shoreface/shelf sandstone reservoirs: Red Fish Bay field, South Texas: Gulf Coast Association of Geological Societies Transactions, v. 44, p. 71–77.

Bebout, D. G., 1994, Dune (Grayburg) field, *in* Pausé, Paul, and Entzminger, David, eds., Oil and gas fields in West Texas, symposium volume VI: West Texas Geological Society Publication No. 94-96, p. 39–46.

Bebout, D. G., 1994, Farmer (Grayburg) field, *in* Pausé, Paul, and Entzminger, David, eds., Oil and gas fields in West Texas, symposium volume VI: West Texas Geological Society Publication No. 94-96, p. 61–69.

Bebout, D. G., 1994, Foster (Grayburg) field, *in* Pausé, Paul, and Entzminger, David, eds., Oil and gas fields in West Texas, symposium volume VI: West Texas Geological Society Publication No. 94-96, p. 71–78.

Bebout, D. G., 1994, *Review of* Mississippian Oolites and Modern Analogs, Brian D. Keith and Charles W. Zuppann, eds., AAPG Studies in Geology, 1993: Journal of Sedimentary Research, v. B64, no. 2, p. 266–267.

Bridge, J. S., and **Willis, B. J.,** 1994, Marine transgressions and regressions recorded in Middle Devonian shore-zone deposits of the Catskill clastic wedge: Geological Society of America Bulletin, v. 106, p. 1440–1458.

Collins, E. W., and **Raney, J. A.,** 1994, Impact of late Cenozoic extension on Laramide overthrust belt and Diablo Platform margins, northwestern Trans-Pecos Texas, *in* Ahlen, Jack, Peterson, John, and Bowsher, A. L., eds., Geologic activities in the 90s: New Mexico Bureau of Mines and Mineral Resources, Bulletin No. 150, p. 71–81.

Collins, E. W., and **Raney, J. A.,** 1994, Tertiary and Quaternary tectonics of the Hueco bolson, Trans-Pecos Texas and Chihuahua, Mexico, *in* Keller, G. R., and Cather, S. M., eds., Basins of the Rio Grande rift: structure, stratigraphy, and tectonic setting: Boulder, Geological Society of America Special Paper No. 291, p. 265–282.

Dellagiarino, George, **Masterson, A. R.,** and **Miller, L. A.,** eds., 1994, Proceedings, Third Symposium on Studies Related to Continental Margins—a summary of year-five and year-six activities: sponsored by U.S. Department of Interior, Minerals Management Service, and Association of American State Geologists, Continental Margins Committee, 214 p.

Dupree, J. A., and **Garner, L. E.,** 1994, The mineral industry of Texas, 1992: U.S. Department of the Interior, Bureau of Mines, 18 p.

Dutton, A. R., ed., 1994, Toxic substances and the hydrologic sciences: Minneapolis, Minnesota, American Institute of Hydrology, 729 p.

Dutton, A. R., 1994, Use of aquifer stratigraphy for building numerical models of ground-water flow: case study of the heterogeneous Gulf Coast aquifer in Matagorda and Wharton Counties, Texas: Gulf Coast Association of Geological Societies Transactions, v. 44, p. 185–192.

Finley, R. J., Levey, R. A., and **Hardage, B. A.,** 1993, Incremental natural gas resources through infield reserve growth/secondary gas recovery, *in* Malone, R. D., ed., Proceedings, Fuels Technology Contractors Review Meeting: Morgantown, West Virginia, U.S. Department of Energy, Office of Fossil Energy, DOE/METC-94/1002, p. 267–280.

Finley, R. J., and **Tyler, Noel,** 1994, Infield development for independent producers: The University of Texas at Austin, Bureau of Economic Geology, GCAGS Short Course No. 1, variously paginated.

Fisher, W. L., 1994, Citation for Don R. Boyd, Dedicatee: Gulf Coast Association of Geological Societies Transactions, v. 44, p. iii–v.

Fisher, W. L., 1994, Citation for Frank W. Harrison, Ben H. Parker Medalist, *in* American Institute of Professional Geologists Awards Program: p. 3–4.

Fisher, W. L., 1994, How technology has compounded U.S. gas resource estimates: Oil and Gas Journal, v. 92, no. 43, p. 100–107.

Fisher, W. L., 1994, Rethinking resources: Gulf Coast Association of Geological Societies Transactions, v. 44, p. 1–12.

Fisher, W. L., 1994, The revolution in natural gas: SIPES Newsletter, v. 32, no. 3, p. 3–6.

Fryar, A. E., and Schwartz, F. W., 1994, A method for studying diagenesis in shallow sediments using flow-through columns: Journal of Sedimentary Research, v. A64, no. 3, p. 679–681.

Fryar, A. E., and Schwartz, F. W., 1994, Modeling the removal of metals from ground water by a reactive barrier: experimental results: Water Resources Research, v. 30, no. 12, p. 3455–3469.

Ge, Hongxing, and **Vendeville, B. C.,** 1994, Origin of the Dongzhuang rollover structure—an insight from scaled physical experiments: Acta Petrolei Sinica, v. 15, p. 17–25.

Guglielmo, Giovanni, Jr., 1994, Interference between pluton expansion and coaxial tectonic deformation: three-dimensional computer model and field implications: Journal of Structural Geology, v. 16, no. 2, p. 237–252.

Gustavson, T. C., 1994, *Review of* Flat Water: A History of Nebraska and Its Water, Charles A. Flowerday, editor, University of Nebraska–Lincoln, Institute of Agriculture and Natural Resources, Resource Report/Conservation and Survey Division, No. 12: Great Plains Research, v. 4, no. 1, p. 167–169.

Gustavson, T. C., Holliday, V. T., and **Hovorka, S. D.,** 1994, Development of playa basins, Southern High Plains, Texas and New Mexico, *in* Urban, L. V., and Wyatt, A. W., eds., Proceedings, Playa Basin Symposium: Texas Tech University, Water Resources Center, p. 5–14.

Gustavson, T. C., Hovorka, S. D., and **Dutton, A. R.,** 1994, Origin of satin spar veins in evaporite basins: Journal of Sedimentary Research, v. A64, no. 1, p. 88–94.

Hamilton, D. S., 1993, Genetic stratigraphic framework, *in* Tadros, N. Z., ed., The Gunnedah Basin, New South Wales: Geological Survey of New South Wales, Memoir Geology 12, p. 145–164.

Hamilton, D. S., 1993, Upper Watermark—lower Black Jack/Arkarula depositional episode, *in* Tadros, N. Z., ed., The Gunnedah Basin, New South Wales: Geological Survey of New South Wales, Memoir Geology 12, p. 213–244.

Hamilton, D. S., Newton, C. B., Smyth, M., Gilbert, T. D., Russell, N., McMinn, A., and Etheridge, L. T., 1993, Petroleum potential of the Gunnedah and Surat Basins, *in* Tadros, N. Z., ed., The Gunnedah Basin, New South Wales: Geological Survey of New South Wales, Memoir Geology 12, p. 367–388.

Hamilton, D. S., and Tadros, N. Z., 1994, Utility of coal seams as genetic stratigraphic sequence boundaries in nonmarine basins: an example from the Gunnedah Basin, Australia: American Association of Petroleum Geologists Bulletin, v. 78, no. 2, p. 267–286.

Hamilton, D. S., Tadros, N. Z., and Thomson, S., 1993, Depositional setting and its influence on the Permian coals, *in* Tadros, N. Z., ed., The Gunnedah Basin, New South Wales: Geological Survey of New South Wales, Memoir Geology 12, p. 389–425.

Hardage, B. A., 1994, Chapter 8, Seismic prediction of overpressure conditions ahead of the bit in real drill time, *in* Fertl, W. H., Chapman, R. E., and Hotz, R. F., eds., Studies in abnormal pressures: Amsterdam, Elsevier, Developments in Petroleum Science No. 38, p. 241–250.

Hardage, B. A., 1994, This month in *Geophysics*: Geophysics, v. 59, nos. 1–11, p. 1, 175, 335, 499, 693, 863, 1027, 1181, 1319, 1491, 1641.

Hardage, B. A., and Turpening, Roger, 1993, Vertical seismic profiling: Boston, Massachusetts, International Human Resources Development Corporation, Training Manual GP606, 142 p. + training video.

Hardage, B. A., Levey, R. A., Pendleton, Virginia, **Simmons, James,** and **Edson, Rick,** 1994, A 3-D seismic case history evaluating fluvially deposited thin-bed reservoirs in a gas-producing property: Geophysics, v. 59, no. 11, p. 1650–1665.

Harris, P. M., **Kerans, Charles,** and **Bebout, D. G.,** 1994, Chapter 18, Ancient outcrop and Modern examples of platform carbonate cycles—implications for subsurface correlation and understanding reservoir heterogeneity, *in* Loucks, R. G., and Sarg, J. F., eds., Carbonate sequence stratigraphy: recent developments and applications: American Association of Petroleum Geologists Memoir 57, p. 475–492.

Hentz, T. F., 1994, Sequence stratigraphy of the Upper Pennsylvanian Cleveland Formation: a major tight-gas sandstone, western Anadarko Basin, Texas Panhandle: American Association of Petroleum Geologists Bulletin, v. 78, no. 4, p. 569–595.

Holtz, M. H., 1994, McFarland (Queen) field, *in* Pausé, Paul, and Entzminger, David, eds., Oil and gas fields in West Texas, symposium volume VI: West Texas Geological Society Publication No. 94-96, p. 169–177.

Holtz, M. H., and **Major, R. P.,** 1994, Geological and engineering assessment of remaining oil in a mature carbonate reservoir: an example from the Permian Basin, West Texas: Society of Petroleum Engineers, Paper No. SPE 27687, p. 565–576.

Holtz, M. H., and **Major, R. P.,** 1994, Keystone (San Andres) field, *in* Pausé, Paul, and Entzminger, David, eds., Oil and gas fields in West Texas, symposium volume VI: West Texas Geological Society Publication No. 94-96, p. 129–136.

Holtz, M. H., and **Major, R. P.,** 1994, Penwell (San Andres) field, *in* Pausé, Paul, and Entzminger, David, eds., Oil and gas fields in West Texas, symposium volume VI: West Texas Geological Society Publication No. 94-96, p. 213–220.

Hovorka, S. D., 1994, Stratigraphic controls on fracture frequency in the Austin Chalk: data from the near surface and its implications for hydrocarbon production, *in* Austin Chalk Symposium: Texas A&M University, p. 1–19.

Hovorka, S. D., Dutton, A. R., Ruppel, S. C., and **Yeh, Joseph,** 1994, Sedimentologic and diagenetic controls on aquifer properties, Lower Cretaceous Edwards carbonate aquifer, Texas: implications for aquifer management: Gulf Coast Association of Geological Societies Transactions, v. 44, p. 277–284.

Hovorka, S. D., and **Nance, H. S.,** 1994, Dynamic depositional and early diagenetic processes in a deep-water shelf setting, Upper Cretaceous Austin Chalk, North Texas: Gulf Coast Association of Geological Societies Transactions, v. 44, p. 269–276.

Hovorka, S. D., Nance, H. S., and **Kerans, Charles,** 1994, Chapter 19, Parasequence geometry as a control on permeability evolution: examples from the San Andres and Grayburg Formations in the Guadalupe Mountains, New Mexico, *in* Loucks, R. G., and Sarg, J. F., eds., Carbonate sequence stratigraphy: recent developments and applications: American Association of Petroleum Geologists, Memoir 57, p. 493–514.

Jackson, M. P. A., and Talbot, C. J., 1994, Chapter 8, Advances in salt tectonics, *in* Hancock, P. L., ed., Continental deformation: Oxford, Pergamon Press, p. 159–179.

Jackson, M. P. A., and **Vendeville, B. C.,** 1994, Regional extension as a geologic trigger for diapirism: Geological Society of America Bulletin, v. 106, no. 1, p. 57–73.

Jackson, M. P. A., Vendeville, B. C., and **Schultz-Ela, D. D.,** 1994, Salt-related structures in the Gulf of Mexico: a field guide for geophysicists: Geophysics, The Leading Edge of Exploration, August, p. 837–842.

Jackson, M. P. A., Vendeville, B. C., and **Schultz-Ela, D. D.,** 1994, Structural dynamics of salt systems: Annual Review of Earth and Planetary Sciences, v. 22, p. 93–117.

Kaiser, W. R., 1994, Development and evaluation of a basin-scale coalbed methane producibility model: In Focus—Tight Gas Sands, v. 10, no. 1, p. 47–52.

Kaiser, W. R., 1994, Texas—description of seams, *in* Keystone coal industry manual: Chicago, Maclean Hunter, p. S148–S154.

Kaiser, W. R., and **Ayers, W. B., Jr.,** 1994, Geologic and hydrologic characterization of coalbed-methane reservoirs in the San Juan Basin: Society of Petroleum Engineers Formation Evaluation, v. 9, no. 3, p. 175–184.

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.

Kerans, Charles, Lucia, F. J., and **Senger, R. K.,** 1994, 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, and **Ruppel, S. C.,** 1994, San Andres sequence framework, Guadalupe Mountains: implications for San Andres type section and subsurface reservoirs, *in* Garber, R. A., and Keller, D. R., eds., Field guide to the Paleozoic section of the San Andres Mountains: Permian Basin Section—SEPM (Society for Sedimentary Geology), Publication No. 94-35, p. 105–115.

Knox, P. R., 1994, Architecture, internal heterogeneity, and resulting drainage efficiency of upper Oligocene Frio Formation inner-shelf sandstone reservoirs in West Fulton Beach field, Aransas County, Texas: Gulf Coast Association of Geological Societies Transactions, v. 44, p. 337–345.

Laubach, S. E., and **Hamlin, H. S.,** 1994, Geological analyses of tight gas sandstones: Canyon Sandstone: In Focus—Tight Gas Sands, v. 10, no. 1, p. 35–38.

Laubach, S. E., and other members of the National Research Council, 1994, Drilling and excavation technologies for the future: Washington, D.C., National Academy Press, 161 p.

Levey, R. A., Tyler, Noel, Hardage, B. A., Carr, D. L., Ruthven, C. L., Lancaster, David, Elphick, Robert, and Ballard, J. R., 1994, Secondary natural gas recovery: targeted technology applications for infield reserve growth in Midcontinent sandstone: In Focus—Tight Gas Sands, v. 10, no. 1, p. 39–42.

Liu, Xijin, and **Galloway, W. E.,** 1993, Sediment accumulation rate: problems and new approach, *in* GCSSEPM Foundation 14th Annual Research Conference, Rates of Geologic Processes: Program with Papers, p. 101–107.

Lucia, F. J., and **Kerans, Charles,** 1994, Taylor Link West (San Andres) field, *in* Pausé, Paul, and Entzminger, David, eds., Oil and gas fields in West Texas, symposium volume VI: West Texas Geological Society Publication No. 94-96, p. 251–259.

Lucia, F. J., and **Major, R. P.,** 1994, Porosity evolution through hypersaline reflux dolomitization, *in* Purser, B. H., Tucker, M. E., and Zenger, D. H., eds., Dolomites, a volume in honour of Dolomieu: International Association of Sedimentologists, Special Publication No. 21, p. 325–341.

Luza, K. V., Jensen, K. M., Fishman, W. D., **Wermund, E. G., Jr.,** and Richmond, G. M., 1994, Quaternary geologic map of the Dallas 4° × 6° quadrangle, United States, *in* Richmond, G. M., and Christiansen, A. C., compilers, Quaternary geologic atlas of the United States: U.S. Department of the Interior and U.S. Geological Survey, Miscellaneous Investigations Series, Map I-1420 (NI-14), 1 sheet, scale 1:1,000,000.

Mace, R. E., 1994, Abandonment of hand-dug wells: a case study in Ellis County, Texas: The Texas Journal of Science, v. 46, no. 4, p. 345–359.

Mace, R. E., and **Dutton, A. R.,** 1994, Hydrogeologic controls on contaminant transport in weathered and fractured chalk, *in* Dutton, A. R., ed., Toxic substances and the hydrologic sciences: American Institute of Hydrology, p. 535–546.

Mace, R. E., Dutton, A. R., and **Nance, H. S.,** 1994, Simulation of regional ground-water flow on a flowline in Cretaceous-bedrock aquifers of North-Central Texas, *in* Factors affecting water resources: Proceedings, American Water Resources Association, Texas Section, p. 97–106.

Mace, R. E., Dutton, A. R., and **Nance, H. S.,** 1994, Water-level declines in the Woodbine, Paluxy, and Trinity aquifers of North-Central Texas: Gulf Coast Association of Geological Societies Transactions, v. 44, p. 413–420.

Major, R. P., ed., 1994, Energy and environment—expanding professional horizons: Gulf Coast Association of Geological Societies Transactions, v. 44, 848 p.

Major, R. P., 1994, *Review of* Carbonate Microfabrics, Richard Rezak and D. L. Lavoie, eds., Frontiers in Sedimentary Geology, Springer-Verlag, 1993: Journal of Sedimentary Research, v. B64, no. 3, p. 433–444.

Major, R. P., and **Holtz, M. H.,** 1994, Jordan (San Andres) field, *in* Pausé, Paul, and Entzminger, David, eds., Oil and gas fields in West Texas, symposium volume VI: West Texas Geological Society Publication No. 94-96, p. 113–120.

Major, R. P., and **Holtz, M. H.,** 1994, Keystone (Colby) field, *in* Pausé, Paul, and Entzminger, David, eds., Oil and gas fields in West Texas, symposium volume VI: West Texas Geological Society Publication No. 94-96, p. 121–128.

McBride, E. F., Picard, M. D., and **Folk, R. L.,** 1994, Oriented concretions, Ionian coast, Italy: evidence of groundwater flow direction: Journal of Sedimentary Research, v. A64, no. 3, p. 535–540.

McRae, L. E., and **Holtz, M. H.,** 1994, Integrated reservoir characterization of mature oil reservoirs: an example from Oligocene Frio fluvial-deltaic sandstones, Rincon field, South Texas: Gulf Coast Association of Geological Societies Transactions, v. 44, p. 487–498.

Miller, J. K., and **Folk, R. L.,** 1994, Petrographic, geochemical and structural constraints on the timing and distribution of post-lithification dolomite in the Rhaetian Portoro ("Calcare Nero") of the Portovenere Area, La Spezia, Italy, *in* Purser, B. H., Tucker, M. E., and Zenger, D. H., eds., Dolomites—a volume in honor of Dolomieu: International Association of Sedimentologists Special Publication No. 21, p. 187–202.

Morton, R. A., 1994, Texas barriers, *in* Davis, R. A., ed., Geology of Holocene barrier island systems: Berlin, Springer-Verlag, Chapter 3, p. 75–114.

Morton, R. A., Paine, J. G., and **Gibeaut, J. C.,** 1994, Stages and durations of post-storm beach recovery, southeastern Texas coast, U.S.A.: Journal of Coastal Research, v. 10, no. 4, p. 884–908.

Mullican, W. F., III, Fryar, A. E., and **Johns, N. D.,** 1994, Vertical transport of contaminants through perched aquifers to the Ogallala aquifer, Pantex Plant area, Southern High Plains, Texas, *in* Dutton, A. R., ed., Toxic substances and the hydrologic sciences: American Institute of Hydrology, p. 547–562.

Mullican, W. F., III, Johns, N. D., and **Fryar, A. E.,** 1994, What a difference a playa can make: defining recharge scenarios, rates, and contaminant transport to the Ogallala (High Plains) aquifer, *in* Urban, L. V., and Wyatt, A. W., eds., Proceedings, Playa Basin Symposium: Texas Tech University, Water Resources Center, p. 97–106.

Nance, H. S., Laubach, S. E., and **Dutton, A. R.,** 1994, Fault and joint measurements in Austin Chalk, Superconducting Super Collider site, Texas: Gulf Coast Association of Geological Societies Transactions, v. 44, p. 521–532.

Nelson, P. P., and **Laubach, S. E.,** eds., 1994, Rock mechanics: models and measurements, challenges from industry: proceedings of the First North American Rock Mechanics Symposium: Brookfield, Vermont, A. A. Balkema, 1200 p.

Paine, J. G., 1994, Determining the role of subsidence in the formation of playa basins using shallow seismic reflection methods, *in* Urban, L. V., and Wyatt, A. W., eds., Proceedings, Playa Basin Symposium: Texas Tech University, Water Resources Center, p. 53–62.

Paine, J. G., 1994, Subsidence beneath a playa basin on the Southern High Plains, U.S.A.: evidence from shallow seismic data: Geological Society of America Bulletin, v. 106, no. 2, p. 233–242.

Piggott, A. R., Bobba, A. G., and **Xiang, Jiannan,** 1994, Inverse analysis implementation of the SUTRA ground-water model: Ground Water, v. 32, no. 5, p. 829–836.

Pincus, H. J., and **Clift, S. J.,** 1994, Repeatability and reproducibility of RQD values for selected sedimentary rocks, interlaboratory testing program for rock properties (ITP/RP), round three: Philadelphia, ASTM Institute for Standards Research, sponsored by Defense Nuclear Agency, Sandia National Laboratories, U.S. Bureau of Mines, and U.S. Corps of Engineers, Waterways Experiment Station, PCN: 33-000011-38, 36 p.

Ruppel, S. C., 1994, Emma (San Andres) field, *in* Pausé, Paul, and Entzminger, David, eds., Oil and gas fields in West Texas, symposium volume VI: West Texas Geological Society Publication No. 94-96, p. 53–60.

Ruppel, S. C., 1994, Monahans (Clear Fork) field, *in* Pausé, Paul, and Entzminger, David, eds., Oil and gas fields in West Texas, symposium volume VI: West Texas Geological Society Publication No. 94-96, p. 195–202.

Ruppel, S. C., 1994, Three Bar (Devonian) field, *in* Pausé, Paul, and Entzminger, David, eds., Oil and gas fields in West Texas, symposium volume VI: West Texas Geological Society Publication No. 94-96, p. 261–268.

Ruppel, S. C., Kerans, Charles, Major, R. P., and **Holtz, M. H.,** 1994, Controls on reservoir heterogeneity in Permian shallow-water platform carbonate reservoirs, U.S.A.: implications for secondary recovery: The Arabian Journal for Science and Engineering, v. 19, no. 2B, p. 215–236.

Scanlon, B. R., 1994, Water and heat fluxes in desert soils—1. Field studies: Water Resources Research, v. 30, no. 3, p. 709–719.

Scanlon, B. R., Goldsmith, R. S., Hovorka, S. D., Mullican, W. F., III, and **Xiang, Jiannan,** 1994, Evidence for focused recharge beneath playas in the Southern High Plains, Texas, *in* Urban, L. V., and Wyatt, A. W., eds., Proceedings, Playa Basin Symposium: Texas Tech University, Water Resources Center, p. 87–95.

Scanlon, B. R., Goldsmith, Richard, and **Mullican, W. F., III,** 1994, Methodology and preliminary results of unsaturated flow studies for a proposed Texas low-level radioactive waste repository, *in* Toxic substances and the hydrologic sciences: American Institute of Hydrology, p. 497–506.

Scanlon, B. R., and Milly, P. C. D., 1994, Water and heat fluxes in desert soils—2. Numerical simulations: Water Resources Research, v. 30, no. 3, p. 721–733.

Scanlon, B. R., Mullican, W. F., III, and **Goldsmith, Richard,** 1994, Unsaturated flow studies at the proposed Texas low-level radioactive waste repository, Texas, *in* Proceedings, 15th Annual U.S. DOE Low-Level Radioactive Management Conference: U.S. Department of Energy, unpaginated.

Scott, A. R., 1994, Coalbed gas composition, Upper Cretaceous, Fruitland Formation, San Juan Basin, Colorado and New Mexico: Colorado Geological Survey, Open File Report 94-2, 28 p., 2 pl.

Scott, A. R., 1994, Composition of coalbed gases: In Situ, v. 18, no. 2, p. 185–208.

Scott, A. R., Kaiser, W. R., and **Ayers, W. B., Jr.,** 1994, Thermogenic and secondary biogenic gases, San Juan Basin, Colorado and New Mexico—implications for coalbed gas producibility: American Association of Petroleum Geologists Bulletin, v. 78, no. 8, p. 1186–1209.

Seggie, R. J., Lansom, P. B., **Hamlin, H. S.,** and Johnson, G. A., 1994, The Tirrawarra oil field: field revitalisation through

reservoir description and characterisation: Australian Petroleum Exploration Association Journal, v. 34, p. 33–54.

Seni, S. J., Desselle, B. A., and **Standen, Allan,** 1994, Scope and construction of a gas and oil atlas series of the Gulf of Mexico: examples from Texas offshore lower Miocene plays: Gulf Coast Association of Geological Societies Transactions, v. 44, p. 681–690.

Seni, S. J., and **Finley, R. J.,** 1993, Gulf of Mexico oil and gas atlas series: play analysis of Oligocene and Miocene reservoirs from Texas State offshore waters, *in* Malone, R. D., ed., Proceedings, Fuels Technology Contractors Review Meeting: Morgantown, West Virginia, U.S. Department of Energy, Office of Fossil Energy, DOE/METC-94/1002, p. 472–481.

Serednytsky, L. M., senior editor, **Finley, R. J.,** technical editor, Petrash-Vaughan, Marta, managing editor and compiler, and Lyubchenko, V. M., senior translator and associate compiler, 1994, English-Russian petroleum technology dictionary: Dallas, Albion Woods, 496 p.

Swift, D. B., Reeves, J. J., Erdlac, R. J., Jr., **Barrow, K. T.,** and **Schoellkopf, A. P.,** 1994, Exploration potential of the Diablo Platform–Delaware Basin margin, Trans-Pecos Texas: New Mexico Bureau of Mines and Mineral Resources Bulletin 150, p. 53–69.

Tadros, N. Z., and **Hamilton, D. S.,** 1993, Distribution, quality and utilisation potential of the main coal seams of the Mullaley Sub-basin, *in* Tadros, N. Z., ed., The Gunnedah Basin, New South Wales: Geological Survey of New South Wales, Memoir Geology 12, p. 445–484.

Tadros, N. Z., and **Hamilton, D. S.,** 1993, Introductory notes on sedimentology, *in* Tadros, N. Z., ed., The Gunnedah Basin, New South Wales: Geological Survey of New South Wales, Memoir Geology 12, p. 167–168.

Tadros, N. Z., **Hamilton, D. S.,** and Whitehouse, J., 1993, Coal resources of the Mullaley Sub-basin, *in* Tadros, N. Z., ed., The Gunnedah Basin, New South Wales: Geological Survey of New South Wales, Memoir Geology 12, p. 485–522.

Tremblay, T. A., Paull, G. J., Rodgers, R. W., and **Wermund, E. G.,** 1994, GIS base data for water management on the Rio Grande delta plain, *in* GIS/LIS: Proceedings: American Congress on Surveying and Mapping, American Society for Photogrammetry and Remote Sensing, AM/FM International, Association of American Geographers, and Urban and Regional Information Systems Association, p. 778–786.

Tremblay, T. A., Wermund, E. G., Paull, G. J., and Rodgers, R. W., 1994, Geographic information system (GIS) of the Rio Grande delta for regional water management, *in* Factors affecting water resources: Proceedings, American Water Resources Association, Texas Section, p. 63–71.

Tyler, Noel, 1994, Geologically constrained approaches for maximizing oil and gas recovery from complex reservoirs: Puerto La Cruz, Venezuela: The University of Texas at Austin, Bureau of Economic Geology, Course Notes, V Simposio Bolivariano, variously paginated.

Tyler, Noel, 1994, Tectono-stratigraphic controls on deltaic reservoir architecture and recovery response in foreland basins, *in* Exploracion petrolera en las cuencas subandinas: Memoria: Puerto La Cruz, Venezuela, V Simposio Bolivariano p. 578–588.

Walker, J. L., and **Knox, P. R.,** 1994, Zilker Park walking tour guidebook: a recreational visit to the Edwards Limestone: Gulf Coast Association of Geological Societies, 48 p., plus 2 maps and brochure in pocket.

Wang, F. P., Lucia, F. J., and **Kerans, Charles,** 1994, Critical scales, upscaling, and modeling of shallow-water carbonate reservoirs: Society of Petroleum Engineers, Paper No. SPE 27715, p. 765–773.

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., 1994, Geology and physical features of the Katy Prairie, *in* Balancing growth and conservation: Proceedings, Katy Prairie Conference: Texas Parks and Wildlife Department, Katy Prairie Land Conservancy, and West Houston Association, Section 2, p. 1–18 (variously paginated).

Wermund, E. G., 1994, Lineation analyses in the Eagle Flat area, Hudspeth County, Texas, *in* Exploration, environment, and engineering: Proceedings, Tenth Thematic Conference on Geologic Remote Sensing, Volume II: Environmental Research Institute of Michigan, p. II-479–II-488.

Xiang, Jiannan, 1994, Improvements in evaluating constant-head permeameter test data: Journal of Hydrology, v. 162, p. 77–97.

Ye, Qiucheng, Matthews, R. K., **Galloway, W. E.,** Frohlich, Cliff, and Gan, Stoney, 1993, High-frequency glacioeustatic cyclicity in the early Miocene and its influence on coastal and shelf depositional systems, NW Gulf of Mexico Basin, *in* GCSSEPM Foundation 14th Annual Research Conference, Rates of Geologic Processes: Program with Papers, p. 287–298.

Abstracts

Ambrose, W. A., Ferrer, E. R., **Dutton, S. P.,** Padron, Antonio, **Wang, F. P., Yeh, J. S.,** Carrasquel, Williams, and **Tyler, Noel,** 1994, Production optimization through characterization of tide-dominated deltaic reservoirs of the lower Misoa Formation (lower Eocene), LL-652 area, Lagunillas field, Maracaibo Basin, Venezuela (abs.), *in* AAPG Annual Convention official program: analogs for the world: Denver, American Association of Petroleum Geologists, p. 93.

BeMent, W. O., **Levey, R. A.,** and Mango, F. D., 1994, The temperature of oil generation as defined with a C7 chemistry maturity parameter (2,4-DMP/2,3-DMP ratio) (abs.), *in* Schneidermann, Nahum, Cruz, Pablo, and Sanchez, Rafael, co-conveners, First Joint AAPG/AMPG Hedberg Research Conference: Geologic aspects of petroleum systems: unpaginated.

Brown, R. L., and **Levey, R. A.,** 1994, Estimation and 3-D modeling of seismic parameters for fluvial systems (exp. abs.), *in* Technical program: expanded abstracts with authors' biographies: SEG International Exposition and 64th annual meeting: Los Angeles, Society of Exploration Geophysicists, p. 338–342.

Burn, M. J., Carr, D. L., and Stuede, John, 1994, Sedimentology and permeability architecture of Atokan valley-fill natural gas reservoirs, Boonsville field, North-Central Texas (abs.): Gulf Coast Association of Geological Societies Transactions, v. 44, p. 758.

Collins, E. W., 1994, Geology of the Balcones Fault Zone along the Growth Corridor of San Antonio, Boerne, Wimberley, and New Braunfels, South-Central Texas (abs.): American Association of Petroleum Geologists Bulletin, v. 78, no. 9, p. 1452–1453.

Collins, E. W., 1994, Geology of the Balcones Fault Zone along the growth corridor of San Antonio, Boerne, Wimberley, and New Braunfels, South-Central Texas (ext. abs.): Gulf Coast Association of Geological Societies Transactions, v. 44, p. 125–126.

Collins, E. W., and **Raney, J. A.,** 1994, Impact of late Cenozoic extension on Laramide overthrust belt and Diablo Platform margins, northwestern Trans-Pecos Texas (abs.): American Association of Petroleum Geologists Bulletin, v. 78, no. 3, p. 494.

Couzens, B. A., Wiltschko, D. V., and **Vendeville, B. C.,** 1994, Mechanical stratigraphy and the formation of triangle zones (abs.): Geological Society of America, Abstracts with Programs, v. 26, no. 7, p. A-184.

Desselle, B. A., 1994, Differences in the stratigraphic framework of the Frio and Anahuac Formations in the Louisiana and Texas Gulf Coast Basin (abs.): Gulf Coast Association of Geological Societies Transactions, v. 44, p. 758.

Dutton, S. P., and **Hamlin, H. S.,** 1994, Compositional, textural, and diagenetic controls on porosity distribution and evolution in Permian Tirrawarra Sandstone, Cooper Basin, South Australia

(abs.), *in* AAPG Annual Convention official program: analogs for the world: Denver, American Association of Petroleum Geologists, p. 140.

Finley, R. J., 1994, Assessment of, and access to, the natural gas reserve appreciation resource (abs.), *in* AAPG Annual Convention official program: analogs for the world: Denver, American Association of Petroleum Geologists, p. 148–149.

Fisher, R. S., 1994, Geologic and geochemical controls on ^{226}Ra in formation water (abs.): Geological Society of America, Abstracts with Programs, v. 26, no. 7, p. A-33.

Fitchen, W. M., Bebout, D. G., and Hoffman, C. L., 1994, Recognition, correlation, and hierarchical stacking patterns of cycles in the Ferry Lake–Upper Glen Rose, East Texas Basin: implications for grainstone reservoir distribution (abs.): Gulf Coast Association of Geological Societies Transactions, v. 44, p. 760.

Folk, R. L., 1994, Dwarf bacteria (nannobacteria) and the precipitation of silica and clay minerals (abs.), *in* 14th International Sedimentological Congress: Recife, Brazil, unpaginated [2 p].

Folk, R. L., 1994, Nannobacteria—major participants in the precipitation of carbonates and other minerals (abs.), *in* Sasowsky, I. D., and Palmer, M. V., eds., Breakthroughs in karst geomicrobiology and redox geochemistry: Karst Waters Institute Special Publication No. 1, p. 17–18.

Folk, R. L., Lynch, F. L., and Rasbury, E. T., 1994, Evidence for bacterial precipitation of clay minerals upon sand grains, in soils, and in the subsurface (abs.): Geological Society of America, Abstracts with Programs, v. 26, no. 7, p. A-508.

Fryar, A. E., and **Mullican, W. F., III,** 1994, Geochemical evolution of recharge and ground water on the Southern High Plains of Texas (abs.), *in* Nash, D. J., ed., From the far corners to the Four Corners: Proceedings, 70th Annual Meeting of the Southwestern and Rocky Mountain Division, American Association for the Advancement of Science: American Association for the Advancement of Science, Southwestern and Rocky Mountain Division, Program and Abstracts, v. 34, no. 1, p. 21–22.

Fryar, A. E., and **Mullican, W. F., III,** 1994, Hydrochemical and hydraulic evidence for flux across perched aquifers to the Ogallala (High Plains) aquifer (abs.): Eos (Supplement), v. 75, no. 44, p. 250.

Fryar, A. E., Romanak, K. D., Macko, S. A., Bennett, P. C., **Mullican, W. F., III,** and **Scanlon, B. R.,** 1994, Stable isotopic evidence for denitrification in the Southern High Plains of Texas (abs.): Geological Society of America, Abstracts with Programs, v. 26, no. 7, p. 118.

Galloway, W. E., 1994, Predictive facies distribution in genetic stratigraphic sequences (ext. abs.), *in* Second High-Resolution Sequence Stratigraphy Conference, abstracts: p. 63–68.

Ge, Hongxing, Jackson, M. P. A., and **Vendeville, B. C.,** 1994, Experimental initiation of salt structures and emplacement of salt sheets by prograding sediment wedges (abs.), *in* Salt tectonics: programme and abstracts: London, Petroleum and Tectonics Groups of the Geological Society, p. 51–52.

Ge, Hongxing, Jackson, M. P. A., and **Vendeville, B. C.,** 1994, Initiation and early growth of salt structures in the Paradox Basin, Utah and Colorado: insights from dynamically scaled physical experiments (abs.), *in* AAPG Annual Convention official program: analogs for the world: Denver, American Association of Petroleum Geologists, p. 154.

Ge, Hongxing, Jackson, M. P. A., and **Vendeville, B. C.,** 1994, Physical modeling of salt withdrawal and dissolution structures (abs.), *in* AAPG Annual Convention official program: analogs for the world: Denver, American Association of Petroleum Geologists, p. 154.

Ge, Hongxing, Vendeville, B. C., Jackson, M. P. A., and Hudec, M. R., 1994, Laramide passive roof duplex along the Uncompahgre front, eastern Paradox Basin (abs.): Geological Society of America, Rocky Mountain Section, Abstracts with Programs, v. 26, no. 6, p. 13.

Gustavson, T. C., 1994, Cyclic eolian sedimentation and pedogenesis on a grassland savanna, Tertiary Ogallala and Quaternary Blackwater Draw Formations, Texas and New Mexico High Plains (abs.): Geological Society of America, Abstracts with Programs, v. 26, no. 7, p. A-494.

Gustavson, T. C., Hovorka, S. D., Mullican, W. F., III, Scanlon, B. R., and **Xiang, Jiannan,** 1994, Stratigraphic controls on preferred pathways for recharge to the Ogallala aquifer, Texas and New Mexico (abs.), *in* Nash, D. J., ed., From the far corners to the Four Corners: Proceedings, 70th Annual Meeting of the Southwestern and Rocky Mountain Division, American Association for the Advancement of Science: American Association for the Advancement of Science, Southwestern and Rocky Mountain Division, Program and Abstracts, v. 34, no. 1, p. 21.

Hamlin, H. S., Clift, S. J., Dutton, S. P., Hentz, T. F., and **Laubach, S. E.,** 1994, Geologically complex gas reservoirs in slope and basin facies, Canyon sandstones, Val Verde Basin, southwest Texas (abs.): Houston Geological Society Bulletin, v. 37, no. 1, p. 11.

Hamlin, H. S., Dutton, S. P., Tyler, Noel, Yeh, J. S., Seggie, R. J., Lansom, Peter, and **Asquith, G. B.,** 1994, Resource optimization through facies-based characterization of a braid-delta sandstone reservoir, Tirrawarra oil field, Cooper Basin, South Australia (abs.), *in* AAPG Annual Convention official program: analogs for the world: Denver, American Association of Petroleum Geologists, p. 162.

Hardage, B. A., 1994, Staggered-line 3D seismic recording (abs.), *in* MESA Technology Conference program: Montgomery, Texas, Green Mountain Geophysics, Inc., and Seismic Image Software Ltd., unpaginated [2 p.].

Holtz, M. H., and **Major, R. P.,** 1994, Effects of depositional facies and diagenesis on calculating petrophysical properties from wireline logs in Permian carbonate reservoirs of West Texas (abs.): American Association of Petroleum Geologists Bulletin, v. 78, no. 3, p. 494–495.

Jackson, M. P. A., 1994, Retrospective and prospective salt tectonics (abs.): Houston Geological Society Bulletin, May, p. 11.

Jackson, M. P. A., and **Vendeville, B. C.,** 1994, Ten lessons in salt tectonics from the Gulf of Mexico (abs.), *in* Salt tectonics: programme and abstracts: London, Petroleum and Tectonics Groups of the Geological Society, p. 19.

Kaiser, W. R., Hamilton, D. S., Scott, A. R., and **Tyler, Roger,** 1994, A basin-scale coalbed methane producibility model: comparison of the San Juan and Sand Wash Basins (abs.), *in* AAPG Annual Convention official program: analogs for the world: Denver, American Association of Petroleum Geologists, v. 3, p. 182–183.

Kaiser, W. R., and **Scott, A. R.,** 1994, Abnormal pressure in the San Juan and Greater Green River Basins: artesian versus hydrocarbon overpressure (ext. abs.), *in* Law, Ben, Ulmishek, Gregory, and Slavin, Viacheslav, co-convenors, AAPG Hedberg Research Conference: Abnormal Pressures in Hydrocarbon Environments: Colorado School of Mines, variously paginated [4 p.]. *And in* Sonnenberg, S. A., compiler, Natural gas in the western United States: Rocky Mountain Association of Geologists and Colorado Oil and Gas Association, First Biennial Conference Extended Abstracts, unpaginated [4 p.].

Kerans, Charles, and Tinker, S. W., 1994, Use of quantitatively calibrated depositional models in constructing high-resolution sequence stratigraphic frameworks for reservoir characterization (abs.), *in* AAPG Annual Convention official program: analogs for the world: Denver, American Association of Petroleum Geologists, p. 186.

Laubach, S. E., Nance, H. S., and **Dutton, A. R.,** 1994, Fault and joint spacing in a normal fault zone (abs.): Eos (Supplement), v. 75, no. 44, p. 678.

Laubach, S. E., Schultz-Ela, D. D., and **Tyler, Roger,** 1994, Differential compaction and shifts in coal fracture patterns: field example and finite element model (abs.), *in* AAPG Annual

Convention official program: analogs for the world: Denver, American Association of Petroleum Geologists, p. 193–194.

Laubach, S. E., Tyler, Roger, Schultz-Ela, D. D., and Tremain, C. M., 1994, Tectonic analysis of weakly deformed foreland areas (abs.), *in* AAPG Annual Convention official program: analogs for the world: Denver, American Association of Petroleum Geologists, p. 194.

Levey, R. A., 1994, Maximizing recovery of natural gas in fluvial-deltaic reservoirs: examples from the onshore Gulf Coast with implications for Midcontinent gas reservoirs (abs.): Tulsa Geological Society Newsletter, v. 32, no. 7, p. 5–6.

Levey, R. A., 1994, Strategies and approaches for infield natural gas reserve growth: examples from the onshore Gulf Coast Basin (abs.): East Texas Geological Society Newsletter, November, unpaginated.

Levey, R. A., Hardage, B. A., and **Finley, R. J.,** 1994, An integrated approach to identifying natural gas reservoir compartments using 3-D seismic, depositional facies analyses, and production tests: examples from middle Frio fluvial reservoirs, Stratton field, South Texas (abs.), *in* AAPG Annual Convention official program: analogs for the world: Denver, American Association of Petroleum Geologists, p. 196–197.

Levey, R. A., Hardage, B. A., and **Finley, R. J.,** 1994, An integrated approach to identifying natural gas reservoir compartments using 3-D seismic depositional facies analysis and production tests: examples from the Middle Frio Fluvial Reservoir, Stratton field, South Texas (exp. abs.), *in* Technical program: expanded abstracts with authors' biographies: SEG International Exposition and 64th annual meeting: Los Angeles, Society of Exploration Geophysicists, p. 802.

Lucia, F. J., Kerans, Charles, Senger, R. K., Wang, F. P., and Mishra, Anil, 1994, Characterization of reservoir heterogeneity in carbonate ramp reservoirs for simulation studies (abs.), *in* AAPG Annual Convention official program: analogs for the world: Denver, American Association of Petroleum Geologists, p. 202.

Mace, R. E., Dutton, A. R., and **Hovorka, S. D.,** 1994, Determination of hydrologic and geomechanical properties of confined water-bearing formations from barometric efficiency (abs.), *in* Gilbert, Robert, coordinator, The First North American Rock Mechanics Symposium poster session abstracts: International Society for Rock Mechanics, p. 83–84.

Major, R. P., and Johnstone, R. D., 1994, Missing stratigraphic sections in Tertiary sandstone reservoirs of the Gulf Coast: faults or unconformities and implications for development strategies (abs.): Gulf Coast Association of Geological Societies Transactions, v. 44, p. 767.

Matthews, R. K., Frohlich, C., and **Galloway, W. E.,** 1993, Model assisted quantification of the geologic record of global change (abs.), *in* SEPM Annual Meeting, program with abstracts: University Park, PA, SEPM (Society for Sedimentary Geology), unpaginated.

McRae, L. E., and **Holtz, M. H.,** 1994, Targeting the unrecovered oil resource in mature field areas: an example from Oligocene Frio fluvial-deltaic reservoirs of South Texas (abs.), *in* AAPG Annual Convention official program: analogs for the world: Denver, American Association of Petroleum Geologists, p. 213.

Meckel, L. D., III, and **Galloway, W. E.,** 1994, Formation of high-frequency sequences and their bounding surfaces in a Paleogene supply-dominated system, Texas Gulf Coast, U.S.A. (abs.): Gulf Coast Association of Geological Societies Transactions, v. 44, p. 768.

Morton, R. A., and Suter, J. R., 1994, Sequence stratigraphic implications of Quaternary shelf-margin deltas, High Island area, northwestern Gulf of Mexico (abs.), *in* AAPG Annual Convention official program: analogs for the world: Denver, American Association of Petroleum Geologists, p. 218.

Mullican, W. F., III, Fryar, A. E., and **Johns, N. D.,** 1994, Vertical transport of solutes through perched aquifers to the Ogallala aquifer, Pantex Plant area, Southern High Plains, Texas (abs.), *in* Annual Spring Meeting of the Texas Section, Association of Engineering Geologists: College Station, Association of Engineering Geologists, Lone Star Student Chapter, p. 9.

Mullican, W. F., III, Johns, N. D., and **Fryar, A. E.,** 1994, Focused recharge—a new approach to the numerical simulation of ground-water flow in the Ogallala aquifer (abs.), *in* Nash, D. J., ed., From the far corners to the Four Corners: Proceedings, 70th Annual Meeting of the Southwestern and Rocky Mountain Division, American Association for the Advancement of Science: American Association for the Advancement of Science, Southwestern and Rocky Mountain Division, Program and Abstracts, v. 34, no. 1, p. 22.

Mullican, W. F., III, Johns, N. D., and **Fryar, A. E.,** 1994, Impact of alternative recharge scenarios on rates of contaminant transport to the Ogallala (High Plains) aquifer (abs.): Geological Society of America, Abstracts with Programs, v. 26, no. 7, p. A-362.

Nance, H. S., and **Laubach, S. E.,** 1994, Fracture geometry and spacing in Austin Chalk: Superconducting Super Collider tunnel, Texas (abs.), *in* The First North American Rock Mechanics Symposium poster session abstracts: International Society for Rock Mechanics, p. 55.

Nance, H. S., Laubach, S. E., and **Dutton, A. R.,** 1994, Fault and joint measurements in Austin Chalk, Superconducting Super Collider site, Texas (abs.): American Association of Petroleum Geologists Bulletin, v. 78, no. 9, p. 1472.

Nance, H. S., and **Mace, R. E.,** 1994, Stratigraphy in modeling ground-water flow in siliciclastic aquifers: an example from the Woodbine Formation, North Texas (abs.), *in* AAPG Annual Convention official program: analogs for the world: Denver, American Association of Petroleum Geologists, p. 221.

Nilsen, K. T., **Vendeville, B. C.,** and Johansen, J.-T., 1994, An example of salt tectonics controlled by regional tectonics: the Nordkapp Basin, Norway (abs.), *in* AAPG Annual Convention official program: analogs for the world: Denver, American Association of Petroleum Geologists, p. 225.

Nilsen, K. T., **Vendeville, B. C.,** and Johansen, J.-T., 1994, Salt tectonics in the Nordkapp Basin, Norway (abs.), *in* Salt tectonics: programme and abstracts: London, Petroleum and Tectonics Groups of the Geological Society, p. 22–23.

Paine, J. G., 1994, Comparing subsidence histories of small and large playa basins on the Southern High Plains, Texas, using shallow seismic reflection data (abs.): Geological Society of America, Abstracts with Programs, v. 26, no. 7, p. A-218.

Scanlon, B. R., 1994, Integration of hydraulic and hydrochemical data to obtain a comprehensive understanding of unsaturated zone processes in arid systems (abs.): Geological Society of America, Abstracts with Programs, v. 26, no. 7, p. A-389.

Scanlon, B. R., Xiang, Jiannan, Goldsmith, Richard, Mullican, W. F., III, and **Hovorka, S. D.,** 1994, Unsaturated zone studies to evaluate subsurface water movement in the vicinity of the Pantex Plant, Amarillo, Texas (abs.), *in* Nash, D. J., ed., From the far corners to the Four Corners: Proceedings, 70th Annual Meeting of the Southwestern and Rocky Mountain Division, American Association for the Advancement of Science: American Association for the Advancement of Science, Southwestern and Rocky Mountain Division, Program and Abstracts, v. 34, no. 1, p. 22.

Schultz-Ela, D. D., 1994, Overburden structures related to extensional faulting beneath an intervening viscous layer (abs.): Eos (Supplement), v. 75, no. 44, p. 678.

Schultz-Ela, D. D., Jackson, M. P. A., Hudec, M. R., Fletcher, R. C., Porter, M. L., and Watson, I. A., 1994, Constraints on the origin of Upheaval Dome, Paradox Basin, Utah (abs.), *in* AAPG Annual Convention official program: analogs for the world: Denver, American Association of Petroleum Geologists, p. 253.

Schultz-Ela, D. D., Jackson, M. P. A., Hudec, M. R., Fletcher, R. C., Porter, M. L., and Watson, I. A., 1994, Structures formed by radial contraction at Upheaval Dome, Utah (abs.): Geological Society of America, Abstracts with Programs, v. 26, no. 7, p. A-72.

Scott, A. R., and **Kaiser, W. R.,** 1994, On the geomechanics of open-hole cavity completions in San Juan Basin coalbed gas wells (extended abs.), *in* The First North American Rock Mechanics Symposium poster session abstracts: International Society for Rock Mechanics, p. 63–66.

Scott, A. R., Tyler, Roger, Hamilton, D. S., and **Zhou, Naijiang,** 1994, Coal and coal gas resources of the Greater Green River Basin: application of an improved approach to resource estimation (ext. abs.), *in* Sonnenberg, S. A., compiler, Natural gas in the western United States: Rocky Mountain Association of Geologists and Colorado Oil and Gas Association, First Biennial Conference Extended Abstracts, unpaginated [4 p.].

Scott, A. R., Tyler, Roger, Hamilton, D. S., and **Zhou, Naijiang,** 1994, Coal and in-place gas resources of the Greater Green River Basin, Wyoming and Colorado (abs.), *in* AAPG Annual Convention official program: analogs for the world: Denver, American Association of Petroleum Geologists, p. 253–254.

Swift, D. B., **Barrow, K. T., Schoellkopf, Alexander,** Reeves, J. J., and Erdlac, R. J., 1994, Late Paleozoic tectonic evolution of the eastern margin of the Diablo Platform, West Texas (abs.), *in* AAPG Annual Convention official program: analogs for the world: Denver, American Association of Petroleum Geologists, p. 498.

Tremblay, T. A., and **White, W. A.,** 1994, Wetland trend analysis in the Galveston Bay estuary system, Texas (abs.), *in* Abstracts, Association of American Geographers 90th Annual Meeting: San Francisco, Association of American Geographers, p. 381–382.

Tyler, Roger, 1994, Syntectonic sedimentation and coal occurrence in the Paleocene Fort Union Formation, Sand Wash Basin, northwestern Colorado and southwestern Wyoming (abs.), *in* AAPG Annual Convention official program: analogs for the world: American Association of Petroleum Geologists, p. 273–274.

Tyler, Roger, Laubach, S. E., Schultz-Ela, D. D., and Tremain, C. M., 1994, Variations in Cretaceous and Tertiary coal fracture patterns, Rocky Mountain Foreland, western United States (abs.): Geological Society of America, Abstracts with Programs, v. 26, no. 7, p. A-209.

Vendeville, B. C., 1994, Scaling, techniques, and limitations of salt tectonics experimental modelling (abs.), *in* Salt tectonics: programme and abstracts: London, Petroleum and Tectonics Groups of the Geological Society, p. 42–43.

Vendeville, B. C., Ge, Hongxing, and **Jackson, M. P. A.,** 1994, Experimental deformation of prograding sedimentary wedges above a viscous source layer (abs.), *in* AAPG Annual Convention official program: analogs for the world: Denver, American Association of Petroleum Geologists, p. 276.

Vendeville, B. C., Jackson, M. P. A., and **Sattar, Asad,** 1994, Synthetic seismic reflection profiles of experimental salt structures (abs.), *in* AAPG Annual Convention official program: analogs for the world: Denver, American Association of Petroleum Geologists, p. 276.

Vendeville, B. C., Nilsen, K. T., and Johansen, J.-T., 1994, Using concepts derived from tectonic experiments to improve the structural interpretation of salt structures: the Nordkapp Basin as an example (abs.), *in* Modern Developments in Structural Interpretation, Validation, and Modelling—highlights meeting held May 24 and 25: London, The Petroleum Group of The Geological Society, unpaginated. *Also in* Modern Developments in Structural Interpretation, Validation, and Modeling: Section 4, Integration of Interpretation and Validation Techniques—meeting held February 23: London, The Petroleum Group of the Geological Society, unpaginated.

White, W. A., Tremblay, T. A., and **Wermund, E. G.,** 1994, Marsh loss in the Galveston Bay system, Texas (abs.), *in* Wetlands: local functions, global dependence: Society of Wetland Scientists, 15th annual meeting, p. 53–54.

Whitelaw, M. J., **Raney, J. A.,** and **Jackson, M. L. W.,** 1994, Paleomagnetic characterization of the proposed Texas low-level radioactive waste repository, Sierra Blanca, West Texas (abs.), *in* Ahlen, Jack, Peterson, John, and Bowsher, A. L., eds., Geologic activities in the 90s: New Mexico Bureau of Mines and Mineral Resources, Bulletin No. 150, p. 136–137.

Xiang, Jiannan, and **Mullican, W. F., III,** 1994, Performance of the multistep constant head borehole test to evaluate hydraulic conductivity of layered media (abs.), *in* The First North American Rock Mechanics Symposium poster session abstracts: International Society for Rock Mechanics, p. 86.

Contract and Grant Reports

Avakian, A. J., and Sansing, Mary, 1994, Geological and climatic survey, Camp Bowie Military Reservation, Brownwood, Texas: supplement: digital line graph data with explanatory notes: The University of Texas at Austin, Bureau of Economic Geology, supplement to contract report prepared for Texas Adjutant General under contract no. IAC(92-93)-1532, 21 p.

Avakian, A. J., and **Wermund, E. G.,** 1994, Physical environment of Fort Wolters Military Reservation, Parker and Palo Pinto Counties, Texas: The University of Texas at Austin, Bureau of Economic Geology, report prepared for Texas Adjutant General's Department under Letter of Agreement Number TX93-ED3-02 ENV244-D3, 90 p.

Bebout, D. G., Major, R. P., and Harris, P. M., 1994, Internal geometry of a modern carbonate grainstone shoal—an analog for hydrocarbon reservoir heterogeneity: The University of Texas at Austin, Bureau of Economic Geology, report prepared for the Chevron Petroleum Technology Company, 44 p.

Collins, E. W., 1994, Geologic map of the Bergheim quadrangle, Texas: The University of Texas at Austin, Bureau of Economic Geology, open-file map prepared for the U.S. Geological Survey under cooperative agreement no. 1434-93-A-1174, 1 sheet, scale 1:24,000.

Collins, E. W., 1994, Geologic map of the Boerne quadrangle, Texas: The University of Texas at Austin, Bureau of Economic Geology, open-file map prepared for the U.S. Geological Survey under cooperative agreement no. 1434-93-A-1174, 1 sheet, scale 1:24,000.

Collins, E. W., 1994, Geologic map of the Camp Bullis quadrangle, Texas: The University of Texas at Austin, Bureau of Economic Geology, open-file map prepared for the U.S. Geological Survey under cooperative agreement no. 1434-93-A-1174, 1 sheet, scale 1:24,000.

Collins, E. W., 1994, Geologic map of the Castle Hills quadrangle, Texas: The University of Texas at Austin, Bureau of Economic Geology, open-file map prepared for the U.S. Geological Survey under cooperative agreement no. 1434-93-A-1174, 1 sheet, scale 1:24,000.

Collins, E. W., 1994, Geologic map of the Kendalia quadrangle, Texas: The University of Texas at Austin, Bureau of Economic Geology, open-file map prepared for the U.S. Geological Survey under cooperative agreement no. 1434-93-A-1174, 1 sheet, scale 1:24,000.

Collins, E. W., 1994, Geologic map of the Longhorn quadrangle, Texas: The University of Texas at Austin, Bureau of Economic Geology, open-file map prepared for the U.S. Geological Survey under cooperative agreement no. 1434-93-A-1174, 1 sheet, scale 1:24,000.

Collins, E. W., 1994, Geologic map of the Sisterdale quadrangle, Texas: The University of Texas at Austin, Bureau of Economic Geology, open-file map prepared for the U.S. Geological Survey under cooperative agreement no. 1434-93-A-1174, 1 sheet, scale 1:24,000.

Collins, E. W., and **Raney, J. A.,** 1994, Geologic map of the Campo Grande Mountain quadrangle, Texas: The University of Texas at Austin, Bureau of Economic Geology, open-file map prepared for the U.S. Geological Survey under cooperative agreement no. 1434-93-A-1173, 1 sheet, scale 1:24,000.

Collins, E. W., and **Raney, J. A.,** 1994, Geologic map of the Canyon West quadrangle, Texas: The University of Texas at Austin, Bureau of Economic Geology, open-file map prepared for the U.S. Geological Survey under cooperative agreement no. 1434-93-A-1173, 1 sheet, scale 1:24,000.

Collins, E. W., and **Raney, J. A.,** 1994, Geologic map of the Cavett Lake quadrangle, Texas: The University of Texas at Austin, Bureau of Economic Geology, open-file map prepared for the U.S. Geological Survey under cooperative agreement no. 1434-93-A-1173, 1 sheet, scale 1:24,000.

Collins, E. W., and **Raney, J. A.,** 1994, Geologic map of the El Paso quadrangle, Texas: The University of Texas at Austin, Bureau of Economic Geology, open-file map prepared for the U.S. Geological Survey under cooperative agreement no. 1434-93-A-1173, 1 sheet, scale 1:24,000.

Collins, E. W., and **Raney, J. A.,** 1994, Geologic map of the Fort Hancock quadrangle, Texas: The University of Texas at Austin, Bureau of Economic Geology, open-file map prepared for the U.S. Geological Survey under cooperative agreement no. 1434-93-A-1173, 1 sheet, scale 1:24,000.

Collins, E. W., and **Raney, J. A.,** 1994, Geologic map of the North Franklin Mountain quadrangle, Texas: The University of Texas at Austin, Bureau of Economic Geology, open-file map prepared for the U.S. Geological Survey under cooperative agreement no. 1434-93-A-1173, 1 sheet, scale 1:24,000.

Collins, E. W., and **Raney, J. A.,** 1994, Summary report for the New Braunfels, Texas, STATEMAP Project, 1994: The University of Texas at Austin, Bureau of Economic Geology, report prepared for U.S. Geological Survey under cooperative agreement no. 1434-93-A-1174, 14 p.

Darling, B. K., Hibbs, B. J., and **Dutton, A. R.,** 1994, Ground-water hydrology and hydrochemistry of Eagle Flat and surrounding area: The University of Texas at Austin, Bureau of Economic Geology, final report prepared for the Texas Low-Level Radioactive Waste Disposal Authority under interagency contract no. (92-93)-I910, 137 p.

Dutton, A. R., 1994, Sources and ages of ground water in unconfined and confined aquifers beneath the U.S. High Plains: The University of Texas at Austin, Bureau of Economic Geology, final report prepared for the U.S. Geological Survey under grant no. 14-08-0001-G1885, 43 p.

Dutton, A. R., Collins, E. W., Hovorka, S. D., Mace, R. E., Scanlon, B. R., and **Xiang, Jiannan,** 1994, Occurrence and movement of ground water in Austin Chalk and Eagle Ford and Ozan Formations at the Superconducting Super Collider (SSC) site, Ellis County, Texas: The University of Texas at Austin, Bureau of Economic Geology, topical report prepared for the Texas National Research Laboratory Commission under contract no. IAC(92-93)-0301, 393 p.

Fisher, R. S., 1994, Development and application of the nitrogen isotope tracer in evaluating hydrogeologic controls on abatement of nonpoint source pollution from livestock confined feeding areas and other agricultural operations: The University of Texas at Austin, Bureau of Economic Geology, final project report prepared for The Texas Institute for Applied Environmental Research under contracts IAC(92-93)1927 and IAC 94-0107, 12 p. + app.

Fisher, R. S., 1994, Geologic, geochemical, and geographic controls on NORM in produced water from Texas oil, gas, and geothermal reservoirs: The University of Texas at Austin, Bureau of Economic Geology, final report prepared for the U.S. Department of Energy under contract no. DE-AC22-92MT92011, 74 p.

Garner, L. E., compiler, 1994, Coastal and shoreline erosion: Gulf of Mexico slide show program: The University of Texas at Austin, Bureau of Economic Geology, prepared for the U.S. Army Corps of Engineers Waterways Experiment Station under contract no. DACA39-93-M-6230, 5 p.

Gustavson, T. C., 1994, Preliminary assessment of regional depositional systems of the Tertiary Ogallala and Quaternary Blackwater Draw Formations, Pantex Plant and vicinity, Carson County, Texas: The University of Texas at Austin, Bureau of Economic Geology, milestone report prepared for the U.S. Department of Energy through the Office of the Governor, State of Texas, 30 p.

Holtz, M. H., and **McRae, L. E.,** 1994, Identification of remaining oil resource potential in the Frio fluvial-deltaic sandstone play, South Texas: The University of Texas at Austin, Bureau of Economic Geology, topical report prepared for U.S. Department of Energy, Assistant Secretary of Fossil Energy, under cooperative agreement no. DE-FC22-93BC14959, 67 p.

Holtz, M. H., McRae, L. E., and **Tyler, Noel,** 1994, Identification of remaining oil resource potential in the Frio fluvial-deltaic sandstone play, South Texas: The University of Texas at Austin, Bureau of Economic Geology, topical report prepared for the U.S. Department of Energy, Bartlesville Project Office, under contract no. DE-FC22-93BC14959, report no. DOE/BC/14959-8 (DE94000132), 67 p.

Hovorka, S. D., 1994, Evaluation of the ground penetrating radar (GPR) survey at TDCJ playa, Carson County: The University of Texas at Austin, Bureau of Economic Geology, milestone report prepared for the U.S. Department of Energy, through the Office of the Governor, State of Texas, 16 p.

Kerans, Charlie, Bebout, Don, and **Kempter, Kirt,** 1994, Cycle hierarchy and sequence framework for predicting reservoir heterogeneity styles—Fredericksburg Division, Cretaceous (Albian) of the Austin area: The University of Texas at Austin, Bureau of Economic Geology, guidebook prepared for StrataModel Conference, 34 p.

Kreitler, C. W., Akhter, M. S., **Mullican, W. F., III, Avakian, A. J.,** and **Fryar, A. E.,** 1994, Abandoned well characterization: a methodology to evaluate regional hydraulic controls on flow from hydrocarbon reservoirs into underground sources of drinking water: The University of Texas at Austin, Bureau of Economic Geology, report prepared for the American Petroleum Institute, 149 p.

Laubach, S. E., Clift, S. J., Hamlin, H. S., Dutton, S. P., Hentz, T. F., Baek, Hwanjo, and Marin, B. A., 1994, Geology of a stratigraphically complex natural gas play: Canyon sandstones, Val Verde Basin, southwest Texas: The University of Texas at Austin, Bureau of Economic Geology, topical report prepared for the Gas Research Institute under contract no. 5082-211-0708, GRI-94/0167, 135 p.

Levey, R. A., 1994, Targeted technology applications for infield reserve growth: a synopsis of the secondary natural gas recovery project research, Gulf Coast Basin: The University of Texas at Austin, Bureau of Economic Geology, final report prepared for U.S. Department of Energy, Office of Fossil Energy, under DOE contract no. DE-FG21-88MC25031 and GRI contract no. GRI-5088-21-1718, 123 p.+ app.

Lorenz, J. C., and **Laubach, S. E.,** 1994, Description and interpretation of natural fracture patterns in sandstones of the Frontier Formation along the Hogsback, southwestern Wyoming: The University of Texas at Austin, Bureau of Economic Geology, topical report prepared for Gas Research Institute under contract no. 5089-211-2059, SAND94-0153, 89 p.

Mace, R. E., 1994, Hydrogeologic studies in fractured chalk in the vicinity of the SSC site: The University of Texas at Austin, Bureau of Economic Geology, topical report prepared for the Texas National Research Laboratory Commission under contract no. IAC(92-93)-0301, 40 p.

Mace, R. E., and **Dutton, A. R.,** 1994, Record of water levels measured in SSCL monitor wells and private wells at the SSC site, Ellis County, Texas: The University of Texas at Austin, Bureau of Economic Geology, data report prepared for the Texas National Research Laboratory Commission under contract no. IAC 94-0108, unpaginated.

McRae, L. E., Holtz, M. H., and **Knox, P. R.,** 1994, Revitalizing a mature oil play: strategies for finding and producing unrecovered oil in Frio fluvial-deltaic 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 cooperative agreement no. DE-FC22-93BC14959, 93 p.

McRae, L. E., Holtz, M. H., and **Knox, P. R.,** 1994, 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, 155 p.

Morton, R. A., 1994, Preliminary assessment of offshore sand resources, South Padre Island, Texas: The University of Texas at Austin, Bureau of Economic Geology, report prepared for Shiner, Moseley, and Associates and the Town of South Padre Island, variously paginated [13 p.].

Morton, R. A., Gibeaut, J. C., and **White, W. A.,** 1994, East Texas and western Louisiana coastal erosion study, year 3: The University of Texas at Austin, Bureau of Economic Geology, annual report prepared for the U.S. Geological Survey, under cooperative agreement no. 14-08-0001-A0912, variously paginated [201 p.].

Mullican, W. F., III, Johns, N. D., and **Fryar, A. E.,** 1994, Calibration and sensitivity analysis of an Ogallala aquifer ground-water flow model: The University of Texas at Austin, Bureau of Economic Geology, milestone report prepared for the U.S. Department of Energy through the Office of the Governor, State of Texas, 82 p.

Nance, H. S., Laubach, S. E., and **Dutton, A. R.,** 1994, Fault and joint measurements in Austin Chalk, Superconducting Super Collider site, Texas: The University of Texas at Austin, Bureau of Economic Geology, topical report prepared for the Texas National Research Laboratory Commission under contract no. IAC(92-93)-0301, 36 p.

Paine, J. G., 1994, Shallow seismic data acquisition, processing, and interpretation at Pantex Lake, Carson County, Texas: The University of Texas at Austin, Bureau of Economic Geology, milestone report prepared for U.S. Department of Energy through the Governor's Office, State of Texas, 33 p.

Paine, J. G., 1994, Shallow seismic data acquisition, processing, and interpretation at Playa 3, Pantex Plant, Carson County, Texas: The University of Texas at Austin, Bureau of Economic Geology, milestone report prepared for U.S. Department of Energy through the Governor's Office, State of Texas, 32 p.

Paine, J. G., Miller, K. C., and Hua, Fa, 1993, Seismic reflection, refraction, and surface wave studies at the proposed Low-Level Radioactive Waste Repository, Hudspeth County, Texas: The University of Texas at Austin, Bureau of Economic Geology, report prepared for Texas Low-Level Radioactive Waste Disposal Authority under contract no. IAC(92-93)-0910, 67 p.

Raney, J. A., and **Collins, E. W.,** 1994, Mineral resource assessment of lands administered by the Texas General Land Office in the Franklin Mountains, El Paso County, Texas: The University of Texas at Austin, Bureau of Economic Geology, report prepared for the Texas General Land Office under contract no. IAC 94-208 R, 34 p. + 2 pl.

Raney, J. A., and **Collins, E. W.,** 1994, Summary report for the El Paso, Texas, STATEMAP Project, 1994: The University of Texas at Austin, Bureau of Economic Geology, report prepared for the U.S. Geological Survey under cooperative agreement no. 1434-93-A-1173, 17 p.

Schultz-Ela, D. D., Vendeville, B. C., Jackson, M. P. A., Guglielmo, Giovanni, Ge, Hongxing, and **Burn, M. J.,** 1994, Applied Geodynamics Laboratory second semiannual progress report to industrial associates for 1993/captions for physical and mathematical models in slide set number 10: The University of Texas at Austin, Bureau of Economic Geology, report prepared for Agip S.p.A., Amoco Production Company, Anadarko Petroleum Corporation, ARCO Oil and Gas Company, BP Exploration Inc., Chevron Petroleum Technology Company, Conoco Inc., EXXON Production Research Company, Marathon Oil Company, Mobil Research and Development Corporation, Petroleo Brasileiro S.A., Phillips Petroleum Company, Société Nationale Elf Aquitaine Production, Texaco Inc., and Total Minatome Corporation, 37 p. plus 94 transparencies.

Schultz-Ela, D. D., Vendeville, B. C., Guglielmo, Giovanni, Jackson, M. P. A., and **Ge, Hongxing,** 1994, Applied Geodynamics Laboratory annual progress report to industrial associates for 1994. Part 1: captions for physical and mathematical models in slide set number 11. Part 2: animations: The University of Texas at Austin, Bureau of Economic Geology, report prepared for Agip S.p.A., Amoco Production Company, Anadarko Petroleum Corporation, ARCO Oil and Gas Company, BP Exploration Inc., Chevron Petroleum Technology Company, Conoco Inc., EXXON Production Research Company, Louisiana Land and Exploration Company, Marathon Oil Company, Mobil Research and Development Corporation, Petroleo Brasileiro S.A., Phillips Petroleum Company, Société Nationale Elf Aquitaine Production, STATOIL, Texaco Inc., and Total Minatome Corporation, 93 p. plus 146 transparencies and 4 animations.

Seni, S. J., and **Desselle, B. A.,** 1994, Oil and gas resource atlas series: offshore northern Gulf of Mexico: The University of Texas at Austin, Bureau of Economic Geology, annual report prepared for the Gas Research Institute under contract no. 5092-212-2324, GRI-94/0434, 27 p.

Tyler, Noel, Ambrose, W. A., Dutton, S. P., Wang, Fred, Yeh, J. S., Ferrer, Eulise, Padron, Antonio, and Carrasquel, Williams, 1994, Characterization of lower Eocene reservoirs in the LL-652 area, Lagunillas field: The University of Texas at Austin, Bureau of Economic Geology, final report prepared for Lagoven, S.A., 425 p.

Tyler, Roger, Kaiser, W. R., Scott, A. R., Hamilton, D. S., McMurry, R. G., and **Zhou, Naijiang,** 1994, Geologic and hydrologic assessment of natural gas from coal seams in the Mesaverde Group and Fort Union Formation, Greater Green River Basin, Wyoming and Colorado: The University of Texas at Austin, Bureau of Economic Geology, topical report prepared for Gas Research Institute under contract no. 5091-214-2261, GRI 93/0320, 120 p.

Wermund, E. G., and **Avakian, A. J.,** 1994, Physical environment of Camp Mabry, Austin, Texas: The University of Texas at Austin, Bureau of Economic Geology, report prepared for Texas Adjutant General's Department under Letter of Agreement Number TX93-ED3-02 ENV244-D3, 34 p.

Services

Core Research Center

The Core Research Center (CRC) 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, whose telephone number is 471-1534, extension 400. The repository, approximately 103,000 square feet, 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 photography lab, gamma-scan facilities, 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 may also be purchased, listing all CRC holdings, by contacting Jon Boldovici, Data Base Manager, at extension 402.

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 12,400 cores and 57,500 drill cuttings 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) 1994, the CRC received more than 500 visitors, who made transactions involving CRC inventory that included materials from more than 900 wells and required the transfer of more than 20,000 boxes of core to and from viewing and shipping areas. In 1994, photographs were taken of 34 wells.

New acquisitions in 1994 totaled 488 new cores, in excess of 4,800 boxes and nonconventional (cuttings, sidewall, unwashed cuttings, outcrop) core samples from 323 wells, totaling 400 boxes. Donations were received from Amerada Hess, Amoco–Tulsa, Bechtel Energy Resources Corporation, Brooks Oil Co., the Bureau of Economic Geology, Cobra Oil and Gas Corporation, Jack Colle and Associates, Conoco, Core Labs–Carrollton, Fina, Fortson Oil Co., Mobil, Prime Energy, Shell Offshore, Superior, Texaco E&P, the U.S. Geological Survey, The University of Texas at Austin Department of Geological Sciences, and Wiser Oil Co.

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 1994, 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—Primitive Atmospheres (ARP-ATM) and ATP Hydraulics, Lavaca River, DOE Outcrops, and Nitrogen Isotopes projects. In addition to supporting Bureau projects, the MSL provided services to The University of Texas at Arlington as well as to the public. The MSL continued to provide services to Sandia National Laboratories during 1994.

The MSL continues to develop in areas of stable isotope studies, quality assurance, and laboratory determinations unique to hydrology.

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 1994, approximately 1,500 such requests were handled by L. Edwin Garner, the Public Information Geologist. In addition, Bureau staff made numerous presentations to public schools in the Austin area and conducted a geology workshop for science teachers as a part of the Gulf Coast Association of Geological Societies annual meeting. The Bureau also displayed many maps and other educational products at the Conference for the Advancement of Science Teaching held in Beaumont by the Science Teachers Association of Texas, October 20 through 22.

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 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; driller's 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 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 1994, the facility had accumulated approximately 100,000 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

Roger J. Barnaby

"Sequence stratigraphic framework, high-frequency cyclicity, and 3-dimensional reservoir heterogeneity: Grayburg Formation, Brokeoff Mountains, New Mexico": presented at the Reservoir Characterization Research Laboratory Annual Meeting, Carlsbad, New Mexico.

Mark D. Barton

"Geological characterization of Ferron fluvial-deltaic systems: precursor to reservoir simulation": presented to the Delta Industrial Associates Project Review Meeting, Austin, Texas.

Alan R. Dutton

"Ground-water isotopic evidence for paleorecharge in U.S. High Plains aquifers": presented to the Austin Geological Society, Austin, Texas.

"Review of waste-water management research at the Bureau of Economic Geology": presented to the Mineral Resources Administration of Romania, Austin, Texas.

"Hydrogeology of the Superconducting Super Collider site, North-Central Texas": presented to Workshops to Define a Geotechnical Facility for Environmental Research at the SSC Site, De Soto, Texas, and Berkeley, California.

"Determination of hydrogeologic properties from barometric efficiency: examples from the Edwards aquifer, the Texas Panhandle, and the Austin Chalk": presented to the Texas Ground Water Association, Ground-Water Science Division, Annual Meeting, Houston, Texas.

Shirley P. Dutton

"Petrography and diagenesis of the Sonora Canyon Sandstone": presented to Conoco, Inc., Austin, Texas.

"Deltas Industrial Associates Project": presented to the U.S. Department of Energy and BDM-Oklahoma, Inc., Austin, Texas.

"Diagenetic controls on permeability of Fall River sandstone": presented to the Deltaic Industrial Associates Group, spring project review meeting, Austin, Texas.

"Reservoir characterization projects at the Bureau of Economic Geology: examples and approaches": presented to the Petrobras Research Lab (CENPES), Rio de Janeiro, Brazil, and to the Petrobras DEBAR office, Natal, Brazil.

"Joint Bureau of Economic Geology—Petrobras study of the Açu Formation, Brazil": presented to participants in the U.S. Economic and Trade Policy Program for Latin American Journalists, Austin, Texas.

"Diagenesis and burial history of Fall River sandstone in the Black Hills and Powder River Basin": presented to the Deltaic Industrial Associates Group fall project review meeting, Spearfish, South Dakota.

"Characterization of heterogeneity style and permeability structure in fluvial-deltaic reservoirs": presented to Unocal, Austin, Texas.

Robert J. Finley

"Recent oil and natural gas production history in Texas, U.S.A.: a lesson in the character of reservoirs": presented to the Conference on Oil and Gas in Ukraine, Kiev, Ukraine.

"Technology applications in the conversion of natural gas resources to reserves": presented at Second Annual Petrie Parkman and Company/Simmons and Company International Energy Conference.

William L. Fisher

"Geoscience policy: adapting to a world of change": presented as National Resource Council Distinguished Lecture in Geosciences, Washington, D.C.

"Energy issues of the 1990's": presented to The University of Texas at Austin School of Business seminar series, Austin, Texas.

"U.S. oil and gas resources: their critical dependence on technology": presented to the IGT Seventh International Symposium on Energy Modeling, Atlanta, Georgia.

"Oil policy trends": presented to the Meet Alaska Conference, Anchorage, Alaska.

"Global oil markets": presented to the Alaskan World Affairs Council, Anchorage, Alaska.

"Technology and concepts in the changed perception of oil and gas resources": presented to the Gas Daily Symposium on Technology, Houston, Texas.

"Response, Sidney Powers Medalist": presented at the American Association of Petroleum Geologists Annual Meeting, Denver, Colorado.

"Global gas resources": presented to the International Symposium on Gas Resources and Markets, American Association of Petroleum Geologists Annual Meeting, Denver, Colorado.

"Resource assessment and recovery: impact of technology": presented to the China National Petroleum Corporation, Dalian, People's Republic of China.

"Concepts in oil recovery": presented to the Petroleum University of China, Chanping, People's Republic of China.

"Exploration and development technology": presented to the Research Institute for Petroleum Exploration and Development, China National Petroleum Corporation, Beijing, People's Republic of China.

"The nonrenewable resources of the coast": presented to the Bay Summit, Corpus Christi Bay National Estuary Program, Corpus Christi, Texas.

Moderator, "Environmental and Conservation Issues of the 90's": Welder Wildlife Foundation, Corpus Christi, Texas.

"The dramatic turnaround in resource perception": presented to the South Texas Geological Society, San Antonio, Texas.

"The revolution in natural gas": presented to SIPES, Austin, Texas.

Citation, Don R. Boyd, *Transactions* Dedicatee, presented at the Gulf Coast Association of Geological Societies Annual Convention, Austin, Texas.

Citation, Frank Harrison, Ben H. Parker Medalist, presented at the American Institute of Professional Geologists Annual Meeting, Flagstaff, Arizona.

"The North American natural gas experience: revitalization of a resource base thought exhausted": presented to the Global Gas Resources Workshop on Impacts of Technology on the Global Gas Resource Base, Vail, Colorado.

"Rethinking resources": presented to the Symposium on Limitations of the Earth Revisited, Gulf Coast Association of Geological Societies Annual Convention, Austin, Texas.

Robert L. Folk

"Dwarf bacteria (nannobacteria), chemical reactions, and mineral precipitation": presented to The University of Texas, Department of Geological Sciences, Soft Rock Seminar, Austin, Texas; Society of Independent Professional Earth Scientists, Austin, Texas; Duke University, Department of Geology, Durham, North Carolina; and Port Aransas Marine Institute, Port Aransas, Texas.

"Egyptian pyramids: concrete poured in place or real stone?": presented to the Austin Gem and Mineral Society, Austin, Texas.

Alan E. Fryar

"Chemical evolution of ground water on the High Plains of Texas": presented to The Ohio State University, Department of Geological Sciences, Columbus, Ohio.

"Evidence of denitrification during ground-water recharge in the Southern High Plains": presented to the Texas A&M Research and Extension Center, Amarillo, Texas.

William E. Galloway

"Depositional systems and sequences": presented to the University of Adelaide, National Centre for Petroleum Geology and Geophysics, Adelaide, South Australia, Australia.

"Submarine canyons": presented to the Australian Society of Exploration Geophysicists, Adelaide, South Australia, Australia.

"Predictive facies distribution in genetic stratigraphic sequences": presented to the Second High-Resolution Sequence Stratigraphy Conference, Tremp, Spain.

Michael H. Gardner

"Sediment volume partitioning in shallow-marine and coastal-plain strata: examples from the Ferron Sandstone (Cretaceous), Utah": presented to ARCO Research and Development Corporation, Dallas, Texas.

"Sequence stratigraphy of fluvial-deltaic depositional systems: examples from the Ferron Sandstone (Cretaceous), Utah": presented to the American Association of Petroleum Geologists in conjunction with field trip, central Utah.

"Sediment volume partitioning in shallow-marine and coastal-plain deposits: Ferron Sandstone (Cretaceous), Utah": presented to the American Association of Petroleum Geologists in conjunction with field trip, central Utah.

L. Edwin Garner

"Public information sources at the Bureau of Economic Geology": presented to the Central Texas Paleontological Society, Austin, Texas.

"Geophysical log library and core repository of the Bureau of Economic Geology": presented to the American Institute of Mining Engineers, Austin, Texas.

Chester M. Garrett, Jr.

"Historical review of University Lands and their remaining oil and gas resource": presented to the Westminster Manor Discussion Group, Austin, Texas.

Giovanni Guglielmo, Jr.

"Animations of salt tectonics" and "3-D visualization of salt walls and grabens": presented to Industrial Associates of Applied Geodynamics Laboratory, Austin, Texas.

Thomas C. Gustavson

"Development of playa basins, Southern High Plains, Texas and New Mexico": presented to the Soil Survey and Land Resource Workshop, College Station, Texas.

Douglas S. Hamilton

"High-resolution sequence stratigraphic and systems tract analysis and resource and play assessment of the Toolachee/Nappacoongee–Murteree blocks": presented to Santos Limited, Adelaide, South Australia, Australia.

H. Scott Hamlin

"Geology of Canyon sands tight-gas reservoirs, Val Verde Basin": presented to the North Texas Geological Society, Wichita Falls, Texas.

"Regional stratigraphic mapping issues and log character and correlations, Wilcox Lobo trend, South Texas" and "Production

statistics and controls on productivity, Wilcox Lobo sandstones, South Texas": presented to Wilcox Lobo operators, Houston, Texas.

"Canyon sandstone: key research issues": presented at Canyon Play Management of Technology meeting, sponsored by the Texas Independent Producers and Royalty Owners Association and the Gas Research Institute, Midland, Texas.

"Geologically complex gas reservoirs in slope and basin facies, Canyon sandstones, Val Verde Basin, southwest Texas": presented to the Society of Independent Professional Earth Scientists, Austin, Texas.

Bob A. Hardage

"3-D seismic imaging of thin-bed reservoirs": presented to the Dallas Geological Society, Dallas, Texas.

"Principles of 3-D seismic acquisition": presented at the Gas Daily Seminar, Houston, Texas.

"Calibrating geologic and engineering data with 3-D seismic images": presented to the Society of Professional Well Log Analysts, Dallas, Texas.

"Geophysical technologies used in Secondary Gas Recovery studies": presented to the Gas Research Institute Technical Advisory Committee, Austin, Texas.

"Seismic imaging of thin-bed gas reservoirs": presented to the Oklahoma City Geophysical Society, Oklahoma City, Oklahoma.

"Geophysical research performed at Boonsville field": presented to the Gas Research Institute Program Advisory Group, Denver, Colorado.

"3-D seismic studies in onshore Gulf Coast gas fields": presented to the Society of Independent Professional Earth Scientists (SIPES), New Orleans, Louisiana.

"The importance of pressure tests in 3-D seismic interpretation": presented to the Abilene Geological Society, Abilene, Texas.

"Imaging heterogeneous reservoirs with crosswell P-waves and S-waves": presented to an industry consortium, Houston, Texas.

"3-D seismic capabilities of the Bureau of Economic Geology": presented to attendees at symposium honoring Dr. William Fisher, Austin, Texas.

"3-D seismic data acquisition in Midcontinent gas fields": presented to the Dallas Geophysical Society, Dallas, Texas.

"3-D seismic survey design": presented to the MESA users conference, Houston, Texas.

"Interpretation techniques used to image thin-bed reservoirs": presented to the Landmark users conference, Houston, Texas.

"An integrated approach to identifying natural gas reservoir compartments using 3-D seismic depositional facies analysis and production tests—examples from Middle Frio fluvial reservoirs, South Texas": presented to the Society of Exploration Geophysicists Annual International Meeting, Los Angeles, California.

Tucker F. Hentz

"Regional diagenesis, reservoir hydrodynamics, and hydrochemical-facies and gas-composition mapping of the Wilcox Lobo trend, South Texas": presented to Wilcox Lobo producers, Houston, Texas.

Susan D. Hovorka

"Log- and core-based studies of the Edwards aquifer, South and Central Texas, using SGM StrataModel": poster session presented at the StrataModel Conference, Austin, Texas.

"Playa studies at Pantex": presented to community meeting of farmers and ranchers, Amarillo, Texas.

Martin P. A. Jackson

"Allochthonous salt sheets, canopies, and fold belts in the northern Gulf of Mexico": presented to The University of Texas at Austin, Department of Geological Sciences, Hard Rock/Structure Seminar, Austin, Texas.

"Seismic interpretation of salt structures": presented to TGS-Calibre, Houston, Texas.

"Origin of salt structures in the Gulf of Mexico": presented to Western Geophysical Company, Houston, Texas.

"Aspects of raft tectonics in West Africa": presented to Amoco Production Company, Houston, Texas.

"Overview of AGL research for 1994," "Ten lessons in salt tectonics from the Gulf of Mexico," "Local and regional balancing of deformed salt sheets," "Multiple breakout of salt sheets during progradation," and "AGL research directions for 1994": presented to Industrial Associates of Applied Geodynamics Laboratory, Austin, Texas.

William R. Kaiser

"Coalbed methane producibility model in the Piceance Basin": presented to the Gas Research Institute, Natural Gas Supply Project Advisors Group Meeting, Golden, Colorado, and to the Piceance Basin Operators Group Meeting, Denver, Colorado.

Charles Kerans

"Quantifying stratal architecture of carbonate grainstone complexes within a high-resolution sequence framework: application to reservoir characterization": presented to Amoco Production Company, Sequence Stratigraphy Group, Houston, Texas.

"Developing a sequence framework for constructing petrophysical–engineering models of carbonate reservoirs": presented to Saudi Aramco, Manama, Bahrain; Oman Production Development, Muscat, Oman; and Abu Dhabi National Oil Company, Abu Dhabi, United Arab Emirates.

"Sequence framework of the San Andres Formation in outcrop and northern Permian Basin": presented to Shell Western Exploration & Production, Carlsbad, New Mexico.

Paul R. Knox

"Unlocking the potential of inner-shelf sandstone reservoirs within the downdip Frio Formation: a key to revitalizing mature oil and gas fields": presented to the South Texas Geological Society, San Antonio, Texas.

"Locating the remaining oil and gas in mature downdip Frio fields: identifying compartmentalization in thin reservoirs": presented to the Corpus Christi Geological Society, Corpus Christi, Texas.

Stephen E. Laubach

"Complex natural gas reservoirs": presented at Gas Research Institute Project Advisors Group meeting, Golden, Colorado.

"Fracture, fault, and stress-pattern issues of the Wilcox Lobo trend, South Texas": presented to Wilcox Lobo operators, Houston, Texas.

Raymond A. Levey

"Gas reservoir characterization and reserve growth experience in Texas": presented to GASPROM, Austin, Texas.

"An overview of natural gas resources research": presented to the Mineral Resources Administration of Romania, Austin, Texas.

"Objectives of natural gas supply research and results from the Secondary Gas Recovery Project conducted by the Bureau of

Economic Geology for the Gas Research Institute and U.S. Department of Energy": presented to the Lakeway Men's Club, Lakeway, Texas.

"The infield reserve growth joint venture for Midcontinent sandstones": presented to the Gas Research Institute's Technical Advisory Committee, Austin, Texas.

"Integrated characterization of gas reservoirs on the Texas Gulf Coast": presented to Maraven, Austin, Texas.

"Maximizing recovery of natural gas in fluvial-deltaic reservoirs: examples from the onshore Gulf Coast with implications for Midcontinent gas reservoirs": presented to the Tulsa Geological Society and Tulsa chapter of the Society of Petroleum Engineers, Tulsa, Oklahoma.

"The Secondary Gas Recovery Project (SGR)": presented to Chevron U.S.A. Gas Group, Houston, Texas.

"An overview of the Secondary Natural Gas Recovery Project (SGR) research": presented to Exxon Production Research field segmentation group, Austin, Texas.

"Integrated characterization of gas reservoirs on the Texas Gulf Coast": presented to Maraven, Austin, Texas.

"Case studies evaluating the benefits of infield reserve growth in the onshore Gulf Coast, South Texas": presented to the Corpus Christi Society of Professional Earth Scientists meeting, Corpus Christi, Texas.

"Natural gas resources and supplies" presented to the Society of Petroleum Engineers Forum on Natural Gas, Dallas, Texas.

"Infield natural gas reserve growth in fluvial-deltaic reservoirs": presented to the Fort Worth Geological Society and Society of Petroleum Engineers special study group, Fort Worth, Texas.

"The future of sustained oil and gas production in Texas": presented to the Bankers Association of Texas, Dallas, Texas.

"The infield reserve growth joint venture for Midcontinent sandstones": presented to the Gas Research Institute's Project Advisory Group, Denver, Colorado.

"Technology transfer from the infield reserve growth joint venture in the Gulf Coast Basin": presented to the Gas Research Institute's Project Advisory Group, Denver, Colorado.

"Geologic models and spatial characterization of continuous bounding units separating natural gas reservoirs in the Gulf Coast for guided wave technology": presented to the Gas Research Institute's Seismic Advisory Group, Houston, Texas.

"Status and update of the infield reserve growth joint venture": presented to the U.S. Department of Energy, Morgantown Energy Technology Center, Morgantown, West Virginia.

"Geocellular modeling of petrophysical and geophysical attributes for characterization of complex fluvial reservoirs (Gulf Coast)": presented to the StrataModel Conference, Austin, Texas.

"The secondary gas recovery project": presented to the Deputy Assistant Secretary of Energy for gas and petroleum technologies, Austin, Texas.

"Energy resources programs at the Bureau of Economic Geology": presented to the Texas Energy Coordination Council, Austin, Texas.

"Techniques and strategies for maximizing natural gas recovery in fluvial and deltaic reservoirs in the Gulf Coast: targeted technology applications for infield reserve growth": presented to the East Texas Geological Society, Tyler, Texas.

F. Jerry Lucia

"Quantification of sequence stratigraphic framework, carbonate ramp reservoirs, San Andres Formation, Permian Basin, Texas and New Mexico, U.S.A.": presented to Saudi Aramco, Manama, Bahrain; Oman Production Development, Muscat, Oman; and Abu Dhabi National Oil Company, Abu Dhabi, United Arab Emirates.

"Rock fabric and stratigraphic controls on fluid flow in porous media": presented at the Gordon Conference on Modeling of Flow in Porous Media, Andover, New Hampshire.

"Geological methods for scaling petrophysical properties for reservoir modeling": presented to the Society of Professional Well Log Analysts, Midland, Texas.

"Quantification of sequence stratigraphic framework, carbonate ramp reservoirs, San Andres Formation, Permian Basin, Texas and New Mexico, U.S.A.": presented to Amoco Production Research Company, Tulsa, Oklahoma.

"Fundamental geological–engineering parameters for 3-D modeling of carbonate ramp reservoirs": presented to the StrataModel Conference, Austin, Texas.

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

"Rock fabric approach for integration of geologic interpretations and petrophysical data to construct carbonate reservoir models": presented at Society of Professional Well Log Analysts luncheon, Fort Worth, Texas.

Robert E. Mace

"Numerical ground-water flow modeling at the Superconducting Super Collider site": presented at the Workshop to Define a Geotechnical Facility for Environmental Research at the SSC Site, De Soto, Texas.

"Historic ground-water production of the Cretaceous sandstone aquifers of North-Central Texas": presented at the Southwestern Association of American Geographers, Hot Springs, Arkansas.

"Prediction of fracture spacing and porosity: statistical and geostatistical analysis of fault and joint measurements in Austin Chalk, Superconducting Super Collider Site, Texas": presented at meeting of the Houston Geological Society, Houston, Texas.

"Fracture hydrology studies in the Austin Chalk of North-Central Texas": presented at the Chapman Conference on Aqueous Phase and Multiphase Transport in Fractured Rock, Burlington, Vermont.

R. P. Major

"Fossil fuel research at the Bureau of Economic Geology, The University of Texas at Austin": presented to the Historically Black Colleges and Universities Second Annual Fossil Fuel Conference, Birmingham, Alabama.

"Review of the State Lands Energy Resource Optimization Program": presented to representatives of the Texas General Land Office, Austin, Texas.

"Review of The University of Texas at Austin, Bureau of Economic Geology, research in reservoir characterization, outcrop reservoir analogs, and modern sediment analogs": presented to representatives of the People's Republic of China National Oil Company and to representatives of the Mineral Resources Administration of Romania, Austin, Texas.

"Overview of Bureau of Economic Geology": presented to the U.S. Economic and Trade Policy Program for Latin American Journalists, Austin, Texas.

Lee E. McRae

"Integrated characterization of mature oil reservoirs: an example from Frio fluvial-deltaic sandstones, Rincon field, South Texas":

presented to the Corpus Christi Geological Society, Corpus Christi, Texas.

Robert A. Morton

"Geologic history and sedimentary framework of the Texas coast," "Beaches, barriers, and bays of the Corpus Christi region," "Sea level, sediment supply, storms, structures, and shoreline changes," and "Texas inlets and harbors—saga of Packery Channel and the Fish Pass": presented to the Texas A&M University Conrad Blucher Institute of Surveying and Science, Corpus Christi, Texas.

"Coastal geology and Texas law": presented to a joint meeting of attorneys from the Texas General Land Office and Texas Office of the Attorney General, Austin Texas.

"Geo-indicators of wetland changes and shoreline movement": presented at the International Union of Geological Sciences Workshop on Geological Indicators of Rapid Environmental Change, Corner Brook, Newfoundland, Canada.

"Geologic characteristics and beach stability of South Padre Island": presented to Mayor and Board of Aldermen, South Padre Island, Texas.

Jeffrey G. Paine

"Geophysics in the shallow subsurface: it's not just for prospecting anymore": presented to the Panhandle Geological Society, Amarillo, Texas, and the Austin Geological Society, Austin, Texas.

"Determining the role of subsidence in the formation of playa basins using shallow seismic reflection methods": presented at the Playa Basin Symposium, Texas Tech University, Lubbock, Texas.

Daniel D. Schultz-Ela

"Effect of salt budget on overburden deformation," "Salt tectonics above multiple basement faults," and "Subsalt and suprasalt fault linkage": presented to Industrial Associates of Applied Geodynamics Laboratory, Austin, Texas.

Carol L. Ruthven

"Impacts of technology on the global gas resource base": presented at Global Energy and Environmental Matters Conference, Jackson Hole, Wyoming.

Andrew R. Scott

"Composition and origins of coalbed gases" and "Calculation of coalbed methane resources": presented to OXY USA, Inc., Austin, Texas.

Steven J. Seni

"Play analysis methodology and rationale": presented to the Minerals Management Service—Bureau of Economic Geology Workshop, Metairie, Louisiana.

"Summary of the Offshore Gas Atlas Program": presented at the 1994 Project Advisors Group Meeting, Gas Research Institute, Golden, Colorado.

"Status of play analysis of lower Miocene reservoirs in Texas State waters, Gulf of Mexico": presented at the Technical Advisors Group Meeting, Metairie, Louisiana.

Noel Tyler

"Characterization of heterogeneous hydrocarbon reservoirs: the upside potential for the nation": presented to the Department of Earth Resources, College of Natural Resources, Colorado State University, Fort Collins, Colorado.

"Exploration and development prospects resulting from the high-resolution sequence stratigraphic and systems tract analysis and resource and play assessment of the Toolachee/Nappacoongee–Murteree blocks": presented to Santos Limited, Adelaide, South Australia, Australia.

"Development and evolution of the Department of Energy's Class Program": presented to the National Academy of Sciences Review Panel of the U.S. Department of Energy's Oil Recovery Program, Houston, Texas.

"Tectono-stratigraphic controls on deltaic reservoir architecture and recovery response in foreland basins": presented to the V Simposio Bolivariano, Puerto La Cruz, Venezuela.

"Advanced recovery strategies for reserve appreciation": presented to Ecopetrol, Bogotá, Colombia.

"Texas' future in oil and gas exploitation": presented to the Lakeway Men's Club, Lakeway, Texas.

"Geologic reservoir characterization: developing a quantified reservoir framework for recovery optimization": presented to the Multidisciplinary Approaches to Reservoir Characterization Spring Symposium sponsored by the University of Tulsa, Tulsa, Oklahoma.

Roger Tyler

"Regional genetic stratigraphy and structural attributes of the Piceance Basin, Colorado: genetic correlation with the Sand Wash Basin, coal and sandstone continuity, net coal trends, shoreline orientation, thrust faulting and duplication of the coal-bearing section, and lineament and fracture characteristics": presented to the Piceance Basin Operators Group Meeting, Denver, Colorado.

"Funding and contract servicing with the multilateral development banks (World, Export-Import, and Inter-American Development Banks)—a progress report" and "The potential for contract servicing with the multilateral development banks (World, Export-Import, and Inter-American Development Banks)": briefing, Austin.

"Geologic and hydrologic characteristics of coalbed methane production in the Rocky Mountain Foreland": presented to the Mineral Resources Administration of Romania, Austin, Texas.

"Tectonic and stratigraphic setting of the Rocky Mountain Foreland, with an emphasis on coalbed methane production, Greater Green River and Piceance Basins," "Marine and nonmarine sequence stratigraphy of the Greater Green River and Piceance Basins, Rocky Mountain Foreland," and "Natural fracture patterns in the Rocky Mountain Foreland: permeability indicators for coalbed methane production": presented to OXY USA, Inc., Austin, Texas.

"Comparison between South African and Texan rocks through plate tectonics and continental drift": presented to the fifth grade at Cypress Creek Elementary School, Cedar Park, Texas.

Bruno C. Vendeville

"Introduction to salt tectonics and experimental modeling," "General mechanics of salt diapirism," "The rise of salt diapirs during thin-skinned extension," "The fall of salt diapirs during thin-skinned extension," "Detached salt tectonics during basement-involved extension," and "Diapir reactivation during regional contraction": presented to British Gas Exploration & Production, Reading, England.

"Normal fault relays over thin salt," "3-D faulting and minibasin growth during progradation," "Diapiric reactivation by horizontal contraction: models," and "Diapiric reactivation by horizontal contraction: Nordkapp Basin": presented to Industrial Associates of Applied Geodynamics Laboratory, Austin, Texas.

Fred P. Wang

"Upscaling, modeling, and simulation of shallow-water carbonate reservoirs": presented to the Reservoir Characterization Research Laboratory Workshop, Austin, Texas.

"Characterization of a lower Eocene reservoir, LL-652 Area, Lagunillas field in Venezuela": presented to the Exploration and Development Research Institute, Chinese Petroleum Corporation, Miaoli, Taiwan.

"Characterization of sandstone and carbonate reservoirs": presented to the Taiwan Petroleum Exploration Division, Chinese Petroleum Corporation, Miaoli, Taiwan.

E. G. Wermund

"Characterization of the physical environment of Texas National Guard training sites": presented to the U.S. Army Third Annual Land Rehabilitation and Maintenance (LRAM) Conference, Aberdeen, Maryland.

Bureau of Economic Geology Seminars

Roger J. Barnaby

"Resource optimization through characterization of downdip Frio shoreface/shelf sandstone reservoirs, Red Fish Bay field, South Texas"

Don G. Bebout

"Internal geometry of a modern carbonate grainstone shoal—an analog for hydrocarbon reservoir heterogeneity"

David L. Carr

"Finding new reserves in 'old' Midcontinent gas fields using sequence stratigraphy: Boonsville (Bend) gas field, Fort Worth Basin, Texas"

Shirley P. Dutton

"Influence of early siderite cementation on reservoir quality in Sonora Canyon sandstones, Val Verde Basin, Southwest Texas"

"Depositional versus diagenetic controls of permeability, Lower Cretaceous Fall River Formation in outcrop and subsurface, Wyoming and South Dakota"

R. Stephen Fisher

"Geologic, geochemical, and geographic controls on natural radioactivity in produced water from Texas oil, gas, and geothermal reservoirs"

Robert L. Folk

"Nannobacteria and chemistry on the face of the Earth"

Alan E. Fryar

"Geochemical evolution of recharge and ground water in the vicinity of the Pantex Plant"

Michael H. Gardner

"A tale of two margins: contrasting low and high accommodation deltaic systems from the Ferron Sandstone of central Utah and Fall River Formation of eastern Wyoming and western South Dakota"

Scott C. Goode

(and Mary L. W. Jackson) "Calculation of lignite resources in Texas using the National Coal Resources Data System and GRASS GIS"

H. Scott Hamlin

"Geologic controls on reservoir properties in a braid-delta sandstone, Tirrawarra oil field, South Australia"

Bob A. Hardage

"Seismic technology in the Secondary Gas Recovery (SGR) Program"

Susan D. Hovorka

"Porosity distribution in the Edwards aquifer—depositional facies; Cretaceous dolomitization, and Cenozoic fresh-water alteration"

Mary L. W. Jackson

(and Scott C. Goode) "Calculation of lignite resources in Texas using the National Coal Resources Data System and GRASS GIS"

Charles Kerans

"Depositional models: semiquantitative revival of a qualitative tool"

Paul R. Knox

"High-frequency cycle stratigraphy: what order is *your* reservoir?"

Raymond A. Levey

(, Carol L. Ruthven, and W. Gerald White) "SGR technology transfer strategy: breaking new ground"

R. P. Major

(and Don G. Bebout) "Internal geometry of a modern carbonate grainstone shoal—an analog for hydrocarbon reservoir heterogeneity"

William F. Mullican III

"The impact of alternative recharge scenarios on rates of contaminant transport to and within the Ogallala (High Plains) aquifer"

H. Seay Nance

"Fracture mapping at the Superconducting Super Collider"

Stephen C. Ruppel

"Implications of geological characterization of the Monahans Clear Fork reservoir to improved recovery in Leonardian carbonate reservoirs, Central Basin Platform"

Carol L. Ruthven

"The impact of price and technology on oil resource recovery"

(, Raymond A. Levey, and W. Gerald White) "SGR technology transfer strategy: breaking new ground"

"Global gas resource assessment"

Andrew R. Scott

"Geological controls on the high productivity fairway, San Juan Basin, Colorado and New Mexico"

Bruno C. Vendeville

"Salt tectonics in the Nordkapp Basin, southern Barents Sea, Norway"

W. Gerald White

(, Raymond A. Levey, and Carol L. Ruthven) "SGR technology transfer strategy: breaking new ground"

Congressional, Legislative, and Special Testimony

William L. Fisher

"Statement on Outer Continental Shelf activity and current state of domestic gas and oil industry": presented to the Committee on Natural Resources, U.S. House of Representatives, Washington, D.C.

"Statement on national energy policy issues": presented to the Department of Energy Hearings on National Energy Plan, Austin, Texas.

Committee Services, Offices, and Other Professional Responsibilities

Mark D. Barton

Co-leader of field trip, "Sequence stratigraphy, facies architecture, and permeability structure of fluvial-deltaic reservoir analogs: the Upper Cretaceous Ferron Sandstone, central Utah," American Association of Petroleum Geologists Annual Meeting, central Utah.

Sigrid J. Clift

Member, Organizing Committee for Secondary Earth Science Teachers Educational Seminar, Gulf Coast Association of Geological Societies Annual Convention.

Organizer, ISR/ASTM, RQD Round Robin and Core Fracture Description Session, 1994 North American Rock Mechanics Symposium, Austin, Texas.

Organizer, Core Research Center core display, 1994 North American Rock Mechanics Symposium, Austin, Texas.

Leader of field trip, "Paleogeography of Austin area during the Cretaceous," Lago Vista High School biology classes, Austin, Texas.

Edward W. Collins

Chairman, Poster Session Committee, Gulf Coast Association of Geological Societies Annual Convention.

Alan R. Dutton

Editor, *The Hydrogeologist*, Geological Society of America, Hydrogeology Division.

Editor, *Toxic Substances and the Hydrologic Sciences*, American Institute of Hydrology.

Convenor, "General hydrogeology" technical session, American Institute of Hydrology Annual Meeting.

Member, Ground-Water Protection Committee, Texas Natural Resources Conservation Commission.

Associate Editor, *Gulf Coast Association of Geological Societies Transactions*.

Shirley P. Dutton

Associate Editor, *Journal of Sedimentary Research*, SEPM (Society for Sedimentary Geology).

General Program Chairman and GCAGS Program Chairman, Gulf Coast Association of Geological Societies Annual Convention.

Member, Aid-to-Students Committee, Gulf Coast Association of Geological Societies.

Member, Grants-in-Aid Committee, American Association of Petroleum Geologists.

Member, Joint Technical Program Committee, Geological Society of America, representing the Sedimentary Geology Division.

Member, Steering Committee, Gulf Coast Association of Geological Societies Annual Convention.

Secretary, Gulf Coast Association of Geological Societies.

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.

Co-chair, South America Session, Global Gas Resources Workshop, Gas Technology Information, Inc.

Co-chair, Regional- and Development-Scale Stratigraphic Studies Session, Gulf Coast Association of Geological Societies.

R. Stephen Fisher

Member, Committee on Hydrology and Environmental Geology, SEPM (Society for Sedimentary Geology).

William L. Fisher

Member, Board of Directors, Gulf Coast Association of Geological Societies.

President, Gulf Coast Association of Geological Societies.

Director, Geology Foundation, The University of Texas at Austin.

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.

Chairman, Committee for Strategic Planning, American Geological Institute.

Member, Research and Development Needs Committee, National Petroleum Council.

Chairman, Faculty Review Committee, Department of Geological Sciences, The University of Texas at Austin.

Chairman, Energy Policy Committee, Association of American State Geologists.

Chairman, Applied Research and Technology Committee, Texas Independent Producers and Royalty Owners Association (TIPRO).

Board of Advisors, Jefferson Energy Foundation Project on Man, Energy, and the Environment.

Foundation Trustee, American Geological Institute.

Member, Advisory Council, Bureau of Business Research, The University of Texas at Austin.

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, Texas Ground-Water Protection Committee.

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.

Vice Chairman, Board of Directors, Texas Low-Level Radioactive Waste Disposal Authority.

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, Coastal Erosion Committee, Association of American State Geologists.

Member, Endowment Fund Steering Committee, Association of American State Geologists.

Member, Steering Committee, National Geoscience Data Repository System.

Member, Nominating Committee, Advisory Council, Gas Research Institute.

Member, National Petroleum Council.

Member, Executive Committee, Texas Independent Producers and Royalty Owners Association (TIPRO).

Trustee Associate, American Association of Petroleum Geologists Foundation.

Chairman, Committee on Resources and Environment of the Continental Margins, Association of American State Geologists.

Member, Commission on Geosciences, Environment, and Resources, National Research Council.

Member, Marginal Well Production Committee, National Petroleum Council.

Member, National Academy of Engineering.

Member, National Association of Corporate Directors.

Member, Producer's Advisory Group, Texas Independent Producers and Royalty Owners Association (TIPRO).

William E. Galloway

Member, Pettijohn Medal Selection Committee, SEPM (Society for Sedimentary Geology).

Michael H. Gardner

Leader of field trip, "Sequence stratigraphy, facies architecture, and permeability structure of fluvial-deltaic reservoir analogs," American Association of Petroleum Geologists Annual Meeting, central Utah.

L. Edwin Garner

Leader of field trip, "Geology of the Austin–Llano area," 1994 North American Rock Mechanics Symposium, Austin, Texas.

Member, Crisis Committee, Gulf Coast Association of Geological Societies Annual Convention.

Member, Steering Committee, Gulf Coast Association of Geological Societies Annual Convention.

Member, Membership Committee, American Association of Petroleum Geologists.

Chester M. Garrett, Jr.

Member, American Association of Petroleum Geologists House of Delegates Nominating Committee.

Chairman, Austin Geological Society delegates to American Association of Petroleum Geologists House of Delegates.

Co-chairman, Exhibits Committee, Gulf Coast Association of Geological Societies Annual Convention.

Member, Registration Committee, Gulf Coast Association of Geological Societies Annual Convention.

Member, Awards Committee, Austin Geological Society.

Thomas C. Gustavson

Leader of field trip, "Tertiary and Quaternary stratigraphy and archeology of the Rio Grande Valley," Friends of the Pleistocene, South-Central Cell, Annual Meeting, El Paso area, Texas.

H. Scott Hamlin

Co-convenor, "Geology and production aspects of a stratigraphically complex natural gas play: Canyon Sandstone, Val Verde Basin, Texas," technology transfer workshop sponsored by the Gas Research Institute, West Texas Geological Society, and Bureau of Economic Geology, Midland, Texas.

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.*

Member, Visiting Committee, Department of Petroleum Engineering, The University of Texas at Austin.

Member, Geophysical Committee, American Association of Petroleum Geologists.

Tucker F. Hentz

Associate Editor, *Gulf Coast Association of Geological Societies Transactions.*

Martin P. A. Jackson

Associate Editor, *Geological Society of America Bulletin.*

Member, International Union of Geological Sciences Commission on Tectonics.

William R. Kaiser

Co-leader of field trip, "Lignite rock mechanics: natural fractures, hydrology, mining, transport, and crushing for ignition," 1994 North American Rock Mechanics Symposium, Austin, Texas.

Member, Steering Committee on Coal Reserves Assessment, U.S. Department of Energy.

Charles Kerans

Co-convenor, "High-resolution sequence stratigraphy applied to carbonate reservoir development," theme session, American Association of Petroleum Geologists Annual Meeting.

Member, Distinguished Lecture Committee, American Association of Petroleum Geologists.

Co-leader of field trip, "Characterization of San Andres reservoirs using outcrop analogs, Algerita Escarpment, Guadalupe Mountains," Shell Western Exploration and Production Company, Carlsbad, New Mexico.

Co-leader of field trip, "Cycle hierarchy and sequence framework for predicting reservoir heterogeneity styles: Fredericksburg Division, Cretaceous (Albian) of the Austin area," StrataModel Conference field trip, Austin, Texas.

Paul R. Knox

Member, Audio-Visual and Speakers Assistance Committee, Gulf Coast Association of Geological Societies Annual Convention.

Member, Poster Session Committee, Gulf Coast Association of Geological Societies Annual Convention.

Member, Sports Committee, Gulf Coast Association of Geological Societies Annual Convention.

Stephen E. Laubach

Member, Committee on Advanced Drilling Technologies, National Academy of Sciences/National Research Council.

Member, Coordinating Committee, Geotechnical Research Facility, On-Site Utilization of Major Assets Developed for the Superconducting Super Collider.

Co-chairman, 1994 North American Rock Mechanics Symposium.

Organizer of workshop, "Characterization of natural fracture patterns with special emphasis on scale and time effects," 1994 North American Rock Mechanics Symposium, Austin, Texas.

Co-convenor, "Geology and production aspects of a stratigraphically complex natural gas play: Canyon Sandstone, Val Verde Basin, Texas," technology transfer workshop sponsored by the Gas Research Institute, West Texas Geological Society, and Bureau of Economic Geology, Midland, Texas.

Raymond A. Levey

Chairman, 3-D Seismic Special Committee, Texas Data Project 1995.

Co-chairman, Audio-Visual and Speakers Assistance Committee, Gulf Coast Association of Geological Societies Annual Convention.

Member, Research Committee, American Association of Petroleum Geologists.

Member, Texas Data Project 1995.

F. Jerry Lucia

Review Chairman, SPE Formation Evaluation, Society of Petroleum Engineers.

Member, Production Geology and Geophysics Committee, Society of Petroleum Engineers.

R. P. Major

Member, Executive Board, Austin Geological Society.

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.

Editor, *Gulf Coast Association of Geological Societies Transactions.*

Member, Steering Committee, Gulf Coast Association of Geological Societies Annual Convention.

Member, Admissions and Support Committee, Department of Geological Sciences, The University of Texas at Austin.

Member, Program Committee, Gulf Coast Association of Geological Societies Annual Convention.

Lee E. McRae

Associate Editor, *Gulf Coast Association of Geological Societies Transactions.*

Member, Program Committee, Gulf Coast Association of Geological Societies Annual Convention.

Member, Registration Committee, Gulf Coast Association of Geological Societies Annual Convention.

Judge, SEPM (Society for Sedimentary Geology) Research Symposium oral session, "Sequence correlatability and sea-level behavior over time-alternative views," American Association of Petroleum Geologists Annual Meeting.

Chairman, Membership Committee, Austin Geological Society.

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).

Associate Editor, *Gulf Coast Association of Geological Societies Transactions.*

Stephen C. Ruppel

Publications Chairman, Austin Geological Society.

Member, Technical Program Committee, Gulf Coast Association of Geological Societies Annual Convention.

Associate Editor, *Gulf Coast Association of Geological Societies Transactions.*

Bridget R. Scanlon

Member, Panel on Wilshire's Report on Radioactive Waste Disposal Site in California, National Academy of Sciences.

Co-convenor, "Integration of hydraulic and hydrochemical data to obtain a comprehensive understanding of unsaturated zone processes in arid systems," technical session, Geological Society of America Annual Meeting.

Daniel D. Schultz-Ela

Convenor, "Numerical modeling I—continuum modeling," special session, 1994 North American Rock Mechanics Symposium.

Co-convenor, "Salt tectonics and deposition of Gulf Coast sediment," technical session, Gulf Coast Association of Geological Societies Annual Convention.

Co-convenor, "Crustal mechanics," technical session, American Geophysical Union Annual Fall Meeting.

Andrew R. Scott

Regional Committee Representative, Energy Mineral Division, Gulf Coast Association of Geological Societies.

Chairman, Energy Minerals Division Luncheon, Gulf Coast Association of Geological Societies Annual Convention.

Co-Convenor, "Geochemistry of source rocks applied to Gulf Coast exploration," special session, Gulf Coast Association of Geological Societies Annual Convention.

Judge, George C. Matson Memorial Award, American Association of Petroleum Geologists Annual Meeting.

Judge, EMD and GCAGS Sessions, Gulf Coast Association of Geological Societies Annual Convention.

Steven J. Seni

Chairman, Sports Committee, Gulf Coast Association of Geological Societies Annual Convention.

Thomas A. Tremblay

Member, Geographic Information Systems Managers Committee and GPS, Remote Sensing, and Data Acquisition Coordination Groups, Texas Department of Information Resources.

Noel Tyler

Member, Board on Earth Sciences and Resources, National Research Council, National Academy of Sciences.

Chairman, Plenary Session, Global Gas Resources Workshop, Vail, Colorado.

Member, National Research Council, National Academy of Sciences, Board on Earth Sciences and Resources.

Member, Texas Independent Producers and Royalty Owners Association (TIPRO) Producer Advisory Group.

Member, Texas STATEMAP Advisory Panel, U.S. Geological Survey.

Member, Council on Texas Data Project 1995, Texas Railroad Commission.

Member, Resources & Environment of the Continental Margins Committee, Association of American State Geologists.

Member, Coastal Erosion Committee, Association of American State Geologists.

Member, Energy Policy Committee, Association of American State Geologists.

Member, Minerals Policy Committee, Association of American State Geologists.

Member, Radioactive Waste Committee, Association of American State Geologists.

Roger Tyler

Member, Local Organizing Committee, 1994 North American Rock Mechanics Symposium.

Member, Committee for Session Development, 1994 North American Rock Mechanics Symposium.

Co-convenor, "Deep mine design and rockburst research and development in Canada, U.S.A., and South Africa," technical session, 1994 North American Rock Mechanics Symposium.

Co-convenor, "Coal mine and pillar design," technical session, 1994 North American Rock Mechanics Symposium.

Co-convenor, "Deep mine design and rockburst research and development in Canada and South Africa," technical session, 1994 North American Rock Mechanics Symposium.

E. G. Wermund

Chairman, Awards Committee, Austin Geological Society.

Co-chairman, Crisis Committee, Gulf Coast Association of Geological Societies Annual Convention.

Member, Texas Natural Resources Information System Task Force.

Member, Texas Mapping Advisory Committee.

Member, Scientific and Technical Advisory Committees, Galveston Bay National Estuary Program and Corpus Christi Bay National Estuary Program.

Member, Environmental Issues Committee, Division of Environmental Geosciences, American Association of Petroleum Geologists.

Member, Membership Committee, Geological Society of America.

Judge, Science Fair, Ortega Elementary School.

William A. White

Co-leader of field survey, "Delineation of wetlands in the Galveston Bay area," U.S. Fish and Wildlife Service, National Wetlands Inventory Program.

Alternate, Remote Sensing and Cartographic Committee, Texas Natural Resources Information System Task Force.

Jiannan Xiang

Member, Local Committee, 1994 North American Rock Mechanics Symposium.

Session Chairman, Numerical Modeling II, 1994 North American Rock Mechanics Symposium.

Member, NEDC Committee, Travis County, National Society of Professional Engineers.

University Teaching/Continuing Education

Sigrid J. Clift

"Stratigraphy and productivity of Ozona Canyon Sandstone, Crockett County": co-lecturer at the Gas Research Institute/West Texas Geological Society/Bureau of Economic Geology workshop, "Geology and production aspects of a stratigraphically complex natural gas play: Canyon Sandstone, Val Verde Basin, Texas," Midland, Texas.

Alan R. Dutton

"Theory and methods of hydrologic measurements in the unsaturated zone": presented to The University of Texas at Austin, Department of Geological Sciences (Geology 391D), Austin, Texas.

Shirley P. Dutton

"Early, methanic-zone precipitation of siderite cement in submarine-fan sandstones, Val Verde Basin, Texas": presented to The University of Texas at Austin, Department of Geological Sciences, Technical Sessions, Austin, Texas.

"Diagenesis of Lower Cretaceous Travis Peak Formation, East Texas Basin": presented to The University of Texas at Austin, Department of Geological Sciences, Gulf of Mexico Sedimentary Basin Seminar (Geology 391), Austin, Texas.

"Perspective on tight gas sands: geological characteristics of major low-permeability sandstone gas reservoirs in the continental United States" and "Diagenesis and reservoir quality of Sonora Canyon sandstones": co-lecturer at the Gas Research Institute/West Texas Geological Society/Bureau of Economic Geology workshop, "Geology and production aspects of a stratigraphically complex natural gas play: Canyon Sandstone, Val Verde Basin, Texas," Midland, Texas.

Robert J. Finley

"Characterization of heterogeneous reservoirs": co-lecturer of short course presented to CEPET, Petróleos de Venezuela, Maracaibo and Caracas, Venezuela.

"Infield development for independent producers": co-lecturer of short course presented to Gulf Coast Association of Geological Societies, Austin, Texas.

"Onshore 3-D seismic technology for increased gas recovery": co-lecturer of short course presented to Tulsa Geological Society.

Michael H. Gardner

"Advanced sequence stratigraphy": presented to The University of Texas at Austin, Department of Geological Sciences (Geology 191), Austin, Texas.

H. Scott Hamlin

"Overview of Canyon Sandstone geology and engineering," "Regional tectonics and stratigraphic framework of the Val Verde Basin," "Submarine fan model and mapping methods applied to Canyon Sandstone," and "Stratigraphy and productivity of Sonora Canyon Sandstone, Sutton County": co-lecturer at the Gas Research Institute/West Texas Geological Society/Bureau of Economic

Geology workshop, "Geology and production aspects of a stratigraphically complex natural gas play: Canyon Sandstone, Val Verde Basin, Texas," Midland, Texas.

Bob A. Hardage

"Seismic principles for nongeophysicists": short course presented on behalf of Society of Exploration Geophysicists, Tulsa, Oklahoma.

"3-D seismic technology": short course presented to independent oil/gas operators, San Antonio and Dallas, Texas.

"Onshore 3-D seismic technology": short course presented to independent oil/gas operators, Oklahoma City and Tulsa, Oklahoma.

"Reservoir geophysics": short course presented to the Canadian Society of Exploration Geophysicists, Calgary, Canada.

"Characterization of thin-bed gas reservoirs": workshop presented to the Tulsa Geological and Geophysical Societies, Tulsa, Oklahoma.

Tucker F. Hentz

"Ozona Canyon sandstone composition and diagenesis": co-lecturer at the Gas Research Institute/West Texas Geological Society/Bureau of Economic Geology workshop, "Geology and production aspects of a stratigraphically complex natural gas play: Canyon Sandstone, Val Verde Basin, Texas," Midland, Texas.

Stephen E. Laubach

"Regional tectonic, stratigraphic, and hydrodynamic framework of the Val Verde Basin," "Ozona Canyon sandstone natural fractures and rock properties," and "Sonora Canyon natural fractures and fracture toughness studies": co-lecturer at the Gas Research Institute/West Texas Geological Society/Bureau of Economic Geology workshop, "Geology and production aspects of a stratigraphically complex natural gas play: Canyon Sandstone, Val Verde Basin, Texas," Midland, Texas.

Raymond A. Levey

"Onshore 3-D seismic technology for increased gas recovery": co-lecturer of short course presented to the South Texas Geological Society and gas operators, San Antonio, Texas; Oklahoma City Geological Society and gas operators, Oklahoma City, Oklahoma; and Dallas Geological Society and gas operators, Richardson, Texas.

F. Jerry Lucia

"Quantification of carbonate ramp reservoir models": short course presented to the industrial sponsors of the San Andres/Grayburg Reservoir Characterization Research Laboratory, Austin, Texas.

Robert E. Mace

"The use of cross-sectional models in the numerical simulation of ground-water flow": presented to The University of Texas at Austin, Department of Geological Sciences (Geology 383C), Austin, Texas.

Stephen C. Ruppel

"Depositional and diagenetic controls on reservoir development in Upper Ordovician—Lower Devonian rocks in the Permian Basin: short course presented to the Permian Basin Graduate Center, Midland, Texas.

Noel Tyler

"Geologically constrained approaches for maximizing oil and gas recovery from complex reservoirs": short course presented at the V Simposio Bolivariano, Puerto La Cruz, Venezuela.

"Geophysical resolution of reservoir heterogeneities": co-lecturer of short course presented at Merton College, Oxford University, Oxford, England.

Bruno C. Vendeville

"Salt tectonics": short course presented to STATOIL, Deminex, Fina, and Agip Norsk, Stavanger, Norway; STATOIL, Amerada Hess, and Saga Petroleum, Harstad, Norway; and Mobil North Sea Limited, London, England.

Support Staff

Administrative/Secretarial

The administrative staff, under the supervision of Wanda LaPlante, Executive Assistant, handle the general administration of the Bureau, which includes personnel, accounts payable and receivable, publication sales, purchasing, travel arrangements and reimbursement, reception/switchboard, 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 $150,000 per year.

Cartography

In 1994 this section's 14-person full-time staff, directed by Chief Cartographer Richard L. Dillon, produced 10 black-and-white plates, 5 full-color maps, 2,050 text figures, and 2,260 visual aids. Text illustrations produced by this staff are published in Bureau publications, contract reports, and articles in professional journals. Slides, posters, handouts, and overhead transparencies are used in presentations at local, national, and international meetings. High cartographic standards are practiced to maintain the Bureau's reputation for quality.

The Cartographic section relies heavily on computers to perform its work. Currently 95 percent of all text figures and visual aids are produced on nine Macintosh computers. Cartography also has a black-and-white laser printer, a 300-dpi color printer, a dye sublimation color printer, 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. Cartographers can also work at a UNIX-based Sun SPARCserver 1000 workstation and digitizing table using ARC/INFO software to construct maps from data entered in the Bureau's Geographic Information System.

Computer Resources

The Computer Resources section supports word processing, graphic design, administrative data bases, scientific application programming, oil and gas data-base applications, multimedia applications, statistical and graphic analysis of data, and computer mapping and modeling on the Bureau's computer system and on the University's Cray computer system.

The Bureau's computer system features a Local Area VAX Cluster (LAVC) that has a VAX 4000 boot node and three VAXstation 3100 satellite nodes. UNIX-based workstations include two DECstation 5000's, an IBM RS6000, a Silicon Graphics, Inc. (SGI), Elan workstation, two SGI Indigo workstations, and an SGI Indigo2 workstation. A Sun SPARCserver 1000 is used for departmental color plotting, as well as for contour plotting (CPS), reservoir simulations, and U.S.–Mexico border-area data archiving. All workstations can be accessed through the Bureau's Xyplex terminal server, and a Xyplex print server provides network access to a high-speed line-printer. An Ethernet network connects all workstations in-house.

Additional hardware resources include 100 Macintoshes, 30 IBM-compatible PC's, 20 Apple LaserWriters, and 75 DEC VT-type terminals. All Macintoshes are networked into a LocalTalk network that connects to the Bureau's Ethernet. The Bureau's local networks are connected to The University of Texas at Austin's broadband Ethernet system, which allows high-speed communications with computer systems on the UT campus, at the Center for High Performance Computing, and at other Internet sites worldwide. NCSA Mosaic, World Wide Web, and Gopher provide interactive computer capabilities on the Internet for Bureau scientists.

Software tools include various data-base, word-processing, spreadsheet, and statistical packages, implemented on VAXcluster, Macintosh, and PC platforms. Seismic data display, interpretation, and modeling can be accomplished on both workstations and Macintoshes. Landmark and Sierra seismic software packages are prominently featured on the Bureau's IBM RS6000 and a DECstation 5000. Water-flow modeling, reservoir modeling, and well log interpretation packages are also supported on Bureau workstations.

Geographic Information System (GIS) resources include ARC/INFO and ArcView software on a DECstation 5000 workstation. Two IBM-compatible PC's and an X-terminal serve as additional "seats" on the system. Several Calcomp digitizing tablets provide input of map data. Hard-copy maps are generated using Hewlett Packard DraftPro and 7475 plotters, as well as both a 36-inch color and a 22-inch black-and-white Versatec electrostatic plotter. The Sun SPARCserver 1000 will be loaded with ARC/INFO by 1995 and serve as the future host for Bureau GIS projects.

Publications

Supervised by Assistant Director for Publications Susann Doenges, the Publications staff, consisting of designers, editors, a proofreader, and a word processor/typesetter operator, produces a variety of printed materials for the Bureau. In addition to Bureau publications, the staff also prepare contract reports, papers and abstracts, and various documents in support of research projects. Bureau reports are produced using desktop publishing technology, by which manuscripts are revised electronically and pages are prepared for the printer using layout programs. Twenty-two new publications were issued by the Bureau in 1994. Fifty-one contract reports were also completed, and 193 papers and abstracts by Bureau authors were published by professional journals and publishers.

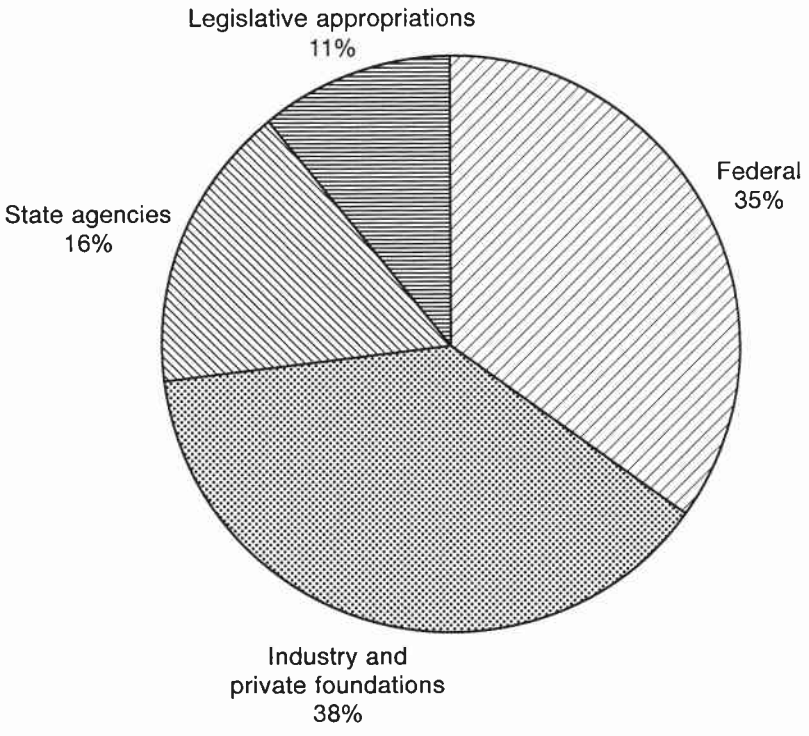
Quality Assurance

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 requirements promulgated by the U.S. Department of Energy and U.S. Environmental Protection Agency.

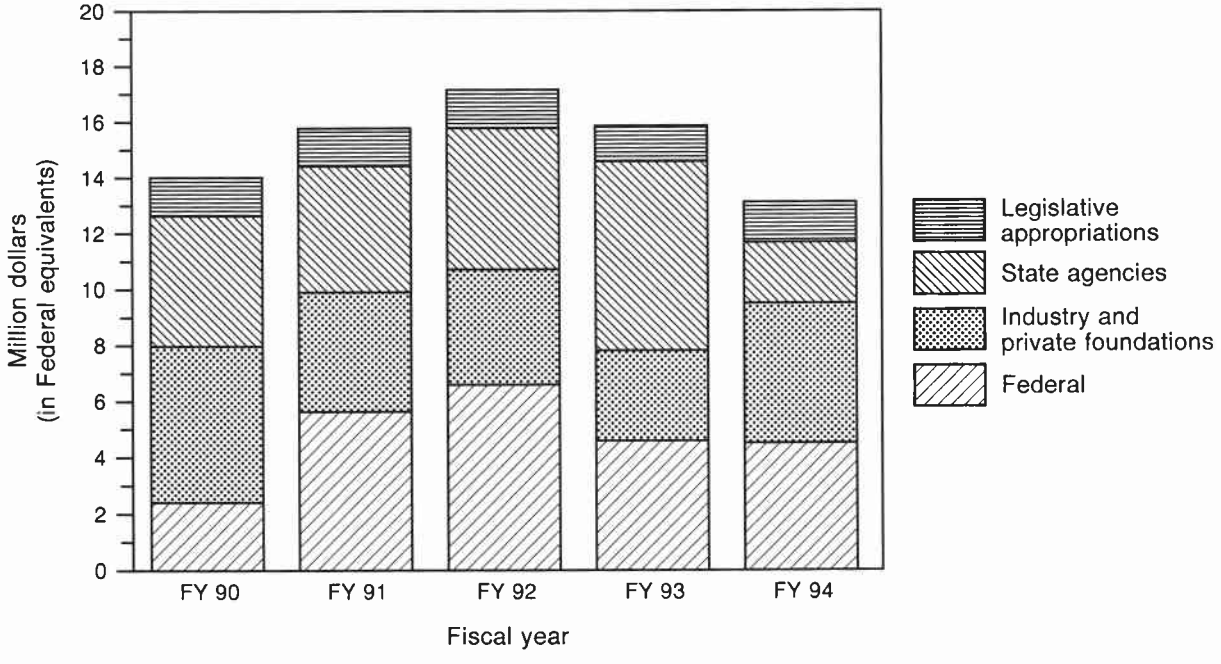
During 1994, quality assurance personnel participated in three Bureau research projects: Geologic and Hydrologic Studies of the Eagle Flat Area—Phase II; Comprehensive Hydrogeologic Investigations of Regional Ground-Water Flow and Ground-Water Resources, Ellis County Area, North Texas; and Geologic and Hydrologic Characterization of the Pantex Plant. In August, quality assurance personnel completed turning over all records associated with the Eagle Flat study to the Texas Low-Level Radioactive Waste Disposal Authority. These records provide detailed documentation of work performed by the Bureau and will be used in future licensing hearings.

Sources of Funding and Budget Trends

FY 94 SOURCES OF FUNDING



FIVE-YEAR BUDGET TRENDS



Bureau of Economic Geology

Dr. Noel Tyler, Director

Dr. Robert J. Finley, Associate Director • Dr. Raymond A. Levey, Associate Director
Dr. Auburn L. Mitchell, Acting Associate Director • Dr. Jay A. Raney, 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. Shirley P. Dutton
Dr. Richard P. Major

Program Coordinators
Lynda A. Miller
G. Stephen Stubbs

Senior Research Scientists/Engineers
Dr. Virgil E. Barnes
Dr. Don G. Bebout
Dr. William L. Fisher (served 3/4 of 1994 as Director)
Dr. Robert L. Folk
Dr. William E. Galloway
Dr. Thomas C. Gustavson
Dr. Claude R. Hocott
Dr. Martin P. A. Jackson
Dr. Robert A. Morton

Research Scientists
Dr. R. Stephen Fisher
Dr. Bob A. Hardage
Dr. William R. Kaiser
Dr. Charles Kerans
Dr. Larry Lake*
Dr. Stephen E. Laubach
Dr. Stephen C. Ruppel
Dr. Bridget R. Scanlon
Dr. Daniel D. Schultz-Ela
Dr. E. G. Wermund

Research Associates
William A. Ambrose
Kenneth T. Barrow
Dr. Mark D. Barton
Dr. Mark J. Burn
Edward W. Collins
Dr. Alan E. Fryar
Dr. Michael H. Gardner
L. Edwin Garner
Dr. James C. Gibeaut
Dr. Douglas S. Hamilton
H. Scott Hamlin
Tucker F. Hentz
Barry J. Hibbs
Dr. Susan D. Hovorka
Mary L. W. Jackson
Paul R. Knox
Dr. Richard P. Langford
Dr. Lee E. McRae
William F. Mullican III
Dr. Jeffrey G. Paine
Dr. Carol L. Ruthven
Dr. Steven J. Seni
Douglas B. Swift
Dr. Bruno C. Vendeville
Dr. Fred P. Wang
William A. White
Dr. Brian J. Willis
Dr. Jiannan Xiang

Research Scientist Associates
Edward S. Angle
Arten J. Avakian
David L. Carr
Sigrid J. Clift
Bruce K. Darling
Bruce A. Desselle
Milagro L. Elneser
Sam A. Epstein*
Chester M. Garrett, Jr.
Richard C. Geesaman
Mark H. Holtz
Robert E. Mace
H. Seay Nance
Lisa E. Remington
Andrew R. Scott
Allan R. Standen
Thomas A. Tremblay
Roger Tyler
Joseph S. Yeh

Senior Research Fellow
Dr. George B. Asquith*
Robert J. Graebner
F. Jerry Lucia

Research Fellows
Dr. Roger J. Barnaby
Sharon L. Gabel*
Dr. Giovanni Guglielmo, Jr.
Dr. Luis A. Sánchez-Barreda
Dr. James L. Simmons

Administrative Staff
Margaret R. Brinson
M. Lorena Cantu
Harold Ciccotti
Dixon E. Coulbourn
Cecil E. Dishman
James A. Doss, Jr.
Patricia O. Downs
Marilynn L. Hall
Lucille C. Harrell
Dana L. Hutto
Dorothy C. Johnson
Mary E. Koch
Sharon G. Lowe
Glynis G. Morse
Diane C. Ruetz
Meanette J. Salgado
Ruth B. Schwab
Marcia G. Sievert

Cartography
Richard L. Dillon
Chief Cartographer
John T. Ames
Michele L. Bailey
William C. Bergquist
Barbara M. Hartmann
Randy H. Hitt
Susan N. Krepps
Joel L. Lardon
Patrice A. Porter
Kerza A. Prewitt
Jana S. Robinson
Maria E. Saenz
David M. Stephens
Teresa L. Weaver

Computer Resources
W. Gerald White
Manager
Sharon A. Bierschenk
Robert J. Claggett
Richard D. Edson, Jr.
Rodney I. Heathcott
Diane M. Spinney

Publications
Amanda R. Masterson
Editor-in-Charge
Lana S. Dieterich
Bobby S. Duncan
Allison M. Faust
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
Raul Herrera
Dr. Bruce N. Turbeville

Core Research Center
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.
Frank D. Meaker
Arthur Medina
Robert G. Richardson
Steven M. Rooks
Robert A. Sanchez
Kenley C. Schroeder

Quality Assurance/ Geophysical Log Facility
G. Stephen Stubbs
Quality Assurance Officer
Daniel H. Ortuño

Student Research Assistants
Salah U. Ahmad
Adnan Ahmed
Syed A. Ali
Stephen R. Allen
Hwanjo Baek
Nina L. Baghai
Mauro R. Becker
Martina U. Blüm
Suhas V. Bodwadkar
Erika M. Boghici
Radu Boghici
Robert H. Brinkman
Charl A. Broquet*
Chun-Yen Chang
Liang Chen
Suk-Joo Choh
Alistair S. Clague
Mary C. Crabaugh
Andrew P. Czebieniak
Douglas C. Dawson
Widya Dharmasamadhi
Patricia W. Dickerson
David G. Edgerton
Qing Fang
Jan Ferrari
Joseph C. Fiduk
William M. Fitchen
Donald E. Formanek
Hongxing Ge
Allison L. Goad
Scott C. Goode*
Sung-Chi Hsu
Mary K. Johns
Norman D. Johns
Dr. Ronald A. Johns
Senira S. Kattah
Kirt A. Kempter
Treavor A. Kendall
Richard A. Ketcham
Eugene M. Kim
Milton H. Kwong
John A. Kyser
Brian S. LaBorde
Ning Li
Jun Liao
Xijin Liu
Kevin T. Lyons
Ronald G. McMurry
Ravi V. Nigudkar
Gregg C. Oetting
Thomas A. Perreault*
Amy K. Sapp
Asad M. Sattar
Alexander P. Schoellkopf
Naresh D. Sen
Ali S. Sikandar
Li Sun
Norman G. Van Broekhoven
William B. Ward
Chengyan Wu
Liangqing Xue
Huade Yang
Qiucheng Ye
Gena B. Yun
Naijiang Zhou

*Temporary staff

Dr. Marcus E. Milling, Associate Director (on leave, Executive Director, American Geological Institute)

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