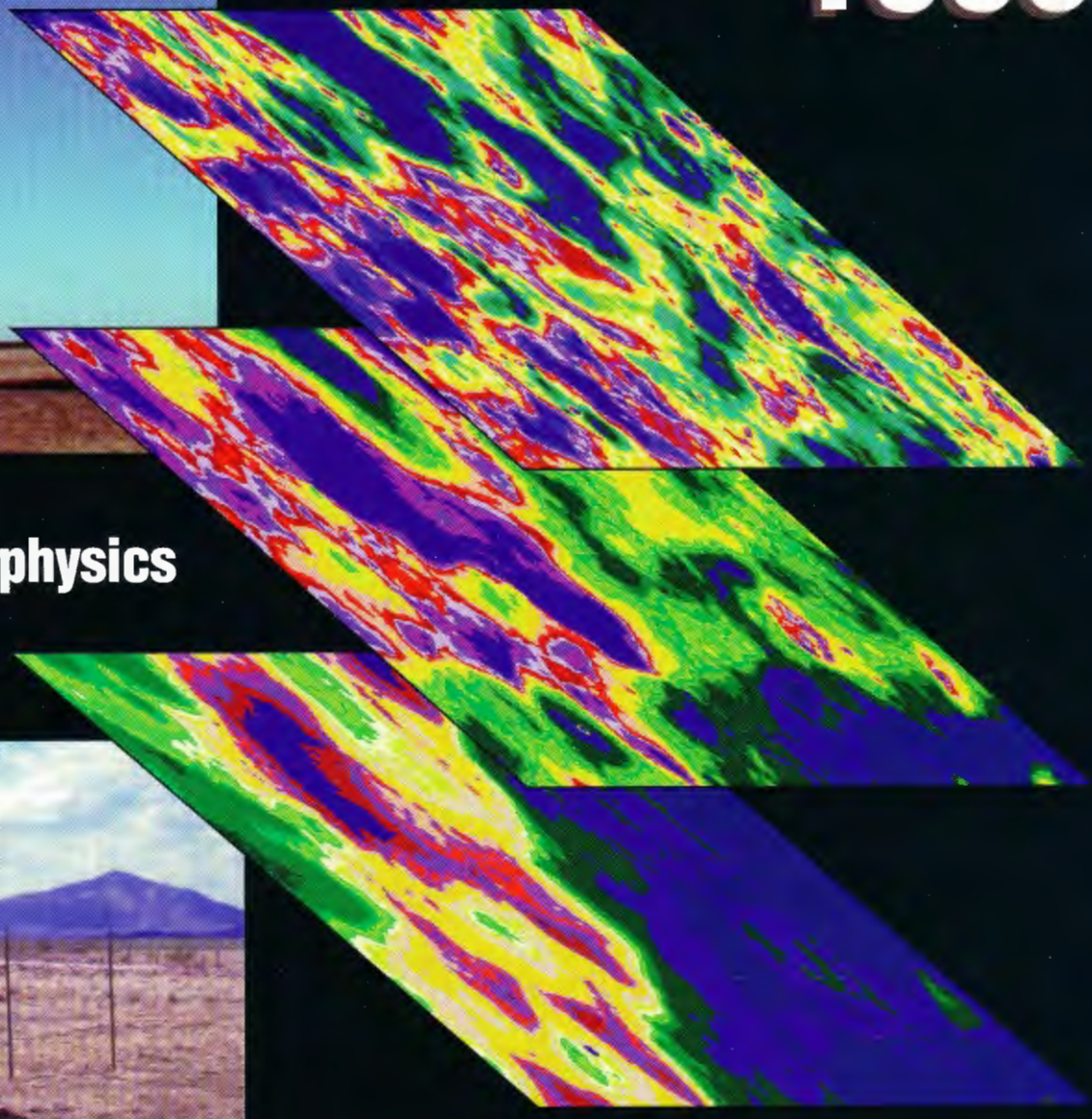
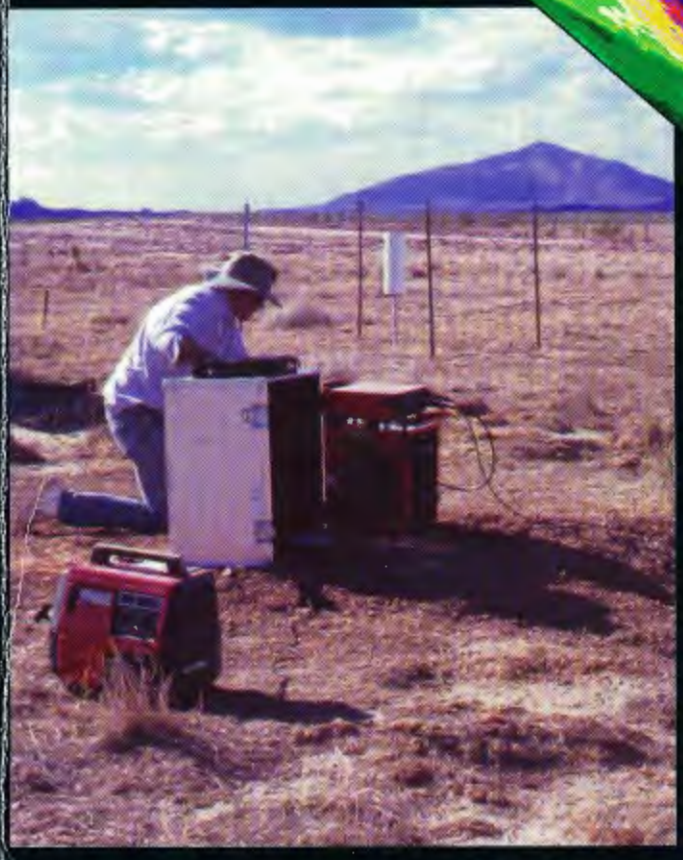
ANNUAL REPORT 1996



Near-surface geophysics



Bureau of Economic Geology

Noel Tyler, Director

The University of Texas at Austin

Austin, Texas 78713-8924

Foreword

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

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

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

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

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

Cover: Near-surface application of geophysics is a new and expanding area of research at the Bureau. Bureau scientists have applied shallow seismic, electromagnetic, and ground-penetrating radar methods in recent projects to locate sources of saline water in Texas watersheds and to help understand High Plains landscape evolution, coastal stratigraphy, and Trans-Pecos fault-basin geometry and fissure development. Highlighted on the cover are images from two recent projects: a high-resolution electromagnetic survey of West Texas, where helicopter-based electromagnetic measurements (upper left) produced maps of ground conductivity at progressively deeper depths (right) that reveal subsurface saltwater distribution, and a borehole study of moisture, clay, and chloride content near fissures in the Trans-Pecos region (lower left).

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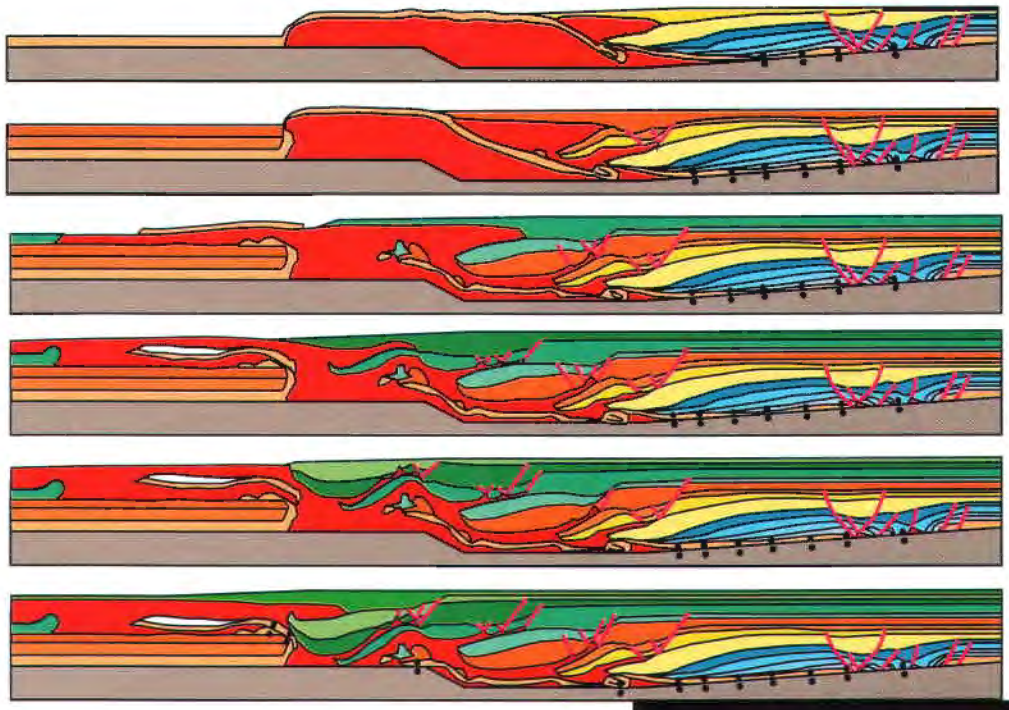
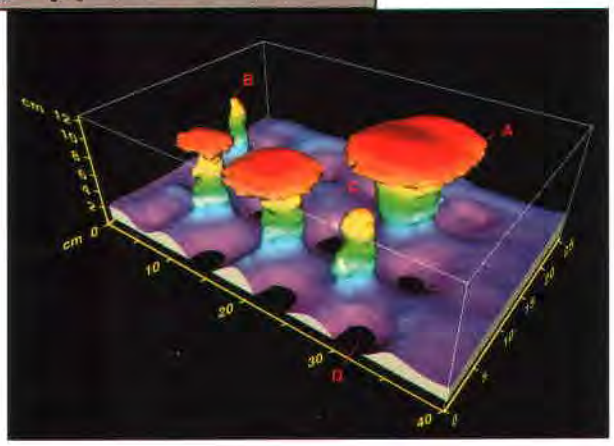


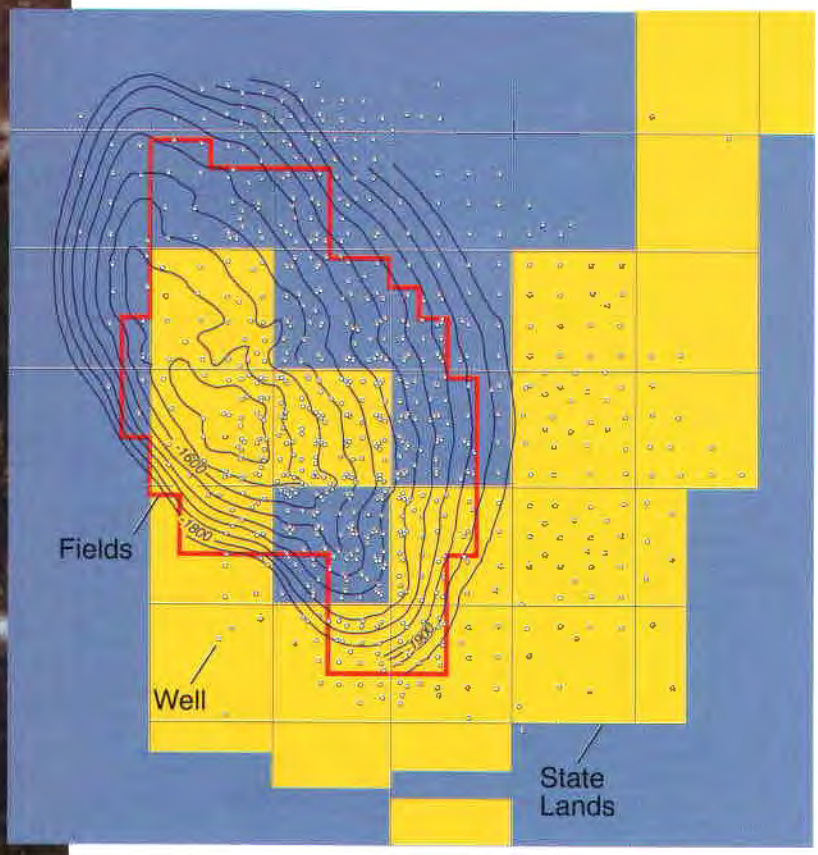


Program Support

In 1996, the Bureau of Economic Geology experienced a banner year in growth of both total research expenditures and number of active research projects. The Bureau's operating budget increased by $3.3 million from the previous year to a total expenditure level of $18.2 million (in Federal equivalents) from 92 contracts and grants and line-item State appropriations. Seventy of these funding sources were from interagency contracts with State and local governments and from various agencies of the Federal government. Twenty-two contracts were with the energy industry and private institutions. In 1996, the Bureau conducted 104 research projects, several of which are highlighted herein.

Oil Resource Investigations

Reservoir characterization and recovery optimization efforts continued to be the primary emphasis of Bureau oil resource research in 1996. In studies wholly or partly supported by the U.S. Department of Energy (DOE), the Bureau investigated strategies to aid in the production of unrecovered mobile oil in several Texas fields. For example, detailed reservoir characterization of siliciclastic slope and basin reservoirs in the Delaware Mountain Group will lead to cost-effective ways to recover a higher percentage of the original oil in place through strategic placement of infill wells and geologically based field development using 3-D seismic, log and core, and outcrop data. Moreover, two multiyear DOE-funded projects were completed in 1996. One demonstrated the use of flow simulation to locate remaining mobile oil in low-permeability carbonate and mixed carbonate/siliciclastic facies of South Cowden field. The other study identified specific opportunities for near-term oil recovery through recompletions or targeted infill drilling in selected reservoirs in the Frio Rincon and T–C–B fields in South Texas.

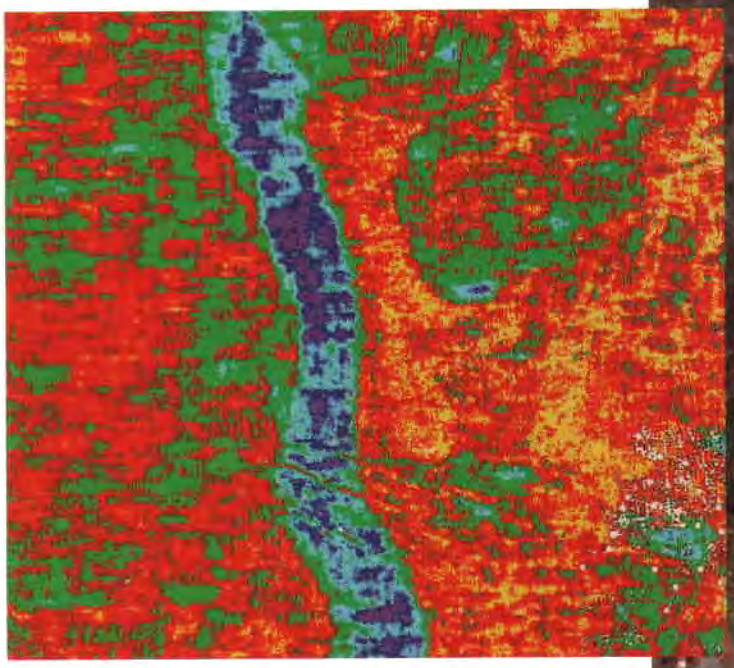


Because of steadily declining royalties from oil and gas production on Texas State and University Lands, the Bureau, with funding received from the Texas Legislature and The University of Texas System, respectively, is researching methods to help producers increase recovery of hydrocarbons from State and University Lands. In 1996, the State of Texas Advanced Resource Recovery (STARR) project assessed eight priority fields in West Texas

and the Gulf Coast. Several prospects have been identified and, with the support of allied producers, are being drilled. The University Lands project, which began in 1996, is similarly designed to foster the use of advanced technologies in the efficient recovery of hydrocarbons from University Lands reservoirs.

Natural Gas Resource Investigations

Gas research projects conducted during 1996 involved diverse topics related to natural gas and coalbed methane. With the active participation of industry partners, one investigation focuses on the identification of karst-related gas reservoirs in the Ellenburger Group in West Texas. The principal effort is concentrated on a 176-mi^2 3-D seismic survey recorded in portions of Pecos, Reeves, and Ward Counties. Research on gas-reservoir compartmentalization in deltaic deposits in low-accommodation Midcontinent basins was completed and documented in technical articles and short courses. A product of this project, a comprehensive 3-D seismic data set from Boonsville field of the Fort Worth Basin, has become one of the Bureau's more popular publications and is described in the "Highlights" section in this annual report. In collaboration with the Gas Research Institute; U.S. Department of Energy; U.S. Department of the Interior, Minerals Management Service; Louisiana State University; and the Geological Survey of Alabama, the Bureau is also nearing completion of the first of two atlas volumes detailing gas and oil reservoirs in the Federal and State offshore waters of the northern Gulf of Mexico.

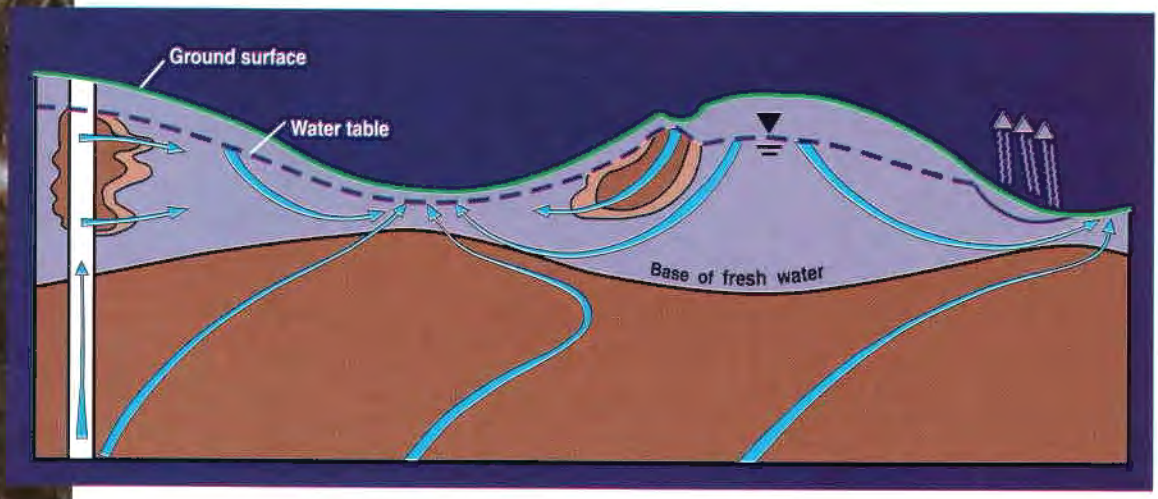


In a new project conducted in partnership with the Alaskan Division of Geological and Geophysical Surveys, Bureau researchers are

investigating the potential for coalbed methane resource development in rural Alaska utilizing the basin-scale coalbed methane exploration model that the Bureau developed for several coal basins in the western United States. The project is designed to select coalbed methane "sweet spots" in the vicinity of several Alaskan villages to test their potential for power generation and home heating. Work also continued on applying this coalbed methane exploration model to productive basins in the lower 48 states, the San Juan and Piceance Basins of New Mexico and Colorado.

Hydrogeology and Environmental Investigations

During 1996, the Bureau conducted a number of projects aimed at ensuring environmental protection for planned future facilities as well as addressing environmental problems from past activities. One example is a project that dealt with brine pollution, which is an environmental and agricultural concern in many parts of Texas. In a study of a 35-mi^2 area near Ballinger in Runnels County, Texas, Bureau researchers employed airborne and ground-based geophysical methods to locate areas of brine infiltration and applied geophysical and hydrogeological methods to determine sources of brine pollution (featured on the cover). Bureau environmental scientists also



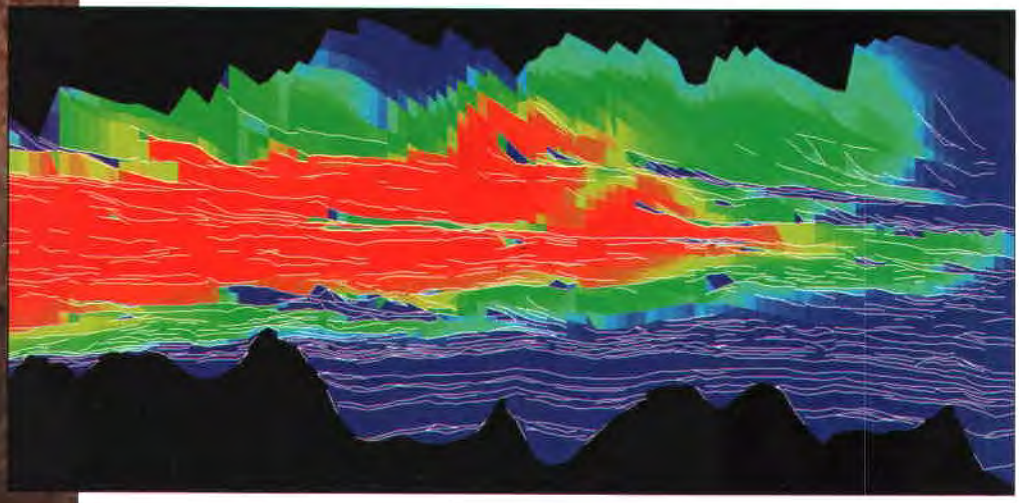
examined abandoned oil-field sites throughout Texas to identify the sources of contamination, to map the extent of contaminants in the subsurface, to prevent ongoing contamination, and to recommend options for site cleanup. This study, funded by the Railroad Commission of Texas, is designed to reduce risk to public health while limiting cost to the State by applying nonintrusive, cost-effective techniques, such as shallow geophysics.

Leaking petroleum storage tanks are also a vexing problem to the State and the country. On behalf of the Texas Natural Resource Conservation Commission, the Bureau performed a statistical analysis of fuel hydrocarbon plumes at leaking petroleum storage tank sites in Texas. The study consisted of compiling and summarizing site information and quantifying the size, mass, and duration of plumes, all important steps in the eventual cleanup of the pollutants.

The Bureau's multiyear site characterization studies of the State's proposed low-level radioactive waste disposal site in the Eagle Flat Region, Hudspeth County, continued in 1996. These studies included examination of ground-water movement in saturated and unsaturated zones, evaluation of the potential upward movement of noxious gases through ground cover, and testing of the prototype engineered barriers of the proposed waste site. As a result of projects in 1996, the Bureau continued to develop special expertise in the geologic and hydrogeologic setting and characteristics of waste sites, the fate and transport of contaminants in the subsurface, aquifer dynamics and architecture, soil-cover mechanics, and other geologic and engineering topics related to environmental issues.

Industrial Associates Programs

In 1996, Bureau projects funded by consortia of industrial associates addressed diverse tasks related to hydrocarbon exploration and production. The current focus of research by the Reservoir Characterization Research Laboratory (RCRL) is to better understand reservoir architecture and its controls on the three-dimensional distribution of petrophysical properties in carbonate-ramp



reservoirs. RCRL researchers are examining carbonate-ramp exposures of two geologic systems, the Permian of West Texas and the Cretaceous of southwest Texas, which are analogs of prolific reservoirs in the Permian Basin and in Mexico and the Middle East, respectively. Outcrop-analog studies are also an integral part of several other industry-funded projects. The Cretaceous Frewens Castle sandstone of the Frontier Formation, central Wyoming, the Cretaceous Ferron Sandstone, Utah, and the Cretaceous Fall River Formation, South Dakota and Wyoming, which represent a spectrum of deltaic systems, are under study to better define the myriad reservoir attributes of deltaic facies.

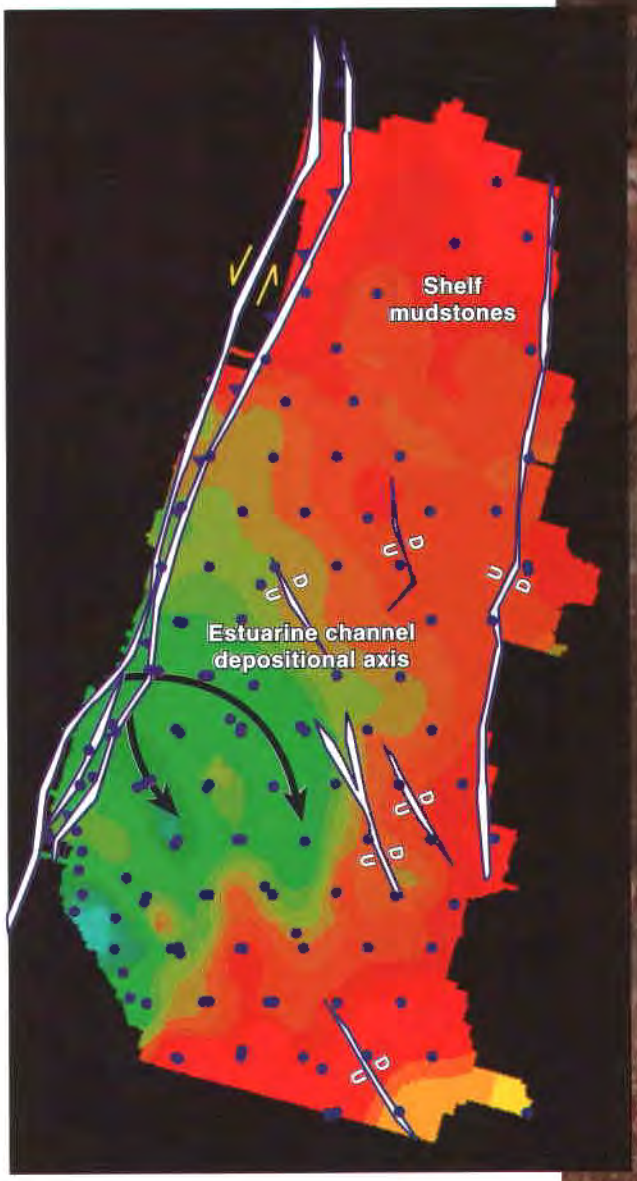
Industry-funded projects investigating advanced geophysical methods in the search for hydrocarbons composed a growing part of Bureau research. Bureau researchers are developing seismic technologies that will increase understanding of the internal architecture of heterogeneous reservoirs by verifying, using actual field tests, how P-waves and S-waves are affected by critical reservoir rock properties. In another project, Bureau geophysicists are determining whether surface-based seismic sources instead of downhole sources can be used to generate crosswell tomographic data. The attraction of surface–source crosswell tomography, an important emerging seismic technology, is that the method allows crosswell data to be acquired significantly quicker than it takes for data using a traditional downhole source.

Through physical-scale and numerical modeling of geologic structures, the Applied Geodynamics Laboratory (AGL) develops new concepts for predicting the location and geometry of structural hydrocarbon traps in a variety of

salt-tectonic settings. In 1996, these settings included the Gulf of Mexico, Norwegian Sea, North Sea, West Africa, offshore Brazil, and the Persian Gulf. AGL's program had 18 supporting oil companies, 5 of which are based overseas. Topics of research emphasis in 1996 included deducing the geometry of folding and thrusting above and within salt, and structural interactions between salt diapirs and adjoining small sedimentary basins.

International Research Programs

The Bureau's international program continued to thrive and grow in 1996, comprising 10 reservoir characterization and environmental projects in Argentina, Austria, Belize, and Venezuela. The professional collaboration and cooperative interchange of research methods between Bureau researchers and their colleagues at the supporting international companies and governmental agencies serve to enhance the Bureau's reputation abroad.



In 1996 Bureau researchers and geoscientists from the three affiliates of the Venezuelan national oil company (Corpoven, S.A., Lagoven, S.A., and Maraven, S.A.) teamed up on five separate projects involving integrated field studies in various basins in the country. Devising strategies to increase oil reserves and ensure sustained production from the fields, some of which are experiencing production decline, are the objectives common to all of these projects. A geoscientific team is examining structurally and depositionally heterogeneous tidal-shelf and estuarine-fill deposits in the VLA-6/9/21 Area, Lake Maracaibo, to raise recovery efficiency above

the current average 25 percent. Fluvial, bay-fill, and barrier-island reservoirs in the Mioceno Norte Area in northeastern Lake Maracaibo similarly have low recovery efficiencies, and researchers are working to improve reservoir-management strategies. Volumetrics and economics analyses are being used to complement rigorous reservoir characterization programs and to devise drilling programs in the Budare, Elotes Sur, and Faja fields of the Eastern Venezuelan Basin.

In a new project for 1996, the Bureau joined Austria's ÖMV Aktiengesellschaft in undertaking an integrated study of Matzen field, Vienna Basin, to determine the field's potential for reserve growth. The field produces oil and gas from Miocene sandstones and is the largest onshore field in Middle Europe, with an estimated 1.31 billion barrels of oil in place and 943 billion cubic feet of gas. Another new project, funded by Lagoveu, S.A., is identifying new exploration opportunities of the Paleocene and Miocene Guasare, Misoa, Icotea, and La Rosa Formations in the Maracaibo Basin of western Venezuela.

In an environmentally related international study completed in 1996 and funded by the United States Agency for International Development, a collaborative investigation between the Bureau and the Center for Space Research determined the extent of deforestation that occurred on mainland Belize within the past decade. With the cooperation of the Land Information Center, Forest Department, and Lands and Survey Department of the Ministry of Natural Resources, Government of Belize, environmental scientists employed Landsat and SPOT satellite imagery to define spatial and temporal changes in forest cover using a geographic information system.

Highlights

Jerry Lucia Wins Prestigious Award

For the second consecutive year, a Bureau researcher has been awarded the prestigious Wallace E. Pratt Memorial Award for best paper published each year in *AAPG Bulletin.*
Last year, Bureau scientists Charles Kerans, F. Jerry Lucia, and Reiner K. Senger won the Pratt Award for their 1994 *Bulletin* article. In a letter dated October 4, AAPG President Robert D. Cowdery notified F. Jerry Lucia that his paper, which appeared in the September 1995 issue of the *Bulletin*, was the best *Bulletin* paper for 1995. Jerry will be presented the award during the opening session of the AAPG annual meeting in Dallas in April.

The innovative article, "Rock-Fabric/Petrophysical Classification of Carbonate Pore Space for Reservoir Characterization," defines and classifies the important geological parameters that can be described and mapped to allow accurate petrophysical quantification of carbonate geological models. Such parameters include grain and crystal size, sorting, interparticle porosity, and vuggy porosity. The author integrates this rock-fabric approach of relating petrophysics to the quantification of engineering parameters with current methods of reservoir characterization.

F. Jerry Lucia, recipient of the 1996 Wallace E. Pratt Memorial Award for best paper published in the *AAPG Bulletin*. Photo by David M. Stephens.

Bureau Establishes Important Industry Alliances

Three major alliances were established in 1996 between the Bureau and industry partners. First, ties with Landmark Graphics Corporation were substantially strengthened with the signing of a Strategic University Alliance Grant Agreement whereby Landmark will provide 10 OpenWorks software licenses that will allow Bureau access to all of Landmark's seismic interpretation and data processing, petrophysical analysis, mapping, and reservoir simulation software. Second was a donation, orchestrated by past Bureau Director and UT President Emeritus Peter T. Flawn, of seismic-acquisition hardware from Input/Output, Inc. This hardware forms the core of an expanded Bureau geophysics program that will develop technology to image reservoir systems with four-dimensional/three-component (4D/3C) seismic data. Third, a research partnership with Visos Energy, a technology start-up company, will facilitate the acquisition of at least four (perhaps as many as eight) seismic vector wavefield surveys per year.

New Publication Concept Well Received

In 1994, the Bureau, in collaboration with the Gas Research Institute and U.S. Department of Energy, developed an innovative method of publication and a new procedure for technology transfer by publicly releasing a digital 3-D seismic data base, the *3-D Seismic and Well Log Data Set: Fluvial Reservoir Systems—Stratton Field, South Texas.* To the Bureau's knowledge, no other organization had ever issued a publication that was structured around a digital version of a fully documented 3-D seismic data base.

In 1996, we continued to set new industry standards for publishing technical information at a time when computer workstations and digital data tend to dictate research strategy by releasing a second workstation-oriented publication, the *Boonsville 3-D Seismic Data Set.* This new publication consists of 5.5 mi^2 of time-migrated 3-D seismic data; vertical seismic profile and checkshot data from a centralized calibration well; digitized log curves from 38 wells inside the image area; specifications of the depths and types of sequence boundaries interpreted from these logs; perforation depths, reservoir pressures, and production and petrophysical data for the 38 wells within the image space; and a 40-page manual that describes the data formats and provides information that allows others to use these data to pursue their own methods of reservoir characterization. With this publication, we have expanded our publication concept to include digital petrophysical, production, and engineering data bases and the Bureau's sequence stratigraphy interpretation of the digital well log data.

The immediate wide reception of this publication format confirms that one of the more effective ways to transfer new technical concepts about reservoir characterization to the public is to provide all the data that are needed for a reservoir analysis in digital form, with instructions on how to use the data and with copies of the Bureau's interpretation of the data. This new publication concept allows other geoscientists to use either of the Bureau's analysis procedures to develop their own innovative approaches.

Data bases and manual composing the *Boonsville 3-D Seismic Data Set.* Photo by David M. Stephens.

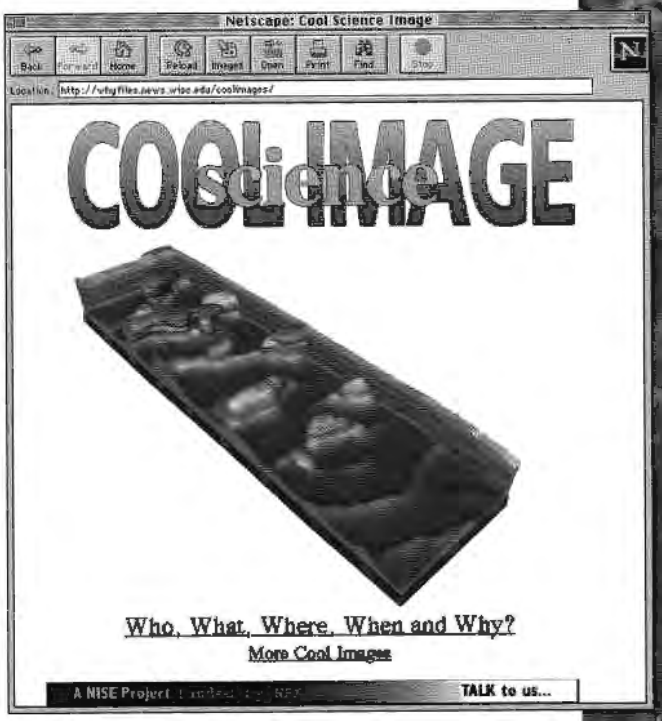
International Collaborative Research Expanded

The Bureau's international geologic studies program continued to thrive and grow in 1996. As evidence of this increased activity, 6 separate projects among the 10 total international projects involved professional collaboration among Bureau researchers and their colleagues from the supporting international oil companies. Research activities are being conducted at the Bureau research facilities in Austin. Geologists, petrophysicists, geophysicists, and petroleum engineers from three Venezuelan companies, Lagoven, S.A.; Maraven, S.A.; and Corpoven, S.A.; from the Argentinian company YPF, S.A., and from the Austrian firm ÖMV Aktiengesellschaft have been working side by side with Bureau scientists on a variety of reservoir characterization and recovery optimization efforts. Study areas include the Lake Maracaibo region, Eastern Venezuelan Basin, Cuyo Basin, Argentina, and the Vienna Basin, Austria.

AGL Researchers' Work Chosen as "Cool Science Image" on the World Wide Web

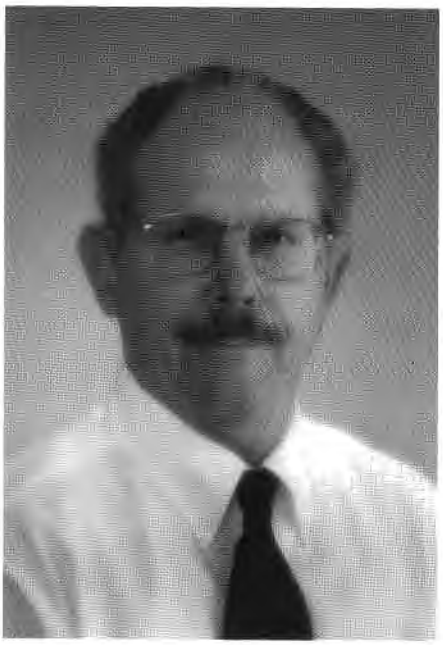
A three-dimensional color image created by Giovanni Guglielmo, Jr., Bruno C. Vendeville, and Sbing-Zhong Lin at the Bureau's Applied Geodynamics Laboratory was selected as a "Cool Science Image" on the Internet in March.

Their color image appeared on "The Whyfiles: Science behind the News," a National Institute for Science Education (NISE) page, supported by the National Science Foundation and located at http://whyfiles.news.wisc.edu/. A caption accompanying the image provided links to the University, the Bureau's Industrial Associates Web page, and Giovanni's research page.



Bureau's "Cool Science Image," which appeared in March 1996 on the National Institute for Science Education's Web page, highlights research conducted by the Applied Geodynamics Laboratory.

James Doss Wins UT Excellence Award for Second Time



James A. Doss, Jr., two-time winner of the UT Excellence Award. Photo by David M. Stephens.

In a letter dated April 26 from UT President Robert M. Berdahl, James A. Doss, Jr., was notified that he had been selected as a recipient of the UT Excellence Award for 1996. This award is given in recognition of consistent, high-level performance by an employee of the University. James, who also won this award in 1986, was selected from hundreds of nominees by a special committee. The award was presented at the 35th Annual Staff Recognition Program and President's Reception in May in the Lyndon B. Johnson Auditorium. Bureau Director Noel Tyler said of James' achievement, "We are very proud of James and his receipt of this prestigious award, not once, but twice in his career. Dedication to our Bureau and his Texas-style 'can-do' attitude are inspirations to us all."

Dick Dillon and Chet Garrett Retire

Richard L. Dillon retired from the Bureau in October after 28 years of dedicated service. Dick began his career as a draftsman in the Bureau's Cartographic Section, where he worked on the many complex mapping projects undertaken by the Bureau in the late 1960's and throughout the 1970's. In 1983–85, Dick served on the committee that helped design and oversee the construction of the Bureau's three-building complex at Balcones Research Center, now J. J. Pickle Research Campus. This assignment required him to apply both his drafting skills and his knowledge of construction and office environments for the 3-year project period.

Cartographic techniques began to change dramatically in the 1980's, and Dick readily embraced the innovative applications made available through computers. Because of his flexibility to accept change and his vision for the future of production of graphics, the Bureau was able to move from hand-drawn maps to a completely automated mapping and graphics system during the term of Dick's employment.

Most missed by Dick's departure will be his natural ability to listen to what a scientist wanted to present graphically and then turn that thought into a publishable figure conveying the researcher's idea to the reader in the best possible fashion.

Chester M. Garrett, Jr., retired from the Bureau as a Research Scientist Associate in February. Chet brought 32 years of petroleum exploration experience in the North American Rocky Mountains and Saharan Algeria when he arrived in 1980. This experience provided him with a comprehensive knowledge about industry exploration and production data bases.

He early established an important liaison with the Oil and Gas Division of the Railroad Commission of Texas.

His industry knowledge and the Railroad Commission liaison were keys to Chet's many contributions to Bureau studies and publications on (1) geological characterization of Texas oil reservoirs, (2) atlases of oil and gas plays, (3) appraisals of reserves, and (4) increased production from University of Texas Lands. His knowledge of Texas petroleum geology is encyclopedic.

Chet was active in the Austin Geological Society, of which he is a former president, and the American Association of Petroleum Geologists, where he was a long-standing member of the House of Delegates. Through his large acquaintance with peer professionals along with numerous visits to local Texas organizations, he effectively publicized Bureau oil and gas research accomplishments.

In addition to losing his technical contributions, the Bureau will miss Chet's warm caring personality, his indefatigable enthusiasm, and his strong sense of commitment to the geological community.

Awards and Honors

A paper by **William A. Ambrose, Fred P. Wang, M. Saleem Akhter**, and **Jirapa Skolnakorn** (Bureau), and Milton Mendez and Regulo Alvarez (Lagoven, S.A.), "Optimal Oil Recovery Strategies in Miocene Transgressive-Barrier, Coastal-Plain, and Mixed-Load Fluvial Systems in the Mioceno Norte Area, Lake Maracaiho, Venezuela," which was presented at the 1996 AAPG International Conference, was selected for presentation at the "Best of AAPG" session at the 1997 Annual Technical Conference and Exhibition of the Society of Petroleum Engineers. **Roger J. Barnaby** won an Excellence of Poster Presentation Award from the American Association of Petroleum Geologists for his paper, "Stratigraphic Hierarchy and Cycle Stacking, Facies Distributions, and Interwell-Scale Heterogeneity: Grayhurg Formation, New Mexico," presented at the 1996 AAPG Annual Meeting. **Sigrid J. Clift** received an Award of Appreciation from the American Society for Testing and Materials, Committee D-18 on Soil and Rock. The AAPG also awarded **Shirley P. Dutton** Honorable Mention for the paper, "Portability of Outcrop Permeability to Subsurface Reservoirs: Diagenetic Complications," which was presented at the AAPG Annual Meeting and coauthored by **Brian J. Willis**, Widya Dharmasamadhi, and Michael H. Gardner. **William L. Fisher** was awarded the Parker Memorial Medal by the American Institute of Professional Geologists and the Public Service Award by the AIPG Texas Chapter. He also received a Special Award for contribution to Brazilian Petroleum Geology by the Associação Brasileira de Geólogos de Petróleo. **Douglas S. Hamilton** won "Best of AAPG/EAGE" for his paper "Application of Integrated Geological, Geophysical, and Engineering Analysis in Identifying Compartmented Reservoirs, Boonsville Field, Fort Worth Basin, Texas" presented at the AAPG/EAGE International Research Conference. The paper was coauthored by **Bob A. Hardage, Robert J. Finley**, David L. Carr, David E. Lancaster, and Robert Y. Elphick. **Martin P. A. Jackson** was selected as the Don R. and Patricia Kidd Boyd Lecturer in Petroleum Exploration for 1996 at the Department of Geological Sciences, The University of Texas at Austin. This is the first time the Boyd lectureship has been awarded to a member of The University of Texas at Austin. **R. P. Major** received a Citation of Excellence

for review of a manuscript published in the *AAPG Bulletin*. **Andrew R. Scott** won the AAPG Energy Minerals Division Award for his paper, "Factors Affecting Gas Content in Coal Beds," presented at the AAPG Rocky Mountain Section Annual Meeting. The paper was coauthored by **W. R. Kaiser**. Andrew and coauthor W. R. Kaiser also received the Best Paper Award from the Coal Geology Division of the Geological Society of America for a paper titled "Hydrogeology in Coalbed Methane Exploration" presented at the 1996 GSA Annual Meeting. Andrew also received a Citation of Excellence from the AAPG for his review of a manuscript published in the *AAPG Bulletin*. The AAPG awards such citations to recognize the critical efforts of peer reviewers in the publication process. **Fred P. Wang**, **F. Jerry Lucia**, and **Charles Kerans** won recognition for their paper, "Integrated Reservoir Characterization of a Carbonate Ramp Reservoir: Seminole San Andres Unit, Gaines County, Texas," as a Best SPE Paper for SEG, which was presented at the 1996 Society of Exploration Geophysicists Annual Technical Conference and Exhibition.

New Research Staff

Robert E. Barba, Jr., is responsible for petrophysical analysis for the Bureau's international projects. Prior to joining the Bureau, he worked for Schlumberger Well Services for 10 years and was an independent industry consultant for 5 years. While with Schlumberger, he was responsible for the successful introduction of the FracHite rock properties package and the QLA log analysis program. He has published 15 technical papers on the integration of wireline log data with completion designs. Bob was an SPE Distinguished Lecturer in 1995–96.
Graeme R. Bullen is working on the Secondary Gas Recovery and Offshore Atlas projects. Originally from South Africa, Graeme has a B.A. in finance from Pietermaritzburg University and an M.A. in energy and mineral resources from The University of Texas at Austin. His responsibilities include economic evaluations and assessment studies. **John F. Gamble** is working on Low-Level Radioactive Waste and Nuclear Regulatory Commission projects. Prior to joining the Bureau, John worked on industrial instrumentation for the oil industry in California. He has a B.A. in anthropology from The University of Texas at Austin and is currently completing a B.Sc. in the Department of Geological Sciences.
F. Leo Lynch, a Postdoctoral Research Fellow, has joined Bureau staff members Robert L. Folk and R. P. Major in working on a project "Bacterially mediated carbonate precipitation: the link between organic and inorganic crystallization." He holds degrees from Tufts University, Dartmouth College, and The University of Texas at Austin. His research interests include clay mineralogy and sandstone and shale diagenesis. **Mark R. Vining** is currently working on the State Lands project as a Research Fellow. He is originally from Seattle, where he earned an undergraduate degree at the University of Washington. Mark received his Master's degree from the University of British Columbia in Vancouver, Canada, and he is completing his Ph.D. at Texas Tech University. His dissertation is on computer simnlation of fluvial system evolution. Prior to coming to the Bureau, Mark worked for Exxon in reservoir evaluation and characterization for 11 years.

Research

Energy Resources Investigations

Petroleum

Reservoir Characterization Research Laboratory: Characterization of Carbonate Reservoirs

F. Jerry Lucia and Charles Kerans, principal investigators; Roger J. Barnaby and James W. Jennings, Jr.; assisted by Andrew P. Czebieniak, Kirt A. Kempter, Qiucheng Ye, William B. Ward, and Laura Zahm

The current goal of the Reservoir Characterization Research Laboratory (RCRL) is to develop new generic methods for describing the three-dimensional distribution of petrophysical properties in carbonate-ramp reservoirs. The RCRL is (1) developing quantified geological-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 Associate sponsors, including Amoco, ARCO, BP, Exxon, JNOC, Marathon, Oxy, Pennzoil, Petroleum Development Oman, Phillips, Saudi Aramco, Shell Canada, Shell Western, Texaco, Total, and Unocal. In addition, the program is supported by Intera, Landmark, TerraScience, and OGCI, which provide state-of-the-art software.

The investigative approach is to combine the study of outcrop analogs of major reservoir types with subsurface reservoir studies. The outcrop is important because it provides the only opportunity available to study the interwell environment directly and collect information to characterize this environment geologically and petrophysically. Subsurface reservoir studies provide a means for developing methods for applying this information to analogous reservoirs.

Two geological systems are being studied, the Permian of West Texas and Cretaceous outcrops of southwest Texas. Grayburg, San Andres, and Clear Fork reservoirs of the Permian Basin have been selected for study because of the vast hydrocarbon resource remaining in these reservoirs and the world-class outcrop of these formations in the nearby Guadalupe and Sierra Diablo Mountains. A world-class Cretaceous outcrop along the Pecos River in southwest Texas has been selected for study because of the vast hydrocarbon reservoirs in Cretaceous fields. The goal of this project is to develop methods for characterizing the geologic framework and petrophysical properties in Cretaceous ramp limestones and to relate these scales to the vast resources in Cretaceous reservoirs in the Middle East.

Outcrop studies have shown that rock-fabric facies compose the basic flow unit of carbonate reservoirs and that the stacking of rock-fabric flow units is systematic within a sequence stratigraphic framework. Subsurface studies have developed methods for using core and log data to describe the sequence stratigraphic framework and to quantify the sequence stratigraphic framework 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.

Extensive investigations have been concluded on Grayburg and San Andres reservoirs and outcrops of Permian age. The Permian program is currently focused on Clear Fork reservoirs. Detailed outcrop mapping and petrophysical characterization have been initiated on the world-class Clear-Fork-equivalent outcrops in the Sierra Diablo Mountains, West Texas. The subsurface study is focused on developing and quantifying the Clear Fork reservoir in Wasson South field where Shell Western is the operator.

The Cretaceous program has resulted in a regional- and reservoir-scale sequence stratigraphic framework for the Pecos River–Devils River area in southwestern Texas. Two reservoir windows have been described in detail, a grainstone/rudist complex and a packstone/wackestone/rudist-bioherm complex. Petrophysical quantification of these reservoir windows and reservoir modeling are goals for 1997.

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

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This project, funded by the U.S. Department of Energy (DOE), was completed in 1996. Its purpose was to investigate styles of reservoir heterogeneity found in low-permeability pelleted wackestone/packstone facies and mixed carbonate/siliciclastic facies found in Permian Basin reservoirs by studying similar facies exposed in the Guadalupe Mountains. Three reports have been submitted to DOE summarizing the subsurface studies of the South Cowden field: "Effects of Stratal Architecture and Diagenesis on Reservoir Development in the Grayburg Formation: South Cowden Field, Ector County, Texas," by Stephen C. Ruppel and Don G. Bebout; "Petrophysical Characterization of the South Cowden Grayburg Reservoir, Ector County, Texas," by F. Jerry Lucia; and "Waterflood Performance Analysis for the South Cowden Grayburg Reservoir, Ector County, Texas," by James W. Jennings, Jr. These reports demonstrate (1) methodology for constructing a sequence stratigraphic framework suitable for use in reservoir modeling, (2) wireline log techniques for quantifying the sequence stratigraphic framework in petro-

Aerial photograph of the Guadalupe Mountains region. Permian strata exposed in these mountains have been the focus of RCRL studies for the past 8 years. El Capitan and Guadalupe Peak appear in the foreground; in the background to the north, Algerita Escarpment and the Queen Plateau are visible. The highly faulted Brokeoff Mountains region is in the left center of the photograph. Photo by Roger J. Barnaby.

physical terms, and (3) the use of flow simulation to locate remaining mobile oil. A final report of the outcrop study is in progress and will summarize (1) methods used to coustruction the sequeuce stratigraphic framework, (2) grainstone-body distribution within the sequence stratigraphic framework, and (3) geostatistical characterization of porosity and permeability.

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

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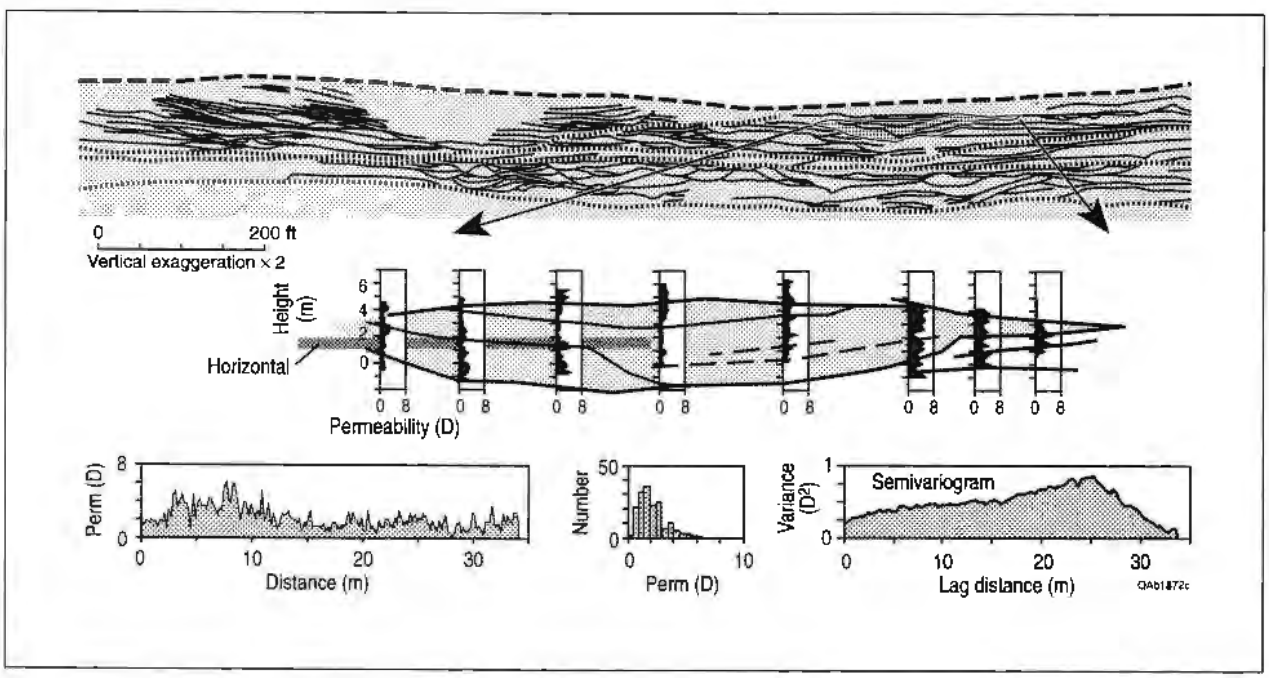
This reservoir characterization program, funded by a consortium of Industrial Associates, focuses on fluvial-deltaic systems because of the large hydrocarbon volumes in this reservoir type. Characterization of fluvial-deltaic reservoir heterogeneity improves production by increasing the efficiency of development plans and recovery processes. The goals of this project are to (1) develop methods to predict facies architecture and permeability structure at the between-well scale in a spectrum of deltaic reservoirs; (2) integrate the quantitative geologic data into realistic, geologically constrained, reservoir models useful for reservoir development, management, and appraisal; and (3) incorporate the geological models into reservoir engineering and simulation models, to systematically scale-up detailed data, study sensitivities, and optimize field development strategies.

Spatial distribution of rock properties is difficult to estimate at the interwell scale in the subsurface. Our approach is to develop a firm quantitative basis for reservoir modeling through study of extensive, continuous outcrops as reservoir analogs. Outcrop studies provide data on sandstone-body architecture, stacking, and continuity; on the distribution and length of shales;



Outcrop images of incised valley-fill channel sandstones are used to quantify facies architecture and permeability structure. Vertical and lateral permeability trends, measured on the outcrops, and bed geometries and shale length statistics are incorporated into reservoir flow simulations. These data can be applied to similar valley-fill reservoirs worldwide.

and on the permeability structure of strata. Permeability and architectural data collected from outcrops are used to construct reservoir models and conduct flow simulation. These stratigraphically accurate reservoir-simulation studies investigate the impact of shales, bedding geometries, and facies distribution on recovery processes. The models also demonstrate how outcrop data can be meaningfully and generally incorporated into object- and geostatistics-based reservoir models.

The focus of the project this year was the Frewens Castle sandstone of the Frontier Formation in central Wyoming, a superbly exposed tide-influenced lowstand delta system. After a second field season studying the Frewens Castle, new concepts for recognizing tidal deltaic deposits have been developed. These concepts will have an important impact on how analogous reservoirs are modeled and produced. In addition, outcrop data previously collected from the Ferron sandstone (a fluvial-deltaic system deposited in a high-accommodation setting) and the Fall River Formation (an incised-valley and associated deltaic system in a low-accommodation setting) were used as input for stratigraphically oriented statistical modeling.

This investigation is funded by a consortium of industrial associates comprising the following companies: Amoco Production Company, BP International Limited, Chevron Petroleum Technology Company, Conoco, Inc., Elf Aquitaine Production, Exxon Production Research Company, Intevep S.A., Japan National Oil Corporation, Maxus Energy Corporation, Occidental International Exploration and Production Company, Oryx Energy Company, OXY USA, Inc., Saga Petroleum, Statoil, and Union Oil Company of California. In addition, the program is supported by Schlumberger/GeoQuest, which provides reservoir-simulation software.

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

Noel Tyler, principal investigator; Mark D. Barton and Christopher D. White

The premise of this Gas Research Institute–funded research is that fluvial-deltaic reservoirs are likely to harbor significant quantities of untapped and bypassed reserves because of stratigraphic compartmentation. Accordingly, the goals of this research are to develop knowledge and techniques that will result in profitable exploitation of this potentially vast economic resource. Our approach is to collect quantitative geologic data from laterally continuous exposures and use this information to construct realistic models of reservoir heterogeneity. The models will be used to predict fluid flow behavior and assess the effects of geologic variability on gas recovery efficiency.

The Cretaceous Ferron Sandstone, located in central Utah, is an analog to fluvial-deltaic reservoirs formed under conditions of high sediment supply and accommodation. It was selected for study because it represents an extremely well exposed fluvial-deltaic system, it displays similarities to many Gulf Coast fluvial-deltaic reservoirs, and abundant subsurface data exist nearby. Sites representative of contrasting stratigraphic settings within the Ferron Sandstone were selected for detailed examination. Each site was characterized by describing facies successions, correlating the bounding discontinuities that terminate the successions, and measuring their petrophysical properties along closely spaced transects. Data were collected from each site along laterally continuous exposures over a distance of several kilometers. As a result, the correlations are largely descriptive rather then interpretative. Data are presented in a cross-sectional format from which both qualitative and quantitative information on the petrophysical property structure, geometry, and continuity of sandstone and mudstone beds can be extracted.

The outcrop images were used as a template to construct architecturally based models of reservoir heterogeneity. Using specially developed software, geologic line drawings of bedding architecture, facies maps, and shale maps were combined consistently and gridded for reservoir simulation. The simulation grids use a cornerpoint geometry and nonneighbor connections to reproduce the distinctly nonrectangular bedding geometry, erosion surfaces, and discontinuous shale layers. Flow simulations demonstrate the importance of draping shales in fluid displacement. Additional simulations are being conducted to compare gas recovery efficiency under contrasting stratigraphic settings.

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

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This project, initiated in 1995 and completed in 1996, was funded by Yacimientos Petroliferas Fiscales (YPF), S.A., of Argentina. The main goal is to maximize oil recovery from the Triassic Potrerillos Formation within the North Barrancas field, Argentina, using advanced reservoir characterization technology. The project integrates (1) outcrop studies of sandstone-body geometries, (2) high-resolution subsurface well and 3-D seismic correlations, (3) reservoir engineering, and (4) geocellular modeling. The Potrerillos Formation was deposited in lacustrine rift basins associated with the opening of the southern Atlantic Ocean and has since been folded in an asymmetric thrusted anticline at North Barrancas and Barrancas fields during Cenozoic Andean contraction.

Fieldwork by Bureau researchers on outcrops of the Potrerillos Formation in the Andean foothills produced valuable geometric data on reservoir dimensions and properties. At North Barrancas field subsurface correlations have identified lacustrine

flooding surfaces, which provided the framework for identifying multiple high-resolution genetic packages. Permeability structure measured in the outcrops was used to predict reservoir compartmentalization in the field. A three-dimensional seismic survey was used to define the structure of the field and provided insight for the basin development. A 6-million-cell 3-D geocellular model was constructed to help determine future drilling locations. Presentations by Bureau scientists documenting project results were made in Mendoza and Buenos Aires, Argentina.

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

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

In 1996, the Bureau of Economic Geology concluded an 18-month study of Miocene fluvial, bay-fill, and transgressive barrier-island reservoirs in the Mioceno Norte Area in northeastern Lake Maracaibo. The maiu objectives of this project, funded by Lagoven, S.A., were to perform an integrated field study to identify and map remaining oil and develop reservoir management strategies to more efficiently recover the remaining oil resource and offset the curreut production decliue.

Since their discovery in the 1930's, Miocene reservoirs in the 18-mi^2 Mioceno Norte Area have produced more than 265 million barrels (MMbbl) of oil. However, these reservoirs are estimated to have a recovery efficiency of only 27 percent at the end of primary recovery operations at the current 20- to 25-acre well spacing. Although production was accelerated in World War II to meet wartime demands, appreciable volumes (commouly 400 to 1,200 MSTB [thousand stock-tank barrels]/20-acre drainage area) remain in multiple, poorly contacted reservoir sandstones. Detailed lithofacies maps document the control of sandstone architecture on hydrocarbon distribution and demonstrate that the current well spacing on a grid pattern is too large to efficiently recover the remaining oil. The complex depositional architecture and reservoir heterogeneities control irregular advancement of oil-water contacts from the western field margin, resulting in multiple areas of bypassed oil. Strategic development of these poorly swept areas could improve ultimate recovery up to an additioual 10 to 15 percent of the original oil in place.

Through a combination of structural, stratigraphic, seismic, palynological, petrophysical, petrographic, and reservoir engineering analyses, a team of Bureau and Lagoven researchers identified more than 180 potential development well locations, including infill wells, recompletions, redrilled wells, horizontal wells, and water-injection wells to effectively produce the remaining oil resource. The Bureau–Lagoven team quantified and mapped volumes of remaining oil in each reservoir and delineated infield-exploratiou fairways and devised development strategies for each reservoir in the field, targeting compartments inferred from production history and analysis of depositional architecture.

Preliminary results from development wells proposed by this study are encouraging, with initial production in strategic infill wells ranging from 200 to 1,000 barrels of oil per day. These and other development wells identified in the study are projected to greatly extend the productive life of the Mioceno Norte Area into the next century.

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

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The VLA-6/9/21 Area occupies a 23.2-mi^2 area in north-central Lake Maracaibo and is operated by Maraven, S.A., an affiliate of Petroleos de Veneznela, S.A. A 28-month, integrated reservoir-characterization study of the VLA-6/9/21 Area by the Bureau and Maraven, S.A., aims to increase oil recovery from tidal-shelf and estuarine-fill deposits in the C Members of the lower Eocene Misoa Formation. Oil reservoirs in the VLA-6/9/21 Area are extremely heterogeneons as a result of the complex structural setting and heterolithic nature of the tide-dominated reservoir sandstones. The average recovery efficiency is less than 25 percent of the nearly 2 billion stock-tank barrels of oil originally in place. Optimizing recovery of the remaining oil resource requires characterizing structural and depositional controls on reservoir architecture, identifying the fluid distribution across the field, and targeting strategic infield development wells to effectively drain individual reservoir compartments and to improve waterflood sweep efficiency by realigning injection wells into effective patterns.

The VLA-6/9/21 Area was divided into three stages for separate analysis. The Stage 2 Area, which includes approximately 60 wells in the central part of the field, was evaluated in 1996 with an integrated analysis including genetic sequence stratigraphy, 3-D seismic interpretation, petrophysics, and production engineering. This analysis identified more than 180 million stock-tank barrels (MMSTB) of unproduced oil in the Stage 2 Area. Uncontacted oil in the Stage 2 Area occurs in fault-bounded compartments, and bypassed oil remains in poorly swept areas adjacent to elongate pathways of water encroachment along sandy estuarine-channel depositional axes. More than 25 new strategic infill wells, recompletions, and water-injection wells are projected to enhance recovery of the remaining oil resource and could recover an additional 64.7 MMSTB in the Stage 2 Area, greatly extending the productive life of the field.

Unrecovered hydrocarbon resources in the VLA-6/9/21 Area were mainly delineated by 3-D seismic amplitude maps. These

maps documented areas of high hydrocarbon saturation in fault-bounded compartments and in poorly swept areas where inferred permeability contrasts occur between estuarine-channel and muddy estuarine-fill facies. Deeper, untested reservoirs have also been highlighted by 3-D seismic amplitude anomalies.

In 1997, the Bureau will complete the reservoir characterization of the VLA-6/9/21 Area, integrate results from each stage of the project, and make field-development recommendations to Maraven, S.A., across the entire study area. Results from this project, combined with those from the neighboring Lagoven LL-652 Area, will present an updated picture of the depositional and structural history of the lower Eocene iu the northern part of the Maracaibo Basin.

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

Douglas Hamilton, principal investigator; Sandra K. Raeuchle, Mark H. Holtz, and Joseph Yeh; Moises Uzcátegui, Toribio Jimenez, Anna Salazar, Carmen E. Cova, Roberto Barbato, and Alberto Rusic (Corpoven, S.A.)

This 6-month project, funded by Corpoven, S.A. (an affiliate of Petróleos de Venezuela, S.A.), and completed in February 1996, was a reservoir characterization study through volumetrics analysis. The primary objective was to define a development plan to increase oil reserves and ensure sustained production from Budare and Elotes Sur oil fields of the Eastern Venezuela Basin over the middle and long term.

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

The project data base comprised a 50-mi^2, 3-D seismic survey, digitized well logs from approximately 100 wells that include directional and horizontal boreholes, core data from 2 wells, and production data spanning abont 30 years. Data were analyzed by means of Landmark and Geographix software installed on computer workstations.

The team that carried out the study was composed of Bureau researchers and Corpoven staff that consisted of reservoir geologists, petrophysicists, geophysicists, and petroleum engineers. The project identified numerous reserve growth opportunities through geologically targeted infill drilling locations, behind-pipe reperforation opportunities, and field extensions. More than 50 new well locations were proposed to Corpoven. Original oil in place calculated by the project was increased by half, and incremental reserve growth was estimated at 52.8 million stock-tank barrels (MMSTB), which more than doubles the current proved reserve estimate. To date, the first four wells drilled on the basis of research results have been successfully completed as oil producers, each averaging more than 1,000 barrels of oil per day.

Using Seismic Vector Wavefields to Analyze Heterogeneous Reservoir Architecture

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

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

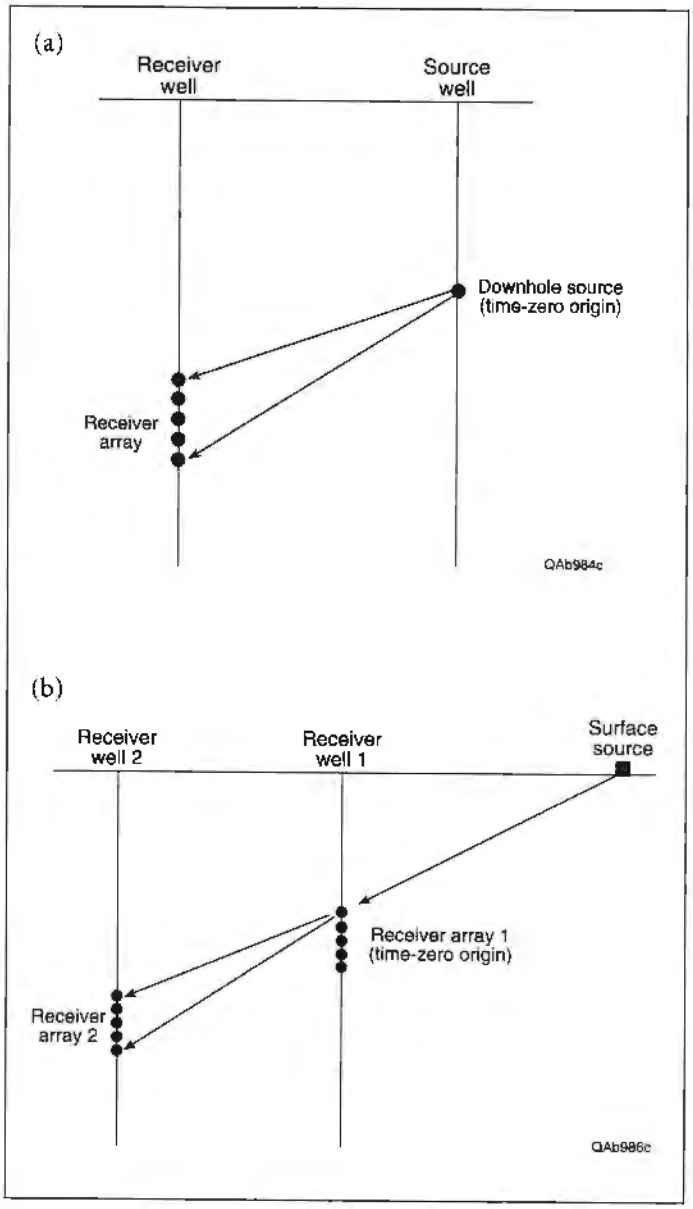
The primary research objective is to analyze three-component crosswell wavefields in various gather formats to (1) determine depths at which one type of seismic wave mode is reflected and another mode is not or depths at which all wave modes are reflected and then (2) acquire and apply geologic and engineering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

An eikonal-based modeling capability has been developed that allows the traveltimes of direct, converted, and reflected P- and S-wave modes to be calculated for an arbitrarily layered, 2-D earth. In this modeling approach, the sources and receivers can be at any arbitrary spatial location, either on the surface or in the subsurface. This capability thus allows P and S wavefields to be modeled for crosswell, vertical seismic profile, reverse vertical seismic profile, and surface-reflection geometries. The model results have been tested and proven using crosswell data.

A Robust Economic Technique for Crosswell Seismic Profiling

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

Crosswell profiling is a seismic measuremeut, made by means of downhole seismic sources and receivers, that images the geology between two wells at a rather high spatial resolution. Crosswell profiling, an important emerging seismic technology, is heing considered by several industries as a way of mapping interwell fluid-flow paths and of monitoring the behavior of secondary recovery processes. The objective of this research



Raypath geometry associated with downhole-source (a) and surface-source (b) crosswell traveltime tomography. Advantages of surface-source over downhole-source crosswell tomography are that it overcomes several technical limitations of downhole sources and it allows faster data acquisition, thus lowering the cost of crosswell surveys.

program, funded by the U.S. Department of Energy, is to determine whether surface-based seismic sources instead of downhole sources can be used to generate crosswell tomographic data. Traditionally, crosswell data are recorded by deploying receivers in one well and a seismic source in a second well and then recording the seismic wavefield that travels across the interwell space. In the method being investigated in this study, workers deploy receiver arrays in two wells, position a seismic source on the surface at an offset location that is in line with the two wells, and then use the two downhole arrays to record the wavefield that traverses the interwell space.

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

These twin-receiver well data have been converted into eikonal-based traveltime wavefields, and crosswell traveltime tomograms are being created by subtracting the inverted traveltimes at receiver well 1 from the inverted traveltimes at receiver well 2. The geologic value of the resulting distributions of interwell velocities will be judged by determining how errors in the inverted traveltime wavefields affect the calculated interwell velocities.

State of Texas Advanced Resource Recovery (STARR) Project

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Revenue income to the Permanent School Fund, largely derived from oil and gas royalties from State Lands, has declined dramatically over the past decade. If current production trends on State Lands continne, this critical revenue stream will diminish to a trickle in 15 years. Yet, an enormous hydrocarbon resource base still remains on State Lands. In fact, State Lands fields contain more oil and gas than have been recovered over the decades-long history of State Lands production. Rather than being unattainable, a large volume of this remaining oil and gas is recoverable through the strategic, or targeted, deployment of advanced recovery technologies.

The Bureau with support from the State of Texas is providing critical technical support in the form of these advanced recovery technologies. Some of the best prospects for increased production have been identified and, with the support of allied producers, are being drilled. This State of Texas Advanced Oil and Gas Resource Recovery Optimization Initiative (Project STARR) has only one goal—increased royalty income to the Permanent School Fund through drilling of profitable wells. To date, eight priority fields are being assessed, includmg the Ozona, Geraldine Ford and Ford West, Lockridge and West Waha, and Keystone East fields of West Texas and Umbrella Point and South Copano Bay fields of the Gulf Coast. Twelve Texas operators are currently involved in the STARR initiative and include Union Pacific Resources, Conoco, Shell, Mobil, Chevron, Bass Enterprises, Hallwood Energy, Parker and Parsley, Vista

Resources, Goldking Oil and Gas, Midland Resources, and Manna Oil and Gas. By achieving even modest levels of incremental oil and gas recovery, Project STARR would generate additional State of Texas taxes and royalties, resulting in a significant contribution to the Permanent School Fund, directly benefiting all the school children of Texas. Importantly, sustained State of Texas funding will permit complete reservoir characterization analysis of several major oil and gas fields on State Lands per year, acting as a catalyst that will bring life back into the Permanent School Fund.

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; Paul R. Knox, Mark H. Holtz, and W. Gerald White; assisted by Syed A. Ali, Radu N. Boghici, Chun-Yen Chang, Jianchun Dai, Hye Won Kim, and Pedro J. Leon

The Bureau has completed 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 of some of the nation's most endangered crude oil reservoirs by stimulating near-term oil recovery. DOE placed the highest priority on fluvial-deltaic reservoirs because their high depositional heterogeneity has resulted in large volumes of unrecovered mobile oil (8.8 billion barrels) and their overall maturity places them in the greatest danger of abandonment. The Oligocene-age Frio Fluvial-Deltaic Sandstone (Vicksburg Fault Zone) play of South Texas, selected as a laboratory for this study, is indicative of the underdeveloped nature of this class of reservoirs: it still contains more mobile oil today (1.6 billion barrels) than has been produced in five decades of active production (1.0 billion barrels).

Most critical to the near-term recovery of oil from these reservoirs is the accurate identification of the specific location and volume of unrecovered mobile oil. To accomplish this objective, we have developed a reservoir characterization technique that integrates advanced approaches in geology, geophysics, and reservoir engineering. Understanding of high-frequency sequence stratigraphic controls on depositional style and reservoir architecture of fluvial-deltaic sandstones was gained from outcrop studies of the Ferron Sandstone, Utah. This information was combined with stratigraphic analysis of three-dimensional seismic data of Frio sandstones to improve the identification of between-well reservoir geometries and heterogeneities that prevent complete reservoir drainage through existing wells. Computerized three-dimensional visualization models of the reservoirs were constructed that incorporated the identified between-well geometries and extrapolated known petrophysical properties measured at wellbores on the basis of identified depositional facies. These models allowed the accurate calculation of original oil in place and the location and volume of unrecovered mobile oil.

The initial project stage involved the evaluation of the range and statistical distribution throughout the play of various reservoir attributes, including porosity, initial water saturation, and residual oil saturation. Subsequently, the integrated characterization methodology was applied to selected reservoirs in two fields, Rincon field, Starr County, and T-C-B field, Jim Wells County, to (1) characterize the range of reservoir architecture and compartmentalization within the play, (2) document the potential for reserve growth, and (3) demonstrate the ability of the characterization method to identify specific opportunities for near-term oil recovery through recompletions or targeted infill drilling. A microcomputer-based software package, the Reservoir Characterization Advisor—Fluvial Deltaic, was developed to illustrate the integrated characterization methodology and provide guidance in prioritizing reservoirs for detailed study. This software, combined with publications, presentations, and short courses, is disseminating these proven technologies to operators in the Frio play as well as other similar plays throughout the United States to stimulate the identification and near-term recovery of oil from domestic fluvial-deltaic reservoirs.

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

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The Bureau is in the second year of a 48-month cooperative agreement funded by the U.S. Department of Energy as part of the Oil Recovery Technology Program for Class III (slope and basin clastic) reservoirs. The Bureau's partner in this project is Conoco, Inc. Matching funds for the project are provided by the Texas Office of State-Federal Relations through State Match Pool Funding awarded in a contract titled "Rejuvenating a Dying Oil Play: Benefits to the State, the Permanent School Fund, and the People and Economy of Far-West Texas" and by the State of Texas Advanced Resource Recovery Project. The objective of this project is to demonstrate that detailed reservoir characterization of slope and basin clastic reservoirs in sandstones of the Delaware Mountain Group in the Delaware Basin of West Texas and New Mexico is a cost-effective way to recover a higher percentage of the original oil in place through strategic placement of infill wells and geologically based field development. The Bureau and Conoco, Inc., are deploying advanced reservoir characterization strategies—including 3-D seismic interpretation and coherence evaluation, subsurface log and core analysis, and outcrop characterization—to optimize recovery from Ford Geraldine unit in Culberson and Reeves Counties, Texas. The study focuses on the Ramsey sandstone,

the most prolific horizon in the Bell Canyon Formation of the Delaware Mountain Group.

Ramsey sandstones occur in the uppermost cycle of the Bell Canyon Formation and represent progradation, aggradation, and retrogradation of an elongate submarine channel and lobe complex formed by sediment gravity flows on the basin floor. On the basis of core description and field mapping of Bell Canyon sandstones exposed in outcrop 24 mi from Ford Geraldine unit, the reservoir sandstones are interpreted to consist of sheetlike lobe deposits overlain and incised by lenticular 1,000-ft-wide channels. Adjacent levee and overbank deposits vertically and laterally separate channel sandstone bodies. Ramsey sandstones are bounded by laterally continuous, organic-rich distal-fan siltstones deposited by settling from suspension. Additional heterogeneity was caused during burial diagenesis by nonuniform precipitation of authigenic calcite and clays in fine-grained and very fine grained reservoir sandstones.

During Phase II of the project, which begins in 1997, knowledge gained from reservoir characterization and simulation will be applied to increase recovery from a pilot area. A geologically designed, enhanced-recovery program (CO_2 flood, waterflood, or polymer flood) and well-completion program will be developed in the pilot area, and one to three infill wells will be drilled and cored.

Petroleum Technology Transfer Program

R. P. Major, principal investigator; L. Edwin Garner, Mark H. Holtz, Lisa E. Remington, and W. Gerald White

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

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

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

During the first year of this project, our Regional Resource Center was developed and began operation. The Resource Center includes a reading room, map room, geophysical log facility, core repositories, and two computer workstations equipped with analytical petroleum software. Programs for contour mapping, reservoir simulation, well log analysis, log digitizing, and reservoir engineering are examples of software that are available to the public. The Texas Region PTTC also established a home page on the Internet, which includes an events calendar; technology news; exploration, production, research and development forums; and resource links. An informational brochure describing the Texas Region of the PTTC was developed, and several hundred copies were distributed at technology transfer workshops, trade shows, and conventions throughout the year. Other program activities included two continuing education focused technology workshops on the Frio Fluvial-Deltaic Sandstone (Vicksburg Fault Zone) play. These were held in Houston and San Antonio, Texas, in conjunction with the Houston Geological Society and South Texas Geological Society, respectively, and co-sponsored by the U.S. Department of Energy.

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

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

Because strontium isotopes do uot fractionate during geological or geochemical processes, the $^{87}Sr/^{86}Sr$ ratio of oil field brines provides a natural tracer for subsurface fluid studies. The $^{87}Sr/^{86}Sr$ composition of samples collected at the wellhead faithfully records that of the reservoir fluid, despite changes in temperature, pressure, or phase induced by extraction. Regional investigations of subsurface fluids have used strontium isotopes to delimeate hydrologic flow regimes, identify fluid sources, and assess geochemical aud fluid migration history.

This 2 1/2-year project, funded by the Advanced Technology Program of the Texas Higher Education Coordinating Board, examined the potential of this technique to resolve more detailed-scale hydrodynamic issues such as fluid flow and compartmentalization within a producing hydrocarbon reservoir. Dagger Draw and Indian Basin fields, southeastern New Mexico, were selected to investigate intrareservoir $^{87}Sr/^{86}Sr$ variation and to evaluate the application of this technique. These fields extend for approximately 125 mi^2 and produce oil and gas from Upper Pennsylvanian platform-margin dolomitized carbonates of the second Canyon, first Canyon, and Cisco sequences. The reservoirs have produced on primary recovery, and a pilot waterflood project began in 1995. Production is confined to dolomitized shelf-margin facies, which grade landward into lagoonal lime mudstones and are flanked basinward by shales and shaly lime mudstones. The updip field limits are defined by the transition into low-porosity lagoonal

lime mudstones. The updip western and southern regions of the field are gas-prone, whereas the downdip eastern and northern regions predominantly produce oil.

Water samples collected from 70 wells throughout the area show that formation fluids in Dagger Draw and Indian Basin fields are Na-Cl-SO_4 type waters having 4,000 to 50,000 ppm total dissolved solids. The strontium isotope data display a well-defined spatial distribution, with more radiogenic values (0.7098–0.7101) on the western updip part of the field grading downdip into less radiogenic waters (0.7090–0.7091) to the east and northeast. Fluid compositions exhibit no relationship to either the sampled stratigraphic interval or depth. Total dissolved solids and major cations (sodium, potassium, calcium, magnesium) display a positive correlation with $^{87}Sr/^{86}Sr$ ratios.

Formation water $^{87}Sr/^{86}Sr$ trends imply influx of radiogenic strontium-enriched formation waters along the western field margin and eastward-directed downdip flow across the field. A hydrodynamic component to the trapping mechanism has long been postulated by field operators from limited mapping of the potentiometric surface, tilted reservoir fluid contacts, and anomalous production trends.

Deuterium and ^{18}O analysis of the waters indicates that they are meteoric in origin. Geochemical and isotopic data from this study imply that the radiogenic and saline fluids to the west resulted from meteoric dissolution of overlying Salado evaporites. These evaporites contain abundant potassium salts with associated rubidium, which radioactively decays to produce radiogenic ^{87}Sr. Subsequent downward flow occurred along Tertiary normal faults, driven by topographic relief and the high density of the meteoric brines. These saline waters flowed away from the fault conduits into flanking permeable reservoir rocks and migrated down structural dip, displacing the less saline existing reservoir fluids and displacing reservoir fluid contacts. Thus, strontium isotopes are most radiogenic in the updip portion of the field. Strontium isotopic compositions are more homogeneous downdip, indicating that these late brines did not penetrate the downdip limits of the reservoirs.

This study demonstrates that considerable $^{87}Sr/^{86}Sr$ heterogeneity can exist within a reservoir and that the variability can be ascertained by detailed sampling of production wells. The isotopic and geochemical trends thus defined reflect intrareservoir fluid flow, which is especially useful in fields with little or no reliable reservoir pressure data. The pattern of intrareservoir isotopic and geochemical trends thus can be a useful tool to resolve hydrodynamic issues and evaluate reservoir heterogeneity.

Bacterially Mediated Carbonate Precipitation: The Link Between Organic and Inorganic Crystallization

Robert L. Folk, principal investigator; F. Leo Lynch III and R. P. Major

Both organic and inorganic precipitation have been identified as processes capable of forming carbonate grains and cements. Recent improvements in high-resolution scanning electron microscopy, the recent discovery of nannobacteria (extremely small forms of bacteria), and the recently established association of fossilized nannobacteria with some carbonate precipitates suggest that some carbonates may form by bacterially mediated precipitation. That is, carbonates previously assumed to have precipitated directly from sea water or sediment pore waters may have in fact precipitated because of close spatial association with metabolizing bacteria.

Ooid grainstones and recently cemented hardgrounds in ooid sand bars of Joulters Cays, Bahamas, provide an ideal natural laboratory for investigating the phenomenon of bacterially mediated carbonate precipitation. We have examined both naturally fractured and HCl-etched samples using a scanning electron microscope (SEM) at magnifications as high as 200,000×. We find that the oolite cortex is made predominantly of cylindrical crystals of aragonite about 0.1 μm in diameter capped by a nannobacterial bead of the same diameter; the bead precipitated the mineral. Borings and some parts of the cortex are filled with aragonite crystals consisting of chains of 0.02-μm beads, which are the size of viruses. We are investigating the idea whether viruses or other protobionts may precipitate minerals. Some borings are also filled with euhedral crystals of inorganically precipitated aragonite.

The hardground cementation process begins with a mucus "bridge" connecting ooids in the form of a meniscus. Crystals of aragonite grow within this bridge; eventually the mucus decays and the hardground is complete. Nannobacteria and virus-sized particles also play a strong role in this process. In conclusion, nannobacteria and smaller quasi-organic particles are critical in the genesis of Bahaman oolites and hardgrounds.

Architecture of Fluvial-Deltaic Reservoirs: Extension of Outcrop Studies into 3-D Using Ground-Penetrating Radar

Noel Tyler, principal investigator; Brian J. Willis, Mark D. Barton, and Richard T. Buffler; assisted by Georgios P. Tsoflias and James E. Lundy

An advanced understanding of complex stratal architectures and the distribution of heterogeneities that control subsurface fluid flow are required to improve reservoir development strategies and increase recovery efficiencies. In recent years detailed two-dimensional (2-D) outcrop studies of fluvial-deltaic deposits have been used to document between-well-scale complexities that can influence reservoir production behavior. However, understanding fluid flow during reservoir development is fundamentally a three-dimensional (3-D) problem, and thus the next generation of reservoir models must be based on records of stratal geometry and heterogeneity documented in 3-D. The objective of this 2-year project, funded by the Advanced Technology Program of the Texas Higher Educational Coordinating Board, is to use ground-penetrating radar (GPR) to interpolate the 3-D geometry and facies of sediment bodies behind outcrop exposures of channel and shoreface deposits in the Cretaceous Ferron Sandstone.

GPR profiling is similar to seismic reflection, except that GPR is based on reflection of electromagnetic radiation. In the Ferron deposits, GPR provided images of the strata at 4-inch

resolution to depths of 23 to 50 ft. Profiles across fluvial sandstones clearly resolved channel-bar and -fill deposits and their internal bedding geometry. Miles-long profiles spanning the transition from fluvial to deltaic deposits showed pronounced changes in bedding-architecture styles and radar facies. Multiple profiles hundreds to thousands of feet long aligned both parallel and perpendicular to several outcrop faces provided serial cross sections through selected sediment bodies. Sediment body shapes and facies can be interpolated between these cross sections. This study provides detailed templates for fine-scale reservoir-analog models that can predict 3-D patterns of subsurface fluid flow through these heterogeneous deposits.

Using Microstructure Observations to Quantify Fracture Properties and Improve Reservoir Simulation

Stephen E. Laubach, William R. Rossen (Department of Petroleum and Geosystems Engineering, The University of Texas at Austin), and Randall Marrett (Department of Geological Sciences, The University of Texas at Austin), principal investigators; Sigrid J. Clift, Shirley P. Dutton, Larry Lake; assisted by Yaguang Gu, Robert M. Reed, and Mengwu Wang

Oil production from U.S. fields is often hindered by the natural fractures in the reservoir rock. Undetected fractures can divert water and other flnids injected into a reservoir, preventing oil from being pushed efficiently to producing wells. If petroleum engineers could locate and map fractures better, recovery operations could be improved. Moreover, the fractures could be targeted as natural pathways for oil, particularly in low-permeability rock. This project, sponsored by the U.S. Department of Energy, working through BDM-Oklahoma, and by a petroleum industry consortium, is developing new fracture characterization approaches for clastic oil reservoirs and methods for incorporating this information into fractured-reservoir simulators. It is a collaborative project among the Bureau, the Department of Petroleum and Geosystems Engineering, and the Department of Geological Sciences at The University of Texas at Austin.

Using samples from outcrops that are analogous to reservoir strata, the research team is conducting comprehensive analysis to determine the relationship between microscale and macroscale fractures and documenting the depositional, structural, and stress-strain history of the units. Using core from industry partners and the Bureau's Core Research Center, two reservoir formations are also being analyzed in similar fashion. Models are being developed to show processes that open and close flow paths. Fracture mapping methods that result from these tasks are being used to develop improved simulation techniques and to adapt outcrop and core data for use in the models. Following verification of the results, a comprehensive technology transfer effort will be conducted at professional meetings and through publications and workshops.

Integrated Reservoir Characterization and Volumetric Analysis of the Arecuna Area of Faja Field, Venezuela

Douglas S. Hamilton, principal investigator; Mark H. Holtz, M. Saleem Akhter, Robert E. Barba, Jr., and Joseph S. Yeh; Milagro Rodriguez, Marel A. Sanchez, Jose J. Castillo, and Pedro Calderon (Corpoven, S.A.); H. Roice Nelson, Jr. (independent consultant); assisted by Felix A. Diáz, Pedro J. Leon, and Senira Kattah

This 5-month project, funded by Corpoven, S.A. (an affiliate of Petrólcos de Venezuela, S.A.), and begun in September 1996, is a reservoir characterization study using volumetrics and economic analysis. The primary objective is defining a developmeut plan for a horizontal well drilling program to increase oil reserves and ensure sustained production from Faja field, Arecuna area, Easteru Venezuela Basin. Faja field is in the early stages of primary productiou.

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

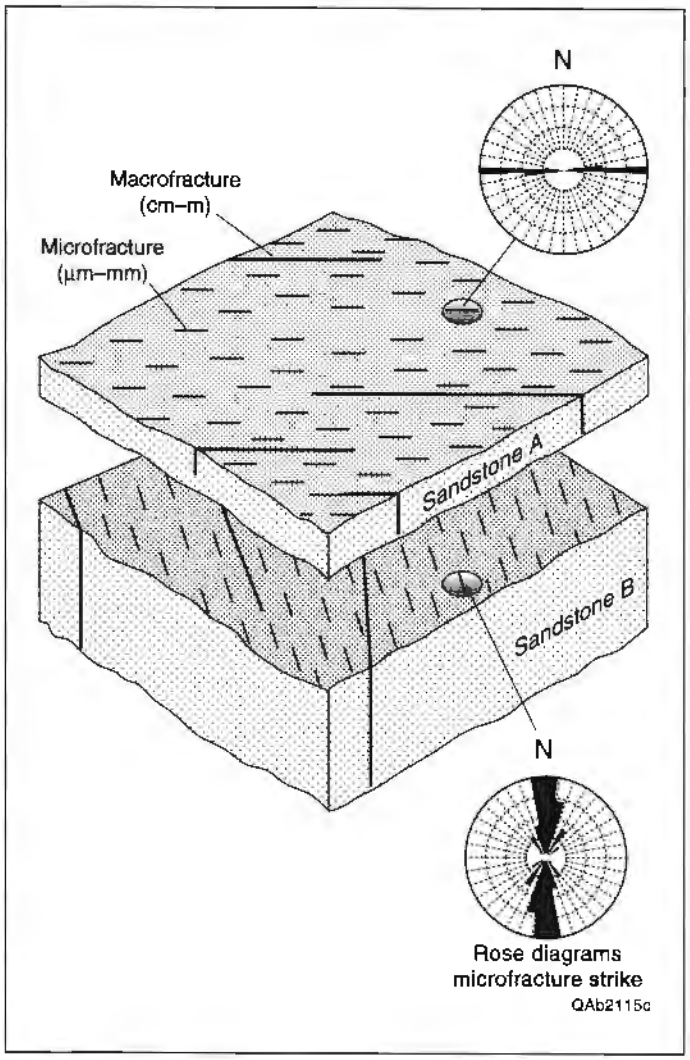
The project data base comprises a 100-mi^2, 3-D seismic survey, digitized well logs from approximately 40 wells that include directional and horizontal boreholes, core data from 1 well, and production data spanning about 15 years. Data are being analyzed by means of Landmark and TerraScience software installed on computer workstations.

The team carrying out the study is composed of Bureau researchers and Corpoven staff that consist of reservoir geologists, petrophysicists, geophysicists, and petroleum engineers. Data were collected in Venezuela, and the project is being conducted at the Bureau.

New Methods of Natural Fracture Characterization

Stephen E. Laubach, principal investigator; Sigrid J. Clift

Revolutionary advauces in analysis of naturally fractured reservoirs are possible using powerful new scanning electron microscope–based imaging devices and quantitative descriptions of how structures of differing scale are related. This project, supported by Chevron U.S.A. Production Company; Conoco, Inc.; Exxon Production Research Company; and Union Pacific Resources Company, with in-kind support from Oxford Instruments, aims to test and perfect this approach in active oil and gas plays. The study shows how it is possible to measure orientation, size distribution, and conductivity of subsurface natural fractures where conventional approaches have failed. These fracture properties must be known for horizontal drilling



New characterization methods being developed by Bureau geoscientists allow key attributes of natural fractures to be assessed, even where fractures large enough to be visible to the naked eye are not sampled in core. This diagram shows schematically how application of microfracture analysis can diagnose variations in fracture strike that could have a profound effect on design of horizontal petroleum wells.

in certain petroleum reservoir rocks to be deployed effectively. The technique uses small rock samples that can be inexpensively retrieved from the subsurface, and it will be particularly advantageous in developing important domestic natural gas resources in fractured low-permeability sandstones. Because the fracture-diagnostics method is simple and inexpensive to apply, these solutions to long-standing technical challenges will lead to more efficient resonrce development.

Targeting High-Potential Exploration Objectives in the South Lake: An Integrated Sequence Stratigraphic, Structural, and Hydrocarbon Habitat Analysis of the Tertiary of South Lake Maracaibo, Venezuela

Noel Tyler, principal investigator; Edgar H. Guevara, project coordinator; Gerhard J. Brink, Edward A. Duncan, and James L. Simmons, Jr.; Carlos L. Camposano and Mauro R. Moya (Lagoven, S.A.); assisted by Dallas B. Dunlap

In October 1996, the Bureau and Lagoven, S.A., an affiliate of Petroleos de Venezuela, S.A., initiated this new project at the Bureau's facilities in Austin. Two Lagoven staff, one geologist and one geophysicist, form part of the project team.

The principal objective of this 1-year project is definition of newly targeted exploration opportunities of the Paleocene to middle Miocene Guasare, Misoa, Icotea, and La Rosa Formations. The study area encompasses approximately 1,000 km^2 in the southwestern part of Lake Maracaibo, western Venezuela. The data base includes 2-D seismic lines, the merged, migrated volume of four 3-D seismic surveys, wireline logs of about 50 wells, and local production data.

Optimizing Hydrocarbon Recovery from the Matzen Field, Vienna Basin, Austria

Robert J. Finley, principal investigator; Paul R. Knox, Jirapa Skolnakorn, Panos Baltas (ÖMV Aktiengesellschaft), and M. Saleem Akhter; assisted by Orlando J. Ortega and Janaka B. Paulis

Matzen field in the Vienna Basin of northeast Austria produces oil and natural gas from middle to upper Miocene (Badenian-Pannonian) sandstones and is the largest onshore oil and gas field in middle Europe. Oil in place is estimated at 1.31 billion barrels and natural gas at 943 billion cubic feet. In collaboration with the field operator, ÖMV Aktiengesellschaft, the Bureau is undertaking an integrated study of the field's potential for reserve growth. The operator recognized numerous anomalies in production potentially related to depositional and structural geologic heterogeneities, which led to initiation of the study in June 1996.

After a period of data collection and assembly, the first phase of the project has focused on developing the genetic stratigraphic framework of the field. A series of maximum flooding surfaces have been defined over an approximately 3,300-ft-thick section defining four third-order genetic cycles. Each of these cycles is distinct in reservoir style and hydrocarbon charge. Combining 3-D seismic data with well log data has defined features such as delta lobes and channels as much as 230 ft thick and delta-front topographic relief as great as 500 ft. The general depositional

and genetic stratigraphic framework, to be completed in January 1997, will serve as the basis for detailed reservoir characterization studies that will be undertaken in several phases in 1997–98, leading to specific opportunities for reserve growth.

Advanced Oil Recovery Technologies for Improved Recovery from Slope Basin Clastic Reservoirs, Nash Draw Brushy Canyon Pool, Eddy County, New Mexico

Bob A. Hardage, principal investigator; James L. Simmons, Jr.; assisted by Virginia M. Pendleton (independent consultant)

The Bureau is interpreting a 3-D seismic survey that was recorded in Nash Draw field, Eddy County, New Mexico, as a part of the U.S. Department of Energy's Oil Recovery Technology Program for Class III (slope and basin clastics) reservoirs. The objectives of the interpretation are to create reliable maps of the reservoir facies contained in thin, complex, turbidite sequences within the Brushy Canyon interval, to provide seismic-based attributes for reservoir simulation studies, and to recommend infield drill sites. The interpretation is a challenging stratigraphic analysis problem in which the targeted thin-bed reservoirs are associated with faint, discontinuous seismic reflection events. Landmark's newest interpretation software, which allows detailed seismic attributes and reflection continuity to be analyzed, is a key component of this research effort.

University Lands Advanced Recovery Initiative

Noel Tyler and Charles Kerans, principal investigators; Raymond A. Levey, Stephen C. Ruppel, and Roger J. Barnaby

Although more than 1.5 billion barrels of oil has been produced from the 101 major reservoirs developed on University Lands, Bureau of Economic Geology studies indicate that more than 2 billion barrels of remaining mobile oil, about 10 times the remaining reserves, still remains as a target for improved recovery. Recognizing the need for implementation of new approaches and technologies for the recovery of this target resource and for improved development strategies, The University of Texas System has provided funding for a series of multidisciplinary studies of University Lands reservoirs. The University Lands Advanced Recovery Initiative, begun in 1996, is designed to foster the use of advanced technologies in the efficient recovery of hydrocarbons from University Lands reservoirs.

The University Lands Advanced Recovery Initiative will be implemented through the Bureau and will comprise five components: (1) advanced reservoir characterization, (2) deployment of advanced recovery technology, (3) identification of underdeveloped reservoirs, (4) definition of the potential for field extensions and deeper pools, and (5) interactive transfer of concepts and approaches to recovery improvement to field operators. The program stresses cooperative interaction with University Lands operators.

Currently negotiations are under way with several operating companies to begin studies on key University Lands properties, including reservoirs in San Andres, Graybnrg, Spraberry, and Devonian units.

Gas

Integrated Strategies for Carbonate Reserve Growth: An Example from the Ellenburger Group, Permian Basin, West Texas

Bob A. Hardage, principal investigator; James L. Simmons, Jr., and Ursula Hammes; assisted by Virginia M. Pendleton (independent consultant)

The Bureau is the lead technical contractor of this 2-year project funded by Gas Research Institute, the U.S. Department of Energy, and the State of Texas. The investigation focuses on the identification of karst-related gas reservoirs in the Ellenburger Group in West Texas, with the principal effort being concentrated inside a 176-mi^2 3-D seismic survey recorded in portions of Pecos, Reeves, and Ward Counties. Two industry partners, Shell Western E&P Inc. and Mobil Exploration and Production U.S. Inc., are actively involved in the study. Both companies have provided a comprehensive well log and velocity survey data base, and Shell has taken primary responsibility for the 3-D seismic data acquisition and processing.

The 176-mi^2 study site encompasses approximately 80 to 90 wells, and digitized logs from more than 60 of these wells are being used to construct models of the karst system. Particular attention has been directed toward correlating FMI* (Fnllbore Formation MicroImager) log data with core control over the karst intervals. The processing and interpretation of the 176-mi^2 of 3-D seismic data were completed in late 1996. The data processing is particnlarly challenging because a thick, near-surface Tertiary fill creates severe static correction problems across a large portion of the 3-D seismic grid.

*Mark of Schlumberger.

Improved Resource Characterization Technology for Tight Gas Sandstones

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

A large energy resource is known to exist in stratigraphically and diagenetically complex sandstones, including tight gas sandstones. In the United States (lower 48 states), the estimated gas in place in tight gas sandstones is 5,000 Tcf, of which a significant volume is technically recoverable. The purpose of

the research in this project is to help effect necessary technology improvements in geologically based exploration and development techniques. Among the formations being studied in this project are the Wilcox Lobo Formation, South Texas, and Canyon Sandstone, Val Verde Basin. This project, which was sponsored by Gas Research Institute, concluded in March 1996.

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

Bob A. Hardage, principal investigator; James L. Simmons, Jr., and Douglas S. Hamilton

Research on gas compartmentalization in deltaic reservoirs deposited in low-accommodation Midcontinent basins was finalized and documented in technical articles and short courses. Numerous requests for the technology transfer publications generated during this study were received, and several hundred copies have been distributed to industry operators.

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

A comprehensive 3-D seismic data set from Boonsville field was released to the public and has become one of the Bureau's more popular publications. Included in this public data package are 5.5 mi^2 of time-migrated 3-D seismic data, digitized log curves from 38 wells inside this 5.5-mi^2 area, vertical seismic profile data, definitions of sequence boundaries at the 38 logged wells, extensive production and petrophysical data, and a 40-page instruction manual.

A Guide to Targeting Coalbed Methane Exploration Fairways

Roger Tyler, principal investigator; Andrew R. Scott, W. R. Kaiser, and H. Seay Nance; assisted by Ronald G. McMurry and Martha Z. Beltran; in cooperation with the Carol M. Tremain (Colorado Geological Survey) and James G. Clough (Alaskan Division of Geological and Geophysical Surveys)

Methane from coal beds is a potentially important source of natural gas worldwide, but to date successful exploitation of coalbed methane resources has been limited to several coal basins in the United States. Triggered by success in the United States, exploration for coal gas has begun in coal-rich areas of the United Kingdom, eastern and western Europe, China, South Africa, Zimbabwe, and Australia. What has not been widely recognized about the U.S. experience is that although coalbed methane resources in some basins have been successfully exploited, other basins with seemingly similar geologic and hydrologic attributes have proven to be disappointing methane producers.

The traditional view of production from coal reservoirs is inadequate to explain the contrasts in coalbed methane producibility among coal basins. In the traditional view, coal gases are generated in situ during coalification and sorbed on the large internal surface area of the coal. Sorption is pressure dependent and is promoted by increasing pressure. Gas production is then achieved by reducing reservoir pressure through depressuring (dewatering) and thereby liberating gases from the coal surface for diffusion to the fracture (cleat) system for subsequent flow to the wellbore. The traditional view is oversimplified because it fails to recognize the need for additional sources of gas, beyond that generated initially during coalification, to achieve high gas content following basinal uplift and cooling. Conventionally migrated and hydrodynamically trapped gases, in situ-generated secondary biogenic gases, and solution gases are required to achieve high gas contents or fully gas-saturated coals for consequent high productivity. To delineate the presence and origin of these additional sources of gas, the Bureau has developed a coalbed methane producibility model that can act as a guide for exploration and development. Importantly, application of the producibility model requires an understanding of the interplay among tectonic and structural setting, depositional systems and coal distribution, coal rank, gas content, permeability, and hydrodynamics to target exploration fairways.

Our understanding of the controls on coalbed methane producibility is based on comprehensive geologic and hydrologic studies of the San Juan, Sand Wash, Greater Green River, and Piceance Basins, funded by Gas Research Institute, and reconnaissance studies of several other producing and prospective coal basins in the United States and worldwide. The San Juan Basin, in which cumulative production exceeds 1 Tcf (28 Bm^3), is the world's most prolific coalbed methane basin. Our basin-scale model for coalbed methane producibility has evolved out of a comparison of the prolific San Juan, and marginally productive Sand Wash, Greater Green River, and Piceance Basins and is now being applied to coalbed methane frontier basins in Alaska.

Coalbed Methane Cooperative Research Agreement

Roger Tyler and Andrew R. Scott, principal investigators; assisted by Ronald G. McMurry

The purpose of the Coalbed Methane Cooperative Research Agreement between the Alaskan Department of Natural Resources, Division of Geological and Geophysical Surveys, and the Bureau is to investigate the potential for rural Alaskan coalbed methane resource development utilizing the Bureau's basin-scale exploration model for coalbed methane production. This cooperative agreement is designed to select coalbed methane "sweet spots" in the vicinity of several rural Alaskan villages for the purpose of drilling and testing their potential for power generation and home heating. Although Alaska's potential for coalbed methane resources may be as high as 1,000 Tcf, the actual number of methane-bearing coal basins is mostly unknown and the extent and magnitude of producible gas is untested.

Coal (dark beds in this Alaskan outcrop) and coalbed methane resources are potentially large in Alaska. Estimated coal resources exceed 5.5 trillion short tons and may coutain as much as 1,000 Tcf of coalbed gas. A cooperative agreement between the Bureau and the Alaskan Department of Natural Resources, Division of Geological and Geophysical Surveys, is investigating potential rural Alaska sites for coalbed methane gas, using the Bureau's basin-scale exploration and development model for coalbed methane production. Photo courtesy of Tom Smith.

The Bureau has developed its basin-scale coalbed methane producibility model on the basis of more than a decade of Gas Research Institute–sponsored research in the Rocky Mountain foreland and worldwide. This model indicates that depositional systems and coal distribution, coal rank, gas content, permeability, hydrodynamics, and tectonic/structural setting are critical controls on coalbed methane producibility and resource assessment. Exceptionally high productivity is governed by (1) thick, laterally continuous coals of high thermal maturity, (2) adequate permeability, (3) basinward flow of ground water though coals of high rank and gas content orthogonally toward no-flow boundaries (regional hingelines, fault systems, facies changes, and/or discharge areas), (4) generation of secondary biogenic gases, and (5) conventional trapping along those boundaries to provide additional gas beyond that generated during gas coalification. Understanding the dynamic interaction among these key geologic and hydrologic factors will delineate "sweet spots" within Alaskan coal basins that potentially have high coalbed methane productivity, benefiting the rural native population.

Atlas of Northern Gulf of Mexico Gas and Oil Reservoirs

R. P. Major and Steven J. Seni, principal investigators; Thomas A. Tremblay, Deborah A. Salazar, E. G. Wermund, and Tucker F. Hentz; assisted by Suhas V. Bodwadkar, Eugene M. Kim, and Naresh D. Sen; subcontracts to Louisiana State University Center for Coastal, Energy and Environmental Resources/Basin Research Institute; and to Alabama Geological Survey

In collaboration with Louisiana State University and the Geological Survey of Alabama, the Bureau is nearing completion of an atlas series of gas and oil reservoirs in the Federal and State offshore waters of the northern Gulf of Mexico. The U.S. Department of Energy (DOE), Minerals Management Service (MMS), and Gas Research Institute (GRI) initiated funding of the 4-year program beginning in the fall of 1992 and the spring of 1993. Collection and analysis of reservoir data were completed in 1996, and the production of atlas figures, text, and the volume 1 folio is nearly complete. Aggregated digital data of plays, fields, and reservoir pools have been made available through the Internet at the home pages of the Bureau, GRI, MMS, and DOE. 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 northern Gulf of Mexico is currently receiving much attention from the oil and gas industry for field extension and infill drilling in mature areas of the basin and for frontier exploration in deeper parts of the Gulf. In 1996, leasing activity reached record levels for both the central and western Gulf of Mexico, emphasizing the region's increasingly important role in supplying domestic energy. The Gulf of Mexico offshore region currently produces 14 and 25 percent, respectively, of the nation's annual production of oil and gas. In addition the Gulf 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 10,000 sandstone-body reservoirs in more than 1,000 fields have produced an estimated 11.0 billion barrels (Bbbl) of oil and 128.7 Tcf of gas.

We have delineated 91 reservoir plays in Federal and State waters of the Gulf of Mexico, typically using age and depositional style as key defining attributes of a play. We identify plays by integrating regional patterns of hydrocarbon occurrence and patterns of depositional style and structure with engineering reservoir data. The combination of various elements of geologic and engineering data is synthesized to determine the bonndaries 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. Innovative strategies are being employed to assure wide distribution of the data. The atlas folios will include reservoir and geographic information system data on a CD-ROM, and the Internet is being used to distribute an aggregated subset of the digital data. These data can be used (1) to identify the areas of greatest potential with the highest concentration of remaining unrecovered hydrocarbons in existing fields and (2) to 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 reservoir play analysis thus provides a logical basis for simultaneously evaluating both field reserve growth potential and opportunities for extension exploration in mature plays. The result will be reduced exploration risk and improved efficiency.

Assessment and Forecasting, by Play, Natural Gas Reserve Appreciation and Quantifying the Role of Technology Advancements in Reserve Growth Additions in the Gulf Coast Basin

William L. Fisher, principal investigator; assisted by Eugene M. Kim

In recent years, reserve growth has become a major component of total U.S. annual natural gas reserve additions. Further, by adding reserves within existing infrastructure and commonly by inexpensive recompletion technology in existing wells, reserve growth has become the dominant factor in ample, low-cost natural gas supply. Although there is a wide range in natural gas reserve-growth potential by play and that potential is a function of drilling and technology applied, current natural gas reservoir-growth studies are gross, averaging wide ranges, disaggregated by broad natural gas provinces, and calculated as a function of time.

It is well known that areas like the northern margin of the Gulf of Mexico Outer Continental Shelf have vertically stacked reservoirs associated with growth faults and compartmentalized reservoirs associated with domal salt structures. These producing environments are especially amenable to several new technologies, such as horizontal drilling, directional drilling, and 3-D seismic imaging, and have been major sources of natural gas reserve growth. It is also known that plays with little natural gas mobility constraint have achieved high rates of conventional recovery and offer little natural gas reserve-growth potential. However, there has not been a quantification of natural gas reserve growth by play, nor a ranking of those plays with the largest remaining potential.

Detection technology, locational diagnostics, horizontal drilling, directional drilling, hydraulic fracturing technology, measurement while drilling (MWD), advanced drilling bits, 3-D seismic, and amplitude versus offset (AVO) are just a few technological advances that have led to an increase in exploration and development efficiency sufficient to offset the depletion effects of declining field size, particularly in natural gas reserve growth of older, large fields. However, neither the impacts of technology by play nor the play-specific amenability of applying advanced technologies has been assessed or quantified.

The primary research objectives of this project, funded by the U.S. Department of Energy, are developing new concepts in (1) realistic and play-specific measures of remaining natural gas reserve-growth potential, (2) assessment of technology necessary and most amenable to realizing natural gas reserve growth, and (3) assessing the economic factors of realizing natural gas reserve growth in the Gulf Coast Basin. Through such assessment the longer term potential and economics of natural gas reserve growth as a contributor to the future natural gas supply from the Gulf Coast Basin can be determined and quantified. The methodology of such an assessment can be verified and applied more broadly to other natural gas resource areas that have significant natural gas reserve-growth potential.

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, Sara L. Burns, and Geoffrey W. Upitis

The Applied Geodynamics Laboratory carries out physical scale-modeling to generate new concepts, test hypotheses, or duplicate specific geologic structures relevant to the location, origin, mechanics, and evolution of structural traps for oil and gas. Research is funded by the Advanced Technology Program of the Texas Higher Education Coordinating Board and by the following consortium of oil companies: Agip Petroleum S.p.A., Amoco Production Company, Anadarko Petroleum Corporation, ARCO Exploration and Production Technology/Vastar Resources Inc., BHP Petroleum (Americas) Inc., BP Exploration Inc., Chevron Petroleum Technology Company, Conoco Inc./DuPont, Exxon Production Research Company, The Louisiana Land and Exploration Company, Marathon Oil Company, Petroleo Brasileiro S.A., Phillips Petroleum Company, Statoil, Texaco, Inc., and Total Minatome.

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 used a high-speed, high-capacity centrifuge equipped with digital speed and temperature controls.

Experimental research focused on the following main topics: (1) gravity-driven compression of clustered salt stocks, (2) multiple breakout of salt sheets and related fault systems, (3) mechanics of diapiric pinch-off, (4) structural coupling and decoupling between extending basement, salt, and overburden, and (5) geometry and evolution of salt-wall relays.

Applied Geodynamics Laboratory: Mathematical Tectonic Modeling

Martin P. A. Jackson, principal investigator; Daniel D. Schultz-Ela, Giovanni Guglielmo, Jr.; assisted by Ryan J. Mann and Geoffrey W. Upitis

The Applied Geodynamics Laboratory (AGL) carries out numerical modeling and computer visualization to generate new concepts or test hypotheses relevant to the formation of structural traps for oil and gas. Research at AGL is funded by the Advanced Technology Program of the Texas Higher Education Coordinating Board and by the following industrial associates: Agip Petroleum S.p.A., Amoco Production Company, Anadarko Petroleum Corporation, ARCO Exploration and Production Technology/Vastar Resources Inc., BHP Petroleum

(Americas) Inc., BP Exploration Inc., Chevron Petroleum Technology Company, Conoco Inc./DuPont, Exxon Production Research Company, The Louisiana Land and Exploration Company, Marathon Oil Company, Petroleo Brasileiro S.A., Phillips Petroleum Company, Statoil, Texaco, Inc., and Total Minatome.

Mathematical modeling nses several Macintosh computers and digitizers, two Silicon Graphics workstations, and a variety of software. The mathematical simulation involves finite-element modeling, using *GEOSIM-2D®*, a program that can simulate combined brittle and ductile deformation, large strains, faulting, sedimentation, and erosion. The following topics were systematically investigated by numerical modeling: (1) controls on structural style of thin-skinned contraction above salt, (2) requirements for basal shear below salt sheets, and (3) various shaped allochthonous sheets loaded by different patterns of synkinematic sediments without regional extension.

Earthvision® is being used for full three-dimensional visualization, volumetrics, mapping, and creation of data volumes of structural traps from digitized cross sections of a physical model of sagging salt walls and associated faults produced during regional extension by gravity spreading. This visualization improves understanding of three-dimensional salt tectonics and can be used to enhance 3-D seismic surveys.

Two-dimensional animations increase comprehension of structural development in numerical models, physical models, and restorations. The following deformation processes were animated: (1) interlayer slip above an active diapir, (2) transtensional diapirism, (3) progradational welding of salt, (4) extension of an encased salt sheet, (5) glacial spreading of extrusive salt, (6) shortening superposed on extensional salt tectonics.

Two sites (one protected by a password) on the World Wide Web allowed users to access and duplicate releasable research results, including multimedia hypertext publications comprising animations, high-resolution color three-dimensional images, and searchable text.

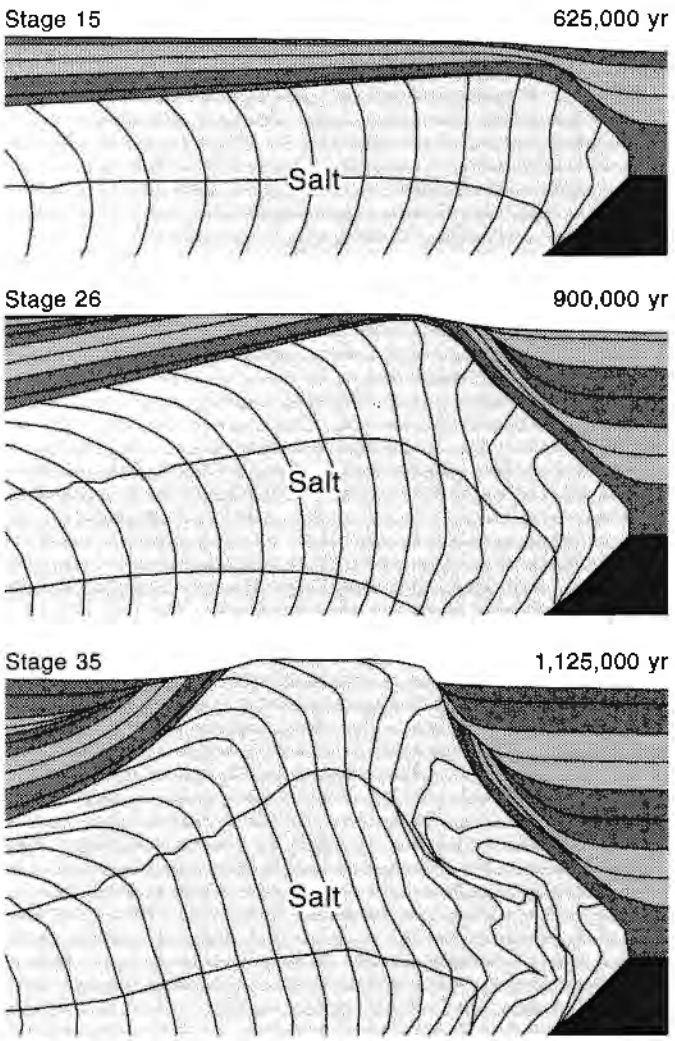
Applied Geodynamics Laboratory: Structure of Upheaval Dome, Utah

Martin P. A. Jackson and Daniel D. Schultz-Ela, principal investigators; Michael R. Hudec, Ian A. Watson, and Michael L. Porter (Exxon Production Research Company)

Field mapping of Upheaval Dome was funded by Exxon Production Research Company. Other funds were supplied by the industrial associates of the Applied Geodynamics Laboratory: Agip Petroleum S.p.A., Amoco Production Company, Anadarko Petroleum Corporation, ARCO Exploration and Production Technology/Vastar Resonrces Inc., BHP Petroleum (Americas) Inc., BP Exploration Inc., Chevron Petroleum Technology Company, Conoco Inc./DuPont, Exxon Production Research Company, The Louisiana Land and Exploration Company, Marathon Oil Company, Petroleo Brasileiro S.A., Phillips Petroleum Company, Statoil, Texaco, Inc., and Total Minatome.

Upheaval Dome is a breached, subcirenlar Mesozoic dome underlain by Pennsylvanian Paradox evaporites. Three-dimensional exposures suggest that Upheaval Dome represents the pinched-off stem of a salt dome. An overhanging salt extrusion abont 2 mi wide is postulated to have overlain the stem and to 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. 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.

Structural and stratigraphic mapping around Upheaval Dome focused on (1) gathering evidence for a growth history over several tens of millions of years, which would support its origin as a salt dome rather than as a meteoritic impact crater, and (2) determining the mode of emplacement of this structure by linked fault systems in the overburden. We synthesized



Finite-element model of the inflating crest of a salt sheet. Deformation was caused by rightward progradation of a sedimentary wedge across a salt sheet extending out of the figure to the left. The model simulates burial, then emergence, of the salt. Layering and unconformities in the sedimentary cover record leftward migration of the salt crest as the depocenter shifted rightward.

kinematic data, prepared a structural reconstruction of the dome's growth history, examined the petrography of clastic dikes in the core of the dome, and weighed evidence for or against diapiric pinch-off or impact. The results have been submitted for publication.

Land, Water, and Environmental Resources Investigations

Environmental, Geologic, and Hydrogeologic Studies

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

Bridget R. Scanlon and Jay A. Raney, principal investigators; Edward W. Collins, Alan R. Dutton, Richard S. Goldsmith, William F. Mullican III, Steven W. Tweedy, assisted by John F. Gamble and Junnrien Lai

Site characterization studies that describe the State's proposed low-level radioactive waste disposal site in northwest Eagle Flat basin continued in 1996. These studies involved continued monitoring of the saturated and unsaturated zones. Additional boreholes were drilled onsite to measure hydraulic and hydrochemical parameters. Investigations to support the installation and monitoring of a prototype engineered barrier were conducted. Expert testimonies were written in support of hearings for the site. The work was supported by the Texas Low-Level Radioactive Waste Disposal Authority and the U.S. Department of Energy.

In 1996, saturated zone investigations shifted from exclusively site characterization efforts to the design and installation of the facility's operational ground-water monitoring network. This effort has also resulted in a better understanding of site-specific controls, rates, and directions of ground-water flow. Two new monitor wells were installed and are now part of the ground-water monitoring network.

Unsaturated zone studies included detailed analysis of core samples collected beneath Grayton lake. Northwest Eagle Flat basin, which is the proposed site for the Texas facility, is a closed topographic basin that drains internally into Grayton lake, an ephemeral lake or playa. Analysis of sediments sampled from one borehole beneath Grayton lake for water content, water potential, and chloride indicated that subsurface water fluxes are low; however, preferential flow occurs along desiccation cracks beneath the playa as indicated by bomb pulse tritium and above-background levels of chlorine-36. Two additional boreholes were drilled in Grayton lake to confirm these findings. Pneumatic pressure tests were conducted to evaluate preferential air movement beneath the playa; however, the results suggest that the air permeability of the sediments is low.

Evaluation of air permeability is important in prediction of the upward movement of noxious gases such as radon, tritium, and carbon-14 through the engineered cover system. Pneumatic pressure tests were also conducted on the sand sheet to evaluate air permeability in this setting. These data are currently being analyzed.

Continued monitoring of hydraulic parameters at the Hueco Bolson and Eagle Flat sites results in a unique data set that evaluates the response of different geomorphic surfaces to atmospheric forcing. Maintenance of a monitoring program is very time consuming, particularly for instruments such as thermocouple psychrometers, which are not very robust and have a limited lifespan. Additional boreholes were drilled, and the installation process for retrievable thermocouple psychrometers was improved in 1996.

Studies of the proposed prototype engineered barrier continued in 1996. The performance of two different designs, the proposed asphalt barrier and a capillary barrier, will be tested. These various designs will be tested under ambient precipitation and enhanced precipitation conditions using an irrigation system. A variety of instruments will be used to monitor water movement through the engineered barrier, such as time domain reflectometry (TDR) and neutron probes for water content, heat dissipation probes and thermocouple psychrometers for water potential, and thermistors for temperature. Instrument trees will be used to install the TDR

Bureau researcher examines calcic soil exposed in exploratory trench at the State's proposed site for a low-level radioactive waste disposal facility in Hudspeth County, Texas. The calcic soil is probably more than 100,000 to 300,000 years old. The exploratory trench was excavated in the fall of 1996 and is about 400 ft long and has a maximum depth of about 30 ft. The trench verified geologic relationships inferred from boreholes at the site. Photo by Jay A. Raney.

and heat dissipation probes in the subplots. Horizontal neutron probe access tubes will be installed at critical depths, and a SEAMIST system will be used to monitor water content with the neutron probe. A new thermocouple psychrometer design that is currently being used in the high-level nuclear waste program at Yucca Mountain is being evaluated for the engineered barrier. The prototype barrier system will be monitored for at least 30 years; therefore, great emphasis has been placed on installing robust or retrievable instrumentation. The data set developed from this program will be unique and will be the first to critically evaluate different designs of engineered barriers to minimize infiltration into the waste. This program involves coordination with many other groups such as civil engineers who conduct performance assessment simulations and geotechnical engineers who are responsible for quality control on the installation of the barrier materials.

Lower Rio Grande Valley Geographic Information System

E. G. Wermund, Gene J. Paull (The University of Texas at Brownsville), and Eric Rieken (The University of Texas–Pan American), principal investigators; Thomas A. Tremblay

This project, funded by the Texas Higher Education Coordinating Board, involves the construction of a geographic information system (GIS) of the Rio Grande delta plain. The GIS will provide data useful for managing the demand for, and supply of, surface water in the region. The study area comprises the late Pleistocene Rio Grande delta, which includes parts of Starr, Hidalgo, Willacy, and Cameron Counties in Texas and part of the State of Tamaulipas, Mexico. Spatial data sets include surficial geology, hydrography (natural and artificial features), topography, transportation, land use, census boundaries, and other cultural features.

The Bureau has gathered and digitized data sets of the hydrography, topography, transportation, and surficial geology GIS layers of the entire delta region. Electronic data sets acquired from the U.S. Geological Survey (USGS) and the Texas Department of Transportation have been extended into Mexico by means of digitization of Instituto Nacional de Estadistica Geografia e Informatica maps. Surficial geology of the Rio Grande delta has been digitized from several sources, including the Bureau's *Environmental Geologic Atlas of the Texas Coastal Zone (EGAT)*, a geologic map from an incomplete University of Texas at Austin dissertation, a geologic map contracted by the Mexican government, aud original mapping interpreted from aerial photography.

Project participants at The University of Texas–Pan American have enhanced USGS hydrographic data by assigning codes to distinguish irrigation from drainage features and by modifying linear hydrographic features to reflect contribution and diversion data and average monthly flow data. The University of Texas at Brownsville group—a principal liaison with Mexican universities—has digitized a historical land use layer from *EGAT* working maps. Interpretation of vintage Edgar Tobin photomosaics completed the historical land use layer for the Lower Rio Grande Valley GIS.

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

Jeffrey G. Paine, principal investigator; Erika M. Boghici, Alan R. Dutton, Thomas A. Tremblay, Steven W. Tweedy; assisted by Martina U. Blüm and Ianthe Nelson

This project, funded by the Railroad Commission of Texas, demonstrated an application by the Bureau and Dighem I-Power of an integrated airborne and ground-based geophysical approach to characterizing near-surface salinization of soil, surface water, and ground water. Near-surface salinization is a chronic environmental and agricultural problem in many parts of Texas and arises from several sources: upward movement of subsurface brine along natural conduits, brine infiltration from leaking oil and gas wells, downward brine migration from surface disposal pits, and evaporative concentration in shallow ground water. In this study of a 35-mi^2 area near Ballinger in Runnels County, Texas, we employed geophysical methods to locate areas of brine infiltration and examined how geophysical and hydrogeological methods can best be used to determine sources of salinity.

Airborne and ground-based geophysical surveys proved to be useful in the search for brine sources in general and leaking wells in particular. Airborne surveys offer the advantages of rapid coverage of large areas, broader context for potential leak sites, and knowledge of the shape and change with depth of conductivity anomalies. The airborue magnetometer used in this study was sensitive enough to detect subtle magnetic field perturbations related to well casings, bnt not every magnetic anomaly was a well casing and not every well casing was detected. Nevertheless, the magnetometer was helpful in locating unknown or mislocated wells and in identifying potentially leaking wells where magnetic and conductivity anomalies coincided.

The airborne data indicated a wide range in ground conductivity. The high-frequency, shallow-penetration coils detected many conductivity anomalies across the study area. Many of these conductivity highs are not caused by leaking wells but rather are related to changes in soil type, soil moisture, or surface features such as brine pits, stock tanks, and streams. The low-frequency, deep-penetration coils detected fewer conductivity anomalies. However, they were useful in determining (a) whether anomalies at shallower depths had surface or subsurface sources and (b) where brines are most likely to naturally infiltrate the near-surface environment. Maps produced with the moderate-frequency coils had less land-surface-related detail than maps produced from the high-frequency coils, yet they contained the conductivity anomalies that were most likely to represent leaking wells.

Ground-based geophysical methods proved valnable in locating actual well sites and determining whether a given well was likely to be leaking. These methods included magnetometer surveys to locate buried well casings, conductivity profiles to determine whether there was evidence of a near-surface leak and to establish the lateral and vertical dimensions of brine infiltration, and time-domain electromagnetic soundings to determine brine plume thickness, explore deeper con-

ductivity changes, and identify subsurface brine-bearing stratigraphic units.

Chemical analyses of soil and water samples collected by the Bureau, the Lower Colorado River Authority, and the Colorado Municipal Water District provided ground truth for the geophysical data and helped differentiate between natural, agricultural, and oil-field-related causes of near-surface salinization. Salinization related to a brine pit and that related to evaporative concentration may be difficult to distinguish using airborne and ground-based geophysical surveys, but their chemical compositions have been shown to differ enough to enable us to distinguish the two sources.

Remediation-Focused Hydrogeological Investigations of Abandoned Oil Field Cleanup Sites

Alan R. Dutton, principal investigator; W. R. Kaiser, Jeffrey G. Paine; Philip C. Bennett (UT Department of Geological Sciences); assisted by Edward S. Angle, Martina U. Blüm, Wanjoo Choi, William H. Doneghy, Jordan W. Forman, Jr., Andy M. Graham, Leslie B. Kelly, Jr., and Steven W. Tweedy

The Railroad Commission of Texas (RRC) has statutory responsibility under S.B. 1103 (72d Legislature, 1991) for oversight of cleanup of abandoned oil field sites throughout Texas. The RRC identifies abandoned sites in need of remediation by receipt of complaints and by routine RRC field inspection. Straightforward solutions for cleanup are readily apparent for many of the sites. At other sites, selecting cost-effective approaches to site cleanup requires information on the less well defined subsurface extent of contaminant plumes and location of contaminant sources. Remediation-focused investigations by the Bureau are designed to limit cost to the State of Texas for reducing risk to public health and safety and the environment by applying to the largest extent possible nonintrusive and cost-effective techniques to define the extent of the problems at selected abandoned oil field sites.

During 1996 the Bureau completed work on two sites begun the previous year. A site in Brazoria County has oil-contaminated drilling mud in mud-disposal pits, and another site in San Patricio County involves continued oil seepage from a subsurface oil lens into a coastal creek. At both of these sites the focus of work was on defining measnres to prevent ongoing contamination, mapping the extent of contamination in the subsurface, characterizing the source of contamination or the waste package, and recommending options for site cleanup.

The Bureau began work in 1996 on eight additional sites at or near abandoned oil fields. One site has a group of salt-water seeps near the Red River in Montague County. A second site is in Jones County where a subsurface oil lens of unknown source has contaminated a water-supply well. A third site involves identifying an unknown source of accumulating natural gas in the shallow subsurface thought to have caused a house explosion. The other five additional investigations involve abandoned oil-reclamation sites and abandoned disposal pits contaminated with salt water or oil or both. Investigations at these eight sites are expected to be completed in 1997.

Hydrogeologic and Biologic Survey of Texas National Guard Training Facilities

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

Bureau scientists conducted ground-water and surface-water investigations on Camps Barkeley, Bowie, Fort Wolters, Mabry, Maxey, and Swift to provide the Texas Army National Guard with information needed to preserve environmental quality and resources while planning training and preparedness

A soil-gas survey was used to delineate the probable extent of a subsurface crude-oil plume in an abandoned oil field, target optimal borehole locations for core samples, and help identify the source of the crude-oil seep. Soil-gas samples were collected using a truck-mounted, hydraulic-driven soil probe and analyzed for volatile aromatic and aliphatic compounds onsite using gas chromatography. Photo shows soil-gas samples being collected along the embankment overlooking the oil seep. Photo by David M. Stephens.

activities. For the ground-water study, the Bureau assembled hydrogeologic data bases; conducted onsite and perimeter well surveys; installed, monitored, tested, and sampled monitoring wells; defined predominant ground-water flow directions, and developed conceptual ground-water flow models for each camp. For the surface-water study, the Bureau identified principal streams and drainage basins, estimated flow duration and flood frequency, and calculated floodplains for each of the camps. All of the ground-water and surface-water spatial information was digitized into a geographic information system and delivered to the Guard in digital form.

The Bureau carried out the study in conjunction with aquatic biology surveys conducted by the Texas Parks and Wildlife Department; the joint project was coordinated by the Nature Conservancy of Texas.

Determination of the Extent of Deforestation in Belize 1989/92–1994/96

William A. White and Jay A. Raney, principal investigators; Thomas A. Tremblay; Melba M. Crawford and Solar S. Smith (UT Center for Space Research)

Funded by the United States Agency for International Development, this project was a collaborative investigation between the Bureau and the Center for Space Research to determine the extent of deforestation that occurred on mainland Belize between 1989/92 and 1994/96. To accomplish this objective, total forest cover, delineated through analysis of recent digital Landsat Thematic Mapper imagery, was compared with total forest cover on existing baseline maps prepared from earlier SPOT satellite imagery. Spatial and temporal changes in forest cover were determined using a geographic information system. Work on the project was in cooperation with the Land Information Center, Forest Department, and Lands and Survey Department of the Ministry of Natural Resources, Government of Belize.

Belize has extensive forest and associated woodland resources characterized primarily by tall, highly diverse broadleaf forests, and secondarily by pine forests, low scrubby woodland areas, and abundant mangroves. Among the environmental issues facing Belize is deforestation. Recognizing the importance of forest resources, the Government of Belize has established numerous protected areas including national forest reserves, nature reserves, wildlife sanctuaries, national parks, and conservation and management areas. Private reserves add to the area of protected lands. Together, national and private protected areas encompass approximately 36 percent of mainland Belize.

Results of the investigation show that from the 1989/92 baseline period to 1994, approximately 78,000 ha of forest and associated woodland cover was cleared. Most losses in forest cover were due to agricultural development ranging from large citrus orchards, to mixed farming and cropland, to individually small but cumulatively large areas of milpa farming (shifting cultivation). Average rates of forest cover loss ranged from less than 5,000 ha/yr in southern Belize to more than 13,000 ha/yr in northern Belize. The rate of loss throughout the country, however, was almost 25,000 ha/yr from the baseline period of 1989/92 to 1994. This is a substantial increase in the rate of clearing of forest and associated woodlands over the past 2 to 5 years relative to previously published rough estimates (<10,000 ha/yr) for the past decade (1981–1990). Even if the estimates in this reconnaissance study are as much as 20 percent too high, the rate of deforestation is still very significant. Of the total loss in forest cover, less than 9 percent occurred in protected areas, which is a testament to their success in protecting forest resources. Results and recommendations of the study were presented in a final report and workshop in Belmopan, Belize, in June 1996.

Calculation of Texas Lignite Resources using the National Coal Resources Data System

W. R. Kaiser, principal investigator

This long-term project funded by the U.S. Geological Survey (USGS) provides estimates of remaining near-surface Texas lignite resources using USGS methodology and the National Coal Resources Data System (NCRDS) and software. The project was completed this year with the calculation of resources in the Jackson Group and Yegua Formation of East Texas and Jackson and Wilcox Groups of South Texas. Resources of the Wilcox Group in three East Texas regions were calculated in previous years of this project. Statewide NCRDS lignite resources, calculated using USGS methodology, total 46,979 million tons, of which 15,767 million tons (34 percent) are demonstrated resources. Most of the resources are in beds 2.5 to 5 ft thick. Two-thirds of the resources are in the Wilcox trend and one-third in the Jackson-Yegua trend. The state's richest lignite regions are the Wilcox trend from Bastrop to Freestone Counties in east-central Texas and the Jackson-Yegua trend from Fayette to Angelina Counties in East Texas.

Salt Cavern Studies—Regional Salt Thickness Map in the Midland Basin

Susan D. Hovorka and Jay A. Raney, principal investigators

Utilization of salt caverns in bedded salt for storage of products or disposal of wastes associated with oil and gas exploration and production activities is an attractive alternative to other storage and disposal options if there is assurance that products or wastes will remain isolated in the salt caverns. Both regulators and salt cavern developers and operators need access to information about bedded salt to assist them in selection of potential areas. This 6-month project maps the thickness of the major salt-bearing unit, the Salado Formation, in the Midland Basin region. Variable salt thickness may correspond to areas of decreased salt quality and potentially higher risk that salt may be locally breached. Decreased salt thickness is recognized in several areas. Salt has been dissolved along the east margin of the basin. Salt has also been dissolved in areas such as over the reef margin in Winkler County. Depositional complexity in salt thickness is recognized in several areas, especially in

areas of complex basin geometry such as Pecos County. Relationships among salt thickness, depositional trends, and structures are noted.

Texas Parks and Wildlife Support, Big Bend Ranch

Jay A. Raney, principal investigator; Deborah A. Salazar; assisted by John R. Andrews

The Texas Parks and Wildlife Department has provided support for the digitization of the geologic map of Big Bend Ranch State Park, the largest of the Texas State parks. This digital map, prepared in a geographic information system, will be published as a plate (scale 1:50,000) in both a techuical repori on the Tertiary igneous history of the park and in a geologic report written for park visitors. The eastern portion of Big Bend Ranch, which includes the Solitario, an enormous dome formed by a laccolithic intrusion, is portrayed on a separate map (scale: 1:24,000) and is described in the Bureau's Report of Investigations No. 240. The preparation of the digital map completes earlier work done in conjunction with Texas A&M University and the Texas Parks and Wildlife Department. The digital map will be used by the Texas Parks and Wildlife Department in management of the park and by researchers to assist with other investigations of Big Bend Ranch. The geology of the park was mapped by Christopher D. Henry of the Nevada Bureau of Mines and Geology and William R. Muehlberger of the Department of Geological Sciences, The University of Texas at Austin.

Scientific and Economic Analysis of Various Natural Resource Issues Related to Designated Real Property Assets of the Permanent School Fund

Alan R. Dutton, principal investigator; William F. Mullican III

The purpose of this work for the Texas General Land Office (GLO) is to reevaluate the ground-water resources and reserves beneath Permanent School Fund (PSF) lands in El Paso and Hudspeth Counties of West Texas. State lands in this region are in need of sustainable water supplies for economic land development but have only limited known surface- and ground-water reserves. Growth of tbese reserves by identification of currently undeveloped ground-water resources would enhance the value of PSF properties being leased or sold for Texas by the GLO. In this pilot study, the Bureau will collate and organize hydrogeologic data for El Paso County and reevaluate the potential for ground-water resources to support development of the East El Paso Planned Community.

Hydrologic Needs Assessment and Technical Support for the Panhandle Ground Water Conservation District No. 3

William F. Mullican III, principal investigator; Robert E. Mace; assisted by Norman D. Johns and Michael R. Harren

The severe drought that has occurred in Texas for the past several years has greatly heightened awareness of the need for careful water resource management if water requirements in the state are to be met into the 21st century. The Panhandle Ground Water Conservation District No. 3 is one of approximately 41 districts set up in Texas to manage and conserve ground water within their boundaries. The District is required to determine the annual amount of depletion of ground-water resources that has occurred for laud owners to meet Federal depletion-tax rules. The Bureau worked with the Panhandle Ground Water Conservation District No. 3 in a study of the Ogallala aquifer to (1) establish reproducible and statistically defensible techniques to monitor and documeut ground-water depletion and (2) develop revised depletion rules that might be implemented to conserve ground-water resources. Bureau scientists reviewed the procedures and tools used by other conservatiou districts to manage ground-water resources and evaluated the impact of adapting these management techniques for the Panhandle Ground Water Conservation District No. 3. Bureau scientists recommended modifying the District's existing depletion-estimation method with calculations based on statistical screening parameters.

Environmental Restoration at the U.S. Department of Energy, Pantex Plant, Texas Panhandle

Thomas C. Gustavson and Jay A. Raney, principal investigators; Richard S. Goldsmith, Susan D. Hovorka, William F. Mullican III, Jeffrey G. Paine, and Bridget R. Scanlon; assisted by Norman D. Johns

Bureau scientists recently completed a 5-year geologic and hydrogeologic characterization study of the U.S. Departuent of Energy's (DOE) Pantex Plant and surrounding region. As a result of this study, the Bureau has developed special expertise regarding the geologic setting and characteristics of the Pantex Plant, perched aquifers, the Ogallala aquifer, and the fate and transport of contaminants at the facility. The Bureau continues to assist the Governor's Office and State agencies in their Pantex-related activities through an Agreement in Principle (AIP) between the Department of Energy and the State of Texas. As part of this program, the Bureau provides technical assistance

and review of environmental monitoring programs and independent review of DOE Pantex National Environmental Policy Act (NEPA) documents submitted to meet environmental requirements.

Bureau participation in the environmental monitoring program has included (1) active monitoring stations to evaluate ground-water flow in the unsaturated zone, (2) review of reports addressing background radioactivity levels in soil and ground water in and around the site, (3) review of ground-water modeling results related to the fate and transport of contaminants in the perched aquifer, and (4) participation in AIP public meetings in Amarillo to discuss State oversight activities. NEPA documents reviewed for this effort included DOE Environmental Assessment, Pantex Plant Environmental Impact Statement, and DOE Defense Nuclear Facility documents.

Investigation of Shallow Class V Injection Wells at TxDOT Maintenance Sections

Alan R. Dutton and Thomas C. Gustavson, principal investigators; Andrew R. Scott, assisted by Martina U. Blüm and Juan C. Jimenez

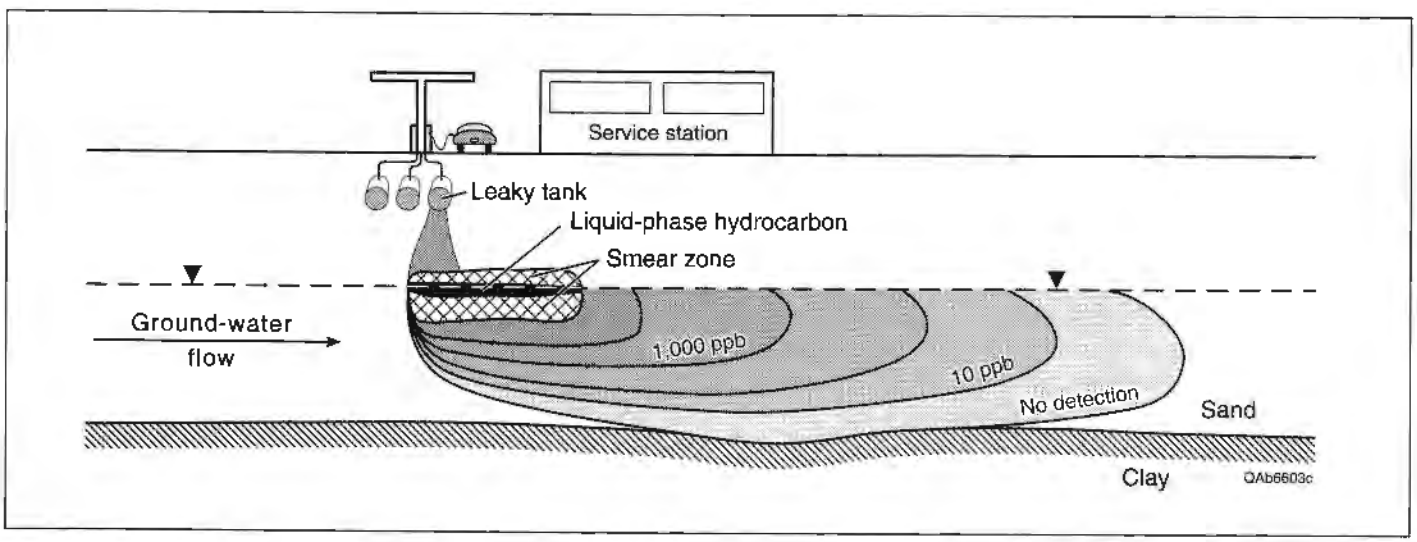
Shallow large-diameter injection wells (Class V injection wells) have been used to dispose of waste fluids at a number of Texas Department of Transportation (TxDOT) maintenance sections. TxDOT has initiated plans to identify maintenance sections with Class V injection wells and to conduct remediation-focused site assessments to reduce risk to public health and safety and the environment. The scope of Bureau investigations during 1996 was to conduct a comprehensive survey of the 310 TxDOT maintenance sections to identify those that have Class V injection wells where contamination might have occurred and to prioritize sites for investigations leading to remediation or closure. On the basis of responses to a written questionnaire and of site visits, approximately 60 maintenance sections have been identified as having used injection wells. Plans for environmental assessments and remedial feasibility studies were prioritized on the basis of ranking criteria that focused on environmental risk factors and waste and injection well characteristics.

Extent, Mass, and Duration of Hydrocarbon Plumes from Leaking Petroleum Storage Tank Sites in Texas

Robert E. Mace, R. Stephen Fisher, and Alan R. Dutton, principal investigators; Edward W. Collins, David M. Welch; assisted by Sandra P. Parra, Michael R. Harren, Carlos I. Huerta-Lopez, Wan-Joo Choi, and Nurlan I. Muratov

The Bureau performed a statistical analysis of fuel hydrocarbon (FHC) plumes at leaking petroleum storage tank (LPST) sites in Texas on behalf of the Texas Natural Resource Conservation Commission (TNRCC). The study consisted of compiling and summarizing LPST site information and quantifying the size, mass, and duration of FHC plumes in Texas to determine (1) plume dimensions, (2) predictability of plume concentrations and lengths, (3) the rate at which plumes self-remediate, and (4) classification of plume behavior for use by the TNRCC in risk assessments.

The Bureau compiled site, soil, hydrogeologic, and analytical information from 605 LPST site files at the TNRCC and entered the information into spreadsheets and data bases. The resulting data base contains analytical and water-level data for more than 4,000 monitoring wells. Well locations and water-level and analytical data were used to determine hydraulic gradients, ground-water flow directions, average plume concentrations, and plume dimensions over time.



Cross section of a hypothetical gasoline leak and resulting plume of dissolved hydrocarbon. The gasoline leaks from an underground storage tank system, moves downward through the unsaturated zone by the force of gravity, collects on top of the capillary fringe of the water table, and slowly dissolves into the ground water. The dissolved hydrocarbon then moves down gradient with the ambient ground-water flow. Our study investigated the lengths of these dissolved hydrocarbon plumes and their relation to hydrogeological properties.

About 25 percent of LPST sites impact or pose a risk to pnblic health and safety. Plnmes, however, are relatively small in lateral and vertical extent, and most have stable concentrations and lengths. Seventy-five percent of the plumes have lengths of less than 250 ft and areas of less than 49,000 ft^2. Almost 40 percent of the plumes extend beyond the property boundaries. Median thickness of the affected water-bearing zone, which generally lies at shallow depth, is 11 ft.

Plume length appears to be mainly determined by the timing, duration, and magnitude of the spill. Estimated plume lengths do not appear to be dependent on hydrogeology or cleanup (pump and treat) history. Another potential contributing factor is that biodegradation rates vary between aquifers and regions of the state.

Plume mass and length appear to follow a predictable life cycle, with most plumes having stable or decreasing concentrations and dimensions. Plume lengths increase, stabilize, slowly decline, and then rapidly decline over time. Plume mass increases, stabilizes, rapidly declines, and eventually approaches low concentrations with time. Only 14 percent of plumes we studied are increasing in average benzene concentration, and 3 percent are still increasing in length. Most plumes are either stable or are decreasing in concentration and length.

Results of the study show that ground water at most sites is relatively fresh and very shallow. About 90 percent of sites have ground water with total dissolved solids less than 3,000 ppm. Approximately 75 percent of sites have depths to water less than 16.2 ft below land surface.

Monitoring Techniques Related to Subsurface Gas Transport

Bridget R. Scanlon, principal investigator; John F. Gamble and Edward S. Angle

A critical issue related to near-surface disposal of low-level radioactive waste is migration of gases generated by the waste to the surface. Gaseous radionuclides in low-level waste include H-3, C-14, and Rn-222. Transport mechanisms include diffusive transport or advective transport resulting from barometric pressure changes or both. Analysis of gas transport is important at many low-level waste disposal facilities, as shown by the inteusive program to monitor concentrations and concentration gradients of gaseous radionuclides proposed for the California low-level radioactive waste disposal facility. The Bureau is involved in evaluatmg methods of monitoring gaseous transport in the unsaturated zone at the Maricopa site, which is part of the University of Arizona. This project is part of a larger program sponsored by the Nuclear Regulatory Commission to evaluate unsaturated zone monitoring techniques. The initial stages of the project involved devcloping an air injection/extraction system for field use and testing of different transducers. Various analytical and numerical techniques are being evaluated for processing the pneumatic pressure data.

Brazos River Erosion Assessment

Thomas C. Gustavson, principal investigator; Graeme R. Bullen

This project, fuuded by the Texas Parks and Wildlife Department, was undertaken to assess the potential for increased erosion in the Brazos River channel caused by sand and gravel mining and to evaluate the economic importance of these mining activities.

The history of lateral migration of the channels in river segments upstream of, within, and downstream of the area of sand and gravel mining operations was used to assess erosion potential. Over a 20-year period, lateral migration of meanders and amplitude of meanders were not as pronounced in the mining area as in the comparative reach upstream of the mined area. This difference is attributed to higher river banks in the mined area. Bar sediment grain-size analysis documented sediment texture. There is no evidence of increased bank erosion due to sand and gravel mining in the Brazos River.

Analysis of economic data indicates that between 1979 and 1995 sand aud gravel operators produced 10,067,848 cubic yards from the Brazos River. The State of Texas received $2,170,153 in royalties from these operations. The operators produce 2 to 3 percent of the sand and gravel in the state and supply a critical component of these resources for the Houston area construction industry.

Identification of Geologic Analogs for Engineered Barriers

Susan D. Hovorka and Jay A. Raney, principal investigators

Engineered barriers constructed primarily of earthen materials are used as a principal containment technology for disposal facilities throughout arid regions of the western United States. The disposal of low-level radioactive materials (as at the proposed Texas low-level radioactive waste disposal facility), toxic and hazardous substances, and mixed wastes relies on similar methodologies. The purpose of this project is to document the physical, chemical, and mineralogic changes in geologic deposits that have been modified by natural processes for thousands of years as analogs to what might happen to engineered deposits over the long time frame. The role of fine-grained clays and marls in limiting vertical permeability and the extent to which in situ gravels function as capillary barriers to flow in the unsaturated zone are of particular interest. Geologic analog studies are intended to complement and add to confidence in numerical simulations of long-term barrier performance.

Ten areas in Texas, New Mexico, Arizona, Utah, and California were selected for field evaluation of geologic analogs. These areas are similar to engineered barriers in terms of climate, texture, and stratigraphic sequence. Holocene and Pleistocene lake deposits and alluvial sediments were examined for evidence indicative of the rates and processes of vertical and lateral moisture flux. Fracturing, soil-forming processes, penetration

by roots and burrows, calcite dissolution and precipitation, precipitation of iron and manganese oxides, and bleaching were the major changes noted. The geomorphic setting exerts a dominant control on the amount and type of alteration. Analogs in alluvial settings where moisture has been intermittently ponded in the river or gully floor, on the surface, or as shallow ground water above bedrock have undergone more alteration than abandoned lake deposits on hill slopes. The amount of alteration also depends on the composition of the fine-grained layers. Clay beds containing a significant component of expansive clays have been cracked and exhibit soil fabrics. Fine-grained sediments with a significant component of carbonate and probable diatomite appear to have been only slightly altered.

These observations compliment site-specific observations and suggest that further experimentation with the composition of the fine-grained layers may be warranted.

Estimating Depth to Bedrock

Jeffrey G. Paine, principal investigator

This project, funded by the Texas Department of Transportation, represents a cooperative effort by the Bureau and the Center for Transportation Research (CTR) to estimate depth to bedrock across the State of Texas using available soil and geologic data along with rapid geophysical tests. Depth to bedrock estimates, which are necessary for roadway design, are currently based on analysis of falling weight deflectometer data without benefit of the abuudance of information available on near-surface soils and rocks. Considerable effort has been expended over the last few decades by geologists, soils scientists, engineers, and geomorphologists to produce maps, cross sections, and soil profiles that focus on the upper few meters of the subsurface, a critical zone for roadway design. These data may provide a semi-quantitative basis for determining regional and local differences in expected depths to bedrock across Texas. Further, they can complement field measurements of depth to bedrock by allowing optimized test design for anticipated bedrock depths and by providing a geological coutext for site-specific test data.

In this project, Bureau and CTR researchers will (1) evaluate the utility of existing soils and geological maps in estimating depth to bedrock, (2) establish regional variations in near-surface rock and soil properties that might allow the state to be subdivided into regions of similar physical properties, (3) establish soil and rock type variations within a region that allow definition of units that have similar physical properties and depth to bedrock ranges, (4) develop guidelines for survey design, acquisition parameters, and analysis of proven seismic refraction technology for accurate depth to bedrock estimates, and (5) develop procedures and guidelines that would allow a project engineer to estimate bedrock depths on the basis of the project region and geologic and soil units within the region, select appropriate sites for seismic refraction surveys if more detail is necessary, and optimize the acquisition parameters for the refraction survey on the basis of the qualitative depth to bedrock estimates from geologic and soil maps.

Coastal Studies

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

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

The shapes, elevations, and sediment and vegetation distributions of barrier islands may change dramatically over a short period of time, such as during a storm. Even between storms sediment is constantly shifting to and from these islands and between different areas of the islands at varying rates and in varying amounts. This 3-year project, which is funded by NASA and jointly conducted by the Bureau and the Center for Space Research at The University of Texas at Austin, is developing the use of airborne synthetic aperture radar (AIRSAR) to map coastal topography and sedimentary environments. We are evaluating the use of AIRSAR to detect old features such as storm scarps, storm channels, former tidal inlets, and beach ridges that have been obscured by vegetation, erosion, deposition, and artificial filliug. We are also modeling polarimetric multiband radar signatures on the barrier island/spit systems. This modeling will aid the interpretation and automated classification of images into subenvironments. Methods developed during this project will provide coastal geologists with an unprecedented tool for detecting and understanding sedimentological changes. This understanding will improve overall coastal management policies and will help reduce the effects of natural aud man-induced coastal hazards.

We are attempting to obtain topographic information by using interferometric techniques to analyze the radar data. The method is based on the concept that radar signals received by two antennas are processed with the same Doppler frequency to form images. Assuming that the two antennas are within the scattered beam of the same ground resolution cell, then the signals reflected from a scatterer on the ground will interfere with each other. The phase difference between the two paths is then used to derive ground elevation. Using this technique, we had hoped to be able to detect topographic change of 30 cm or less. It appears, however, that we will not be able to obtain vertical resolution of better than about 60 cm. For this reason, NASA is currently considering flying an airborne laser altimeter mission over our area next year. The altimeter data should have a vertical resolution of 10 cm or better.

In addition to operating the AIRSAR instrument in a topographic mode, we obtained, in 1995 and 1996, fully polarimetric multiband radar data. Using the 1995 data, we have shown that radar can discriminate sedimentary sub-environments on barrier island systems. L-band (wavelength

Interior of NASA's DC-8 aircraft configured for obtaining airborne synthetic aperture radar (AIRSAR) over the upper Texas coast. This joint project of the Bureau and the Center for Space Research at The University of Texas at Austin is exploring the usefulness of AIRSAR for studying coastal environments. Photo by James C. Gibeaut.

of 24 cm) appears to best delineate beach ridge and swale morphology and different wetland environments. L- and P-bands (wavelength of 68 cm) appear to indicate extensions of tidal creeks and faults cutting across the islands that may not be visible on aerial photographs. L- and P-bands can also delineate former breaches caused by storms and dredging. C-band (wavelength of 5.7 cm) provides the greatest detail related to vegetation. In addition, AIRSAR data can image subtidal features, wave refraction, and current patterns in shallow (less than 4 m) tidal-inlet systems.

We successfully completed our second AIRSAR mission on June 24 and 25, 1996. During the flight, we collected sediment, vegetation, and topographic data. These ground data will aid the mathematical modeling and interpretation of the radar data. In 1996, we obtained radar data that will provide pixel sizes 4 m × 4 m, which is twice the spatial resolution as our 1995 data. The higher resolution will provide significantly better images and allow more detailed mapping. Our third mission over the area is scheduled for the fall of 1997.

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

Robert A. Morton, principal investigator; William A. White, Edward S. Angle, Sigrid J. Clift, L. Edwin Garner, James C. Gibeaut, and Tucker F. Hentz; assisted by Laura B. Stewart and Kami Norlin

Coastal erosion and wetland loss in Texas are occurring at rapid rates in some areas that are undergoing rapid economic development. Erosion and submergence threaten transportation networks, a large industrial complex, ports, and high-density development. Understanding and solving these problems requires an extensive quantitative data base and predictive models that can forecast future changes. To address these needs, the Bureau 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 assure that future economic development of the coastal region is compatible with a dynamic system. Specific objectives of the study include (1) providing technical data on coastal erosion and land loss to government, industry and coastal planners, (2) predicting future 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 1996 we (1) conducted a real-time differential kinematic GPS (global positioning system) survey of the upper Texas coast Gulf shoreline from Sabine Pass to Galveston, (2) completed an investigation of the lower Sabine, Neches, Trinity, and San Jacinto Rivers and associated incised valleys that documented the differences in the late Pleistocene and Holocene fluvial systems and how those systems responded to fluctuations in climate and sea level, (3) completed an investigation of recent wetlands changes along the upper Texas coast associated with active faults near oil and gas fields, (4) completed an investigation of foraminiferal assemblages in five deep auger cores taken from the coastal plain interfluve near High Island, chenier plain near Sabine Pass, and incised valley (Sabine Lake), (5) collected and described 11 vibracores taken from Galveston Island and Bolivar Peninsula to determine the composition and age of sediments underlying anomalously high topographic features in the barrier island complexes, (6) developed the Shoreline Shape and Projection Program (SSAP), a computer program that predicts future shoreline positions on the basis of past shoreline changes, and (7) completed an analysis of wave refraction in the study area and its relationship to historical changes in position of the Gulf shoreline. This multidisciplinary approach is designed to provide a better understanding of the geological evolution of the southeastern Texas coast and to offer a basis for predicting environmental changes that might occur in the future.

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

Michael D. Blum (University of Nebraska–Lincoln) and Robert A. Morton, principal investigators

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

responded to climatic and eustatic changes during the last 150,000 years. An improved understanding of the interaction between coastal evolution and threshold values of sea-level rise will provide better predictions of possible future changes in coastal environments and natural resources.

In 1996, personnel from the Bureau and the U.S. Geological Survey Coastal Division (St. Petersburg, Florida) conducted high-resolution seismic surveys throughout Nueces Bay and in portions of northern Corpus Christi Bay, northwestern Copano Bay, and western Redfish Bay. The digital seismic profiles recorded during these surveys image the incised valleys and postglacial fills. The profiles also provide a stratigraphic framework for correlating surfaces of subaerial exposure and marine erosion with similar surfaces observed in auger cores and vibracores taken across the valley and within the fill. Integration of the seismic profiles and cores provides a basis for interpreting the geologic history of the region and how sediment loads, river discharge, and channel patterns evolved as climate and sea level changed during the last glacio-eustatic cycle.

Shallow-Water, High-Accuracy, High-Resolution Bathymetric Surveying System

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

Developing and testing conceptual and theoretical models of coastal sedimentation require bathymetric surveys more precise than those that are currently available. Precise surveys are difficult to make 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 errors inherent in conventional bathymetric surveys. The improved surveying system will include a portable computer for integrating digital records from (1) precision depth recorder, (2) heave compensator, (3) electronic compass, and (4) global positioning system (GPS). The heave compensator, which is a motion sensor, will correct for the boat motion, whereas the GPS elevations will provide a way of correcting for water-level differences.

The work in 1996 focused on conducting and analyzing data from controlled laboratory and field tests. These tests have driven numerous design improvements and have begun to determine the vertical accuracy and repeatability of the system in depths from 1 to 6.5 ft. To test the accuracy of the system, we obtained a reference transect with conventional land surveying equipment and a rod person who waded into a lake. Compared to this transect, the system had an average error of 0.1 ft for five repeated surveys when the boat was rolling 10 degrees. Vertical repeatability for these five surveys is described by their standard deviations, which ranged from 0.1 to 0.2 ft at fixed positions along the profile. We now think that we can reduce our error by improving the synchronization of the various data streams. We are continuing this work in 1997 under a new grant.

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

Investigating the Status and Trends in Seagrass in the Corpus Christi Bay System

William A. White, principal investigator; Warren Pulich (Texas Parks and Wildlife Department)

As part of a project sponsored by the Corpus Christi Bay National Estuary Program, the Bureau was subcontracted by the Texas Parks and Wildlife Department (TPWD) to assist in determining the status and trends of seagrass iu the Corpus Christi Bay system. Major objectives of this study were to assist TPWD in (1) documenting historical changes in seagrass distribution since the 1950's and (2) determining natural and artificial processes that have contributed to the changes. Because seagrass beds are dominant and essential ecological habitats in the Corpus Christi Bay system, understanding their spatial and temporal distribution patterns is important for developing sound management programs to maintain the health of the bay system. Investigative methods were patterned after those used in the Galveston Bay system, where dramatic losses in submerged aquatic vegetation have occurred since the 1950's as a result of a combination of natural and human processes. In the Corpus Christi Bay system, historical aerial photographs dating from the 1950's, 1960's, 1970's, and 1980's, providing more than 40 years of records through 1994, were used to document changes in seagrass beds. Analyses were carried out using a geographic information system. Areas in which historical changes in seagrass beds were investigated included the Redfish Bay/Harbor Island complex and Mustang Island. Preliminary results indicate an expansion of seagrasses between the 1950's and mid-1970's in the Harbor Island and Mustang Island areas and losses in seagrasses in Redfish Bay. Expansion of seagrasses is attributed to relative sea-level rise (a combination of subsidence and secular and eustatic sea-level rise) and the subsequeut conversion of broad wind-tidal flats, prominent in the 1950's, to permanently inundated subaqueous flats characterized by abundant seagrass in the mid-1970's. Among the causes for declines in seagrasses in Redfish Bay were dredging and disposal activities.

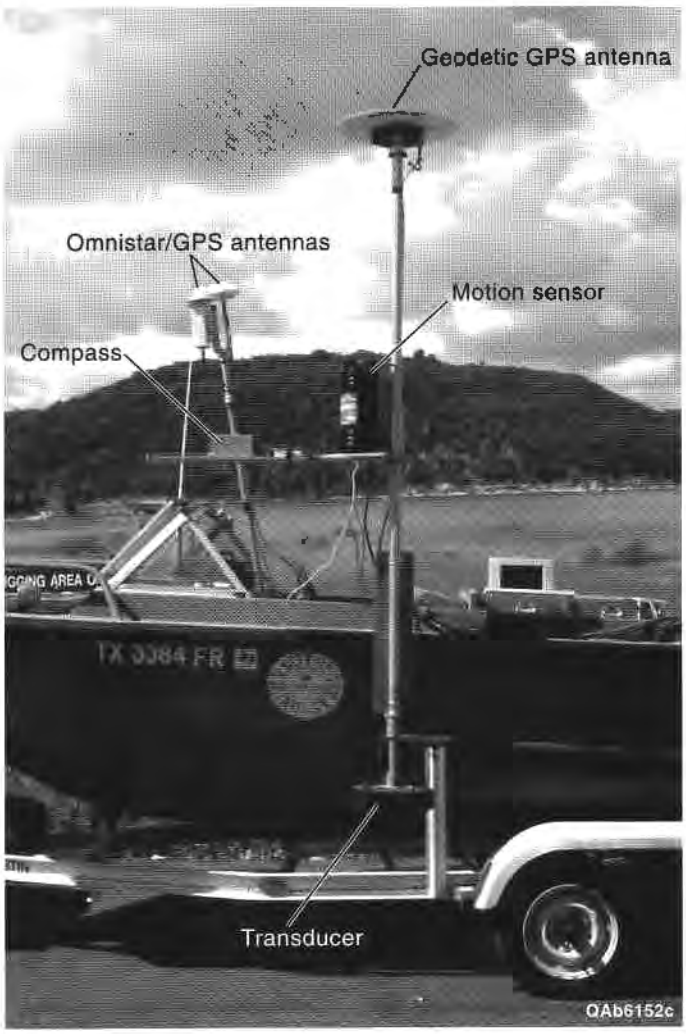
High-Accuracy Bathymetric Surveying and Real-Time GPS Positioning System

James C. Gibeaut and Bob E. Schutz (UT Center for Space Research), principal investigators; Roberto Gutierrez and Robert A. Morton; assisted by Eric M. Matzel, Cheng-Fang Lo, and Sung Byun

This project continues the work begun under an earlier project titled "Shallow-Water, High-Accuracy, High-Resolution Bathymetric Surveying System," which is described earlier in this annual report. This is a joint project between the Bureau and the Center for Space Research (CSR) at The University of Texas at Austin. The primary focus is to develop and integrate with our bathymetric surveying system a method to obtain horizontal and vertical positions in real time with an accuracy of 2 to 3 cm while the vessel is moving. This robust positioning component, which will use the global positioning system (GPS), is required to meet our goals for bathymetric surveying but will have a variety of commercial and research applications. We are also continuing the refinement of the entire bathymetric surveying system through further testing. We are improving data logging software and portability, and we are adding the capability to precisely measure the speed of sound in water.

Three-dimensional (X,Y,Z) GPS positioning accurate to 0.8 to 1.2 inches is critical to achieving our survey goals. Currently, our kinematic differential GPS software requires static initialization to estimate the phase biases. To initialize land kinematic surveys, the GPS rover remains stationary near the GPS base station for 20 to 30 minutes at the beginning of the survey. It is difficult, however, to keep a vessel stationary, and if the static initialization is attempted at dock side, a considerable amount of useless GPS data is collected while the vessel travels to the survey area. The answer to this limitation imposed by the static initialization is to develop kinematic software with the ability to estimate phase biases "on-the-fly" (OTF), that is, while the vessel is in motion. In addition to the OTF enhancement, we are developing a real-time GPS positioning capability for our bathymetric system. Real-time GPS requires that the phase data from the base stations be broadcast to the GPS rover by a radio link. There are three major advantages of real-time GPS positioning for bathymetric surveying: (1) The position is immediately available to produce an accurate chart and to check for spurious data. (2) Extremely accurate navigation information is provided, allowing precise vessel positioning and speed control. (3) Data processing is simplified because the bathymetry and positioning information can be immediately integrated.

CSR has begun the coding of a GPS positioning software capable of providing an ionospherically corrected L3 phase solution in real time. An initial design for the software that is modular in concept with each major module responsible for a distinct computational task has been completed. The major tasks (modules) addressed this year include (1) computation of GPS satellite X,Y,Z positions using the broadcast GPS ephemerides, (2) computation of a navigation-quality rover position using double-differenced, ionospherically corrected, carrier phase-smoothed pseudoranges, (3) OTF estimation of the wide-lane carrier phase ambiguities using the initial rover position from the double-differenced code solutions, (4) OTF estimation of the L1 and L2 phase ambiguities derived from the wide-lane ambiguities and adjusted through a search routine in 3-D space, and (5) estimation of the precise rover position and refinement of the L1 and L2 ambiguities using a Kalman filter methodology. Modules 1 through 3 have been coded and tested, and modules 4 and 5 are still being designed. We have also developed initial versions of communications software for the GPS receivers. This software queries the GPS receiver about its status and satellite availability and obtains the broadcast satellite ephemerides, pseudorange, and phase observations in real time for input to the GPS positioning software.



High-accuracy, high-resolution bathymetric surveying system (HARBSS) installed on the Bureau's boat. HARBSS combines state-of-the-art technology to achieve survey accuracy of better than 5 cm (2 inches). The Bureau and the Center for Space Research at The University of Texas at Austin are developing HARBSS through a Texas Higher Education Coordinating Board Applied Technology Program grant. Photo by David M. Stephens.

Analysis of Current Status and Historical Trends of Selected Estuarine and Coastal Habitats in the Corpus Christi National Estuary Program Study Area

William A. White, principal investigator; E. G. Wermund, liaison and coordinator; Thomas A Tremblay

The Bureau is the lead contractor in this cooperative study with the Texas Parks and Wildlife Department (TPWD) and Texas A&M University–Corpus Christi (TAMU–CC). The project is part of the Corpus Christi Bay National Estuary Program (CCBNEP) funded by the Environmental Protection Agency and the Texas Natural Resource Conservation Commission. The CCBNEP area encompasses an extensive, biologically productive estuarine and lagoonal system composed of numerous diverse and essential habitats and vast array of associated organisms. Understanding the status and trends of these habitats is critical for sound and comprehensive management practices. Major objectives of this 1-year study are to determine the status and trends of wetlands, wind-tidal flats, and riparian woodlands, to classify and map hardened and natural shorelines, to characterize estuarine and palustrine emergent wetlands in terms of their prevalent plant associations, and to determine the trends in vegetation cover on natural and dredged-material rookery islands.

The project area for the study is defined by thirty 7.5-minute quadrangles that encompass Corpus Christi and Aransas Bays and secondary bays including Copano, Nueces, Mesquite, and Redfish Bays and upper Laguna Madre. Barrier islands that are part of the study area include south Matagorda, San José, Mustang, and north Padre Islands. Wetlands status and trends are being determined by geographic information system analysis of U.S. Fish and Wildlife Service (USFWS) National Wetlands Inventory (NWI) maps of wetlands and aquatic habitats interpreted from 1950's, 1979, and 1992–93 aerial photographs. Hardened and natural shorelines are being mapped from high-quality, recent low-altitude aerial videotape surveys. Aerial photographs, USFWS NWI maps, TPWD land cover maps, and field surveys are the primary sources of information for analysis of riparian woodlands. Prevalent wetland plant associations and rookery island vegetation are being characterized from field surveys, maps, aerial photographs, and existing reports. Results of the study will provide information on the health of the bay system and will be incorporated in the CCBNEP comprehensive conservation management plan.

Evaluation of Marsh Creation and Restoration Projects and Their Potential for Large-Scale Application, Galveston-Trinity Bay System

Robert A. Morton and William A. White, principal investigators; Thomas C. Calnan (General Land Office)

Marsh restoration and creation are important goals for the State of Texas, especially in areas where large-scale losses in marsh habitat have occurred as a result of both natural processes and human activities. There have been numerons efforts by many agencies, including Federal, State, local, and private entities, to restore, enhance, and create wetlands in the Galveston–Trinity Bay system. Unfortunately, most of these efforts have been uncoordinated and carried out at a relatively small scale. In addition, most completed projects have not been systematically monitored and evaluated on a long-term basis to determine their success in meeting performance goals and creating productive, functional wetlands. There is a need to inventory and evaluate wetland restoration, enhancement, and creation projects in terms of their original design criteria, success in meeting performance goals, and feasibility for large-scale application. Plans for large-scale restoration of wetlands will assist the State of Texas in achieving the goal of no overall net loss of State-owned wetlands. In addition, the Galveston Bay Plan considers wetlands loss and degradation as the number-one management problem for the Galveston–Trinity Bay system, and, therefore, gives a high priority to increasing the quality and quantity of wetlands, setting as a goal the expansion of the area of vegetated wetlands in the Galveston Bay area by 15,000 acres within 10 years.

This 1-year study to evaluate marsh creation and restoration projects is in cooperation with the Texas General Land Office (GLO) and is funded by GLO and the Environmental Protection Agency. The major objectives of this investigation are to inventory and evaluate marsh restoration and creation projects in the Galveston–Trinity Bay system in terms of achieving project objectives and potential for large-scale application. In an area where thousands of acres of marshes have been lost since the mid-1950's, there is a need for planning and implementing marsh restoration and creation at a much larger scale than a few tens of acres. Among the goals of this study are to evaluate and synthesize primary physical criteria for large-scale marsh creation.

As part of this investigation with GLO, the Bureau will assist in creating an interagency working group, inventorying and locating marsh restoration/creation projects in the Galveston–Trinity Bay system, developing a matrix of site characteristics and design criteria, selecting several sites and conducting detailed field surveys, summarizing design criteria and best available techniques for large-scale marsh creation and restoration, and presenting methods and results in a technical report.

Mapping of Erosion Hazard Areas along the Gulf Shorelines of Galveston and Brazoria Counties, Texas

Robert A. Morton, principal investigator; Edward S. Angle; assisted by Erika M. Boghici

Determining the future position of the Gulf shoreline in Texas is of vital concern to State and Federal agencies and coastal planners who are responsible for maintaining the existing infrastructure and promoting economic development of the region. This study of the Gulf shoreline between High Island and the Brazos River is being conducted for the Texas General Land Office and the Federal Emergency Management Agency. It involves GPS (global positioning system) mapping of the

1996 position of the Gulf shoreline, comparing that position to others mapped in 1974 and 1990, calculating the rate of shoreline retreat or advance, and plotting the historical positions of the Gulf shoreline to establish treuds and to predict future positions of the Gulf shore. This analysis served as the basis for calculating long-term average annual erosion rates and predicting the position of the shoreline during the next 60 years. This information provides a scientific method of projecting where coastal flooding zones and erosion hazard areas will be in the future.

A major accomplishment of the project was completion of an electronic data base of historical shoreline positions, monitoring transects, and other layers in a geographic information system that permit rapid analyses of shoreline movement. The digitized shorelines span the time interval from the mid-1860's to 1996. Electronic results of this effort have been used by universities and by State and Federal agencies in a variety of applications. The study culminated in a report entitled "Identification of Shoreline Erosion Features and 60-Year Projection of the Gulf Shoreline Position, Galveston and Brazoria Counties, Texas," which was submitted to the Texas General Land Office for incorporation into their coastal zone management program.

Sediment Characteristics, History, and Recent Transport, Laguna Madre, Texas

Robert A. Morton, principal investigator; Edward S. Angle, James A. Doss, Jr., assisted by Allison J. Goldberg

The U.S. Army Corps of Engineers is responsible for maintaining navigable depths in the Gulf Intracoastal Waterway, a dredged channel that traverses the shallow waters of Laguna Madre in South Texas. Placement of the dredged material in areas where sediment reworking is minimized will lower costs of channel maintenance by reducing the frequency of future dredgmg and also will protect the aquatic habitats that are important to the commercial and recreational fisheries industries.

The Bureau investigation of Laguna Madre focuses on regional sediment characteristics, sediment budget, sources of fine-grained sediments, and historical changes in bathymetry and sediment types. It is one of several investigations being conducted by universities and Federal agencies that are intended to address environmental concerns regarding sediment suspension around islands of dredged material and its possible adverse impact on seagrasses, which are an important component in the ecosystem. The Bureau study emphasizes physical factors that may contribute to historical changes in marine grasses, such as storms, climate variations, internal transfers of sediment within the lagoon, and rewurking and redistrihution of material dredged from the Iutracoastal Waterway. Laboratory and field work is concentrated on placement areas of dredged material where historical losses of marine grasses have been significant or where substantial dredging is necessary to maintain the waterway.

The technical approach includes compilation and synthesis of historical data, such as aerial photographs, topographic maps, hydrographic charts, climate records, records of upland runoff and fresh-water inflow, documents pertaining to significant engineering projects, summaries of dredging records, and data for major hurricanes impacting the area. Each technical task has both field and laboratory components that integrate geological observations, physical measurements, and historical changes derived from morphological and sedimentological analyses.

In 1996 we prepared a site-sampling plan for field coring and historical analysis of changes in placement areas. Six field sites were visited, and we collected 21 fixed-piston cores and 27 vibracores (total of 48 cores). Also, 21 topographic profiles were surveyed along transects oriented both perpendicular to and parallel to the placement areas. Analysis of historical aerial photographs and field observations showed a high correlation between reworking of dredged material and the frequency and volume of dredging. Greatest reworking of dredged material occurs where the Gulf Intracoastal Waterway crosses the transition zones between the shallowest and deepest portions of Laguna Madre. The degree of reworking of dredged material is directly related to water depth and to the surface area of dredged material exposed to waves and currents. On the mud flats of the Land Cut and across the shoals of Laguna Madre, reworking of dredged material is minimal, but reworking increases as water depth increases.

Assistance to State Agencies Regarding Coastal Issues

Robert A. Morton, principal investigator

In 1996, the Bureau conducted several short-terin projects that were designed to assist natural resource agencies in Texas with their missions. This was accomplished by reviewing pertinent technical reports and historical documents, such as maps and aerial photographs; conducting field investigations at specific sites; conducting historical analyses of coastal geomorphology and site stability; meeting with agency representatives, natural resource specialists, and other experts to discuss issues; and preparing brief reports that describe physical characteristics and coastal processes at the site.

We assisted the Texas General Land Office Natural Resource Damage Assessment (NRDA) division by examining bird nesting islands in Nueces Bay that are proposed sites of marsh restoration and rookery island enhancement. We also examined mounds of sand and tar balls scraped from the beach and placed at the toe of the dunes on North Padre Island following au oil spill. The Bureau assisted the Texas Historical Commission in their marine archeology excavation of LaSalle's shipwreck, the *Belle*, from Matagorda Bay. We coordinated the collection of cores that were used to construct the coffer dam surrounding the site. Samples of the cores are stored at the Bureau's Core

Research Center. We also consulted with the Texas Office of the Attorney General regarding geologic process and legal boundaries in coastal areas.

Documenting Recent Wetland Losses at the GSU Marsh Restoration Site, Neches River Valley, Texas

Robert A. Morton and William A. White, principal investigators; Thomas A. Tremblay

This investigation, funded by the Texas Parks and Wildlife Department (TPWD) and completed in mid-1996, documented the extent and rate of recent wetland losses at a planued marsh restoration site near the Gulf States Utilities (GSU) power plant in the Neches River valley. The site is in an area of known historical marsh loss due partly to subsidence and fanlting, and there was a need to determine potential long-term impacts of subsidence on emergent vegetation. Marsh restoration efforts could fail if the area continues to subside at a rate that exceeds marsh vertical accretion.

Delineation of wetlands on sequential aerial photographs allowed us to document the magnitude and rate of marsh loss through time. Previous Bureau studies have indicated that subsidence and faulting are among factors contributing to the transformation of areas of emergent vegetation to open water in the Neches River valley, where more than 9,000 acres of marsh loss has occurred since 1956. The marsh system in the Neches River valley is intersected by two high-angle normal faults that are dowuthrown toward an oil and gas field located in the valley. One of the faults intersects the GSU marsh site and can be traced on aerial photographs for a distance of 3.4 mi.

Analysis of the GSU marsh on aerial photographs taken in 1938, 1956, 1978, and 1993–95, shows a net transformation of marsh to open water through time. Marsh loss has been continuous, but not constant. In 1956, open water was 4 percent of the map area; by 1978, 43 percent; and by 1993–95, 48 percent. The highest rate of change occurred during the period from 1956 through 1978, when 604 acres of marsh was converted to open water. The average rate of loss of marsh habitat was 27.5 acres per year for this 22-year period, during which time about 40 percent of the total marsh was lost. The rate of marsh loss decreased from 1978 through 1993–95 to 4.8 acres per year, a rate just slightly greater than the 3.9 acres per year for the period 1938 to 1956. Among the factors apparently contributing to marsh loss are subsidence and faulting, in part thought to be associated with oil and gas production. The highest rate of gas production occurred in the mid-1950's to early 1960's, which correlates with the period of highest marsh loss and the appearance of surface faults. Still, the analysis is complicated by the fact that dredging activities and natural processes also contributed to marsh loss.

Mapping Investigations

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

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

The Bureau conducted a 2-year project for the Environmental Protection Agency (EPA), Region 6, using real-time differential global positioning system (GPS) technology to locate regulated facilities in Texas and New Mexico along the Mexico border. Differential GPS eliminates the need for postprocessing and allows a corrected position to be collected in real time. Accurate locations of these facilities are required to establish a geographic information system (GIS) that will provide State and Federal regulators with a more functional tool for their oversight responsibilities. The Texas Natural Resource Conservation Commission and the New Mexico Environmental Department, along with EPA Region 6, provided records from their regulatory data bases that include toxic release inventory sites, industrial waste producers/transporters, Superfund sites/landfills, and underground storage tanks. These facilities are described in 7,380 records within 10 data bases.

The goal of this project was to provide spatial data of 1,000 to 1,500 facilities using a geographic information system. Using a Pathfinder Basic Plus and an Omnistar receiver, a single field worker can collect as many as 18 sites per day in urban settings such as the City of El Paso, Texas, or about 7 sites per day in more rural areas such as Cameron County, Texas. In 100 days of field work we collected locational data on 1,116 facilities from 6 Texas counties and 1 New Mexico county that relate to 2,371 records across 10 regulatory data bases. The coordinates for these facilities have been loaded into GIS coverages. Efficient application of this technology has resulted in a much improved set of spatial data that can be nsed to link other records on these regulated facilities to actual locations portrayed in a GIS. The use of this technology will help ensure that EPA Region 6 meets its goal of having locational data for all its regulated facilities throughout the five-state region by the end of calendar year 2000.

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

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

The purpose of this project, which was completed duriug 1996, is to provide geologic base maps to support the mapping of biologic (vegetation) resources in the Sierra del Carmen,

Coahuila, Mexico, and adjacent areas in Big Bend National Park, Texas, by the National Biologic Service and National Park Service. The mountain range, which is within the Chihuahuan Desert, rises abruptly from the desert floor and has topographic relief that exceeds 6,600 ft. Terrane is rugged, and the range is marked by numerous narrow and steep-sided canyons and valleys. The stratigraphic framework of the range is one aspect that controls the distribution of vegetation throughout the area. Funding for this project was from the National Biologic Service, and the project's primary goal, production of 1:50,000- to 1:100,000-scale geologic maps that are a synthesis of existing geologic maps and new aerial-photograph and field mapping, has been completed as open-file geologic maps. Maps of this region are intended to assist other scientists, students, and interested visitors in understanding the geology of this fascinating area, and in interpreting the influence of the geologic framework on related sciences. The maps emphasize Paleozoic, Cretaceous, and Tertiary bedrock and upper Tertiary and Quaternary surficial units that can be important controls on the distribution of plant communities. Additionally, the geologic maps will aid Park management and support other ongoing future studies.

Geologic Atlas of Texas

Virgil E. Barnes, principal investigator

The Bureau's Geologic Atlas of Texas provides geologic map coverage of the State of Texas at a scale of 1:250,000. This series of maps provides the most detailed geologic map coverage that is available for the entire state. The continued strong demand for these publications is evidence of the importance of these maps. New work focuses on reprinting older maps as they go out of print. In 1996, the Dallas, Hobbs, Houston, Llano, and San Antonio sheets were reprinted.

STATEMAP Project: Digital Geologic Map of New Braunfels, Texas

Jay A. Raney, principal investigator; Edward W. Collins; assisted by John R. Andrews and Sarah B. Dale

The objective of this 1-year project is to compile a digital geologic map of the New Braunfels, Texas, 1:100,000-scale quadrangle. This project, part of the U.S. Geological Survey's (USGS) STATEMAP program, is funded jointly by the USGS and the Bureau. The geology of the area was recently mapped for the STATEMAP program as 32 open-file geologic maps at 1:24,000 scale. The availability of a digital geologic map of the area will enhance the utility of the geologic data presented by the 32 open-file maps and the cost-effectiveness of their application to the many environmental, development, and policy issues that are of great significance to San Antonio and adjacent communities. The New Braunfels 1:100,000-scale quadrangle includes a large part of the rapidly developing San Antonio-to-Austin growth corridor. Many environmental issues related to economic and resource development require a high-quality baseline of geologic information as the foundation for intelligent decision-making.

STATEMAP Project: Geologic Mapping of 7.5-Minute Quadrangles to Support Responsible Development in Karst Aquifer Areas Undergoing Rapid Urban Growth, South-Central Texas

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

The objective of this mapping project is to develop geologic base maps that are sufficiently detailed and accurate to meet the needs of a variety of professionals who must respond to the demands placed on the environment and resources of a south-central Texas region that is undergoing rapid urban growth. An improved geologic base is needed for studies of recharge and hydraulic flow in the Edwards limestone aquifer, which is crucial to the economic well-being of the region and is also critical for responsible urban development and construction needs. Engineers, developers, and planners need detailed maps of the geology for land use planning and design of construction projects. Expansive clays are a major problem associated with some of the Cretaceous units, and other units host limestone of high quality that is actively being quarried at many localities. This project, part of the U.S. Geological Survey's (USGS) STATEMAP program, is funded jointly by the USGS and the Bureau.

Mapping is being done in three geologically critical areas that are undergoing rapid urban growth and that contain a portion of the karst Edwards aquifer and recharge zone. All three areas are within the Balcones Fault Zone, which is the main structural control on the geology of the region and the Edwards aquifer. The west San Antonio corridor is within an intensely faulted part of the Balcones Fault Zone and within the San Antonio segment of the Edwards aquifer and recharge zone, the sole-source aquifer for the rapidly expanding San Antonio urban area. The Austin–Georgetown corridor is within the Austin region's northern segment of the Edwards aquifer, an urban growth corridor that is undergoing some of the most rapid development in Central Texas. The Del Rio corridor is within the southern part of the Edwards Plateau aquifer region and western extension of the Balcones Fault Zone. It is traversed by U.S. Highway 90, a major transportation route from Mexico to San Antonio that is contributing to the growth and development of this area.

STATEMAP Project, El Paso, Texas

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

The objective of this completed multiyear project was to map the El Paso–Rio Grande border area that includes parts of the Hueco Bolson and bounding Franklin Mountains, Hueco Mountains, and Diablo Plateau. Geologic mapping is critical in this area because development and exploitation of geologic and other resources are stressing the environment. This project, part of the U.S. Geological Survey's (USGS) STATEMAP program, was funded jointly by the USGS and the Bureau. The

geology is 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 digitization of the open-file geologic maps is completed. Twenty-nine open-file geologic maps, scale 1:24,000, were mapped for this project. The Canutillo, Smeltertown, North Franklin Mountain, and El Paso quadrangles cover the Franklin Mountains and its flanks and include Franklin Mountains State Park. The Fort Bliss Northeast and Fort Bliss Southeast quadrangles are within part of the basin-floor area of the northern Hueco Bolson. The Nations East Well, Nations South Well, Hueco Tanks, Helms West Well, Clint Northeast, Padre Canyon, T P Well, and Whiterock Hills quadrangles encompass the eastern margin of the basin floor and the western and southern edge and foothills of the Hueco Mountains. The Ysleta, San Elizario, Clint Northwest, Clint, Clint Southeast, Isla, Tornillo, Fort Hancock Northwest, Acala, Fort Hancock, McNary, Campo Grande Mountain, and Esperanza quadrangles contain the basin floor, Rio Grande valley, and valley border. Cavett Lake and Diablo Canyon West quadrangles cover part of the southern Diablo Plateau rim and margin of the southeastern Hueco Bolson.

The Franklin Mountains are a west-dipping, tilted fault block that trends northerly. 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 Hueco basin to the east and into the Mesilla basin to the west. Strata within the range are cut by faults that strike north, northeast, and northwest. These faults may predate the range-bounding faults that represent the latest episode of range uplift and tilting. The range is bounded on the east by a distinct, north-striking Quaternary fault.

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

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

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

The southeast Hueco Bolson is bounded on the northeast by the Diablo Plateau and Finlay Mountains. The Finlay Mountains consist of two broad structural domes having radiating dikes and sills. Permian limestone and marl and Cretaceous limestone, marl, and sandstone of the Campagrande, Cox, and Finlay Formations dip as much as abont 20 degrees away from the central domal area. Cox and Finlay strata are also exposed along the Diablo Plateau rim. A gentle monocline strikes northwestward along the plateau rim and basin margin. Strata along the monocline dip mostly about 5 to 7 degrees southwestward. Alluvial-fan and drainageway alluvium composes the piedmont deposits shed from the Finlay Mountains and Diablo Plateau.

Other Geologic Investigations

Geomorphic Studies of Archeological Sites

L. E. Garner, principal investigator

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

The geomorphic studies are conducted to determine the geomorphologic character of locales, the influences on past human activities, and the effects of natural processes on deposits of cultural materials. Investigations during the 1996 have included sites along Culebra Creek at Highway 1604 in the San Antonio area and the Elm Creek Project near Eagle Pass.

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 1996, the following 92 contracts, each of which had reporting requirements, were active at the Bureau:

Federal

"Advanced Oil Recovery Technologies for Improved Recovery from Slope Basin Clastic Reservoirs, Nash Draw Brushy Canyon Pool, Eddy County, New Mexico": supported by Strata Production Company through the U.S. Department of Energy.

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

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

"Assessment and Forecasting, by Play, Natural Gas Reserve Appreciation and Quantifying the Role of Technology Advancement in Reserve Growth Additions in the Gulf Coast Basin": supported by the U.S. Department of Energy.

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

"Determination of the Extent of Deforestation in Belize between 1989 and 1995": supported by the U.S. Agency for International Development.

"Digital Geologic Map of New Braunfels, Texas Quadrangle 1:100,000 Scale": 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.

"Exhibit Poster Session Presenters (Class III Project)": supported by BDM-Oklahoma, Inc.

"Geologic Mapping of 7.5-Minute Quadrangles to Support Responsible Development in Karst Aquifer Areas Undergoing Rapid Urban Growth, South Central Texas": supported by the U.S. Geological Survey, U.S. Department of the Interior.

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

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

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

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

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

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

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

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

"Oral Presenters (BEG Clear Fork Project)": supported by BDM-Oklahoma, Inc.

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

"Preparation of a Regional Salt Thickness Map in Support of Salt Cavern Site Selection / Development in a Critical Salt Cavern Area": supported by the U.S. Department of Energy.

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

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

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

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

"Sediment Characteristics, History, and Recent Transport, Laguna Madre, Texas": supported by the U.S. Army Corps of Engineers.

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

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

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

"Using Microstructure Observations to Quantify Fracture Properties and Improve Reservoir Simulations": supported by BDM-Oklahoma, Inc.

State and Local

"Analysis of Current Status and Historical Trends of Selected Estuarine and Coastal Habitats in the Corpus Christi National Estuary Program Study Area": supported by the Texas Natural Resource Conservation Commission.

"Archeological Projects—Assistance to the Texas Department of Transportation": supported by the Texas Department of Transportation.

"Architecture of Fluvial-Deltaic Reservoirs: Extension of Outcrop Studies into 3-D Using Ground-Penetrating Radar": supported by the Texas Higher Education Coordinating Board.

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

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

"Bacterially Mediated Carbonate Precipitation: The Link Between Organic and Inorganic Crystallization": supported by the Texas Higher Education Coordinating Board.

"Brazos River Erosion Assessment": supported by the Texas Parks and Wildlife Department.

"Computer Modeling of Hydrocarbon Traps Formed around Deformed Salt Sheets in the Gulf of Mexico": supported by the Texas Higher Education Coordinating Board.

"Core Assistance and Preservation on the Matagorda Bay (*Belle*) Project": supported by the Texas Historical Commission.

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

"Digital Map Preparation": supported by the Texas Natural Resource Conservation Commission.

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

"Estimating Depth to Bedrock Feasibility Study": supported by the Texas Department of Transportation through Center for Transportation Research.

"Evaluation of Marsh Creation and Restoration Projects and Their Potential for Large-Scale Application, Galveston-Trinity Bay System": supported by the Texas General Land Office.

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

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

"High-Accuracy Bathymetric Surveying and Real-Time GPS Positioning System": supported by the Texas Higher Education Coordinating Board.

"Hydrogeological Investigations of Abandoned Oil Field Cleanup Sites": supported by the Railroad Commission of Texas.

"Hydrologic Needs Assessment and Technical Support for the Panhandle Ground Water Conservation District No. 3": supported by the Panhandle Ground Water Conservation District No. 3.

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

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

"Investigating the Status and Trends of Seagrasses in the Corpus Christi Bay System": supported by the Texas Parks and Wildlife Department.

"Investigation of Shallow Class V Injection Wells at TxDOT Maintenance Sections": supported by the Texas Department of Transportation.

"Mapping of Erosion Hazard Areas along the Gulf Shorelines of Galveston and Brazoria Counties": 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.

"Predicting the Extent, Mass, and Duration of Hydrocarbon Plumes from Leaking Petroleum Storage Tanks in Texas": supported by the Texas Natural Resource Conservation Commission.

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

"Review of Documents and Dissemination of Environmental Geologic Information Related to Environmental Restoration at the U.S. Department of Energy's Pantex Plant, Carson County, Texas": supported by the Office of the Governor of the State of Texas.

"Scientific and Economic Analysis of Various Natural Resource Issues Related to Designated Real Property Assets of the Permanent School Fund": supported by the Texas General Land Office.

"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.

"Targeting Alaskan Coalbed Methane Exploration Fairways and Sweet Spots Based on a Basin-Scale Producibility Model": supported by the Alaska Department of Natural Resources.*

"Technology Center for Oil and Gas Recovery Optimization on Texas State Lands": supported by the State of Texas.

"Texas Parks and Wildlife Support": supported by the Texas Parks and Wildlife Department.

"University Lands Advanced Recovery Initiative": supported by The University of Texas System.

*State of Alaska

Private

"Applied Geodynamics Laboratory": supported by Agip Petroleum S.p.A., Amoco Production Company, Anadarko Petroleum Corporation, ARCO Exploration and Production Technology/Vastar Resources Inc., BHP Petroleum (Americas) Inc., BP Exploration Inc., Chevron Petroleum Technology Company, Conoco Inc./DuPont, Exxon Production Research Company, The Louisiana Land and Exploration Company, Marathon Oil Company, Petroleo Brasileiro S.A., Phillips Petroleum Company, Statoil, Texaco, Inc., and Total Minatome.

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

"Characterization of Heterogeneity Style and Permeability Structure in a Sequence Stratigraphic Framework in Fluvio-Deltaic Reservoirs": supported by Amoco Prodnction Company, BP International Limited, Chevron Petroleum Technology Company, Conoco, Inc., Elf Aquitaine Production, Exxon Production Research Company, Intevep, S.A., Japan National Oil Corporation, Maxus Energy Corporation, Occidental International Exploration & Production Company, Oryx Energy Company, OXY USA Inc., Saga Petroleum, Schlumberger/GeoQuest, Statoil, and Union Oil Company of California.

"Characterization of Carbonate Reservoirs": supported by Amoco Production Company, ARCO, BP International Limited, Exxon Production Research Company, Japan National Oil Company, Marathon Oil Company, Occidental International Exploration and Production, OXY USA Inc., Pennzoil Exploration and Production Company, Petroleum Development Oman L.L.C., Phillips Petroleum Company, Saudi Aramco, Shell Canada Limited, Shell Western E&P Inc., Texaco Inc., Total, and Unocal.

"Characterize Miocene Reservoirs That Are Found in the Mioceno-Norte Area of Maracaibo Lake": supported by Lagoven, S.A.

"Conduct Technology Transfer and Review of ÖMV Data to Help Define Near-Term Opportunities for Improved Productivity Based on Reservoir Characteristics in Matzen Field": supported by OMV Aktiengesellschaft.

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

"Develop Digital Map and Database of Spraberry Depositional Trends": supported by Parker & Parsley Development L.P.

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

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

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

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

"Gulf of Mexico Subsalt Structure Study": supported by AGIP.

"Integrated Reservoir Characterization and Volumetric Analysis of the Arecuna Area of Faja Field, Veneznela": supported by Corpoven, S.A.

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"Reservoir Characterization of the Potrerillos Formation and Recovery Optimization Project Barrancas Norte Field": supported by YPF, S.A. (two contracts).

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

"Seminar on Advanced Modeling of Heterogeneous Reservoirs": supported by Statoil.

"Targeting High-Potential Exploration Objectives in the South Lake": supported by Lagoven, S.A.

Publications

In its role as a public geological research unit, the Bureau of Economic Geology disseminates the results of research projects and programs primarily through its own publication series. During its 86-year history, the Bureau has published nearly 2,300 reports, bulletins, circulars, maps, and other publications covering major aspects of the geology and natural resources of Texas. In addition to publishing traditional printed reports and maps, the Bureau continues its efforts to serve the geological community via the Internet (http://www.utexas.edu/research/beg/). Summaries of Bureau publications and information about the Bureau's programs may be viewed on our home page.

Publications are sold at nominal prices to recover printing or duplication costs. To date, more than 1.7 million publications have been distributed worldwide, mostly through direct sales but also through charitable donation. In 1996, more than 20,000 titles were distributed. The Bureau issued the following publications in 1996:

Reports of Investigations

RI 237. Combining P-Wave and S-Wave Seismic Data to Improve Prospect Evaluation

by Bob A. Hardage. 47 p., 37 figs., 2 tables, $4.50

This report presents evidence that the combination of compressional wave (P-wave) and shear wave (S-wave) seismic data provides significant advantages over the use of conventional P-wave data alone in evaluating oil and gas prospects and potential infield drill sites. The report consists of three parts: (1) the basic physics and research findings related to P and S seismic wavefield behavior, (2) the application of the research findings to field-recorded 2-D P and S data to site successful wells, and (3) recommended hydrocarbon plays in Texas where P and S seismic data should be acquired to better evaluate reservoir systems and to reveal new hydrocarbon accumulations. The authors encourage user demand for three-component three-dimensional (3C3D) seismic technology because of its superior results in evaluating reservoir conditions.

RI 238. Edwards Aquifer Ground-Water Resources: Geologic Controls on Porosity Development in Platform Carbonates, South Texas

by Susan D. Hovorka, Alan R. Dutton, Stephen C. Ruppel, and Joseph S. Yeh. 75 p., 39 figs., $10.50

Focusing on the highly developed Edwards aquifer, which supplies water for a large area of south-central Texas, this report presents a three-dimensional model of the porosity distribution in the aquifer, which quantifies the spatial distribution of water resources and provides information that can be used in ground-water flow and transport models. Geologic factors that played a strong role in the spatial distribution of water in the aquifer by controlling the development of porosity are identified. The study provides a detailed assessment of the amount of water in the Edwards aquifer on the basis of a large data set and a reproducible methodology. Funding for the project was provided by the Edwards Underground Water District.

RI 239. Fluvial and Eolian Depositional Systems, Paleosols, and Paleoclimate of the Upper Cenozoic Ogallala and Blackwater Draw Formations, Southern High Plains, Texas and New Mexico

by Thomas C. Gustavson. 62 p., 42 figs., 2 tables, 4 pls., $10.50

The Ogallala (High Plains) aquifer, which lies in the upper Tertiary Ogallala Formation, is the major source of water for agricultural and domestic use on the Southern High Plains of Texas and New Mexico. This report summarizes results of a study based on outcrop and subsurface data that establishes a regional stratigraphic framework for assessments of the Ogallala and related perched aquifers. Results are broadly applicable to water resource investigations and efforts to remediate contaminated areas of the aquifer as well as to the understanding of depositional environments, paleoclimate, and soil development during the late Tertiary and Quaternary. This study, which is part of a regional geologic and hydrologic characterization of the U.S. Department of Energy's (DOE) Pantex Plant and vicinity, provides information necessary to evaluate DOE's program to remediate contamination of a perched aquifer and the vadose zone above the Ogallala aquifer at the Pantex Plant.

RI 240. Geology of the Solitario Dome, Trans-Pecos Texas: Paleozoic, Mesozoic, and Cenozoic Sedimentation, Tectonism, and Magmatism

Christopher D. Henry and William R. Muehlberger, Editors. 182 p., 73 figs., 2 tables, 1 app., 2 pls., $25.00

The first of three Bureau reports resulting from new, detailed geologic mapping of the Big Bend Ranch State Park, this report comprises 12 chapters describing the structural, sedimentologic, volcanologic, petrographic, and geochronologic features of the Solitario dome and recommends directions for further research in the area. The Solitario dome is a circular, 14- to 16-km-diameter, mid-Tertiary laccolithic dome and caldera complex in southern Trans-Pecos Texas, largely within the Big Bend Ranch State Park. Two color plates accompany the report: a geologic map of the dome (scale 1:24,000) and a series of geologic cross sections of the dome. Funding for mapping of the Solitario was provided by the Texas Parks and Wildlife Department and the U.S. Geological Survey through its COGEOMAP program.

Geological Circular

GC 96-1. Facies Heterogeneity in a Modern Ooid Sand Shoal—An Analog for Hydrocarbon Reservoirs

by R. P. Major, Don G. Bebout, and Paul M. Harris. 30 p., 19 figs., $4.00

The ooid-sand shoals of the Joulters Cays area of Great Bahama Bank were chosen for detailed sedimentologic study to investigate patterns of internal heterogeneity within a modern carbonate sand deposit and to develop criteria for predicting the lateral extent of porous and permeable carbonate grainstone facies in hydrocarbon reservoirs. Using aerial photographs, surface observations, and shallow coring, the authors documented three sedimentary facies in a 2.7-km^2 study area dominated by mobile ooid sands. Cores were collected at the spacing characteristic of wells in mature hydrocarbon reservoirs. Modern sediment analog studies such as this one are an important addition to subsurface reservoir and outcrop analog characterization. Results aid in successfully deploying production technology and predicting the efficiency of enhanced recovery operations. Partial funding for this project and for publication was provided by Chevron Petroleum Technology Company, La Habra, California.

Data Set

Boonsville 3-D Seismic Data Set

by Bob A. Hardage, James L. Simmons, Jr., David E. Lancaster, Robert Y. Elphick, Richard D. Edson, and David L. Carr. 40 p., 9 figs., 5 tables, 1 app., 3-D data on an Exabyte tape in SEGY format, well log and petrophysical data on floppy disks, $145.00

This 3-D seismic data set is made publicly available as part of the technology transfer activities of the Secondary Gas Recovery program funded by the U.S. Department of Energy and Gas Research Institute. The data were derived from a study of the Bend Conglomerate reservoir system in Boonsville field, located in the Fort Worth Basin of North-Central Texas. This publication provides an affordable copy of digital 3-D seismic data, together with supporting geologic and reservoir engineering information, which can be used for educational and training purposes for a broad range of industry and academic interests. This data set should be particularly appealing because the 3-D seismic data have a high signal-to-noise ratio and a wide frequency range of approximately 10 to 115 Hz. When coupled with the geologic and engineering control provided with this publication, the 3-D data present a challenging opportunity to study a complex reservoir system of genetic sequences that were deposited in a low- to moderate-accommodation basinal setting.

This public data set consists of the following components:

- 5.5 mi^2 of time-migrated 3-D seismic data,
- digitized well log curves from 38 wells inside this 3-D seismic grid,
- depths to the boundaries of many Bend Conglomerate genetic sequences interpreted from these logs,
- perforation depths, reservoir pressures, and production and petrophysical data for the 38 wells, and
- vertical seismic profile data and explosive-source checkshot data recorded in a calibration well near the center of the seismic grid.

Maps

Physiographic Map of Texas *and* River Basin Map of Texas

by E. G. Wermund. $0.25 each

Two new maps have been added to the Bureau's series of color page-sized maps. The physiographic map displays seven physiographic provinces of the state along with their subdivisions and describes their distinguishing characteristics. The river basin map depicts the 13 major river basins of Texas and describes how they are shaped by the climate, geology, topography, and vegetation of their respective areas. Both maps may be useful as teaching tools for understanding some of the natural features that shape the state.

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

Papers

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Services

Core Research Centers

The Bureau manages two core research facilities, the Core Research Center (CRC) in Austin and the Midland Core Research Center (MCRC). The CRC, located adjacent to the Bureau's Research and Administration building at J. J. Pickle Research Campus, houses the largest public collection of subsurface geological materials in the United States and is open Monday through Friday from 8:00 a.m. to 5:00 p.m. The Curator is George Bush. The repository, approximately 103,000 ft^2, houses nearly 50 linear miles of shelving. Roughly 10 percent of the repository is isolated and climate controlled for storing unstable core materials.

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

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

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

During (fiscal) 1996, the CRC received more than 350 visitors, who made transactions involving CRC inventory that included materials from more than 602 wells and required the transfer of more than 11,009 boxes of core to and from viewing and shipping areas.

New acquisitions in 1996 totaled 228 new core samples, in excess of 560 boxes and nonconventional (cuttings, sidewall, unwashed cuttings, outcrop) core samples from 23 wells, totaling 83 boxes. Donations were received from BP Exploration; Brigham Oil and Gas, L.P.; the Bureau of Economic Geology; Reservoirs, Inc.; Snyder Oil Corporation; the Texas Historical Commission; 39 Crude L.C.; and Earle F. McBride (UT Department of Geological Sciences) and Richard L. Watson.

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

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

Public Information

Requests for information about the mineral, geology, 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 1996, approximately 1,500 such requests were handled by L. Edwin Garner, the Public Information Geologist. In addition to direct inquiries Bureau staff have contributed directly to educational programs by making presentations to public school classes in the Austin area.

Reading Room/Data Center

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

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

The Data Center houses an extensive collection of surface and subsurface geological data pertaining to Texas and adjacent states. Open-File Document Storage data consisting of original maps, cross sections, and other data used in preparing Bureau publications are available to staff and the public. Topographic and geologic maps, aerial photographs, and Landsat images are also available. Subsurface data files include well logs for more than 150,000 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.

The Reading Room staff cataloged, indexed, shelved, and eutered 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 Geology (Walter) 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, telephone, fax, or E-mail.

By the end of 1996, the facility had accumulated approximately 170,000 well logs of various types from the Texas Railroad Commission, at a rate of 800 logs per month. All logs are entered into the GLF's computer data base.

Research Staff Activities

Lectures and Public Addresses

William A. Ambrose

"Opportunities and strategies for optimizing oil recovery in lower Eocene tide-dominated deltaic reservoirs in Lagunillas field, Lake Maracaibo, Venezuela": presented at seminar hosted by Statoil, Ltd.: Advanced Modeling of Heterogeneous Reservoirs, Stavanger, Norway.

Janok P. Bhattacharya

"Lithostratigraphy, allostratigraphy, and sequence stratigraphy: mopping up the mess in the Western Canada Foreland Basin": presented to The University of Texas at Austin, Department of Geological Sciences, Soft Rock Seminar, Austin, Texas.

"Mixing tide-, wave-, and river- influenced shoreline deposits in the Cretaceous Interior of North America": presented at International Conference on Tidal Sedimentology, Savannah, Georgia.

William L. Fisher

"Technology and the modern oil and natural gas industry": presented to the Energy Policy Forum, Aspen Institute, Aspen, Colorado.

"Gas finding rates, supply, and prices": presented to the U.S. Department of Energy, Energy Information Administration, Fourth National Energy Modeling System/Annual Energy Outlook Conference, Arlington, Virginia.

"Fundamentals of U.S. natural gas supply": presented to the New Mexico Department of Energy, Minerals and Natural Resources, 9th Annual Natural Gas Marketing Conference, Santa Fe, New Mexico.

"The geosciences: adapting to a world of change": presented to the Sociedade Brasileira de Geologia, XXXIX Congresso Brasileira de Geologia, Salvador, Brazil.

"Petroleum geologists in a changing world": presented to the Associação Brasileira de Geólogos de Petróleo, Rio de Janeiro, Brazil.

"Natural gas supplies": presented to Lakeway Men's Club, Lakeway, Austin, Texas.

"Citation for Robert R. Jordan, AGI Campbell Medalist": presented to the Geological Society of America, Denver, Colorado.

"Citation for Charles J. Mankin, Honorary Membership": presented to the American Institute of Professional Geologists, Columbus, Ohio.

"Citation for William E. Gipson, Hall of Honor Induction": presented to The University of Texas at Austin, College of Natural Sciences, Austin, Texas.

"Citation for Bernold M. Hanson, Environment Achievement": presented to Midland College, Midland, Texas.

Robert L. Folk

"Egyptian pyramids: made of poured concrete or real rock?" and "Nannobacteria and the precipitation of minerals": presented to the University of California, Berkeley, Department of Geology, Berkeley, California.

"Il piccolo mondo dei nannobatterie, ed il loro precipitazione dei minerali": presented to the University of Siena, Siena, Italy.

"Il ruolo dei nannobatterie nel mondo geochimico": presented to the University of Pisa, Pisa, Italy.

William E. Galloway

"Role of tectonics and sediment supply in the Tertiary depositional history of the North Sea Basin": presented to the Geologists' Association, London, England, and the Tulsa Geological Society, Tulsa, Oklahoma.

"Sedimentary processes, regime variables, and development of stratigraphic sequences": presented to the Department of Geosciences, University of Tulsa, Tulsa, Oklahoma.

Invited member of panel for "Debate on sequence stratigraphy": American Association of Petroleum Geologists Annual Meeting, San Diego, California.

Robert K. Goldhammer

"Sequence stratigraphy and systems tract development of the Latemar platform, Middle Triassic of the Dolomites: outcrop calibration keyed by cycle stacking patterns": presented to Baylor University, Department of Geology, Waco, Texas.

"Sequence stratigraphic architecture and cycle stacking patterns of platform carbonates—an evaluation of autocyclic, deterministic, and stochastic controls": presented to the University of Michigan, Ann Arbor, Michigan.

"The origin of high-frequency platform carbonate cycles and third-order sequences (the Lower Ordovician of West Texas): constraints from outcrop data, inverse and forward stratigraphic modeling" presented to The University of Texas at El Paso, Department of Geology, El Paso, Texas.

"Third-order vertical variations in parasequence character of the Lower Grey Craggy Member, Katakturuk Dolomite (Proterozoic), northeast Brooks Range (ANWR), Alaska": presented to New Mexico State University, Department of Geology, Las Cruces, New Mexico.

"Stratigraphic control on local detachment levels and fracture density in the Lower Cretaceous Cupido Formation, the Sierra Madre fold-thrust belt, northeast Mexico": presented to The University of Texas at Austin, Department of Geological Sciences, Austin, Texas.

Douglas S. Hamilton

"Infield natural gas reserve growth in Midcontinent compartmented reservoirs": presented to the Dallas Geological Society, Dallas, Texas.

H. Scott Hamlin

"Canyon sandstones—a geologically complex natural gas play in slope and basin facies, Val Verde Basin, southwest

Texas": presented to the South Texas Geological Society, San Antonio, Texas.

Ursula Hammes

"Development of a multiphase cave system: Ellenburger Formation, Lower Ordovician, West Texas": presented to The University of Texas at Austin, Department of Geological Sciences, Softrock Seminar, Austin, Texas.

"New insights from interpreting borehole electrical images in carbonate rocks": presented to the Geological Applications of Borehole Imaging Conference, Honston, Texas.

Bob A. Hardage

"Amplitude mapping": presented to the Geophysical Society of Houston, Houston, Texas.

"Seismic interpretation of low-accommodation sequences": presented to the Gulf Coast Section of the Society of Exploration Geophysicists, Houston, Texas.

"New exploration application using P and S waves": presented to Austin SIPES chapter, Austin, Texas.

Martin P. A. Jackson

"Rough diamonds from the annals of salt tectonics": Don R. and Patricia Kidd Boyd Lecture in Petroleum Exploration presented to The University of Texas at Austin, Department of Geological Sciences, Austin, Texas.

"Stretching and squeezing: the salt-tectonics workout": Don R. and Patricia Kidd Boyd Lecture in Petroleum Exploration presented to The University of Texas at Austin, Department of Geological Sciences, Austin, Texas.

"Salt's allochthonous underworld": Don R. and Patricia Kidd Boyd Lecture in Petroleum Exploration presented to The University of Texas at Austin, Department of Geological Sciences, Austin, Texas.

"Upheaval Dome: 'NASA: big meteorite whacked Utah'—or did it?": Don R. and Patricia Kidd Boyd Lectnre in Petroleum Exploration presented to The University of Texas at Austin, Department of Geological Sciences Technical Sessions, Austin, Texas.

James W. Jennings

"Modeling the impact of stratigraphic compartmentalization on waterflood infill performance in the Kuparuk Field, North Slope, Alaska": presented at AAPG/EAGE Research Symposium on Compartmentalized Reservoirs, Houston, Texas.

Charles Kerans

"New advances in geologic technologies": presented to Mobil Exploration and Producing Co., Midland, Texas.

"Sequence stratigraphy correlation exercise": presented to The University of Texas at Austin, Department of Geosciences (Geology 380N), Austin, Texas.

"High-frequency sequence stratigraphy of Cretaceous ramp carbonate reservoirs": presented to the Society of Explorationists in the Emirates, Abu Dhabi, United Arab Emirates, and the Dhahran Geological Society, Dhahran, Saudi Arabia.

"New frontiers in development of Ellenburger reservoirs" and "The use of stratigraphic frameworks for construction of reservoir models in San Andres and Grayburg fields, Central Basin Platform": presented at the University Lands Advanced Recovery Workshop, Midland, Texas.

Paul R. Knox

"New opportunities in mature fields: finding the cream left behind using integrated advanced characterization methods": presented to the Corpus Christi Geological Society, Corpus Christi, Texas.

"Overview of deltaic facies and stratigraphic concepts": presented to Houston Geological Society Continuing Education Short Course, Houston, Texas.

"3-D seismic applications and other topics included in the reservoir characterization advisor—fluvial deltaic": presented to the U.S. Department of Energy, Bartlesville, Oklahoma.

Stephen E. Laubach

"New fracture characterization methods for siliciclastic rocks": presented to the North American Rock Mechanics Symposium, Montreal, Canada.

"Investigations of fractured coal and sandstone reservoirs": presented to North China petroleum industry delegation, Anstin, Texas.

"Differential compaction of interbedded sandstone and coal": presented at international symposium on Forced (Drape) Folds and Associated Fractures, London, England.

"New fracture characterization methods" and "Practical application of new methods": presented to fracture workshop sponsored by Bureau of Economic Geology, Gas Research Institute, and Geological Society of America, Anstin, Texas.

"Core analysis and curation": presented to The University of Texas at Anstin, Department of Petrolenm and Geosystems Engineering (PGE 383), Austin, Texas.

Raymond A. Levey

"Meeting the challenge of global energy research": presented to the Northeast Austin Rotary Organization, Austin, Texas.

"New techniques for identifying gas reserves": presented to the Independent Oil and Gas Association of Pennsylvania, Warrendale, Penusylvania.

F. Jerry Lucia

"Rock-fabric/petrophysical classification of carbonate pore space for log analysis and reservoir characterization": presented to the Society of Professional Well Log Analysts, Houston, Texas.

Robert E. Mace

"Diffusion in fractured rocks": presented to The University of Texas at Austin, Department of Geological Sciences (Geology 391), Austin, Texas.

"Determination and distribution of permeability in the Edwards aqnifer": presented to The University of Texas at Austin, Department of Geological Sciences, Hydrology/Hydrogeology Brown Bag Seminar, Austin, Texas.

R. P. Major

"Diagenesis of metastable carbonate marine cements under conditions of rapid burial and low water-rock ratio" and "Geochemical indicators of the origins and pathways of dolomitizing fluids and their effects on porosity and

permeability: example from the Plio-Pleistocene of Bonaire, Netherlands Antilles": presented to the University of South Florida, Department of Geology, Tampa, Florida.

"Carbonate reservoir case study": presented to The University of Texas at Austin, Department of Geological Sciences (Geology 394), Austin, Texas.

Robert Morton

"Recent erosion rates at Sargent Beach and their causes": presented to town meeting, Sargent, Texas.

"Mapping shoreline boundaries—geological and legal implication": presented to the University of Maryland, Department of Geography and Coastal Research Laboratory, College Park, Maryland.

"Impacts of human activities on the coastal zone, San Juan, Puerto Rico": presented to an international workshop sponsored by the Scientific Committee on Problems of the Environment (SCOPE), Bogota, Colombia.

"Methods of environmental monitoring and mitigation in the coastal zone" and "Causes of coastal changes and possible responses": presented to an international seminar sponsored by INGEOMINAS and Ministerio del Medio Ambiente, Bogota, Colombia.

William F. Mullican III

"Ground-water remediation at the Pantex Plant": presented to the Pantex Plant Citizens Advisory Board September Meeting, Amarillo, Texas.

Jeffrey G. Paine

"Shallow reflection programs at DOE's Pantex plant, Texas: different methods, different results": presented to the U.S. Department of Energy, Lawrence Berkeley National Laboratory, Berkeley, California.

"Geophysical screening of salinity sources in West Texas": presented to Clean Rivers Program Steering Committee meeting, Lower Colorado River Authority, Austin, Texas.

"Hydrogeological applications of seismic reflection and electromagnetic methods": presented to The University of Texas at Austin, Department of Geological Sciences, Hydrogeology Brown Bag Seminar, Austin, Texas.

"Near-surface geophysical methods in hydrogeological investigations": presented to The University of Texas at Austin, Department of Geosciences (GEO 376L), Austin, Texas.

"Locating salinity sources with remotely sensed geophysical data": presented to EPA/NASA Remote Sensing Environmental Monitoring Conference, Washington, D.C.

Jay A. Raney

"Regional and site-specific geologic setting of proposed site for Texas low-level radioactive waste disposal facility and summary of vadose zone studies": presented to the national Technical Review Committee of the Low-Level Radioactive Waste Forum, El Paso, Texas.

"The role of the Bureau of Economic Geology in the Texas effort to site a low-level radioactive waste disposal facility": presented to committee of Association of American State Geologists, Environmental Affairs Committee, Saint Louis, Missouri.

"Role of state geological surveys in the national low-level radioactive waste disposal program, a Texas perspective" and "Effective site characterization, good science and good people": presented to the Association of American State Geologists Subcommittee on Low-Level Radioactive Waste Disposal, St. Louis, Missouri.

Stephen C. Ruppel

"Controls of heterogeneity in Clear Fork shallow platform carbonate reservoirs": presented to DOE/BDM workshop, "Improving production from shallow shelf carbonate reservoirs," Midland, Texas.

"Styles of reservoir development in Devonian and Silurian reservoirs, West Texas" and "Depositional and diagenetic controls on reservoir heterogeneity in the Clear Fork Group, Central Basin Platform": presented at the University Lands Advanced Recovery Workshop, Midland, Texas.

Bridget R. Scanlon

"Quantification of air flow through the unsaturated zone": presented to a review meeting on Monitoring Issues Related to the Unsatnrated Zone, the University of Arizona and the Nuclear Regulatory Agency, Maricopa, Arizona.

"Basic principles of unsaturated zone hydrology" and "Evaluation of liquid and vapor flow in arid unsaturated zones": presented to The University of Texas at Austin, Department of Civil Engineering Seminar Series, Austin, Texas.

Daniel D. Schultz-Ela

"Salt diapirism dogmas debunked: a resistible force meets a movable object": presented to Colorado College, Colorado Spriugs, Colorado.

Andrew R. Scott

"Exploration strategies based on a coalbed methane producibility model": presented to the Alaskan Department of Natural Resources, Division of Geological and Geophysical Surveys, Fairbanks, Alaska.

"Review of coalbed methane resource calculation techniques": presented to the Alaskan Department of Natural Resources, Division of Geological and Geophysical Surveys, Fairbanks, Alaska.

"Hydrogeology of coalbed methane reservoirs": presented to The University of Texas at Austin, Department of Geological Sciences, Hydrology/Hydrogeology Brown Bag Seminar, Austin, Texas.

"Coalbed methane exploration strategies": presented to North China Bureau of Petroleum Geology, Ministry of Geology and Mineral Resources, Austin, Texas.

"Review of geologic and hydrologic factors affecting coal gas geochemistry": presented to the State Key Laboratory of Gas Geochemistry, Chinese Academy of Sciences, Austin, Texas.

Steven J. Seni

"Can technology expand a shrinking lower 48 resource base?": presented to the National Association of Petroleum Investment Analysts, San Antonio, Texas.

"Atlas of Northern Gulf of Mexico Gas and Oil Reservoirs": presented to the South Texas Geological Society, San Antonio, Texas.

"Can technology expand our shrinking resource base?": presented to Morgan Keegan and Company, Inc., 6th annual Oilfield Technology and Energy Conference, New York, New York.

Roger Tyler

"Geologic and hydrologic controls critical to coalbed methane producibility: the Rocky Mountain Foreland experience": presented to the Alaskan Department of Natural Resources, Division of Geological and Geophysical Surveys, Fairbanks, Alaska.

"Defining coalbed methane exploration and development strategies based on a coalbed methane producibility model: the Rocky Mountain Foreland experience": presented to The University of Texas at Austin, Department of Geological Sciences (Geology 391), Austin, Texas.

"Hydrogeologic factors affecting coalbed methane producibility": presented to the State Key Laboratory of Gas Geochemistry, Chinese Academy of Sciences, Austin, Texas.

Bruno C. Vendeville

"New concepts in salt tectonics": presented to Elf Norge, Stavanger, Norway.

William A. White

"The extent of deforestation in Belize, 1989/92–1994/96": presented at workshop for government and private agencies and public, Belmopan, Belize.

Bureau of Economic Geology Seminars

Janok P. Bhattacharya

"Mixing waves, tides, rivers and sea-level in deltaic deposits of the Cretaceous Interior Seaway: revision of conventional facies models for shallow marine sandstones"

Robert K. Goldhammer

"Tectono-stratigraphic evolution of the Triassic Cuyana Basin: evidence for syn-rift transpression"

Giovanni Guglielmo, Jr.

"Animations of salt tectonics"

Douglas S. Hamilton

"Approaches to identifying reservoir heterogeneity and reserve growth opportunities in a continental-scale bed-load fluvial system: the Hutton Sandstone, Jackson field, Australia"

Martin P. A. Jackson

"Allochthonous salt tectonics"

James W. Jennings

"Analysis of petrophysical data from carbonate outcrops"

Paul R. Knox

"Getting out the gospel in floppy format: methodology for reservoir characterization and prioritization presented in 'The Reservoir Characterization Advisor—Fluvial Deltaic'"

Jeffrey G. Paine

"Finding salinity sources in West Texas with airborne and ground-based electromagnetic surveys"

Stephen C. Ruppel

"Destruction of depositional controls on reservoir heterogeneity in a shallow-water carbonate reservoir: Grayburg Formation, South Cowden field"

Daniel D. Schultz-Ela

"Structure of Upheaval Dome, Utah"

Andrew R. Scott

"Exploration strategies based on a coalbed methane producibility model"

Bruno C. Vendeville

"A hands-on crash course in tectonic modeling"

Christopher D. White

"Stratigraphically oriented reservoir simulation"

Congressional, Legislative, and Special Testimony

William L. Fisher

"Status of domestic oil and gas": presented to the U.S. House of Representatives, Committee on Resources, Houston, Texas.

Committee Services, Offices, and Other Professional Responsibilities

Sigrid J. Clift

Member, Organizing Committee for Fractured Petroleum Reservoirs and Aquifers Workshop, Geological Society of America, South-Central Section, Annual Convention, Austin, Texas.

Edward W. Collins

Co-leader field trip, "Rocks, landscapes, development—geology and man in the San Antonio area": Gulf Coast Association of Geological Societies Annual Convention, San Antonio, Texas.

Alan R. Dutton

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

Panelist, "Community forum on the Edwards aquifer," KSTX 89.1 Public Radio, San Antonio, Texas.

Shirley P. Dutton

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

Co-convenor, "Results of joint DOE/industry programs," technical session, American Association of Petroleum Geologists Annual Meeting.

Robert J. Finley

Chairman of Poster Sessions, "Exploring in mature basins," technical session, American Association of Petroleum Geologists Annual Meeting.

Member, Program Committee, 1997 NIPER Reservoir Characterization Conference.

Member, Program Committee, American Association of Petroleum Geologists Annual Meeting.

William L. Fisher

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

Chair, Faculty Review Committee, Department of Geological Sciences, The University of Texas at Austin.

Vice Chair, Board of Directors, Texas Low-Level Radioactive Waste Disposal Authority.

Foundation Trustee, American Geological Institute.

Trustee, Southwest Research Institute.

Trustee Associate, American Association of Petroleum Geologists Foundation.

Member, Committee on Governmental Relations, Natural Sciences Foundation, The University of Texas at Austin.

Member, Research Committee, Interstate Oil and Gas Compact Commission.

Member, Advisory Council, Gas Research Institute.

Member, University Advisory Board, Center for Legislative Energy and Environmental Research, South/West Energy Council.

Member, Faculty Council, The University of Texas at Austin.

Member, Advisory Board, World Energy Update.

Member, Committee on Resources, American Association of Petroleum Geologists.

Member, Steering Committee, National Geoscience Data Repository System.

Member, National Petroleum Council.

Member, Commission on Geosciences, Environment, and Resources, National Research Council.

Member, National Academy of Engineering.

Member, Technical Planning Committee, World Energy Conference.

William E. Galloway

Member, Bureau of Economic Geology Review Committee, Office of the Vice President for Research, The University of Texas at Austin.

James C. Gibeaut

Member, Topography and Surface Change Investigators Working Group, NASA.

Leader of field trip, "Coastal processes along the upper Texas coast": presented to The University of Texas at Austin, Geology Emerging Scholars Class, Galveston County, Texas.

Robert K. Goldhammer

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

Douglas S. Hamilton

Associate Editor, *Journal of Petroleum Science and Engineering*.

Ursula Hammes

Co-leader of field trip, "Lower Paleozoic stratigraphy of the Franklin Mountains," West Texas Geological Society Fall Field Conference.

Bob A. Hardage

Chairman, Publications Committee, Society of Exploration Geophysicists.

Editor-in-Chief, *Journal of Petroleum Science and Engineering*.

Member, Publications Committee, Society of Exploration Geophysicists.

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*.

Martin P. A. Jackson

Member, International Union of Geological Sciences Commission on Tectonics.

James W. Jennings

Discussion Leader, "Geologic modeling and field studies," technical session, 1996 Gordon Research Conference on the Modeling of Flow in Permeable Media.

Charles Kerans

Session Chairman, "Reservoir characterization," 3rd International DOE/SPE Reservoir Characterization Conference.

Co-convenor, "Carbonate reservoirs of the world: an integrated perspective," technical session, Society of Economic Paleontologists and Mineralogists, Gulf Coast Section Research Conference.

Member, Distinguished Lecture Committee, American Association of Petroleum Geologists.

Member, Development Geology Committee, Society of Petroleum Engineers.

Stephen E. Laubach

Convenor, "Rock mechanics of petroleum and geothermal reservoirs," technical session, North American Rock Mechanics Symposium.

Convenor, "Geology and structural geology," technical session, Second International Conference on Mechanics of Jointed and Faulted Rock.

Convenor, "Fractured aquifers and petroleum reservoirs," technical session, Geological Society of America, South-Central Section, Annual Meeting.

Co-convenor, "Scale effects of fluid flow and fractures," technical session, Geological Society of America Annual Meeting.

Organizer, "Using microstructure observations to quantify natural fracture properties and improve reservoir simulations," workshop, BDM/DOE-Fractures project.

Co-convenor, "New technology in exploration and exploitation of fractured reservoirs," technical session, American Association of Petroleum Geologists Annual Meeting.

Co-convenor, "New development in formation evaluation techniques and technology," technical session, American Association of Petroleum Geologists Annual Meeting.

Member, Editorial Review Committee, Society of Petroleum Engineers.

Member, Editorial Board, Society of Petroleum Engineers Formation Evaluation.

Raymond A. Levey

Member, Research Committee, American Association of Petroleum Geologists.

Member, Texas Oil & Gas Forum.

Member, Governor of Texas Technology Council.

Delegate, House of Delegates, American Association Petroleum Geologists.

Representative, Texas Energy Coordination Council.

F. Jerry Lucia

Chairman, Technical Review Committee, Society of Petroleum Engineers.

Review Chairman, SPE Formation Evaluation, Society of Petroleum Engineers.

Couvenor, "Best of AAPG," technical session, Society of Petroleum Engineers Annual Technical Conference.

Member, Production Geology and Geophysics Committee, Society of Petroleum Engineers.

R. P. Major

Secretary, Gulf Coast Section, Society of Economic Paleontologists and Mineralogists.

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

Associate Editor, American Association of Petroleum Geologists *Bulletin*.

Delegate, House of Delegates, American Association of Petroleum Geologists, representing the Austin Geological Society.

Robert A. Morton

Member, Working Group, Scientific Committee on Problems of the Environment and International Union of Geological Sciences, Earth Surface Processes, Materials Use and Urban Development; Understanding the Human Contribution to Global Geomorphological Change.

Member, Editorial Board, *Journal of Coastal Research*, Coastal Education and Research Foundation.

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

William Franklin Mullican III

Member, Texas Groundwater Protection Committee.

Co-Chairman, Technical Program Committee, Geological Society of America, South-Central Section, Annnal Meeting.

Member, Advisory Panel for the Texas Rehabilitation Commission Supported Employment Systems Change Grant.

Jeffrey G. Paine

Associate Editor, *Environmental & Engineering Geoscience*, Association of Engineering Geologists and the Geological Society of America.

Sandra K. Raeuchle

Member, Interpretation Committee, Society of Exploration Geophysicists.

Member, Student Section and Academic Liaison Committee, Society of Exploration Geophysicists.

Member, Association of Women Geoscientists.

Member, Society of Texas Environmental Professionals.

Jay A. Raney

Moderator of workshop, "Rates of deforestation in Belize 1989/92 to 1994/96": presented to government officials, non-governmental organizations, and the public, Belmopan, Belize.

Moderator of workshop, "Application of geographic information systems and real-time GPS to regulated facilities in the United States-Mexico border region": presented to representatives of Texas State agencies, Austin, Texas.

Member, Digital Mapping Committee, Association of American State Geologists.

Leader of field trip, "Geologic characteristics of the proposed site for the Texas low-level radioactive waste repository, Hudspeth County, Texas," National Technical Review Committee of the Low-Level Radioactive Waste Forum.

Member, Texas GIS Planning Council and Data Acquisition Committee, Texas Department of Information Resources.

Lisa E. Remington

Membership Chairman, Austin Geological Society.

Stephen C. Ruppel

Chairman, Publications Committee, Austin Geological Society.

Bridget R. Scanlon

Co-convenor, "The role of preferential flow in the unsaturated zone," technical session, Geological Society of America Annual Meeting, Denver, Colorado.

Co-chair, Symposium on Unsaturated Zone Hydrology, Geological Society of America, South-Central Section, Anuual Meeting.

Associate Editor, *Ground Water*, Association of Ground Water Scieutists and Engineers.

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

Member, Committee on Unsaturated Zone Hydrology, American Geophysical Union.

Andrew R. Scott

Councilor, Gulf Coast Section, Energy Minerals Division, American Association of Petroleum Geologists.

Member, Operation Subcommittee of the Task Force for the Registration of Geologists, Geophysicists, Soil Scientists in Texas.

James L. Simmons, Jr.

Associate Editor of Amplitude-Versus-Offset (AVO), *Geophysics*, Society of Exploration Geophysicists.

Noel Tyler

Chairman, Continental Margins Committee, Association of American State Geologists.

Member, Coastal Processes Committee, Association of American State Geologists.

Member, Energy & Minerals Policy Committee, Association of American State Geologists.

Member, Environmental Affairs, Association of American State Geologists.

Member, Digital Mapping Committee, Association of American State Geologists.

Member, Committee on Earth Resources, National Research Council.

Member, Texas Oil & Gas Forum.

Member, Texas Mapping Advisory Committee.

Roger Tyler

Member, South African Council for Natural Scientists.

Member, Fossil Fuel Foundation, Geological Society of South Africa.

Bruno C. Vendeville

Convener, "Exploring and modeling complex structural regimes," poster session, American Association of Petroleum Geologists Annual Meeting.

Member, Editorial Board, *Tectonophysics*.

E. G. Wermund

Chairman, Awards Committee, Austin Geological Society.

Member, Task Force, Texas Natural Resources Information System.

Member, Texas Mapping Advisory Committee.

Member, Scientific and Technical Advisory Committee, Corpus Christi Bay National Estuary Program.

Member, Clean Waters Committee, Galveston Bay National Estuary Program.

William A. White

Member, Wetland and Shoreline Status and Trends Project Development Team, Corpus Christi Bay National Estuary Program.

Member, Research Group for a Seagrass Conservation Plan for Texas (Symposium on Texas Seagrasses), Texas Parks and Wildlife Department.

University Teaching/ Continuing Education

William L. Fisher

"Sequence stratigraphy": presented to The University of Texas at Austin, Department of Geological Sciences (Geology 380N), Austin, Texas.

"Reservoir geology and advanced recovery": presented to The University of Texas at Austin, Department of Geological Sciences (Geology 391), Austin, Texas (with Noel Tyler).

"Petroleum workstations": presented to The University of Texas at Austin, Department of Geological Sciences (Geology 191), Austin, Texas (with William E. Galloway and Noel Tyler).

"Natural resources and the environment": presented to The University of Texas at Austin, Department of Geological Sciences (Geology 379K), Austin, Texas (with Mark P. Cloos).

Bob A. Hardage

"3-D seismic imaging and interpretation of complex reservoir systems": short course presented on behalf of the Society of Exploration Geophysicists, Jakarta, Indonesia.

"Reservoir geophysics": short course preseuted on behalf of the Society of Exploration Geophysicists, Lafayette, Louisiana; Bartlesville, Oklahoma; and Reynosa, Mexico.

"3-D seismic technology": short course presented on behalf of the U.S. Department of Energy, San Antonio and Houston, Texas.

Charles Kerans

"Current processes and technology": co-lecturer of short course presented to the American Association of Petroleum Geologists Annual Meeting.

Paul R. Knox

"Geologic identification of reservoir architecture" and "Reservoir prioritization": co-lecturer of short course presented to the Houston Geological Society Continuing Education Short Course, Houston, Texas.

Stephen E. Laubach

"New methods to quantify fracture attributes in deeply buried clastic rocks": workshop presented to the Geological Society of America, South-Central Section, Annual Meeting, Austin, Texas.

F. Jerry Lucia

"Geological/engineering characterization of carbonate reservoirs": presented to The University of Texas at Austin, Department of Geological Sciences (Geology 391), Austin, Texas.

Jeffrey G. Paine

"Geophysical identification of reservoir architecture": co-lecturer of short course presented to South Texas Geological Society, San Antonio, Texas.

"Applying 3-D seismic data to image geologic features and identify reservoir compartments: analysis at T-C-B field, South Texas": co-lecturer of short course presented to the Houston Geological Society, Houston, Texas.

Jay A. Raney

"Course to update personnel protection and safety certification" workshop presented to the Occupational Safety and Health Administration, Washington, D.C.

Bridget R. Scanlon

"Unsaturated zone hydrology": presented to The University of Texas at Austin, Department of Geosciences (Geology 391), Austin, Texas.

Andrew R. Scott

"Geologic and hydrologic controls critical to coalbed methane producibility and resource assessment: comparative studies of the San Juan, Greater Green River, and Piceance Basins": co-lecturer of United Nations–funded short course presented to the Ministry of Coal Industry, Xi'an, People's Republic of China.

"Sequence stratigraphic concepts: introduction to facies identification in deltaic systems" and "Geological identification of reservoir architecture": co-lecturer of short course presented to the South Texas Geological Society on behalf of the U.S. Department of Energy, San Antonio, Texas.

James L. Simmons, Jr.

"Data processing 1": presented to The University of Texas at Austin, Department of Geological Sciences (Geology 384R), Austin, Texas.

"Geophysical modeling and inversion": presented to The University of Texas at Austin, Department of Geological Sciences (Geology 391), Austin, Texas.

Noel Tyler

"Reservoir geology and advanced recovery": presented to The University of Texas at Austin, Department of Geological Sciences (Geology 391), Austin, Texas (with William L. Fisher).

"Petroleum workstations": presented to The University of Texas at Austin, Department of Geological Sciences (Geology 191), Austin, Texas (with William L. Fisher and William E. Galloway).

Roger Tyler

"Geologic and hydrologic controls critical to coalbed methane producibility and resource assessment: comparative studies of the San Juan, Greater Green River, and Piceance Basins": coordinator of United Nations–funded short course presented to the Ministry of Coal Industry, People's Republic of China, Xi'an, Peoples's Republic of China.

Support Staff

Administrative/Secretarial

Administrative staff members handle the general management of the Bureau, which includes payroll and personnel, accounts payable and receivable, purchasing, travel arrangements and reimbursements, receptionist duties, correspondence, and coordination of meetings. The Bureau's involvement in numerous contracts and research projects results in processing numerous electronic documents 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. This section is supervised by Wanda LaPlante, Executive Assistant.

Computer Resources

The Bureau has state-of-the-art computing hardware and software, which its Computer Resources staff use to support Bureau scientists in interpretation, 3-D modeling, visualization, reservoir characterization, computer mapping, programming, data-base applications, and statistical and graphical analysis of data. The Bureau's research staff also has access to the University's IBM, VAX, and Cray computer systems.

The Bureau's computer environment consists of a Silicon Graphics Onyx Reality Engine server that has 7 SGI workstations, a Sun Ultra Enterprise 2 server that has 11 Sparc and UltraSparc workstations, a VAX cluster, and a departmental NT server that integrates the Unix platforms with 120 Macintoshes and 60 IBM-compatible PC's. Additional hardware resources include 25 LaserWriter printers, a Versatec 36-inch electrostatic plotter, a Hewlett-Packard 36-inch DesignJet plotter, a 22-inch Versatec electrostatic plotter, and a 36-inch drum scanner. All computer systems on the Bureau's Local Area Network are connected to a 100-MB ethernet backbone that is connected via a T-1 circuit to the UT campus and other Internet sites worldwide.

Editing

The Editing staff, supervised by chief editor Susann Doenges, handle editing, word processing, and proofreading of manuscripts for Bureau publications, contract reports, and other documents. They support the text processing needs of the research staff and work closely with the Graphics section to produce publications that are made available to the public and to sponsors of Bureau research. During 1996, the staff prepared 8 Bureau publications, 39 contract reports, and 2 Technical Summaries for the Gas Research Institute. In addition, 65 papers and 65 abstracts by Bureau authors were published by professional journals and publishers.

Graphics

In 1996, the Computer Graphics section's 14-person full-time staff, under the direction of Chief Cartographer Richard L. Dillon, produced 4 black-and-white plates, 9 full-color cross sections, 10 full-color maps, 2,561 text figures, and 2,671 photographic slides, posters, and overhead transparencies.

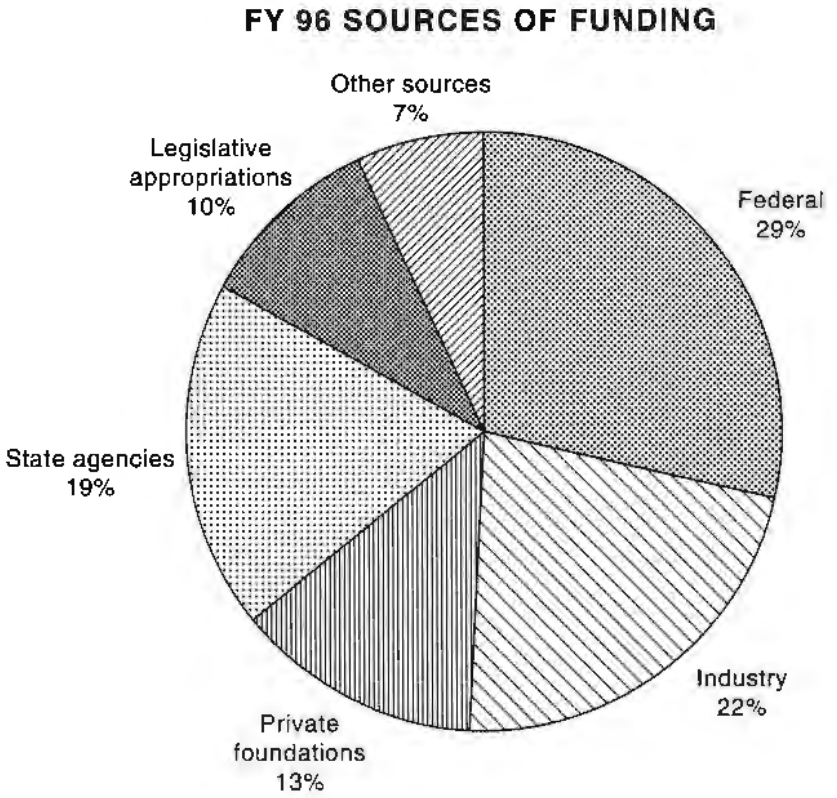
All text figures, photographic slides, posters, and overhead transparencies are produced entirely on computers. Maps and plates, both in color and black and white, are being completed on computers as well. High cartographic standards are practiced to maintain the Bureau's reputation for quality. The Computer Graphics section has a two 600-dpi black-and-white laser printers, a 300-dpi color printer (11 × 17 inches), a dye-sublimation color printer, a 36-inch-wide color ink-jet plotter, a 36-inch-wide hot laminator, a monochrome scanner, a high-resolution color scanner, and a film recorder for production of 35-mm slides—all of which support the Macintosh computers. All computers and equipment are networked through an Ethernet system.

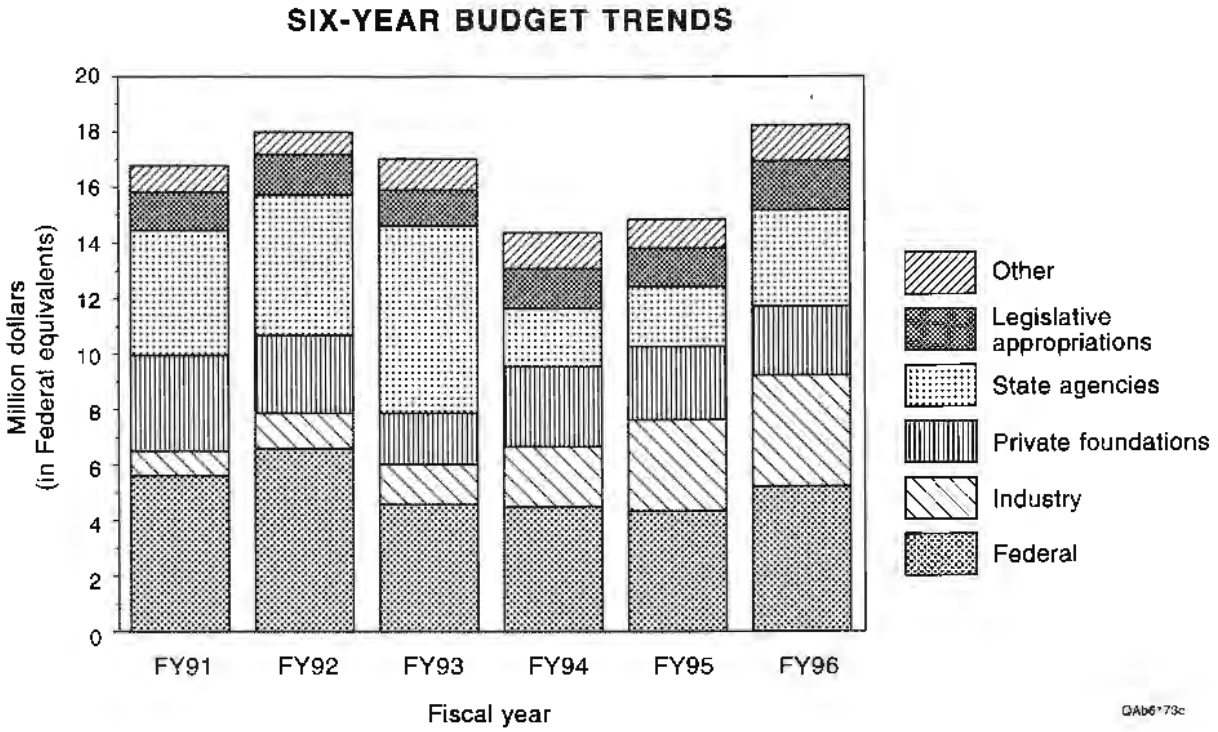
Quality Assurance

The Bureau 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 provided by Congress, such as 10 CFR 50, Appendix B, by professional entities such as ANSI/ASME Nuclear Regulatory Documents, and as directed by contract. The Bureau's QA Program meets the requirements of both the U.S. Department of Energy and the U.S. Environmental Protection Agency.

During 1996, quality assurance personnel participated on three Bureau research projects. In addition to providing guidance to researchers on quality assurance issues, the QA staff continued to update and revise the Bureau's QA Program and Procedures. James Donnelly, Quality Assurance Specialist, organized a 40-hour Basic Health and Safety Course that was taught by the U.S. Environmental Protection Agency. Twenty-six Bureau researchers and one employee from UT's Center for Electromechanics participated in this course, which renews the employee's knowledge of health and safety regulations when working in the field.

Sources of Funding and Budget Trends





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