BUREAU OF ECONOMIC GEOLOGY

THE UNIVERSITY OF TEXAS AT AUSTIN

ANNUAL REPORT

1990

Foreword

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

Extensive advisory, technical, and informational services relating to the resources and geology of Texas are provided by the Bureau. In addition, the Bureau conducts basic and applied research projects in energy resources, mineral resources and statistics, coastal and environmental studie
geologic mapping, and a variet
programs in areas such as h
analysis, and geochemistry.
conducted jointly with other unit
well as with State, Federal, and
Texas Mining and Mineral R
Institute is an administrative unit
The Bureau provides on
governmental agies incl

(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,
neral Resource Circulars,
blications are sold for a
inting costs. A complete
le on request.
he Bureau of Economic
e and status of current
ons, personnel activities,
of Texas resources and
governmental agencies,

Annual Report 1990

Research and Administrative Office
and Laboratories
Balcones Research Center

10100 Burnet Road
Austin, Texas 78758-4497
(512) 471-7721 (512) 471-1534
FAX 471-0140

Mailing address

The University of Texas at Austin
University Station, Box X
Austin, Texas 78713-7508

Bureau of Economic Geology

W. L. Fisher, Director

The University of Texas at Austin
Austin, Texas 78713

Contents

Research

During 1990, the Bureau of Economic Geology continued the trend of yearly growth that started a decade ago in the number and scope of research projects, the number of funding sources, and the amount of funding for these projects. Fifteen new projects were begun in 1990, expanding the Bureau's operating budget from $10 million (1989) to more than $12 million. The new projects (funded by State, Federal, and industrial entities) represent a range of geoscientific topics, complementing the Bureau's existing variety of energy-resource, hydrogeologic, waste-isolation, experimental- and applied-tectonic, coastal, mineral-resource, and mapping investigations. Prominent among these new projects are

(1) four structural-modeling, diagenetic, and hydrogeologic research topics funded by the Texas Higher Education Coordinating Board's Advanced Technology and Advanced Research Programs,

(2) three waste-isolation and hydrogeologic topics funded by the U.S. Department of Energy (DOE),

(3) two regional hydrogeologic and mapping topics funded by the U.S. Geological Survey, and

(4) two topics involving study of Gulf of Mexico coastal processes funded by the Minerals Management Service of the U.S. Department of the Interior and the U.S. Fish and Wildlife Service.

Moreover, several Bureau energy-resource projects that are supported by consortia of domestic and international petroleum companies attracted additional funding from new industrial sponsors this year.

Several multiyear endeavors of interest to the Texas public and to the petroleum and mineral industries were successfully concluded during 1990. Surveys of the industrial-mineral and portland cement industries of Texas are currently being prepared for publication. Two separate investigations of the causes of short-term and historical changes in the development and maintenance of commercially important Gulf coastal marshlands have been useful to the Texas fishing industry, local urban planning commissions, and river authorities, among others. Completed geologic and econometric analyses of Texas hydrocarbon fields containing unswept mobile oil and bypassed gas zones provided producers with specific recommendations on strategies to expand resource reserves economically. Investigation of upper Paleozoic cyclothemic successions of the Eastern Shelf and adjacent Midland Basin, based on Bureau research conducted over more than 15 years, culminated in 1990 with the publication of an expanded Bureau report in which the latest sequence-stratigraphic concepts are integrated with more traditional subsurface correlations and mapping.

Energy-resource investigations, constituting more than 40 percent of all active projects, continued to receive primary emphasis in Bureau research during 1990. The Geoscience Institute, housed at the Bureau and comprising a consortium of state and university research agencies, is investigating how to develop advanced hydrocarbon-recovery technology. Now in its third year, the Geoscience Institute is currently trying to classify and enter in the DOE's petroleum-resource data base some 1,500 reservoirs throughout the United States. A reservoir-classification system is being used that was developed by the Institute. The State Lands Energy Resource Optimization (SLERO) project began its first full year of activity in 1990. The project is managed by the Bureau and is composed of a consortium of Texas state universities to develop improved strategies for petroleum recovery from State Lands. The first two phases of the SLERO project, regional play analysis and site-specific reservoir characterization, are under way. Other, long-term programs involving investigation of the regional genetic stratigraphy, structure, and energy resources of the outer shelf and deep-water slope systems of the western Gulf Coast Basin received continued industry support during 1990.

Reflecting a shift in research focus begun last year, other Bureau reservoir-characterization studies have increasingly integrated outcrop analysis of reservoir facies with subsurface data. Continuing efforts to describe the three-dimensional geometry of carbonate-reservoir flow units in the Permian San Andres Formation of the Guadalupe Mountains of New Mexico are aimed at better defining lithologic baffles (flow barriers) that are typical of undrained or partly drained, compartmentalized oil reservoirs. This investigation will provide a clearer perspective on complex but resolvable heterogeneities within carbonate reservoirs of the Midland Basin, which are being examined in parallel Bureau studies. Field analysis of the superbly exposed Ferron delta system in east-central Utah is designed to help predict the location of compartmentalized reservoirs and internal seals in gas-producing Gulf Coast fluvial-deltaic facies tracts. The Ferron is a close analog.

Developing the necessary geologic and engineering knowledge to produce natural gas efficiently from low-permeability sandstone reservoirs remains the focus of several Bureau projects funded by the Gas Research Institute. An 8-year Bureau program continues that involves investigating factors controlling porosity and permeability, fracture distribution, and state of stress in low-permeability gas reservoirs in Texas and Wyoming. This program was expanded this year to include characterization of the Upper Pennsylvanian Canyon Sandstone in the Val Verde Basin and on the Ozona Arch of southwest Texas. This new study complements sim-

ilar ongoing projects involving the Lower Cretaceous Travis Peak Formation and Jurassic Cotton Valley Group in East Texas, the Upper Cretaceous Frontier Formation of Wyoming, and the Upper Pennsylvanian Cleveland Formation in the Texas Panhandle. Now in its second year, the project "Secondary Natural Gas Recovery: Targeted Technology Applications for Infield Reserve Growth" examines critical industrial concerns regarding extraction methods of unrecovered natural gas resources remaining in heterogeneous nonassociated gas reservoirs. During 1990, testing and implementation of emerging and traditional data-acquisition techniques in four gas fields in the Gulf Coast Basin have enabled detection of potentially compartmentalized reservoirs with vastly improved resolution. Bureau researchers also expanded their examination of the geologic and hydrologic factors that control the distribution and producibility of coalbed methane in coal-bearing strata of the Fruitland Formation in the San Juan Basin, Colorado and New Mexico.

The Bureau's Applied Geodynamics Laboratory (AGL), funded by a consortium of industrial associates, directs an experimental tectonics program that has immediate application to the varied energy-resource projects. The AGL uses a variety of deformation devices, largely custom-designed by AGL researchers, to produce dynamically scaled models that replicate specific geologic structures, such as subtle hydrocarbon traps. Experimental research at the AGL during 1990 involved a range of gravity-driven tectonics involving extension, salt tectonics, and combinations of these structural styles as a way to find and develop hydrocarbon traps. Two studies initiated this year concentrated on the mechanical genesis of traps in regimes of salt diapirism and of traps associated with rollover anticlines created by extension along listric normal growth faults. To aid explorationists in the structural interpretation of seismic images, the Macintosh-based *Restore*© computer program was developed at the AGL. It provides structural restoration of cross sections by geometrically reversing structural and sedimentation effects. The program removes layers and fault slip sequentially while correcting for compaction, rotation, and faulting.

In 1990 ground-water and waste-isolation studies examined a range of resource and environmental problems affecting Texas and the United States. The Lower Colorado River Authority is funding a program to study ground-water availability in areas of the Gulf Coastal Plain currently undergoing residential and commercial development. Investigations of aquifers in Matagorda and Wharton Counties were completed this year, and work began on ground-water resources in Fayette and Colorado Counties. The new multiyear project "Paleohydrology of the Nonglaciated Great Plains: Climatic and Geomorphologic Implications" may be crucial to understanding the late Cenozoic climatic history of the continental interior and to improving hydrologic models used to predict water-level changes in the vital High Plains aquifer. The primary objective of another new long-term Bureau program, funded by the DOE, is to demonstrate the economic viability of geopressured-geothermal water as an alternative energy resource. Also using funding from the DOE, Bureau scientists are characterizing the extent and geologic controls on contaminant migration from mill tailings at an inactive uranium-ore processing plant in western Karnes County. Finally, the Bureau's long-standing geologic and hydrologic program to evaluate the potential site for a Texas repository of low-level radioactive wastes successfully concluded this year with the submission of comprehensive reports to the Texas Low-Level Radioactive Waste Disposal Authority.

Most coastal studies conducted during 1990 involved monitoring Texas Gulf shoreline changes and examining their causes and potential remedies. Interest in these projects is especially keen among management councils of coastal communities and local property owners. In three separate studies funded by State and Federal agencies, Bureau scientists examined (1) historical shoreline changes in Copano, Aransas, and Redfish Bays using sets of aerial photographs from the 1930's, 1950's, and 1980's, (2) the magnitude and rates of recovery of the beach and vegetation line since Hurricane Alicia in 1983 and the influence of human activities on the recovery process, and (3) differences in historical changes between wetland and seagrass habitats during the years 1956, 1979, and 1989 in the Galveston Bay system. Coastal erosion—whether by hurricanes, waves, sea-level rise, or subsidence—is common to the Texas Gulf shoreline. Increasing recognition of the environmental and economic importance of shoreline changes makes it imperative that current information on the status and trends of coastal erosion be available.

The Texas Mining and Mineral Resources Research Institute (TMMRRI), partly funded by the U.S. Bureau of Mines and administered by the Bureau, supports education of mining and mineral-resource students through competitive graduate fellowships, postdoctoral research positions, research assistantships, and undergraduate scholarships. For the 1990–1991 academic year, four fellowships, two research assistantships, and one postdoctoral position were awarded by the TMMRRI for study of ore deposition, mineral economics, and petroleum recovery in Texas.

Bureau geologic mapping projects conducted this year include (1) mapping of volcanic centers in the mid-Tertiary volcanic field of Trans-Pecos Texas, (2) mapping of the newly designated Big Bend Ranch State Natural Area in the Bofecillos Mountains of the Trans-Pecos, and (3) 1:100,000-scale mapping of the New Braunfels, Texas, Quadrangle, an area of rapid development in Central Texas.

Further descriptions of these and other Bureau research projects are provided on the following pages.

Energy Resources Investigations

Petroleum

Geoscience Institute for Oil and Gas Recovery Research

Marcus E. Milling, Institute Director

The Geoscience Institute, established by The University of Texas at Austin and housed at the Bureau, is a national consortium composed of leading universities and other state entities that have advanced recovery research programs in petroleum engineering, geophysics, and geology. In 1990 the Institute's membership increased to 25 organizations in the 19 states that represent all major hydrocarbon provinces in the United States.

The Institute's goal is to develop support for a nationally based interdisciplinary oil and gas recovery research program to help public-sector programs fill the petroleum industry's technology needs. Future breakthroughs in the area of recovery technology require a multidisciplinary team approach.

The Institute, under contract to the U.S. Department of Energy (DOE), completed its report, "Major Program Elements for an Advanced Geoscience Oil and Gas Recovery Research Initiative," in 1989. This past year at DOE's request the Institute's Reservoir Classification Task Force developed a classification system for categorizing reservoirs according to their depositional system type, structural style, and diagenetic overprint. Currently the Institute is coordinating the five-region classification of some 1,500 reservoirs in DOE's TORIS data base using the new system. The study will provide the basis for analyzing the distribution of remaining oil resources in existing U.S. fields.

The Institute expects to develop broad-based support for its program through a joint industry/university consortium. Industry's participation is required to ensure effective and timely transfer of new technology to the end-users. To support such joint industry/university consortia the DOE has requested $17 million in FY91.

Genetic Stratigraphy, Depositional Systems, Structural Evolution, and Petroleum Exploration Potential: Northwest Gulf of Mexico Continental Shelf

Robert A. Morton, principal investigator; assisted by Gyorgy L. Marton and Beate Sterrenberg

This long-term industry-sponsored research program focuses on regional genetic stratigraphy, structure, and energy resources of the western Gulf Coast Basin. The primary data base, which has been gathered over the past 6 years, includes more than 2,500 conventional well logs, numerous paleontologic reports, seismic lines selected from regional grids, scout tickets, and production records. In 1985 an industrial associates group was organized to maintain the research and to increase the exchange of information with potential users. Companies involved in 1990 were BP Exploration, Consolidated Natural Gas, Mobil Exploration and Producing U.S., Inc., Oryx Energy Company, Union Texas Petroleum, Fairfield Industries, and Halliburton Geophysical Services.

In 1990, quantitative mapping and correlation of Plio-Pleistocene stratigraphic units in the West Cameron and western Garden Banks areas were completed, a set of structural cross sections was drafted, and a series of maps depicting structural trends and sandstone distribution were prepared. Featured in the map series are isopach maps of net sand and percent sand for six stratigraphic units, and maps illustrating principal depositional features, structural elements, and hydrocarbon plays. By year-end the project was directed toward the completion of both maps and seismic facies interpretations in order to produce a regional synthesis and a report of depositional systems, structural framework, and petroleum resources of Plio-Pleistocene depositional sequences on the outer shelf and upper slope.

Depositional Styles of Neogene Slope Systems, Texas Continental Shelf

Robert A. Morton, principal investigator; assisted by Gyorgy L. Marton

Geographic and geologic extension of mature hydrocarbon plays requires an understanding of deep-water sedimentation and recognition of various types of slope systems that offer the greatest exploration potential. The purpose of this research, funded by the Minerals Management Service, U.S. Department of the Interior, as part of its Studies Related to Continental Margins project, is to compare and contrast the characteristics of slope-related systems in the western Gulf Coast Basin and to develop depositional models that will synthesize their salient features.

Two hydrocarbon-producing slope systems of offshore Texas that are being investigated in detail are (1) middle Miocene (*Cibicides opima*) strata of the Galveston Area and (2) middle Pliocene (pre-*Globoquadrina altispira*) strata of the High Island South Addition Area. A common characteristic of these slope systems is that each represents deposition near the paleoshelf margin. Beyond that similarity, preliminary examination suggests that they are distinctly different in areal distribution, geometry and continuity of sandstones, facies archi-

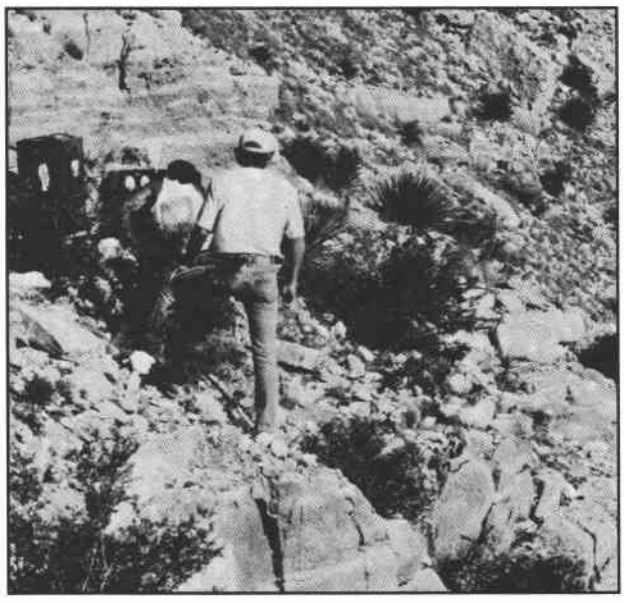
tecture, seismic expression, and relationship to relative sea-level fluctuations within the basin.

During 1990 final cross sections that illustrate the changes in lithofacies and paleoecological zones within the slope systems were constructed. These cross sections were integrated with available seismic lines to interpret the history of submarine pediment excavation and subsequent deposition. Maps of net sandstone and percent sandstone were prepared for each of the stratigraphic units in order to document depositional patterns and to identify pathways of sediment transport. In addition, a summary of the depositional history and reservoir characteristics of the middle Miocene and middle Pliocene slope sandstones was written and submitted for publication.

Reservoir Characterization Research Laboratory: Characterization of San Andres and Grayburg Reservoirs, West Texas and New Mexico

Charles Kerans, principal investigator; Ekrem Kasap, F. Jerry Lucia, H. Seay Nance, Rainer K. Senger, and Susan D. Hovorka; assisted by Malcolm A. Ferris, Andrew P. Czebieniak, and Robert S. Single

The Reservoir Characterization Research Laboratory (RCRL) began studies of the San Andres and Grayburg Formations in 1988 with the express goal of developing improved methods of reservoir description and models of reservoir heterogeneity for these complex but prolific reservoirs of the West Texas Permian Basin. Critical data for this research have resulted from parallel studies of San Andres strata in the Seminole San Andres reservoir and of outcrops of the San Andres in the Guadalupe Mountains. Funding for this research is supplied by an industrial associates group.



Bureau and industry geologists gathering in situ permeability data from the San Andres Formation of the Algerita escarpment, Guadalupe Mountains, New Mexico. These data help researchers establish critical constraints on the permeability structure of subsurface reservoir flow models.

RCRL research stresses integration of geologic, rock-fabric, petrophysical, geostatistical, and flow-modeling disciplines, and many of the unique contributions of the project can be directly attributed to this integration. A key development in this second year of the program is the conversion of a 180-ft by 2,600-ft parasequence-scale facies cross section of outcropping San Andres grainstones into petrophysical parameters of porosity, permeability, and saturation for use in two-phase fluid-flow simulations, which make use of finite-element and finite-difference models. These models will serve to quantify the impact of various depositional and diagenetic heterogeneities on sweep efficiency in strata analogous to upper portions of San Andres reservoirs.

Ongoing research focuses on developing genetic models of reservoir heterogeneity for shallow-water carbonate strata within a sequence stratigraphic framework.

Characterization of Facies and Permeability Patterns in Carbonate Reservoirs Based on Outcrop Analogs, Texas and New Mexico

Charles Kerans and F. Jerry Lucia, principal investigators; H. Seay Nance and Ekrem Kasap; assisted by Malcolm A. Ferris and Robert S. Single

The primary objective of this research is to develop better methods for describing the 3-dimensional geometry of carbonate reservoir flow units as related to conventional or enhanced recovery of oil. The research is being funded by the U.S. Department of Energy. Detailed characterization of geologic facies and rock permeability in reservoir-scale outcrops of the Permian San Andres Formation in the Guadalupe Mountains of New Mexico will provide the key data base. Improved techniques for estimating permeability on the basis of geologic description are being developed using emerging geostatistical techniques and reservoir flow-simulation experiments. Methodologies developed from outcrop studies are being tested by the Bureau through parallel studies of San Andres and Grayburg reservoirs in the Permian Basin designed to seek new strategies for recovering remaining mobile and residual oil.

Most San Andres and Grayburg reservoirs are composed of a lower, predominantly subtidal, and an upper, predominantly shallow subtidal to intertidal, part. How remaining mobile oil within these two intervals is distributed must be resolved on a reservoir-by-reservoir basis, but detailed analysis of several reservoirs indicates

that more than 50 percent of the remaining resource lies in the geologically and petrophysically less well understood subtidal part (typically the lower two-thirds of the oil column). Geologic studies have defined an inclined flow-unit geometry in the equivalent strata in San Andres outcrops that were deposited as prograding clinoforms in an outer ramp setting. Permeability mapping and rock fabric/petrophysical studies of these clinoform strata are under way, and flow-modeling experiments will follow. A key question that the reservoir models are designed to answer is: What is the effect of inclined flow-unit geometry, defined by the clinoform strata, on fluid flow and sweep efficiency?

Characterization of Carbonate Sandbar Facies in Grayburg Formation Reservoirs, West Texas

Charles Kerans, principal investigator; Don G. Bebout, H. Seay Nance, and Susan D. Hovorka

This project is devoted to integrated geologic/engineering analysis of the lithologically and petrophysically heterogeneous shallow-water grainstone-rich parts of restricted-platform carbonate reservoirs of the Permian Basin. The U.S. Department of Energy is funding the project through agreement with the State of Texas. Reservoirs of the restricted-platform play contain 30 billion barrels of remaining oil, or 40 percent of the remaining resource in Texas. Bureau and other reservoir studies of this class of reservoirs have emphasized the grainstone-rich upper parts of these reservoirs because of the degree of heterogeneity and potential for hydrocarbons remaining in bypassed or unswept compartments.

The methodology includes (1) the study of a selected reservoir for information on producing characteristics (for example, recovery efficiency) and the nature of key productive facies tracts and (2) outcrop studies of analogous facies tracts for collecting continuous facies and permeability data at the interwell scale to describe and model heterogeneity in the subsurface. The study focuses on grainstone complexes of the Grayburg Formation, one of the most productive units of the Permian Basin's restricted-platform carbonate play. Outcrop studies of the Grayburg are in the Stone Canyon/Shattuck Valley area of the Guadalupe Mountains, which provide excellent 3-dimensional and dip-oriented cross-sectional views of the upper Grayburg. Subsurface studies are being carried out in the ARCO North Foster Unit and adjacent Cities Service Johnson Grayburg Unit to the north.

Fourteen detailed measured sections spaced at a regional scale were used to define the sequence stratigraphic framework of the Grayburg in a completely exposed dip-oriented section. This framework demonstrated the presence of lowstand wedge, transgressive, and highstand systems tracts, although pay-quality facies in the highstand tract clearly dominated.

The Grayburg was subdivided further into 34 parasequences within which facies distributions were mapped. Particularly noteworthy is the distribution of ooid grainstone bars and oo-peloid packstone sheets that compose the main reservoir intervals in the subsurface. Seventeen ooid grainstone bars were mapped within the parasequence framework, most of which were 6 to 10 ft thick and continuous in a dip direction for less than 1 mi.

The subsurface geologic study of the Grayburg in the ARCO North Foster Unit and the Cities Service Johnson Grayburg Unit involved constructing 4 detailed cross sections from cores of 27 wells—2 across the North Foster Unit and 2 across the Johnson Grayburg Unit to the north. Nine major correlation units have been traced throughout the study area. However, 24 cycles (parasequences) are recognizable at least locally in these core sections, indicating a cycle frequency and accommodation potential comparable to the outcropping Grayburg of the Guadalupe Mountains (22 in equivalent outcrop section).

Thickness/facies maps of the correlation units demonstrate the dominance of tidal-flat mudstone and intertidal to shallow-water subtidal coarse-grained grainstone facies in the west part of the North Foster Unit. These facies change eastward into dominantly very fine grained facies that, largely as a result of leaching of sulfates, have high porosity and permeability. The thickest part of the highly altered facies corresponds to the highest part of the structure in the unit and, consequently, the area of greatest production.

Heterogeneity in Modern Ooid Grainstones as Analogs for Ancient Hydrocarbon Reservoirs

Don G. Bebout, principal investigator; Paul M. Harris (Chevron), Charles Kerans, Richard P. Major, Douglas C. Ratcliff, and Noel Tyler

The Bureau's study of modern ooid grainstones at Joulters Cays, Bahamas, has been designed to provide a detailed modern analog for ancient carbonate grainstones that compose many hydrocarbon reservoirs worldwide. This modern grainstone-bar analog will be especially applicable to interpretation of internal textural variations within grainstone oil reservoirs of the Permian Basin, West Texas.

The first phase of field work is now complete. Thirty-nine cores were collected across a 1-mi² section of the bar complex. The 1,000-ft spacing between these cores is comparable to well spacing in a maturely developed oil field. The cores of the largely unconsolidated sediment

have been epoxy impregnated to preserve details of stratigraphy, large- to small-scale sedimentary structures, and early diagenesis.

Cross sections based on detailed core descriptions illustrate the internal geometry of the Joulters bar complex. Three facies are distinguishable in these cores: (1) crossbedded, well-sorted, ooid grainstone, (2) poorly sorted ooid grainstone, and (3) ooid packstone. The well-sorted grainstone represents the high-energy bar front and storm-washover lobes, which prograde landward and probably form intermittently at times of high-energy storms. This facies overlies the poorly sorted grainstone facies, which forms in slightly deeper water both landward and seaward of the washover crest. The seaward location is also the site of syndepositional cementation that resulted in the formation of hardground and lithoclast zones. The ooid-packstone facies forms landward of the washover crest, in a low-energy setting sparsely colonized by the red alga *Goniolithon* and the sea grass *Thalassia*.

Multiple sets of individual storm-washover bars and crosscutting tidal channels result in complex internal textural variations. Because porosity and permeability contrast among the depositional facies and because flow barriers could form as diagenetic hardgrounds, the Joulters Cays ooid-bar study provides a modern analog for understanding and predicting the internal heterogeneities that control the distribution of remaining mobile oil in ancient grainstone reservoirs.

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

Noel Tyler and Robert J. Finley, principal investigators; R. Stephen Fisher and Mark D. Barton

Co-funded by the Gas Research Institute and the U.S. Department of Energy, this research has been designed to investigate the poorly understood subjects of composition, extent, geometry, and geometric predictability of flow units and associated intrareservoir bounding surfaces in a superbly exposed and cored outcrop belt, the Ferron Delta System in east-central Utah. The Ferron is an excellent analog of Gulf Coast fluvial-deltaic reservoirs. Research is directed at examining the causes and predictability of heterogeneity in this reservoir class because it accounts for 64 percent of the gas produced from Texas Gulf Coast fields. Predictability of reservoir and seal properties composes the crux of the project.

Activities of this project have included the initiation of field work and the convening of a workshop at which project goals and structure were reviewed with scientists from industry and academe who were involved in similar projects. Field studies have targeted a 0.5-mi section of canyon wall in which retrogradational delta-front and distributary sandstones are exposed. Sections have been measured at 100- to 200-ft intervals. Within this window of detailed study two additional grids have been developed for permeability sampling. One sample grid covers 40 ft^2, within which samples were taken every 2 ft, vertically and horizontally. A more detailed, 6-ft^2 grid, wherein samples were taken every 3 inches, both horizontally and vertically, is also contained within the window. All sections include lithofacies descriptions and permeability measurements. Representative facies and potential bounding elements have been sampled so that the influence of primary depositional heterogeneities on the distribution of cements and secondary porosity may be investigated, as well as the effect of cementation and porosity generation on the internal microstructure of the sandstones. Facies architecture and permeability structure of seaward sediments in this facies tract will subsequently be contrasted.

Maximization of Petroleum Recovery Efficiency in West Texas

Noel Tyler, consortium principal investigator; Stephen C. Ruppel, principal investigator; Mark H. Holtz; assisted by Mark W. Andreason, Thomas E. McKenna, Shahid A. Ghauri, and Suhas V. Bodwadkar

This project, which is funded by the State of Texas through the Energy Research in Applications Program (ERAP), is a detailed, multifaceted study of advanced reservoir characterization and improved recovery processes directed toward improving oil recovery from restricted-platform carbonate reservoirs. The Bureau is the lead institution in this multidisciplinary study involving more than 30 principal scientists and engineers from The University of Texas at Austin, Texas A&M University, the University of Houston, and Texas Tech University.

As a class, restricted-platform carbonate reservoirs contain more than 15 billion barrels of remaining oil and nearly half of the remaining mobile oil in the State. Research is currently focused on the Monahans Clear Fork reservoir. Among restricted-platform reservoirs, Clear Fork Group carbonates are especially appropriate for study because of their extremely low recovery efficiencies (about 20 percent); additionally, they contain about 30 percent of the mobile oil projected to remain in restricted-platform reservoirs at abandonment.

Preliminary results of reservoir characterization studies indicate that the Clear Fork is composed of very thin, upward-shallowing cycles, which exhibit a high degree of variability in internal facies composition and porosity development. Porosity development is associated with both original depositional textures and subsequent

diagenesis. Vertical changes in facies-stacking patterns suggest that deposition was strongly influenced by repeated rise and fall of relative sea level. Diagenetically related porosity trends also appear to be related to these sea-level oscillations.

Current research is directed toward defining facies and porosity trends and geometries in the reservoir and establishing whether a cause and effect relationship exists between these trends and sea-level cyclicity. The ultimate goal of the project is to develop detailed predictive models that will facilitate application of improved methods of hydrocarbon recovery in the Monahans reservoir and in other restricted-platform carbonate reservoirs in West Texas.

State Lands Energy Resources Optimization (SLERO) Project

Noel Tyler, director; Richard P. Major, principal investigator; Kenneth T. Barrow, Chester M. Garrett, Jr., Douglas S. Hamilton, Mark H. Holtz, J. Ulises Ricoy, Fred P. Wang, and Joseph S. Yeh

The Bureau is the lead contractor and coordinating institution for a study of hydrocarbon resources in Texas State Lands involving a four-university consortium—The University of Texas at Austin, Texas A&M University, the University of Houston, and Texas Tech University. Additional related projects are being conducted by the Houston Area Research Center, and the entire program is aided by the cooperation of the General Land Office of Texas. Funding is from the Office of the Governor of Texas; project personnel include geologists, petroleum engineers, geophysicists, and chemists.

The goals of this research are to quantify the hydrocarbon resources in Texas State Lands and to develop strategies for maximizing ultimate cumulative recovery through both advanced secondary recovery and enhanced recovery operations. The interdisciplinary nature of this project is expected to result in (1) a more thorough understanding of the geologic controls on production and (2) development of appropriate recovery technologies to fill the specific needs of State Lands reservoirs.

Play Analysis and Resource Assessment

The first phase of the SLERO project, play analysis and resource assessment, culminated in the completion of preliminary play analysis of State Lands hydrocarbon resources. Of a total 1,240 hydrocarbon reservoirs on State Lands having cumulative productions of 1 million barrels of oil or 6 million cubic feet of gas, 526 are oil reservoirs and 714 are gas reservoirs. The majority of State Lands gas reservoirs are concentrated in the Gulf Coast region, principally the Frio Deep-Seated Salt Domes, Frio Barrier/Strandplain Sandstone, and Frio Fluvial/Deltaic Sandstone plays. Additionally, a major Gulf Coast oil play is the Jackson Barrier/Strandplain play. Three major oil plays in the western and central parts of the state also contain large numbers of reservoirs: the Delaware Sandstone, Leonardian Platform Carbonate, and Permian Sandstone and Carbonate plays. Together these seven plays account for 37 percent of the major reservoirs contained in Texas State Lands.

Reservoir Characterization

The second phase of the project, site-specific reservoir characterization research on reservoirs that typify key State Lands plays, is under way. The Bureau has identified five fields and one subregional area for detailed geologic and engineering study.

Keystone (Colby) Field

The Keystone Colby reservoir in Winkler County is part of the Permian Sandstone and Carbonate play. The Keystone Colby is of late Guadalupian age, equivalent to that of the Queen Formation. Reservoir rocks are gray to tan, fine- to medium-grained sandstones interbedded with varying amounts of dolostone and anhydrite. These rocks were deposited in eolian, tidal-flat, and shoreface environments. The principal producing facies are thin sandstones, although dolostone beds are productive in some locations.

Las Tiendas (Olmos) Field

The Upper Cretaceous Olmos Formation reservoir at Las Tiendas field in Webb County is part of the Upper Cretaceous Olmos Deltaic and Delta-Flank Sandstone play. Core examination indicates that these low-permeability sandstones were deposited in storm-dominated shelf environments between deltaic depocenters. Reservoir heterogeneity in the stratigraphically trapped Las Tiendas field is expressed in the dissimilarity between sand isopach maps and productivity trends.

Lavaca Bay Field

Lavaca Bay field, located in Calhoun County, is representative of the Oligocene Frio Barrier/Strandplain Sandstone play. This field contains productive strandplain barrier-bar system sandstones at depths between 7,000 and 12,500 ft. These sandstones are composed of stacked progradational and aggradational depositional sequences on the downthrown block of a major growth fault. Rocks of the upper Frio Formation were only slightly deformed by this major fault, and reservoirs have structural closure on the updip side of the block. Lower and middle Frio rocks were greatly influenced by this fault, resulting in as much as four-fold thickening in the northwest margin of Lavaca Bay field relative to the southeast rollover structural high of the field.

The reservoirs of the lower and middle Frio contain both structural and stratigraphic traps that have closures toward this rollover.

Seventy-Six West Field

Seventy-Six West field was selected as representative of the Eocene Jackson–Yegua Barrier/Strandplain Sandstone play. Production is primarily from shallow, strike-elongate barrier-bar sandstones, with some production from barrier-flat, washover, and tidal-delta sandstone facies. The principal trapping mechanism is structural closure with updip stratigraphic pinch-outs. The secondary trapping mechanism is rollover dip on the downthrown block of reactivated growth faults, which originated in the deeper Wilcox Group.

Powderhorn Field

Powderhorn field, located in Calhoun County, produces gas and oil from multiple reservoirs within the lower Miocene Oakville Formation and is representative of the Miocene Barrier/Strandplain Sandstone play. Detailed well log cross sections at Powderhorn field show that the producing sandstones were deposited in a variety of environments in and behind a barrier island. The complex interrelationships among the back-barrier washover fan, tidal inlet, and tidal delta environments provide significant opportunities for recovery of bypassed mobile oil in these highly compartmentalized reservoirs.

Bell Canyon Formation of the Delaware Basin

Hydrocarbon production in the Delaware Basin is mostly from reservoirs in channel sandstones and conglomerates of the upper part of the Permian Bell Canyon Formation of the Delaware Mountain Group. These reservoirs comprise the Delaware Sandstone play. They are composed of channel-fill facies that range from fine-grained well-sorted subarkosic sandstones, which have no sedimentary structures and were likely deposited by saline density currents, to sequences of graded beds ranging from conglomerates to shales having sedimentary structures that suggest deposition by turbidity currents. Moderately sorted, laminated arkosic siltstones that were derived from sediment carried to the basin by eolian processes are interbedded with channel-fill facies. Siltstones are relatively poorly permeable and envelop the permeable channel reservoir rocks. Thin laminated siltstones also separate depositional units within the channel facies. Consequently, siltstones also form the bounding elements of flow units within channel reservoir rocks.

Advanced Extraction Technology

The final phase of the study will involve engineering-oriented studies conducted within the context of the site-specific geologic studies. The advanced extraction technology part will be concentrated on the potential for advanced well stimulation and enhanced oil recovery technologies, including modeling to predict performance, in order to maximize the ultimate impact on State Lands reservoirs.

Accurate Modeling of Fluid Flow in Hydrocarbon Reservoirs and Aquifers Using Scale-Averaged Rock Properties

Graham E. Fogg (University of California, Davis), principal investigator; Rainer K. Senger and James D. Baumgardner (University of California, Davis)

This project is aimed at developing procedures for more realistic modeling of heterogeneous reservoirs. Specifically this involves devising and testing methods for translating local-scale data on absolute permeability and relative permeability of reservoirs into "effective" rock properties that are representative of fluid flow and mass transport at the scale of a reservoir simulator block. This problem has historically hindered efforts to model heterogeneous reservoirs accurately.

Through the use of numerical modeling experiments, both empirical and theoretical relationships between effective permeability and certain properties of a fluvial sand and mud sediment package are being established. These properties include sand percent and the ratio between average horizontal and vertical facies dimensions relative to dimensions of the simulator block. The effective hydraulic conductivity of sand-clay mixtures in formations where highly conductive sand bodies are surrounded by a matrix of low-conductivity clays is a function of sand fraction, individual material hydraulic conductivities, and sand-body geometry parameters. Numerical simulation is used to calculate the effective hydraulic conductivity for geometry scenarios, including single sand bodies, regular multiple sand bodies, and stochastically generated sand bodies. The reciprocal of the effective hydraulic conductivity varies linearly with the ratio of the sand-body lengths in the single bodies. In the multiple-body cases, the single-body analogy holds for regional domain ratios on the order of the conductivity contrast of the two materials.

The results show that the power-averaging exponent obtained from the single-body analysis depends on both sand-fraction and sand-body geometry parameters. Mean material residence lengths of the streamlines passing through each material were found to vary linearly with both the reciprocal of the effective hydraulic conductivity and the ratio of the sand-body length parameters regardless of regional domain ratio. The mean material residence lengths for the stochastically generated sand bodies showed a strong correlation with mean material residence lengths of the single and the regular multiple bodies of identical material conductivities, geometries, and sand fractions.

Econometric Analysis of the Supply Impact of Specific Tax and Other Incentives Including the Advanced Secondary Recovery of Oil

W. L. Fisher, principal investigator; Mark H. Holtz, Noel Tyler, and Chester M. Garrett, Jr.

The object of this project, which has been funded by the Office of the Governor of the State of Texas, is to create a model that will predict the impact that specific tax incentives provided by Senate Bill S.828 will have on advanced secondary and enhanced oil recovery and, in turn, oil supply. In creating the model, historic time series analysis of oil prices, development and production costs, and reserve additions will be used to assess the impact of tax incentives on domestic oil production. Tax incentives analyzed include research and development tax credit, depletion allowance, treatment of intangible drilling costs, and investment tax credit. The supply model is based on a historic time series analysis of the previous 10 years. These historical data were used to model the next 20 years of production and reserve additions based on Energy Information Administration oil price projections.

Over the past 10 years (1978–1988), advanced secondary recovery (ASR) added 1.3 billion stock barrels (BSTB) of reserves to the continental U.S., and enhanced oil recovery (EOR) added 2.5 BSTB. This 3.8 BSTB accounts for 26 percent of the total 14.7 BSTB of development oil reserves added over this time period. During the next 20 years under the currently proposed bill S.828, ASR and EOR are estimated to add 5.2 and 5.5 BSTB of reserves, respectively. With additional tax incentives added to the modified S.828 bill, ASR will add 8.9 BSTB in reserves, which is an incremental reserve addition of 3.7 BSTB. EOR oil reserve additions, if the bill is modified, will be 7.7, thus adding an incremental 2.2 BSTB of reserves. These results predict that with additional tax incentives for ASR and EOR a 55-percent incremental reserve additions increase would take place over the next 20 years.

Geologic Support of Cross-Hole Tomography

Richard P. Major, principal investigator; Douglas S. Hamilton

The Bureau is providing geologic support for a series of cross-hole tomography experiments being conducted by the Allied Geophysical Laboratories of the University of Houston under funding from the University of Houston. Cross-hole tomography is a geophysical technique in which a seismic source and a seismic recorder (geophone) are placed in adjacent boreholes. The high-frequency seismic waves emitted by the source result in very fine resolution of matrix velocity contrasts, and data generated by this new technology can be interpreted to describe geologic heterogeneity between adjacent wells within a hydrocarbon reservoir.

After a review of potential test sites for tomography experiments, the Bureau selected Seventy-Six West field in Duval County, Texas. Seventy-Six West produces oil from a depth of 1,300 ft in an Eocene Jackson–Yegua reservoir. The reservoir is composed of complex arrangements of barrier/strandplain sandstones, tidal-inlet channel fills, and associated lagoonal facies. The trap is a combination of structural closure and updip sandstone pinch-outs. Cross-hole tomography data have the potential of identifying untapped reservoir compartments by locating between-well pinch-outs. This would be especially useful in the Jackson–Yegua Barrier/Strandplain play for locating "attic" oil that remains updip from, and therefore undrained by, wells along the margin of the reservoir.

Preliminary results of these experiments indicate that resolution of 1-ft-thick features can be obtained between wells as far apart as 600 ft. Future experiments will be conducted in wells that are selected because the resulting data can be used to develop geologically targeted infill drilling prospects.

Kinetic and Geochemical Aspects of Near-Surface Dolomitization

Richard P. Major, principal investigator; F. Jerry Lucia and Robert L. Folk

One of the greatest enigmas in sedimentary geology is how large bodies of dolostone are formed. Thirty-five percent of global carbonate sedimentary rock is dolo-

Bureau scientist F. Jerry Lucia examining a coral-rubble ridge on the island of Bonaire, Netherlands Antilles. Isolated by this ridge, lagoonal waters evaporate, become hypersaline, and precipitate dolomite. This setting is a modern analog for the dolomitization process that has affected many of the reservoir rocks in West Texas oil fields.

stone, yet examples of Holocene dolostone occur as only partly dolomitized carbonate rock bodies generally containing 30 percent or less bulk volume of poorly ordered, metastable dolomite. This lack of a Holocene analog for thick, massive dolostone has been a major stumbling block in solving "the dolomite problem."

The Bureau, using funding from the Texas Higher Education Coordinating Board, has initiated study of relatively young (Plio-Pleistocene) dolostone on the island of Bonaire, Netherlands Antilles. The setting provides an ideal natural laboratory for investigation of the origin of dolostone because (1) Bonaire dolostones are very young; (2) these dolostones have never been deeply buried and, therefore, have never been exposed to elevated temperatures; and (3) Bonaire is an island isolated from large continental landmasses and, thus, the possible sources of dolomitizing fluids are limited.

Preliminary data based on field observations and thin-section petrography indicate that the dolostone formed as the result of replacement of forereef skeletal grainstones that are presently exposed in the highlands of Bonaire. These forereef deposits, which retain a seaward-facing depositional dip of 35 degrees, were dolomitized by fluids from an updip source that has since been removed by erosion. In the coming year we will collect geochemical data from the dolostones and downdip limestones to place constraints on the nature of these dolomitizing fluids.

Marine shoreface sandstones form prominent ledges in the upper part of this outcrop of the Cretaceous Frontier Formation along the Gros Ventre River in western Wyoming. Low-permeability Frontier gas reservoirs lie in analogous sandstone facies in the nearby Green River Basin where they are the focus of a Bureau research program supported by the Gas Research Institute.

Gas

Geological Investigations of Low-Permeability Gas Sandstone Reservoirs

Shirley P. Dutton, principal investigator; Robert W. Baumgardner, Jr., Sigrid J. Clift, Edward W. Collins, H. Scott Hamlin, Tucker F. Hentz, Karen L. Herrington, and Stephen E. Laubach; assisted by Robert L. Buehring and Kyle L. Kirschenmann; in cooperation with the Wyoming Geological Survey

Since 1982 the Gas Research Institute (GRI) has supported the Bureau's geologic investigations designed to discover how to produce natural gas efficiently from low-permeability sandstone reservoirs. This effort by the Bureau is part of a broader program designed to increase the understanding and ultimate utilization of gas resources in low-permeability formations through integration of geology, formation evaluation, and reservoir engineering. In 1990, the Bureau's research focused on the following formations: (1) Lower Cretaceous Travis Peak (Hosston) Formation and Jurassic Cotton Valley Group in East Texas, (2) Upper Cretaceous Frontier Formation, Green River Basin, Wyoming, (3) Upper Pennsylvanian Canyon Sandstone, southwest Texas, and (4) Upper Pennsylvanian Cleveland Formation, Texas Panhandle. The Wyoming Geological Survey has been subcontracted for parts of the study of the Frontier Formation.

Work on the Travis Peak Formation in 1990 concentrated on synthesizing the results of structural, stratigraphic, and diagenetic studies that were conducted from 1982 through 1989. A summary contract report on the geology of the Travis Peak was completed, and the results will be published in a Bureau Report of Investigations.

Research on the Frontier Formation along the Moxa Arch in the Green River Basin, Wyoming, focused on locating, drilling, and evaluating the fourth Staged Field Experiment (SFE) well, a GRI-operated test well. The well was drilled in Chimney Butte field, Sublette County, through the Frontier Formation to a depth of 8,100 ft. A total of 323 ft of core was recovered. Cased-hole experiments, hydraulic fracturing, and completion of this research well will continue into 1991. Additionally, regional studies of the depositional history, reservoir distribution, diagenesis, and structure of the Frontier Formation continued. Geologic results are being integrated with geophysical well logging, petrophysics, and reservoir engineering research conducted by other contractors to GRI.

Research was extended in 1990 to include the Canyon Sandstone in southwest Texas. Regional geologic investigation of the Canyon Sandstone is being conducted in a five-county (Schleicher, Sutton, Edwards, Val Verde, and Crockett) study area in the Val Verde Basin and on the Ozona Arch. Detailed studies, including mapping of structure and sandstone geometry, construction of detailed stratigraphic cross sections, and description and interpretation of core, have concentrated on Sawyer and Sonora fields, Sutton County.

Stratigraphic study of low-permeability sandstone in the Cleveland Formation continued in a seven-county (Hansford, Ochiltree, Lipscomb, Hutchinson, Roberts, Hemphill, and Wheeler) area of the Anadarko Basin. Mapping of structure, formation thickness, and sandstone thickness was used to delineate reservoir distribution of this progradational clastic depositional system, interpret depositional history, and characterize component facies.

Finally, a screening process was initiated in 1990 for choosing an appropriate low-permeability formation for the proposed GRI Hydraulic Fracture Test Site (HFTS). The objective of the HFTS will be to provide a field laboratory for tests of techniques to improve hydraulic stimulation of fractures in low-permeability sandstones. A national screening of low-permeability sandstones was conducted by the Bureau to identify a formation that has the qualities necessary for this natural laboratory.

Atlas of Major Gas Reservoirs: Central and Eastern Gulf Coast and Midcontinent

Don G. Bebout, principal investigator; Chester M. Garrett, Jr., and William A. White; assisted by Matt L. McCullough; subcontracts to Arkansas Geological Commission, Louisiana Geological Survey, Mississippi Department of Natural Resources, and Geological Survey of Alabama for the Central and Eastern Gulf Coast portion; and to Arkansas Geological Commission, Kansas Geological Survey, and Oklahoma Geological Survey for the Midcontinent portion

The National Gas Atlas Project, funded by the Gas Research Institute, has been under way for almost 1 year. The objective of this 3-yr project is to produce two atlases ([1] Central and Eastern Gulf Coast and [2] Midcontinent) that will contain detailed tables of production and reservoir statistics for each major reservoir that has produced more than 10 Bcf of gas. These reservoirs will be assembled into plays on the basis of similarity of geological and engineering attributes.

During the first year detailed data on major associated and nonassociated gas reservoirs have been collected and compiled for the Central and Eastern Gulf Coast Region. Most of this work has been done by the geological surveys of Alabama, Arkansas, Louisiana, and Mississippi through subcontracts from the Bureau. By the end of 1990, 18 months into the project, all atlas sheets for this region should be completed and ready for editing and drafting. This atlas is scheduled to be distributed by mid-1991.

Data collection and compilation for major reservoirs in the Midcontinent region began in September, and this atlas is scheduled to be printed and ready for distribution by mid-1992.

Secondary Natural Gas Recovery: Targeted Technology Applications for Infield Reserve Growth

Robert J. Finley, project director; Edgar H. Guevara and Raymond A. Levey, principal investigators; Shirley P. Dutton, Jeffry D. Grigsby, Lee A. Jirik, Dennis R. Kerr, Richard P. Langford, and E. G. Wermund; assisted by James G. Brewton, Laura L. Brock, Julian J. Castro, Gilbert Gabaldon, Steven J. Rainey, Randy L. Remington, Ali S. Sikandar, Lisa E. Sparlin, Katie S. Tauxe, and Liangqing Xue

Activities in the second year of this gas-field-oriented research project centered on delineation of key evidence of stratigraphic compartmentalization in sandstone reservoirs. Research is funded by the Gas Research Institute, the U.S. Department of Energy, and the State of Texas. Geologic studies conducted by the Bureau, which also functions as the Lead Technical Contractor, were integrated with formation evaluation by ResTech, Inc., of Houston and engineering and reservoir modeling by Research and Engineering Consultants of Englewood, Colorado. Envirocorp Services and Technology of Houston monitored drilling and completion activity and coordinated field-data acquisition.

Goals of this joint venture are (1) to confirm that incremental conventional gas resources represent a significant percentage of new gas reserves, (2) to assess the distribution of incremental natural gas resources by depositional system, and (3) to help define and test innovative, cost-effective tools and strategies for incremental recovery. Activities during 1990 consisted of continuing studies in four gas fields: fluvial reservoirs of the Frio Formation are being analyzed in Stratton/Agua Dulce and Seeligson field; deltaic reservoirs are being analyzed in McAllen Ranch (Vicksburg geopressured) and Lake Creek (Wilcox nongeopressured) fields.

Well activity in cooperation with Union Pacific Resources (UPR) focused on data acquisition in Stratton field. Microresistivity borehole images, offset vertical seismic profiles (VSP's), wireline pressure measurements, and conventional cores were collected. In addition, single-well pressure tests using downhole shut-in gauges were conducted in five wells in the south part of the field to determine permeability and detect near-well flow barriers. Finally, cores, VSP's, and wireline-log and pressure data were acquired in two wells drilled by Mobil Exploration & Producing U.S., Inc., in Lake Creek field. Studies of this field will be compared with results of the Bureau's GRI-supported research of facies anatomy and petrophysical properties in outcrops of the Ferron Sandstone (Cretaceous) in central Utah that formed in a similar depositional setting.

Studies of Seeligson field focused on detailed geological, petrophysical, and engineering analysis leading

to an integrated data-acquisition program with Oryx Energy Company and Mobil Research & Development Corporation. Geologic studies in McAllen Ranch field, operated by Shell Western E & P, Inc., demonstrated a hierarchy in the scales of heterogeneity (delta lobes, delta foresets, diagenetic banding), which can affect gas production in deltaic reservoirs. VSP data and interpretation of local areas of a 3-dimensional seismic survey were used to define the lateral extent of gas reservoirs further by correlating seismic-waveform attributes of the gas-productive intervals.

This research program has successfully implemented, at an effective incremental cost, improved data-acquisition techniques at both the well and the interwell scale. Acquisition of closely spaced formation-pressure measurements helped in identifying potentially compartmentalized reservoirs within a single well bore. VSP's modified to include fine station spacing (FSS-VSP) of 30 to 40 ft facilitated an improvement in subsurface resolution required to delineate the extent of reservoirs beyond the well bore.

Activities in 1991 will include the drilling of a Staged Field Experiment well in a clastic gas reservoir for testing concepts of stratigraphic compartmentalization and tool modification. Phase two of this project will involve study of carbonate reservoirs, which represent more than 30 percent of the gas reserves in Texas. Screening of carbonate fields for future cooperative study is under way, with emphasis on Cretaceous reservoirs in East Texas and late Paleozoic reservoirs in West Texas.

Gas Saturation as a Limit on Pore-Fluid Composition and Diagenetic Alteration in Deep Sedimentary Environments, Texas Gulf Coast

Regina Capuano (University of Houston), and Rainer K. Senger

This study, funded by the Texas Higher Education Coordinating Board's Texas Advanced Research Program, is part of a 2-year program to study fluids from kerogen-rich geopressured sediments along the Texas Gulf Coast. Previous research has shown that CO_2 and CH_4 are released as products of kerogen decomposition during sediment diagenesis and that the hydrologic conditions present in geopressured sediments favor enrichment of pore fluids in these gases (in contrast to hydrologic conditions present in normally pressured sediments that do not favor enrichment of these gases).

Two hydrologically distinct geopressured areas along the Texas Gulf Coast were studied, Chocolate Bayou field in Brazoria County, Texas, and Northeast Hitchcock field in Galveston County, Texas. Wells from Chocolate Bayou field derive their fluid from the C zone of the T5 unit of the Oligocene Frio Formation, which is composed of sandstone-shale units. Fluids from Chocolate Bayou wells originate within the geopressured section where fluid pressures approach lithostatic. Wells from Northeast Hitchcock field derive their fluids from a shallower and stratigraphically higher part of the Frio Formation, the Frio A sand. In contrast to wells of Chocolate Bayou field, Northeast Hitchcock field wells generally derive fluids from the upper parts of the geopressured section, where fluid pressures are hydrostatic or greater, but do not approach lithostatic as closely as do the deeper and warmer Chocolate Bayou fluids. Fluids from the deeper, more evenly geopressured Chocolate Bayou field are higher in carbon dioxide relative to methane than fluids from the shallower Northeast Hitchcock field.

Another goal of this study is to model the effects of gas separation on fluid flow within the upper parts of the geopressured section. The physical processes of gas separation and fluid flow occurring during the upward movement of fluids in geopressured sediments into lower-temperature and lower-pressure environments can be represented mathematically by coupled liquid/gas flow and energy transport in porous media. The computer code TOUGH (Karsten Pruess, TOUGH User's Guide, Lawrence Berkeley Laboratory, 1986), a multidimensional numerical model for simulating coupled transport of water, vapor, air, and heat in porous fractured media, was implemented for this study. By assigning the appropriate boundary conditions, workers can reproduce the observed temperature and pressure conditions in geopressured systems. However, the specific phase and solubility relationships for the system CO_2-CH_4-H_2O must be implemented in order that the hydrologic processes in geopressured environments might be examined.

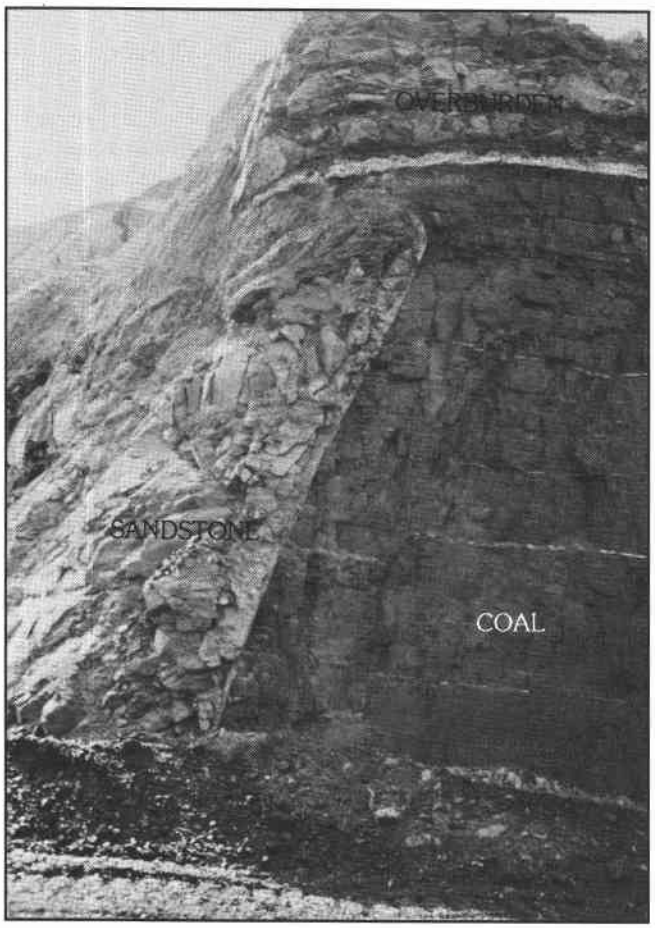
Geologic Evaluation of Critical Production Parameters for Coalbed Methane Resources

Walter B. Ayers, Jr., principal investigator; William R. Kaiser, William A. Ambrose, Robert W. Baumgardner, Jr., Stephen E. Laubach, Andrew R. Scott, Roger Tyler, and Joseph S. Yeh; assisted by Areef Ahamad, David R. Grote, Sy-Jye Guo, Garth J. Hawkins, Ting-Ya Hsieh, Sonya A. Jones, and Ronald G. McMurry; in cooperation with the Geological Survey of Alabama, Colorado Geological Survey, New Mexico Bureau of Mines and Mineral Resources, and West Virginia Geological and Economic Survey

Coal seams in the United States contain an estimated 500 Tcf of coalbed methane, which has been increasingly exploited over the past decade. By the end of 1990, more than 3,000 wells are expected to be completed or producing, and annual production is forecasted to exceed 200 Bcf, primarily from the San Juan and Black Warrior Basins. The goals of this project,

funded by the Gas Research Institute (GRI), are to determine the geologic and hydrologic factors that control the availability and producibility of coalbed methane. The Bureau is leading research on the Upper Cretaceous Fruitland Formation of the San Juan Basin; the Colorado Geological Survey and the New Mexico Bureau of Mines and Mineral Resources are subcontracted for parts of the study. The Geological Survey of Alabama is subcontracted to study coalbed methane in the Lower Pennsylvanian Pottsville Formation of the Black Warrior Basin, and the West Virginia Geological and Economic Survey is beginning a subcontracted study of Pennsylvanian-age strata in the Northern Appalachian coal basin; the Pennsylvania Geological Survey has been invited to participate in that study.

In 1990, research in the San Juan Basin included studies of sedimentology, fractures, lineaments, hydrology, and gas composition. The sedimentologic study showed that Fruitland coal beds are complex reservoirs in the area of Cedar Hill field in northern New Mexico.



Fault in the Fruitland Formation, exposed in a 40-ft highwall at La Plata Mine in the northwestern San Juan Basin of New Mexico, juxtaposes low-permeability sandstone and thick (as much as 35 ft) coal beds. Such faults may define the southwestern boundary of overpressured Fruitland strata and create traps for coalbed methane.

Complexities are due to facies relations between coal beds and framework sand bodies, tectonic and compactional folding, and minor faulting. Coalbed permeability is the most critical parameter for the production of coalbed methane; it is controlled primarily by natural fractures, or cleats. Cleats in Fruitland coal seams and fractures in the underlying Pictured Cliffs Sandstone were studied in cores and outcrops. Fracture zones in Pictured Cliffs sandstones commonly are expressed as zones of greater fracture intensity in overlying Fruitland coal beds. Preliminary study of lineaments using Landsat TM imagery showed that few lineament characteristics correlate with coalbed-methane production in the San Juan Basin, suggesting that lineament analysis is not a useful tool for locating areas of fracture-enhanced permeability in Fruitland coal beds. In hydrologic studies, ground-water flow in the Fruitland Formation was simulated in a cross-sectional model to verify an artesian origin of overpressuring and to identify permeability pathways and barriers. Hydrochemical studies showed that high-alkalinity coalbed waters are due to high levels of bicarbonate. The composition of Fruitland coalbed gases varies regionally. Dry gases having a high carbon dioxide content characterize the overpressured part of the San Juan Basin, whereas wet gases having a low carbon dioxide content are common to the west-central part of the basin. Results of this San Juan Basin study will be summarized in a topical report to the Gas Research Institute, which will be available in early 1991, and the Bureau will begin evaluating coalbed methane in another western basin under this contract.

Studies of coalbed methane in the Pottsville Formation in the Black Warrior Basin focused on Oak Grove field, which includes GRI's Rock Creek field experimental laboratory. In Oak Grove field, researchers at the Geological Survey of Alabama investigated structural controls on sedimentation and coal occurrence, fracture architecture, and cleat trends and variations, and they related geologic factors and well-completion practices to coalbed-methane producibility. In 1990, researchers at the Geological Survey of Alabama completed their coalbed-methane research in the Black Warrior Basin under this contract. The results will be summarized in a topical report to GRI in late 1990.

Coal

Computerized Calculation of Lignite Resources in Texas

William R. Kaiser, principal investigator; Mary L. W. Jackson; assisted by Laura L. Moffett

This ongoing project, funded by the U.S. Geological Survey (USGS) since 1979, provides estimates of remaining near-surface lignite resources. The computerized data base and graphics software of the National

Coal Resources Data System (NCRDS) are used to calculate resources according to criteria set down in USGS Circular 891 (Coal Resource Classification System of the U.S. Geological Survey) and criteria suggested by current mining practice in Texas.

In 1990, data entry and digitization for the Jackson and Wilcox trends of South Texas were completed. Resource calculation was begun but not completed because of a software problem. Programming assistance has been requested from the USGS, and resource calculation is now scheduled for 1991. However, the software problem identified during calculation of South Texas resources led to the discovery that resources calculated previously for the Jackson–Yegua trend of East Texas and reported in the 1989 Annual Report are incorrect. Resources in East and South Texas will therefore be recalculated and revised in 1991. Resources in the Wilcox trend of East Texas were calculated earlier, and a Bureau report on them is scheduled for publication in 1991.

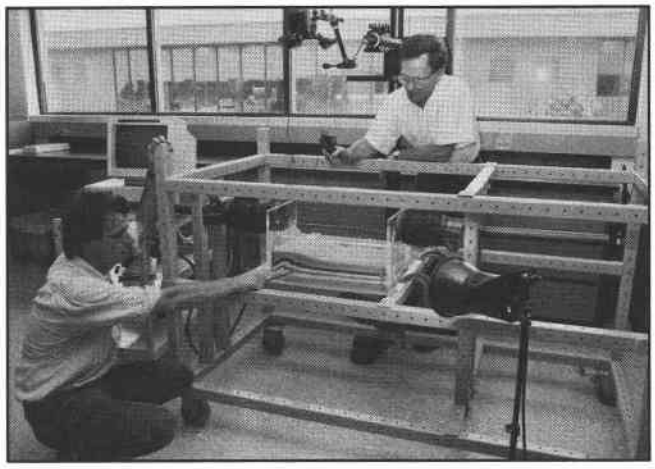
Experimental and Applied Tectonics Investigations

Applied Geodynamics Laboratory

Martin P. A. Jackson, laboratory director; Bruno C. Vendeville, Daniel D. Schultz-Ela, Ruud Weijermars, Peter R. Cobbold, and John G. Sclater; assisted by Shing-Tzong Lin, Hongxing Ge, Karen E. Carter, Kathleen M. Strub, and Ridha C. Gharbi

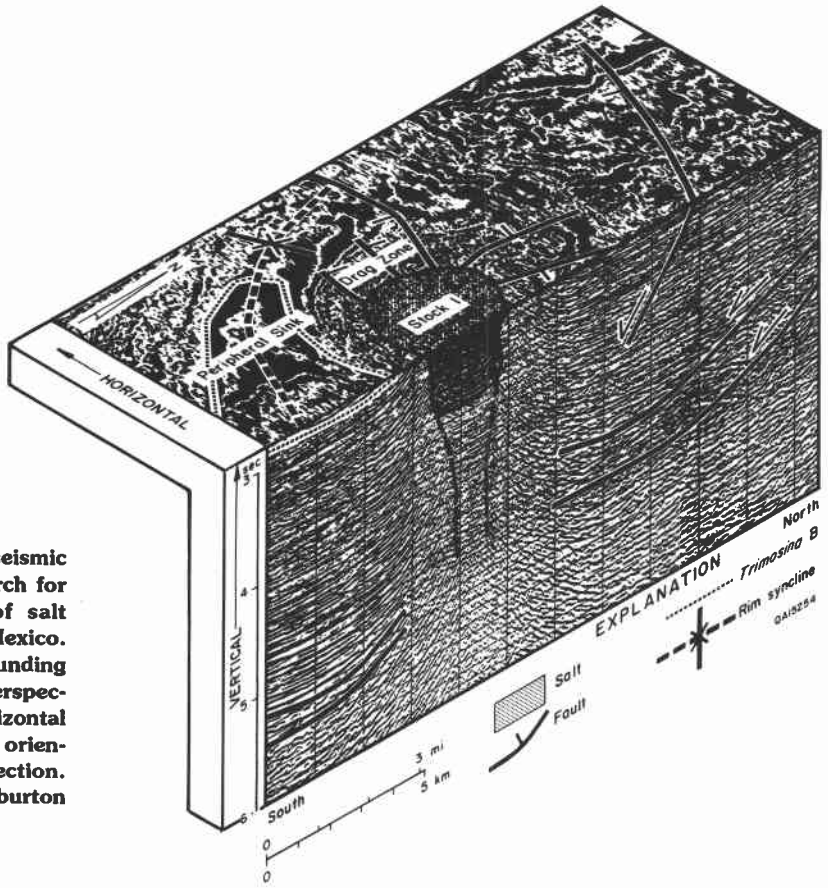
The Applied Geodynamics Laboratory (AGL) performs physical and mathematical scale-modeling of the mechanics of tectonic and structural geologic processes. Research at AGL is funded by a consortium of industrial associates comprising the following oil companies: Agip S.p.A.; Amoco Production Company; ARCO Oil and Gas Company; BP Exploration, Inc.; Chevron O.F.R. Company and Chevron U.S.A., Inc.; Conoco, Inc.; Elf-Aquitaine Petroleum; Exxon Production and Research Company; Marathon Oil Company; Mobil Research and Development Corporation; Petroleo Brasileiro S.A.; Phillips Petroleum Company; Texaco, Inc.; and Total Minatome Corporation.

For modeling in an accelerated gravity field, a high-speed, high-capacity centrifuge, which includes a rotor designed specifically for tectonic modeling, was used. The machine is equipped with a viewing hatch, stroboscopic lighting, and digital speed and temperature control. A deformation rig used for modeling in a normal-gravity field was designed and fabricated. Its flexible design allows simulation of almost any structural style, including extension, shortening, wrenching, doming, and drape folding, or any combination of these styles. The rig has (1) a modular framework, 6 × 4 × 3 ft in size, that can be assembled in many configurations, (2) four 2-ton screw jacks, (3) flexible drive shafts, (4) a stepper motor, (5) an electronic indexer, and (6) a personal computer for control, as well as a wide variety of modeling boxes and three cameras and attachments. Modeling materials include silicone polymer, silicone putties, Plasticine, quartz sands, glass sand, glass bubbles 25–60 mm in diameter, clays, paraffin waxes, petrolatum, rosin, dyes, and computer-generated, printable grids of strain markers.



Computer-controlled deformation rig used at the Bureau's Applied Geodynamics Laboratory to deform tectonic models made of layered sand and silicone polymers under a normal-gravity field. Pictured are Bruno Vendeville (left), who designed and constructed the rig, and Martin Jackson, director of the laboratory.

Experimental research during the year continued to focus on a wide range of gravity-driven tectonics, involving extension, salt tectonics, and combinations of these structural styles. The research aims to elucidate the location, origin, mechanics, and evolution of structural hydrocarbon traps. The dynamically scaled models are designed to test hypotheses or duplicate specific geologic structures. Experiments covered the following topics: (1) growth and intrusion mechanisms of salt



Advances in acquiring and processing seismic data have furthered both industry's search for hydrocarbons and academe's study of salt tectonics in the deep-water Gulf of Mexico. The geometry of a salt stock and surrounding strata is illustrated in this isometric perspective by means of a seiscrop map (horizontal orientation) and seismic line (vertical orientation) joining along a line of intersection. Seismic data provided courtesy of Halliburton Geophysical Services, Inc.

tongues, (2) interaction of brittle overburden and ductile substrate and influence of sediment-deposition rate and extension rate on structural style during gravity tectonics, (3) piercement of grabens in brittle overburden by postdepositional diapirs, (4) control on the shape of downbuilding diapirs by concurrent sedimentation, (5) salt-withdrawal structures and salt welds, and (6) control of basement-block faulting on diapirism and overburden faulting and folding.

The Macintosh-based *Restore©* computer program for structurally restoring cross sections was improved by developing interfaces for printing and high-precision input from digitizing tablets and CAD programs. The program was expanded with additional options and improved user interface, and a comprehensive user's manual and tutorial guide were written and distributed to the industrial associates. The program geometrically reverses the effects of faulting, diapirism, and sedimentation by sequentially removing layers and fault slip while correcting for compaction, rotation, and folding.

Salt Tectonics on the Continental Slope, Northern Gulf of Mexico

Martin P. A. Jackson, principal investigator; Steven J. Seni; assisted by Jeffrey W. Black

The project, funded by the Texas Higher Education Coordinating Board, Advanced Technology Program, ends this year after a 2-year investigation of salt tectonics on the continental slope of the northern Gulf of Mexico. The principal objective of the project has been insight into the 3-dimensional structure and evolution of salt features on the slope.

Halliburton Geophysical Services, Inc. (formerly Geophysical Services, Inc.) donated, for use in exploration, a 3-dimensional seismic data grid, 2,000 km² in extent, from the Green Canyon area. Although these data are the primary source of information used to study salt tectonics, additional data include regional 2-dimensional seismic lines and information from more than 30 wells and paleontologic reports.

A wide range of salt structures and depositional basins can be found on the slope. Allochthonous salt sheets, irregular salt massifs, cylindrical salt stocks, and salt-confined depotroughs all occur in proximity on the continental slope in the Green Canyon area. Large counterregional growth faults typically form the updip margin of many allochthonous salt sheets and massifs. These faults form ramps connecting sheets of allochthonous salt at different levels. Thrust ramps are recognizable at the toe of arcuate fault blocks bounding intrasalt basins. Other features include remnant salt structures, turtle-structure anticlines, and salt welds in areas from which most salt has already been evacuated.

The current distribution of salt structures results from burial of a widespread salt sheet that extruded or

shallowly intruded across the lower slope in the early Pliocene–Miocene. Differential loading during the Pliocene and Pleistocene separates salt stocks and massifs from the trailing margin of the salt sheet. The former presence of salt is inferred on the basis of the remnant-salt structures, a turtle-structure anticline, and a discordant salt weld.

Mechanics of Segmentation along Normal Faults

Jay A. Raney, principal investigator; Stephen E. Laubach and Bruno C. Vendeville; assisted by Ridha C. Gharbi

In this project, funded by the Texas Higher Education Coordinating Board, we are investigating how segments of normal faults grow and link to form larger faults and are attempting to determine the location of subsidiary structures that develop along segmented normal faults. The research utilizes physical models, field studies, and computer simulations of segmented normal faults. Although normal fault systems do provide economic opportunities in parts of Texas, they pose environmental hazards in other parts of the state as well. This study is thus intended to provide a better understanding of the mechanics of normal faulting that will lead not only to better prediction of economic mineral deposits localized along faults, but also to mitigation of environmental hazards associated with normal faults.

In 1990, laboratory scale-modeling experiments were undertaken on the new modular deformation rig of the Applied Geodynamics Laboratory. Field studies for the project were completed, and a field seminar was conducted for researchers from industry who were interested. Results of the study were presented at national and international meetings, and a paper describing some of the results of this project is in press as a Norwegian Petroleum Society Special Publication.

Rollover Kinematics of Growth Faults

Martin P. A. Jackson, principal investigator; Daniel D. Schultz-Ela and Bruno C. Vendeville; assisted by Karen E. Carter, Hongxing Ge, and Shing-Tzong Lin

This new 2-year project is funded under the Advanced Research Program by the Texas Higher Education Coordinating Board. The project has been designed as an investigation of the mechanical genesis of rollover anticlines, which are created by extension along listric normal growth faults. These folds and faults commonly create hydrocarbon traps in the Gulf of Mexico region. Knowledge of the mechanics and kinematics of rollover genesis would therefore help explorationists predict structural geometry at depths where seismic reflection data are indistinct.

The study uses a combination of research approaches. Carefully scaled physical models will be experimentally deformed to produce analogs of the natural structures, emphasizing 3-dimensional deformation and high finite strains. The interplay between sedimentation, folding, and faulting will also be studied. The geometry of the physical models and of natural examples throughout the world will be analyzed by computers to determine both of their modes of formation. Activities at this early stage of the project have involved the design and fabrication of an experimental assembly used for embedding strain markers and the collection of seismic images of growth faults having rollover structure.

Scale Modeling of Hydrocarbon Traps Formed by Diapirism and Growth Faulting

Martin P. A. Jackson and Jay Raney, principal investigators; Bruno C. Vendeville, Daniel D. Schultz-Ela, Ruud Weijermars, and Paul L. Stoffa; assisted by Shing-Tzong Lin, Hongxing Ge, and Karen E. Carter

This new 2-year project is funded under the Advanced Technology Program by the Texas Higher Education Coordinating Board and is a program of physical and seismic modeling of structural hydrocarbon traps in regimes of extensional salt tectonics. Initially the project has focused on systematic modeling of structures in three dimensions to determine the evolutionary steps and mechanical principles of their formation. However, the aim of this research is to improve the efficiency of petroleum exploration and development. The topics investigated are summarized in the project description titled "Applied Geodynamics Laboratory," p. 14.

The physical modeling will be followed by seismic modeling at the Institute for Geophysics of The University of Texas at Austin under the direction of Paul L. Stoffa. Such modeling will simulate the appearance of the physically modeled traps and structures on reflection seismic images. The synthetic seismic images will be compared with seismic profiles of natural structures to yield guidelines for interpreting such structures and recognizing associated hydrocarbon traps.

Land, Water, and Environmental Resources Investigations

Waste Isolation Studies

Geologic and Hydrologic Studies near Fort Hancock, Texas

Jay A. Raney and Alan R. Dutton, principal investigators; M. Saleem Akhter, Robert W. Baumgardner, Jr., Edward W. Collins, Carolyn E. Condon, R. Stephen Fisher, Thomas C. Gustavson, Rodney I. Heathcott, William F. Mullican III, Bernd C. Richter, Bridget R. Scanlon, Rainer K. Senger, and Steven W. Tweedy; assisted by George T. Bush, James A. Doss, Jiunnren Lai, Sung Chi Hsu, Heng Tsai, and Fred P. Wang

In 1990 most of the geologic and hydrologic studies evaluating a potential site for the Texas repository of low-level radioactive wastes were completed. These studies were funded by the Texas Low-Level Radioactive Waste Disposal Authority at a study area selected by the Authority northeast of Fort Hancock in Hudspeth County, Texas. The Bureau also coordinated geophysical studies conducted by The University of Texas at El Paso. By July of 1990, contract reports describing the regional and site-specific stratigraphy, structural geology, geomorphology, surface water, unsaturated zone, saturated zone, seismicity, gravity, and other surveys and monitoring had been completed and delivered to the Authority. The Authority will use the results of these investigations to complete the assessment of the site for performance and to ensure proper engineering and design of the proposed facility. Continuing work by the Bureau consists of monitoring, evaluating infiltration scenarios and impacts on cap design, and assuring quality.

The investigations have produced an integrated description of the geology and hydrology of this area in the Hueco Basin. New insights have been gained into the stratigraphic development of the Tertiary and Quaternary basin-fill sediments, the structural development of the basin, and the geomorphic evolution of the land surface. Integration of the description of the geologic setting with a study of the hydrology has resulted in an understanding of the flow of surface waters, the distribution of moisture and active processes in the vadose zone, and an evaluation of the underlying saturated zone. Ground-water studies are especially important in evaluating the ability of the site to perform over the 300- to 500-year containment period. The results of many of these studies, important to other areas in the arid to semiarid southwest, are being prepared for publication both by the Bureau and by peer-reviewed journals.

Contaminated-Ground-Water Investigations, Falls City, Texas: Uranium Mill Tailings Remediation Action (UMTRA) Site

Charles W. Kreitler, principal investigator; Jonathan G. Blount; assisted by Patricia W. Dickerson

The Falls City UMTRA site is an inactive uranium ore processing site at the abandoned Susquehanna Western, Inc., uranium mines in western Karnes County, Texas. Mill tailings from the uranium processing were disposed of in two ways: (1) the acid wastes were slurried into large holding embankments constructed above land surface and (2) wastes were slurried into inactive open-pit mines below grade. Ground-water contamination subsequently resulted from leaching of these wastes into the ground water of the Deweesville Sandstone Member and Conquista Clay Member of the Whitsett Formation. High concentrations of uranium (as high as 105 mg/L), radium (as high as 121 pCi/L), chloride (as high as 2,300 mg/L), sodium (as high as 7,000 mg/L), aluminum (as high as 1,400 mg/L), iron (as high as 1,200 mg/L), and sulfate (as high as 17,000 mg/L) and low pH values (as low as 2.6) have been observed around the pits and mapped at distances significantly far away from the disposal areas.

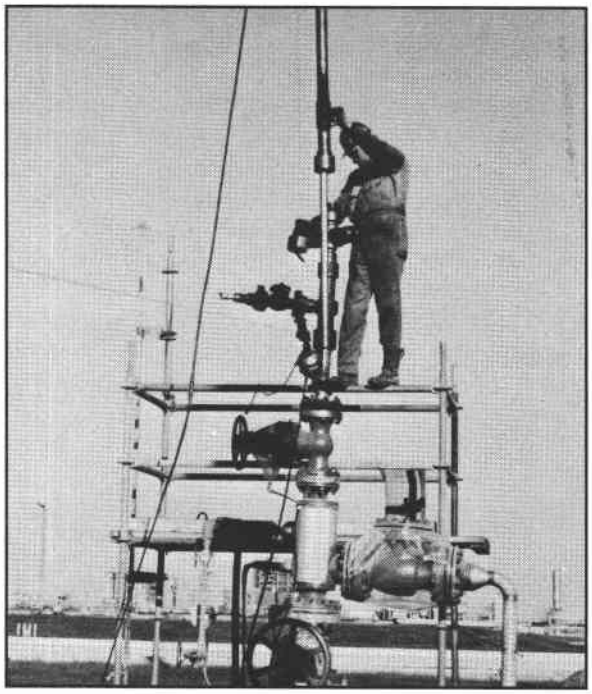
The Bureau is conducting two investigations at the site to help better characterize the extent and geologic controls on contaminant migration. The first part of the program is to characterize the size and shape of the oxidizing zone at the site to determine whether aqueous metal contaminants will be precipitated if they flow through geochemically reducing sediments. The second part of the program is to determine (by means of petrographic and geochemical analysis of cores from the site) whether precipitation of reduced minerals has already occurred. Funded by the U.S. Department of Energy, this program will provide valuable information for designing remediation programs at the site.

Experimental Determination of Hazardous Waste Degradation Reactions during Deep-Well Injection into Saline Formations of the Gulf Coast

Charles W. Kreitler, principal investigator; assisted by Mark E. Erwin

More than 8.6 billion gallons of liquid hazardous waste is disposed of nationwide by deep-well injection each year. About 90 percent is injected into the Gulf Coast region. Federal legislation (*Federal Register* 40 FR 146) now limits deep-well injection unless the injector can demonstrate that there will be no migration of hazardous constituents from the injection zone for as long as the waste remains hazardous. The injector can do so by showing either that the waste will not migrate from the injection zone for 10,000 years or that the wastes will degrade to nontoxic chemicals. Recent investigations by the Bureau have indicated that as much as 80 percent of the injected hazardous waste is organic and can be degraded to nontoxic chemicals by a variety of chemical processes. Biologic degradation may be the most important reaction for neutralizing these hazardous wastes. In a related investigation on the zones used for injection within the Frio Formation of the Texas Gulf Coast, naturally occurring organic material appears to be biodegraded to depths of approximately 7,000 ft. Hazardous organic waste may undergo similar reactions.

This program, funded by the Gulf Coast Hazardous Substance Research Center, will be sampling an injection waste plume after the organics have been in the subsurface long enough for potential degradation reactions to have started. We have evaluated the chemical composition of a waste stream most suitable for sampling and found an injection facility where it may be possible to collect samples from back-flushing of the injection well. Sediment infilling of the injection wells also appears common in many injection wells. These sediments are being analyzed to determine whether they are waste degradation byproducts in the well bores.



Researcher sampling sediments that have accumulated in a liquid-waste disposal well in the Houston area. The sampling is part of a Bureau project that involves examining degradation reactions of hazardous waste associated with deep-well injection.

Ground-Water Studies

Hydrogeologic Investigations of Gulf Coastal Plain Aquifers in Support of Lower Colorado River Authority Water Resources Management

Alan R. Dutton, principal investigator

Ground water across the Gulf Coastal Plain supplies a large amount of the total water used in the counties near the Colorado River. Planning for and managing further development of available ground water beneath the lower Colorado River basin and smaller adjacent river basins are needed to meet projected growth in demand for water supplies. The purpose of these investigations is to develop ground-water models for assessing ground-water resources and for evaluating water-resource management strategies.

Phase 1 of the investigations for the Lower Colorado River Authority (LCRA), focusing on aquifers in Pliocene and Pleistocene formations, was completed in 1990 with a final contract report titled, "Regional Hydrogeology of the Gulf Coast Aquifer in Matagorda and Wharton Counties, Texas: Development of a Numerical Model to Estimate the Impact of Water-Management Strategies." The described model represents the complex interrelation among aquifer stratigraphy, hydrologic properties, and ground-water availability and is based on detailed mapping of sand-bed distribution, hydraulic head, and hydrochemical facies. It differs from previous regional models of the Gulf Coast aquifer in that the Beaumont Formation is treated as a hydrostratigraphic unit distinct from the Chicot aquifer unit and a smaller grid is used to represent the study area in greater detail. The numerical model is implemented by using the U.S. Geological Survey computer code MODFLOW, and transmissivity and storativity are assigned to model blocks as functions of sand percentage. The model uses head-dependent source terms to simulate interaction be-

tween rivers and aquifers as well as regional recharge and discharge. The model includes cross-formational leakage between hydrostratigraphic units. "No-flow" lateral boundaries reflect original ground-water-basin divides. The model excludes interbasin loss of water into the cone of depression underlying much of Harris County. The seaward edges of the model layers also are treated as no-flow boundaries where the base of fresh water rises above the top of the aquifer units. Transmissivity, vertical conductance, river leakage rates, and recharge and discharge rates were adjusted to attain a satisfactory match between simulated and estimated prepumping hydraulic heads. To estimate future water-level changes, the numerical model was calibrated by adjusting storativities so that simulated hydraulic heads match historic head values.

In September, work began on the evaluation of ground-water availability in the Gulf Coastal Plain aquifers in Fayette and Colorado Counties. This work will be integrated with the models developed previously by the Bureau and the Texas Water Development Board. The scope of the work includes hydrogeologic model design, grid design for the numerical model, specification of hydrologic boundaries, enumeration of ground-water production history, model calibration, integration of model results with previous studies, and sensitivity analyses. Future changes in ground-water levels will be simulated on the basis of Texas Water Development Board and Lower Colorado River Authority projections of water demand.

Consolidated Research Program: U.S. Gulf Coast Geopressured-Geothermal Program

Steven J. Seni and Jay A. Raney, principal investigators; Timothy G. Walter

The Gulf Coast Geopressured-Geothermal Program is part of a long-term cooperative agreement between the Department of Energy, the University of Texas Center for Petroleum and Geosystems Engineering, and the Bureau. The ultimate goal of the program is to demonstrate the economic viability of geopressured-geothermal water as an alternative energy resource. In 1990, research concentrated on evaluating the use of geopressured-geothermal water for hot-water flooding of heavy-oil reservoirs. In a five-county (Zapata, Webb, Duval, Jim Hogg, and Starr) area of South Texas, known geopressured-geothermal fairways in the deep Wilcox Group lie below the shallow Mirando heavy-oil trend. Geothermal fluids produced from the Wilcox Group could be injected into shallow heavy-oil reservoirs to supply both the heat energy and fluid necessary for enhanced oil recovery by steam or hot-water flooding.

In the early 1980's, the Bureau characterized geothermal fairways in the deep Wilcox of South Texas. Since that time, extensive exploration has led to the discovery of thick geothermal-fluid-bearing sandstones in areas previously undrilled. In the Fandango field area, Zapata County, temperatures of geopressured-geothermal waters locally exceed 250°C (500°F). The thickness and distribution of these sandstones are now being characterized to determine the extent of the geothermal resource. Net sandstone and maximum sandstone are key parameters being mapped for analyzing the extent of the geothermal resource.

In South Texas, location of geothermal resources below heavy-oil reservoirs and the thickness and lateral continuity of the heavy-oil and geothermal-energy resources suggest thermally enhanced oil recovery could be economically viable. The heavy-oil reservoirs of the Jackson Group/Mirando trend have notoriously poor recoveries of oil in place using conventional and secondary recovery methodologies, despite favorable porosity, permeability, and continuity of the heavy-oil reservoir. Using geothermal waters as a source of steam and hot water to mobilize the oil could greatly improve recovery and prevent premature abandonment of reservoirs that still have as much as 70 percent oil remaining in place. Work associated with this task will involve characterizing the distribution of heavy-oil resources colocated near geothermal fairways.

Developing Guidelines for Wellhead Protection Areas in Confined Aquifer Settings

Charles W. Kreitler, principal investigator; Rainer K. Senger

Much of the ground water of the United States is produced from confined aquifers. The threat of contamination to wells in these aquifers is not as great as it is in water-table aquifers because the contamination is confined. All public water supply wells, however, need wellhead protection programs. Wellhead protection programs for wells in unconfined aquifers can be established through existing techniques such as calculated or arbitrary fixed radius, simplified variable shapes, analytical solutions, and numerical models. These techniques work on the assumption that recharge occurs uniformly around the well.

The protection of confined aquifers requires several different approaches. The zone of major recharge to a confined aquifer may be located far away from the producing well. Hydrologic and geologic discontinuities, however (such as fractures or abandoned wells that have inappropriate sealing of well casings), may permit localized leakage of water and contaminants into a producing zone.

The Bureau has developed a methodology for the U.S. Environmental Protection Agency, Office of

Ground-Water Protection, for delineating wellhead protection areas for wells in confined aquifers. Delineation is a two-step process. The first step defines the nature of confinement (unconfined, semiconfined, or confined) and can be accomplished through geologic, hydrologic (pump testing, interpretation of elevation of the potentiometric surface and continuous water-level data, and numerical modeling), and geochemical (interpretation of absolute age measurements using radioactive isotopes) approaches. The second step delineates the size of the protection area. A technical manual has been prepared for state water agencies to use in defining wellhead protection areas for their respective states.

Identification of Sources of Ground-Water Salinization Using Geochemical Techniques

Charles W. Kreitler, principal investigator; Bernd C. Richter

Sodium chloride has probably contaminated more ground water in the United States than any other contaminant. Contamination results when fresh water is mixed with sodium chloride derived from a variety of sources, including oil-field operations, salt dissolution, sedimentary basin brine discharge, and seawater intrusion. Oil-field operations have been considered a prime source of contamination; however, multiple sources may exist at the same location. In some contaminated areas, two or more sources may be active, making it difficult to identify a dominant source. When taking remedial measures, therefore, it is important not only to detect the contamination but also to document individual sources as accurately as possible.

Geochemical analyses of brackish contaminated water and its brine sources may permit separation of different brines and, in turn, identification of the more important sources. A variety of methods have been applied in the past, including the use of ion ratios such as Na/Cl, Ca/Cl, Mg/Cl, and SO_4, isotopic compositions, and distributions of organic compounds that are found in nature.

This investigation, funded by the U.S. Environmental Protection Agency (EPA), is divided into three major tasks: (1) review of literature and evaluation of existing data and methodologies, (2) field testing of identified methodologies at selected sites across the United States, and (3) preparation of a technical manual for the EPA. Stepwise discriminant analysis (a statistical technique) has proved a valuable new approach for differentiating sources of salt-water pollution. Saline water samples from the San Juan Basin, New Mexico, and El Paso, Texas, regions have been collected. The duration of the project is 2 years; it will be completed in the spring of 1991.

Plan for General Hydrogeologic Characterization of Pantex Plant

Jay A. Raney and Alan R. Dutton, principal investigators

This work, supported by the U.S. Department of Energy (DOE) through a purchase order from Mason & Hanger–Silas Mason, Inc., operator of the DOE's Pantex Plant near Amarillo, Texas, has as its purpose the preparation of a ground-water-protection management plan. The Pantex Plant is the nation's site for assembly, maintenance, and disassembly of nuclear weapons. Previous DOE environmental surveys revealed possible local contamination of soil and perched ground water. An anticipated grant by DOE to the State of Texas will fund geological and hydrological site characterization of the Pantex Plant.

As part of State of Texas oversight, site characterization will include an examination of the ground-water and surface-water regimes at the Pantex Plant to determine the probable transport fate of inorganic and organic solutes. A team of geologists, hydrologists, geochemists, and civil engineers at the Bureau of Economic Geology and at the Department of Geological Sciences, The University of Texas at Austin, and the Water Resources Center, Texas Tech University, will review the DOE's ground-water-monitoring programs and will take an interdisciplinary systems approach to characterizing the water flow and transport processes at and around the Pantex Plant.

Site characterization, to be carried out in close cooperation with the U.S. Army Corps of Engineers and Mason & Hanger-Silas Mason, Inc., will include defining the subsurface geological framework and the hydrological processes involved in recharge from playa and interplaya areas, formation of perched ground water, and ground-water flow in the Ogallala aquifer, the largest in the area. Studies will focus on the unsaturated zone, a particularly sensitive hydrological environment at the Pantex Plant, and on the Ogallala aquifer, the region's main water supply. Results of these integrated, multidisciplinary site-characterization studies are intended to promote successful remediation and ground-water-monitoring programs at the Pantex Plant.

Hydrogeologic Description of Pressure Chambers and Application to Enhanced Oil and Gas Recovery

Alan R. Dutton and Charles W. Kreitler, principal investigators; M. Saleem Akhter

Work began in 1990 on this 2-year project funded under the Advanced Technology Program by the Texas Higher Education Coordinating Board. The objectives of this study are to investigate the hydrogeologic and

hydrodynamic factors contributing to the occurrence of isolated "pressure chambers" in the Tertiary formations of the Texas Gulf Coast sedimentary basin. Exhibiting complex internal geology and atypical pressure/production relationships, these formations behave like separate compartments, preventing efficient and uniform drainage of oil and gas toward the producing wells. Therefore, large volumes of oil and gas remain trapped after the conventional methods of recovery have been employed.

Anticipated results of the study will help us understand the influence of reservoir heterogeneities on the production performance of pressure chambers. To help predict the presence of recoverable hydrocarbon reserves within the pressure chambers, engineering techniques will be developed, which in turn could be applied to enhanced recovery.

Abandoned-Well Characterization Study

Charles W. Kreitler, principal investigator; M. Saleem Akhter, William F. Mullican III, and Arten J. Avakian

In the continental United States, the oil and gas industry operates approximately 166,000 water-injection wells that inject 60 million barrels of water per day into 39 geologic basins in 31 states. There are also approximately 2 million abandoned oil and gas wells in the United States, some of which may be proximal to brine-injection operations. Upward leakage of brine into shallow, fresh ground-water aquifers may result because abandoned boreholes coincide with areas of reservoir pressures that have increased with injection. However, leakage can only occur if increased fluid potentials in the injection zone are greater than fluid potentials (water levels) in overlying aquifers.

As a test case, researchers at the Bureau, with support from the American Petroleum Institute, are mapping critical areas within the San Juan Basin, New Mexico, and the greater Permian Basin, Texas, the sum of whose injection fluid potential and static fluid potentials (preinjection reservoir pressures) are higher than the fluid potential (water levels) in overlying fresh-water aquifers. Potentiometric data—fresh-water aquifers, the pressures within oil and gas reservoirs, and injection pressures for saltwater-injection operations—are all being used to identify those injection operations that have the potential for brine contamination of ground water by upward leakage through abandoned boreholes. This study will help in developing a methodology to assess the risk to underground sources of drinking water posed by abandoned wells in a given area.

Paleohydrology of the Nonglaciated Great Plains: Climatic and Geomorphologic Implications

Alan R. Dutton, principal investigator

This study, funded by the U.S. Geological Survey as part of its Water Resources Research Section 105 Grant Program, began in September. The work is designed to determine the origin of isotopically light ground water found in the confined aquifer in Triassic sandstones beneath the southern Great Plains in Texas and eastern New Mexico. During hydrogeologic studies conducted for the U.S. Department of Energy from 1984 to 1986, as part of its program to evaluate Permian salt beds as a possible nuclear-waste repository, researchers learned that this ground water has δD and $\delta^{18}O$ values that are isotopically lighter than those of the ground water in the overlying unconfined High Plains aquifer. The isotopically light ground water was interpreted to be ancient water that had been recharged before the Pecos River valley was incised during the Pleistocene and that is preserved in the now erosionally truncated, confined aquifer system. In the study, ground waters will be dated using radioactive isotopes such as ^{14}C and ^{36}Cl. Ground-water flow systems will be simulated using numerical models to evaluate effects of physiographic evolution and climatic change on recharge rates and flow patterns.

An additional objective of the research is to document whether the paleorecharge model correctly predicts the distribution of other ancient and isotopically depleted ground waters beneath the central and northern Great Plains, for example, east of the Colorado Piedmont where the High Plains is separated from the Rocky Mountains by the Arkansas and South Platte Rivers. The implications of using ground-water isotopic variations to interpret late Cenozoic geomorphologic evolution and paleoclimatology of the continental interior will then be evaluated. Research results will (1) establish a general model that relates modern ground-water composition in regional aquifers to long-term patterns of physiographic and paleohydrologic change and (2) contribute fundamental insights into the hydrology and geochemistry of infiltration processes, water flow and mass transport, the sensitivity of water quality in regional aquifers to changes in recharge-water composition, and the paleohydrology of Quaternary recharge across the nonglaciated Great Plains. If isotopic variations in ground waters can be related partly to climatic variation, significant information for understanding the late Cenozoic climatic history in the continental interior could be gained. Also, evidence supporting the paleorecharge hypothesis in the southern and central Great Plains could alter the hydrologic models being

used to predict water-level changes in the High Plains aquifer, and thus influence numerical simulations of aquifers and water-resource management strategies.

Hydrogeologic Studies in Support of the Superconducting Super Collider

Alan R. Dutton, principal investigator; Bridget R. Scanlon and William F. Mullican III; assisted by Matthew K. Wickham

Knowledge of the regional hydrogeology of the Ellis County area, site of the Superconducting Super Collider (SSC), is vital for several reasons. It will (1) provide scientific information about ground water to an inquiring and concerned Texas public, (2) satisfy environmental review requirements in the ongoing environmental impact statement (EIS) process, (3) establish important preconstruction and preoperation baseline data for ongoing monitoring of ground-water quality and ground-water resources, and (4) characterize hydrologic processes that are crucial to the engineering design of the SSC underground facilities.

A pilot hydrologic study by the Bureau, begun in April 1990 at the request of the Texas National Research Laboratory Commission (TNRLC), is the first part of a multiphase investigation. Phase 1 of the investigation focuses on surficial (<50 ft in depth) ground-water resources located between Red Oak and Brushy Creeks in Ellis County along a small portion of the northeast part of the SSC ring. Objectives of this study are to (1) supplement the existing data base for an environmental hydrogeologic inventory and water-resources assessment of the surficial ground waters and (2) determine the environmental controls on the recharge, discharge, occurrence, residence time, chemical composition, and velocity of ground water in alluvial and terrace deposits in the Ellis County area. Specific tasks included in the pilot study are (1) mapping the thickness and extent of major alluvial and terrace deposits that compose surficial aquifers using geophysical surveys (including seismic refraction and resistivity), (2) measuring the water levels and hydrologic properties, as well as the chemical composition of water, (3) evaluating the geochemical data through modeling programs, and (4) refining the conceptual hydrologic model of the occurrence, origin, and circulation of water in the surficial aquifer on the basis of geochemical data and maps of aquifer thickness, potentiometric surface, and other hydrogeologic properties.

A numerical model of ground-water flow in a surficial aquifer unit in the Ellis County area will be constructed and calibrated. The model will be used interpretively to evaluate flow velocity, flow paths, residence time, and discharge of ground water before ground-water production began (steady-state condition). Simulation of future water levels in the surficial aquifer and changes in discharge to streams will be based on projections of future ground-water usage.

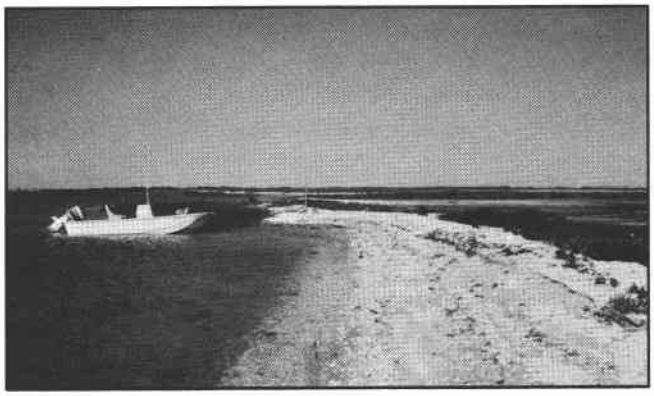
Coastal Studies

Historical Shoreline Changes in Copano, Aransas, and Redfish Bays, Texas Gulf Coast

Robert A. Morton, principal investigator; Jeffrey G. Paine

As more industries and people move to the Texas coast, both the economic and more directly human impacts of pervasive coastal erosion become more acute. This erosion, whether caused in a moment by hurricanes or over the years by waves, sea-level rise, and subsidence, is common to Texas gulf and bay shorelines. Increasing recognition of the environmental and economic importance of coastal wetlands, which are also diminished by continued coastal erosion, makes it imperative that current information on status and trends of coastal erosion be available. Historical shoreline monitoring by the Bureau continued in 1990 in the Copano Bay system of the central Texas coast.

Common shoreline types in the Copano Bay system include low deltaic and bay-margin marshes, sandy shores fringing a late Pleistocene strandline, clay bluffs formed on upper Pleistocene fluvial and deltaic sediments, and sand and shell beaches in areas of high wave activity. Movement of the bay shorelines, determined from aerial photographs dating from the early 1930's, the late 1950's, and the 1980's, is generally slower than movement along gulf shorelines because wave energy is lower, the tide range is less, and there is less movable sediment in the littoral system. Nevertheless, significant shoreline movement has occurred



Field studies augmenting aerial photographic analysis of bay shoreline erosion in Texas. This sand and shell beach on San José Island is retreating at an average rate of 23 ft per year.

in the past and continues at an accelerated rate today. A report on these changes and factors affecting them is moving through the publication process at the Bureau and will soon join similar reports that are available about the Gulf shoreline and most other Texas bays.

Assessment of the Sand Resources of Heald and Sabine Banks, Texas Exclusive Economic Zone

Jules R. DuBar, principal investigator; Jeffrey G. Paine

Many Texas beaches are eroding as the result of natural causes such as waves, compactional subsidence, and sea-level rise; the recent increase in rates of erosion can be attributed to human influences such as global warming, barriers to longshore transport, and reductions in fluvial sediment. One way to offset erosion locally is to add sand to the sediment budget (beach nourishment). Offshore sand sources for beach-nourishment projects are attractive because sand-size requirements for these projects are strict, on-land sources are limited and environmentally sensitive, and expensive overland transport can be avoided. Although a recent assessment of nonfuel minerals on the Texas continental shelf demonstrated that insufficient geological and geophysical data exist to locate and quantify all potential sources of sand, some shore-parallel sand deposits show promise. Two of these deposits, Sabine and Heald Banks, lie along the upper Texas coast and are relatively close to potential markets in Texas and Louisiana. This multiyear study of Sabine and Heald Banks, funded cooperatively by the Bureau and the U.S. Bureau of Mines, will include attempts to define the geometric attributes of these banks, to assess their textural characteristics, and ultimately to determine the volume of available beach-quality sand in the banks.

During 1990, the first year of the project, nearly 200 mi of high-resolution seismic data were collected over Heald Bank and the eastern margin of Sabine Bank, and surface samples were collected from Heald Bank. Data collected in cooperation with Rice University supplement additional data on Sabine Bank recently acquired by Rice. Future work is expected to include interpretation of seismic data, collection of vibracores over the banks, analysis of sediment texture, and volumetric calculations.

Monitoring the Beach and Vegetation Line on Galveston Island

Robert A. Morton, principal investigator; Jeffrey G. Paine

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

Results of the field work more than 7 years after Hurricane Alicia show that dunes are reforming in undeveloped areas but not in developed areas; furthermore, the backbeach elevation of West Beach is still lower than it was before the storm. Significant dune construction, backbeach aggradation, and shoreline stabilization on northeastern Follets Island indicate that most of the sand permanently removed from Galveston Island by Hurricane Alicia was transported southwestward by strong nearshore currents.

Characterization of Sand Bodies within Seismic Sequences, Texas Continental Margin

Robert A. Morton, principal investigator; assisted by Beate Sterrenberg

This project, which was initiated in 1989, is funded by the U.S. Department of the Interior, Minerals Management Service, as part of its Continental Margins Program. The primary objective of this research is to improve the prediction of lithologies and the recognition of potential reservoir facies within depositional sequences on the basis of seismic patterns and reflection terminations. Upper Quaternary depositional sequences preserved beneath the continental shelf were selected for detailed study because of the existing shallow subsurface control and the constraints on sea-level fluctuations that occurred during the past 100,000 years. This work is being accomplished by integrating and analyzing two data sets—high-resolution seismic surveys and foundation borings. The seismic surveys were performed either as regional geologic framework investigations jointly conducted by the Bureau and the U.S. Geological Survey or as geohazards investigations conducted for oil and gas lease sales in the western Gulf Coast Basin. The foundation borings are obtained by offshore operators to determine the engineering properties of the near-surface sediments so that drilling rigs and production platforms can be safely placed on the seafloor.

In 1990, records of foundation borings were compiled for the Texas continental shelf, and strip logs were constructed for each boring showing the lithologies and descriptive properties of strata to a depth of about 300 ft below the seafloor. A second major effort involved the acquisition and inventory of seismic profiles from the U.S. Geological Survey and the Minerals Management Service. A subregional study site was selected that encompasses the middle and outer shelf near the Texas–Louisiana offshore boundary. This area was selected because previous studies have shown that the shelf margin in this area was formed by several deltas of moderate size during the Wisconsinan sea-level lowstands. Preliminary lithologic cross sections of the lowstand deltas were constructed using the strip logs of foundation borings. A velocity function was used to project lithologies from the borings onto selected seismic lines, and the seismic lines were interpreted to establish the subregional correlation framework.

Wetland and Aquatic Habitats in the Galveston Bay System

E. G. Wermund and Laurence R. Handley (USFWS), principal investigators; William A. White, Thomas R. Calnan, and Jeffrey G. Paine

The Bureau and the U.S. Fish and Wildlife Service (USFWS) are cooperating in a 20-month study that involves examining trends of losses and gains in wetland and seagrass habitats for the years 1956, 1979, and 1989 in the Galveston Bay System. The work is funded by the Texas Water Commission in support of the Galveston Bay National Estuary Program (GBNEP). Results of the study will be a significant indicator of the health of the bay system in the GBNEP Comprehensive Conservation Management Plan for presentation to the Environmental Protection Agency in 1994.

The Bureau and the USFWS have previously published maps of the Galveston Bay wetlands for the years 1956 and 1979; Bureau maps depict the areal distribution of seagrasses. The USFWS digitized its results for those years and performed preliminary trend analyses. In 1989, the National Aeronautics and Space Administration collected 1:65,000-scale color-infrared photographs for the Texas coastal region, a data set that has contributed greatly to the comprehensiveness of the study.

In 1990, the Bureau constructed a bibliography of wetland and aquatic habitats and an inventory of the available aerial photographs for the Galveston Bay System. From two field traverses wetland assemblages were characterized for their relation to elevation and water salinity. Bureau scientists led USFWS aerial photographic interpreters into the Christmas Bay and Trinity Delta wetlands so that they could standardize their interpretations of habitats on the 1989 color-infrared aerial photographs.

Coastal Mapping and Shoreline Monitoring Projects

Robert A. Morton, principal investigator; Jeffrey G. Paine

During 1990, the Bureau served in an advisory capacity or conducted minor coastal studies for two State agencies and two Federal agencies. Bureau coastal scientists conducted field surveys, analyzed aerial photographs, and provided information to the Office of the Texas Attorney General regarding beach dynamics and recent historical movement of the shoreline and vegetation line. Studies were conducted along the Intracoastal Waterway in Redfish Bay near Corpus Christi and along the Gulf shoreline of the upper Texas coast west of Sabine Pass. Bureau scientists also participated in workshops and planned meetings as part of the Texas Coastal Management Program sponsored by the General Land Office of Texas. These work sessions were designed to identify coastal erosion issues, assess the environmental and economic impact of coastal erosion, and examine mitigation alternatives.

Bureau coastal scientists also conducted work for the U.S. Environmental Protection Agency as part of its Gulf of Mexico Program, Coastal and Shoreline Erosion Subcommittee, activities. Rates of historical Gulf shoreline erosion in Texas were summarized, classified, and compiled on a map showing shoreline stability for the entire northern Gulf of Mexico. A section for the map text was written describing the regional geology and coastal processes of Texas, the data base and methods used to document shoreline changes, the areas where erosion is greatest, the types of human activities that have contributed to erosion, and the trends in shoreline movement that can be predicted for the near future. The Bureau also prepared a brief report describing coastal processes, shoreline movement, and the geology of the shoreline and inner shelf near Sabine Pass. This work was conducted at the request of the National Transportation Safety Board.

Mineral Resources Investigations

Texas Mining and Mineral Resources Research Institute

Christopher D. Henry, director; Eric W. James

The Texas Mining and Mineral Resources Research Institute (TMMRRI), administered by the Bureau, is one of 30 state organizations partly funded and administered by the U.S. Bureau of Mines and dedicated to research and education in mineral resources. The University of Texas at Austin, Texas A&M University, and Prairie View A&M University are academic affiliates. An advisory board for TMMRRI consists of the President of The University of Texas at Austin, the Vice-Chancellor and Dean of Engineering at Texas A&M University, and a member of the Railroad Commission of Texas. Funds from the Bureau of Mines are matched at least two-to-one by non-Federal sources.

TMMRRI supports training and education of mining and mineral resource personnel through competitive graduate fellowships, postdoctoral research positions, research assistantships, and undergraduate scholarships. Applications are reviewed by a committee composed of representatives of the advisory board and two members of the Texas mining industry. For the 1990–1991 academic year, four fellowships were awarded to support graduate research in ore deposition, mineral economics, and petroleum recovery. Two graduate students received support through research assistantships on TMMRRI-funded mineral resource projects. A postdoctoral research fellow also participated in TMMRRI research.

Research under TMMRRI focuses on the origin and distribution of mineral deposits in Texas and mineral exploration techniques in general. These projects range widely in scope and include basic geologic mapping, resource assessment of specific areas, studies of igneous petrogenesis, evaluation of industrial minerals, and studies of energy minerals. Basic geologic mapping and studies of igneous petrogenesis are concentrated in Trans-Pecos Texas, in areas of known deposits or of significant hydrothermal alteration. Many hard-mineral deposits, including silver-lead-zinc, molybdenum, and beryllium occur in or are related to the alkalic rocks of the mid-Tertiary Trans-Pecos volcanic province. Areal resource assessment emphasizes lands owned by the University of Texas or the State of Texas; an assessment of the minerals of the new Big Bend Ranch State Natural Area was recently completed for the Texas Parks and Wildlife Department. Industrial minerals studied by TMMRRI include sulfur, limestone, dimension stone, and talc. Energy mineral studies currently focus on lignite and coalbed methane. Results of TMMRRI research are published through Bureau reports, contract reports to other funding agencies, and reports in international journals.

Mapping Investigations

Geologic Studies of the Big Bend Ranch State Natural Area

Christopher D. Henry, principal investigator; Eric W. James

The Big Bend Ranch State Natural Area is a new and large addition to the state parks system in the Bofecillos Mountains of Trans-Pecos Texas. Much of the attraction of the area derives from its rugged scenery, which is a result of nearly 600 million years of complex geologic evolution. The area is administered by the Texas Parks and Wildlife Department, and it is funding this multiyear study, which is being coordinated by Parks and Wildlife personnel to examine the biological, archeological, and cultural resources of the area. The Bureau will produce a detailed geologic map and report of the entire area. It is also assisting the Texas Parks and Wildlife Department in preserving the area to develop it for public visitation and to provide information and education about the natural history of the area to visitors. Research by the Bureau will focus on how geology has formed or influenced the scenic, biological, and cultural resources of the area.

The first year of the project, which started in September, is focusing on the southeastern part of the area, which is most accessible to visitors. This part includes the Solitario, a remarkable dome formed during mid-Tertiary igneous activity, and areas along the Rio Grande, where faulting during Basin and Range extension has created a complex graben system that controls the river's course.

Geologic Atlas of Texas

Virgil E. Barnes, principal investigator

Now that geologic atlas sheets have been published for the entire state, new work focuses on revision of older maps as they go out of print. Cartography on the

Senior Cartographer Barbara Hartmann performing color separation on the *Geologic Map of Texas*, which was last compiled in 1937. This 4-quadrant, 1:500,000-scale map, displaying more than 350 geologic units, is expected to be completed in the spring of 1992.

revised Sherman sheet is approximately 60 percent complete. The Beaumont, Abilene, Tyler, Waco, and Palestine sheets are also being worked on.

Geologic Map of Texas

Virgil E. Barnes, principal investigator; Barbara M. Hartmann, cartographer

A new 1:500,000-scale geologic map of Texas is being prepared to replace the U.S. Geological Survey's "Geologic Map of Texas," which was published in 1937 and has been out of print for many years. The new map will be published in four quadrants; the entire map will measure approximately 7 × 8 ft and will depict approximately 350 geologic units. Color separation is complete for the southwestern and southeastern quadrants and is in progress for the northwestern quadrant.

Tectonic Map of Texas

Thomas E. Ewing (consultant, San Antonio, Texas), principal investigator; Martin P. A. Jackson, Christopher D. Henry, Roy T. Budnik (consultant, Poughkeepsie, New York), Stephen C. Ruppel, Charles M. Woodruff, Jr. (consultant, Austin, Texas), William R. Muehlberger (The University of Texas at Austin, Department of Geological Sciences), James R. Garrison (consultant, Arlington, Texas), Richard L. Nicholas (Shell Oil Company, Houston, Texas), and Arthur G. Goldstein (Colgate University, Department of Geology); John T. Ames, cartographer

A 1:750,000-scale tectonic map of Texas was printed this year. The map, which is in four quadrants, incorporates extensive surface and subsurface data from all of Texas as well as adjoining parts of Mexico, New Mexico, Oklahoma, Arkansas, Louisiana, and the Gulf of Mexico. Lithotectonic units are shown in areas of basement exposure, such as the Van Horn area of Trans-Pecos Texas and the Llano region of Central Texas. Subsurface stratigraphic horizons are shown in the many sedimentary basins of Texas. Small-scale inset maps depict statewide gravity, magnetic, neotectonic, and isotopic age data. A text describing the complex tectonic setting and evolution of Texas, which will accompany the map, is in review.

Geologic Mapping of the Infiernito Caldera, Trans-Pecos Texas

Christopher D. Henry, principal investigator; Eric W. James; Mick Kunk and John Sutter (U.S. Geological Survey, Reston, Virginia)

Geologic mapping of volcanic centers in the mid-Tertiary volcanic field of Trans-Pecos Texas is a continuing project funded by the U.S. Geological Survey's Cooperative Geologic Mapping Program (COGEOMAP). The current year's work focused on the Infiernito caldera of the northern Chinati Mountains, one of the major eruptive centers of the field. Mapping involved extensive field work, aerial photographic analysis, and sampling for geochemical analysis and isotopic dating. The study revealed that volcanism in the area began 37 Ma ago with eruption of a sequence of rhyolitic to trachytic lavas. These were followed by eruption of a peralkaline ash-flow tuff and contemporaneous collapse of the Infiernito caldera. The tuff ponded within the caldera, where it is interbedded with breccias derived from the caldera wall during eruption.

After ash-flow eruption, the caldera was filled by a quartz trachyte lava flow and interbedded sandstones and debris-flow deposits that represent continued failure of the caldera wall. The entire caldera-fill sequence, as well as precaldera lavas and underlying Cretaceous and Permian sedimentary rocks, were uplifted and tilted outward by a quartz monzonite intrusion, which represents the last major igneous activity of the caldera. Extensive hydrothermal alteration associated with the intrusion produced numerous mineral prospects, including epithermal veins, skarns, and porphyry molybdenum.

Volcanism continued episodically in the Chinati Mountains for another five million years. About 34 Ma, several rhyolite intrusions were emplaced west of the Infiernito caldera, and a moderate-volume ash-flow tuff erupted from sources now buried beneath the younger Chinati Mountains caldera. Volcanism in the Chinati Mountains culminated with eruption of the 32-m.y.-old Mitchell Mesa Rhyolite, the largest ash-flow tuff of Trans-Pecos Texas. Eruption of the Mitchell Mesa induced collapse of the Chinati Mountains caldera, the largest caldera of the region. The caldera was sub-

sequently filled by a complex sequence of mafic to silicic lavas and ash-flow tuff and intruded by a composite granitic stock.

Mapping (1:100,000) of New Braunfels, Texas, Quadrangle

Jay A. Raney and E. G. Wermund, principal investigators; Robert W. Baumgardner, Jr., and Edward W. Collins; William P. Elder (U.S. Geological Survey, Menlo Park, California)

Geologic mapping of the 1:100,000-scale New Braunfels, Texas, Quadrangle was initiated in 1990 as part of a new multiyear mapping project funded partly by the U.S. Geological Survey (USGS). This is part of the Survey's national Cooperative Geologic Mapping Program (COGEOMAP). In-kind services provided by the Survey include paleontologic studies.

Initial investigations are starting in the northeast part of the quadrangle near the city of New Braunfels. Mapping in subsequent years will expand westward through the northern suburbs of San Antonio and farther onto the Edwards Plateau. The objective of the mapping is to provide a high-quality geologic map of this rapidly developing area of Texas. The map eventually will be published using the new USGS 1:100,000-scale topographic map of the quadrangle as a base. The map area lies on the southwest limb of the San Marcos Arch and includes a complex part of the Balcones Fault Zone where its strike changes markedly. The Balcones Fault Zone is the southeastern limit of the Cretaceous outcrops that are part of the recharge zone of the Edwards limestone aquifer, and it marks the northwest edge of the Texas coastal plain.

Other Geologic Investigations

Mined Lands Inventory, Industrial Minerals, South and East Texas

William R. Kaiser, principal investigator; William A. White, Mary L. W. Jackson, and Robert H. Blodgett; assisted by Thomas A. Hickson, Michelle M. Mallien, Laura L. Moffett, and Richard A. Page

This project, funded by the Surface Mining and Reclamation Division of the Railroad Commission of Texas, began in June 1988 with an inventory of abandoned and active mines in South Texas. The South Texas phase of the study was completed last year. The East Texas phase of the study was completed this year and covers an 84-county area north of the Colorado River and east of the Balcones Escarpment.

In East Texas, 6,492 mined sites were identified, 3,341 having more than 2 acres and 3,112 having less than 2 acres. Among the sites larger than 2 acres, 1,637 are abandoned, 1,166 are active, and 573 have been reclaimed by humanity or nature. Approximately 140,000 acres have been disturbed by surface mining, primarily by sand and gravel mining. In East and South Texas, approximately 240,000 acres have been disturbed.

Dallas, Harris, Tarrant, Montgomery, and Grayson Counties contain 27 percent of the sites larger than 2 acres. Harris and Montgomery Counties contain dominantly sand and gravel pits, whereas Dallas, Tarrant, and Grayson Counties contain both sand and gravel and limestone quarries. San Jacinto and Harris Counties contain the most abandoned mined sites, and Dallas and Tarrant Counties, the most active sites. Priority sites (290) are found in 45 East Texas counties, the largest number in Dallas, Orange, and Harris Counties.

Final reports for South and East Texas have been submitted to the Railroad Commission. They contain a description of project methodology, regional and county maps showing mined sites by status, commodity, size, and summary statistics on mined lands. Included as appendices are the Texas Mined Lands Data Base in electronic form and an accompanying explanation manual, topographic maps showing locations of all inventoried sites, and priority site ownership. These reports are on open file in Austin at the Bureau and Railroad Commission offices.

Clay Diagenesis in Evaporite Environments

R. Stephen Fisher, principal investigator

This project was funded by the Texas Higher Education Coordinating Board to investigate the geochemical conditions and timing of clay mineral alteration in marine evaporite environments through combined field and laboratory studies. The major goals of this project are to advance the basic understanding of clay and feldspar stability in the earth's crust as well as to improve the ability to predict clay mineralogy in oil and gas reservoirs and thereby allow selection of more appropriate methods for drilling and well completion.

During the past year, the mineralogy and chemical composition of clays and feldspars beneath, within, and above Permian bedded evaporites in the Palo Duro Basin, Texas Panhandle, and the mineralogy and chemical composition of clays in evaporite strata from the Midland and Delaware Basins, West Texas, were determined to document diagenetic reactions. Laboratory experiments were then designed to simulate physical and chemical conditions in evaporite environments, and standard reference minerals were reacted with various solutions to quantify the geochemical conditions of evaporite diagenesis.

Results of the field studies indicate that detrital, aluminum-rich clays are altered to magnesium-rich varieties such as chlorite/smectite and corrensite. The detrital feldspar assemblage contains subequal amounts of plagioclase and potassium feldspar, whereas feldspars in evaporite strata are nearly stoichiometric potassium feldspar. Geologic and radiometric (Rb/Sr) evidence suggests that clay and feldspar alteration occurs syndepositionally; elevated temperatures associated with deep burial are not required for extensive diagenesis of either clay or feldspar minerals. Experimental results demonstrate that high brine salinity (concentration to halite saturation) is unnecessary for diagenetic reactions to proceed; seawater concentrated only to gypsum saturation is sufficient to alter detrital silicate minerals.

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 1990, the following 70 contracts, each of which had reporting requirements, were active at the Bureau:

Federal

"Annex I to the Agreement 'Relating to Fossil Energy Resource Characterization, Research, Technology Development and Technology Transfer'": supported by the U.S. Department of Energy through the Office of the Governor.

"Assessment of the Sand Resources of Heald and Sabine Banks, Texas Exclusive Economic Zone": supported by the Marine Minerals Technology Center, University of Mississippi.

"Characterization of Facies and Permeability Patterns in Carbonate Reservoirs Based on Outcrop Analogs": supported by the U.S. Department of Energy.

"Computerized Calculation of Lignite Resources, Jackson and Wilcox Trends, South Texas": supported by the U.S. Geological Survey, U.S. Department of the Interior.

"Consolidated Research Program: U.S. Gulf Coast Geopressured-Geothermal Program": supported by the U.S. Department of Energy.

"Develop Guidelines for Wellhead Protection Areas in Confined Aquifer Settings": supported by the U.S. Environmental Protection Agency.

"Geologic Mapping of the Big Bend State Natural Area": supported by the U.S. Geological Survey, U.S. Department of the Interior.

"Geologic Studies of West Texas Bedded Salt Deposits": supported by the U.S. Department of Energy.

"Identification of Sources of Ground-Water Salinization Using Geochemical Techniques": supported by the U.S. Environmental Protection Agency.

"Mapping (1:100,000) of New Braunfels, Texas, Quadrangle": supported by the U.S. Geological Survey, U.S. Department of the Interior.

"Mapping Volcanic Centers in the Davis Mountains, Trans-Pecos Magmatic Province": supported by the U.S. Geological Survey, U.S. Department of the Interior.

"Paleohydrology of the Non-Glaciated Plains: Climatic and Geomorphologic Implications": supported by the U.S. Geological Survey, U.S. Department of the Interior.

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

"Studies Related to Continental Margins (years 1 through 7)": supported by the Minerals Management Service, U.S. Department of the Interior (six contracts).

"Texas Mining and Mineral Resources Research Institute (twelfth and thirteenth allotments)": supported by the Bureau of Mines, U.S. Department of the Interior (two contracts).

State

"Accurate Modeling of Fluid Flow in Hydrocarbon Reservoirs and Aquifers with Scale Averaged Rock Properties": supported by the Texas Higher Education Coordinating Board.

"Administrative and Geologic Assistance Associated with Establishing a Superconducting Super Collider in Texas": supported by the Texas National Research Laboratory Commission.

"Assistance to the Attorney General's Office Concerning Coastal Dynamics": supported by the Attorney General's Office.

"Center for State Lands Energy Resource Optimization": supported by the Office of the Governor.

"Clay Diagenesis in Evaporite Environments": supported by the Texas Higher Education Coordinating Board.

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

"Econometric Analysis of the Supply Impact of Specific Tax and Other Incentives Including the Advanced Secondary Recovery of Oil": supported by the Office of the Governor.

"Edwards Aquifer Committee": supported by the Texas Water Development Board.

"Environmental Characterization of Armand Bayou and Christmas Bay as Potential Texas Coastal Preserves": supported by the Texas Water Commission and the Texas Parks and Wildlife Department.

"Experimental Determination of Hazardous Waste Degradation Reactions during Deep-Well Injection into Saline Formations of the Gulf Coast": supported by Lamar University (three contracts).

"Gas Saturation as a Limit on Pore-Fluid Composition and Diagenetic Alteration in Deep Sedimentary Environments": supported by the Texas Higher Education Coordinating Board.

"Geologic and Hydrologic Site Characterization of the Pantex Plant": supported by the Office of the Governor.

"Geological Support of Cross-Hole Tomography": supported by the University of Houston.

"Geologic and Hydrologic Studies near Fort Hancock, Texas": supported by the Texas Low-Level Radioactive Waste Disposal Authority (three contracts).

"Geology of the Big Bend Ranch State Natural Area": supported by the Texas Parks and Wildlife Department.

"Hydrologic Study of Fayette and Colorado Counties": supported by the Lower Colorado River Authority.

"Hydrogeologic Description of Pressure Chambers and Application to Enhanced Oil and Gas Recovery": supported by the Texas Higher Education Coordinating Board.

"Kinetic and Geochemical Aspects of Near-Surface Dolomitization": supported by the Texas Higher Education Coordinating Board.

"Maximization of Petroleum Recovery Efficiency": supported by the Texas Higher Education Coordinating Board.

"Mechanics of Segmentation along Normal Faults": supported by the Texas Higher Education Coordinating Board.

"Mined Lands Inventory, East Texas": supported by the Railroad Commission of Texas.

"Quality Assurance Assistance to the Texas Low-Level Radioactive Waste Disposal Authority and Quality Assurance for Bureau of Economic Geology Technical Activities": supported by the Texas Low-Level Radioactive Waste Disposal Authority.

"Rollover Kinematics of Growth Faults": supported by the Texas Higher Education Coordinating Board.

"Salt Tectonics on the Continental Slope, Northern Gulf of Mexico": supported by the Texas Higher Education Coordinating Board.

"Scale Modeling of Hydrocarbon Traps Formed by Diapirism and Growth Faulting": supported by the Texas Higher Education Coordinating Board.

"Technical Assistance Proposal for the Falls City, Texas, UMTRA Project": supported by the Texas Department of Health.

"Texas Highway Department–Archeological Projects": supported by the State Department of Highways and Public Transportation.

"Trends and Status for Wetland and Aquatic Habitats Report for the Galveston Bay National Estuary Program": supported by the Texas Water Commission (two contracts).

Private

"Abandoned Well Characterization Study": supported by the American Petroleum Institute.

"Applied Geodynamics Laboratory": research continued with new support from Total Minatome Corporation, ARCO Oil and Gas Company, Chevron Field Research Company, Phillips Petroleum Company, Mobil Research and Development Corporation, Petroleo Brasileiro, DuPont, Agip S.p.A., Marathon Oil Company, Texaco Services, Inc., Exxon Production Research Company, and Amoco Production Company.

"Atlas of Major Gas Reservoirs: Central and Eastern Gulf Coast and Midcontinent": supported by the Gas Research Institute.

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

"Characterization of San Andres and Grayburg Reservoirs": research continued with new support from Texaco Services, Inc., Agip, S.p.A., UNOCAL, Exxon Company, U.S.A., and Fina Oil and Chemical Company.

"Characterization of Selected Venezuelan Reservoirs": supported by Intevep.

"Extrapolation of Gas Reserve Growth Potential: Development of Examples from Macro Approaches": supported by the Gas Research Institute.

"Genetic Stratigraphy, Depositional Systems, Structural Evolution, and Petroleum Exploration Potential: NW Gulf of Mexico Continental Shelf": research continued with new support from Oryx Energy Company, Mobil Exploration and Producing U.S., Inc., and Union Texas Petroleum.

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

"Geologic Evaluation of Critical Production Parameters for Coalbed Methane Resources": supported by the Gas Research Institute.

"IOCC Multi-State Light Oil Recovery Assessment, DOE Fossil Energy Oil and Gas Research and Development Program": supported by ICF Resources, Inc.

"Plan for General Hydrogeologic Characterization of Pantex Plant": supported by Mason & Hanger—Silas Mason Co., Inc.

"Support of Hulin Well Test Program of IGT": supported by the Institute of Gas Technology.

"Support of the Pleasant Bayou Well Test Program of IGT": supported by the Institute of Gas Technology.

Contract and Grant Reports

A variety of reports are prepared annually under terms of grants and contracts with sponsoring entities. Some of these reports are eventually published by the Bureau as part of its own series. Contract reports are kept on open file at the Bureau and may be consulted by interested persons. The following reports were prepared during the year:

Akhter, M. S., and **Dutton, A. R.,** 1990, The alluvial fan method for analyzing flood potential at the proposed low-level radioactive waste isolation site, Hudspeth County, Texas: The University of Texas at Austin, Bureau of Economic Geology, report prepared for the Texas Low-Level Radioactive Waste Disposal Authority under Interagency Contract Number IAC(90-91)0268, 50 p.

Akhter, M. S., and **Dutton, A. R.,** 1990, Surface-water hydrology of the proposed low-level radioactive waste isolation site, Hudspeth County, Texas: The University of Texas at Austin, Bureau of Economic Geology, report prepared for the Texas Low-Level Radioactive Waste Disposal Authority under Interagency Contract Number IAC(90-91)0268, 10 p.

Baumgardner, R. W., Jr., 1990, Geomorphology of the Hueco Bolson in the vicinity of the proposed low-level radioactive waste disposal site, Hudspeth County, Texas: The University of Texas at Austin, Bureau of Economic Geology, report prepared for the Texas Low-Level Radioactive Waste Disposal Authority under Interagency Contract Number IAC(90-91)0268, 98 p.

Blount, J. G., and **Kreitler, C. W.,** 1990, Alternate site selection process for the Falls City, Texas, UMTRA Project: The University of Texas at Austin, Bureau of Economic Geology, final report prepared for U.S. Department of Energy under contract no. DE-FC04-87AL20532, 27 p.

Collins, E. W., and **Raney, J. A.,** 1990, Description and Quaternary history of the Campo Grande fault of the Hueco Basin, Hudspeth and El Paso Counties, Trans-Pecos Texas: The University of Texas at Austin, Bureau of Economic Geology, final report prepared for the Texas Low-Level Radioactive Waste Disposal Authority under Interagency Contract Number 90-008 IAC(90-91)0268, 61 p.

Dutton, A. R., and **Richter, B. C.,** 1990, Regional geohydrology of the Gulf Coast aquifer in Matagorda and Wharton Counties, Texas—development of a numerical model to estimate the impact of water-management strategies: The University of Texas at Austin, Bureau of Economic Geology, final report prepared for the Lower Colorado River Authority under Interagency Contract Number IAC(88-89)0910, 116 p.

Dutton, S. P., Laubach, S. E., Tye, R. S., **Baumgardner, R. W., Jr.,** and **Herrington, K. L.,** 1990, Geology of the Lower Cretaceous Travis Peak Formation, East Texas—depositional history, diagenesis, structure, and reservoir engineering implications: The University of Texas at Austin, Bureau of Economic Geology, final report prepared for the Gas Research Institute under contract no. 5082-211-0708, 170 p.

Finley, R. J., Guevara, E. H., Jirik, L. A., Kerr, D. R., Langford, R. P., Wermund, E. G., Zinke, S. G., Collins, R. E., Hower, T., Howard, W. E., Lord, M., and Ballard, J. R., 1990, Secondary natural gas recovery: targeted technology applications for infield reserve growth: The University of Texas at Austin, Bureau of Economic Geology, annual report prepared for the Gas Research Institute under contract no. 5088-212-1718, 194 p.

Fisher, R. S., and **Mullican, W. F., III,** 1990, Ground-water hydrochemistry in the southeastern Hueco Bolson and southwestern Diablo Plateau, Trans-Pecos Texas: The University of Texas at Austin, Bureau of Economic Geology, report prepared for the Texas Low-Level Radioactive Waste Disposal Authority under Interagency Contract Number IAC(90-91)0268, 66 p.

Gustavson, T. C., 1990, Sedimentary facies, depositional environments, and paleosols of the upper Tertiary Fort Hancock Formation and the Tertiary–Quaternary Camp Rice Formation, Hueco Bolson, West Texas: The University of Texas at Austin, Bureau of Economic Geology, report prepared for the Texas Low-Level Radioactive Waste Disposal Authority under Interagency Contract Number IAC(90-91)0268, 94 p.

Holloway, M. S., **Holtz, M. H., Tyler, Noel,** and **Fisher, W. L.,** 1990, An economic analysis of the Enhanced Oil and Gas Recovery Tax Act of 1989 (S.828): The University of Texas at Austin, Bureau of Economic Geology and Southwest Econometrics, Inc., final contract report prepared for Energy Division, Office of the Governor, 24 p.

Jackson, M. L. W., Ambrose, W. A., Finley, R. J., Haas, M. R., McFall, K. S., Rushing, J. A., and Kuuskraa, V. A., 1990, Assessment of gas resources for secondary gas recovery technology: The University of Texas at Austin, Bureau of Economic Geology, final report prepared for the Gas Research Institute, under contract no. 5087-212-1526A and B, 201 p.

Jackson, M. P. A., Vendeville, B. C., and **Schultz-Ela, D. D.,** 1990, Applied Geodynamics Laboratory 1989 annual report to industrial associates: The University of Texas at Austin, Bureau of Economic Geology, report prepared for Agip S.p.A., Amoco Production Company, ARCO Oil and Gas Company, BP Exploration Inc., Chevron O.F.R. Company and Chevron U.S.A. Inc., Conoco Inc., Elf-Aquitaine Petroleum, Exxon Production and Research Company, Marathon Oil Company, Mobil Research and Development Corporation, Petroleo Brasileiro S.A., Phillips Petroleum Company, Texaco Inc., and Total Minatome Corporation, 21 p. plus 80 transparencies.

Kreitler, C. W., Capuano, R. M., **Akhter, M. S., Hamlin, H. S., Erwin, M. E.,** and **Walter, T. G.,** 1990, Consolidation of geologic studies of geopressured geothermal resources in Texas: The University of Texas at Austin, Bureau of Economic Geology, 1989 annual report prepared for the U.S. Department of Energy, Advanced Technologies Division, under Cooperative Agreement No. DE-FC07-85NV10412, 241 p.

Laubach, S. E., Hamlin, H. S., Buehring, R. L., Baumgardner, R. W., Jr., and **Monson, E. R.,** 1990, Application of borehole-imaging logs to geologic

analysis, Cotton Valley Group and Travis Peak Formation, GRI Staged Field Experiment Wells, East Texas: The University of Texas at Austin, Bureau of Economic Geology, topical report prepared for the Gas Research Institute under contract no. 5082-211-0708, 115 p.

Lucia, F. J., and **Milling, M. E.,** 1990, Geologic reservoir classification for characterization and analysis of oil resources in known reservoirs—classification description and procedures: Geoscience Institute for Oil and Gas Recovery Research, Reservoir Classification Task Force, report prepared for U.S. Department of Energy, Office of Fossil Energy, Bartlesville Project Office, 17 p.

Morton, R. A., 1990, Contrasting styles of late Neogene deep-water sandstone deposition, offshore Texas: The University of Texas at Austin, Bureau of Economic Geology, final report prepared for the U.S. Department of the Interior, Minerals Management Service, under cooperative agreement no. 14-12-0001-30387, 35 p.

Mullican, W. F., III, and **Senger, R. K.,** 1990, Hydrologic characterization of ground-water resources in south-central Hudspeth County: The University of Texas at Austin, Bureau of Economic Geology, report prepared for the Texas Low-Level Radioactive Waste Disposal Authority under Interagency Contract Number IAC(90-91)0268, 88 p.

Pulich, W. M., and **White, W. A.,** 1990, Decline of submerged vegetation in the Galveston Bay system: chronology and relationships to physical processes: The University of Texas at Austin, Bureau of Economic Geology, report prepared as part of a cooperative agreement between the Texas Parks and Wildlife Department and the Bureau of Economic Geology for the Texas Parks and Wildlife Department, Resource Protection Division, in accordance with Interagency Contract No. (88-89)1423, 27 p.

Raney, J. A., and **Collins, E. W.,** 1990, Regional geologic setting of the Fort Hancock study area, Hudspeth County, Texas: The University of Texas at Austin, Bureau of Economic Geology, report prepared for the Texas Low-Level Radioactive Waste Disposal Authority under Interagency Contract Number IAC(90-91)0268, 69 p.

Scanlon, B. R., 1990, Unsaturated flow along arroyos and fissures in the Hueco Bolson, Texas: The University of Texas at Austin, Bureau of Economic Geology, report prepared for the Texas Low-Level Radioactive Waste Disposal Authority under Interagency Contract Number IAC(90-91)0268, 21 p.

Scanlon, B. R., and **Richter, B. C.,** 1990, Analysis of unsaturated flow based on chemical tracers (chloride, ^{36}Cl, ^{3}H, and bromide) and comparison with physical data, Chihuahuan Desert, Texas: The University of Texas at Austin, Bureau of Economic Geology, report prepared for the Texas Low-Level Radioactive Waste Disposal Authority under Interagency Contract Number IAC(90-91)0268, 58 p.

Scanlon, B. R., Wang, F. P., and **Richter, B. C.,** 1990, Analysis of unsaturated flow based on physical data related to low-level radioactive waste disposal, Chihuahuan Desert, Texas: The University of Texas at Austin, Bureau of Economic Geology, report prepared for the Texas Low-Level Radioactive Waste Disposal Authority under Interagency Contract Number IAC(90-91)0268, 102 p.

Schultz-Ela, D. D., and **Duncan, K. M.,** 1990, Applied Geodynamics Laboratory semi-annual progress report to industrial associates for 1990, Part I: *Restore*©: a tool for reconstructing cross sections: The University of Texas at Austin, Bureau of Economic Geology, report prepared for Agip S.p.A., Amoco Production Company, ARCO Oil and Gas Company, BP Exploration Inc., Chevron O.F.R. Company and Chevron U.S.A. Inc., Conoco Inc., Elf-Aquitaine Petroleum, Exxon Production and Research Company, Marathon Oil Company, Mobil Research and Development Corporation, Petroleo Brasileiro S.A., Phillips Petroleum Company, Texaco Inc., and Total Minatome Corporation, 68 p. plus floppy disk for Macintosh II.

Tyler, Noel, Bebout, D. G., Garrett, C. M., Jr., Guevara, E. H., Hocott, C. R., Holtz, M. H., Hovorka, S. D., Kerans, Charles, Lucia, F. J., Major, R. P., Ruppel, S. C., and **Vander Stoep, G. W.,** 1990, Opportunities for additional recovery in University Lands reservoirs—characterization of University Lands reservoirs: The University of Texas at Austin, Bureau of Economic Geology, final report prepared for The University of Texas System, 255 p.

Vendeville, B. C., and **Jackson, M. P. A.,** 1990, Applied Geodynamics Laboratory semi-annual progress report to industrial associates for 1990, Part II: Captions for experimental models in slide set number 3: The University of Texas at Austin, Bureau of Economic Geology, report prepared for Agip S.p.A., Amoco Production Company, ARCO Oil and Gas Company, BP Exploration Inc., Chevron O.F.R. Company and Chevron U.S.A. Inc., Conoco Inc., Elf-Aquitaine Petroleum, Exxon Production and Research Company, Marathon Oil Company, Mobil Research and Development Corporation, Petroleo Brasileiro S.A., Phillips Petroleum Company, Texaco Inc., and Total Minatome Corporation, 13 p. plus 40 transparencies.

White, W. A., and **Calnan, T. R.,** 1990, Sedimentation and historical changes in fluvial-deltaic wetlands along the Texas Gulf Coast with emphasis on the Colorado and Trinity River deltas: The University of Texas at Austin, Bureau of Economic Geology, report prepared for the Texas Parks and Wildlife Department, Resource Protection Division, in accordance with Interagency Contract No. (88-89)1423, 124 p.

White, W. A., and **Calnan, T. R.,** 1990, Sedimentation in fluvial-deltaic wetlands and estuarine areas, Texas Gulf Coast—literature synthesis: The University of Texas at Austin, Bureau of Economic Geology, report prepared for the Texas Parks and Wildlife Department, Resource Protection Division, in accordance with Interagency Contract No. (88-89)0820 and 1423, 261 p.

White, W. A., and **Calnan, T. R.,** 1990, Sedimentation in fluvial-deltaic wetlands and estuarine areas, Texas Gulf Coast—summary: The University of Texas at Austin, Bureau of Economic Geology, report prepared for the Texas Parks and Wildlife Department, Resource Protection Division, in accordance with Interagency Contract No. (88-89)0820 and 1423, 34 p.

Publications

In its role as a public geological research unit, the Bureau disseminates the results of research projects and programs primarily through its own publication series. During its 81-year history, the Bureau has published nearly 2,200 reports, bulletins, circulars, special publications, and maps covering major aspects of the geology and natural resources of Texas. Publications are sold at nominal prices to recover printing or duplication costs. To date, more than 1.7 million publications have been distributed worldwide, mostly through direct sales. During 1990, about 30,000 volumes were distributed. The Bureau issued the following publications in 1990:

Reports of Investigations

RI 190. Reservoir Modeling of Restricted Platform Carbonates: Geologic/ Geostatistical Characterization of Interwell-Scale Reservoir Heterogeneity, Dune Field, Crane County, Texas,

by G. E. Fogg and F. J. Lucia. 66 p., 58 figs., 4 tables, 2 appendices, $4.25

Application of geostatistical techniques for estimating discontinuous interwell permeability patterns

Accurately predicting oil recovery requires realistic estimates of interwell porosity and permeability patterns. Previous recovery efficiency (through 1981) of Section 15 of Dune field was only 25 percent; thus, several two-dimensional simulation experiments were conducted to determine why recovery efficiency is low and how it might be improved with infill drilling. Waterflooding was simulated in cross sections in which interwell permeability (k) distribution was estimated on the basis of detailed vertical profiles of k estimated at certain well locations, and interwell permeability heterogeneity was estimated using a statistic known as a variogram. The geostatistical technique of conditional simulation allowed the authors systematically to assess the maximum and minimum expected recovery efficiencies as a function of well spacing. Results of this study, which show the effects of geologic heterogeneity on fluid flow and oil recovery efficiency, are applicable to many other carbonate and noncarbonate fields worldwide. Funding provided by The University of Texas System as part of a larger study of University Lands

RI 191. Identification of Sources and Mechanisms of Salt-Water Pollution Affecting Ground-Water Quality: A Case Study, West Texas,

by B. C. Richter, A. R. Dutton, and C. W. Kreitler. 43 p., 32 figs., 3 tables, 2 appendices, $3.50

Investigation of regional hydrogeology and salinization sources in Concho, Irion, Runnels, and Tom Green Counties

Salinization of soils and ground water is widespread in the Concho River watershed and other semiarid areas in Texas and the United States. Using more than 1,200 chemical analyses of water samples, the authors were able to differentiate various salinization mechanisms by mapping salinity patterns and hydrochemical facies and by analyzing isotopic compositions and ionic ratios. Results revealed that in Runnels County evaporation of irrigation water and ground water is a major salinization mechanism, whereas to the west, in Irion and Tom Green Counties, saline water appears to be a natural mixture of subsurface brine and shallowly circulating meteoric water recharged in the Concho River watershed. The authors concluded that the occurrence of poor-quality ground water is not a recent or single-source phenomenon; it has been affected by terracing of farmland, by disposal of oil-field brines into surface pits, and by upward flow of brine from the Coleman Junction Formation via insufficiently plugged abandoned boreholes. Funded by the Railroad Commission of Texas under Interagency Contract Number IAC(84-85)-2122 and IAC(86-87)-1003

RI 192. Hydrogeology of the Northern Segment of the Edwards Aquifer, Austin Region,

by R. K. Senger, E. W. Collins, and C. W. Kreitler. 58 p., 34 figs., 2 tables, $3.50

Hydrogeochemical assessment of the Edwards aquifer in the Georgetown–Round Rock area and characterization of recharge and discharge

Geologic mapping and fracture analysis of Lower Cretaceous Edwards aquifer strata were conducted to provide a better understanding of the geology of the Balcones Fault Zone as it relates to the hydrogeology of the aquifer's northern segment. Hydrochemical, water-level, and precipitation data were studied to evaluate ground-water flow characteristics, recharge and discharge mechanisms, and the hydrochemical evolution of ground water in the Edwards aquifer. The authors found that ground water generally flows eastward, and main discharge of the unconfined, fast-flowing system occurs along fractures through springs and seeps at the major creeks and rivers in the Georgetown area. Some recharge water moves downdip past these springs into a confined section farther east, along a much reduced hydraulic gradient, and discharges by leaking through the confining units. Hydrochemistry of Edwards ground water indicates an evolution from a Ca-HCO_3 and Ca-Mg-HCO_3 to a mixed-cation-HCO_3 farther downdip to a Na-HCO_3, and finally to a Na-mixed-anion-type water. Report prepared for the Texas Water Development Board under Interagency Contract Number IAC(86-87)-1046

RI 193. Depositional Systems and Karst Geology of the Ellenburger Group (Lower Ordovician), Subsurface West Texas,

by Charles Kerans. 63 p., 37 figs., 2 tables, 1 appendix, 6 plates, $9.50

Analysis of the regional depositional and diagenetic framework of the Ellenburger Group

The Ellenburger Group of Texas contains estimated reserves of 1.15 billion barrels of oil and 2.2 billion barrels of oil equivalent. Despite its economic significance, comparatively little is known about the subsurface Ellenburger in West Texas; thus, this study presents a regional model of Ellenburger deposition and diagenesis. Using associations of lithologies and sedimentary structures observed in core, the author identified six depositional systems in the Ellenburger: fan delta–marginal marine, lower tidal flat, high-energy restricted shelf, low-energy restricted shelf, upper tidal flat, and open shallow water shelf. Diagenesis was dominated by three major styles of dolomitization: very fine crystalline dolomite (5–20 μm), in tidal-flat facies; fine to medium crystalline dolomite (20–100 μm), widespread in all facies; and coarse crystalline replacement mosaic dolomite and saddle dolomite cement, which formed in a burial setting after pre-Simpson karst formation and before Pennsylvanian faulting, uplift, and erosion. Other diagenetic events were karst-related dissolution episodes associated with repeated uplift and exposure and subsequent dedolomitization of the Ellenburger platform. Funding provided by The University of Texas System as part of a larger study of University Lands

RI 194. Delineation of Unrecovered Mobile Oil in a Mature Dolomite Reservoir: East Penwell San Andres Unit, University Lands, West Texas,

by R. P. Major, G. W. Vander Stoep, and M. H. Holtz. 52 p., 51 figs., 2 tables, $4.00

Geologic and engineering study of the East Penwell San Andres Unit, West Texas

Since discovery in 1927, the East Penwell San Andres Unit has produced 43 million barrels of primary and waterflood oil of an estimated 164 million barrels of original oil in place. Approximately 30 million barrels of mobile oil remains in the primary reservoir of this unit. The objective of this investigation was to locate this remaining mobile oil using geologic and engineering techniques. Results indicate that the San Andres Formation in the north part of the unit contains a thick section of reservoir-quality pellet grainstone/packstone, which was affected by a postburial leaching event that increased permeability. The overlying nonreservoir peritidal rock is thin. In the south part of the unit this peritidal rock is thicker, and this part of the unit has relatively low production and low volumes of remaining mobile oil. East-west-trending tidal channels in the north part of the unit are potential targets for infill development drilling. Funding provided by The University of Texas System as part of a larger study of University Lands

RI 195. Deposition and Diagenesis in a Marine-to-Evaporite Sequence: Permian Upper Wolfcamp Formation and Lower Wichita Group, Palo Duro Basin, Texas Panhandle,

by R. S. Fisher and H. H. Posey. 34 p., 22 figs., 3 tables, $5.00

Isotopic analyses of formation waters and Wolfcamp and Wichita anhydrite, Palo Duro Basin

The Wolfcamp-to-Wichita lithologic transition provides an excellent record of the depositional and diagenetic processes that occur as depositional environments change from normal marine to marine evaporite. In this report, depositional and diagenetic sequences were established from lithologic and mineralogic examinations of core and thin section, and geochemical conditions were interpreted from isotopic (C, O, S, and Sr) compositions of calcite, dolomite, and anhydrite. The age of the Wolfcamp–Wichita transition was determined using sulfur and strontium isotopic chronostratigraphy. The timing of formation of various types of anhydrite was inferred from textural and isotopic relations between anhydrite varieties and the host carbonate rocks. Funding provided by the U.S. Department of Energy under contract number DE-AC97-83WM46651 and the Texas Higher Education Coordinating Board

RI 196. Neotectonic History and Structural Style of the Campo Grande Fault, Hueco Basin, Trans-Pecos Texas,

by E. W. Collins and J. A. Raney. 39 p., 20 figs., 5 tables, 1 appendix, 2 plates, $6.00

Structural analysis of the Campo Grande fault area

The Campo Grande fault, a major bounding fault of the Hueco Basin in Trans-Pecos Texas, formed in response to Basin and Range extensional tectonism. Previously there have been few detailed descriptions of faults that offset Quaternary deposits within this region of Texas. In this report the authors describe fault scarps, natural outcrops, and excavations across the fault. They analyze the crosscutting relationships between the fault strands and Quaternary units to evaluate the late Tertiary and Quaternary history of the fault. Buried calcic soil horizons and compound scarps indicate multiple displacements, and the rates of movement have been relatively constant over the last 2.5 Ma. Vertical offsets during single faulting events have been 1 to 2 m. The average recurrence interval of major surface ruptures is about 0.1 Ma (maximum), and the last faulting episode was late Pleistocene. Plates are a geologic map and logs of excavations. Funded by the Texas Low-Level Radioactive Waste Disposal Authority under Interagency Contract Number IAC(90-91)-0268

RI 197. Regional Depositional Systems Tracts, Paleogeography, and Sequence Stratigraphy, Upper Pennsylvanian and Lower Permian Strata, North- and West-Central Texas,

by L. F. Brown, Jr., R. F. Solís-Iriarte, and D. A. Johns. 116 p., 43 figs., 2 tables, 1 appendix, 27 plates, $25.00

Cross sections and text depicting regional depositional framework

This report and a companion volume of cross sections published by the same authors in 1987 provide a regional stratigraphic and depositional framework of the Virgilian and Wolfcampian Series of North-Central Texas. The authors have identified 16 major and several minor depositional sequences, commonly called cyclothems, deposited during Late Pennsylvanian and Early Permian regressive-transgressive episodes. These cyclothems were mapped from outcrop across the Eastern Shelf and into the Midland Basin. Seventeen maps and 23 cross sections were constructed to show regional net-sandstone distribution within siliciclastic systems, to document sequential depositional history and paleogeography, to analyze depositional response to paleobathymetry and tectonics, and to offer a regional sequence-stratigraphic framework for evaluating controls on relative sea level. Regional perspective provided by the map series will, the authors hope, stimulate new ideas about inadequately tested sandstone trends and unrealized stratigraphic-trap potential in this large, mature petroleum province.

Geological Circulars

GC 90-1. Geologic Significance of Remotely Sensed Physiographic Features of the Texas Panhandle and Adjacent Regions,

by E. W. Collins. 39 p., 15 figs., 2 tables, 4 appendices, $2.50

Comparison of remotely sensed (Landsat) data with geologic data

Remotely sensed features such as linear drainages, escarpments, ridges, and aligned playas were identified on 1:250,000-scale Landsat images of the Texas Panhandle, eastern New Mexico, and the Oklahoma Panhandle and compared with detailed regional and site-specific geologic data from 32 field stations in these areas. The physiographic regions studied are the High Plains, Canadian Breaks, Rolling Plains, Pecos Valley, and Raton section. The authors collected structural data at and near features depicted on the 63 remotely sensed images, thus providing a case study of the correlation of surface geologic data with remotely sensed features in areas of differing physiography. Results showed that about 70 percent of drainages, escarpments, and ridges coincide with the orientations of fracture sets, faults, or dikes, in all areas except the low-relief High Plains. Detailed statistical analyses of lineaments performed for this study indicate that lineament interpretations only partly reflect the orientations of fracture sets and the structural grains of subsurface strata; thus, the combination of remotely sensed data and geologic data offers a more complete assessment of the surficial geology of the Texas Panhandle. Funding provided in part by the U.S. Department of Energy under contract number DE-AC97-83WM46651

GC 90-2. Opportunities for Horizontal Drilling in Texas,

by R. J. Finley, S. E. Laubach, Noel Tyler, and M. H. Holtz. 32 p., 14 figs., 2 tables, $3.50

Assessment of horizontal drilling applications to Texas oil and gas plays

Highly productive wells drilled in the Pearsall field (Austin Chalk) of South Texas have shown that horizontal drilling is an extremely effective technique for developing unrecovered oil and natural gas, particularly in mature hydrocarbon provinces that contain natural fractures. Production can also be enhanced where the reservoir-quality zone or the oil column is thin or where gravity-drainage production occurs. Although they are not current targets of horizontal drilling activity, many other kinds of reservoirs contain depositional heterogeneities that interfere with recovery by vertical wells. Use of horizontal drilling to tap multiple reservoir compartments in these reservoirs has significant potential but has yet to be fully tested. The resource target of unrecovered mobile oil in the nine Texas plays and subplays discussed in this report, amounting to more than 8 billion barrels of oil, warrants further testing of horizontal drilling in areas of depositional heterogeneities and multiple reservoir compartments. This circular summarizes geological and engineering characteristics of selected formations in Texas that have been targets or are potential targets for horizontal drilling.

GC 90-3. Field Extension in a Carbonate Reservoir: An Example from the Central Basin Platform, Permian Basin, West Texas,

by R. P. Major. 28 p., 16 figs., 1 table, $2.00

Evaluation of oil and gas reserves in the PJWDM field complex, Permian Basin

In light of current oil prices, old fields in mature hydrocarbon provinces are being reexplored, and data from old, previously uneconomic, wells are being reevaluated. One reexploration strategy, reservoir framework analysis, has been applied to Guadalupian reservoirs in and adjacent to University Block 35 in Ector and Crane Counties, Texas. Although present production on University Lands is exclusively from the San Andres Formation, evaluation of old University Lands well records and review of production in fields downdip (east) of University Block 35 indicate an untapped gas reservoir and a potential oil reservoir in the Grayburg Formation. The presence of production facilities and the development of a strong market for gas suggest that this new reservoir zone can be economically produced, thus potentially increasing the reserves in this area. Funding provided by The University of Texas System as part of a larger study of University Lands

GC 90-4. Facies Heterogeneity and Brine-Disposal Potential of Miocene Barrier-Island, Fluvial, and Deltaic Systems: Examples from Northeast Hitchcock and Alta Loma Fields, Galveston County, Texas,

by W. A. Ambrose. 35 p., 24 figs., 1 table, 1 appendix, $2.50

Analysis of Miocene sands along the eastern Texas Gulf Coast for brine disposal

Large volumes of brine must be produced from watered-out, geopressured gas reservoirs in the Gulf Coast to recover remaining gas in solution. Secondary-gas recovery in an upper Frio (Oligocene) reservoir in Northeast Hitchcock and Alta Loma fields in Galveston County, Texas, requires the disposal of approximately 20,000 barrels of brine per day into several disposal wells. Lower and middle Miocene barrier-island sands in these fields contain reservoir volumes sufficient for brine disposal at rates of more than 5,000 barrels per well per day for 10 years or more. These sands are continuous and homogeneous and have permeabilities in excess of 2,000 millidarcys. Optimal areas for brine disposal are where new wells contact several of these sands. In contrast, there are fewer well sites for brine disposal in upper Miocene fluvial and deltaic sands in Northeast Hitchcock and Alta Loma fields because these sands are heterogeneous and discontinuous. This circular provides core data and net-sand and log-facies maps of several Miocene sands and evaluates sites in these fields for cost-efficient disposal of large volumes of brine. Funded by the Gas Research Institute under contract number 5084-212-0924

GC 90-5. Integration of Ground-Water and Vadose-Zone Geochemistry to Investigate Hydrochemical Evolution: A Case Study in Arid Lands of the Northern Chihuahuan Desert, Trans-Pecos Texas,

by R. S. Fisher and W. F. Mullican III. 36 p., 11 figs., 7 tables, 3 appendices, $4.00

Hydrogeochemical study of Trans-Pecos Texas

This circular summarizes the results of an extensive ground-water-sampling program conducted in the Hueco Bolson and Diablo Plateau area of West Texas. The origin, hydrochemical evolution, and age of ground water in arid lands of Trans-Pecos Texas were investigated by combining mineralogic analyses of soils and aquifer matrix, chemical analyses of readily soluble materials in soils and water extracted from the thick, unsaturated zone, and chemical and isotopic analyses of ground water from three principal aquifers, the Diablo Plateau, Hueco Bolson, and Rio Grande alluvial aquifers. Repeated ground-water sampling over a 3-year period and quarterly sampling of selected wells revealed no significant short-term chemical or isotopic variability. Ground-water ages range from recent to nearly 28,000 years; the distribution of ages reflects relative permeability (transmissivity) of the aquifers. Most ground waters evolve from calcium-bicarbonate to sodium-sulfate types because of carbonate and sulfate mineral dissolution coupled with exchange of aqueous calcium and magnesium for sodium on clay minerals. Water in the Rio Grande alluvial aquifer evolved to a sodium-chloride type as a result of extensive evapotranspiration on irrigated fields. The appendices list detailed results of field measurements of temperature, pH, Eh, dissolved oxygen, and major ion concentrations. Funding provided by the Texas Low-Level Radioactive Waste Disposal Authority under Interagency Contract Number IAC(90-91)-0268

Guidebooks

GB 24. Tertiary and Quaternary Stratigraphy and Vertebrate Paleontology of Parts of Northwestern Texas and Eastern New Mexico,

T. C. Gustavson, Editor. 128 p., 53 figs., 10 tables, $5.00

Field guide to upper Cenozoic stratigraphy of the Southern High Plains and Rolling Plains in Texas and New Mexico

Discussions of upper Cenozoic stratigraphy, climate, and fauna of the Texas–New Mexico High Plains area are presented in this guidebook in the context of 17 field trip stops. Fluvial, lacustrine, and eolian facies (loess and sheet sands) and calcic paleosols that characterize the Quaternary Blackwater Draw and Tule Formations and the upper part of the Neogene Ogallala and Blanco Formations are emphasized in several field trip stop descriptions. Sections

in the Ogallala, Blanco, and Tule Formations containing local vertebrate faunas of Clarendonian, Hemphillian, Blancan, and Irvingtonian age are highlighted and complemented by extensive faunal lists. Illustrations include numerous regional and site-specific geologic, soil, and faunal-distribution maps. Funding provided in part by the U.S. Department of Energy under contract number DE-AC97-83WM46651

GB 25. Hydrogeology of Trans-Pecos Texas,

C. W. Kreitler and J. M. Sharp, Editors. 120 p., 30 figs., 1 table, $6.00

Field trip road log, research papers, and reprints of articles on the hydrogeology of the Trans-Pecos area

Prepared as a guidebook for a 1990 Geological Society of America field trip, this volume brings together a road log from that trip, six new research articles, and seven reprints on the hydrogeology of the Trans-Pecos area of West Texas and eastern New Mexico. Four of the technical papers and one of the reprints resulted from investigations conducted for the Texas Low-Level Radioactive Waste Disposal Authority as part of an analysis of the area as a potential site for low-level radioactive waste disposal; the remaining papers are from various other sources. This guidebook presents a detailed survey of the hydrogeology specific to Trans-Pecos Texas yet applicable to many other arid environments worldwide.

Bibliography and Index Series

Bibliography and Index of Texas Geology, 1981–1985,

by A. R. Masterson and Lana Dieterich. 463 p., $25.00

Compilation of more than 4,000 references on Texas geology and related fields, indexed by author and subject

This four-part volume lists selected abstracts, articles, books, reports, maps, and theses and dissertations on Texas geology and related fields that were published in 1981 through 1985 and that were available as of 1990. The first section provides a list of abbreviations, acronyms, and addresses of source materials used in compiling the bibliography. Arranged alphabetically by individual author or issuing agency name and then by year of publication, the second section lists the bibliographic citation and a citation number that is keyed to the third and fourth sections, the subject and author indexes, respectively. Topics in the subject index are derived primarily from keywords and geographic locators. This volume, the sixth in a series, is intended to guide students, faculty and staff, landowners, and the general public to the abundant literature on Texas geology.

Other Publications

Geologic and Engineering Approaches in Evaluation of San Andres/Grayburg Hydrocarbon Reservoirs–Permian Basin,

D. G. Bebout and P. M. Harris, Editors. 13 papers, 297 p., 271 figs., 8 text plates, 8 tables, 1 plate in pocket, $15.00

Analyses of selected oil and gas fields of the Permian Basin

Reservoirs of the San Andres and Grayburg Formations of the Permian Basin have a combined cumulative production of 7.7 billion barrels of oil. These reservoirs have produced 46 percent of the oil from the Permian Basin and 17 percent of that from the entire State of Texas. Because of their high cumulative production but low recovery efficiency (30 percent), these reservoirs are prime candidates for improved infill drilling, selective completion, and enhanced recovery. Attaining improved field development requires a thorough knowledge of the reservoirs that can be obtained only through integration of geological and engineering data. The first three papers in this volume

introduce the San Andres and Grayburg Formation by presenting an overview of the regional facies framework, diagenesis, and correlation of these rocks on the Central Basin Platform and Northern Shelf. The remaining 10 papers are detailed case studies of specific reservoirs in Andrews, Cochran, Crane, Ector, Gaines, and Hockley Counties in Texas and Lea County, New Mexico. An oversized plate in the back of the book presents a regional cross section of the Guadalupian Series from the Central Basin Platform to the Southern Shelf.

Geologic Framework and Regional Hydrology: Upper Cenozoic Blackwater Draw and Ogallala Formations, Great Plains,

T. C. Gustavson, Editor. 13 papers, 244 p., 97 figs., 38 tables, 5 appendices, $10.00

Proceedings of a symposium on the upper Tertiary Ogallala and Quaternary Blackwater Draw Formations

Papers in this volume describe elements of the stratigraphy, biostratigraphy, soils, hydrology, and geomorphology of the Ogallala and Blackwater Draw Formations. The Ogallala Formation covers much of the Great Plains region, extending from South Dakota to Texas and eastern New Mexico. The Blackwater Draw Formation overlies the Ogallala in New Mexico, Oklahoma, and Texas, but its northern limit is unknown. Soils from these units and ground water contained in these strata support an extensive agricultural industry. The strata have also yielded one of the best records of late Tertiary–Quaternary biostratigraphy in the world. Fossil plant data indicate that the predominant vegetation during the late Tertiary was open grassland and scattered trees and shrubs, which existed in a warm-temperate to subtropical climate. Hydrogeologic data indicate recharge from precipitation and playa lake basins ranging from 1.3 cm/yr in New Mexico to 8.1 cm/yr elsewhere in the Southern High Plains. Funding provided in part by the U.S. Department of Energy under contract number DE-AC97-83WM46651

The Wilcox Group (Paleocene-Eocene) in the Sabine Uplift Area, Texas: Depositional Systems and Deep-Basin Lignite,

by W. R. Kaiser. 20 p., 11 figs., 2 tables, 16 plates, $12.50

Subsurface analysis of the Sabine Uplift area, East Texas

In anticipation of future energy needs, the Bureau undertook this study to evaluate Wilcox depositional systems and deep-basin lignite in a 12-county area in East Texas. Using 1,100 geophysical logs, the author identified regional depositional systems and constructed 16 regional cross sections, lithofacies maps, and lignite-occurrence maps. A companion drilling program tested lignite in the deep basin to improve its identification on old electric and induction logs and to refine an evolving depositional model to demonstrate its predictive capability. Results indicate that the thickest and most laterally extensive lignite seams lie in Shelby and Panola Counties in the lower Wilcox at the transition from the marine Midway Group to the deltaic Wilcox Group. Deep lignite resources at depths of less than 2,000 ft and in seams at least 5 ft thick amount to approximately 5.5 billion short tons. Lignite resources in Panola and Shelby Counties have the highest potential for ultimate recovery by deep surface mining and underground coal gasification. Funded by the Texas Energy and Natural Resources Advisory Council, under Interagency Contract Number IAC(82-83)-0822, and by special appropriation from the Texas Legislature

Services

Core Research Center

The Core Research Center (CRC) houses the largest public collection of subsurface geological materials in the United States and is open from 8:00 a.m. to 5:00 p.m. Monday through Friday. Visitors may view core or cuttings, have grain sizes analyzed, or use the photographic or gamma-scan facilities for a nominal charge. Information on holdings, policies, and computer listings may be obtained by contacting Allan R. Standen, Curator, at (512) 471-1534, Ext. 400. A brochure describing the CRC is available upon request.

Approximately 7,000 cores and drill cuttings from 55,000 wells are available for study at the CRC and may be viewed on-site or checked out for a period of 6 weeks. Patrons are asked to provide results of analyses of borrowed material, which then become part of the center's reference material. Information regarding wells is stored in a relational data base, and customized data-base searches may be purchased.

During 1990, the CRC received more than 400 visitors. Transactions were made involving CRC inventory that included geologic materials from more than 800 wells and required the transfer of more than 20,000 boxes of core (30 linear miles) to and from viewing and shipping areas. Core processing, including slabbing and reboxing, exceeded 50,000 linear feet. The Thin Section Laboratory produced a total of 3,000 thin sections for Bureau and non-Bureau patrons. More than 4,000 photographs were taken of geologic materials during 1990.

New acquisitions in 1990 totaled more than 175 new cores (more than 20,000 linear feet of core) and drill cuttings from more than 1,500 wells. Donations were received from American Exploration, Basin Operating, Bridge Oil, Cashflow Exploration, Columbia Gas, Core Labs (Dallas and Houston), W. G. Ellis, Fortson Oil Co., Germany Oil Co., Greenbriar Exploration, Gunn Oil, International Boundary & Water Commission, International Technology Corporation, K-N Operating, Kohler Energy, McMoran Corporation, Midland International Sample Library, Mitchell Energy, Porter Montgomery, Power Exploration, Radian Corporation, Reservoirs, Inc., Rosewood Resources, Southwestern Energy, Department of Energy (Superconducting Super Collider), Texaco, Inc., Texas A&M University, Triton Energy, The University of Texas at Austin (Department of Geological Sciences), and The University of Texas at Dallas.

Mineral Studies Laboratory

The Mineral Studies Laboratory (MSL) serves as the Bureau's analytical geochemistry facility. Located in approximately 18,000 ft^2 of laboratory space adjacent to the Bureau's Research and Administrative Office, the MSL can provide near-complete geochemical, mineralogical, and textural characterization of most geological materials. The MSL is currently staffed by Chief Chemist Steven W. Tweedy and other analytical staff. The facility contains several major instrumental systems capable of performing many functions, including inductively coupled plasma optical and mass spectrometry (ICP-OES, ICP-MS), stable isotope mass spectrometry, electron microprobe analysis, scanning electron microscopy examination, and X-ray diffractometry. Complete wet-chemical analysis, coal/fuel analysis, sample comminution, and fire assays can also be performed within the MSL. These services are available to the Texas geological community but are primarily for support of Bureau research programs.

Many Bureau programs were supported by MSL analysis and characterization during 1990. Among these are programs for the Texas Low-Level Radioactive Waste Disposal Authority, Texas Mining and Mineral Resources Research Institute, Gas Research Institute, Secondary Natural Gas Recovery, Ferron Sandstone, low-permeability gas sandstone reservoirs, EPA ground water, Superconducting Super Collider hydrology, University Lands, Texas Advanced Research, clay diagenesis and Bonaire dolomite, and coalbed methane. In addition to supporting projects for the Bureau, MSL staff provided analytical services to the Institute of Gas Technology's Pleasant Bayou and Hulin test wells, UT Center for Energy Studies (DOE Logging), UT Center for Transportation Research, UT Mechanical Engineering, Sandia National Laboratories, and the University of Houston Department of Geosciences.

The MSL continued its participation in several professional societies and associations devoted to standardizing and developing analytical methods. The MSL is a member of the International Geostandards Working Group and also participates in the work of the American Society for Testing and Materials.

Public Information

Requests for information about the mineral, geology and 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 1990, approximately 2,000 such requests were handled by L. Edwin Garner, the Public Information Geologist.

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 Carolyn Condon and L. Edwin Garner, is open to the public for reference use from 8:00 a.m. to 5:00 p.m. Monday through Friday.

The Reading Room houses a collection of more than 5,000 monographs and serials and 50 periodicals. Included in the collection are extensive reports and open-file materials received from the U.S. Geological Survey, the U.S. Bureau of Mines, and the U.S. Department of Energy, as well as unpublished open-file reports and contract reports prepared by the Bureau for various contracting agencies.

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

In 1990, the physical area and the quantity of materials housed in the Reading Room were reduced to create space for expansion of the Geophysical Log Facility. More than 300 boxes of duplicate and unused materials were transferred to the Geology Library. The Reading Room staff cataloged, indexed, shelved, and entered into a computer data base more than 1,800 items. More than 150 items including photographs, negatives, slides, glass negatives, lantern slides, and manuscript materials from the collections of Walter Scott Adkins, W. Armstrong Price, and the Bureau are now archived at the University's Barker History Center.

Geophysical Log Facility

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

By the end of 1990, the facility had accumulated approximately 60,000 well logs of various types, at a rate of 800 logs per month, which are being entered into the GLF's computer data base.

Highlights

Fisher Appointed to Secretary of Energy Advisory Board

Bureau Director William L. Fisher has been appointed by U.S. Secretary of Energy James D. Watkins to the newly established Secretary of Energy Advisory Board (SEAB). SEAB is composed of experts in a variety of energy-related fields and will be responsible for advising the Secretary on all aspects of the operations of the U.S. Department of Energy, including long-range planning and analysis of economic, energy, and conservation issues now confronting the United States.

Bureau Streamlines Publication-Sales and Inventory Procedures

The Bureau has recently made major changes in its procedures for recording and processing publication-sales information. For 80 years, the Bureau kept its records in ledgers. However, because of the recent expansion of the Bureau and the resulting increase in number of scientific publications produced and sold, the need for a more efficient method of record keeping and inventory arose. Improvements were introduced in 1990 by (1) computerizing all sales histories for the past 25 years, (2) periodically accounting for the entire inventory, (3) improving ways to preserve the inventory, especially for long-term storage, (4) updating the mailing list by using professional-society rosters and by purging obsolete and duplicate entries, and (5) beginning to advertise more aggressively. The resulting data base will serve the public more efficiently by streamlining the sales process, helping to anticipate the need to reprint fast-selling publications, and determining the geologic topics of most interest to Bureau customers.

Awards and Honors

During 1990, Bureau researchers garnered several prestigious awards and attained high elective offices. **William L. Fisher** was elected an honorary member of the American Association of Petroleum Geologists, was given the Distinguished Service Award by the West Texas Geological Society, and was named president-elect of the American Geological Institute. **Robert L. Folk** was awarded the Henry Clifton Sorby Medal by the International Association of Sedimentologists (IAS) at the Thirteenth International Sedimentological Congress in Nottingham, England. The Sorby Medal is the highest honor bestowed by the IAS. **Martin P. A. Jackson** earned the 1990 George C. Matson Award for best paper presented at the annual convention of the American Association of Petroleum Geologists. The paper, "The Rise and Fall of Diapirs during Thin-Skinned Extension," was coauthored by Bureau scientist Bruno C. Vendeville and was chosen from a record 420 papers presented at the meeting. **Charles Kerans** was named one of 11 Distinguished Lecturers for 1990–91 by the American Association of Petroleum Geologists. **Alan R. Dutton** and **Charles W. Kreitler** were elected into the American Institute of Hydrology and certified as Professional Hydrogeologists. A poster presented by **Stephen E. Laubach** at the Geological Society of America (GSA) 1990 annual meeting received Honorable Mention from the Coal Division of GSA.

New Research Staff

Kenneth T. Barrow, until recently a staff geologist with Chevron in Denver and Midland, joined the Bureau as a Research Associate and is engaged in reservoir chacterization for the SLERO project. **Peter Cobbold** worked at the Bureau's Applied Geodynamics Laboratory this year as a visiting Senior Research Scientist. Trained in structural geology and rock mechanics, Cobbold received his Ph.D. from the University of London, England, and is currently Research Professor of Tectonophysics at the University of Rennes, France. While at the Bureau, Cobbold conducted experiments in thermal equilibrium of thickened lithosphere and on folding and thrusting related to gravity sliding over salt. **Raymond A. Levy** joined the Secondary Gas Recovery project as a Research Scientist. Levy, formerly an exploration geologist with Shell Oil Company in Houston, received his Ph.D. from the University of South Carolina, where he studied the sedimentology of Upper Cretaceous coal-bearing strata of southwestern Wyoming. **Roger Tyler** was assigned to the Coalbed Methane project as a Research Scientist Associate conducting research on the enhancement of natural gas recovery. Tyler had been employed as an exploration geologist with Rand Mines, Limited, and as a research fellow with the Economic Geology Research Unit at the University of Witwatersrand in Johannesburg, South Africa. **Ruud Weijermars**, a native of The Netherlands, joined the Bureau's Applied Geodynamics Laboratory as a visiting Research Fellow. His work centers on the development of scaling theory for structural models involving brittle overburdens and viscous substrates, a topic that has direct application to exploration for hydrocarbon structural traps around salt domes. Weijermars received a Ph.D. in geodynamics from the University of Uppsala, Sweden, and worked previously at the Swiss Federal Institute of Technology in Zurich.

Research Staff Publications and Activities

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

Papers

Akhter, M. S., and **Kreitler, C. W.,** 1990, Reliability and applicability of DSTs and bottomhole pressure measurements in Texas Gulf Coast Tertiary formations: Journal of Petroleum Science and Engineering, v. 3, p. 287–303.

Ayers, W. B., Jr., 1990, Geologic controls on coalbed methane occurrence and producibility: Gas Research Institute Coalbed Methane Workshop, Section II.A, 36 p.

Ayers, W. B., Jr., and Pashin, J. C., 1990, Geologic evaluation of critical production parameters for coalbed methane resources: Quarterly Review of Methane from Coal Seams Technology, v. 7, no. 3, p. 36–39.

Ayers, W. B., Jr., and Pashin, J. C., 1990, Geologic evaluation of critical production parameters for coalbed methane resources: Quarterly Review of Methane from Coal Seams Technology, v. 7, no. 4, p. 25–29.

Barnes, V. E., 1990, Tektite research 1936–1990: Meteoritics, v. 25, p. 149–159.

Caran, S. C., and **Baumgardner, R. W., Jr.,** 1990, Quaternary stratigraphy and paleoenvironments of the Texas Rolling Plains: Geological Society of America Bulletin, v. 102, no. 6, p. 768–785.

Coleman, Janet, and **Galloway, W. E.,** 1990, Petroleum geology of the Vicksburg Formation, Texas: Gulf Coast Association of Geological Societies Transactions, v. 40, p. 119–130.

Coleman, Janet, and **Galloway, W. E.,** 1990, Petroleum geology of the Vicksburg Formation, Goliad County, Texas: South Texas Geological Society Bulletin, v. 30, no. 19, p. 9–25.

Collins, E. W., and **Laubach, S. E.,** coordinators, 1990, Faults and fractures in the Balcones Fault Zone, Austin Region, Central Texas: Austin Geological Society Guidebook 13, 34 p.

Collins, E. W., Laubach, S. E., and **Vendeville, B. C.,** 1990, Faults and fractures in the Balcones Fault Zone, Austin Region, Central Texas, *in* Collins, E. W., and Laubach, S. E., coordinators, Faults and fractures in the Balcones Fault Zone, Austin Region, Central Texas: Austin Geological Society Guidebook 13, p. 1–28.

Dingus, W. F., and **Galloway, W. E.,** 1990, Morphology, paleogeographic setting, and origin of the middle Wilcox Yoakum canyon, Texas Coastal Plain: American Association of Petroleum Geologists Bulletin, v. 74, no. 7, p. 1055–1076.

Dutton, A. R., 1990, Vadose-zone recharge and weathering in an Eocene sand deposit, East Texas, U.S.A.: Journal of Hydrology, v. 114, p. 93–108.

Dutton, S. P., 1990, Mobeetie field, *in* Beaumont, E. A., and Foster, N. H., eds., Atlas of oil and gas fields, structural traps volume II: traps associated with tectonic faulting: American Association of Petroleum Geologists Treatise of Petroleum Geology, p. 127–159.

Dutton, S. P., and **Diggs, T. N.,** 1990, History of quartz cementation in the Lower Cretaceous Travis Peak Formation, East Texas: Journal of Sedimentary Petrology, v. 60, no. 2, p. 191–202.

Fisher, W. L., 1990, Capability of U.S. oil resource base for stable production: prepared for U.S. Senate Finance Committee, Lloyd Bentsen, chairman, 11 p.

Fisher, W. L., 1990, Oil recovery tax incentives: U.S. Senate Committee on Finance, Committee Print: Washington, D.C., U.S. Government Printing Office, p. 20–21, 37–41.

Fisher, W. L., and others, 1990, Technical factors in Edwards aquifer use and management: a report for the Special Committee on the Edwards Aquifer, Texas Senate and House of Representatives, 57 p.

Gao, Guoqiu, **Hovorka, S. D.,** and Posey, H. H., 1990, Limpid dolomite in Permian San Andres halite rocks, Palo Duro Basin, Texas Panhandle: characteristics, possible origin, and implications for brine evolution: Journal of Sedimentary Petrology, v. 60, no. 1, p. 118–124.

Garner, L. E., and Werner, M. L., 1990, Geology of the Superconducting Super Collider project area: International Symposium on Unique Underground Structures, Proceedings Volume 1, Chapter 45, p. 45-1–45-7.

Grigsby, J. D., 1990, Detrital magnetite as a provenance indicator: Journal of Sedimentary Petrology, v. 60, no. 6, p. 940–951.

Gustavson, T. C., 1990, Stratigraphy and geomorphic evolution of the southern Hueco Bolson, West Texas and Chihuahua, Mexico: West Texas Geological Society Bulletin, v. 30, no. 3, p. 5–11.

Hamlin, H. S., 1990, Hydrocarbon production and exploration potential of the distal Frio Formation, Texas Gulf Coast and offshore, *in* Hunt, M. C., Doenges, Susann, and Stubbs, G. S., eds., Studies related to continental margins—a summary of year-three and year-four activities: sponsored by Minerals Management Service, U.S. Department of the Interior, and Continental Margins Committee, Association of American State Geologists, Proceedings, p. 61–73.

Hamlin, H. S., Walter, T. G., and **Kreitler, C. W.,** 1990, Colocation of heavy oil and geopressured-

geothermal brine resources, examples from South Texas and Kern County, California, *in* Negus-de Wys, J., ed., Proceedings of the First Meeting of the Industrial Consortium for the Utilization of the Geopressured-Geothermal Resource: Idaho Falls, Idaho, EG&G Idaho, Inc., p. 17–55.

Hentz, T. F., 1990, Native sulfur deposits in the western Delaware Basin, Trans-Pecos Texas: origin, distribution, and exploration strategy, *in* Kyle, J. R., ed., Industrial mineral resources of the Delaware Basin, Texas and New Mexico: Society of Economic Geologists Guidebook Series, v. 8, p. 115–140.

Holbrook, D. F., Gilliland, W. A., Luza, K. V., Pope, D. E., **Wermund, E. G.,** Miller, R. A., Bush, W. V., Jensen, K. N., and Fishman, W. D., 1990, Quaternary geologic map of the Vicksburg 4° × 6° quadrangle, United States, *in* Quaternary geologic atlas of the United States: U.S. Geological Survey Map I-1420 (NI-15), scale 1:1,000,000.

Hunt, M. C., **Doenges, Susann,** and **Stubbs, G. S.,** eds., 1990, Second symposium on studies related to continental margins—a summary of year-three and year-four activities: sponsored by Minerals Management Service, U.S. Department of the Interior, and Continental Margins Committee, Association of American State Geologists, Proceedings, 206 p.

Jirik, L. A., 1990, Reservoir heterogeneity in middle Frio fluvial sandstones: case studies in Seeligson field, Jim Wells County, Texas: Gulf Coast Association of Geological Societies Transactions, v. 40, p. 335–352.

Johnson, W. D., Jr., Hawley, J. W., Stone, W. J., Kottlowski, F. E., **Henry, C. D.,** and Price, J. G., 1989, Geology, *in* Bedinger, M. S., Sargent, K. A., and Langer, W. H., eds., Studies of geology and hydrology in the Basin and Range province, southwestern United States, for isolation of high-level radioactive waste—characterization of the Rio Grande region, New Mexico and Texas: U.S. Geological Survey Professional Paper 1370-C, p. 7–19.

Kaiser, W. R., and **Ayers, W. B., Jr.,** 1990, Hydrologic evaluation of coalbed methane producibility: Gas Research Institute Coalbed Methane Workshop, Section II.B, 23 p.

Kaiser, W. R., Norris, M. J., and Hall, W. D., field trip leaders, 1990, Hydrogeology of the Jewett Lignite Mine, East Texas: Geological Society of America Field Trip Guidebook 22, 37 p.

Kasap, Ekrem, and Lake, L. W., 1990, Calculating the effective permeability tensor of a gridlock: Society of Petroleum Engineers Formation Evaluation, June, p. 192–200.

Kasap, Ekrem, and Lake, L. W., 1990, Dynamic effective relative permeabilities for crossbedded flow units: Society of Petroleum Engineers/U.S. Department of Energy, SPE/DOE Paper 20179, p. 71–82.

Kerans, Charles, 1990, Karst-controlled reservoir heterogeneity in Ellenburger Group carbonates of West Texas: reply: American Association of Petroleum Geologists Bulletin, v. 74, no. 7, p. 1124–1125.

Kerr, D. R., 1990, Reservoir heterogeneity in the middle Frio Formation: case studies in Stratton and Agua Dulce fields, Nueces County, Texas: Gulf Coast Association of Geological Societies Transactions, v. 40, p. 363–372.

Kerr, D. R., and **Jirik, L. A.,** 1990, Fluvial architecture and reservoir compartmentalization in the Oligocene middle Frio Formation, South Texas: Gulf Coast Association of Geological Societies Transactions, v. 40, p. 373–380.

Kittridge, M. G., Lake, L. W., **Lucia, F. J.,** and Fogg, G. E., 1990, Outcrop/subsurface comparisons of heterogeneity in the San Andres Formation: Society of Petroleum Engineers Formation Evaluation, September, p. 233–240.

Langford, R. P., Grigsby, J. D., Howard, W. E., Hall, J. D., and Maguregui, J., 1990, Sedimentary facies and petrophysical characteristics of cores from the lower Vicksburg gas reservoirs, McAllen Ranch field, Hidalgo County, Texas: Gulf Coast Association of Geological Societies Transactions, v. 40, p. 439–450.

Langford, R. P., and Lynch, F. L., 1990, Diagenesis and cement fabric of gas reservoirs in the Oligocene Vicksburg Formation, McAllen Ranch field, Hidalgo County, Texas: Gulf Coast Association of Geological Societies Transactions, v. 40, p. 451–458.

Laubach, S. E., Hamlin, H. S., and **Dutton, S. P.,** 1990, Frontier Formation and Grand Teton National Park: Gas Research Institute Tight Gas Sands Field Trip: Gas Research Institute, Natural Gas Supply Project Advisors Meeting Guidebook, 12 p.

Laubach, S. E., and **Jackson, M. L. W.,** 1990, Origin of arches in the northwestern Gulf of Mexico basin: Geology, v. 18, no. 7, p. 595–598.

Lucia, F. J., and Fogg, G. E., 1990, Geologic/stochastic mapping of heterogeneity in a carbonate reservoir: Journal of Petroleum Geology, October, p. 1298–1304.

Luffel, D. L., and **Herrington, K. L.,** 1990, Effect of extraction and drying on flow, capillary, and electrical properties of Travis Peak cores containing fibrous illite: Society of Petroleum Engineers Annual Technical Conference Proceedings, SPE Paper 20725, p. 131–138.

Major, R. P., 1990, Hydrocarbon reexploration in the Grayburg Formation, Ector and Crane Counties, Texas, *in* Flis, J. E., and Price, R. C., eds., Permian Basin oil and gas fields: innovative ideas in exploration and development: West Texas Geological Society Symposium, publication no. 90-87, p. 159–181.

Major, R. P., 1990, *Review of* Carbonate-clastic transitions, Doyle, L. J., and Roberts, H. H., eds. (Developments in Sedimentology: Elsevier, Amsterdam, The Netherlands, v. 42, 304 p.): American Association of Petroleum Geologists Bulletin, v. 74, no. 2, p. 207–208.

Major, R. P., and **Holtz, M. H.,** 1990, Depositionally and diagenetically controlled reservoir heterogeneity at Jordan field: Journal of Petroleum Technology, v. 42, no. 10, p. 1304–1309.

Masterson, A. R., 1990, Index, *in* Morse, J. W., and Mackenzie, F. T., Geochemistry of sedimentary carbonates: New York, Elsevier, Developments in Sedimentology 48, p. 681–707.

McBride, M. W., 1990, Nonpetroleum minerals, *in* 1990–1991 Texas almanac and state industrial guide: Dallas, The Dallas Morning News, p. 553–558.

Milling, M. E., 1990, Advanced research and development needed to stabilize domestic oil and gas supplies: Geotimes, v. 35, no. 5, p. 5.

Milling, M. E., 1990, Energy security through advanced research and development: The Professional Geologist, v. 27, no. 4, p. 3–6.

Morton, R. A., and **Paine, J. G.,** 1990, Coastal land loss in Texas—an overview: Gulf Coast Association of Geological Societies Transactions, v. 40, p. 625–634.

Paine, J. G., 1990, Appendix G: Late Quaternary geology of the Peggy Lake area, *in* Gadus, E. F., and Howard, M. A., Hunter-fisher-gatherers on the upper Texas coast: archeological investigations at the Peggy Lake disposal area, Harris County, Texas: Austin, Prewitt and Associates, Inc., Reports of Investigations, No. 74, p. 375–400.

Pope, D. E., Gilliland, W. A., and **Wermund, E. G.,** 1990, Quaternary geologic map of the White Lake 4° × 6° quadrangle, United States, *in* Quaternary geologic atlas of the United States: U.S. Geological Survey Map I-1420 (NH-15), scale 1:1,000,000.

Price, J. G., Rubin, J. N., **Henry, C. D.,** Pinkston, T. L., **Tweedy, S. W.,** and Koppenaal, D. W., 1990, Rare-metal enriched peraluminous rhyolites in a continental arc, Sierra Blanca area, Trans-Pecos Texas; chemical modification by vapor-phase crystallization: Geological Society of America, Special Paper 246, p. 103–120.

Richard, S. M., **Laubach, S. E.,** Reynolds, S. J., and Spencer, J. E., 1990, Mesozoic thrusting, synplutonic deformation, and Miocene overprinting, Harcuvar Complex: a section through the pre-Tertiary crust of west-central Arizona, *in* Gehrels, G. E., and Spencer, J. E., eds., Geologic excursions through the Sonoran Desert region, Arizona and Sonora: Arizona Geological Survey Special Paper 7, p. 66–75.

Rubin, J. N., Price, J. G., **Henry, C. D.,** and Kyle, J. R., 1990, Geology of the beryllium-rare earth element deposits at Sierra Blanca, West Texas, *in* Kyle, J. R., ed., Industrial mineral resources of the Delaware Basin, Texas and New Mexico: Society of Economic Geologists Guidebook Series, v. 8, p. 191–203.

Ruppel, S. C., and **Hovorka, S. D.,** 1990, Controls on reservoir heterogeneity in the Three Bar Devonian chert reservoir, Andrews County, Texas, *in* Flis, J. E., and Price, R. C., eds., Permian Basin oil and gas fields: innovative ideas in exploration and development: West Texas Geological Society Symposium, publication no. 90-87, p. 57–73.

Scanlon, B. R., 1990, Relationships between groundwater contamination and major-ion chemistry in a karst aquifer: Journal of Hydrology, v. 119, p. 271–291.

Scanlon, B. R., Kubik, P. W., Sharma, P., **Richter, B. C.,** and Gove, H. E., 1990, Bomb chlorine-36 analysis in the characterization of unsaturated flow at a proposed radioactive waste disposal facility, Chihuahuan Desert, Texas: Nuclear Instruments and Methods in Physics Research, v. 52, no. 3, 4, p. 489–492.

Scanlon, B. R., Richter, B. C., Wang, F. P., and **Mullican, W. F., III,** 1990, Analysis of unsaturated flow related to low-level radioactive waste disposal, Chihuahuan Desert, Texas, *in* Proceedings of 'Focus '89' Conference on Nuclear Waste Isolation in the Unsaturated Zone: American Nuclear Society, p. 351–358.

Schultz-Ela, D. D., 1990, A method for estimating errors in calculated strains: Journal of Structural Geology, v. 12, no. 7, p. 939–943.

Senger, R. K., and Fogg, G. E., 1990, Stream functions and equivalent freshwater heads for modeling regional flow of variable-density groundwater, 1. Review of theory and verification: Water Resources Research, v. 26, no. 9, p. 2089–2096.

Senger, R. K., and Fogg, G. E., 1990, Stream functions and equivalent freshwater heads for modeling regional flow of variable-density groundwater, 2. Application and implications for modeling strategy: Water Resources Research, v. 26, no. 9, p. 2097–2106.

Tyler, Noel, and **Finley, R. J.,** 1990, Reservoir redevelopment in mature hydrocarbon provinces: approach and potential in the lower 48 states: Houston Geological Society Short Course Notes, variously paginated.

Tyler, Noel, and **Lucia, F. J.,** 1990, Opportunities and strategies for additional recovery from Permian Basin reservoirs: Permian Basin Graduate Center Short Course Notes, variously paginated.

Wermund, E. G., 1990, Editorial: A state geological survey commitment to environmental geology—the Texas Bureau of Economic Geology: Environmental Geology and Water Sciences, v. 15, no. 2, p. 73–75.

Wermund, E. G., and Handley, L. R., 1990, Status and trends of wetlands and seagrasses (1956-1989) of the Galveston Bay Estuary: a GIS approach, *in* Bringing the user community together: National Computer Graphics Association GIS '90 Conference Proceedings, p. 304–310.

Abstracts

Ambrose, W. A., and **Ayers, W. B., Jr.,** 1990, Barrier-strandplain deposits of the Pictured Cliffs Sandstone and coal occurrence in the Fruitland Formation, northern San Juan Basin, Colorado and New Mexico (abs.): American Association of Petroleum Geologists Bulletin, v. 74, no. 8, p. 1313.

Ambrose, W. A., and **Ayers, W. B., Jr.,** 1990, Geologic controls on occurrence and producibility of coal-bed methane resources in the Upper Cretaceous Fruitland Formation, San Juan Basin, Colorado and New Mexico (abs.): American Association of Petroleum Geologists Bulletin, v. 74, no. 5, p. 598.

Ambrose, W. A., and **Tyler, Noel,** 1990, Depositional and structural origin of oil and gas plays in the Upper Cretaceous Olmos Formation, Maverick Basin, South Texas (abs.): Corpus Christi Geological Society Bulletin, January, p. 2.

Baumgardner, R. W., Jr., 1990, Surface fissures in desert basins of West Texas (abs.): Geological Society of America, Abstracts with Programs, v. 22, no. 7, p. 152.

Bebout, D. G., Harris, P. M., **Holtz, M. H., Kerans, Charles, Major, R. P., Ratcliff, D. C., Tyler, Noel,** and **Vander Stoep, G. W.,** 1990, Heterogeneity in grainstone reservoirs—investigation of a modern analog, Joulters Cays, Bahamas (abs.): American Association of Petroleum Geologists Bulletin, v. 74, no. 5, p. 607.

Bebout, D. G., Major, R. P., Harris, P. M., **Tyler, Noel,** and **Kerans, Charles,** 1990, Internal textural and diagenetic variations within a modern ooid grain bar—Joulters Cays, Bahamas (abs.): Geological Society of America, Abstracts with Programs, v. 22, no. 7, p. A132.

Buehring, Robert, Laubach, S. E., and **Hamlin, H. S.,** 1990, Stratigraphic analysis of fluvial and marine sandstone with borehole-imaging geophysical logs and core (abs.): Geological Society of America, Abstracts with Programs, v. 22, no. 7, p. A47.

Coleman, Janet, and **Galloway, W. E.,** 1990, Depositional systems distribution of the lower Oligocene Vicksburg Formation, Texas (abs.): American Association of Petroleum Geologists Bulletin, v. 74, no. 5, p. 631.

Collins, E. W., and **Raney, J. A.,** 1990, Tertiary and Quaternary faulting of the Hueco Basin, Trans-Pecos Texas and Chihuahua, Mexico (abs.): Geological Society of America, Abstracts with Programs, v. 22, no. 7, p. A329–A330.

Dutton, S. P., 1990, Variations in diagenesis and reservoir quality in the Frontier Formation along the Moxa Arch, Green River Basin, Wyoming (abs.): American Association of Petroleum Geologists Bulletin, v. 74, no. 8, p. 1321–1322.

Dutton, S. P., and **Diggs, T. N.,** 1990, Episodic quartz cementation in the Lower Cretaceous Travis Peak Formation, East Texas (abs.): American Association of Petroleum Geologists Bulletin, v. 74, no. 5, p. 646.

Duval, Bernard, Cramez, Carlos, and **Jackson, M. P. A.,** 1990, Raft tectonics in the Kwanza basin, Angola (abs.): Geological Society of America, Abstracts with Programs, v. 22, no. 7, p. A48.

Finley, R. J., 1990, An assessment of the natural gas resource base of the United States (abs.): Amarillo, Texas, Panhandle Geological Society Newsletter, January, unpaginated.

Finley, R. J., Jirik, L. A., Zinke, S. G., Kerr, D. R., and Smith, Bruce, 1990, Facies architecture of gas-bearing fluvial sandstones: geological and geophysical assessment of heterogeneity, South Texas, U.S.A. (abs.), *in* Sediments 1990: 13th International Sedimentological Congress, Abstracts of Papers, p. 168.

Fisher, R. S., 1990, Feldspar and clay diagenesis in marine evaporite brines: examples from Permian strata of the Palo Duro Basin, Texas Panhandle (abs.): Geological Society of America, Abstracts with Programs, v. 22, no. 7, p. A313.

Fisher, W. L., 1990, Resources of the Earth (abs.): Eos, v. 71, no. 17, p. 468.

Folk, R. L., and Campbell, D. H., 1990, Egyptian pyramids: geopolymer concrete cast-in-place, or true sedimentary rock? (abs.): Geological Society of America, Abstracts with Programs, v. 22, no. 7, p. A152.

Grigsby, J. D., 1990, Multiple stages of calcite and chlorite precipitation in the lower Vicksburg Formation, McAllen Ranch field, Hidalgo County, Texas (abs.): Geological Society of America, Abstracts with Programs, v. 22, no. 7, p. 313.

Guevara, E. H., Coates, G. R., **Tyler, Noel,** and Graham, R. L., 1990, Reservoir characterization in the Spraberry Trend, Midland Basin, Texas: delineation of target areas for additional oil recovery using old gamma-ray and neutron logs (abs.): American Association of Petroleum Geologists Bulletin, v. 74, no. 5, p. 666.

Guevara, E. H., Coates, G. R., **Tyler, Noel,** and Graham, R. L., 1990, Reservoir characterization in the Spraberry Trend, Midland Basin, Texas: delineation of target areas for additional oil recovery using "old" gamma-ray and neutron logs (abs.), *in* Flis, J. E., and Price, R. C., eds., Permian Basin oil and gas fields: innovative ideas in exploration and development: West Texas Geological Society Symposium, publication no. 90-87, p. 132.

Gustavson, T. C., 1990, Late Tertiary alluvial fan—playa lake sedimentation, pedogenesis, and paleoclimate, Rio Grande Rift Basin, West Texas, USA, and Chihuahua, Mexico (abs.), *in* Sediments 1990: 13th International Sedimentological Congress, Abstracts of Papers, p. 202–203.

Gustavson, T. C., 1990, Siltstones of the Permian Bell Canyon Formation, Delaware Basin, West Texas: deposition by wind transport or by density interflow? (abs.): Geological Society of America, Abstracts with Programs, v. 22, no. 7, p. A360.

Gustavson, T. C., 1990, Timing and effects of integration of the northern and southern segments of the ancestral Rio Grande, Hueco Bolson, West Texas (abs.): Geological Society of America, Abstracts with Programs, v. 22, p. 7–8.

Hamlin, H. S., and **Buehring, R. L.,** 1990, Facies-related permeability trends in the Frontier Formation along the Moxa Arch, Green River Basin, Wyoming (abs.): American Association of Petroleum Geologists Bulletin, v. 74, no. 8, p. 1325.

Henry, C. D., Price, J. G., Aguirre-Diaz, Gerardo, McDowell, F. W., and **James, E. W.,** 1990, Mid-Cenozoic stress evolution and magmatism in the southern Cordillera, Texas and Mexico: transition from continental arc to intraplate extension (abs.): Geological Society of America, Abstracts with Programs, v. 22, p. 29.

Holtz, M. H., 1990, Detailed reservoir characterization of geologic heterogeneity and production characteristics of Jordan field, West Texas (abs.), *in* 14th Annual CPS Users' Conference and Training Seminars Abstracts: Austin, Radian Corporation, p. 3.

Holtz, M. H., and **Garrett, C. M.,** 1990, Geologic and engineering characterization of Leonardian carbonate oil reservoirs: a framework for strategic recovery practices in four oil plays (abs.), *in* Flis, J. E., and Price, R. C., eds., Permian Basin oil and gas fields: innovative ideas in exploration and development: West Texas Geological Society Symposium, publication no. 90-87, p. 76.

Hovorka, S. D., and **Ruppel, S. C.,** 1990, Controls on porosity evolution in Devonian cherts of West Texas (abs.): American Association of Petroleum Geologists Bulletin, v. 74, no. 5, p. 678.

Jackson, M. L. W., Tewalt, S. J., and **Kaiser, W. R.,** 1990, Comparison of computer and manual estimates of lignite resources in the Paleocene–Eocene Wilcox Group, East Texas (abs.): Geological Society of America, Abstracts with Programs, v. 22, no. 7, p. A58.

Jackson, M. P. A., Cornelius, R. R., Craig, C. H., Gansser, A., Stöcklin J., and Talbot, C. J., 1990, Some lessons in salt tectonics from the Great Kavir, Central Iran (abs.): Geological Society of America, Abstracts with Programs, v. 22, no. 7, p. A47.

Jackson, M. P. A., and **Vendeville, B. C.,** 1990, The rise and fall of diapirs during thin-skinned extension (abs.): American Association of Petroleum Geologists Bulletin, v. 74, no. 5, p. 683.

James, E. W., Henry, C. D., and Price, J. G., 1990, Geochemical variations in mid-Cenozoic magmatism at the eastern fringe of the Cordillera, Trans-Pecos Texas and adjacent Chihuahua, Mexico (abs.): Geological Society of America, Abstracts with Programs, v. 22, p. 32.

Jirik, L. A., 1990, Reservoir heterogeneity in middle Frio fluvial sandstones: case studies in Seeligson field, Jim Wells County, Texas (abs.): American Association of Petroleum Geologists Bulletin, v. 74, no. 9, p. 1498.

Jirik, L. A., Kerr, D. R., Zinke, S. G., and **Finley, R. J.,** 1990, Fluvial architecture and reservoir heterogeneity of middle Frio sandstones, Seeligson field, Jim Wells and Kleberg Counties, South Texas (abs.): American Association of Petroleum Geologists Bulletin, v. 74, no. 5, p. 686.

Kaiser, W. R., and Swartz, T. E., 1990, Hydrology of the Upper Cretaceous Fruitland Formation and the producibility of coalbed methane, San Juan Basin, Colorado and New Mexico (abs.): American Association of Petroleum Geologists Bulletin, v. 74, no. 5, p. 690.

Kerans, Charles, Nance, H. S., and **Bebout, D. G.,** 1990, Outcrop analogs for modeling heterogeneous restricted platform reservoirs: Grayburg Formation (Guadalupian) of the Guadalupe Mountains and subsurface Permian Basin (abs.): American Association of Petroleum Geologists Bulletin, v. 74, no. 5, p. 693.

Kerr, D. R., 1990, Reservoir heterogeneity in the middle Frio Formation: case studies in Stratton and Agua Dulce fields, Nueces County, Texas (abs.): American Association of Petroleum Geologists Bulletin, v. 74, no. 9, p. 1499.

Kerr, D. R., and **Jirik, L. A.,** 1990, Fluvial architecture and reservoir compartmentalization in the Oligocene middle Frio Formation of South Texas (abs.): American Association of Petroleum Geologists Bulletin, v. 74, no. 9, p. 1499.

Langford, R. P., Wermund, E. G., Zinke, S. G., Guevara, E. H., Finley, R. J., and **Brewton, J. G.,** 1990, Facies architecture and reservoir compartmentalization in the McAllen Ranch gas field, Hidalgo County, Texas (abs.): American Association of Petroleum Geologists Bulletin, v. 74, no. 5, p. 700.

Laubach, S. E., Tremain, C. M., Whitehead, N. H., III, and **Baumgardner, R. W., Jr.,** 1990, Fracture-trace maps of upper Pictured Cliffs Sandstone pavements, San Juan Basin, Colorado: implications for coalbed methane exploration (abs.): Geological Society of America, Abstracts with Programs, v. 22, no. 7, p. A202.

Laubach, S. E., Vendeville, B. C., and Reynolds, S. J., 1990, Downward-steepening normal faults (abs.): Geological Society of America, Abstracts with Programs, v. 22, no. 7, p. A114–A115.

Lucia, F. J., Bebout, D. G., and **Kerans, Charles,** 1990, The Archie approach to characterizing carbonate reservoirs (abs.), *in* Sneider, Robert, Massell, Wulf, Mathis, Rob, Loren, Dennis, and Wichmann, Paul, The integration of geology, geophysics, petrophysics and petroleum engineering in reservoir delineation, description and management: American Association of Petroleum Geologists, Society of Exploration Geophysicists, Society of Petroleum Engineers, and Society of Professional Well Log Analysts, The Archie Conference Abstracts and Program, unpaginated.

Lucia, F. J., and **Major, R. P.,** 1990, Porosity destruction by near-surface dolomitization of Plio-Pleistocene carbonates, Bonaire, Netherlands Antilles (abs.), *in* Sediments 1990: 13th International Sedimentological Congress, Abstracts of Papers, p. 324–325.

Lucia, F. J., and **Vander Stoep, G. W.,** 1990, Quantification of geologic descriptions for reservoir characterization in carbonate reservoirs (abs.): American Association of Petroleum Geologists Bulletin, v. 74, no. 5, p. 709.

Major, R. P., and **Holtz, M. H.,** 1990, Depositional and diagenetic controls on heterogeneity in a dolomite oil reservoir, Jordan field, Permian Basin, U.S.A. (abs.), *in* Sediments 1990: 13th International Sedimentological Congress, Abstracts of Papers, p. 325.

Mijnssen, F. C. J., and **Tyler, Noel,** 1990, Knowledge base development for the estimation of reservoir rock properties in the interwell area—examples from the Texas Gulf Coast (abs.), *in* Sediments 1990: 13th International Sedimentological Congress, Abstracts of Papers, p. 358.

Milling, M. E., Lucia, F. J., Hocott, C. R., Miller, M. A., and Neitzel, E. B., 1990, Program priorities for interdisciplinary oil and gas recovery research (abs.): American Association of Petroleum Geologists Bulletin, v. 74, no. 5, p. 137.

Morton, R. A., and **Galloway, W. E.,** 1990, Depositional, tectonic, and eustatic controls on hydrocarbon distribution in divergent margin basins—Gulf of Mexico case history (abs.): American Association of Petroleum Geologists Bulletin, v. 74, no. 5, p. 726.

Paine, J. G., 1990, Coastal plain development along the central Texas coast during the late Quaternary (abs.): Geological Society of America, Abstracts with Programs, v. 22, no. 7, p. A375.

Paine, J. G., 1990, Recent vertical movement and sea-level changes, Texas Coastal Zone (abs.): Eos, v. 71, no. 17, p. 479–480.

Pursell, V. J., and **Folk, R. L.,** 1990, Aragonite, calcite dendrites, and microfluorite in Mammoth Hot Springs travertine, Yellowstone National Park, Wyoming (abs.): Geological Society of America, Abstracts with Programs, v. 22, no. 7, p. A90.

Reynolds, S. J., Spencer, J. E., **Laubach, S. E.,** and Richard, S. M., 1990, Mesozoic evolution of western Arizona (abs.): Geological Society of America, Abstracts with Programs, v. 22, no. 3, p. 77.

Ruppel, S. C., 1990, Siluro-Devonian carbonates in West Texas: regional patterns of facies and diagenesis (abs.): West Texas Geological Society Bulletin, v. 29, no. 5, p. 11.

Ruppel, S. C., Tyler, Noel, McDonald, J. A., Miller, M. A., and Startzman, R. A., 1990, Integrated study of a heterogeneous, restricted platform carbonate reservoir, Dollarhide Clear Fork, West Texas (abs.): Society of Exploration Geophysicists, 43rd Annual Midwest Meeting and Exposition Official Program, p. 49–50.

Scanlon, B. R., 1990, Relative importance of liquid and vapor transport in arid soils (abs.): Eos, v. 71, no. 43, p. 1718.

Scanlon, B. R., and **Richter, B. C.,** 1990, Environmental tracers as indicators of unsaturated flow: comparison with hydraulic data (abs.): Geological Society of America, Abstracts with Programs, v. 22, no. 7, p. A53–A54.

Scanlon, B. R., and Wierenga, P. J., 1990, Numerical simulations of unsaturated flow related to radioactive waste disposal (abs.): Agronomy Abstracts, p. 218.

Schultz-Ela, D. D., 1990, Cross section balancing from terranes of growth faulting and salt tectonics (abs.): Geological Society of America, Abstracts with Programs, v. 22, no. 7, p. A105.

Schultz-Ela, D. D., 1990, Reconstructions of growth faults and rollover anticlines above a ductile substratum (abs.): Eos, v. 71, no. 43, p. 1635.

Tyler, Noel, 1990, Basin morphological controls on depositional patterns of a submarine-fan complex, Permian Spraberry Formation, West Texas (abs.): American Association of Petroleum Geologists Bulletin, v. 74, no. 5, p. 782.

Tyler, Noel, Barton, M. D., and Gorody, A. W., 1990, Quantification of flow unit and bounding element properties and geometries, Ferron sandstone, Utah, USA: implications for heterogeneity in Gulf Coast Tertiary deltaic reservoirs—a progress report (abs.), *in* Sediments 1990: 13th International Sedimentological Congress, Abstracts of Posters, p. 223.

Tyler, Noel, Bebout, D. G., Kerans, Charles, Major, R. P., and **Ruppel, S. C.,** 1990, Potential for additional recovery in restricted platform carbonate reservoirs, Permian Basin, Texas (abs.): American Association of Petroleum Geologists Bulletin, v. 74, no. 5, p. 782.

Tyler, Noel, and **Finley, R. J.,** 1990, Semi-quantitative classification of vertical and lateral heterogeneity: a predictive tool for advanced conventional recovery (abs.), *in* Sediments 1990: 13th International Sedimentological Congress, Abstracts of Papers, p. 562.

Tyler, Noel, and **Guevara, Edgar,** 1990, Basin morphological controls on facies architecture and hydrocarbon recovery in submarine-fan reservoirs, Permian Spraberry Formation, West Texas (abs.), *in* Flis, J. E., and Price, R. C., eds., Permian Basin oil and gas fields: innovative ideas in exploration and development: West Texas Geological Society Symposium, publication no. 90-87, p. 185.

Vendeville, B. C., and **Jackson, M. P. A.,** 1990, Modes of diapiric piercement through brittle overburden (abs.): Geological Society of America, Abstracts with Programs, v. 22, no. 7, p. A104.

Vendeville, B. C., and **Jackson, M. P. A.,** 1990, Physical modeling of the growth of extensional and contractional salt tongues on continental slopes (abs.): American Association of Petroleum Geologists Bulletin, v. 74, no. 5, p. 784.

Wermund, E. G., and **Langford, R. P.,** 1990, Production data as an indicator of gas reservoir compartmentalization in the Vicksburg sandstones (Oligocene), McAllen Ranch field, Hidalgo County, Texas (abs.): Gulf Coast Association of Geological Societies Transactions, v. 40, p. 861.

Worrall, D. M. P., Cloos, M. P., and **Jackson, M. P. A.,** 1990, New advances in salt tectonics (abs.): Geological Society of America, Abstracts with Programs, v. 22, no. 7, p. A47.

Xue, Liangqing, and **Galloway, W. E.,** 1990, Genetic stratigraphic framework and depositional system of Q-Y-N Formations in the north Songliao lacustrine basin, northeast of China (abs.): American Association of Petroleum Geologists Bulletin, v. 74, no. 5, p. 794.

Zinke, S. G., Jirik, L. A., and **Finley, R. J.,** 1990, Geophysical applications for definition of reservoir heterogeneity—South Texas Vicksburg and Frio sandstones: the Secondary Gas Recovery Project (abs.), *in* The Twenty-First Annual Appalachian Petroleum Geology Symposium Program and Abstracts: West Virginia Geological and Economic Survey and West Virginia University Department of Geology and Geography, Publication No. 2, p. 79.

Zinke, S. G., Jirik, L. A., Langford, R. P., and **Finley, R. J.,** 1990, Vertical seismic profile applications for definition of reservoir heterogeneity—South Texas, Vicksburg and Frio sandstones: a secondary gas recovery project (abs.), *in* Sneider, Robert, Massell, Wulf, Mathis, Rob, Loren, Dennis, and Wichmann, Paul, The integration of geology, geophysics, petrophysics and petroleum engineering in reservoir delineation, description and management: American Association of Petroleum Geologists, Society of Exploration Geophysicists, Society of Petroleum Engineers, and Society of Professional Well Log Analysts, The Archie Conference Abstracts and Program, unpaginated.

Lectures and Public Addresses

William A. Ambrose

"Depositional and structural origin of oil and gas plays in the Upper Cretaceous Olmos Formation, Maverick Basin, South Texas": presented to the Corpus Christi Geological Society, Corpus Christi, Texas.

"Depositional origin of oil and gas production in the Upper Cretaceous Olmos Formation, Maverick Basin, South Texas": presented to The University of Texas at Austin, Department of Geological Sciences, Soft Rock Seminar, Austin, Texas.

"Geologic controls on occurrence and producibility of coalbed methane in the Fruitland Formation, San Juan Basin": presented to the Society of Independent Professional Earth Scientists (SIPES), Houston, Texas.

"Using electric logs to correlate sandstone reservoirs": presented to The University of Texas at Austin, Department of Geological Sciences (Geology 391), Austin, Texas.

Walter B. Ayers, Jr.

"Depositional and structural controls on occurrence and producibility of coalbed methane": presented to Oryx Energy Co., Advance Exploration Group, Dallas, Texas.

"Geologic and hydrologic controls on coalbed methane occurrence and producibility, Fruitland Formation, San Juan

Basin": presented to the Panhandle Geological Society, Amarillo, Texas.

"Geologic and hydrologic settings of the Fruitland Formation, San Juan Basin": presented at the Alberta Geological Survey San Juan Basin Field Seminar, Durango, Colorado.

"Geologic controls on the occurrence and producibility of coalbed methane, Fruitland Formation, San Juan Basin": presented to the University of New Orleans, Department of Geology and Geophysics, and Tulane University, Department of Geology, New Orleans, Louisiana.

"Geologic evaluation of critical production parameters for coalbed methane resources": presented to the Gas Research Institute Executive Committee, Austin, Texas.

"Geologic evaluation of critical production parameters for coalbed methane resources, San Juan Basin": presented to the Gas Research Institute, Coalbed Methane Project Advisors Group, Durango, Colorado.

"Natural gas supply for environmental uses—a national supply overview": presented to the Pennsylvania Gas Association, 82nd annual meeting, Hershey, Pennsylvania.

Don G. Bebout

"Characterization of heterogeneity in the Joulters Cays ooid shoal—application to the study of Grayburg reservoirs in the Permian Basin": presented to Baylor University, research seminar, Waco, Texas.

"Heterogeneity in grainstone reservoirs—investigation of a modern analog, Joulters Cays, Bahamas": presented to the American Association of Petroleum Geologists, annual meeting, San Francisco, California.

"Internal textural and diagenetic variations within a modern ooid grain bar—Joulters Cays, Bahamas": presented to the Geological Society of America, annual meeting, Dallas, Texas.

"Joulters Cays research at the Bureau": presented to the Austin Geological Society, Austin, Texas.

"Logging and interpreting carbonate core": presented to The University of Texas at Austin, Department of Geological Sciences (Geology 383N), Austin, Texas.

"Reservoir-scale investigation of a modern sand shoal, Joulters Cays, Bahamas": presented to the Society of Independent Professional Earth Scientists (SIPES), luncheon meeting, Midland, Texas.

"Uso de facies carbonáticas y ambientes depositacionales en caracterización datallada de yacimientos, para recuperación de hidrocarburo movil remanente—ejemplos de la cuenca Pérmica de West Texas y del Reciente en Joulters Cays, Bahamas": presented to geologists and engineers, Lagoven, Caracas, Venezuela.

Alan R. Dutton

"Geohydrology of the Gulf Coast aquifer, Wharton and Matagorda Counties": presented to The University of Texas at Austin, Department of Geological Sciences, Hydrogeology Seminar Series, Austin, Texas.

"The instantaneous-profile hydraulic conductivity test as a teaching tool for vadose-zone hydrology": presented to The University of Texas at Austin, Department of Geological Sciences (Geology 381D), Austin, Texas.

Shirley P. Dutton

"Geology of the Frontier Formation": presented to the Gas Research Institute, Natural Gas Supply Project Advisors Meeting, Tight Gas Sands Project Area, Jackson, Wyoming.

"Tight gas sandstones": presented to the Gas Research Institute Executive Committee, Austin, Texas.

Robert J. Finley

"An assessment of the natural gas resource base of the United States": presented at the International Energy and Environmental Symposium and Exposition, San Diego, California.

"Gas reserve growth: a new source of natural gas supply": presented at the Second Annual North American Natural Gas Supply and Markets Industry Conference, Denver, Colorado.

"Natural gas supplies: present and future": presented at An Overview of the Texas CNG Industry Conference, Austin, Texas.

"Natural gas supply and gas reserve growth in the U.S. and Texas": presented to the Joint Meeting of Natural Gas Producers Association, West Texas Producers Forum, and Producers Forum, Midland, Texas.

"Natural gas resource availability": presented to the El Paso Natural Gas Company, Customer Meeting, Carefree, Arizona.

"Reevaluating the U.S. natural gas resource base: reserves, resources, and reserve growth": presented to the South Texas Geological Society, San Antonio, Texas.

William L. Fisher

"Cautious optimism for the new decade": presented to the East Texas Geological Society, Tyler, Texas.

"Trends in natural gas: the case for optimism": presented to the *Oil Daily* Annual Gas Conference, Houston, Texas.

"Energy from fossil fuels: world's salvation or damnation?": presented to The University of Kansas, Hollis D. Hedberg Memorial Lecture, Lawrence, Kansas.

"Geologic opportunities for horizontal drilling": presented to the World Oil Second International Conference on Horizontal Well Technology, Houston, Texas.

"The global dimension of oil: role of the three critical players": presented to the Texas International Law Journal Symposium on International Energy Trade and Regulation, Austin, Texas.

"How long will fossil fuels last?": presented to LAMP, Current Science Topics, The University of Texas at Austin, Austin, Texas.

"Natural gas: reaching stability": presented to the Fourth Annual Winter Natural Gas Symposium, Newport Beach, California.

"New frontiers in natural resource research": presented to the American Geophysical Union, annual meeting, "Promotion of Solid Earth Sciences Study," National Academy of Sciences, Baltimore, Maryland.

"The new look at natural gas": presented to the American Institute of Chemical Engineering session on "Energy policy: natural gas," annual meeting, Chicago, Illinois.

"The 1990's: looking good or at least better": presented to the Society of Economic Paleontologists and Mineralogists, Permian Basin Section, Midland, Texas.

"Oil and gas resource recovery": presented to the Geological Society of America Symposium on "Future energy needs and utilization of fossil fuels," annual meeting, Dallas, Texas.

"Oil reserve growth: understanding complex reservoirs": presented to AAAS Symposium on "Improved recovery of oil and gas from existing fields," New Orleans, Louisiana.

"Opportunities for horizontal drilling in Texas oil and gas plays": presented to the Gas Daily Symposium on Horizontal Drilling, Houston.

"Permian Basin and the global oil situation": presented to the Permian Basin Center for Energy and Economic Diversification, Midland, Texas.

"Petroleum geology: where are we heading?": presented to the Symposium on the Future of Geology, University of New Mexico, Albuquerque, New Mexico.

"The potential of oil and gas recovery through horizontal drilling": presented to the Executive Enterprises Conference on Horizontal Drilling, Houston, Texas.

"Price and technological sensitivities in U.S. oil and gas development": presented to the Johns Hopkins Foreign Policy Institute conference on "Energy and environmental agenda for the 1990's and role of energy technologies," Washington, D.C.

"Research in secondary gas recovery": presented to the U.S. Department of Energy briefing on oil and gas research directions, Washington, D.C.

"Reserve growth and the Permian Basin: new frontiers": keynote presentation to the Society of Exploration Geophysicists, Permian Basin Section, Midland, Texas.

"Rethinking the U.S. oil and gas resource base": presented to the Society of Petroleum Engineers/University of Houston Emerging Technologies Conference, Houston, Texas.

"Separation of exploration and production leasing": presented to the U.S. Department of Interior, OCS Advisory Board Panel, Anchorage, Alaska.

"U.S. oil and gas: outlook for the 1990's": presented to the North Texas Association of Petroleum Landmen, Wichita Falls, Texas.

Briefing to U.S. Department of Energy and U.S. Congressional staff on National Research Council report on production of liquid fuels, Washington, D.C.

Briefing to College of Natural Sciences Advisory Council, Government Affairs Committee on strategies in research funding, The University of Texas at Austin, Austin, Texas.

Briefing to State Land Board on oil and gas recovery research on State-owned lands, Austin, Texas.

Robert L. Folk

"Egyptian pyramids: real rock or man-made concrete?": presented to The University of Texas at Austin, Department of Geological Sciences, Soft Rock Seminar, Austin, Texas, and to ARCO Research Laboratory, Plano, Texas.

"Etching of quartz in boiling hydrofluoric acid": presented to the University of Cincinnati, Geology Department, Cincinnati, Ohio, and to ARCO Research Laboratory, Plano, Texas.

William E. Galloway

"Cenozoic history of the northwest Gulf of Mexico": presented to the Geological Society of America, annual meeting, Dallas, Texas.

L. Edwin Garner

"The geologic extent of expansive soils in Texas": presented to the American Society of Civil Engineers, Texas Section, Austin, Texas.

Jeffry D. Grigsby

"Detrital magnetite as a provenance indicator": presented to The University of Texas at Austin, Department of Geological Sciences, Soft Rock Seminar, Austin, Texas.

Edgar H. Guevara

"Geological characterization of Wilcox (Eocene) gas reservoirs, Lake Creek field, Montgomery County, Texas: an analog to outcrops of the Ferron Sandstone (Cretaceous), Utah": presented to the Reservoir Characterization Contractor Meeting of the Gas Research Institute Geoscience Project Area in Physical Sciences, Lakeway, Texas.

"The Secondary Gas Recovery project and Lake Creek field—a companion study": presented to the Workshop on Characterization and Quantification of Geologic and Petrophysical Heterogeneity in Fluvial Deltaic Reservoirs, organized by the Gas Research Institute and the Bureau of Economic Geology, Austin, Texas.

Thomas C. Gustavson

"Paleovertisols of the Pliocene Fort Hancock Formation": presented to the soil survey and land resource workshop, Texas A&M University, College Station, Texas.

H. Scott Hamlin

"Bureau of Economic Geology studies on Canyon Sandstone, Val Verde Basin, West Texas": presented to the Gas Research Institute, Tight Gas Sands Project Board of Advisors Meeting, Jackson, Wyoming.

Christopher D. Henry

"Beryllium and other rare metal resources in Trans-Pecos Texas": presented to the Central Texas Mining Section of AIME, Austin, Texas.

"Post-Laramide stress evolution, Texas and northern Mexico: implications for magmatism, tectonics, and ore deposition": presented to the University of New Orleans, Department of Geology and Geophysics, and Tulane University, Department of Geology, symposium on "The Tectonics, Geophysics, and Volcanism of Mexico," New Orleans, Louisiana.

Mark H. Holtz

"Detailed reservoir characteristics of geologic heterogeneity and production characteristics of Jordan field, West Texas:" presented to the CPS Users Conference, annual meeting, Austin, Texas.

Susan D. Hovorka

"Diagenetic studies of San Andres outcrop strata": presented to San Andres/Grayburg Field Seminar, Carlsbad, New Mexico.

"Evaporite depositional systems" and "Styles of cyclicity in evaporites": presented to The University of Texas at Austin,

Department of Geological Sciences (Geology 383N), Austin, Texas.

"Parasequence-selective diagenesis and associated secondary porosity evolution, upper San Andres parasequence no. 7": presented to Unocal, Austin, Texas.

Martin P. A. Jackson

"Advance of salt tongues through anisotropic overburden": presented to the Industrial Associates of the Applied Geodynamics Laboratory, Austin, Texas.

"Extension of anisotropic overburden above salt": presented to the Industrial Associates of the Applied Geodynamics Laboratory, Austin, Texas.

"Fall of diapirs during thin-skinned extension": presented to the Industrial Associates of the Applied Geodynamics Laboratory, Austin, Texas.

"Overview of Applied Geodynamics Laboratory research for 1990": presented to the Industrial Associates of the Applied Geodynamics Laboratory, Austin, Texas.

"Systematic experiments of extension and salt structures induced by gravity spreading": presented to the Industrial Associates of the Applied Geodynamics Laboratory, Austin, Texas.

Eric W. James

"Three isotopic and geochronologic ties linking California suspect terranes: the Independence dike swarm, Eagle Rest Peak–Logan and Ben Lomond–San Emigdio Mountains": presented to the U.S. Geological Survey Colloquium on California Terranes, Menlo Park, California.

William R. Kaiser

"A geologic approach to coal resources assessment": presented to the U.S. Department of Energy, Coal Reserves Assessment Conference, Arlington, Virginia.

"Hydrology of the Fruitland Formation": presented to the Alberta Research Council, Calgary, Alberta, Canada.

Charles Kerans

"Carbonate buildups and associated facies, lower Paleozoic of the Llano Uplift": presented to The University of Texas at Austin, Department of Geological Sciences (Geology 383N), Austin, Texas.

"Carbonate reservoirs: quantitative characterization of facies and permeability using outcrop analogs": presented as part of the American Association of Petroleum Geologists 1990–1991 Distinguished Lecture Program to the following groups: Roswell Geological Society, Roswell, New Mexico; New Mexico Bureau of Mines and Mineral Resources and New Mexico Institute of Technology, Socorro, New Mexico; University of Utah Department of Geological Sciences, Salt Lake City, Utah; Colorado School of Mines Department of Geological Sciences, Golden, Colorado; Wyoming Geological Association, Casper, Wyoming.

"Geologic description for fluid flow modeling: an example from the San Andres Formation, Guadalupe Mountains, New Mexico": presented to The University of Texas at Austin, Department of Geological Sciences Hydrogeology Seminar series, Austin, Texas.

"The importance of paleokarst in carbonate reservoirs of West Texas": presented to the University of Kentucky, Department of Geological Sciences, Lexington, Kentucky.

"Petrology and stratigraphy of Devonian reef complexes, Canning Basin, western Australia": presented to Rice University, Department of Geology, Houston, Texas.

"Stratigraphy and reservoir modeling of San Andres carbonates, West Texas and New Mexico": presented to The University of Texas at Austin, Department of Geological Sciences (Geology 383N), Austin, Texas.

Dennis R. Kerr

"Effects of eustasy on erg development: an example from the Permo-Pennsylvanian Tensleep Sandstone": presented to the Society of Economic Paleontologists and Mineralogists, Eolian Research Group, Bluff, Utah.

Charles W. Kreitler

"Deep-well injection of chemical wastes": presented to the Environmental Solutions Program Workshop, Balcones Research Center, Austin, Texas.

"Evaluation of the abandoned-well population in the United States": presented to the Underground Injection Practice Council, Tampa, Florida.

"Geopressured-geothermal research at The University of Texas at Austin": presented to the first meeting of the U.S. Department of Energy Geopressured-Geothermal Energy Consortium, Rice University, Houston, Texas.

"In situ experimentation of degradation reactions associated with deep-well injection of chemical wastes": presented to the Gulf Coast Hazardous Substance Center, Board of Advisors, Beaumont, Texas.

"Pressure buildup and sedimentation in Class I injection wells": presented to the Texas Water Commission, UIC annual meeting, Austin, Texas.

"San Juan abandoned-well study": presented to the Underground Injection Practice Council Meeting, Dearborn, Michigan.

"Use of water chemistry for identifying sources of brine in fresh ground water": presented to the U.S. Environmental Protection Agency, Robert S. Kerr Laboratory, annual meeting, Oklahoma City, Oklahoma.

"Wellhead protection strategies for confined aquifer settings": presented to the U.S. Environmental Protection Agency, Region 6, Dallas, Texas.

Richard P. Langford

"Downwind changes in deposition within a Permian sand dune sea, Cedar Mesa Sandstone, southeastern Utah": presented to The University of Texas at Austin, Department of Geological Sciences, Soft Rock Seminar, Austin, Texas.

Stephen E. Laubach

"Analysis of in situ stress and fractures in reservoir rocks": two lectures presented to The University of Texas at Austin, Department of Geological Sciences (Geology 391), Austin, Texas.

"Geometry of normal faults and the structure of fault zones": field seminar presented to Exxon Production Research, Parker, Arizona.

"Natural fractures in gas reservoirs": briefing presented to the President of the Gas Research Institute, Austin, Texas.

"Tectonics, fractures, and implications for horizontal drilling in the western United States": presented to The University of Texas at El Paso, Department of Geological Sciences, El Paso, Texas.

F. Jerry Lucia

"Petrophysical aspects of the San Andres outcrop, Algerita Escarpment, New Mexico": presented to the Society of Petroleum Engineers Forum, Crested Butte, Colorado.

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

Richard P. Major

"Carbonate reservoir geology": presented to The University of Texas at Austin, Department of Geological Sciences (Geology 383N), Austin, Texas.

"Depositionally and diagenetically controlled reservoir heterogeneity, Jordan field, University Lands, Ector and Crane Counties, Texas": presented to the University of Houston, Department of Geosciences, Houston, Texas.

"Energy resources and environmental program review: oil resources": presented to the Society of Independent Professional Earth Scientists, San Antonio Chapter, Austin, Texas.

"Production and reexploration (including core-logging exercise)": presented to The University of Texas at Austin, Department of Geological Sciences (Geology 391), Austin, Texas.

"Reservoir characterization for reexploration of mature oil fields": presented to The University of Texas of the Permian Basin, Permian Basin Energy Institute for Educators, Odessa, Texas.

Marcus E. Milling

"Geoscience research needs and opportunities for improved recovery of oil and gas resources": presented to the Society of Petroleum Engineers/University of Houston Emerging Technologies Conference, Houston, Texas.

"Improving oil and gas recovery efficiency through integrated 3-D reservoir modeling": presented to the Silicon Graphics Seminar Series, Calgary, Alberta, Canada, and Houston, Texas.

"Research and technology priorities for improved recovery efficiency from existing U.S. oil and gas fields": presented to the Kentucky Oil and Gas Association, Louisville, Kentucky.

"Research and technology priorities for improved recovery efficiency from existing U.S. oil and gas fields": presented to the Shreveport Geological Society, Shreveport, Louisiana.

Robert A. Morton

"Beach stability along Mustang and North Padre Islands: past, present and future": presented to the Society of Independent Professional Earth Scientists, Corpus Christi, Texas.

"Coastal erosion—an introduction to the solutions": presented at meeting sponsored by the U.S. Environmental Protection Agency, New Orleans, Louisiana.

"Location, causes, and mitigation of coastal erosion in Texas": presented to the Coastal Management Advisory Committee Meeting sponsored by the Texas General Land Office, Austin, Texas.

"Origin, evolution, and recent history of Packery Channel and environs, Texas Gulf Coast": presented to the Corpus Christi Geological Society, Corpus Christi, Texas.

"Plio-Pleistocene depositional systems and related hydrocarbon accumulation, Texas continental shelf": presented to Mobil Exploration and Producing U.S., Inc., Houston, Texas, and Oryx Energy Co., Dallas, Texas.

William F. Mullican III

"Hydrogeology of the San Juan Basin, New Mexico, and implications toward abandoned-well characterization": presented to the American Petroleum Institute, Underground Injection Control Issues Group, Austin, Texas.

"Instrumentation and performance of aquifer slug tests": presented to The University of Texas at Austin, Department of Geological Sciences (Geology 382), Austin, Texas.

Jeffrey G. Paine

"Late Quaternary depositional units, sea level, and vertical movement, Copano Bay area, Texas coastal zone": presented to The University of Texas at Austin, Department of Geological Sciences, Technical Sessions, Austin, Texas.

"Pattern of erosion and deposition on Galveston Island during and after a major hurricane": presented to the U.S. Army Corps of Engineers, Coastal Engineering Research Center, Vicksburg, Mississippi.

Bernd C. Richter

"Geochemical identification of salt-water sources using scattergrams and stepwise discriminant analyses": presented to the First International Symposium on Oil and Gas Waste Management Practices, New Orleans, Louisiana.

Stephen C. Ruppel

"Controls on reservoir heterogeneity in the Three Bar Devonian chert reservoir, Andrews County, Texas": presented to the West Texas Geological Society Symposium, Midland, Texas.

"Patterns of depositional and diagenetic facies development in the Silurian and Devonian of West Texas": presented to Phillips Petroleum Co., Midland, Texas.

"Siluro-Devonian carbonates in West Texas: regional patterns of facies and diagenesis": presented to the West Texas Geological Society, Midland, Texas.

"The Silurian and Devonian of the Permian Basin: regional patterns of deposition and diagenesis": presented to the Roswell Geological Society, Roswell, New Mexico.

"The Silurian and Devonian of West Texas: facies, depositional setting, and reservoir development": presented to the University of Houston, Department of Geosciences and Allied Geophysical Laboratory, Houston, Texas.

"Stratigraphic framework and facies geometry: Monanhans Clear Fork reservoir, West Texas": presented to the Texas Higher Education Coordinating Board, Austin, Texas.

Bridget R. Scanlon

"Bomb Chlorine-36 analysis in the characterization of unsaturated flow at a proposed radioactive waste disposal facility, Chihuahuan Desert, Texas": presented at the Tandem Accelerator Mass Spectrometry Conference, Paris, France.

"Comparison of physical and chemical approaches to evaluation of moisture flux in desert soils": presented at the Land and Water Research Center, University of California, Davis, California.

"Results of monitoring soil physical parameters at a proposed low-level radioactive waste disposal facility": presented at the premeeting field trip, "The Hydrogeology of Trans-Pecos Texas" sponsored by the Geological Society of America, Fort Hancock, Texas.

"Unsaturated flow and solute transport'': presented to The University of Texas at Austin, Department of Geological Sciences (Geology 382), Austin, Texas.

Daniel D. Schultz-Ela

"Enhancements to *Restore©*": presented to the Industrial Associates of the Applied Geodynamics Laboratory, Austin, Texas.

"Numerical modeling with boundary elements": presented to The University of Texas at Austin, Department of Geological Sciences (Geology 391), Austin, Texas.

"Restoration of cross sections from extensional terranes": presented to The University of Texas at Austin, Department of Geological Sciences (Geology 391), Austin, Texas.

"Use of section balancing constraints to infer mechanics of rollover formation": presented to the Industrial Associates of the Applied Geodynamics Laboratory, Austin, Texas.

"Workshop on section balancing using *Restore©*": presented to the Industrial Associates of the Applied Geodynamics Laboratory, Austin, Texas.

Steven J. Seni

"Colocation of geothermal and heavy-oil reservoirs: a South Texas update": presented to Industrial Consortium for the Utilization of the Geopressured-Geothermal Resource, Austin, Texas.

"A comparison of salt tectonics in Gulf Interior basins and the continental slope of the northern Gulf of Mexico": presented to Unocal, Inc., Lafayette, Louisiana.

"Evolution of stocks and massifs from salt sheets, continental slope, northern Gulf of Mexico": presented to the Dallas Geological Society, Dallas, Texas.

"Salt tectonics on the continental slope: evolution of stocks and massifs during reactivation of salt sheets, northern Gulf of Mexico": presented to The University of Texas at Austin, Department of Geological Sciences, Technical Sessions, Austin, Texas.

"Salt tectonics on the continental slope, northeast Green Canyon Area, northern Gulf of Mexico": presented to Texas A&M University/University of Texas Institute for Geophysics Gulf of Mexico Structural and Stratigraphic Synthesis Project Meeting, College Station, Texas.

"Salt tectonics on the continental slope, northern Gulf of Mexico": presented to ARCO, Inc., Dallas, Texas.

"Salt tectonics on the continental slope, northern Gulf of Mexico": presented to the New Orleans Geological Society, New Orleans, Louisiana.

"Salt tectonics on the continental slope, northern Gulf of Mexico": presented to Unocal, Inc., Houston, Texas.

"What core can tell us about properties of salt domes": presented to the Solution Mining Research Institute, Austin, Texas.

Noel Tyler

"Architecture of heterogeneous reservoirs—problems and promise for increased hydrocarbon recovery": presented to Texas Tech University, Department of Geology colloquium, Lubbock, Texas.

"Field-sampling pilot study—Ferron Sandstone (Lower Cretaceous) central Utah": presented to workshop on "Characterization and quantification of geologic and petrophysical heterogeneity in fluvial-deltaic reservoirs," Austin, Texas.

"Heterogeneity in fluvial-dominated deltaic reservoirs": presented to workshop on "Characterization and quantification of geologic and petrophysical heterogeneity in fluvial-deltaic reservoirs," Austin, Texas.

"Methodology to assess the geometry of flow boundaries in fluvial-deltaic reservoir analogs, Ferron Sandstone, Utah": presented to the Gas Research Institute, Contractors Meeting, Lakeway, Texas.

"Potential for energy savings in Clear Fork reservoirs, Permian Basin": presented to the Second Annual Review of the Energy and Research Applications Program, Austin, Texas.

"Reservoir architectural styles and recovery response": presented to the Houston Geological Society, Houston, Texas.

"Structure and activities of the Maximization of Petroleum Recovery Efficiency Consortium": presented to the Second Annual Review of the Energy and Research Applications Program, Austin, Texas.

Bruno C. Vendeville

"Compression and salt-withdrawal structures": presented to the Industrial Associates of the Applied Geodynamics Laboratory, Austin, Texas.

"Effects of basement faults on diapirism and overburden extension": presented to the Industrial Associates of the Applied Geodynamics Laboratory, Austin, Texas.

"Fault experiment": presented to Austin Geological Society field trip, "Faults and Fractures in the Balcones Fault Zone," Austin, Texas.

"Modes of diapirism through brittle overburden'': presented to ARCO Oil and Gas Company, Plano, Texas.

"Results of the Applied Geodynamics Laboratory program for 1989'': presented to Mobil Research and Development Corporation, Dallas, Texas.

"The rise of diapirs during thin-skinned extension": presented to the Industrial Associates of the Applied Geodynamics Laboratory, Austin, Texas.

"Simple mechanical considerations on diapirism through brittle rock": presented to the Industrial Associates of the Applied Geodynamics Laboratory, Austin, Texas.

"Workshop on scale modeling": presented to The University of Texas at Austin, Department of Geological Sciences (Geology 391), Austin, Texas.

Edmund G. Wermund

"Coastal erosion on the Texas coast": presented to the U.S. Geological Survey/Association of American State Geologists Central Region Cluster Meeting, Baton Rouge, Louisiana.

"The physical setting of the Texas coast": presented at "Coastal Concern from an Inland Perspective," Earth Fair Texas Conference, Dallas, Texas.

"Potential of Armand Bayou and Christmas Bay areas for inclusion as Texas coastal preserves": presented to the Galveston Bay National Estuary Program, Management Committee, Houston, Texas.

William A. White

"Wetland loss in fluvial-deltaic areas, Texas Gulf Coast": presented at "America's Sea! The Environmental and Economic Status of the Gulf of Mexico" [The Gulf of Mexico Program, Washington, D.C.] in New Orleans, Louisiana.

Bureau of Economic Geology Seminars

The Bureau holds in-house seminars and short courses to promote communication among scientists, to encourage guidance and peer review of Bureau research, and to foster professional development of junior staff.

M. Saleem Akhter

"Production characteristics of geopressured reservoirs"

"Characterization of abandoned wells and their potential for contamination of drinking water sources"

William A. Ambrose

"Geologic controls on occurrence and producibility of coalbed methane in the Fruitland Formation, San Juan Basin, Colorado and New Mexico"

Don G. Bebout

"Characterization of a Modern ooid carbonate sand shoal: Joulters Cays, Bahamas"

Edward W. Collins

"Description and Quaternary fault history of the Campo Grande fault, Hueco Basin, Hudspeth County, Texas"

Alan R. Dutton

"Geohydrology of the Gulf Coast aquifer, Wharton and Matagorda Counties"

"Hydrogeology of a surficial aquifer at the Superconducting Super Collider site, Ellis County, Texas"

Shirley P. Dutton

"Diagenesis of Frontier tight gas sandstones"

Jeffry D. Grigsby

"Diagenesis of the lower Vicksburg Formation, McAllen Ranch field, Hidalgo County, Texas"

Edgar H. Guevara

"Wilcox reservoirs in the Lake Creek gas unit, Montgomery County, Texas"

Douglas S. Hamilton

"Sydney Basin (Australia) reservoir study: some exploration techniques for diagenetically complex reservoir sandstones"

"Genetic stratigraphy and its application to coal exploration, Gunnedah Basin, Australia"

H. Scott Hamlin

"Frontier Formation stratigraphy and sandstone geometry, Green River Basin, Wyoming"

Christopher D. Henry

"Basin and Range extension and magmatism in Mexico"

Mark H. Holtz and Chester M. Garrett, Jr.

"Leonardian carbonate reservoir framework for strategic recovery practices"

Martin P. A. Jackson

"The rise and fall of salt diapirs during thin-skinned extension"

Dennis R. Kerr

"Fluvial sedimentology of middle Frio Formation (Oligocene), Jim Wells, Kleberg, and Nueces Counties, South Texas"

Dennis R. Kerr and Lee A. Jirik

"Fluvial architecture and reservoir heterogeneity in the Oligocene middle Frio of South Texas"

Charles W. Kreitler

"Guidelines for wellhead protection areas in confined aquifer settings"

"Origin of geopressures in the Texas Gulf Coast: new observations and ideas"

"Wellhead protection strategies for confined aquifer settings"

Richard P. Langford and Edmund G. Wermund

"Relationship between geology and production, lower Vicksburg deltaic reservoirs, McAllen Ranch field, Hidalgo County, Texas"

F. Jerry Lucia

"Application of capillary pressure data to reservoir characterization"

H. Seay Nance

"San Andres RCRL: results of outcrop/borehole correlations, Algerita Escarpment, Guadalupe Mountains, New Mexico"

Bernd C. Richter

"Geochemical identification of salt-water sources in ground water"

Bridget R. Scanlon

"Relative importance of liquid and vapor transport in the unsaturated zone of an arid region"

Daniel D. Schultz-Ela

"Computer-aided restorations of extensional-style cross sections"

Steven J. Seni

"Salt tectonics on the continental slope, northeast Green Canyon area, northern Gulf of Mexico: evolution of stocks and massifs from reactivation of salt sheets"

"Co-location of geothermal and heavy-oil resources"

Bruno C. Vendeville

"Deposition, extension, and the shape of downbuilding diapirs"

Sally G. Zinke

"Geophysical applications for definition of reservoir heterogeneity"

Congressional, Legislative, and Special Testimony

Robert W. Baumgardner, Jr.

Expert testimony on geomorphology of the proposed low-level radioactive waste disposal site, Hudspeth County, Texas: given to the Special Assistant County Attorney, County of El Paso, and Assistant Attorney General, Environmental Protection Division, Austin, Texas.

William L. Fisher

"Technical factors in Edwards Aquifer use and management": report of the Technical Advisory Panel to the Special Joint Committee on the Edwards Aquifer, Texas Senate and House of Representatives, Austin,Texas.

Charles W. Kreitler

Panelist, U.S. Environmental Protection Agency, for public hearing on reauthorization of U.S. Safe Drinking Water Act.

Jay A. Raney

Expert testimony and oral deposition on the geologic setting of the proposed site for the Texas low-level radioactive waste repository near Fort Hancock, Texas: given to the Special Assistant County Attorney, County of El Paso, and Assistant Attorney General, Environmental Protection Division, Austin, Texas.

Committee Services, Offices, and Other Professional Responsibilities

Walter B. Ayers, Jr.

Chairman, Field Trip Committee, Energy Minerals Division, American Association of Petroleum Geologists, 1991 annual meeting.

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

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

Co-leader of field trip, "Geologic and hydrologic controls on coalbed methane in the Menefee and Fruitland Formations, San Juan Basin," Alberta Geological Survey, Durango, Colorado.

Co-leader of field trip, "Geology of coalbed methane in the northwestern San Juan Basin, including the **COAL** site," Gas Research Institute, Project Advisors Group, Durango, Colorado.

Robert W. Baumgardner, Jr.

Member, Remote Sensing and Cartographic Committee, Texas Natural Resources Information System Task Force.

Don G. Bebout

Member, Preservation of Cores and Samples Committee, American Association of Petroleum Geologists.

Member, Convention Policy Committee, Society of Economic Paleontologists and Mineralogists.

Edward W. Collins

Chairman, Field Trip Committee, Austin Geological Society.

Co-leader of field trip, "Faults and fractures in the Balcones Fault Zone, Austin Region, Central Texas," Austin Geological Society, Austin, Texas.

Carolyn E. Condon

Chairman, Newsletter Committee, Austin Geological Society.

Treasurer, Austin Geological Society.

Coordinator, Technical Advisory Panel of the Special Committee on the Edwards Aquifer, Texas State Legislature.

Alan R. Dutton

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

Member, Editorial Board, *Ground Water*, Journal of the Association of Ground Water Scientists and Engineers, a Division of the National Water Well Association.

Chairman, Technical Program Committee, Hydrogeology Division, Geological Society of America, 1990 annual meeting, Dallas, Texas.

Co-presider, Technical Session, Hydrogeology II, Geological Society of America, 1990 annual meeting.

Member, Abstract Review Committee for Hydrogeology, Geological Society of America, 1990 annual meeting.

Technical Reviewer, Research Proposals, National Science Foundation, Division of Earth Sciences, Geology and Paleontology Program.

Shirley P. Dutton

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

Co-Chairman, Diagenesis Technical Session, Society of Economic Paleontologists and Mineralogists, American Association of Petroleum Geologists, 1990 Rocky Mountain Section Meeting.

Co-Chairman, Clay Minerals in Sandstones Symposium 3, 1990 Clay Minerals Society Annual Meeting.

Co-Convenor, Porosity Prediction in Siliciclastic Rocks Technical Session, Society of Economic Paleontologists and Mineralogists, 1991 annual meeting.

Co-leader of field trip, "Frontier Formation and Grand Teton National Park," Gas Research Institute, Natural Gas Supply Project Advisors Meeting, Tight Gas Sands Project Area.

Member, Abstract Review Committee for Sedimentary Petrology, Geological Society of America, 1990 annual meeting.

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

Member, Pettijohn Medal Selection Committee, Society of Economic Paleontologists and Mineralogists.

Member, Program Committee, "Expanding your horizons in science and mathematics," 1991 Austin Conference, Math/Science Network.

Robert J. Finley

Chairman, Committee on Development Geology, American Association of Petroleum Geologists.

Chairman, AAPG/SEG/SPE/SPWLA Development Geology: Application and Technology, American Association of Petroleum Geologists, 1990 annual meeting.

Member, Committee on Undiscovered Oil and Gas Resources, National Research Council/National Academy of Sciences.

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

Alternate Representative, Texas Natural Resources Information System Task Force.

William L. Fisher

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

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

Chairman, Faculty Review Committee, Geology Foundation, The University of Texas at Austin.

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

Chairman, Technical Advisory Panel, Texas Senate-House Special Joint Committee on the Edwards Aquifer.

Chairman, Search Committee, American Geological Institute.

Chairman, Applied Research and Technology Committee, Texas Independent Producers and Royalty Owners.

Co-Chairman, Board of Earth Sciences and Resources, National Academy of Sciences.

Vice-Chairman, Committee on Production Technologies for Liquid Fuels, National Academy of Engineering/National Research Council.

Vice-President and President-Elect, American Geological Institute.

Councilor, Geological Society of America.

Representative to the International Union of Geological Sciences, American Association of Petroleum Geologists.

Liaison to Geological Society of America, Association of American State Geologists.

Ex Officio Member, U.S. National Committee for the International Union for Quaternary Research, National Academy of Sciences/National Research Council.

Ex Officio Member, U.S. National Committee for the International Geophysical Union, National Academy of Sciences/National Research Council.

Ex Officio Member, U.S. National Committee for the International Union of Geology and Geophysics, National Academy of Sciences/National Research Council.

Charter Member, Governor's Energy Council (Texas).

Member, U.S. National Committee on Geology, National Academy of Sciences/National Research Council.

Member, Executive Committee, Committee on Status and Research Objectives in the Solid Earth Sciences, National Academy of Sciences/National Research Council.

Member, Policy Advisory Board for the Outer Continental Shelf, U.S. Department of the Interior.

Member, Advisory Council, Gas Research Institute.

Member, Nominating Committee, Gas Research Institute.

Member, National Petroleum Council.

Member, Agenda Committee, National Petroleum Council.

Member, U.S. National Committee for the World Petroleum Congress, American Petroleum Institute.

Member, Research Committee, Interstate Mining Compact Commission.

Member, Research Committee, Interstate Oil Compact Commission.

Member, Texas Scientific Advisory Council.

Member, Economic Advisory Council, Office of the Comptroller, State of Texas.

Member, Audit Committee, Geological Society of America.

Member, Geology and Public Policy Committee, Geological Society of America.

Member, Industry Liaison Committee, American Association of Petroleum Geologists.

Member, Advisory Board, Geology Associates, The University of Kansas.

Member, Geology Advisory Group, Southern Illinois University.

Member, Advisory Council, Bureau of Business Research, The University of Texas at Austin.

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

Member, Artificial Reef Advisory Committee, Texas Parks and Wildlife Department.

Member, Secretary of Energy Advisory Board, U.S. Department of Energy.

Member, Texas Coastal Zone Management Plan Advisory Committee.

Member, Finance Committee, American Geological Institute.

Member, *Oil Daily* Advisory Board.

L. Edwin Garner

President, Austin Geological Society.

Member, Executive Committee, Austin Geological Society.

Member, Geotechnical Advisory Panel, Superconducting Super Collider Project.

Chester M. Garrett, Jr.

Delegate, House of Delegates, American Association of Petroleum Geologists.

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

Member, Public Information Committee, American Association of Petroleum Geologists.

Judge, Matson Award and Energy Minerals Division Best Paper Award, American Association of Petroleum Geologists, 1990 annual meeting.

Jeffry D. Grigsby

Judge, Best Paper Award, Gulf Coast Association of Geological Sciences, 1990 annual meeting.

Edgar H. Guevara

Chairman, Membership Committee, Austin Geological Society.

Judge of Poster Session, 1990 Annual Convention of the American Association of Petroleum Geologists.

Member, Newsletter Committee, Austin Geological Society.

H. Scott Hamlin

Co-leader of field trip, "Frontier Formation and Grand Teton National Park," Gas Research Institute, Tight Gas Sands Project Board of Advisors.

Claude R. Hocott

Member, Research Committee, Interstate Oil Compact Commission.

Martin P. A. Jackson

Associate Editor, Geological Society of America *Bulletin*.

Associate Editor, American Association of Petroleum Geologists Bulletin.

Co-Chairman, New Concepts of the Structural Geometry of Petroleum Traps Technical Session, American Association of Petroleum Geologists, 1990 annual meeting.

Co-Chairman and Co-Convenor, Salt Tectonics Symposium for Structure and Tectonics Division, Geological Society of America, 1990 annual meeting.

Co-Convenor, Salt Tectonics Theme Session, Geological Society of America, 1990 annual meeting.

Member, International Union of Geological Sciences Commission on Tectonics.

William R. Kaiser

Member, Steering Committee on Coal Reserves Assessment, U.S. Department of Energy.

Co-leader of field trip, "Hydrogeology of the Jewett Lignite Mine, East Texas," Geological Society of America, 1990 annual meeting.

Charles Kerans

Associate Editor, *Journal of Sedimentary Petrology*, Society of Economic Paleontologists and Mineralogists.

Co-Chairman, Recent Advances in Reservoir Characterization and Formation Evaluation Technical Session, Society of Petroleum Engineers Research Forum.

Charles W. Kreitler

Member, Technical Advisory Panel, Special Joint Committee on the Edwards Aquifer, Texas State Legislature.

Member, National Drinking Water Advisory Council, U.S. Environmental Protection Agency.

Co-leader of field trip, "Hydrogeology of Trans-Pecos Texas," Geological Society of America, 1990 annual meeting.

Richard P. Langford

Leader of field trip, "Ergs and erg margin deposits," Society of Economic Paleontologists and Mineralogists Field Research Conference, Moab, Utah.

Stephen E. Laubach

Co-leader of field trip, "Mesozoic thrusting, synplutonic deformation, and Miocene overprinting, Harcuvar Complex: a section through the pre-Tertiary crust of west-central Arizona," Geological Society of America, Cordilleran Section Meeting, Tucson, Arizona.

Co-leader of field trip, "Frontier Formation and Grand Teton National Park," Gas Research Institute Natural Gas Supply (Tight Gas Sands Project Area) Project Advisors Meeting.

Co-leader of field trip, "Fractures and subsidiary faults associated with normal faults of the Balcones Fault Zone, Austin Region, Central Texas," Austin Geological Society, Austin, Texas.

F. Jerry Lucia

Associate Editor, *Journal of Petroleum Technology*, Society of Petroleum Engineers.

Richard P. Major

Vice-President, Austin Geological Society.

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

Co-Chairman, Eustatic Signatures in Carbonate Deposits: Deep vs. Shallow, Technical Session, Society of Economic Paleontologists and Mineralogists/American Association of Petroleum Geologists, 1990 annual meeting.

Co-Chairman, International Symposium: The Geological Modeling of Hydrocarbon Reservoirs, 13th International Sedimentological Congress.

Co-Chairman, Bathurst Symposium, Dolomites and Dolomitization, 13th International Sedimentological Congress.

Member, Resolutions Committee, American Association of Petroleum Geologists House of Delegates.

Judge, Diagenesis and Sedimentation in Carbonate Environments, Technical Session, Society of Economic Paleontologists and Mineralogists/American Association of Petroleum Geologists, 1990 annual meeting.

Marcus E. Milling

Chairman, Human Resources Advisory Committee, American Geological Institute.

Vice-Chairman, Foundation Board of Trustees, American Geological Institute.

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

Member, Committee on Geology and Public Policy, Geological Society of America.

Member, Advisory Board, Department of Geology, The University of Iowa.

Member, Enhanced Oil Recovery Committee, Interstate Oil Compact Commission.

Co-Convenor, Geological Society of America Geology and Public Policy Forum, "Future needs and utilization of fossil fuels—implications for national security, environmental controls, and geoscience employment."

Robert A. Morton

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

Associate Editor, *Journal of Sedimentary Petrology*, Society of Economic Paleontologists and Mineralogists.

Member, Coastal and Shoreline Erosion Subcommittee, U.S. Environmental Protection Agency, Gulf of Mexico Program.

Leader of field trip, "Coastal land loss in the Galveston–Houston area," Geological Society of America, 1990 annual meeting.

Jeffrey G. Paine

Member, Coastal Tracts Module Group, Coastal Ocean Management, Planning, and Assessment System (COMPAS), National Oceanic and Atmospheric Administration and Texas Water Commission.

Jay A. Raney

Representative, Texas Governor's Office, State and Tribal Government Working Group, U.S. Department of Energy.

Member, External Review Group, Formal Priority System for Environmental Restoration, U.S. Department of Energy.

Bridget R. Scanlon

Co-Chairman, Arid Zone Hydrology Technical Session, Geological Society of America, 1990 annual meeting.

Allan R. Standen

Member, Core and Sample Committee, American Association of Petroleum Geologists.

Member, Youth Activity Committee, American Association of Petroleum Geologists.

Noel Tyler

Co-Chairman, Sediment Body Geometries, Architecture and Heterogeneities Technical Session in Symposium on Geological Modeling of Hydrocarbon Reservoirs, International Sedimentological Congress (Nottingham, England), 1990 annual meeting.

Convenor, Workshop on Characterization and Quantification of Geologic and Petrophysical Heterogeneity in Fluvial-Deltaic Reservoirs, Austin, Texas.

Member, Development Geology Committee, American Association of Petroleum Geologists.

Member, Technical Study Committee, Geoscience Institute for Oil and Gas Recovery Research.

Member, Awards and Admissions Committee, The University of Texas at Austin, Department of Geological Sciences.

Member, Public Lands Committee, Interstate Oil Compact Commission.

Edmund G. Wermund

Chairman, Galveston Bay National Estuary Program Scientific/Technical Advisory Committee, Loss of Physical Habitat and Living Resources Subcommittee.

Chairman, Core and Sample Committee, Association of American State Geologists.

Co-Chairman and Representative for Texas, Gulf of Mexico Regional Technical Working Group, Minerals Management Service, U.S. Department of the Interior.

Member, Environmental Geology Committee, American Association of Petroleum Geologists.

Member, Texas Natural Resources Information System Task Force.

Member, Texas Mapping Advisory Committee.

Member, Texas Department of Information Resources and TNRIS Texas Geographic Information System Advisory Committee.

Member, Committee on Nueces Bay Fresh-Water Inflow, Texas Water Commission.

William A. White

Alternate Member, Remote Sensing and Cartographic Committee, Texas Natural Resources Information System Task Force.

Participant, Scientific/Technical Advisory Committee, Galveston Bay National Estuary Program.

University Teaching/ Continuing Education

Walter B. Ayers, Jr.

"Geologic methods in subsurface studies, San Juan Basin": short course presented to the Gas Research Institute, Coalbed Methane Contractors Workshop, Austin, Texas.

"Geologic controls on coalbed methane occurrence and producibility": short course presented to the Gas Research Institute, Coalbed Methane Workshop, Denver, Colorado.

"Hydrologic evaluation of coalbed methane producibility": short course presented to the Gas Research Institute, Coalbed Methane Workshop, Denver, Colorado.

Don G. Bebout

"Carbonate and evaporite depositional systems": core exercise presented to the graduate class of The University of Texas at Austin, Department of Geological Sciences, Austin, Texas.

"Description and interpretation of Cretaceous carbonate from core": workshop presented to the Shreveport Geological Society, Shreveport, Louisiana.

"Logging and interpreting carbonate core": presented to The University of Texas at Austin, Department of Geological Sciences (Geology 383N), Austin, Texas.

"Lower Cretaceous platform carbonates, Central Texas: surface to subsurface": co-leader of field seminar, sponsored by the American Association of Petroleum Geologists, Kerrville, Fredericksburg, and Austin areas (Texas).

Shirley P. Dutton

"Geology of the Frontier Formation, Moxa Arch, Green River Basin, Southwestern Wyoming": co-lecturer of short course presented to the Gas Research Institute Frontier Formation Workshop, Denver, Colorado.

"Geology of the Travis Peak Formation and Cotton Valley Group, East Texas": co-lecturer at Gas Research Institute East Texas Cotton Valley and Travis Peak Formations Workshop, Tyler and Houston, Texas.

Robert J. Finley and Noel Tyler

"Characterization of heterogeneous reservoirs": short course presented to Universidad Federal de Ouro Preto, Escola de Minas, Ouro Preto, Brazil.

William L. Fisher and Noel Tyler

"Petroleum geology: exploration and redevelopment" (Geology 391): The University of Texas at Austin, Department of Geological Sciences, Austin, Texas.

H. Scott Hamlin

"Geology of the Frontier Formation, Moxa Arch, Green River Basin, Southwestern Wyoming": co-lecturer of short course presented to the Gas Research Institute, Frontier Formation Workshop, Denver, Colorado.

Claude R. Hocott

"Fundamentals of petroleum engineering" (PEN 320): The University of Texas at Austin, Department of Petroleum Engineering, Austin, Texas.

Charles Kerans

"Paleokarst reservoirs, examples from the Lower Ordovician Ellenburger Group of West Texas": short course presented to Texaco Exploration and Production Technology Division, Houston, Texas.

"Quantification of geologic and permeability patterns in restricted platform carbonate outcrops for use in improved reservoir description and flow stimulation, Permian Basin, U.S.A.": workshop presented to the International Energy Agency, Paris, France.

Charles W. Kreitler

"Methods for determining wellhead protection areas for confined aquifers": continuing education course presented to state regulators for ground-water protection, U.S. Environmental Protection Agency, Chicago, Illinois; Denver, Colorado; Dallas, Texas; and Washington, D.C.

Richard P. Major

"Carbonate core logging exercise": short course presented to The University of Texas at Austin, Department of Geological Sciences (Geology 391), Austin, Texas.

Robert A. Morton

"Exploring a barrier island system": co-lecturer of short course sponsored by the University of Texas Marine Science Institute, Port Aransas, Texas.

"Coastal land loss": short course presented to the Geological Society of America, 1990 annual meeting, Dallas, Texas.

Noel Tyler and Robert J. Finley

"Reservoir redevelopment in natural hydrocarbon provinces: approach and potential in the Lower 48 states": short course presented to the Houston Geological Society, Houston, Texas.

Noel Tyler and F. Jerry Lucia

"Opportunities and strategies for additional recovery from Permian Basin reservoirs": short course presented to the Permian Basin Graduate Center, Midland, Texas.

Support Staff

Administrative/Secretarial

The Administrative/Secretarial staff manages the general administration of the Bureau—personnel matters, accounting, publication sales, purchasing and vouchering, travel, reception/switchboard duties, and preparing correspondence. The Bureau's involvement in many different contracts and research projects requires the Administrative section to process more than 3,000 appointment forms each year to allocate staff time properly among funding sources. In addition, this section controls more than $4 million in purchases and subcontracts and handles publication sales in excess of $140,000 per year. Wanda L. LaPlante, Executive Assistant, supervises the section.

Cartography

The Cartographic staff produces high-quality, full-color maps, black-and-white plates, text figures, slides, posters, and display materials and provides in-house photographic services for Bureau research. Under the supervision of Richard L. Dillon, Chief Cartographer, 1 half-time and 12 full-time staff members produced 21 black-and-white plates, 6 full-color maps, 2,000 text figures, and 1,600 visual aids during the year. All items produced by this section are either published in the Bureau's publication series, technical journals, or contract reports or used as presentation material at professional meetings. Because the public uses these materials, high standards of quality are maintained.

The use of computers as tools to produce the visual aids and text figures continues to expand. Currently two IBM-PC-based systems are used to produce slides, and three Macintosh computers are used to produce certain posters, slides, and text figures. To date the Cartographic staff has not used computers for mapping but hopes to do so in the future.

Computer Resources

The Computer Resources staff provides three types of services to research, administrative, and support personnel: system services (facilities and hardware, operations and software), user education and consulting, and systems analysis and programming. The section supports programming and data-base applications on Bureau computers (a VAX-VMS cluster, a Unix workstation, more than 55 networked personal computers, and 20 high-quality output devices), the University's Cyber computers, and the Center for High Performance Computing's VAX and Cray systems.

In 1990, under the supervision of Elizabeth D. Orr, Manager of this section, the Computer Resources staff added two VAXstation 3100's to the VAX cluster, bringing the total number of nodes in the cluster to five. One VAXstation is dedicated to hydrogeologic modeling; the other is dedicated to a new inventory and tracking system for the Core Research Center. Two new 386 PC-based workstations support a Geographical Information System (GIS), computer mapping and digitizing, geophysical modeling, and oil simulation. The staff completed development of *Restore©*, a marketable Macintosh program that enables geoscientists sequentially to backstrip and balance cross sections from extensional terranes. Significant progress was also made on the implementation of (1) the Core Research Center's automated inventory and tracking system, (2) a charge-back system for personal computer use, and (3) a publication sales and inventory system.

Publications

The Publications staff, consisting of word processor/typesetter operators, proofreaders, editors, and designers, produces a variety of printed materials for the Bureau. Susann Doenges, Editor-in-Charge, supervises the section. In addition to producing Bureau publications, the staff also prepares contract reports, papers and abstracts, and various documents in support of research projects. Most reports published by the Bureau are now produced through desktop publishing technology. Manuscripts are revised electronically, and pages are prepared for the printer through layout programs. This year 19 new publications were issued by the Bureau. Twenty-nine contract reports also were completed, and 137 papers and abstracts by Bureau authors were published by professional journals and publishers.

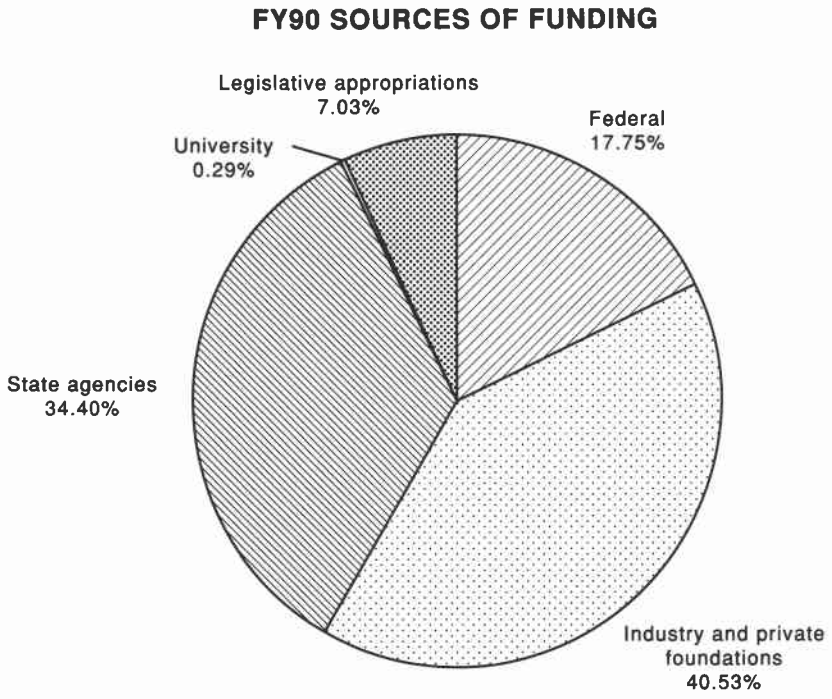
Quality Assurance

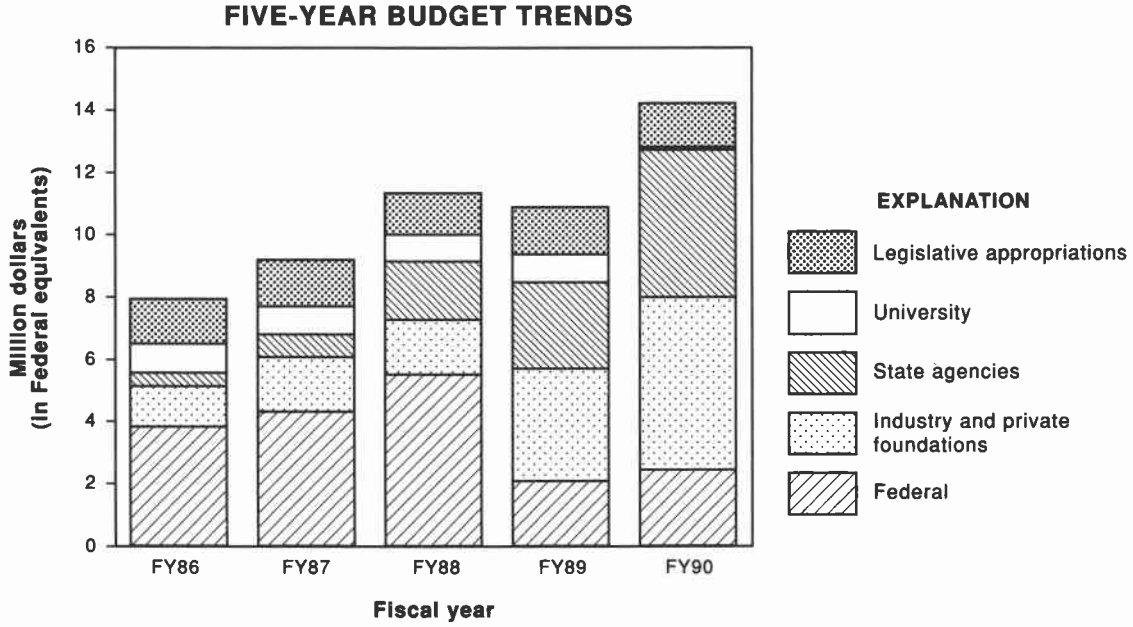
The Quality Assurance Group, supervised by Carolyn Condon, monitors and coordinates the Bureau's Quality Assurance Program. The group directly supports scientific research and administration by interpreting regulatory and contractual requirements and preparing and issuing Quality Assurance Procedures to ensure compliance with those requirements. The staff consists of trained Lead Auditors who, in addition to preparing documents, conduct audits to determine effective implementation of the Quality Assurance Program.

During 1990, the Quality Assurance Group was responsible for the preparation and issuance of a revised Quality Assurance Plan and one new and seven revised Quality Assurance Procedures associated with low-level radioactive waste-site investigations. Two new and seven revised Specific Work Instructions were also issued. Additionally, the Quality Assurance Group conducted two vendor-evaluation audits on behalf of the Texas Low-Level Radioactive Waste Disposal Authority and eight audits of technical activities associated with the low-level radioactive waste repository project and the Superconducting Super Collider.

The Quality Assurance Group manages the Quality Assurance Records Center, where Quality Assurance records are stored for future access by or delivery to contracting agencies.

Sources of Funding and Budget Trends





Bureau of Economic Geology

Dr. William L. Fisher, Director

Dr. Robert J. Finley, Associate Director • Dr. Marcus E. Milling, Associate Director
Douglas C. Ratcliff, Associate Director for Administration • Wanda L. LaPlante, Executive Assistant

Program Coordinators

Dr. Walter B. Ayers, Jr.
Gas Resources
Dr. Robert A. Morton
Land and Marine Resources
Dr. Jay A. Raney
Environmental Resources and Minerals
Dr. Noel Tyler
Oil Resources

Senior Research Scientists

Dr. Virgil E. Barnes
Dr. Don G. Bebout
Dr. Robert L. Folk
Dr. William E. Galloway
Dr. Christopher D. Henry
Dr. Claude R. Hocott
Dr. Martin P. A. Jackson
Dr. Robert A. Morton
Dr. John G. Sclater

Research Scientists

Dr. Walter B. Ayers, Jr.
Dr. Edward C. Bingler (on leave)
Dr. Jules R. DuBar
Dr. Alan R. Dutton
Dr. Shirley P. Dutton
Dr. R. Stephen Fisher
Dr. Edgar H. Guevara
Dr. Thomas C. Gustavson
Dr. William R. Kaiser
Dr. Charles Kerans
Dr. Charles W. Kreitler
Dr. Stephen E. Laubach
Dr. Raymond A. Levey
Dr. Jay A. Raney
Dr. Stephen C. Ruppel
Dr. Noel Tyler
Dr. E. G. Wermund

Research Associates

Kenneth T. Barrow
Robert W. Baumgardner, Jr.
Edward W. Collins
L. Edwin Garner
Tucker F. Hentz
Mary L. W. Jackson
Dr. Ekrem Kasap
Dr. Dennis R. Kerr
Dr. Richard P. Langford
Dr. Richard P. Major
Dr. Bridget R. Scanlon
Dr. Daniel D. Schultz-Ela
Dr. Rainer K. Senger
Dr. Steven J. Seni
Dr. Bruno C. Vendeville
William A. White
Clark R. Wilson
Sally G. Zinke

Research Scientist Associates

M. Saleem Akhter
William A. Ambrose
Arten J. Avakian
Jonathan G. Blount
Thomas R. Calnan
Sigrid J. Clift
Chester M. Garrett, Jr.
Roselle M. Girard
H. Scott Hamlin
Karen L. Herrington
Mark H. Holtz
Dr. Susan D. Hovorka
Lee A. Jirik
Mary W. McBride
William F. Mullican III
H. Seay Nance
Dr. Jeffrey G. Paine
Bernd C. Richter
Andrew R. Scott
Kathleen M. Strub
Roger Tyler
Gary W. Vander Stoep
Joseph S. Yeh

Senior Research Fellow

F. Jerry Lucia

Research Fellows

Dr. Robert H. Blodgett
Dr. Peter R. Cobbold
Dr. Jeffry D. Grigsby
Dr. Douglas S. Hamilton
Dr. Eric W. James
Dr. J. Ulises Ricoy
Dr. Fred P. Wang
Dr. Ruud Weijermars

Administrative Staff

Margaret R. Brinson
Harold Ciccotti
Dixon E. Coulbourn
Richard B. Curlee
James A. Doss
Patricia O. Downs
Marjorie A. Gilliam
Marilynn L. Hall
Lucille C. Harrell
Dorothy C. Johnson
Mary E. Koch
Frank D. Meaker
Lynda A. Miller
Diane C. Ruetz
G. Stephen Stubbs
Melinda J. Taylor
Pamela M. Trice
Peggy J. Trunnell
Virginia C. Zeikus

Publications

Susann V. Doenges
Editor-in-Charge
Catharine B. Challstrom
Jamie H. Coggin
J. Devon Dederich
Lana S. Dieterich
Bobby S. Duncan
Margaret L. Evans
Chief Designer
Susan J. Lloyd
Amanda R. Masterson
Jennifer Schaudies
Melissa Snell
Maris V. Strautmanis

Computer Resources

Elizabeth D. Orr
Manager
Sharon A. Bierschenk
Robert J. Claggett
Kenneth M. Duncan
Richard D. Edson, Jr.
Diane M. Spinney
W. Gerald White

Mineral Studies Laboratory

Steven W. Tweedy
Chemist-in-Charge
Raul Herrera
Sharon G. Lowe

Core Research Center

Allan R. Standen
Curator
Jack Bailey, Jr.
Jon D. Boldovici
George T. Bush
Alex Y. Colunga
William H. Doneghy
Mark J. Donnelly
Jordan W. Forman, Jr.
Byra G. Harpole
Billy D. Horton
Mark W. Jeffers
Jim J. Kizer
Clifton W. Neely
Robert G. Richardson
Steven M. Rooks
Danny Sanchez
Robert A. Sanchez

Cartography

Richard L. Dillon
Chief Cartographer
John T. Ames
Karel H. Cromie
Barbara M. Hartmann
Margaret D. Koenig
Wade W. Kolb
Anne I. Kubert
Michele L. LaHaye
Joel L. Lardon
Yves H. Oberlin
Patrice A. Porter
Kerza A. Prewitt
Jana S. Robinson
David M. Ridner
Maria E. Saenz
Teresa L. Weaver

Quality Assurance/Reading Room/Data Center

Carolyn E. Condon
Quality Assurance Officer
Rodney I. Heathcott
Daniel H. Ortuño

Research Assistants

Areef Ahamad
Mark W. Andreason
Edward S. Angle
Nina L. Baghai
Angela B. Baker
Nancy J. Banta
Mark D. Barton
Scotty D. Baumgartner
Steven C. Beda
Dieter K. Beike
Jeffrey W. Black
Suhas V. Bodwadkar
James G. Brewton
Laura L. Brock
Robert L. Buehring
Karen E. Carter
Harold A. Cartey
Julian J. Castro
Hwei-Mei Chen
Susan Cisco
Becky J. Coel
Rebecca L. Curry
Andrew P. Czebieniak
Bruce K. Darling
Loli D. de Llano
Patricia W. Dickerson
Joey B. Dodgen
Robin D. Dommisse
Mark E. Erwin
Malcolm A. Ferris
William M. Fitchen
Amynta J. Franklin
Gilbert Gabaldon
Jose Galvan
Wendy J. Garey
Hongxing Ge
Ridha C. Gharbi
Shahid A. Ghauri
Richard S. Goldsmith
David R. Grote
Tathagata Guha
Sy-Jye Guo
Garth J. Hawkins
Allison B. Henry
Lily A. Hewgley
Thomas A. Hickson
Randall K. Hill
Pharaoh A. Hirani
Chunkong G. Ho
Brian C. Hoskins
Ting-Ya Hsieh
Sung-Chi Hsu
Ali J. Jan
Sonya A. Jones
Peggy E. Killgore
Kyle L. Kirschenmann
Jennifer Kopf
David C. Koran
Jiunnren Lai
Bradley J. Lambert
Shing-Tzong Lin
Michelle M. Mallien
Barbara A. Marin
Kendrea K. Markle
Vichai Maroongroge
Mark T. McCoy
Matt L. McCullough
Ronald G. McMurry
Thomas E. McKenna
John M. Mendenhall
Laura L. Moffett
Todd J. Muelhoefer
Peter K. Nance
Edward R. Newby
Christopher M. Norman
Gregg C. Oetting
Richard A. Page
Pradip M. Patel
Derek R. Peacock
Steven J. Rainey
Syed A. Rasool
James R. Reistroffer
Randy L. Remington
Syed H. Rizvi
Asad M. Sattar
Mohammad A. Sattar
Shahzada A. Shah
Ali S. Sikandar
Robert S. Single
Jorie G. Smith
William G. Smithhart
Lisa E. Sparlin
Bart B. Spraberry
Michael A. Starcher
Burgess H. Stengl
Beate Sterrenberg
Katie S. Tauxe
Chris L. Tice
Lynda K. Timm
Thomas A. Tremblay
Heng Tsai
Patricia Van Rensburg
Timothy G. Walter
Gregory E. Waner
Brian M. Welch
Robert W. Welch
Shane W. White
Matthew K. Wickham
John Wilcox
Debra E. Williams
Liangqing Xue
Hongliu Zeng
Omer Zobairi

BUREAU OF ECONOMIC GEOLOGY
The University of Texas at Austin
University Station, Box X
Austin, Texas 78713-7508

Address correction requested

NON-PROFIT ORGANIZATION
U.S. POSTAGE
PAID
Austin, Texas
Permit 391

BOOKS

BOOKS