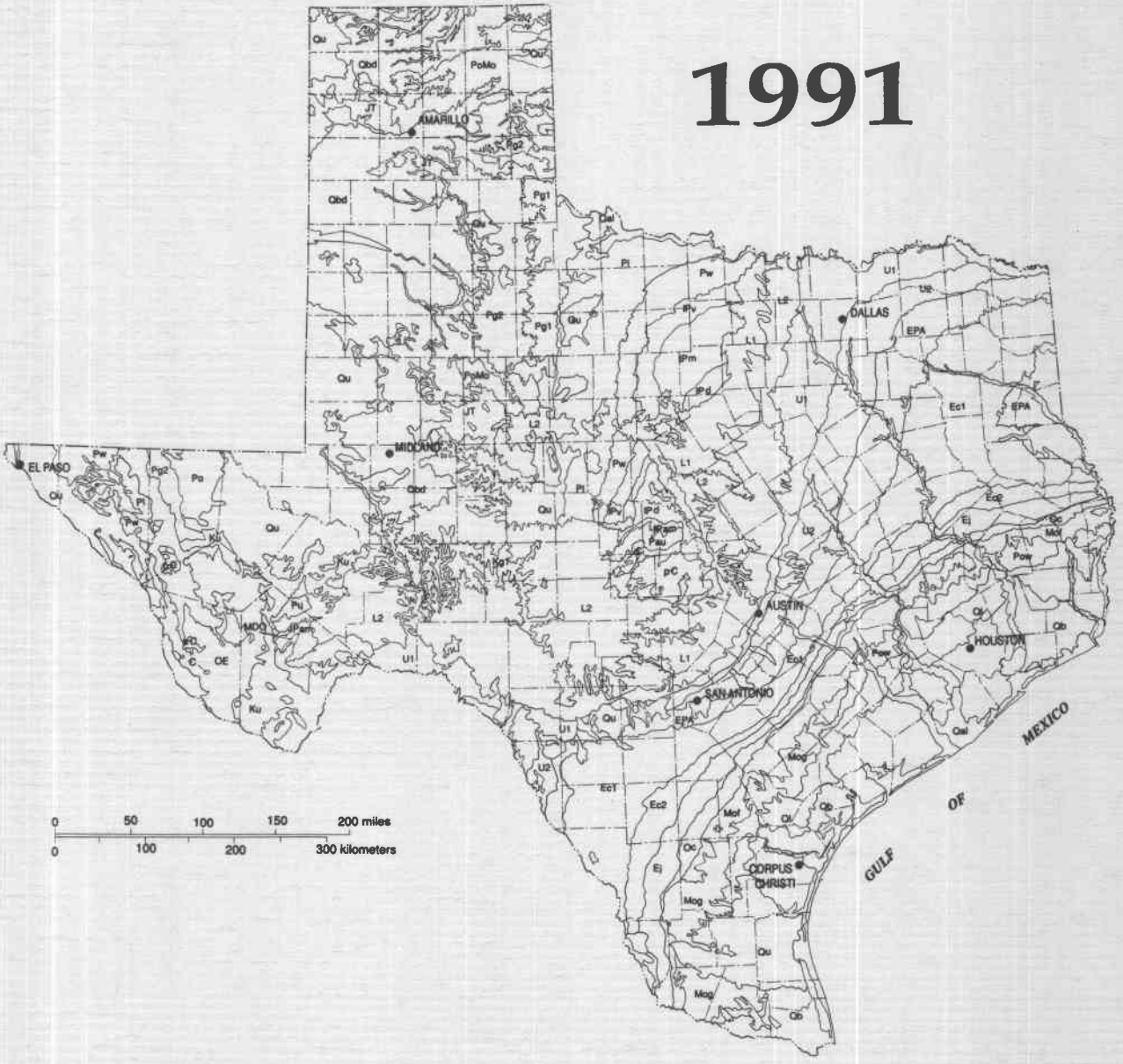
Annual Report

1991



Bureau of Economic Geology

W. L. Fisher, Director • The University of Texas at Austin • Austin, Texas 78713-7508

Foreword

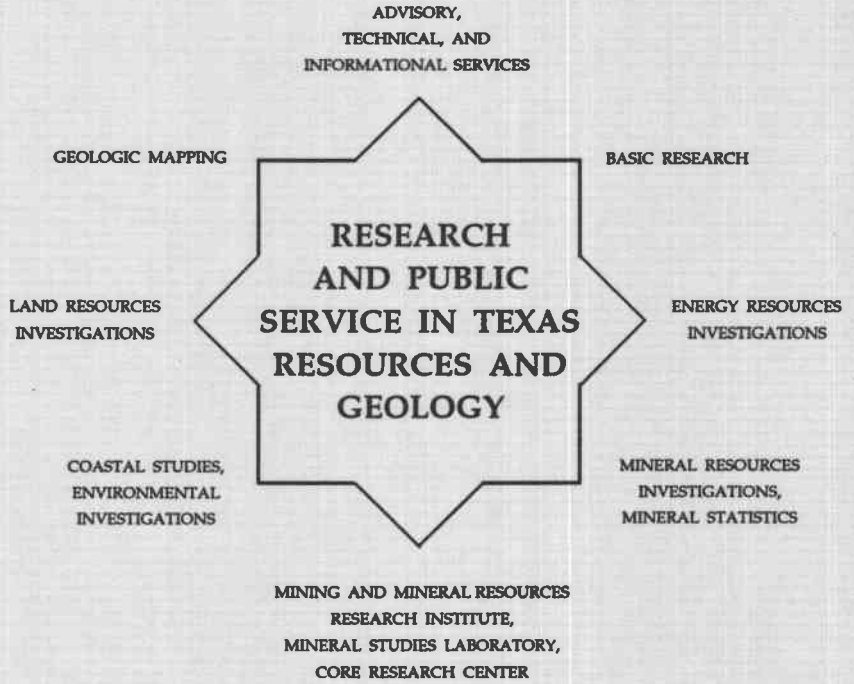
The Bureau of Economic Geology, established in 1909 as the successor to the Texas Geological Survey and the Texas Mineral Survey, is a research entity of The University of Texas at Austin. It also functions as the State Geological Survey, a quasi-State agency, and the Bureau Director represents Texas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

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

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

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

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



Cover: The full-color page-size Geologic Map of Texas and accompanying text will be published in 1992.

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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

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Austin, Texas 78713

Contents

Research

The Bureau of Economic Geology was involved in 56 research projects during 1991; 21 new projects were initiated during the year. 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. The Bureau's operating budget expanded from $12 million (1990) to more than $14 million from line-item State appropriations and from 71 outside contracts and grants. Interagency contracts with State and local governments numbered 32; 17 contracts were with the petroleum industry and private institutional foundations such as the Gas Research Institute; the remaining contracts and grants were with various agencies of the Federal government.

Several notable long-term projects of interest to the Texas public and to industry were successfully concluded during 1991. The *Tectonic Map of Texas,* mapped in 4 quadrants at 1:750,000 scale, incorporates extensive surface and subsurface geologic data from Texas and adjoining parts of Mexico, New Mexico, Oklahoma, Arkansas, Louisiana, and the Gulf of Mexico into a full-color representation of the regional structural configuration of Texas. An accompanying text describes the complex tectonic setting and evolution of Texas. *Restore,*© developed in-house by a researcher and a computer specialist, is a copyrighted program that enables a user to sequentially backstrip and balance geologic cross sections of extensional terranes, common settings for large hydrocarbon accumulations. Such restorations are vital for establishing the migration pathways of hydrocarbons and the evolution of structural traps. In a report published this year, Bureau geologists described the depositional framework and hydrocarbon distribution of Plio-Pleistocene strata of the southeastern Texas continental shelf and slope; many of these exploration plays offer potential for either new field discoveries or reserve growth.

Most of the 21 new projects initiated in 1991 address prominent environmental concerns within the state, reflecting recent nationwide interest in waste isolation, contaminant remediation, water quality, and coastal degradation. These new projects include

(1) a 5-year study funded by the U.S. Department of Energy to characterize the geology and hydrology at the Pantex Plant near Amarillo,

(2) geologic and ground-water characterization of the Eagle Flat region in Trans-Pecos Texas to enable the Texas Low-Level Radioactive Waste Disposal Authority to determine the suitability of the site as a waste repository,

(3) a study funded by the Lower Colorado River Authority to evaluate ground-water availability in a rapidly developing area in southeast Texas, and

(4) a Federally funded 5-year investigation of coastal land loss along the Texas Gulf Coast.

Ongoing (multiyear) environmental investigations emphasize ground-water and waste-isolation issues of importance to Texas and the nation. These projects include (1) investigation of the late Cenozoic climatic history of the continental interior to improve hydrologic models used to predict water-level changes in the critically important High Plains aquifer, (2) study of the colocation of geothermal-water reservoirs in the deep Wilcox Group below heavy-oil plays in the Mirando trend of South Texas and the economic viability of thermally enhanced oil recovery from this trend, (3) an assessment of the risk that abandoned exploration wells and brine-injection wells in New Mexico and Texas pose to underground sources of drinking water, and (4) characterization of the extent and geologic controls on contaminant migration from mill tailings at an inactive uranium-ore processing plant in western Karnes County, Texas.

As they did last year, energy-resource investigations continued to receive primary emphasis in Bureau research during 1991. The regional dimensions, internal complexity, and permeability structure of the fluvial-deltaic Ferron Sandstone of Utah are being studied to derive a better understanding of reservoir heterogeneity in subsurface reservoir analogs in Texas. The Bureau's multiyear study of San Andres and Grayburg reservoirs, another field-oriented project, received more funding from industry sponsors during the year. Continued focus on these reservoirs is warranted by the superb exposures in the Guadalupe Mountains, the extensive well-log data base, and the vast potential for reserve growth in these reservoirs. The State Lands Energy Resource Optimization (SLERO) project, managed by the Bureau, is a consortium of Texas State universities focusing on developing improved strategies for petroleum recovery from State Lands. Other long-term programs involving investigation of the regional genetic stratigraphy, structure, and energy resources of the Outer Continental Shelf and deep-water slope systems of the western Gulf Coast Basin received continued industry support during 1991.

Developing the necessary geologic and engineering knowledge to efficiently produce natural gas from low-permeability sandstone reservoirs remains a prominent focus of several Bureau projects funded by the Gas Research Institute. A 9-year Bureau program continues to investigate factors controlling porosity and permeability, fracture distribution, and state of stress in low-permeability gas reservoirs in Texas and Wyoming. Under this program, the Upper Pennsylvanian Cleveland Formation (western Anadarko Basin), the Upper Pennsylvanian Canyon Sandstone (Val Verde Basin and Ozona Arch), and the Upper Cretaceous Frontier Formation (Green River Basin, Wyoming) were studied. Another multiyear project funded by the Gas Research Institute, the U.S. Department of Energy, and the State of Texas addressed critical industry concerns regarding methods of extracting unrecovered natural gas resources remaining in heterogeneous nonassociated gas reservoirs. During 1991, 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) uses a variety of deformation devices, largely custom-designed by AGL researchers, to produce dynamically scaled models that replicate specific geologic structures. Two studies active during 1991 concentrated on the mechanical genesis of hydrocarbon traps in regimes of salt diapirism and of traps associated with rollover anticlines created by extension along listric normal growth faults.

Coastal studies conducted by the Bureau in 1991 involved examination of sediment-volume and vegetation changes along the Texas Gulf Coast. Such studies include (1) monitoring of losses and/or gains in wetland and seagrass habitats in the Galveston Bay System to help gauge the health of the bay environment, (2) determining the magnitudes and rates of recovery of the beach and vegetation line on Galveston Island, and (3) analyzing beach dynamics and recent historical variation in the shoreline and vegetation line of the upper Texas coast west of Sabine Pass. Interest in these studies is especially keen among local property owners and management councils of Texas coastal communities. Increased recognition of the environmental and economic impact of shoreline changes necessitates the gathering of current information on the status of coastal erosion.

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 1991–1992 academic year, four fellowships were awarded to support graduate research in ore deposition, mineral economics, and petroleum recovery in Texas.

Bureau geologic mapping projects conducted this year include (1) mapping of the recently designated Big Bend Ranch State Natural Area around the Solitario, (2) mapping of 70 7.5-minute quadrangles around the Dallas/Fort Worth area for use primarily in urban and land-use planning by the North-Central Texas Council of Governments, and (3) 1:100,000-scale mapping of the New Braunfels, Texas, Quadrangle, an area of rapid development in Central Texas.

Energy Resources Investigations

Petroleum

Geoscience Institute for Oil and Gas Recovery Research

Marcus E. Milling, Institute Director; F. Jerry Lucia

The Geoscience Institute coordinated a six-region, multistate, play-based classification of oil reservoirs in support of the U.S. Department of Energy's new recovery research program. The Institute established a six-member working committee to provide regional coordination for specific areas. Approximately 2,500 oil reservoirs in 25 states included in DOE's TORIS data base were classified in the study.

The classification system groups reservoirs into 1 of 14 depositional systems types. Additionally, each reservoir was categorized by diagenetic overprint and structural type. On the basis of this threefold classification approach, 70 reservoir categories were established that included 1,633 siliciclastic and 656 carbonate reservoirs having total original oil in place (OOIP) resources of 307 billion barrels (Bbbl). The largest oil reservoir classes are deltaic reservoirs, which have more than 850 reservoirs containing some 80 Bbbl OOIP.

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

Robert A. Morton, principal investigator; assisted by Michelle Mallien and Elizabeth J. Priday

This long-term industry-sponsored research program focuses on regional genetic stratigraphy, struc-

ture, and energy resources of the western Gulf Coast Basin. The primary data base, which has been gathered over the past 7 years, includes more than 2,500 conventional well logs and numerous paleontologic reports, seismic lines selected from regional grids, velocity surveys, scout tickets, and production records.

In 1991, 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 was 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. Also during 1991 a report was prepared that describes the depositional systems, structural framework, and petroleum resources of Plio-Pleistocene depositional sequences on the outer shelf and upper slope.

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 Andrew P. Czebieniak and William M. Fitchen

The long-term goal of the Reservoir Characterization Research Laboratory's San Andres/Grayburg program is the development of new generic methods for quantitatively describing carbonate ramp reservoirs that will provide better estimates of the quantities and location of remaining hydrocarbons. Continued focus on San Andres Formation reservoirs is driven by study of the superb outcrop exposures in the Guadalupe Mountains, the extensive subsurface data bases of some of the most mature oil reservoirs known throughout the world, and the vast potential for reserve growth in these reservoirs. However, increased emphasis is being placed on development of integrated geologic/engineering models of shallow-water nonfractured carbonate reservoirs worldwide.

Key elements of the generic model include development of sequence-scale and parasequence-scale carbonate ramp depositional models, a rock-fabric-based petrophysical model linked to the vertical facies succession of the parasequence, and geostatistical scaling functions for rock-fabric types. A standardized rock fabric-petrophysical classification utilizing associated porosity-permeability relative-permeability-saturation data is being developed to facilitate translation of geological facies into reservoir parameters for improved reservoir simulation.

Optimal translation of large-scale (third-order) sequence relationships from the outcrop-based stratigraphic model to the reservoirs is now strongly enhanced by the addition of a regional two-dimensional grid of high-resolution reflection seismic data covering the Northwestern Shelf and northern Central Basin Platform areas of the Permian Basin. Enhanced three-dimensional geologic and numerical modeling workstation capabilities are forming a basis for the quantitative evaluation of the high-resolution parasequence-scale geologic and petrophysical models. These additions have provided significant dividends in the form of outcrop-based stochastic and deterministic numerical models that provide new conceptual insights on the processes by which hydrocarbons become trapped or bypassed within reservoirs.

Testing of the outcrop analog approach for improved characterization of subsurface carbonate reservoirs is actively under way using the Seminole San Andres Unit as a pilot area. Subdivision of the reservoir into a parasequence framework and quantification of that framework through development of petrophysical transforms for calculating rock fabric, total and intergranular porosity, permeability, and initial and present saturation have been completed. Both two-dimensional and three-dimensional deterministic and stochastic models are currently being constructed to allow quantitative evaluation of the utility of this approach for understanding the distribution and producibility of remaining hydrocarbons.

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 Rainer K. Senger; assisted by Anil K. Mishra

The goal of this research program is to develop improved approaches to describing the heterogeneous flow architecture of carbonate reservoirs as related to conventional and enhanced recovery of hydrocarbons. This project, funded by the U.S. Department of Energy, is integrating geologic and petrophysical data from both the outcrop and selected reservoirs in order to better assess the interaction between stratal geometries, their defining rock-fabric elements, and fluid-flow behavior. Geostatistical approaches for scaling permeability and experiments using detailed numerical models give a quantitative evaluation of such critical processes as bypassing and cross flow in complex reservoirs.

In many carbonate-ramp reservoirs of the Permian Basin, much of the hydrocarbon resource is contained in subtidal outer-ramp clinoform strata whose inclined stratification is commonly not incorporated in standard

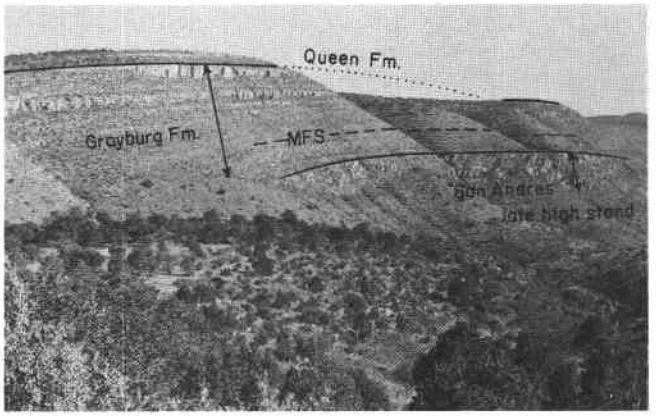
reservoir descriptions or reservoir simulations. This study thus focused on the outer-ramp clinoform portions of the San Andres outcrop along the Algerita Escarpment, northern Guadalupe Mountains, New Mexico, and equivalent strata in the Seminole San Andres Unit, Gaines County, Texas. Clinoform strata in these areas are characterized by low depositional dips (1 to 5 degrees) and subtle rock-fabric variations between mud-rich and grain-rich strata. Quantification of this rock-fabric structure was carried out using densely spaced geologic cross sections and core plug sample grids in outcrop and using core descriptions and permeameter data from the subsurface. Geostatistical analyses of petrophysical data from these clinoform strata show a maximum of one order of magnitude difference in permeability between mud-rich and grain-rich rock-fabric layers of the clinoforms.

Numerical models constructed using outcrop stratal geometries and both outcrop and subsurface petrophysical data suggest that where clinoforms are composed of carbonates with less than an order of magnitude difference in permeability and have 2 to 5 degrees of depositional slope, waterflood sweep efficiency is relatively high and early breakthrough problems should not occur. Additional experiments are currently testing alternate model parameters to evaluate when clinoform ramp stratal geometries will adversely affect waterflood sweep efficiency in the reservoirs. Characterization of this outer ramp facies tract is one element of a larger effort that is looking at productive intervals in other facies tracts of the San Andres.

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

Complex carbonate ramp reservoirs of the Permian Basin are characterized by large volumes of in-place hydrocarbons and low ultimate recovery factors. These reservoirs thus represent a main target area for improved incremental recovery of remaining hydrocarbons in Texas. Delineating a detailed genetic stratigraphic framework that can be quantified and integrated with an engineering model of the reservoir is an essential component of a recovery strategy. This project was designed to develop regional and detailed reservoir-scale models of the stratigraphic setting, external and internal characteristics, and petrophysical makeup of carbonate sand bodies and associated key reservoir facies that compose Grayburg reservoirs in the Permian Basin. The U.S. Department of Energy is funding the project through an agreement with the State of Texas.



Outcrop and subsurface reservoir studies of the Grayburg Formation were conducted during the Grayburg Carbonate Sandbar Facies study to elucidate the sequence framework and variability of petrophysical facies on an interwell scale. This updip exposure of the San Andres, Grayburg, and Queen Formations along the Shattuck Valley wall, central Guadalupe Mountains, includes a spectacular karst unconformity between the Grayburg and San Andres Formations. The complete 270-ft section of the Grayburg is exposed. MFS=maximum flooding surface.

A fundamental barrier to improved understanding of reservoir performance is the inability to predict continuity of reservoir flow units away from the well bore. This uncertainty has driven much of this research to be focused on Grayburg outcrops of the Guadalupe Mountains. These studies provide the distinct advantage of allowing complex lateral variations in geological and petrophysical properties to be analyzed across areas comparable to multiple well spacings in the reservoirs. Both regional scale (270 ft vertical by 5 mi lateral) and "interwell" scale (50 ft vertical by 2,500 ft lateral) studies were conducted. Regional-scale studies delineated the sequence stratigraphic framework of the Grayburg, consisting of a minimum of 34 parasequences contained in lowstand/transgressive and highstand systems tracts. Initial comparisons to producing Grayburg reservoirs show that highstand parasequences, and particularly shelf crest and outer shelf facies tracts, were those with the greatest development potential, as deduced by patterns of primary and secondary production.

Detailed outcrop studies in the Stone Canyon area included 1- and 0.5-ft grid sampling for facies, rock-fabric type, porosity, and permeability within individual parasequences. These data displayed a complex pattern of porosity and permeability both within and between depositional facies of single parasequences. Scale-averaging methodologies are being derived from these and other data collected in the Bureau's Reservoir Characterization Research Laboratory, and numerical models are being run to evaluate the impact of these scaling factors on fluid-flow simulation.

The ARCO North Foster Grayburg Unit was studied to evaluate potential benefits of applying an outcrop-based sequence stratigraphic model to guide construction of the reservoir framework. Seven cores and logs from 127 wells from the North Foster Unit and 17 cores and associated logs from adjoining units were used to establish both detailed and semiregional frameworks. A combination of comparable subsidence rates, geologic setting, and position relative to the precursor San Andres shelf margin for both the Shattuck Valley outcrop area and the North Foster Unit, situated on the eastern side of the Central Basin Platform, led to development of remarkably similar stratigraphic records.

Per-well production data for the North Foster leases show a trend of greatest production occurring along the eastern margin of the reservoir paralleling the shelf margin. This trend correlates with the facies change from shelf crest to outer shelf within the highstand systems tract. An increase in interparticle porosity, in addition to diagenetic enhancement of porosity along this basinward side of the unit, appears to be the primary control on productivity. Further, outcrop studies indicate that the outer shelf facies tract is characterized by high facies continuity and relatively thick, homogeneous rock-fabric units.

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; assisted by Edward S. Angle and Charles W. Cluck

This investigation of sandstone geometry and permeability structure is co-funded by the Gas Research Institute and the U.S. Department of Energy. Primary goals of the project are to (1) quantify the dimensions, internal complexity, and permeability structure of fluvial-deltaic sandstones within a sequence stratigraphic setting through detailed analyses of Ferron Sandstone outcrops in Utah and (2) derive a better understanding of reservoir heterogeneity in Gulf Coast sandstone reservoirs by transferring results of field investigations to the subsurface.

Field activities during the second year of the 3-year project included completion of outcrop quantification of seaward-stepping Ferron unit 5 and initiation of investigations of the landward-stepping Ferron unit 2. Vertical transects, in which the exposed rocks are described in detail and permeability is measured with a field minipermeameter, form the basis of the study. Locations of the measured sections are selected on the basis of degree of heterogeneity, as determined from continuous outcrop photomosaics that also provide information on the geometric attributes of the sandstone bodies. Particular attention is given to elements that could behave as flow units, flow baffles, and flow barriers in sandstone reservoirs. Vertical transects of unit 5 sandstones were measured in three canyons that expose sandstones deposited in progressively more distal environments than those studied during the first year of investigation. Permeability was measured at 6-inch intervals along each transect, and samples were collected for petrographic analysis. Exposures of unit 2 sandstones were selected for study after field reconnaissance, and a detailed grid was established for description and permeability measurement. To date, more than 150 transects have been described, more than 7,000 permeability measurements have been made on the outcrop, and approximately 250 samples have been collected for petrographic analysis. Permeability has also been measured at 1-inch intervals on slabbed core from the Ferron Sandstone to investigate the fine-scale permeability structure and to allow comparison of permeability values from outcrop and subsurface.

Permeability structure has been analyzed by means of semivariogram statistics. Results show that permeability structure is present at a range of scales that reflects depositional processes and architectural style. In laterally extensive sandstone bodies, permeability correlations correspond to features such as average distance between erosional discontinuities, channel dimensions, average vertical distance between lithologic discontinuities, average distance between stratal types, and dimensions of upward-fining sandstone bodies. Field mapping reveals a five-level hierarchy of bounding elements and flow barriers. The large-scale bounding elements are caused by transitions in depositional environment that result in sandstone-to-shale interfaces and by facies variations that result in sandstone-to-siltstone or sandstone-to-mudstone interfaces, whereas the smaller scale elements result from stratal contacts characterized by accumulation of mudclasts on erosional surfaces, or interfacies and intrafacies differences in grain size or bedding type. Petrographic analyses have demonstrated systematic differences in both detrital and authigenic mineralogy among the facies studied; preliminary results suggest that differences in pore structure may also be present.

Also during the second year of the study, two field trips were led to discuss preliminary results of the study with representatives of the oil and gas industry. Approximately 50 geologists and engineers from 12 companies participated in this technology transfer program.

Maximization of Petroleum Recovery Efficiency in West Texas

Noel Tyler, Consortium principal investigator; Stephen C. Ruppel, principal investigator; Mark H. Holtz; assisted by Randall K. Hill, Ronald A. Johns, and Robin D. Dommisse

Funded by the State of Texas through the Energy Research in Applications Program (ERAP), this project is a multidisciplinary, multifaceted study of advanced reservoir characterization and improved recovery processes directed toward improving oil recovery in the Monahans Clear Fork reservoir in West Texas. Research is being focused on Monahans field because it is typical of Clear Fork restricted platform reservoirs, which exhibit low recovery efficiencies and contain a large hydrocarbon resource potential. The Bureau is the lead institution in this consortium of 4 universities and more than 30 principal scientists and engineers.

Reservoir characterization research at the Bureau includes geological characterization and resource delineation studies of the Monahans reservoir. Geological studies indicate that the cause of the low recovery efficiencies exhibited by the Monahans reservoir is extreme vertical and lateral facies heterogeneity caused by high-frequency oscillations of sea level. The Clear Fork reservoir at Monahans records deposition during a single, 900-ft-thick, third-order eustatic cycle. The lower half of the reservoir is composed of predominantly subtidal, transgressive deposits formed during the third-order sea-level rise. Porosity and permeability in this part of the reservoir developed largely in grain-dominated pellet and skeletal packstones. The upper half of the reservoir, which was deposited during a third-order sea-level highstand, contains highly cyclic, upward-shallowing, progradational and aggradational inner-platform deposits. These rocks define higher frequency, fourth-order (50-ft-thick) and fifth-order (5-ft-thick) eustatic cycles. Porosity is locally developed in both base-of-cycle subtidal deposits as well as cycle-top tidal-flat deposits. Permeability, however, is largely restricted to subtidal facies. Tidal-flat porosity is generally composed of molds and small vugs (isolated leached fenestrae), whereas subtidal rocks contain intercrystalline, intergranular, and moldic porosity. Ongoing geological characterization research focuses on mapping fourth-order cycles and defining three-dimensional facies geometries across Monahans field. Flow-unit geometries are being defined through integration of core-derived petrophysical data with the facies model. The resulting flow-unit model will serve as the basis for reservoir simulation studies being conducted at other consortium institutions.

Resource delineation studies at the Bureau are directed toward defining the distribution of the remaining oil resource in the field. This research entails detailed analysis of production histories and trends and determination of petrophysical relationships based on analysis of core and wireline log data. Models of the distribution of original and remaining oil will be derived by incorporating these studies with the geological model and with engineering and geophysical data gathered by other consortium researchers.

State Lands Energy Resource Optimization (SLERO) Project

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

Project SLERO is a continuing project in which the Bureau serves as lead contractor for a five-university consortium—The University of Texas at Austin, Texas A&M University, The University of Houston, Texas Tech University, and Lamar University. Funding for this project is from the Office of the Governor of Texas, and the project is aided by the cooperation of the General Land Office of Texas.

The goal of the project is to evaluate oil and gas resources remaining on Texas State Lands and to develop strategies for maximizing the ultimate recovery of these resources. The project is divided into three parts: (1) play analysis and resource assessment, (2) reservoir characterization, and (3) advanced extraction technology. The project is interdisciplinary, involving geologists, petroleum and chemical engineers, geophysicists, and chemists.

Play Analysis and Resource Assessment

Texas State Lands contain 2,200 oil and gas reservoirs, including 926 reservoirs that have produced more than 1 million barrels of oil equivalent (MMboe). Of these reservoirs, 385 are major oil reservoirs, having a cumulative production of greater than 1 million barrels (MMbbl), and 541 are major gas reservoirs, having a cumulative production greater than 6 billion cubic feet (Bcf). Preliminary estimates indicate 1,900 MMbbl of mobile oil, 4,100 MMbbl of residual oil, and 2,300 Bcf of gas remaining in State Lands reservoirs.

Play analysis and resource assessment has focused on choosing candidate reservoirs for detailed study and analysis. The reservoirs chosen for detailed study represent four geologic oil plays and two geologic gas plays; together they encompass a major portion of the entire State Lands reserve base. The geologic plays are (1) the Permian Sandstone and Carbonate play (57 major reservoirs), (2) the Jackson–Yegua Barrier/Strandplain Sandstone play (132 major reservoirs), (3) the Delaware Sandstone play (34 major reservoirs), (4) the Miocene Barrier/Strandplain Sandstone play

(24 major reservoirs), (5) the Upper Cretaceous Olmos Deltaic and Delta-Flank Sandstone (tight gas) play (176 major reservoirs), and (6) the Downdip Frio Barrier/Strandplain Sandstone play (13 major reservoirs).

Reservoir Characterization

Six fields and one subregional study have been selected as representative of the major State Lands plays. Each of these reservoirs is undergoing detailed interdisciplinary study. A thorough geological, engineering, and geophysical understanding of these individual reservoirs will provide a model of similar reservoirs within each of the plays.

Keystone Field

Keystone field, in Winkler County, produces oil from multiple reservoirs. Two Permian reservoirs, the Colby (Queen equivalent) and the San Andres, have been chosen as representative of the Permian Sandstone and Carbonate play. Colby oil production is from thin, very porous sandstones deposited as widespread sheetlike sands in a shallow marine environment seaward of a carbonate tidal flat. These sandstones are interbedded with low-porosity dolostone and anhydrite beds deposited in a tidal-flat depositional environment. Updip pinchouts of the productive sandstones provide opportunities for recompletion and infill drilling in porous sandstones structurally higher than the most updip producing wells.

The San Andres reservoir produces from subtidal dolomitic wackestone and packstone that are cemented with anhydrite and gypsum. There are two porous and oil-productive zones in the San Andres Formation at Keystone field. Most production from the lower zone occurs at structurally high locations, whereas most production from the upper zone occurs at structurally low locations. Some overlap of these two zones at intermediate structural elevations provides recompletion opportunities. This reservoir has never been waterflooded, and the operator has requested the assistance of SLERO researchers to design and evaluate a pilot waterflood.

Seventy-Six West Field

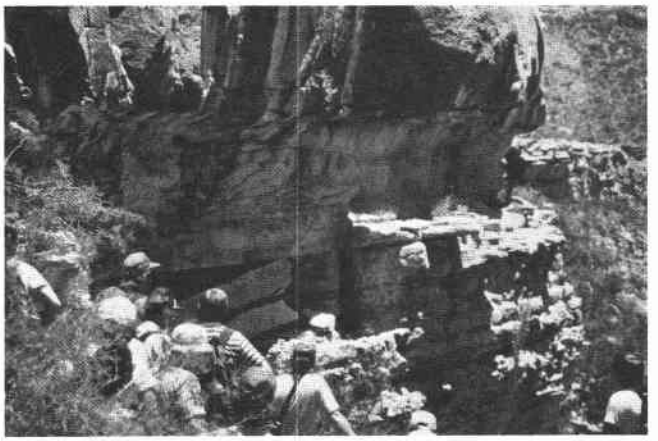
Seventy-Six West field, which is representative of the Jackson–Yegua Barrier/Strandplain Sandstone play, produces oil primarily from shallow, strike-elongate barrier-bar sandstones, crosscutting channel facies, washover sandstones, and tidal inlet-fill. Geologic characterization of this reservoir demonstrates compartmentalization within the reservoir caused by the complex facies arrangement, and structural elements further complicate reservoir distribution. Results of the study indicate zones within the reservoir that are either inefficiently drained or uncontacted at existing well spacing, and several infill drilling locations have been proposed to the field operator.

Although engineering analysis is still in progress, one significant finding suggests that additional oil can be recovered if reservoir pressure is increased. A geologically optimized pilot waterflood project, using produced water, is a major objective of the study.

Delaware Mountain Group Subregional Study

The Guadalupian Delaware Mountain Group in Loving, Reeves, and Culberson Counties produces oil and gas from multiple, thin, deep-water sandstones in the 1,000-m-thick Brushy, Cherry, and Bell Canyon Formations. Hydrocarbon accumulations in these shallow reservoirs are generally related to stratigraphic and hydrodynamic traps. Although hydrocarbons are produced from sandstones in all three formations, the bulk of production on State Lands occurs in the Bell Canyon, and to a lesser degree the Cherry Canyon, Formations.

Preliminary outcrop and core analysis and subsurface correlation indicate that sandstones were deposited during sea-level lowstands by dune progradation to the shelf edge and downslope transport of eolian sands as sediment gravity flows. This produces cyclical, sheetlike, upward-thickening sandstone packages. Subsequent sea-level rise resulted in progressively thinner sandstone beds and increased bioturbation, culminating in deposition of regionally extensive, black, organic-rich siltstones (lutites). Relating the eolian-turbidite depositional model to



Sandstones of the Cherry Canyon tongue of the San Andres Formation, Last Chance Canyon, Guadalupe Mountains. Study of this productive unit as part of the SLERO project is enabling Bureau geologists to more precisely correlate these basinal facies with San Andres platform carbonates and to clarify the Guadalupian evolution of the Delaware Basin of West Texas.

permeability-reducing northeast-trending lineaments explains Bell Canyon production trends and provides a preliminary exploration and development model for Delaware Mountain Group reservoirs on State Lands.

Powderhorn Field

Both oil and gas are produced from the lower Miocene Oakville Formation at Powderhorn field, a typical field in the Miocene Barrier/Strandplain Sandstone play. The 10 reservoir horizons were deposited in a variety of depositional environments, including fluvial channels and crevasse splays, bay-head deltas, tidal inlets, flood-tidal deltas, and washover fans. Current research is aimed at creating a geological-geophysical model of the field from existing well control and two-dimensional seismic data. The integrated model will enable prediction of the distribution of key reservoir properties such as porosity and fluid saturations between existing wells. A new three-dimensional seismic program scheduled for late 1991 will refine the geophysical model and allow mapping of reservoir facies and rock properties throughout the field.

Las Tiendas Field

The Olmos Formation reservoir at Las Tiendas field is representative of the Upper Cretaceous Olmos Deltaic and Delta-Flank Sandstone play. Gas is produced from strike-oriented shelf sandstones reworked by storms from nearby deltas and lower shoreface deposits. Porosity and permeability are preserved in the basal parts of individual sandstone units, below the depth to which burrowing fauna intermixed sand with overlying silt and clay. High oil productivity occurs in wells that penetrate only a few relatively thick sandstone units. Current research efforts are directed at constructing depositional models that predict the geometry of these storm deposits.

Lavaca Bay Field

Lavaca Bay field in Calhoun County is representative of the Downdip Frio Barrier/Strandplain Sandstone play. The productive stratigraphic section at Lavaca Bay can be divided into 5 major depositional sequences that contain 26 individual units, each of which may be a gas reservoir. There are now 19 proven gas reservoirs in the field.

Individual reservoirs are generally characterized by upward-coarsening sandstones deposited as stacked beach ridges or proximal shoreface deposits, which are vertically separated by shales deposited as shelf, prodeltaic-distal shoreface deposits. Sandstone thicknesses and depositional facies have been controlled somewhat by syndepositional growth faulting, and the structural and stratigraphic effects of this faulting have compartmentalized the reservoirs.

Preliminary results suggest infill drilling and multiple recompletion opportunities. Field development activity is largely dependent on the control of gas prices on the economics of drilling and recompleting.

Advanced Extraction Technology

Advanced extraction technology, the final phase of the project, involves using the results of reservoir characterization to design the most efficient strategies for recovering the remaining resource in State Lands reservoirs. Although most of the activity in this task will occur later in the project, work in collaboration with associated academic institutions is already under way to design waterflood programs, surfactant flood fluids, and well-stimulation strategies in the context of the specific geological and engineering characteristics of State Lands reservoirs.

Geologic Support of Cross-Hole Tomography

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

This continuing project, funded by The University of Houston, provides geologic support for a series of cross-hole tomography experiments being conducted by The University of Houston's Allied Geophysical Laboratories. 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.

Seventy-Six West field in Duval County, Texas, is the test site. Initial cross-hole experiments, which were designed to test several different prototype source tools, were conducted in the Oligocene Frio Formation at a depth of 600 ft. The Frio is composed of sandstones occurring in channels of dip-oriented, mixed-load to bed-load fluvial systems. Preliminary results suggest that this technique has the potential to image features as thin as 1 ft between wells as far apart as 600 ft. Although the Frio Formation is not productive at Seventy-Six West field, this formation contains numerous prolific reservoirs on the Texas Gulf Coast.

Future cross-hole experiments at Seventy-Six West field will be conducted in the Eocene Jackson-Yegua reservoir, which produces oil from a depth of 1,300 ft. The Jackson-Yegua reservoir is composed of sandstones deposited as a complex of barrier/strandplain sand bodies. Cross-hole tomography in this reservoir could identify untapped reservoir compartments and, thus, infill drilling and recompletion targets.

Kinetic and Geochemical Aspects of Near-Surface Dolomitization

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

This continuing project, funded by the Advanced Research Program of the Texas Higher Education Coordinating Board, is investigating a geologically young (Plio-Pleistocene) partially dolomitized carbonate formation on the Island of Bonaire, Netherlands Antilles. Because these rocks have never been buried more than a few meters deep, and because the island setting limits the sources for dolomitizing fluids, Bonaire Plio-Pleistocene rocks are an important young analog for interpreting the near-surface diagenetic processes that may have been critical in the formation of ancient, deeply buried dolomites.

Field relationships, mineralogy, and geochemistry indicate that the Plio-Pleistocene rocks of Bonaire were formed by seawater-derived brines that were evaporatively concentrated to salinities beyond the point of gypsum saturation in a sea-margin lagoon. The density of these brines caused them to move downward, and gypsum precipitation elevated the magnesium/calcium ratio, resulting in a pore water capable of dolomitization. Pore spaces in dolomitic rocks close to the source of the brine have been more thoroughly filled by dolomite than those several hundred feet from the source of the brine. This observation has important implications for understanding porosity distribution in, and, therefore, oil production from, dolostone oil fields of the Permian Basin, West Texas.

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

William L. Fisher, principal investigator; Mark H. Holtz, Noel Tyler, and Chester M. Garrett, Jr.; and Milton Holloway, Southwest Econometrics

The object of this project, funded by the Office of the Governor 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 were 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.

From 1978 through 1988, advanced secondary recovery (ASR) added 1.3 billion stock tank 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 during this period. During the next 20 years under proposed Senate 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 bill, ASR will add 8.9 BSTB in reserves, which is an incremental reserve addition of 3.7 BSTB. If the bill is modified EOR oil reserve additions will be 7.7, thus adding an incremental 2.2 BSTB of reserves. These results indicate that with additional tax incentives for ASR and EOR a 55-percent incremental reserve additions increase would take place within the next 20 years.

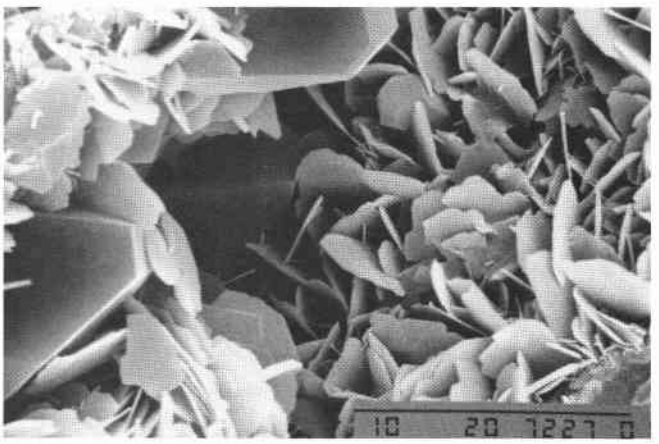
Gas

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, and Stephen E. Laubach; assisted by David W. Hill, Glenn A. Klimchuk, Jennifer Kopf, John M. Mendenhall, and Robert S. Single; in cooperation with the Wyoming Geological Survey

Low-permeability formations contain an estimated 900 Tcf of gas in place in the lower 48 states, and increased production from these reservoirs would contribute significantly to the supply of natural gas. Since 1982 the Gas Research Institute (GRI) has supported Bureau investigations of the geology of low-permeability sandstone reservoirs because geologic properties exert a fundamental influence on reservoir performance and gas production. This effort by the Bureau is part of a broader program designed to increase the understanding and ultimate utilization of gas resources in low-permeability formations through integration of geology, formation evaluation, reservoir engineering, and fracture modeling.

In 1991, the Bureau's research consisted of two major components: (1) conducting a screening of low-permeability formations to identify a suitable location for the GRI Hydraulic Fracture Test Site (HFTS) and (2) investigating reservoir geology of three low-permeability formations, the Upper Pennsylvanian Canyon Sandstone, Val Verde Basin, Texas, the Upper Pennsylvanian Cleveland Formation, Anadarko Basin, Texas, and the Upper Cretaceous Frontier Formation, Green River Basin, Wyoming. The Wyoming Geo-



Scanning electron microscope (SEM) photograph of authigenic chlorite flakes and quartz overgrowths (blocky grains) lining a pore in a low-permeability gas-bearing sandstone from the Cleveland Formation, Anadarko Basin, Ochiltree County, Texas. This type of iron-rich chlorite reacts to HCl acid treatments by forming a pore-plugging iron-hydroxide gel. Sample depth equals 7,227 ft; bar length equals 10 µm. Photograph by John Mendenhall.

logical Survey has been subcontracted for parts of the study of the Frontier Formation.

The objective of the HFTS is to provide a field laboratory for conducting multidisciplinary research projects to assess the mechanics of hydraulic fracturing of low-permeability sandstones. As a result of the screening process to identify a formation that has the qualities necessary for this natural laboratory, the Lower Pennsylvanian Davis Sandstone in the Fort Worth Basin, Texas, emerged as the formation that best fit the selection criteria. The Davis Sandstone was tested in a research well in Wise County, but an abundance of natural fractures in core recovered from the well indicated that the Davis would not be a suitable test site. However, analysis of Davis Sandstone core from the research well and other nearby wells provided useful insight into the natural-fracture systems of this low-permeability gas reservoir. Other candidate formations that were identified in the HFTS screening process are now being investigated.

Regional geologic studies of the low-permeability Canyon Sandstone are being conducted in southwest Texas (Schleicher, Sutton, Edwards, Val Verde, and Crockett Counties) in the area of the Val Verde Basin and Ozona Arch. Detailed studies, including mapping of structure and sandstone geometry, construction of detailed cross sections, and description and interpretation of core, have been 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 Texas Panhandle. Mapping of structure, formation thickness, and sandstone thickness was used to delineate reservoir distribution, interpret depositional history, and characterize component facies. Cores from Ellis Ranch field, Ochiltree County, and Lipscomb SW field, Lipscomb County, were used for calibrating well logs and interpreting depositional processes and facies.

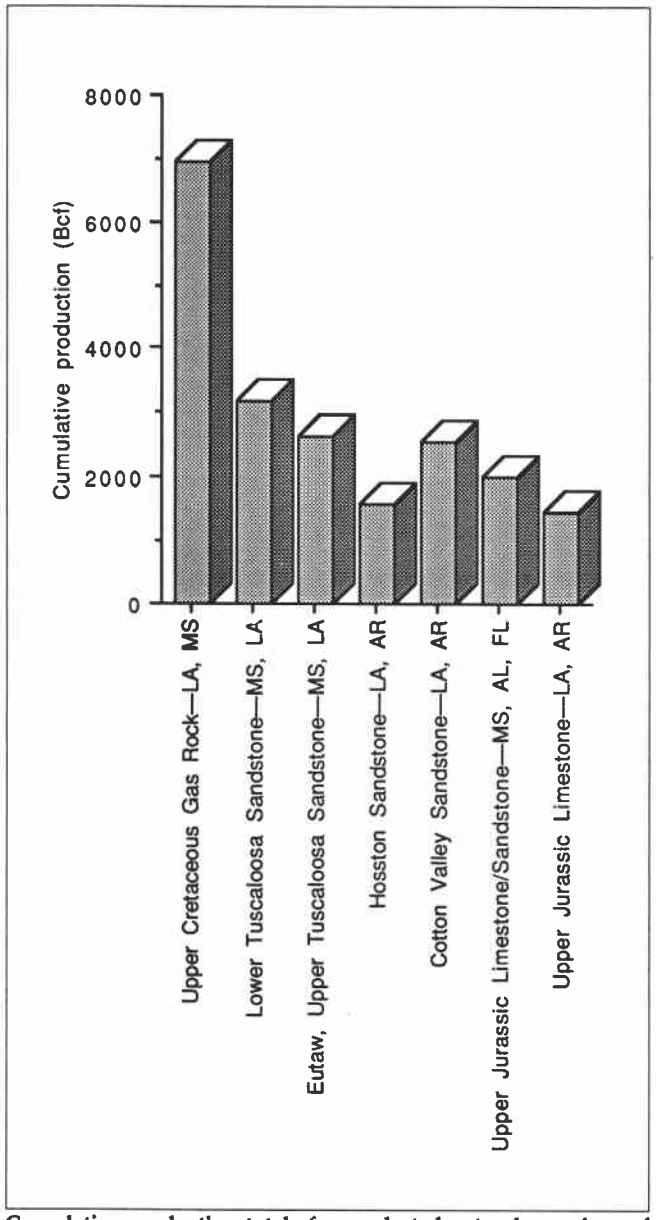
Work on the Frontier Formation in 1991 concentrated on synthesizing the results of regional studies of the depositional history, reservoir distribution, diagenesis, and structure of the Frontier along the Moxa Arch in the western Green River Basin. Summary contract reports on the stratigraphy and diagenesis of the Frontier Formation were completed.

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 Rick W. Reeves and Syed A. Rasool; 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 Gas Research Institute has funded this 3-year project to produce two gas atlases encompassing production from (1) Central and Eastern Gulf Coast and (2) Midcontinent. Reservoirs in these two regions that have produced more than 10 Bcf of associated and nonassociated gas will be organized into plays based on geological and engineering features. The geological surveys have been responsible for collecting the data for reservoirs in their respective states.

Twenty-three plays have been recognized in Alabama, Mississippi, northern Louisiana, and southern Arkansas. Two of these plays are in the Pennsylvanian and Mississippian sections of the Black Warrior Basin, 6 are in upper Jurassic sandstones and carbonates, 13 are in Cretaceous sandstones and carbonates, and 2 are in Eocene sandstones. The largest of these plays is the Upper Cretaceous Gas Rock with cumulative production of 7 Tcf of nonassociated gas, followed by Lower Tuscaloosa Fluvial to Shallow-Marine Sandstone—Mississippi and Louisiana with 3.2 Tcf, Eutaw-Upper Tuscaloosa Shallow-Marine Sandstone—Mississippi Interior Salt Basin with 2.6 Tcf, Cotton Valley Shallow-Marine Sandstone—North Louisiana/South Arkansas with 2.2 Tcf, Upper Jurassic Shallow-Marine Carbonate and Sandstone—Mississippi Interior Salt Basin with 2 Tcf, and Upper Jurassic Shallow-Marine Carbonate—ARKLATEX Region with 1.5 Tcf. This Central and Eastern Gulf Coast atlas, scheduled to be completed by mid-1992,



Cumulative production totals from selected natural gas plays of the central and eastern Gulf Coast and Midcontinent.

will include production and engineering data that have not previously been available for Louisiana on a per-reservoir basis. For this atlas, all plays except the Oligocene and Miocene plays of southern Louisiana are now complete.

Basic production, engineering, and geological data are still being collected by the geological surveys of Arkansas, Kansas, and Oklahoma for reservoirs in the Midcontinent region. Several of the plays in the Oklahoma Arkoma Basin and in southwestern Kansas have been completed. Work on the Midcontinent atlas was initiated in mid-1990 and is scheduled to be completed 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, Bob A. Hardage, Richard P. Langford, Jeffry D. Grigsby, Lee A. Jirik, Dennis R. Kerr, and Andrew R. Scott; assisted by Nina L. Baghai, Laura L. Brock, Najah F. Ghandour, Autumn L. Laughrun, John M. Mendenhall, Randy L. Remington, Asad M. Sattar, Robert S. Single, Lisa E. Sparlin, and Liangqing Xue

The Bureau is the lead technical contractor for the Secondary Natural Gas Recovery project that is funded by the Gas Research Institute (GRI), the U.S. Department of Energy (DOE), and the State of Texas. Activities in the third year of this gas-field-oriented research project focused on fluvial-deltaic reservoirs of the middle Frio and Vicksburg Formations and the Wilcox Group. Significant progress was achieved toward the goals of this joint venture, including (1) confirmation that incremental conventional gas resources represent a large percentage of new gas reserves, (2) assessment of the distribution of incremental natural gas resources by depositional system, and (3) definition and testing of state-of-the-art, cost-effective tools and strategies for incremental recovery.

Engineering analysis and reservoir modeling are being conducted by Research and Engineering Consultants of Englewood, Colorado, and formation evaluation by ResTech, Inc., of Houston. Envirocorp Services and Technology of Houston monitored drilling and completion activity and coordinated field-data acquisition in four Texas gas fields. In 1991 analysis of the Vicksburg Formation culminated in two GRI topical reports that document the degree of reservoir compartmentalization and use of dipmeter log evaluation in Gulf Coast Basin gas reservoirs. A two-dimensional finite-element reservoir simulation integrated geologic, petrographic, formation evaluation, and engineering data and documented the existence of gas resources within laterally continuous reservoirs with long production histories (>30 years) deposited in delta-front sandstones.

Two cooperative wells drilled by Mobil Exploration and Producing U.S., Inc., at Lake Creek field provided whole cores, wireline pressure tests, resistivity measurement while drilling, microresistivity borehole images, and a dipole sonic log. Analyses of well logs and cores at Lake Creek field show that gas reservoir units comprise laterally extensive, sandstone-rich delta-front facies capped by transgressive delta-destructional sandstones. Results are being compared with the parallel effort of the Bureau's GRI-supported research on outcrops of the Cretaceous Ferron Sandstone in central Utah. Geophysical data acquisition to analyze thin gas reservoirs typical of the onshore Gulf Coast

Basin included the collection and processing of a three-dimensional surface seismic grid and a unique reverse three-dimensional vertical seismic profile data set across Seeligson field with the cooperation of Oryx Energy and Mobil Research and Development Corporation. Reprocessing of conventional two-dimensional reflection seismic data from Stratton field documented significant frequency improvement as an advantage in reservoir delineation.

Petrophysical analysis of middle Frio gas reservoirs included special core analysis and state-of-the-art cased-hole log evaluation for bypassed gas. Progress was made in determining formation pressure by indirect well-log measurements in both open and cased holes. Cooperative engineering tests with Union Pacific Resources (UPR) in Stratton field and with Oryx Energy in Seeligson field included shut-in and build-up pressure measurements using single well tests for determination of near-borehole permeability and reservoir boundaries. A key project product is the development of user-friendly, personal-computer-based software for analyzing multicompartment behavior of gas reservoirs to help operators identify incremental gas within incompletely drained reservoirs.

Carbonate field screening focused on upper Paleozoic reservoirs in West Texas and Cretaceous reservoirs in East Texas, and results point to the existence of incremental gas resources. Activities in 1992 may include limited cooperative field evaluations with gas operators to test concepts developed during the research program. Evaluation of gas reservoirs in the Wilcox Group (Lake Creek field) and Frio Formation (Stratton and Seeligson fields) will be completed. Technical transfer of results will include short courses, technical presentations, and published articles and reports designed to help gas producers maximize the recovery of gas in existing fields by implementing cost-effective strategies during field development.

Extrapolation of Gas Reserve Growth Potential: Development of Examples from Macro Approaches

Robert J. Finley, project director and principal investigator; Mary L. W. Jackson, Laura Lee Moffett, Chih-Peng Yu, and Pedro J. Gamboa

The Macro Approaches project, a 1-year project funded by the Gas Research Institute (GRI), focused on analysis of gas reserve growth from infield drilling in South Texas. The project was designed to geologically validate a large-scale statistical analysis of South Texas natural gas-well completions undertaken by Energy and Environmental Analysis, Inc. (EEA), for GRI.

Large volumes of production data and analyses of existing completion density and per-well recoveries were used to identify stratigraphically defined trends that suggest potential for incremental gas recovery using conventional recompletion methods. This "macro assessment" suggested significant reserve growth potential in the Frio Formation, where more than 30 vertically stacked reservoirs may occur in a single field within a 2,000-ft interval.

In the Macro Approaches project, reservoir completion intervals were examined on well logs to verify stratigraphic position of producing intervals defined in the EEA macro assessment. Well logs were grouped into 2- to 7-completion sets within a 640-acre area and within a single reservoir. More than 150 completion sets were examined for geological continuity in the Frio Formation using depositional systems analysis and production information. Completion examples in the Wilcox Group, Vicksburg Formation, and Miocene strata in South Texas were also analyzed for reserve growth.

In about 20 percent of the completion sets studied, the completions are not in the same genetic sandstone unit but are in sandstones separated by 10 to 100 ft of shale. Potential for incremental gas recovery may come from completions in partially or totally shale-isolated sandstones within multichannel reservoir zones. Potential incremental gas indicated by the remaining examples may come from perforations made between more subtle intrareservoir barriers similar to those being tested in the Secondary Natural Gas Recovery (SGR) project.

In addition to validation of the EEA macro assessment analysis, this project provides a regional perspective for field-specific analyses performed in the SGR project. The Macro Approaches project complements SGR project goals by confirming that playwide opportunity for gas reserve growth exists in reservoirs similar to those tested in the Frio Formation within Stratton and Seeligson fields.

Geologic Evaluation of Critical Production Parameters for Coalbed Methane Resources

Walter B. Ayers, Jr., and William R. Kaiser, principal investigators; Roger Tyler, William A. Ambrose, Andrew R. Scott; assisted by Stephen E. Laubach, Douglas S. Hamilton, Mary L. W. Jackson, Garth J. Hawkins, Ronald G. McMurry, Naijiung Zhou, and Sonya Jones; in cooperation with the West Virginia Geological and Economic Survey, Pennsylvania Topographic and Geologic Survey, and Colorado Geological Survey

The goal of this project, funded by the Gas Research Institute (GRI), is to determine geologic and hydrologic controls on the production of coalbed methane. The

Bureau researcher Roger Tyler examining an intrusive igneous dike in coal (upper and lower dark layers) and sandstone (middle light layer) of the Upper Cretaceous Vermejo Formation in the Raton Basin, south of Trinidad, Colorado. Geologic features such as dikes, natural fractures, faults, folds, and coalbed pinchouts locally affect continuity, permeability, and producibility of coalbed methane reservoirs.

Bureau is leading the evaluation of the coalbed methane potential of intermontane basins in the western United States; the Colorado Geological Survey is subcontracted for data collection and logistical support. The West Virginia Geological and Economic Survey (WVGES) and Pennsylvania Topographic and Geologic Survey (PTGS) were subcontracted to study the Northern Appalachian Coal Basin.

A comprehensive topical report completed in 1991 on behalf of GRI (GRI-91/0072) characterized geologic and hydrologic controls on the occurrence and producibility of coalbed methane in the San Juan Basin, the nation's leading producer of coalbed methane; in 1990, production was 154 Bcf. The report summarized 3 years of research and is being revised for joint publication by the Bureau, Colorado Geological Survey, and New Mexico Bureau of Mines and Mineral Resources. Geologic studies showed that coal-seam occurrence and geometry are controlled by depositional setting. The thickest coal seams trend northwestward and occur in the north-central part of the basin, northeast of a structural hingeline and southwest of and parallel to Pictured Cliffs shoreline sandstones. Hydrologic studies delineated reservoir conditions. Potentiometric anomalies and abnormal pressure were numerically simulated and reflect regional permeability contrasts. Overpressuring is artesian in origin. In an integration of geology and hydrology, the San Juan Basin was divided into regions having similar geologic and hydrologic characteristics to define areas with optimal conditions for coalbed methane production. The overpressured north-central part of the basin is the most productive region. The basin's most productive wells deliver up to 15,000 Mcf/d and occur along a structural hingeline in association with a regional permeability barrier where large volumes of gas may be conventionally trapped.

As part of GRI's ongoing assessment of natural gas supply, the Bureau reviewed geologic and hydrologic characteristics of seven other western basins to help select a basin suitable for continued coalbed methane research. In the context of lessons learned in the San Juan Basin, the Bureau evaluated, on the basis of available data, the coalbed methane potential of the Greater Green River, Piceance, Powder River, and Raton Basins. The results of this comparative study are summarized in a topical report to GRI that will be available in early 1992.

The Greater Green River and Piceance Basins have the highest near-term coalbed methane potential, and the Piceance Basin has the highest reported gas resources. Assuming that structural complexity and regional dip changes translate into fracture enhanced permeability and conventional trapping of gas, the Greater Green River Basin is judged slightly more favorable. Depositional setting favors the Greater Green River Basin because the greater overall thickness of its coal-bearing stratigraphic interval offers numerous coalbed methane targets basinwide at economically exploitable depths. Hydrologically, the Greater Green River Basin is favored because hydrologic elements suggest overall high permeability and extensive areas where exceptional production could occur. In contrast, generally low permeability is inferred from the hydrology of the Piceance Basin. Higher rank, higher gas-content coals give the Piceance Basin an advantage over the Greater Green River Basin. Coalbed methane production and industry activity are highest in the Piceance Basin, but an intrastate pipeline system limits deliverability of gas out of the basin. Overall, the Greater Green River Basin was judged to be a potentially significant contributor to the nation's gas supply and was recommended for continued coalbed methane research. The Bureau began work in this basin in September.

Studies of coalbed methane in the Northern Appalachian Coal Basin focused on Pennsylvanian-age coal beds of the Pittsburgh-Huntington Synclinorium (Dunkard Basin) in northern West Virginia and southwestern Pennsylvania. Although the Pittsburgh coal is the best known coalbed methane target, coal beds below the Pittsburgh are also potential targets. Thus, researchers at the WVGES and PTGS investigated the stratigraphy, structure, resources, production, and petrography of Monongahela through Pottsville Group coal beds. The Allegheny, basal Conemaugh, and basal Monongahela Groups contain the most prospective coal beds. Conventional structural trapping is an important control on the occurrence and producibility of coalbed methane. Production is associated with the crests and flanks of anticlines. A positive correlation between maceral and gas content was demonstrated. The results of the Appalachian

study are summarized in a report to GRI that will be available in early 1992.

Coal

Computerized Calculation of Lignite Resources in Texas

William R. Kaiser, principal investigator; Mary L. W. Jackson

This long-term project, funded by the U.S. Geological Survey (USGS), 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 in USGS Circular 891 (Coal Resource Classification System of the U.S. Geological Survey) and criteria consistent with current mining practice in Texas.

No resources were calculated in 1991 because programming assistance requested from the USGS was delayed by its acquisition of new hardware and software. With funds provided by the USGS, a Silicon Graphics IRIS Indigo RISC workstation was purchased to implement the new software. Resource calculation is now scheduled to resume in 1992 in the Jackson-Yegua trend of East Texas and Jackson and Wilcox trends of South Texas.

Trinity Lignite Mine

William R. Kaiser, principal investigator

This project was funded by the Public Utility Commission of Texas (PUC) to evaluate lignite resources at the proposed Trinity mine in western Henderson County south of Malakoff, Texas. The evaluation was done on behalf of the PUC's General Counsel as part of a larger application by Houston Lighting & Power Company (Docket No. 9850) to change electric rates. Written testimony provided to the General Counsel in March reviewed the mine's geology and hydrology, verified the quantity and quality of the reserves, and established a fair market value for the lignite in 1985 and 1990.

Experimental and Applied Tectonics Investigations

Applied Geodynamics Laboratory

Martin P. A. Jackson, laboratory director; Bruno C. Vendeville, Daniel D. Schultz-Ela, Hemin Koyi, and John G. Sclater; assisted by Hongxing Ge, Shing-Tzong Lin, and Kathleen M. Strub

The Applied Geodynamics Laboratory (AGL) carries out 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 Petroli S.p.A., Amoco Production Company, ARCO Oil and Gas Company, BP Exploration, Inc., Chevron Oilfield Research Company, Chevron U.S.A. Inc., Conoco, Inc., Elf Exploration, Inc., Exxon U.S.A., Inc., Exxon Production and Research Company, Marathon Oil Company, Mobil Research and Development Corporation, Petroleo Brasileiro, Phillips Petroleum Company, Shell Oil Company, Texaco Services, Inc., and Total Minatome Corporation.

For modeling in an accelerated gravity field, a high-speed, high-capacity centrifuge was used. The machine is equipped with a viewing hatch, stroboscopic lighting, and digital speed and temperature controls. During the year, the centrifuge rotor was reconfigured to accommodate a sliding ram for experiments on extension and shortening. Most experiments were carried out in a deformation rig in a normal gravity field, allowing simulation of almost any structural style, including extension, shortening, wrenching, doming, and drape folding, or any combination of these styles. The rig comprises (1) a modular framework that can be assembled in many configurations, (2) six 2-ton screw jacks, (3) seven flexible drive shafts, (4) two stepper motors, (5) two electronic indexers, and (6) a personal computer for control. A biaxial rig built during the year allows experiments with simultaneous shortening or extension in two directions. Other equipment built includes a highly accurate coaxial viscometer for measuring flow properties of modeling materials and a motorized sheet roller for manufacturing sheets of putty. Accessory equipment includes two motorized deformation tables and four cameras. Modeling materials include silicone polymers, silicone putties, Plasticine, quartz sands, glass sand, glass bubbles and beads 25–60 μm in diameter, clays, paraffin waxes, petrolatum, rosin, dyes, and computer-generated, printable grids of strain markers.

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 lateral intrusion mechanisms of salt tongues, (2) influence of basement faulting on the growth of salt diapirism and overburden faulting and folding, (3) piercement of transtensional grabens in brittle overburden by postdepositional diapirs, (4) control on the shape of downbuilding diapirs by concurrent sedimentation, and (5) influence of progradation on growth faulting and diapirism. The first synthetic seismograms were

generated by the raytracing software QUIK™. Additionally, a pilot version of a program for numerical modeling by boundary elements was used to model the stress conditions for faulting above an actively intruding salt diapir.

The Macintosh-based *Restore©* computer program for structurally restoring cross sections was published and is being marketed by the Bureau. The program was demonstrated in the Apple™ booth at meetings of the SEG and AAPG and at an Apple Technical Solutions Conference. *Restore©* was expanded with modules for simple depth-conversion and for correcting vertical exaggeration, and several other modifications suggested by users have been made.

Rollover Kinematics of Growth Faults

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

This 2-year project is funded under the Advanced Research Program by the Texas Higher Education Coordinating Board. The project investigated 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 helps explorationists predict structural geometry at depth where seismic reflection data are indistinct.

The study uses a combination of research approaches. Carefully scaled physical models were experimentally deformed to produce analogs of the natural structures, with particular emphasis on three-dimensional deformation and high finite strains. The interplay between sedimentation, folding, and faulting was studied. The geometry of the physical models and of natural examples throughout the world was analyzed by computer to determine their modes of formation. Results will be published in *Marine and Petroleum Geology.*

Scale Modeling of Hydrocarbon Traps Formed by Diapirism and Growth Faulting

Martin P. A. Jackson and Jay A. Raney, principal investigators; Bruno C. Vendeville, Daniel D. Schultz-Ela; assisted by Shing-Tzong Lin, Hongxing Ge, and Kathleen M. Strub

This 2-year project is funded under the Advanced Technology Program by the Texas Higher Education Coordinating Board. It is a program of physical and seismic modeling of structural hydrocarbon traps in regimes of extensional salt tectonics. The project focused on systematic modeling of structures in three dimensions to determine the evolutionary steps and mechanical principles of their formation. 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." Physical modeling was followed by seismic modeling to simulate the appearance of the physically modeled traps and structures on time-migrated and nonmigrated reflection seismic images. Synthetic seismograms were generated using the raytracing program QUIK™. They 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

Hydrologic Studies near Fort Hancock, Texas

Alan R. Dutton, principal investigator; Bridget R. Scanlon; assisted by Sung-Chi Hsu and Yao-Chang C. Chang

Hydrologic studies to evaluate unsaturated flow processes for a potential low-level radioactive waste repository in Trans-Pecos Texas included monitoring water potential with psychrometers and conducting numerical flow simulations. Water potential was monitored in two profiles to a maximum depth of 20 m. This long-term monitoring provides a unique data set for evaluating the effect of varying climatic conditions on subsurface moisture flux. Numerical simulations were used to examine the hydrologic processes in the unsaturated zone and to evaluate the controlling hydraulic parameters. Results from these simulations indicated that the wetting front penetration depth was most sensitive to variations in the applied flux and was insensitive to differences in the initial water potentials and hydraulic conductivities. The relative importance of liquid and vapor flow in the shallow unsaturated zone was determined using nonisothermal flow simulations and showed that downward vapor flow in response to temperature gradients is dominant in the upper meter of the unsaturated zone.

Results of the monitoring program and the numerical simulations have important implications for repository cap design. Decreasing water potential with depth suggests an upward-driving force for liquid and isothermal vapor movement. This characteristic of the natural system is favorable for waste disposal and suggests that the repository cap design should mimic as much as possible the natural system. Sensitivity of the wetting front penetration depths to variations in the applied flux suggests that leakage rates from the disposal facility will be critical in controlling migration of contaminants. Downward vapor transport shown by the nonisothermal flow simulations indicates that volatile contaminants in the surficial sediments should migrate deeper than nonvolatile contaminants. This assumes that the natural temperature gradients prevail in the trench cap.

In addition to providing information relevant to disposal of low-level radioactive waste, the results of these studies further our understanding of unsaturated flow processes in arid systems. These findings are being published by the Bureau and by peer-reviewed journals.

Geologic and Geohydrologic Studies of the Eagle Flat Region, Hudspeth County, Texas

Jay A. Raney, principal investigator; Jonathan G. Blount, Charles W. Kreitler, and E. G. Wermund; assisted by Bruce K. Darling and Randall K. Hill

In 1991 the State of Texas continued its search for a site for a repository for low-level radioactive wastes. The Texas Legislature designated the Eagle Flat region, near Sierra Blanca, Hudspeth County, Texas, as the region in which the Texas Low-Level Radioactive Waste Disposal Authority should attempt to locate a site for the repository. The Bureau was asked to conduct geologic and hydrologic investigations that will provide data for the Authority to use to locate potential sites. Further investigations by the Bureau will evaluate specific locations determined by the Authority and will contribute to characterizations of both the region and the sites.

Preliminary work included synthesis of available data on the region. Published and unpublished data and available aerial photographs were used to compile information on drainage characteristics, outcrop distributions, and the locations of earthquake epicenters, fissures, and potentially capable faults. Limited well data were used to map the potentiometric surface in some areas and to investigate the chemistry of the ground water. Shallow drilling tested the thickness of the alluvial fill at several locations. Ongoing studies will include deeper drilling, collection of water well data, analysis of water samples, and additional field work.

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 Susequehanna 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 and Conquista sands and clays. High concentrations of uranium (up to 105 mg/L), radium (up to 121 pCi/L), chloride (up to 2,300 mg/L), sodium (up to 7,000 mg/L), aluminum (up to 1,400 mg/L), iron (up to 1,200 mg/L), and sulfate (up to 17,000 mg/L) and low pH values (as low as 2.6) have been observed around the pits and mapped at significant distances away from the disposal areas. The Bureau is conducting two investigations at the site to help better characterize the extent and geologic controls of contaminant migration. The first program will 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 program, which will be accomplished by petrographic and geochemical analysis of cores from the site, will determine whether precipitation of reduced minerals has already occurred.

During 1991, 17 monitoring wells were constructed and sampled to better define the lateral extent of the plume and the importance of the different strata in controlling the size and orientation of discrete plumes associated with the tailings. The computer model Stratamodel was used to map the three-dimensional distribution of permeable strata and contaminants. Twelve cores were collected for detailed geochemical analysis. Geochemical characterization of the core was initiated in the fall. This program, funded by the U.S. Department of Energy, will provide valuable information for designing remediation programs at the site.

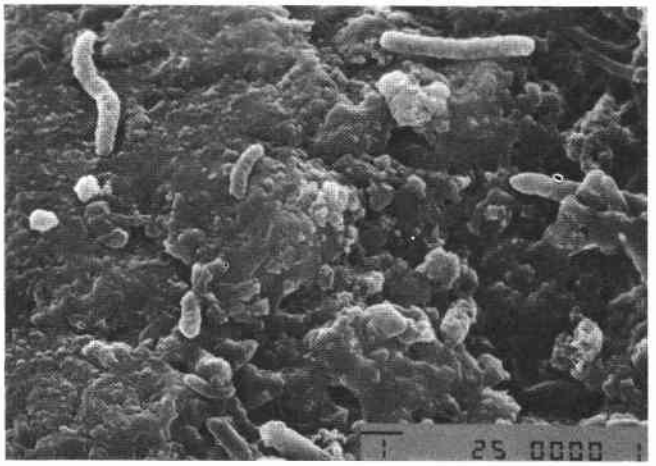
Experimental Determination of Hazardous Waste Degradation Reactions during Deep-Well Injection into Saline Formations of the Gulf Coast

Charles W. Kreitler, principal investigator; assisted by Bruce K. Darling

More than 8.6 billion gallons of liquid hazardous waste are disposed of nationwide by deep-well injection each year. About 90 percent is injected in 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. This can be accomplished 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 up to 80 percent of the injected hazardous wastes is organic and can be degraded to nontoxic chemicals by a variety of chemical processes. Biologic degradation may be the most important reaction remediating these hazardous wastes.

This program, funded by the Gulf Coast Hazardous Substance Research Center, has sampled an injection waste plume after the organics have been in the subsurface long enough for potential degradation reactions to have started. The initial injected organic chemical for this plume was formaldehyde, which has disappeared at the point of sampling approximately 2,000 ft from the point of injection but is still within the plume. Sediment infilling of the injection wells also appears to be common. These sediments are being analyzed to determine if they are waste degradation byproducts as well as to determine whether this degradation results in a loss of injectivity, which is common to most injection wells. Analysis of the sediments indicates the presence of bacteria and a high concentration of organic constituents that may represent biodegraded organics rather than the original injected chemical.



Injection wells used for the disposal of industrial waste commonly accumulate organic sludges around the well screen. This SEM photograph depicts anaerobic, sulfate-reducing(?) bacteria that are probably degrading low-solubility organics into insoluble sludges.

Ground-Water Studies

Evaluation of Ground-Water Availability in Gulf Coastal Plain Aquifers of Fayette and Colorado Counties, Texas

Alan R. Dutton, principal investigator;
Karen L. Herrington

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 adjacent river basins are needed to meet projected growth in demand for water supplies. This study, which began late in 1990 with support from the Lower Colorado River Authority, is developing a ground-water flow model for evaluating ground-water availability in Gulf Coastal Plain aquifers in Fayette and Colorado Counties and parts of adjacent counties. The ground-water model represents the complex interrelation between aquifer stratigraphy, hydrologic properties, and ground-water availability. The model is intended for use as a tool for assessing ground-water resources and for evaluating the benefits and impacts of alternative water-resource management strategies. It will be designed to be used in conjunction with existing ground-water flow models of adjacent coastal plain aquifers.

Work tasks involved in building the numerical model include compiling and rescaling geologic maps analyzing hydrologic data, defining hydrostratigraphic units as model layers, deriving a relationship between sand percent distribution and transmissivity, preparing water-level hydrographs and historic pumping data for model calibration, specifying a regional finite difference grid, and assigning parameter values and boundary conditions to model blocks. The flow model is being implemented using the finite-difference code MODFLOW. The model consists of eight layers representing the various aquifer units in the study area. The model is based on maps of sandstone distribution, and hydrologic properties are assigned from correlated values of transmissivity. Recharge and movement of water between rivers and the aquifers are simulated using head-dependent boundary terms. "No-flow" lateral boundaries reflect original ground-water-basin divides. The model includes cross-formational leakage between hydrostratigraphic units. Downdip limits of ground-water flow are inferred from the elevation of the base of fresh water. Transmissivity, storativity, vertical conductance, river leakage rates, and recharge and discharge rates are being adjusted on the basis of constraint of observed hydraulic heads and long-term water-level hydrographs and other hydrologic data.

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 U.S. Department of Energy, The University of Texas Center for Petroleum and Geosystems Engineering, and the Bureau of Economic Geology. The ultimate goal of the program is to demonstrate the economic viability of geopressure-geothermal water as an alternative energy resource. In a five-county area of South Texas (Zapata, Webb, Duval, Jim Hogg, and Starr Counties), 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 for enhanced oil recovery by steam or hot-water flooding. In 1991, research concentrated on characterizing heavy-oil reservoirs of the Eocene Jackson Group.

In South Texas, colocation of geothermal resources below heavy-oil reservoirs and the character of the heavy-oil and geothermal energy resource suggest that thermally enhanced oil recovery would be economically viable. One valuable resource is the available inventory of deep abandoned gas wells that penetrate potential hot-water reservoirs in the Wilcox. Well histories of approximately 300 Wilcox wells from the five-county area of South Texas have been inventoried using the Railroad Commission of Texas Well Bore Data Base. At least 60 wells have been identified as abandoned gas producers. These wells have an average depth of 14,765 ft.

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 characteristics of the reservoir strata. Using geothermal waters as a source of steam and hot water to mobilize the oil could greatly improve recovery efficiencies and prevent premature abandonment of reservoirs that still have 70 percent oil remaining in place. Charco Redondo field in Zapata County produces 20° API-gravity oil from Cole sandstones in the Jackson Group. Charco Redondo field was characterized because it is typical of Jackson Group heavy-oil reservoirs that produce from shallow (200-ft depth), strike-elongate barrier-bar sandstones and have an updip stratigraphic pinch-out as the principal trapping mechanism. Where examined, the reservoir sandstone is a relatively simple upward-cleaning fine sandstone that is 10 to 20 ft thick. However, interesting reservoir heterogeneities result from tight calcite-cemented zones that compartmentalize hydrocarbon distribution. Such calcite-cemented zones may accentuate the accretionary grain of the prograding beach ridges.

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 from mixing of fresh water with sodium chloride derived from a variety of sources, including oilfield operations, salt dissolution, sedimentary basin brine discharge, and sea-water intrusion. Oilfield operations have been considered a prime source for contamination. However, multiple sources may exist at the same location. In some contaminated areas, two or more sources may be active, making it more difficult to identify a dominant source. For taking remedial measures, however, it is important not only to detect the contamination but also to document individual sources as accurately as possible.

Geochemical analyses of the brackish contaminated water and the brine sources may permit separation of the different brines and therefore identify the relative importance of different sources. Various methods have been used in the past, including ion ratios such as Na/Cl, Ca/Cl, Mg/Cl, and SO_4, isotopic compositions, and distribution of naturally occurring organic compounds.

This investigation, funded by the U.S. Environmental Protection Agency (EPA), is divided into three major tasks: (1) literature review 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 proven a valuable new approach for differentiating sources of salt water pollution. Saline water samples from the San Juan Basin, New Mexico, and the El Paso and Stephenville, Texas, regions have been collected. The technical manual is being published by the EPA.

Geologic and Hydrogeologic Characterization of Pantex Plant

Thomas C. Gustavson, principal investigator; Robert W. Baumgardner, Jr., Carolyn E. Condon, Rodney I. Heathcott, William F. Mullican III, Jeffrey G. Paine, Jay A. Raney, Bernd C. Richter, and Bridget R. Scanlon; assisted by Martina U. Bluem, George T. Bush, James A. Doss, Jr., Frank D. Meaker, Steven M. Rooks, and Claude R. Stricklin

Work began in September 1990 on this 5-year project to characterize the hydrology and geology of the U.S. Department of Energy's (DOE) Pantex Plant near

Amarillo, Texas. This effort is funded by a DOE grant to the Governor's Office. The Pantex Plant currently is the nation's site for assembly, maintenance, and disassembly of nuclear weapons. Previous DOE environmental surveys revealed local contamination of soil, sediment, and perched ground water beneath the Pantex Plant.

Federal law requires that DOE remediate and monitor areas of contamination at DOE facilities. As a part of the State of Texas' responsibility to provide oversight of DOE's reclamation efforts, the Bureau of Economic Geology and its subcontractors will describe the stratigraphy, structure, hydrology, geochemistry, and playa lake biological systems to determine the fate and transport of contaminants at the Pantex Plant. The Bureau is responsible for stratigraphic, structural, ground-water hydrologic, and certain geochemical studies. The Department of Geological Sciences at The University of Texas at Austin and the Center for Water Resources at Texas Tech University are responsible for studies of the geochemistry of playa sediments, surface-water hydrology, and the fate and transport of contaminants in playa-lake sediments. Data from these studies, in conjunction with other data from characterization studies being carried out by the U.S. Army Corps of Engineers and Mason & Hanger-Silas Mason, Inc., will provide an integrated view of the geologic framework and hydrologic processes involved in ground-water recharge from playa and interplaya areas, formation of perched ground water, and flow in the Ogallala aquifer.

During the first year, field studies of the upper Tertiary Ogallala and Quaternary Blackwater Draw Formations and playa lake basins were initiated. Several water wells at the Pantex Plant were instrumented, sampled, and monitored, and approximately 25 mi of high-resolution reflection seismic data was collected. Ogallala ground-water and subsurface stratigraphic data bases were assembled for the Pantex Plant and surrounding region. Preliminary hydrologic modeling of the unsaturated zone was initiated.

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

This work is supported by the Texas Higher Education Coordinating Board under the Advanced Technology Program. Objectives of these investigations are to evaluate the geologic and hydrologic controls on the production performance of compartmentalized Tertiary reservoirs in the Texas Gulf Coast sedimentary basin and to improve resource-evaluation techniques for these reservoirs. These reservoirs are recognized by their abnormal fluid pressures, which are controlled by depositional, tectonic, and diagenetic processes. Oil and gas fields contained within such compartmentalized reservoirs exhibit production and pressure abnormalities. The Chocolate Bayou reservoir in Brazoria County, Texas, was selected for detailed geologic and hydrologic description. Sand sequences in the Frio Formation have been correlated across fault blocks for identifying horizontal and vertical continuity. The graphical material balance method of the "P/Z plot" is used for estimating original gas in place. Other plots of production rate versus cumulative production and time, bottom-hole pressure versus time and cumulative production, and the complementary P/Z plot are utilized to provide additional information about the type of reservoir drive mechanism and performance characteristics of the gas fields. Most Frio plays seem to experience bottom-water influx. The gas recovery factor from these Frio plays ranges from 70 to 98 percent. Further study of the pressure-production decline trends will help to better estimate ultimate recovery from these reservoirs.

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, which inject 60 million barrels of water per day in 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 close to brine-injection operations. Upward migration of brine into shallow fresh ground-water aquifers may result because of the coincidence of abandoned boreholes with areas of increased reservoir pressures from injection or natural formation pressures. This can occur only if pressures in the injection zone are greater than water levels in overlying aquifers.

Researchers at the Bureau, with support from the American Petroleum Institute, are regionally mapping subsurface pressures of reservoirs and shallow aquifers in the San Juan Basin, New Mexico, the greater Permian Basin, Texas, and the South Texas Basin, Texas. This is being accomplished by using the potentiometric data from fresh-water aquifers, the pressures within oil and gas reservoirs, and injection pressures for salt-water-injection operations to better identify areas that have the potential for upward migration of brines through abandoned boreholes. This study will help in developing a methodology to assess the risk that abandoned wells in a given area pose to the underground sources of drinking water. Within areas of potential upward flow, the condition of the abandoned wellbores can then be assessed, as can the

location of the higher density populations of plugged and abandoned wells and locations of injection wells used for enhanced oil recovery.

Paleohydrology of the Nonglaciated Great Plains: Climatic and Geomorphologic Implications

Alan R. Dutton, principal investigator; assisted by Gregg Oetting

This research, funded by the U.S. Geological Survey as part of its Water Resources Research Section 105 Grant Program, is designed to determine the origin of ground water in Triassic sandstones that have δD and $\delta^{18}O$ values that are isotopically lighter than those of ground water in the overlying unconfined High Plains aquifer in Texas and eastern New Mexico. Previous hydrogeologic studies interpreted the light ground water as ancient water recharged before the Pecos River valley was incised during the Pleistocene and that is preserved in the now erosionally truncated, confined aquifer system.

During 1991, ground waters from the southern Great Plains were sampled for chemical analyses and age dating using carbon-14 and ^{36}Cl radioactive isotopes to test the paleorecharge model. Nine irrigation- and municipal-supply wells and windmills in the Texas Panhandle and eastern New Mexico that were previously sampled for δD and $\delta^{18}O$ isotopes were resampled. These wells are located along a west-to-east transect following presumed paleohydrologic and modern ground-water flow paths and along a north-to-south transect that is perpendicular to the presumed flow path. Water samples were collected beginning in early summer after many water-supply wells are turned on to meet seasonal water demands. Carbon-14 activities were found to be low; seven of the nine samples had less than 5 percent of Modern C-14 activity (PMC) and three had less than 2 PMC. Samples with low C-14 activity will be analyzed for ^{36}Cl using a tandem Van de Graaff accelerator mass spectrometer at the University of Rochester Nuclear Structure Laboratory to further study the age of these apparently old waters.

Another task is to test whether the paleorecharge model can be extended to other parts of the nonglaciated Great Plains. Late in 1991, 15 additional wells were sampled in the central Great Plains to better determine the extent of isotopic stratification and to determine distribution of ground-water ages. This work is being coordinated with hydrogeologists at the Kansas Geological Survey who are investigating the water resources of a confined aquifer in the Cretaceous Dakota Formation. Their previous work indicated that there is isotopic stratification between the confined and overlying unconfined aquifers.

Quantitative estimates of ground-water flow rates in the Triassic sandstones are needed to evaluate sources of isotopically depleted water found beneath parts of the Great Plains. A quasi-three-dimensional numerical model of ground-water flow was constructed during this first year of the investigation. The model was based on maps of sandstone distribution, and hydrologic properties were assigned from correlated values of transmissivity. The model is being implemented with the integrated finite-difference program MODFLOW and consists of 1,089 block-centered nodes at 10-mi uniform spacing. Previously constructed maps of hydraulic head are being used for model calibration. Aquifer dimensions and hydrologic properties that represent formations in the Pecos River valley prior to its excavation have been inferred for paleohydrologic modeling. The calibrated model is used to simulate paleorecharge conditions with varying geomorphologically and climatically controlled recharge rates.

Hydrogeologic Studies in Support of the Superconducting Super Collider

Alan R. Dutton, principal investigator; Don G. Bebout, Alan J. Cherepon, Edward W. Collins, Karen L. Herrington, Susan D. Hovorka, Stephen E. Laubach, Robert E. Mace, Rainer K. Senger, and Matthew K. Wickham; assisted by Ganesh P. S. Rao

The purpose of this study is to develop a comprehensive account of the occurrence and movement of ground water in the Austin Chalk, Taylor Marl, and Quaternary alluvium throughout the Ellis County area. The scope of work during 1991, supported through the Texas National Research Laboratory Commission (TNRLC), includes completion of Phase I studies in an alluvial aquifer and initiation of Phase II investigations, including development of a regional hydrologic data base and analysis of ground-water flow in the Austin Chalk and Taylor Marl.

Phase I of the investigation focuses on surficial ground-water resources in a Pleistocene terrace deposit that overlies planned Superconducting Super Collider (SSC) subsurface facilities along a northeastern segment of the SSC ring. A water-well inventory, geophysical surveys, hydrologic testing, water-level monitoring, ground-water sampling, and numerical flow modeling were used to interpret ground-water flow and chemical composition in the unconfined to semi-unconfined aquifer. An interpretive numerical flow model was implemented using the finite-difference code MODFLOW. Model results show that most ground water is discharged in seeps and springs around the aquifer's perimeter where Modern streams are incised into bedrock; well discharge is only a small percentage of discharge. Ground-water flow from underlying

Bureau researchers Robert Mace and Alan Dutton discuss techniques for measuring water levels in wells with high school students enrolled in the Earth Watch program, sponsored by the Superconducting Super Collider (SSC) Laboratory. Students from Maine, New York, Connecticut, Maryland, and New Jersey assisted in collecting data at several monitoring wells at the SSC site in Ellis County, Texas.

bedrock probably is negligible. Travel times along path lines calculated by the computer code MODPATH agree with measured tritium unit activities.

Work in progress under Phase II includes hydrologic testing, water-level monitoring, and collecting water samples for chemical analyses, inventorying water wells near the SSC beam alignment, and studying subsurface stratigraphy and fractures to provide geologic data for interpreting ground-water flow.

Between March and June an inventory and measurement of the 350 public and private water wells in the vicinity of the SSC ring were completed. This work was conducted to document well locations for the SSC project and to characterize the use of ground-water resources. The inventory is being extended in less detail inside and outside the SSC ring. Water levels are being monitored monthly and hourly in 37 monitoring wells operated by the TNRLC and in several dozen of the privately owned wells identified in the inventory. The purpose of the monitoring is to determine seasonal and short-term fluctuations for interpreting controls on movement of water and response of water levels to pumping and dewatering operations. Samples also are being collected for analyses of water chemical composition from these various monitoring and private wells. Chemical composition can indicate age of ground water and style of ground-water circulation.

Geologic investigations have focused on analyzing fracture characteristics in core and in the field to support modeling of flow in fractured chalk and marl. Several units making up the lower 60–70 ft and upper 140 ft of the Austin Chalk are generally more fractured than the middle 250–260 ft. Fracture intensity locally may be high in all the units where faults with throws of about 15 ft and greater cut the units. Mapping of the outcrop and subcrop of the more fractured zones will assist the interpretation of hydrologic properties and water chemical composition.

Coastal Studies

Monitoring the Beach and Vegetation Line on Galveston Island

Robert A. Morton, principal investigator; Jeffry 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 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 8 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 Rochelle R. Leach and Matthew W. Wells

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 1991, 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, U.S. Fish and Wildlife Service (USFWS), principal investigators; William A. White and Jeffrey G. Paine; assisted by Damon E. Waitt

The Bureau and the U.S. Fish and Wildlife Service (USFWS) have been cooperating in a 20-month study to interpret losses and/or 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 and will be incorporated in the 1994 GBNEP Comprehensive Conservation Management Plan.

In 1991, the Bureau completed identification of representative field assemblages of Galveston Bay System wetland habitat types and reported these results. USFWS constructed digital line graph tapes in ArcInfo format for previously digitized interpretations of 1956 and 1979 wetland habitats. Also, USFWS completed interpretations of the wetland habitats on 1989 aerial photographs for the 30 quadrangles composing the Galveston Bay System. The Bureau is analyzing digital maps of USFWS 1956, 1979, and 1989 interpretations on an ArcInfo geographic information system to determine trends and causes of changes in Galveston Bay wetland habitats during the control years.

Coastal Mapping and Shoreline Monitoring Projects

Robert A. Morton, principal investigator; Diane M. Spinney

During 1991, the Bureau served in an advisory capacity or conducted minor coastal studies for two State agencies, a Federal agency, and a county agency. 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 of the upper Texas coast west of Sabine Pass. Bureau scientists also participated in workshops and 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. Also included was a list of references and sources of information regarding coastal erosion in Texas.

A study was conducted for the Texas General Land Office that evaluated the potential environmental impacts of a proposed opening between the Brownsville Ship Channel and a broad, shallow depression on the Rio Grande delta plain known as Bahia Grande. The work involved ground observations, aerial reconnaissance flights, examination of aerial photographs, and interviews with individuals familiar with the area and its historical uses. A brief report was prepared that summarized the origin of Bahia Grande, described recent alterations to water circulation patterns, compared Bahia Grande with adjacent water bodies, discussed the anticipated physical effects if Bahia Grande were flooded, and

made recommendations concerning the construction of the proposed project.

Bureau researchers also conducted a study of recent erosion of the Gulf shoreline at Sargent Beach and the factors that cause the erosion. The study, which was funded by the Matagorda County Commissioners Court, used field observations and 1991 aerial photographs to analyze beach retreat and land loss where erosion rates are the highest of any Texas beaches and where operation of the Intracoastal Waterway is threatened. The accompanying report contained information regarding current rates of erosion, coastal processes, volumetric losses along the beach, historical changes in sediment budget, beach nourishment efforts, and an evaluation of potential breaching between the Gulf shoreline and the Intracoastal Waterway during a hurricane.

Geologic Mapping in the North-Central Texas Council of Governments Region

E. G. Wermund, principal investigator; L. Edwin Garner, coordinator; Arten J. Avakian, Tucker F. Hentz, and Allan R. Standen

The Bureau of Economic Geology has remapped areal geology in 70 7.5-minute quadrangles of the North-Central Texas Council of Governments (NCTCOG) region.

Previous mapping was compiled at a 1:250,000 scale; updated mapping was completed at a 1:24,000 scale. A dual legend was provided that describes both classical geologic units and land-resource units, the latter emphasizing the siting of solid waste disposal. The NCTCOG plans to digitize the Bureau mapping and include the digital maps in its geographic information system.

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

Robert A. Morton, principal investigator

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

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

The 5-year study will include six major work elements: (1) coastal erosion analysis, (2) regional geologic framework investigations, (3) coastal processes analysis, (4) predictions of future coastal responses, (5) sand-resources investigations, and (6) technology transfer activities. The first year of the study will be used to identify the regional coastal issues, to compile and assemble existing data and information, to update shoreline-change maps, to establish priorities for the 5-year investigation, and to coordinate work plans with the USGS as well as with State and other Federal agencies having responsibilities along the Texas coast. This reconnaissance and planning phase will result in development of field survey techniques, preparation of detailed work plans for each year of the 5-year program, and development of a pilot coastal geographic information system for Texas, which emphasizes digitization of historical shorelines derived from maps and aerial photographs.

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) is supported by the U.S. Bureau of Mines and dedicated to research and education in mineral resources. The Bureau of Economic Geology administers TMMRRI; 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.

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. In the 1991–1992 academic year, four fellowships were awarded to support graduate research in ore deposition, mineral economics, and petroleum recovery.

Research under TMMRRI focuses on the relationship between ore formation and contemporaneous igneous and tectonic activity and on mineral exploration techniques using field mapping, geochemical analysis, detailed petrography, potassium-argon dating, and computer modeling of hydrothermal processes. Igneous magmas may supply both the metals that form an ore body and the heat and fluids that transport and concentrate the metals. Two major and overlapping topics were addressed this year: (1) beryllium and other rare metals in Trans-Pecos Texas and (2) the sources of metals for ore deposits.

A belt of alkalic, highly evolved rhyolitic intrusions that trends southeastward through New Mexico, Texas, and northern Mexico constitutes potentially major resources of several rare metals, including beryllium, lithium, thorium, yttrium, niobium (columbium), zirconium, tantalum, tin, and rare earth elements. At several locations along this belt, fluorite deposits developed at contacts of the rhyolites with Cretaceous limestone contain mineable concentrations of these elements. TMMRRI research has included geochemical studies and geologic mapping of the type and distribution of the rhyolites and fluorite deposits. Initial work, now largely complete, focused on major beryllium deposits in fluorspar replacements at Sierra Blanca, Texas, and on the distribution of rare-element-enriched rhyolites and fluorite deposits of the Christmas Mountains. Research on the peralkaline rhyolites of southern Trans-Pecos Texas is a followup to the Sierra Blanca and Christmas Mountains work. These rhyolites are also enriched in fluorine and rare metals. Associated fluorite deposits are locally highly enriched in beryllium, molybdenum, thorium, and uranium. Results of these investigations have applications not only to exploration in this particular region but also to understanding rare-metal enrichment and mineralization in alkalic intrusions worldwide.

Geochemical tracers, particularly the isotopes of lead, are being used to identify metal sources. Lead compositions in igneous rocks are very different southeast and northwest of the Ouachita front. Samples from ore deposits northwest of the Ouachita front generally have lead isotopic ratios that indicate that they were derived from igneous rocks that had interacted with Precambrian basement. For example, the lead isotopic compositions of galenas from the Shafter mining district are close to the compositions of adjacent Tertiary igneous rocks. Galenas from prospects in the West Chinati stock, on the opposite side of the Chinati Mountains from Shafter, have lead isotopic ratios different from those of the Shafter district but close to those of adjacent igneous rocks. Similarly, lead isotope ratios in galena collected from several mines in the Quitman Mountains are significantly different from analyses from either Shafter or the West Chinati districts but are similar to local igneous rocks. This type of relationship between igneous rocks and ore deposits is common and suggests that either the ore-bearing solutions derived lead and other metals from the igneous rocks or that the igneous rocks and hydrothermal fluids shared a common source.

Isotopic analyses of galenas from silver-copper-lead deposits in the Indio Mountains show a different source. The data indicate that hydrothermal fluids leached metals from local Cretaceous sedimentary rocks and did not interact with Precambrian basement. Research on similar deposits hosted by Paleozoic and Precambrian strata is in progress.

Mapping Investigations

Geologic Atlas of Texas

Virgil E. Barnes, principal investigator

Geologic atlas sheets depicting the entire state have been published, so new work focuses on revision and reprinting of older maps as they go out of print. Cartography to revise the Sherman sheet is complete; the map has been sent to the printers. Revision of the Perryton sheet began in late 1991. The Abilene, Austin, Crystal City–Eagle Pass, Del Rio, Tyler, and Wichita Falls–Lawton sheets were reprinted without revision this year.

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 first published in 1937 and has been out of print for many years. The new map will be issued in four quadrants; the entire map will measure approximately 7 by 8 ft and will depict approximately 350 geologic units. Initial color separation has been done on all four quadrants; review and revision are in progress. The map is scheduled for completion in the first half of 1992.

Geologic Studies of the Big Bend Ranch State Natural Area

Christopher D. Henry and Eric W. James; William R. Muehlberger, Department of Geological Sciences; Mick Kunk and John Sutter (U.S. Geological Survey, Reston, Virginia); assisted by Linda L. Davis

Geologic mapping of volcanic centers in the mid-Tertiary volcanic field of Trans-Pecos Texas is a continuing project of the Bureau of Economic Geology. Mapping of the Big Bend Ranch State Natural Area, the newest and by far the largest part of the Texas Parks System, is jointly funded by the Texas Parks and Wildlife Department and by the U.S. Geological Survey's Cooperative Geologic Mapping Program (COGEOMAP).

The first year of the project focused on the southeastern part of the Natural Area, including areas along the Rio Grande that are most accessible to visitors, and the Solitario, a remarkable dome formed during mid-Tertiary igneous activity. Rocks exposed in this region represent more than 500 million years of Earth history. Major events in this history include (1) deposition of a complex sequence of sedimentary rocks during Paleozoic time, from about 520 Ma to 300 Ma ago, (2) folding and thrust faulting of these rocks during the Ouachita-Marathon orogeny toward the end of the Paleozoic about 300 Ma ago, (3) deposition of limestone and shale during the Cretaceous between about 120 and 80 Ma ago, (4) folding and thrust and strike-slip faulting during the Laramide orogeny about 50 Ma ago, (5) formation of the Solitario dome about 38 Ma ago during some of the earliest igneous activity in and around the Natural Area, (6) continued igneous activity in several distinct episodes at about 35, 32, 28, and 24 Ma ago, and (7) normal faulting of the Basin and Range province beginning about 24 Ma and continuing to the present.

The study, which is being coordinated with Parks and Wildlife personnel examining the biological, archeological, and cultural resources of the area, will consist of a detailed geologic map of and report on the entire Natural Area. The Bureau's work is assisting Parks and Wildlife to preserve the Natural Area, to develop it for public visitation, and to interpret the natural history of the area for visitors. Much of the attraction of the Natural Area derives from its rugged scenery, which is a direct result of the long and varied geologic evolution. Research by the Bureau is designed to show how geology has formed or influenced the scenic, biological, and cultural resources of the area.

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)

The first year of a multiyear project to map the geology of the 1:100,000-scale New Braunfels, Texas, Quadrangle produced draft geologic maps of four 7.5-minute quadrangles near New Braunfels, Texas. The second year will expand the mapping onto adjacent quadrangles. This project is part of the U.S. Geological Survey's (USGS) Cooperative Geologic Mapping Program (COGEOMAP). It is funded jointly by the USGS and the Bureau of Economic Geology. In-kind services provided by USGS include paleontologic studies.

The objective of the mapping is to provide a high-quality geologic map of this rapidly developing area of Texas. This 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 northwestern edge of the Texas Coastal Plain.

Other Geologic Investigations

Trail Guide—McKittrick Canyon Permian Reef Geology Trail, Guadalupe Mountains National Park

Don G. Bebout and Charles Kerans, principal investigators

Geologists from the Bureau and from industry research laboratories are preparing a trail guide for use by industry and university groups that regularly

Steeply dipping slope grain flow exposed along the McKittrick Canyon Permian Reef Geology Trail, Guadalupe Mountains National Park.

visit the Permian reef in Guadalupe Mountains National Park. Designated stops in basin, slope, reef, and backreef/shelf carbonate and sandstone facies will be located by permanent 100-ft elevation markers, which were leveled in from a benchmark on U.S. Highway 62/180. Field descriptions, sampling, and extensive low-level aerial and ground photography are complete, and the guide is in preparation. Participating in this project are Bob Loucks and Alton Brown, ARCO; Mitch Harris, Chevron; Brenda Kirkland-George, Louisiana State University; Denise Mruk, Marathon; and Emily Stoudt and Susan Longacre, Texaco. The cost of publishing this trail guide, in which all photographs are in full color, is supported by contributions from industry. Logistical support has been provided by Larry Henderson and Bob Valen, National Park Service, Guadalupe Mountains National Park.

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 1991, the following 71 contracts, each of which had reporting requirements, were active at the Bureau:

Federal

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

"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.

"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 (Revision) and Jackson-Yegua Trend, East Texas (Revision)": 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.

"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.

"Geology of the Bofecillos Mountains and Big Bend State Natural Area, Trans-Pecos Texas": supported by the U.S. Geological Survey, U.S. Department of the Interior.

"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 (two contracts).

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

"Physical and Environmental Assessment of Sand Resources—Texas Continental Shelf": 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 3 through 7)": supported by the Minerals Management Service, U.S. Department of the Interior (five contracts).

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

State

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

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

"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 (two contracts).

"Continuation of Geologic and Hydrologic Studies near Fort Hancock, Texas": supported by the Texas Low-Level Radioactive Waste Disposal Authority.

"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.

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

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

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

"Geological Support of Cross-hole Tomography": supported by The University of Houston.

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

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

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

"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.

"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.

"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 (two contracts).

"Technology Transfer to Independent Oil and Gas Operators": supported by the Texas Higher Education Coordinating Board.

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

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

"State Contribution to the Revision of the Geologic Atlas of Texas": supported by the Texas Water Development Board.

"Assistance in Resource Evaluation to the Public Utility Commission": supported by the Public Utility Commission.

"Assistance to the General Land Office to Determine Possible Effects of Flooding Bahia Grande, Cameron County, Texas": supported by the General Land Office.

Private

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

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

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

"Bureau to Provide Copies of Aerial Photos": supported by Exxon Production Research Company.

"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 Amoco Production Company, Mobil Exploration & Producing U.S., Inc., Unocal Midland, ARCO Oil and Gas Company, Exxon Production Research Company, Marathon Oil Company, Shell Oil Company, Japan National Oil Corporation, Oxy USA, Inc., Phillips Petroleum Company, The Chevron Companies, and TOTAL Compagnie Française des Petroles.

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

"Evaluation of Texas Reservoirs for Inclusion in the TORIS Database": supported by ICF, Inc.

"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 and Unocal Exploration Corporation.

"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.

"Geologic Mapping of Selected Quadrangles in North-Central Texas": supported by the North-Central Texas Council of Governments.

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

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

"Technical Review Workshop—Geological Reservoir Classification System": supported by the Idaho National Engineering Laboratory.

"Update Shoreline Erosion Rates along Sargent Beach, Matagorda County, Texas": supported by the Matagorda County Commissioners Court.

Contract and Grant Reports

Ayers, W. B., Jr., Kaiser, W. R., Laubach, S. E., Ambrose, W. A., Baumgardner, R. W., Jr., Scott, A. R., Tyler, Roger, Yeh, Joseph, Hawkins, G. J., Swartz, T. E., **Schultz-Ela, D. D.,** Zellers, S. D., Tremain, C. M., and Whitehead, N. H., III, 1991, Geologic and hydrologic controls on the occurrence and producibility of coalbed methane, Fruitland Formation, San Juan Basin: The University of Texas at Austin, Bureau of Economic Geology, topical report prepared for the Gas Research Institute under contract no. 5087-214-1544, 314 p.

Dutton, S. P., 1991, Diagenetic controls on reservoir properties of low-permeability sandstone, Frontier Formation, Moxa Arch, southwest Wyoming: The University of Texas at Austin, Bureau of Economic Geology, topical report prepared for the Gas Research Institute under contract no. 5082-211-0708, 48 p.

Hamlin, H. S., 1991, Stratigraphy and depositional systems of the Frontier Formation and their controls on reservoir development, Moxa Arch, southwest Wyoming: The University of Texas at Austin, Bureau of Economic Geology, topical report prepared in cooperation with the Geological Survey of Wyoming for the Gas Research Institute under contract no. 5082-211-0708, 45 p.

Kerans, Charles, Lucia, F. J., Senger, R. K., Fogg, G. E., Nance, H. S., Kasap, Ekrem, and **Hovorka, S. D.,** 1991, Characterization of reservoir heterogeneity in carbonate-ramp systems, San Andres/Grayburg, Permian Basin: The University of Texas at Austin, Bureau of Economic Geology, Reservoir Characterization Research Laboratory, final contract report, 245 p., 4 pl.

Kreitler, C. W., and **Senger, R. K.,** 1991, Wellhead protection strategies for confined-aquifer settings: The University of Texas at Austin, Bureau of Economic Geology, contract report under cooperative agreement no. CX-815385-01-0 prepared for U.S. Environmental Protection Agency, Office of Ground Water and Drinking Water, Ground-Water Protection Division, 168 p.

Morton, R. A., 1991, Physical evaluation of proposed flooding of Bahia Grande, Cameron County, Texas: The University of Texas at Austin, Bureau of Economic Geology, contract report prepared for Texas General Land Office under interagency contract no. IAC 91-064 R, 15 p.

Morton, R. A., 1991, Recent rates of shoreline erosion at Sargent Beach, Matagorda County, Texas: The University of Texas at Austin, Bureau of Economic Geology, contract report prepared for Matagorda County Commissioners Court, 23 p.

Morton, R. A., and **Ayers, W. B., Jr.,** 1991, Plio-Pleistocene depositional sequences of the southwestern Louisiana continental shelf and slope: geological framework, sedimentary facies, and hydrocarbon distribution: The University of Texas at Austin, Bureau of Economic Geology, final report prepared for BP Exploration, Inc., CNG Producing Company, Fairfield Industries, Halliburton Geophysical Services, Mobil Exploration and Producing U.S., Inc., Oryx Energy Company, and Union Texas Petroleum, 114 p.

Raney, J. A., 1991, Review of the geology and hydrology of the Eagle Flat area, Hudspeth County, Texas: The University of Texas at Austin, Bureau of Economic Geology, final contract report prepared for the Texas Low-Level Radioactive Waste Disposal Authority, under interagency contract no. IAC(90-91)1290, 19 p.

Raney, J. A., Baumgardner, R. W., Jr., Collins, E. W., and **Wermund, E. G.,** 1991, Initial report on the geology of the northeastern part of the New Braunfels, Texas, 30 × 60 minute quadrangle: The University of Texas at Austin, Bureau of Economic Geology, contract report prepared for U.S. Geological Survey under cooperative agreement 14-08-001-A0812, variously paginated, 4 pl.

Raney, J. A., Seni, S. J., DuBar, J. R., and **Walter, T. G.,** 1991, Consolidation of geologic studies of geopressured-geothermal resources in Texas: The University of Texas at Austin, Bureau of Economic Geology, 1990 annual report prepared for the U.S. Department of Energy, Advanced Technologies Division, under cooperative agreement no. DE-FC07-85NV10412, 61 p., appendix, 3 pl.

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Richter, B. C., and Kreitler, C. W., 1991, Identification of sources of ground-water salinization using geochemical techniques: The University of Texas at Austin, Bureau of Economic Geology, contract report prepared for the U.S. Environmental Protection Agency, Office of Research and Development, under cooperative agreement no. CR-815748, 258 p.

Tyler, Noel, Fisher, R. S., Barton, M. D., Miller, M. A., Holder, Jon, and Gray, K. E., 1991, Quantification of flow unit and bounding element properties and geometries, Ferron Sandstone, Utah: implications for heterogeneity in Gulf Coast Tertiary deltaic reservoirs: The University of Texas at Austin, Bureau of Economic Geology, annual report prepared for the Gas Research Institute under contract no. 5089-260-1902, 127 p.

Tyler, Roger, Ambrose, W. A., Scott, A. R., and **Kaiser, W. R.,** 1991, Coalbed methane potential of the Greater Green River, Piceance, Powder River, and Raton Basins: The University of Texas at Austin, Bureau of Economic Geology, topical report prepared for the Gas Research Institute under contract no. 5087-214-1544, 244 p.

Vendeville, B. C., Jackson, M. P. A., and **Schultz-Ela, D. D.,** 1991, Applied Geodynamics Laboratory first semiannual progress report to industrial associates for 1991/captions for experimental models in slide set number 5: 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 Exploration, Inc., 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., 60 transparencies.

Vendeville, B. C., Jackson, M. P. A., and **Schultz-Ela, D. D.,** 1991, Applied Geodynamics Laboratory second semiannual progress report to industrial associates for 1990/captions for experimental models and cross-section restoration in slide set number 4: 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 Exploration, Inc., 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, 20 p., 64 transparencies.

Wickham, M. K., and **Dutton, A. R.,** 1991, Transient simulation of ground-water flow and particle pathlines: hydrogeologic case study of Pleistocene alluvium overlying the SSC site, Ellis County, Texas: The University of Texas at Austin, Bureau of Economic Geology, final report prepared for the Texas National Research Laboratory Commission under interagency contract no. IAC(90–91)1650, 117 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 1991, about 30,000 volumes were distributed. The Bureau issued the following publications in 1991:

Reports of Investigations

RI 198. Arid Basin Depositional Systems and Paleosols: Fort Hancock and Camp Rice Formations (Pliocene–Pleistocene), Hueco Bolson, West Texas and Adjacent Mexico,

by T. C. Gustavson. 49 p., 29 figs., 3 tables, 1 appendix, $6.50

Analysis of deposition, paleosols, and paleoclimate of the Fort Hancock and Camp Rice Formations

In this study, the Fort Hancock and Camp Rice Formations in the Hueco Bolson of West Texas were investigated to reconstruct the depositional environments and paleoclimatic conditions that prevailed in the southern Hueco Bolson during the late Tertiary and early Quaternary and to provide a stratigraphic framework for hydrogeologic studies of the area. Depositional environments in the middle Pliocene Fort Hancock Formation include alluvial fans and ephemeral lakes, which suggest an arid to semiarid climate during deposition. Paleosols in the Fort Hancock include buried Vertisols and calcic soils. The Camp Rice Formation, which is late Pliocene to Pleistocene in age, unconformably overlies the Fort Hancock Formation and contains five lithofacies that were deposited in fluvial, lacustrine, and eolian environments. Several cycles of buried calcic soils in loess and buried Vertisols with pedogenic $CaCO_3$ nodules exist in the Camp Rice Formation and indicate subhumid to arid paleoclimates. Thus, an arid to subhumid, but probably semiarid, climate prevailed in the Hueco Bolson during the Pliocene to early Pleistocene. *Funded by the Texas Low-Level Radioactive Waste Disposal Authority under Interagency Contract Number IAC(90-91)0268.*

RI 199. Field Studies and Numerical Modeling of Unsaturated Flow in the Chihuahuan Desert, Texas,

by B. R. Scanlon, F. P. Wang, and B. C. Richter. 56 p., 37 figs., 6 tables, 2 appendices, $5.50

Evaluation of ground-water movement in the vadose zone

Hydrogeologic studies of the vadose zone are an integral part of site characterization of current and future waste-disposal sites. This report describes in detail field techniques, analytical laboratory methods, and numerical modeling useful in evaluation of the hydraulic controls on unsaturated flow. An innovative technique to calibrate and install field psychrometers is described, together with other field instrumentation, such as neutron-access tubes, Guelph permeameters, soil samplers, tensiometers, and the instantaneous-profile test. This innovative technique avoided many problems of psychrometer data encountered in previous studies and, in combination with the other field techniques, provided unequivocal data for evaluating the direction of potential water movement. Hydraulic data derived from field measurements were compared and complemented with data derived from soil samples in the laboratory, using laboratory psychrometers and pressure-plate extractors, which are also described in detail. Field and laboratory data were subsequently used in numerical simulations of unsaturated flow. The numerical code described in this report, TRACRN, offers many advantages over other codes and yields accurate mass balance for numerically difficult problems. *Funded by the Texas Low-Level Radioactive Waste Disposal Authority under Interagency Contract Number IAC(90-91)0268.*

RI 200. Plio-Pleistocene Depositional Sequences of the Southeastern Texas Continental Shelf and Slope: Geologic Framework, Sedimentary Facies, and Hydrocarbon Distribution,

by R. A. Morton, R. H. Sams, and L. A. Jirik. 80 p., 40 figs., 1 table, 1 appendix, 3 plates, $5.00

Assessment of depositional history and oil and gas reserves, Texas Outer Continental Shelf

Plio-Pleistocene reservoirs have produced more than 40 million barrels of oil and 2.5 trillion cubic feet of gas from Texas offshore leases. The reservoirs initially contained about 1.6 billion barrels of oil equivalent, or nearly two-thirds of the estimated total recoverable reserves beneath the Texas Outer Continental Shelf. The 75 fields that host these resources are located near diapirs or faults associated with late salt movement. The authors of this report used data on structural style, reservoir facies, and hydrocarbon composition to group the fields into six exploration plays, all of which offer some potential for either new field discoveries or reserve growth. Among the sources of data used were two grids of seismic profiles, approximately 350 geophysical logs of wells penetrating all or part of the Plio-Pleistocene section, and paleontological reports from nearly two-thirds of the wells used for correlation. Results showed that although each play produces gas and some oil, the most prolific play encompasses stacked sandstone reservoirs and broad rollover anticlines located between the *Trimosina* regional and counterregional fault system and that most of the oil comes from the oldest lowstand submarine fans. *An industry-sponsored research project supported by CNG Producing Company, the Louisiana Land & Exploration Company, Mobil Producing Texas and New Mexico, Inc., Oryx Energy Company, Pennzoil Producing Company, Standard Oil Production Company, Tenneco Oil Exploration and Production, Texaco, Inc., Total Minatome Corporation, and Unocal Corporation.*

RI 201. Stratigraphic Analysis of the Upper Devonian Woodford Formation, Permian Basin, West Texas and Southeastern New Mexico,

by J. B. Comer. 63 p., 12 figs., 4 appendices, 7 pls., $6.50

Stratigraphy of the Woodford Formation

The Upper Devonian Woodford Formation is an organic-rich petroleum source that extends throughout West Texas and southeastern New Mexico. Currently it is generating oil or gas in the subsurface and is a potential hydrocarbon reservoir where it is highly fractured, such as in the Central Basin Platform, southernmost Midland Basin, and parts of the Northwestern Shelf. The depositional model of the Woodford developed in this report is based on stratigraphic sequence, patterns of onlap, and lithologic variations, together with published information on global paleogeography, paleoclimate, and eustasy. Petrologic and organic geochemical data were used to ascertain the origin of the unit and provided information necessary for predicting potential locations and lithologies of commercial petroleum reservoirs within the Woodford. Data were obtained from 558 well logs, 13 cores, and 3 measured sections. In cores and outcrops, the Woodford and correlative formations were identified by their high radioactivity and unique lithologies of black shale and siltstone. Detailed information on the location and description of cores and section and point-count and TOC data is given in the four appendices; the plates are structure and isopach maps and cross sections. Results of this study are applicable where the potential for hydrocarbon reserves exists.

RI 202. Regional Hydrodynamics of Variable-Density Flow Systems, Palo Duro Basin, Texas,

by R. K. Senger. 54 p., 30 figs., 4 tables, $5.00

Hydrologic modeling of the Palo Duro Basin

In this report, the effect of variable-density fluids on the hydrodynamics of a mature sedimentary basin were investigated using a regional ground-water flow model along a west-east cross section through the Palo Duro Basin, Texas. Modeling was based on steady-state simulation of equivalent fresh-water heads and stream functions incorporating observed fluid densities and viscosities that vary in space but not in time. Paleohydrologic modeling of the basin was configured to different water-table conditions during basin development, including uplift, deposition, and erosion. Results show that the overall ground-water circulation

in the Palo Duro Basin is not greatly affected by regional fluid-density variations, indicating that the flow component arising from the present-day topographic relief dominates buoyancy forces associated with dense fluids. However, during recent geological past, prior to maximum basin uplift, when the topographic relief across the basin was much lower than it is today, a buoyancy-dominated flow pattern may have existed, characterized by continuous overturn of fluids in the deep aquifers.

RI 203. Integrated Characterization of Permian Basin Reservoirs, University Lands, West Texas: Targeting the Remaining Resource for Advanced Oil Recovery,

by Noel Tyler, D. G. Bebout, C. M. Garrett, Jr., E. H. Guevara, C. R. Hocott, M. H. Holtz, S. D. Hovorka, Charles Kerans, F. J. Lucia, R. P. Major, S. C. Ruppel, and G. W. Vander Stoep. 136 p., 67 figs., 2 tables, $5.00

Reservoir characterization of University Lands

As are most Texas oil reservoirs, University Lands reservoirs are nearing depletion using conventional recovery methods. However, a substantial resource (more than 2 billion barrels) of conventionally recovered mobile oil still resides in these reservoirs. This unrecovered mobile oil is movable from the reservoir but is prevented from reaching existing well bores because of geologic heterogeneity. To assess the potential for incremental recovery of this unrecovered mobile oil from lands owned by The University of Texas System, the authors of this report conducted a 5-year geologic and engineering characterization of 10 reservoirs selected from a set of 101 large University Lands reservoirs in West Texas. Each of the 101 reservoirs has produced more than 1 million stock-tank barrels of oil and contains 200 million stock-tank barrels of reserves. All 101 reservoirs were grouped on the basis of geologic similarity into 11 major and minor plays, and 10 reservoirs from 3 major plays were selected for detailed analysis. Results showed that the location of unrecovered mobile oil depends on degree of lateral or vertical heterogeneity within the reservoir; thus, recovery strategies should be deployed on the basis of type of reservoir heterogeneity: in vertically heterogeneous reservoirs like the Ellenburger, deepening of existing wells and drilling of new wells would be advantageous, whereas in laterally heterogeneous reservoirs like the Spraberry submarine fan reservoir, a better strategy might be targeted infill drilling in areas of high remaining saturation. Projected oil recovery from these University Lands could be increased to 30 percent of the oil in place, thus adding more than 400 million stock-tank barrels of reserves and tripling the reserve base. Production could thereby be stabilized at current rates for the next 30 years. *Funding was provided by The University of Texas System.*

RI 204. Geologic Characterization of Low-Permeability Gas Reservoirs, Travis Peak Formation, East Texas,

by S. P. Dutton, S. E. Laubach, R. S. Tye, R. W. Baumgardner, Jr., and K. L. Herrington. 84 p., 71 figs., 5 tables, $4.00

Geologic study of the Travis Peak Formation

The Lower Cretaceous Travis Peak Formation of East Texas and North Louisiana, which contains an estimated 6.4 trillion cubic feet of gas in place, was the focus of an intensive study of the geology of this low-permeability ("tight") gas sandstone. Geologic characterization included interpretation of stratigraphy and depositional systems, evaluation of reservoir sandstone diagenesis, and analysis of structure and in situ stress. Travis Peak depositional systems comprise braided to meandering fluvial, deltaic, paralic, and shelf systems. Petrographic studies indicate that extensive quartz cement is the major cause of low permeability in the Travis Peak, but permeability is locally enhanced by natural fractures. Maximum horizontal stress, the direction in which hydraulic fractures will propagate, is oriented subparallel to the natural fractures. The authors used more than 300 well logs to correlate depositional packages and construct regional cross sections; a total of 3,680 ft of core was described for this study. Information acquired during this study could lead to improved recovery and lowered completion costs through better field-development and well-completion programs, both in the Travis Peak Formation and in similar tight gas sandstones elsewhere. *Funding was provided by the Gas Research Institute under contract no. 5082-211-0708.*

Geological Circulars

GC 91-1. Estimation of Lignite Resources in the Wilcox Group of Central and East Texas Using the National Coal Resources Data System,

by S. J. Tewalt and M. L. W. Jackson. 44 p., 29 figs., 6 tables, 1 appendix, $5.25

Assessment of the lignite resources of the Wilcox Group in Texas

As part of an ongoing USGS-funded program to provide current, uniformly derived U.S. coal resource estimates, near-surface lignite resources in Texas were calculated using the National Coal Resources Data System (NCRDS) and the PACER, VLATLONG, and GARNET geographic information systems. Measured, indicated, and inferred near-surface resource estimates in 2.5–5 ft, >5–10 ft, and >10–20 ft USGS thickness categories were calculated for the Paleocene–Eocene Wilcox Group in the east-central, northeast, and Sabine Uplift geographic regions of Texas. East-central Texas contains 47 percent of the total measured and 38 percent of the total indicated Wilcox resources; it is the most lignite-rich area in the state. This circular compares the NCRDS method with that used by W. R. Kaiser and others (1980) in Bureau Report of Investigations No. 104, "Lignite Resources in Texas." The NCRDS method involves using resource circles that have constant dimensions and allows uniform comparison of estimates from different states. Kaiser and others' method is subjective and requires extensive geologic mapping in each coal-bearing region to allow extrapolation of resource limits beyond known deposits. *Funded by the U.S. Geological Survey under cooperative agreement nos. 14-08-0001-G-639 and 14-08-0001-A-0098.*

GC 91-2. Tertiary and Quaternary Structure and Paleotectonics of the Hueco Basin, Trans-Pecos Texas and Chihuahua, Mexico,

by E. W. Collins and J. A. Raney. 44 p., 17 figs., 1 appendix, $4.50

Tectonic analysis of the Hueco Basin

The Hueco Basin, or Hueco Bolson, is an intermontane basin that lies within the northern Chihuahuan Desert in El Paso and Hudspeth Counties, Texas, and northeastern Chihuahua, Mexico. In this study, the authors used subsurface data in conjunction with aerial-photographic and geologic mapping to determine the basin's structural development and history of faulting. Scarp morphologies, fault geometries, histories of fault movements, amounts of offset on strata of different ages, and amounts of offset during single surface-rupture events are described for young faults that have surface expression in the basin. These fault characteristics are useful for evaluating the seismic risk potential of faults in this region. The Hueco Basin comprises a northwest subbasin that has north-striking normal faults and a southeast basin that has northwest-striking normal faults. Studies revealed that Cenozoic basin fill is thin on the east and northeast basin margins and thicker in the central basin and on the west and southwest basin margins. Major faults bounding the basin on the west and southwest, the East Franklin Mountains fault and the Amargosa fault, respectively, have been more active and exhibit greater offset than do boundary faults on the east and northeast, a disparity that has created an asymmetric graben. The most recent surface rupturing of the Amargosa and East Franklin Mountains faults occurred in the late Pleistocene–Holocene; middle Pleistocene surficial deposits are offset between 24 and 32 m. Boundary faults on the northeast side of the basin, Campo Grande, Caballo, and unnamed faults, had their most recent surface rupture during the late Pleistocene. Middle Pleistocene surficial deposits cut by these faults are offset between 1.6 and 24 m. Because published information on neotectonics of Trans-Pecos Texas is limited, this circular adds insight into the Cenozoic tectonic history of the region. *Funded by the Texas Low-Level Radioactive Waste Disposal Authority under Interagency Contract Number IAC(90-91)0268.*

GC 91-3. Structural History and Origin of the Sabine Arch, East Texas and Northwest Louisiana,

by M. L. W. Jackson and S. E. Laubach. 47 p., 26 figs., 2 tables, $5.50

Structural analysis of the Sabine Arch

The Sabine Arch is a large (12,000 mi^2 [31,000 km^2]), low-amplitude anticline centered on the Texas–Louisiana border. A basement-cored feature that formed in the Jurassic, the arch has been interpreted as (1) a Jurassic horst that persisted throughout the Cretaceous as a topographic relict of rifting, (2) a dome caused by deep-seated Cretaceous plutons, and (3) a fold caused by regional tectonism. The authors suggest that the origin of the Sabine Arch is not adequately explained by conventionally accepted causes of uplift, interpretations (1) and (2). Using regional maps and cross sections derived from approximately 800 well logs, the authors outlined the depositional history of the arch region, thus documenting the arch-movement history. The timing, amount, and mechanisms of Sabine Arch movement were ascertained, and the results were combined with regional tectonic interpretations to evaluate possible causes of uplift. The shape of the Sabine Arch is compatible with an origin by folding and that arch movement is broadly contemporaneous with crustal shortening in the nearby Cordilleran orogenic belt. The authors propose that the Sabine Arch is a fold caused by Late Cretaceous and early Tertiary tectonic compression of the northern Gulf of Mexico Basin. Ideas presented in this circular are relevant to the thermal and structural history and crustal composition of the Gulf of Mexico Basin and may lead to new concepts about the response of passive margin basins to intraplate stresses. *Funding provided by the Gas Research Institute under contract number 5082-211-0708.*

GC 91-4. A Glossary of Salt Tectonics,

by M. P. A. Jackson and C. J. Talbot. 44 p., 19 figs., 2 tables, 3 appendices, $2.50

Lexicon of salt tectonics nomenclature

Because of the significant advances in research on salt tectonics made in the 1980's, a need arose for a compendium containing concise, standardized definitions of new concepts and terminology. Hence this glossary was compiled, focusing on recently developed ideas. Unlike conventional glossaries, this one is conceptual rather than alphabetical; each of the 138 terms is defined in the context of preceding terms, so that understanding increases step-by-step if the glossary is read through in sequence. Ideas thus progress from simple to complex, from qualitative to quantitative, and from geometric description to dynamic interpretation. The authors cite the papers in which new terms were first used or recorded, and subsequent papers are also mentioned if they offer a redefinition or conceptual advance. The 19 figures in the glossary illustrate some of the new ideas and nomenclature, and an index provides rapid access to definitions of a particular word or phrase. Three appendices are included: the first summarizes how and at what rates salt responds to deviatoric stresses; the second quantifies the effects of shortening of strata over a salt layer; and the third outlines principles of creeping flow in salt bodies. *Funding provided in part by the Texas Advanced Research Program and the Texas Advanced Technology Program under Grant Nos. 3658-292 and 3658-061.*

Other Publications

Tectonic Map of Texas,

Compiled by T. E. Ewing. 4 sheets, in full color, scale 1:750,000, $15.00

Statewide tectonic map

This 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, neotectonics, and isotopic age data. An accompanying text, "The Tectonic Framework of Texas," describes the complex tectonic setting and evolution of Texas.

Restore© User's Manual and Software,

by Dan Schultz-Ela and Ken Duncan. 1 Macintosh® disk and 75-page user's manual, $249.95 ($49.95 for nonprofit organizations)

Computer program and manual for restoring cross sections

Restore© is a copyrighted program that enables a user to sequentially backstrip and balance cross sections from extensional terranes possibly involving flow of salt or ductile shale. It fully utilizes the fast, user-friendly, graphics-oriented capabilities of a Macintosh® II. *Restore*© reconstructs the section to earlier depositional stages by assuming that deformed horizons were originally planar and that fault blocks maintained constant area (apart from compaction). Folding and deformation within fault blocks are removed by a user-specified shear angle and rotation to a regional datum. Through the use of different geometries and unfolding parameters, a user can reconstruct viable cross sections for the deposition time of each horizon. Such restorations are vital for establishing the migration paths of hydrocarbons and the evolution of structural traps. The program runs on the Macintosh® II series of microcomputers that have color monitors and at least 2 megabytes of RAM; a hard drive is not required but will expedite running *Restore*©. Output can be sent to a laser printer or to a PICT file that can be edited using most Macintosh® drawing programs. The accompanying user's manual consists of 4 chapters, 57 figures, an appendix on using the program with AutoCAD, and an index. Customer assistance in running the program is offered by the Bureau to all registered purchasers.

The Wilcox Group and Carrizo Sand (Paleogene) in the Sabine Uplift Area, Texas: Ground-Water Hydraulics and Hydrochemistry,

by G. E. Fogg, W. R. Kaiser, and M. L. Ambrose. 70 p., 37 figs., 1 table, 1 appendix table, 19 pls., 4 appendices (3 on microfiche), $12.50

Hydrogeology of the Sabine Uplift area

This study was designed to provide industry, regulatory agencies, and the general public the hydrogeological framework of the Sabine Uplift area to better predict the aquifer system's response to lignite mining. Part of a series of four reports on the geology and hydrology of the East Texas lignite belt, this report emphasizes the regional hydrogeology of a 12-county area in northeast Texas, presenting a comprehensive picture of ground-water circulation and hydrochemical evolution. Subdivision of the Wilcox-Carrizo groundwater system into two subsystems for potentiometric-surface mapping, improved mapping of vertical hydraulic gradients, and complementary mapping of major chemical species resulted in more accurate description of shallow and deep ground-water circulation. Results indicate that potential ground-water contamination from mining in the Wilcox Group is primarily a local problem that will probably not impact large areas of the aquifer unless the number of lignite mines increases greatly; however, depressuring and dewatering for deep surface mining could have more widespread effects on the aquifer system. Maps showing well locations, hydraulic heads, vertical gradients, base of fresh water, and distribution of chemical species are presented as 19 plates; data on hydraulic head, water chemistry, and molar concentrations used in the hydrochemical maps are presented in 3 microfiche appendices. These maps and data should also be useful to the hydrological and environmental consulting community. *Funding was provided by the Texas Energy and Natural Resources Advisory Council under interagency cooperation contract IAC (82-83)-0822 and by special appropriation from the Texas Legislature.*

In addition to these publications, the Bureau also issued two data bases in 1991, the **Atlas of Major Texas Oil Reservoirs: Data Base,** by M. H. Holtz, Noel Tyler, C. M. Garrett, Jr., W. G. White, and N. J. Banta ($40), and the **Atlas of Major Texas Gas Reservoirs: Data Base,** by C. M. Garrett, Jr., E. C. Kosters, N. J. Banta, and W. G. White ($40). Texts accompanying the disks describe the contents and formats of the data files, which are designed for use in an IBM PC-compatible data base such as dBASE Plus. The disks contain tables of geologic, engineering, and production parameters for plays discussed in the Bureau's Oil Atlas (1983) and Gas Atlas (1989) publications.

Services

Core Research Center

The Core Research Center (CRC) houses the largest public collection of subsurface geological materials in the United States. 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 7,500 cores and drill cuttings from 55,000 wells may be viewed on-site at the CRC 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 1991, the CRC received more than 400 visitors. Transactions were made involving CRC inventory that included geologic materials from more than 1,000 wells and required the transfer of more than 27,000 boxes of core (40 linear miles) to and from viewing and shipping areas. Core processing, including slabbing and reboxing, exceeded 40,000 linear feet. The Thin Section Laboratory produced about 2,400 thin sections for Bureau and non-Bureau patrons. More than 5,000 photographs were taken of geologic materials during 1991.

New acquisitions in 1991 totaled more than 400 new cores (more than 20,000 linear feet of core) and drill cuttings from more than 200 wells. Donations were received from American Exploration, ARCO Oil & Gas, Ball Exploration, Ballard Exploration, Bell Laboratories, Brazos River Authority, Chevron, Core Laboratories, Cross Timbers Oil Co., David K. Davies & Associates, Dow Chemical, W. G. Ellis, Ensearch, Gold Fields Mining, Halliburton Logging, Hill Country Water Conservation, J. McShane, Inc., Arkansas Geological Commission, K & A Laboratories, Kinlaw Oil Corporation, Lower Colorado River Authority, Maxus Energy Corporation, McKenzie Petroleum Co., Mobil Oil, Oxy U.S.A., Phillips Petroleum, Placer Dome, Inc., Reservoirs, Inc., Terra-Tek, Shell Western E & P, Texas A&M University, Texstar North American, Tuskar Oil, U.S. Army Corps of Engineers, U.S. Geological Survey (Denver), and Wesley Weichman.

Visiting researcher in one of several core viewing rooms at the Bureau's Core Research Center.

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 Steve Tweedy and other professional analytical personnel. The facility contains several major instrumental systems capable of performing a variety of analyses, including inductively coupled plasma optical and mass spectrometry (ICP-OES, ICP-MS) for major, minor, and trace element measurements, stable isotope mass spectrometry (hydrogen and oxygen in waters, carbon and oxygen in carbonate materials), electron microprobe analysis (four automated wavelength dispersive X-ray spectrometers), scanning electron microscopy (SEM) examination and photography, X-ray diffractometry (XRD) for mineral identifications, thermal analysis (thermo-gravimetric analyzer), ion chromatography (IC), and gas chromatography (GC). Complete wet-chemical analysis, coal/fuel analysis, and sample comminution can also be performed at the MSL.

Many Bureau projects were supported by MSL services during 1991. Among these were programs for the Texas Mining and Mineral Resources Research Institute, Texas Advanced Research Program—Bonaire Dolomite, Gas Research Institute (GRI) Ferron Sandstone, Superconducting Super Collider, Hazardous Waste, GRI's Secondary Natural Gas Recovery, EPA Ground Water, Tight Gas, Uranium Mine Tailing Recovery Act, Gulf Coast Geothermal, Paleohydrology, Energy Research in Applications Program, Texas Low-Level Radioactive Waste Disposal Authority, and Pantex projects. In addition to support of Bureau

projects, the MSL has also provided analytical services to the Institute of Gas Technology's Pleasant Bayou test well and UT's Center for Energy Studies and Center for Material Science and Engineering, and Petroleum Engineering, Mechanical Engineering, and Civil Engineering departments, as well as several private entities.

The MSL continued its membership in the International Geostandards Working Group and the American Society for Testing and Materials. The laboratory also participated in the Water Pollution Laboratory Performance Evaluation Studies sponsored by the U.S. Environmental Protection Agency.

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 1991, 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 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.

The Reading Room staff cataloged, indexed, shelved, and entered into a computer data base more than 1,800 items. More than 1,000 items were received from other states through the Bureau's publication-exchange program. Most of the exchange volumes were transferred to the Department of Geological Sciences library.

Geophysical Log Facility

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

By the end of 1991, the facility had accumulated approximately 70,000 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

Soviet Geoscientists Visit the Bureau

During 1991, the Bureau was visited by two separate groups of Soviet geoscientists interested in learning more about environmental and petroleum-recovery research being conducted in the United States. A delegation of six Ukrainian geoscientists, headed by the USSR Deputy Minister of Geology, was given details of the Bureau's various programs involving water quality, waste isolation, and contaminant remediation. Their visit, sponsored by Amoco Production Company, enabled them to discuss their country's environmental needs and to see how Texas addresses similar problems. Later in the year, a contingent of geologists from Byelorussia spent a week with Bureau researchers under the sponsorship of the U.S. Geological Survey. They received summaries of several past and current Bureau studies of oil and gas distribution in the Permian Basin and were given the opportunity to examine the Capitan Reef complex and exposed Delaware Basin stratigraphy of West Texas and New Mexico. Reservoir characterization techniques and hydrocarbon-assessment methods were of particular interest to the Soviets.

Russian geologists viewing San Andres Formation outcrops in the Guadalupe Mountains on a joint Bureau/U.S. Geological Survey/Chevron field seminar. From left to right: V. Bogino (Director, Byelorussian Geological Prospecting Research Institute), M. Keller (research geologist, VNIGNI at Moscow), Z. Pozniakevitch (Deputy Director, Byelorussian Geological Prospecting Research Institute), R. Lindsay (exploration geologist, Chevron), and G. Ulmishek (research geologist, U.S. Geological Survey).

Bureau Conducts Statewide Forums on Improved Oil and Gas Recovery

The Bureau of Economic Geology and the Texas Independent Producers and Royalty Owners Association, in cooperation with regional oil and gas associates, organized and conducted a series of seminars and workshops across the state to assess the needs and opportunities for advanced technology applications for improved discovery and recovery of hydrocarbons throughout Texas. The program is supported by the Texas Higher Education Coordinating Board and consists of two phases. The first phase, completed during the fall of 1991, involved forums specifically designed to gain input from Texas' independent oil and gas producers in identifying their various technology needs. In 1992 during phase two of the program, a series of seminars and workshops will be developed, on the basis of priorities set for regional technology needs. Seminar presentations will be provided by university research staff, technical staffs from petroleum-producing companies, service company personnel, and private consultants.

Bureau Geophysical Program Expanded

During 1991, the Bureau has markedly expanded its geophysical capabilities by acquiring a DEC-5000 workstation and extensive software, which was donated by Sierra (a Halliburton Company). Under the leadership of **Bob A. Hardage,** the Bureau's geophysics program now includes two- and three-dimensional seismic imaging and interpretational capabilities to support traditional subsurface reservoir-characterization studies. The program has already demonstrated a powerful capacity to (1) plan projects by modeling three-dimensional study areas to better locate seismic profiles for detailed data collection and (2) interpret the data by creating synthetic seismic profiles in any orientation to determine reservoir-facies distribution.

Awards and Honors

In 1991, **Walter B. Ayers, Jr.,** was awarded the 1991 Best Paper Award by the Energy Minerals Division of the American Association of Petroleum Geologists.

William L. Fisher was elected the American Institute of Professional Geologists President-Elect. He was also awarded the Ian Campbell Medal by the American Geological Institute and the Hollis D. Hedberg Award in Energy by the Institute for the Study of Earth and Man. He also served as a Hearst Distinguished Lecturer at the University of California at Berkeley. **Martin P. A. Jackson** was named 1 of 11 Distinguished Lecturers for 1991–1992 by the American Association of Petroleum Geologists.

New Research Staff

Michael H. Gardner came to the Bureau as a Research Associate to work on the State Lands Energy Resource Optimization project. At the Colorado School of Mines, Gardner studied the sequence stratigraphy of mid-Cretaceous strata of the western United States. Gardner has worked for ARCO in Alaska and for a geological consulting firm in Colorado. **Bob A. Hardage,** who received his Ph.D. from Oklahoma State University, joined the Secondary Gas Recovery project as a Research Associate specializing in geophysics. Twenty-two of his 25 years of industry experience were at Phillips Petroleum, where he had assignments in geophysical research, seismic stratigraphy development, and exploration management. Before coming to the Bureau, Hardage had management responsibilities at Western Atlas International and was vice-president of geophysical development and marketing for Atlas Wireline Services. **Hemin Koyi,** originally from Kurdistan of Iraq but now a naturalized Swede, joined the Bureau's Applied Geodynamics Laboratory as a Research Fellow to study the effect of basement faulting on overlying salt diapirs. Koyi received his Ph.D. from Uppsala University in Uppsala, Sweden, where he also worked as a Research Scientist on projects for the Swedish Space Corporation, a mining company, and SAGA Petroleum of Norway. **Robert E. Mace** is engaged in a study of the shallow aquifer in Ellis County, Texas, for the Superconducting Super Collider hydrological project. Mace received his M.S. in hydrology from the New Mexico Institute of Mining and Technology, where he studied the effect of clay content on the trapping of immiscible organic fluids. **Auburn L. Mitchell** joined the Bureau as coordinator of Special Projects. Mitchell has a B.S. in industrial engineering from Oklahoma State University and a Doctor of Jurisprudence from the University of Oklahoma School of Law.

Jules R. DuBar Retires

Jules R. DuBar retired in December after 10 years of service to the Bureau. DuBar came to the Bureau with extensive experience in academia, the petroleum industry, Federal and State agencies, and private geologic consulting. He has written more than 40 scientific publications on a variety of subjects, including Tertiary paleontology and paleoecology, litho-stratigraphy of the southern Atlantic coastal plain, and history of geology. Throughout his career, DuBar garnered numerous professional awards and was a member of several honorary scientific societies. While at the Bureau he worked on the geopressured-geothermal programs, the State Lands Energy Resource Optimization project, and studies of Gulf Coast sand resources. For much of his Bureau tenure he was also Technical Editor of all Bureau publications.

Jules DuBar (right) accepting a plaque from William L. Fisher honoring his retirement from the Bureau. Photograph by David M. Stephens.

Research Staff Publications and Activities

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

Papers

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Lectures and Public Addresses

Arten J. Avakian

"Minerals, rocks, and fossils": presented to the kindergarten class of Matthews Elementary School, Austin, Texas.

Walter B. Ayers, Jr.

"Coalbed methane research and development in the San Juan Basin": presented to Midland Chapter, Society of Independent Professional Earth Scientists, Midland, Texas.

"Coalbed methane in the Fruitland Formation, San Juan Basin, Colorado and New Mexico—controls on occurrence and producibility": presented to Central Texas Mining Section, Society of Mining Engineers, American Institute of Mining, Metallurgical, and Petroleum Engineers, Austin, Texas.

Robert W. Baumgardner, Jr.

"Central Texas flood hazards": presented to Austin Community College Environmental Geology Class, Austin, Texas.

"Overview of Bureau activities related to soils and land resources": presented to 1991 Annual Soil Survey and Land Resource Workshop, College Station, Texas.

"Surface fissures at Texas' proposed low-level radioactive waste repository": presented to the Austin Geological Society, Austin, Texas.

Don G. Bebout

"Reservoir-scale investigation of a modern sand shoal—Joulters Cays, Bahamas": presented to the West Texas Geological Society, Midland, Texas.

Sigrid J. Clift

"Geologic history of Central Texas": presented to Lago Vista Middle School eighth grade science classes, Lago Vista, Texas.

Alan R. Dutton

"Paleohydrologic evolution of basin-scale flow and associated transport based on the geochemical record": presented to the Geological Society of America Penrose Conference on Flow and Associated Transport in Basins: Driving Forces, Coupling and Geologic Controls, Bodega Bay, California.

"Isotopic evidence for paleohydrologic evolution of ground-water flow paths, southern Great Plains, United States": presented to The University of Kansas, Department of Geology and Kansas Geological Survey, Lawrence, Kansas.

Shirley P. Dutton

"Hydraulic fracture test site: geologic setting": presented to the Gas Research Institute, Natural Gas Supply Project Advisors Meeting, Tight Gas Sands Project Area, Irving, Texas.

"Integrated geological characterization of low-permeability ("tight gas") sandstone reservoirs": presented to the Forum on Improved Oil & Gas Recovery sponsored by TIPRO and the Bureau of Economic Geology, Amarillo, Texas.

"Natural gas reserves, supply, and demand: an assessment of the natural gas resource base of the United States": presented to the Commercial and Industrial Space Conditioning Alternatives Seminar, Austin, Texas.

Robert J. Finley

"Future resource potential of the Permian Basin": presented to The University of Texas of the Permian Basin, Emerging Ventures and Regional Development: Entrepreneurship for Economic Diversification Meeting, Center for Energy and Economic Diversification, Midland/Odessa, Texas.

"Compartmentalized reservoirs": presented to Oryx Energy Company, 1991 Technology Futures Symposium, Dallas, Texas.

"Characterization of heterogeneous natural gas reservoirs: applications for incremental recovery in the Texas Gulf Coast": presented to A Forum on Improved Oil and Gas Recovery, Houston, Texas.

"Infield natural gas reserve growth/secondary gas recovery joint venture": presented to the Gas Research Institute, Natural Gas Supply Project Advisors Enhanced Production from Conventional Resources Meeting, Houston, Texas.

"Opportunities for horizontal drilling in Texas": presented to the American Association of Petroleum Geologists, Southwest Section, and to the Abilene Geological Society, Abilene, Texas.

"Variability in deltaic reservoir heterogeneity: implications for mobile and residual oil recovery": presented to the U.S. Department of Energy, Opportunities to Improve Oil Productivity in Unstructured Deltaic Reservoirs Symposium, Office of Fossil Energy, Dallas, Texas.

"Horizontal drilling: applications after the chalk": presented to the Dallas Energy Council, Professional and Development Institute, Inc., and The University of North Texas, The Third Annual Dallas Energy Symposium, Dallas, Texas.

R. Stephen Fisher

"Petrography of Ferron sandstones": presented to field trip participants as part of the presentation "Architecture and Permeability Structure of Fluvial- Deltaic Sandstones: A Field Guide to Selected Outcrops of the Ferron Sandstone, East-Central Utah," Emery, Utah.

"Relations between petrography and permeability in a deltaic reservoir analog, Ferron Sandstone, Utah": presented to the Gas Research Institute annual Project Advisors Group meeting, Houston, Texas.

(with Noel Tyler and M. D. Barton)

"Reservoir architecture and permeability structure in a deltaic reservoir analog, Ferron Sandstone, Utah": poster session at the Gas Research Institute annual Project Advisors Group meeting, Houston, Texas.

William L. Fisher

"Technology and price: basic elements of U.S. oil and gas outlook": presented to The University of California, Berkeley, Phoebe Apperson Hearst Distinguished Lecture Series, Berkeley, California.

"Toward a rational energy policy: will we ever get there?": presented to the California State University, Fresno, University Lecture Series, Fresno, California.

"U.S. potential for oil and gas production": presented to the Aspen Institute Energy Policy Forum, Aspen, Colorado.

"Changing dimensions in natural gas supplies": special briefing for Secretary of Energy, Washington, D.C.

"Natural gas supplies from the Midcontinent and Gulf Coast, U.S.A.": presented to the Industrial Gas Users Association/L'Association des Consommateurs Industriels de Gaz, Toronto, Canada.

"From gushers to reserve growth: a brief history of Texas oil and gas": presented to the American Association of Petroleum Geologists, Symposium on History of AAPG and the Petroleum Industry, annual meeting, Dallas, Texas.

"The U.S. potential in oil and gas": presented to the Society of Exploration Geophysicists, first annual meeting of trustee associates, Point Clear, Alabama.

"Natural gas markets: ample supply in the 1990's and beyond": presented to the DRI Energy/Chemical Conference, New Orleans, Louisiana.

"Changing perspectives in natural gas": presented to the Central Texas R&D Society, Radian Corporation, Austin, Texas.

"Technology and geologic know how": presented to the South Texas Geological Society, keynote address to the Austin Chalk Symposium, San Antonio, Texas.

"Research and development directions in oil and gas recovery": presented to the Texas Independent Producers and Royalty Owners, midyear meeting, Austin, Texas.

"Surprising events in natural gas reserve additions": presented to the Gas Research Institute, Advisory Council, Washington, D.C.

"Energy concerns in America": presented to the Austin Kiwanis Club, Austin, Texas.

"Geology and the new energy frontiers": presented to The University of Texas at El Paso, Geology Building dedication, El Paso, Texas.

"Energy and the environment: conflicts in the making?": presented to the Permian Basin Oil Association/University of Texas System Seminar on Environment, Midland, Texas.

"The natural gas supply outlook for Texas": presented to the 2nd annual conference on moving gas on Texas intrastate, Houston, Texas.

"Characterization of Texas oil and gas resource base": presented to A Forum on Improved Oil and Gas Recovery, Houston, Texas.

Robert L. Folk

"Pyramids of Egypt: real stone or cast concrete?": presented to the University of Oklahoma, Department of Geology, Norman, Oklahoma; The University of Texas at Austin, Center for Middle Eastern Studies and Bureau of Economic Geology, Austin, Texas.

"Lovely bacterial bodies in carbonate sediments and rocks": presented to the West Texas Geological Society, Midland, Texas.

"Egyptian pyramids: the cast-in-place hypothesis": presented to the American Research Center in Egypt, 1991 annual meeting, Boston, Massachusetts.

"Etching of quartz in hydrofluoric acid": presented to New York State University at Stony Brook, Department of Geology, Stony Brook, New York.

"Calcite in dendrites and the Ca^{++}/CO_3 ratio": presented to New York State University at Stony Brook, Department of Geology, Stony Brook, New York.

Michael H. Gardner

"Sequence stratigraphy of mid-Cretaceous clastic wedges, central Utah": presented to Mobil Research and Development Corporation, Sequence Stratigraphy Program, Dallas, Texas.

Jeffry D. Grigsby

"Cementation and burial history of the lower Vicksburg Formation, McAllen Ranch field, Hidalgo County, South Texas": presented to Bowling Green State University, Department of Geology, Bowling Green, Ohio.

"Petrography and diagenesis of the lower Vicksburg Formation, McAllen Ranch field, Hidalgo County, South Texas": presented to Ball State University, Department of Geology, Muncie, Indiana.

Edgar H. Guevara

"Stratigraphic architecture of the Wilcox G reservoir, Lake Creek unit, Texas: results from the Secondary Gas Recovery project and implications for parallel research on outcrops of the Ferron Sandstone": poster presentation at the Shaly Sandstone Reservoir Characterization Project Advisor Meeting, Gas Research Institute, Houston, Texas.

"Reserve growth potential in deltaic reservoirs: Lake Creek unit, Texas": combined poster-core display: presented at GRI-BEG's short course titled "Infield gas reserve growth potential: Gulf Coast sandstone reservoirs (Frio, Vicksburg, Wilcox)," Houston, Texas.

"Core description and lithofacies architecture of the lower Wilcox G sandstone, Lake Creek unit, Texas": presented at the Gulf Coast Association of Geological Societies, annual meeting field trip No. 3, Austin, Texas.

Douglas S. Hamilton

"Reservoir heterogeneity at Seventy-Six West field": presented to The University of Texas at Austin, Department of Petroleum Engineering, Austin, Texas.

"Reservoir heterogeneity at Seventy-Six West field and potential for infill drilling opportunities": presented to the Texas General Land Office, Austin, Texas.

"The Seventy-Six West field, Texas: an opportunity for increased oil recovery from barrier/strandplain reservoirs of the Jackson-Yegua trend by geologically targeted infill drilling": presented as a poster display to the Houston Geological Society, Houston, Texas.

Bob A. Hardage

"Advanced petrophysical methods for improved formation evaluation": presented at A Forum on Improved Oil and Gas Recovery, Houston, Texas.

Mark H. Holtz

"Plans and goals of the State Lands Energy Resource Optimization project": presented to The University of Houston, U.S. Department of Energy Grant Review of Crosshole Geotomography in a Partially Depleted Reservoir, Allied Geophysical Laboratories, Houston, Texas.

"Sensitivity of West Texas oil supply on oil price": presented to the San Antonio Society of Independent Professional Earth Scientists, San Antonio, Texas.

"SLERO progress report on play analysis and resource assessment": presented at the State Lands Energy Resource Optimization project 1991 annual internal review meeting, College Station, Texas.

"Targets for additional oil recovery in Leonardian carbonate reservoirs through horizontal drilling": presented to the Roswell Geological Society, Roswell, New Mexico.

"Use of GIS in the analysis of relationships among geologic oil plays": presented to the Texas Natural Resources Information System (TNRIS) Geographic Information System (GIS) Data Exchange Forum 1991, Austin, Texas.

"Analysis of reserve growth potential in Leonardian restricted platform carbonate reservoirs, Permian Basin: an integrated approach": presented to the 1991 Annual Technical Conference and Exhibition of the Society of Petroleum Engineers, Dallas, Texas.

"Price effects on developmental well completions, reserve additions, and oil production in West Texas": presented to the 1991 SPE Hydrocarbon Economics and Evaluation Symposium, Dallas, Texas.

Martin P. A. Jackson

"Overview of AGL research for 1991": presented to The University of Texas at Austin, Bureau of Economic Geology, Industrial Associates of the Applied Geodynamics Laboratory, Austin, Texas.

"Rates of passive diapirism: extension of anisotropic overburden above salt": presented to The University of Texas at Austin, Bureau of Economic Geology, Industrial Associates of the Applied Geodynamics Laboratory, Austin, Texas.

"Extreme extensional salt tectonics in models and Angola": presented to The University of Texas at Austin, Bureau of Economic Geology, Industrial Associates of the Applied Geodynamics Laboratory, Austin, Texas.

"Extensional salt tectonics": presented to British Petroleum Exploration, Slough, United Kingdom.

"Progradation and salt-sheet emplacement and evacuation": presented to The University of Texas at Austin, Bureau of Economic Geology, Industrial Associates of the Applied Geodynamics Laboratory, Austin, Texas.

"Raft tectonics: the ultimate in thin-skinned extension": presented to The University of Texas at Austin, Department of Geological Sciences Structure/Hardrock Seminar, Austin, Texas.

"The rise and fall of diapirs during thin-skinned extension": AAPG Distinguished Lecture presented to the University of Oklahoma, Norman, Oklahoma; University of Tennessee, Knoxville, Tennessee; University of Kentucky, Lexington, Kentucky; Virginia Tech, Blacksburg, Virginia; and University of Alabama, Tuscaloosa, Alabama.

William R. Kaiser

"Hydrology of the Fruitland Formation, San Juan Basin": presented to the Alberta Research Council, San Juan Basin Coalbed Methane field trip, Durango, Colorado.

"Coalbed methane potential of the Greater Green River, Piceance, Powder River, and Raton Basins, geologic and hydrologic overview": presented to Gas Research Institute, Austin, Texas.

"Evaluation of coalbed methane: Greater Green River, Piceance, Powder River, and Raton Basins": presented to GRI's National Gas Supply Project Advisors Group, Birmingham, Alabama.

Charles Kerans

"Carbonate reservoirs: quantitative characterization of facies and permeability using outcrop analogs": AAPG Distinguished Lecture presented to Miami Geological Society, Miami, Florida; University of Kentucky, Lexington, Kentucky; Wright State University, Dayton, Ohio; Ohio State University, Columbus, Ohio; St. Lawrence University, Canton, New York: Rensselaer Polytechnic Institute, Troy, New York; Western Michigan University, Kalamazoo,

Michigan; Michigan Geological Society, Lansing, Michigan; Notre Dame University, South Bend, Indiana; and Baylor University, Waco, Texas.

"Integrated characterization of San Andres reservoirs, Permian Basin": presented to Industrial Associates of the Reservoir Characterization Research Laboratory (Oxy, Midland, Texas; Fina, Midland, Texas; Phillips Petroleum, Midland, Texas; Marathon Technology Center, Littleton, Colorado; Amoco, Houston, Texas); Amerada Hess Corporation, Tulsa, Oklahoma; Halliburton Geophysical Services, Houston, Texas); Stratamodel 3-D Geological Modeling Conference, Dallas, Texas; and the Fort Worth Geological Society, Fort Worth, Texas.

"Sequence stratigraphic framework of the San Andres and Grayburg Formations, Guadalupe Mountains, New Mexico, and implications for reservoir characterization and modeling": presented to SEPM (Society for Sedimentary Geology), Permian Basin Section, Midland, Texas.

"Karst model for Ellenburger Group reservoirs, West Texas": presented to the Oklahoma City Geological Society, Oklahoma City, Oklahoma.

Dennis R. Kerr

"Microresistivity imaging applications for the assessment of gas reservoir compartments in fluvial deposits of the Middle Frio Formation": presented at Geological Aspects of Borehole Imaging Conference sponsored by Society of Professional Well Log Analysts, Houston, Texas.

Hemin Koyi

"Basement extension below salt diapirs; salt-sheet emplacement and segmentation": presented to The University of Texas at Austin, Bureau of Economic Geology, Industrial Associates of the Applied Geodynamics Laboratory, Austin, Texas.

Charles W. Kreitler

"In situ investigations of deep well injection of liquid wastes": presented to the Hoechst Celanese Annual Operations Meeting, Houston, Texas, and to the annual Underground Injection Control meeting of the Texas Water Commission, Austin, Texas.

"Hydrogeology of the Frio Formation, Texas Coastal Zone, and implications to deep-well injection of hazardous wastes": presented to The University of Arizona, Department of Hydrology and Water Resources, Tucson, Arizona, and to The University of Texas at Austin, Department of Geological Sciences, Austin, Texas.

"Identification of the source of ground-water salinization with geochemical techniques": presented to the annual meeting of the U.S. Environmental Protection Agency, Robert S. Kerr Laboratory, Oklahoma City, Oklahoma.

"Hydrogeology of the Edwards aquifer": presented to the monthly meeting of LAMP (Learning Activities for Mature Persons), The University of Texas at Austin, Austin, Texas.

Stephen E. Laubach

"Pitfalls of fracture identification and characterization with borehole imaging logging systems": presented to the Houston Westside Society of Professional Well Log Analysts, Houston, Texas.

"Fracture patterns in low-permeability-sandstone reservoir rocks of the Rocky Mountain region": presented to the Society of Petroleum Engineers Joint Rocky Mountain Regional Meeting and Low-Permeability Reservoir Symposium, Denver, Colorado.

"Regional coal fracture patterns": presented to The University of Oklahoma, 32nd U.S. Symposium on Rock Mechanics, Rock Mechanics as a Multidisciplinary Science, Norman, Oklahoma.

"Observations of subsurface fractures and implications for interpreting seismic and borehole acoustic data": presented to the Society of Exploration Geophysicists Workshop, Houston, Texas.

"Geologic aspects of fractured reservoir characterization": presented to the Texas Independent Producers and Royalty Owners Association Forum on Improved Oil and Gas Recovery, San Antonio and Longview, Texas.

Raymond A. Levey

"An integrated geological, geophysical, and engineering study of a gas reservoir": presented to the Society of Exploration Geophysicists, Development and Production Forum, Durango, Colorado.

"Vertical seismic profile applications for definition of reservoir heterogeneity—South Texas, Vicksburg, and Frio Sandstone: A Secondary Gas Recovery Project": presented to the Houston Geological Society, Houston, Texas.

"Infield natural gas reserve growth joint venture—results in 1990": presented to the Project Advisors meeting organized by the Gas Research Institute, Houston, Texas.

"Research in secondary gas recovery": presented to Oxy U.S.A., Inc., Technical Conference, Houston, Texas.

"Future directions of the infield natural gas reserve growth joint venture": presented to Gas Research Institute, Chicago, Illinois.

"Gas research programs at the Bureau of Economic Geology": presented to the Texas Independent Producers and Royalty Owners Association, Austin, Texas.

"Secondary gas recovery research": presented to Marathon Oil Company, Oxy U.S.A., Inc., Texaco U.S.A., Mobil Exploration Producing Company, ARCO Oil and Gas Company, U.S. Geological Survey, Soviet Union Ministry of Oil and Gas, Petroleos de Venezuela, S.A., and Halliburton Geophysical Services, Austin, Texas.

Briefing to representatives of the Texas Independent Producers and Royalty Owners Association on Gas Research Programs at the Bureau of Economic Geology, Austin, Texas.

"Natural gas reserve replacement through infield reserve growth: An example from Stratton Field, Onshore Texas Gulf Coast Basin": presented to the Third International Reservoir Characterization Technical Conference, Tulsa, Oklahoma.

"Potential gas reserve growth in Texas: examples from Gulf Coast reservoirs": presented at A Forum on Improved Oil and Gas Recovery: Wichita Falls and Dallas, Texas.

F. Jerry Lucia

"Modern petrophysical methods for improved formation evaluation": presented at A Forum on Improved Oil and Gas Recovery, Houston, Texas.

"Economics of the oil business": presented to The University of Texas at Austin, Department of Geological Sciences (Geology 368N), Austin, Texas.

"Recognition of second, third, and fourth/fifth order scales of cyclicity in the El Paso Group and their relationship to karsting": presented to The University of Texas at Austin, Department of Geological Sciences (Geology 383M), Austin, Texas.

Robert E. Mace

"Colloids and immiscible organics: how colloids and the physical activity of an immiscible organic phase can lead to greater capillary trapping of the organic phase": presented to 65th Colloid and Surface Science Symposium, American Chemical Society, Norman, Oklahoma.

R. P. Major

"Heterogeneity and remaining resource in the San Andres reservoirs at Penwell and Jordan fields, University Lands, West Texas": presented to Phillips Petroleum Company, Odessa, Texas.

"Oil research programs and Permian Basin oil resources": presented to the Joint U.S. Geological Survey–Soviet–Bureau of Economic Geology Workshop, Austin, Texas.

"Diagenetic controls on San Andres reservoir heterogeneity": presented to the Joint U.S. Geological Survey–Soviet–Bureau of Economic Geology Workshop, Austin, Texas.

"Geology of Keystone field": presented to The University of Texas at Austin, Department of Petroleum Engineering (Petroleum Engineering 373L), Austin, Texas.

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

"Near-surface dolomitization on the Island of Bonaire, Netherlands Antilles": presented to The University of Texas at Austin, Department of Geological Sciences, technical sessions, Austin, Texas.

Marcus E. Milling

"Advanced 3-D visualization applications for improved oil and gas recovery": presented to Houston Geotech '91, Houston, Texas.

"The U.S. oil resource base": presented to Houston Geotech '91, Houston, Texas.

"Integrated geoscience reservoir characterization": presented to The Petroleum Science and Technology Institute Technical Forum, Edinburgh, Scotland.

"A geologic classification of U.S. reservoirs": presented to the Interstate Oil Compact Commission, midyear meeting, Casper, Wyoming.

"Opportunities for incremental recovery from existing reservoirs": presented to Unocal, Oxy U.S.A., Inc., Midland, Texas, and Phillips Petroleum Company, Odessa, Texas.

"Macro trends in Texas oil and gas resource base": presented at TIPRO-BEG Technology Forums at Abilene, Amarillo, San Antonio, Wichita Falls, Dallas, and Longview, Texas.

Robert A. Morton

"Shoreline erosion in Aransas Bay—causes and solutions": presented to the Key Allegro Canal and Property Owners Association, Rockport, Texas.

"Late Tertiary and Quaternary depositional sequences and hydrocarbon plays of the northwestern Gulf Coast Basin": presented to the Unocal exploration staff, Sugar Land, Texas.

"Plio-Pleistocene depositional sequences and hydrocarbon plays of the northwestern Gulf Coast Basin": presented to the CNG exploration staff, New Orleans, Louisiana.

"Texas geologic framework": presented to the Environmental Protection Agency, Gulf of Mexico Program, Coastal Erosion Workshop, Clear Lake, Texas.

Jeffrey G. Paine

"Exposure of offshore gas pipelines, northern Gulf of Mexico": presented to the Gas Research Institute, Austin, Texas.

Jay A. Raney

"Overview of Pantex Project: geologic and hydrologic investigations": presented to the Office of the Governor, Energy Director, Energy Management Center, Austin, Texas.

"Workshop on the geologic and hydrologic framework of the Eagle Flat region, Hudspeth County, Texas": presented to the Texas Low-Level Radioactive Waste Disposal Authority, Board of Directors, Austin, Texas.

J. Ulises Ricoy

"Lavaca Bay field reservoir characterization": presented to State Lands Energy Resource Optimization (SLERO) Project, 1991 annual review meeting, College Station, Texas.

"Research approach for the stratigraphic and structural characterization of Lavaca Bay field": presented to Neumin Production Company, Point Comfort, Texas.

"Reservoir distribution and operative results (recompletions and infill and/or stepout wells) of Lavaca Bay field": presented to Neumin Production Company, Point Comfort, Texas.

Stephen C. Ruppel

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

"Controls on oil and gas distribution, Siluro-Devonian": presented to Joint U.S. Geological Survey–Soviet–Bureau of Economic Geology Workshop, Austin, Texas.

"Significance of parasequences and parasequence sets in development of porosity and permeability trends": presented to Energy Research and Applications Program consortium scientists, Austin, Texas.

"Targeting remaining resources in Permian Basin oil and gas fields": presented at Texas Independent Producers and Royalty Owners Association/Bureau of Economic Geology Forum, Abilene, Texas.

Bridget R. Scanlon

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

"Comparison of chemical and hydraulic approaches in evaluation of moisture flux in desert soils": presented to the U.S. Geological Survey, Denver, Colorado.

"Importance of vapor transport in unsaturated flow in arid systems: A case study in the Chihuahuan Desert of Texas": presented at the University of Nevada, Las Vegas.

Daniel D. Schultz-Ela

"Computerized balancing of extensional cross sections": presented to Chevron U.S.A., Inc., New Orleans, Louisiana; and Texaco Exploration, Houston, Texas.

"Enhancements to *Restore*©": presented to The University of Texas at Austin, Bureau of Economic Geology, Industrial Associates of the Applied Geodynamics Laboratory, Austin, Texas.

"*Gridstran*: calculating deformation from model grids": presented to the Industrial Associates of the Applied Geodynamics Laboratory, Austin, Texas.

"Boundary-element modeling of active piercement": presented to the Industrial Associates of the Applied Geodynamics Laboratory, Austin, Texas.

Rainer K. Senger

"Comparison of hydrologic and hydrochemical characteristics between the northern and the Barton Springs segments of the Edwards aquifer, Austin region": presented to The University of Texas at Austin, Department of Geological Sciences Hydrogeology Seminar, Austin, Texas.

"Regional flow of variable-density ground water: implications of buoyancy dominated flow on basin hydrology": invited presentation to the Geological Society of America Penrose Conference on "Flow and Associated Transport in Basins: Driving Forces, Coupling and Geologic Controls": Bodega Bay, California.

Steven J. Seni

"Evolution of stocks and massifs during burial of salt sheets, northern Gulf of Mexico": presented to the Austin Geological Society, Austin, Texas.

Allan R. Standen

"Gemstones of the world": presented to the Austin Geological Society, Austin, Texas.

"Gemstones, minerals, and fossils of the world": presented to the Austin Gem and Mineral Club, Georgetown Gem and Mineral Club, Tarrytown Baptist Church Seniors Club, and five elementary schools in Austin and Round Rock, Texas.

Noel Tyler

"Outcrop characterization of flow unit and seal properties and geometries, Ferron Sandstone, Utah": presented to the Society of Petroleum Engineers annual meeting, Best of AAPG session, Dallas, Texas.

"Quantification of permeability structure in a fluvial-deltaic reservoir analog, Ferron Sandstone, Utah": presented to the Society of Petroleum Engineers Forum Series, Crested Butte, Colorado.

"Outcrop characterization of deltaic reservoir heterogeneity": presented to Onyx Energy, Dallas, Texas.

"Opportunities and strategies for advanced recovery in Permian Basin Reservoirs": presented at TIPRO/BEG Workshop on Technology Transfer, Midland, Texas.

"Characterization of flow unit and bounding element properties and geometries, Ferron Sandstone, Utah": presented to the Gas Research Institute Natural Gas Supply Project Advisors meeting, Basic Sciences, Houston, Texas.

"Geologic setting and style of reservoir heterogeneity in landward-stepping deltaic sandstones, Ferron Delta System": presented to participants in field workshop on deltaic reservoir heterogeneity, Emery, Utah.

"Oil recovery research at the Bureau of Economic Geology": presented to ARCO Oil and Gas Company, Marathon Oil Company, Texaco U.S.A., Mobil Exploration and Producing Company, Petroleos de Venezuela, S.A., Austin, Texas, and Halliburton Geophysical Services, Houston, Texas.

Bruno C. Vendeville

"Results of AGL research for 1991": presented to EUROSIM, Les Ulis, France.

"Experimental tectonic models: valid data or just pretty pictures?": presented to Austin Geological Society, Austin, Texas.

"New experimental techniques": presented to The University of Texas at Austin, Bureau of Economic Geology, Industrial Associates of the Applied Geodynamics Laboratory, Austin, Texas.

"Mechanics of extensional diapirism," presented to The University of Texas at Austin, Bureau of Economic Geology, Industrial Associates of the Applied Geodynamics Laboratory, Austin, Texas.

"Active piercement of pluglike and sheetlike intrusions": presented to The University of Texas at Austin, Bureau of Economic Geology, Industrial Associates of the Applied Geodynamics Laboratory, Austin, Texas.

"Fold-and-thrust detachments with and without salt": presented to The University of Texas at Austin, Bureau of Economic Geology, Industrial Associates of the Applied Geodynamics Laboratory, Austin, Texas.

E. G. Wermund

"Progress of wetland habitat mapping of the Galveston Bay System": presented to the Galveston Bay National Estuary Program Workshop, Nassau Bay, Texas.

"A proposal to conduct benthic and geochemical studies of the Galveston Bay System": presented to the Galveston Bay National Estuary Program, Management Committee, Houston, Texas.

Bureau of Economic Geology Seminars

Alan R. Dutton
(and **Matthew K. Wickham**) "Ground-water hydrology of an alluvial aquifer at the SSC site, Ellis County, Texas"

Robert L. Folk
"Bacteria and diagenetic carbonates: the biologic connection"
(and Donald H. Campbell) "Pyramids of Egypt: poured concrete or real rock?"

William E. Galloway
"Tectonics, depositional rates, and sequences—Paleogene Gulf of Mexico basin"

Jeffry D. Grigsby
"Impact of volcanic glass detritus on diagenesis in middle Frio Formation gas reservoirs, Stratton and Seeligson fields, South Texas"

Karen L. Herrington
"Effect of morphology and distribution of fibrous illite on the permeability measurements of two tight gas sandstones"

Mark H. Holtz
"Concepts and analysis of oil reserve growth: An example from the Permian Basin Leonardian restricted platform carbonate play"

Martin P. A. Jackson
"The Kwanza Basin, Angola: type area for raft tectonics"

Mary L. W. Jackson
"Texas mined lands inventory—environmental friend and outcrop locator"

Charles Kerans
"The sequence framework of the San Andres Formation: implications for Leonardian–Guadalupian stratigraphy of the Permian Basin"
(and **H. Seay Nance**) "Grayburg Formation, Guadalupe Mountains: sequence stratigraphy and facies mosaics"

Hemin Koyi
"A trip to Iran: a choice between the threat of war and the pleasure of exploring giant salt diapirs"

Charles W. Kreitler
"Hydrologic and hydrochemical characterization of Texas Frio Formation used for deep-well injection of chemical wastes"

Richard P. Langford
"Deposition and deformation of deltas in the lower Vicksburg Formation (Oligocene), South Texas Gulf Coast"

Stephen E. Laubach
"Current views of fracture development in rock"

F. Jerry Lucia
"Holocene and Plio-Pleistocene near-surface dolomitization on Bonaire, Netherlands Antilles"
(and **Fred P. Wang** and **Rainer K. Senger**) "Locating remaining mobile oil in carbonate reservoirs"

R. P. Major
(and **F. Jerry Lucia**) "Holocene and Plio-Pleistocene near-surface dolomitization on Bonaire, Netherlands Antilles"

Robert A. Morton
"Response of Holocene depositional system tracts to sediment influx, northern Gulf of Mexico"

H. Seay Nance
(and **Charles Kerans**) "Grayburg Formation, Guadalupe Mountains: sequence stratigraphy and facies mosaics"

J. Ulises Ricoy
"Stratigraphic and structural characterization of Lavaca Bay field, Calhoun County, Texas—SLERO"

Stephen C. Ruppel
"Controls of porosity development in a highly cyclic, low-recovery-efficiency, restricted platform carbonate reservoir: Monahans Field, West Texas"

Andrew R. Scott
"Composition and origin of Fruitland coalbed and Pictured Cliffs Sandstone gases, San Juan Basin, Colorado and New Mexico"

Rainer K. Senger
"Quantification of reservoir heterogeneity observed on continuous outcrop along the Algerita Escarpment, New Mexico"

Robert Single
(and **Raymond A. Levey** and **Bob A. Hardage**)
"Integrated seismic-well log interpretation of onshore Frio Formation gas reservoirs: An example from Stratton Field, South Texas"

Steven W. Tweedy
"New happenings at the MSL—What can we do for you?"

Roger Tyler
"Stratigraphic and structural controls on gold mineralization within an early Proterozoic carbonate platform succession, Pilgrim's Rest goldfield, South Africa"

Fred P. Wang
(and **F. Jerry Lucia**) "The application of advanced log analysis to reservoir characterization of a vuggy dolomite reservoir under waterflood—Seminole San Andres Unit"

Congressional, Legislative, and Special Testimony

William L. Fisher
"The improved oil recovery programs of the National Energy Strategy": presented to the U.S. House of Representatives, Committee on Interior and Insular Affairs, Subcommittee on Energy and the Environment, Washington, D.C.

William R. Kaiser
Written testimony prepared for General Counsel, Public Utility Commission of Texas (Docket No. 9850).

Auburn L. Mitchell
Statement to the Committee on Energy, Texas House of Representatives, Austin, Texas.

Robert A. Morton
Panelist, public hearing on the impacts of hard shoreline structures on beaches: presented to the North Carolina Coastal Resources Commission, Beaufort, North Carolina.

Panelist, public hearing on the potential environmental impacts of a proposed opening into East Matagorda Bay: presented to the Matagorda County and the Texas A&M Marine Extension Service, Bay City, Texas.

Jay A. Raney
Expert testimony on the geology and hydrology of the Fort Hancock radioactive waste repository site, Hudspeth County, Texas: presented at the trial of the Texas Low-Level Radioactive Waste Disposal Authority, El Paso, Texas.

Noel Tyler
"Activities and progress in Project SLERO": presented to the Commissioner, General Land Office, and representatives of the Office of the Governor, and the Speaker of the House and the Lieutenant Governor's Offices, Austin, Texas."

Committee Services, Offices, and Other Professional Responsibilities

Walter B. Ayers, Jr.
Councilor, Gulf Coast Section, Energy Minerals Division, American Association of Petroleum Geologists.

Co-chairman (with S. E. Laubach) of technical session on coalbed methane, Geological Society of America, Rocky Mountain/South-Central Section Meeting.

Co-chairman of technical session on Coalbed Methane, Energy Minerals Division of American Association of Petroleum Geologists, 1991 annual meeting.

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

Robert W. Baumgardner, Jr.
Member, Remote Sensing and Cartographic Committee, Texas Natural Resources Information System Task Force.

Alternate, Texas Natural Resources Information System Task Force.

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

Edward W. Collins
Chairman, Field Trip Committee, Spring 1991, Austin Geological Society.

Carolyn E. Condon
Vice-President, Austin Geological Society.
Treasurer, Austin Geological Society.

Jules R. DuBar
Representative of the Bureau of Economic Geology to Geological Society of America.

Alan R. Dutton
Member, Editorial Board, *Ground Water*.
Editor, *The Hydrogeologist*.

Shirley P. Dutton
Co-convenor, Porosity Prediction in Siliciclastic Rocks Technical Session, American Association of Petroleum Geologists, 1991 annual meeting.

Member, Abstract Review Committee for Sedimentary Petrology, Geological Society of America, 1991 annual meeting.

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

Member, Pettijohn Medal Selection Committee, SEPM (Society for Sedimentary Geology).

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.

Judge, Archie Conference, Selection of papers for Best of Archie Conference Session, American Association of Petroleum Geologists, 1991 annual meeting.

Member, Source and Supply Task Group, Natural Gas Study, National Petroleum Council.

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

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

Member, Geoscience Institute for Oil and Gas Recovery Research Board, The University of Texas at Austin.

R. Stephen Fisher

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

Co-leader of field trips, "Architecture and permeability structure of fluvial-deltaic sandstones, Ferron Sandstone, Utah," Emery, Utah.

William L. Fisher

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

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

President, American Geological Institute.

Chairman, Faculty Review Committee, Geology Foundation, The University of Texas at Austin.

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

Chairman, Applied Research and Technology Committee, Texas Independent Producers and Royalty Owners.

Chairman, Board on Earth Sciences and Resources, National Academy of Sciences.

Chairman, American Geological Institute, Member Society Council.

Chairman, Board on Earth Sciences and Resources and American Geological Institute Summit Meeting of Earth Science Societies.

Chairman, Workshop on Arctic National Wildlife Refuge, National Research Council/National Academy of Sciences.

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).

Ex Officio Member, U.S. National Committee on Geology, National Academy of Sciences/National Research Council.

Member, University Advisory Board, Center for Legislative Energy and Environmental Research, South/Southwest Energy 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, National Governor's 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, 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, 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, Secretary of Energy Advisory Board, Task Force on National Energy Strategy.

Member, Secretary of Energy Advisory Board, Task Force on Economic Modeling.

Member, Finance Committee, American Geological Institute.

Member, *Oil Daily* Advisory Board.

Member, U.S. Department of Energy/Federal Energy Regulatory Commission, Natural Gas Deliverability Task Force.

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

Member, Editorial Advisory Board, *Offshore.*

Member, Advisory Board, Jefferson Energy Foundation, Project on Man, Energy, and Environment.

Michael H. Gardner

Leader of field trip, "High resolution sequence stratigraphy of Mid-Cretaceous strata," Mobil Research and Development Corporation, Emery, Utah.

Leader of field trip, "High resolution sequence stratigraphy of Ferron Sandstone (Cretaceous)," Amoco Production Company, Emery, Utah.

Co-leader of field trip, "High resolution sequence stratigraphy of coal-bearing delta complexes, Ferron Sandstone (Cretaceous), Utah," Geological Society of America, 1991 annual meeting, San Diego, California.

Co-leader of field trip, "Architecture and permeability strucure of fluvial-deltaic sandstones, Ferron Sandstone, Utah," Emery, Utah.

Chester M. Garrett, Jr.

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

Judge, Best Paper Award, Energy Minerals Division, American Association of Petroleum Geologists.

Member, Ad Hoc Nominating Committee, Austin Geological Society.

Judge, A. I. Levorsen Memorial Award, Gulf Coast Association of Geological Societies.

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

Member, American Association of Petroleum Geologists Public Information Committee.

Jeffry D. Grigsby

Judge, Best Poster Award, American Association of Petroleum Geologists, 1991 annual meeting.

Co-leader of field trip, "Core and log analysis of depositional systems and reservoir properties of Gulf Coast natural gas reservoirs: an integrated approach to infield reserve growth in Frio, Vicksburg, and Wilcox sandstones," Gulf Coast Association of Geological Sciences, 1991 annual meeting.

Edgar H. Guevara

Chairman, Membership Committee, Austin Geological Society.

Douglas S. Hamilton

Finance officer, Austin Geological Society.

Bob A. Hardage

Assistant Editor, *Geophysics*, Society of Exploration Geophysicists.

Judge, Best Poster Award, Society of Exploration Geophysicists, 1991 international meeting.

Member, Organizing Committee, Society of Exploration Geophysicists Forum, Reservoir Description Using Geophysical Techniques.

Member, Development and Production Committee, Society of Exploration Geophysicists.

Member, Editorial Board, *Journal of Seismic Exploration.*

Member, Editorial Board, *Journal of Science and Engineering.*

Mark H. Holtz

Technical Editor, *Computer Applications*, Society of Petroleum Engineers.

Judge, Matson Best Paper Award for the Building and Maintaining Large Data Bases session, American Association of Petroleum Geologists, 1991 annual meeting.

Susan D. Hovorka

Co-chairman, Evaporites Technical Session, SEPM (Society for Sedimentary Geology), American Association of Petroleum Geologists, 1991 annual meeting.

Martin P. A. Jackson

Associate Editor, Geological Society of America *Bulletin.*

Co-convenor, Planning Committee for Hedberg Research Conference on Salt Tectonics, United Kingdom, organized and sponsored by American Association of Petroleum Geologists.

Member, International Union of Geological Sciences Commission of Tectonics.

Mary L. W. Jackson

Judge of poster session, American Association of Petroleum Geologists, 1991 annual meeting.

William R. Kaiser

Co-leader of field trip, "Hydrogeology of the Jewett Lignite Mine, East Texas," American Association of Petroleum Geologists, 1991 annual meeting, and Austin Geological Society, spring 1991 field trip.

Co-leader of field trip, "Coalbed methane, San Juan Basin," Alberta Research Council.

Member, Steering Committee on Coal Reserves Assessment, U.S. Department of Energy.

Charles Kerans

Member, Steering Committee, Third International Reservoir Characterization Technical Conference.

Co-leader of field trip, "Sequence stratigraphy, facies, and reservoir geometries of the San Andres, Grayburg, and Queen Formations, Guadalupe Mountains, New Mexico and Texas," American Association of Petroleum Geologists and Permian Basin-SEPM field trip, 1991 annual meeting.

Co-leader of field trip, "Sequence stratigraphic framework of the San Andres and Grayburg Formations, Guadalupe Mountains, New Mexico, and implications for reservoir characterization and modeling," U.S. Geological Survey/Russian Delegation, Austin, Texas, and Carlsbad, New Mexico.

Charles W. Kreitler

Associate Editor, *Water Resources Research*, American Geophysical Union.

Member, National Drinking Water Advisory Council, U.S. Environmental Protection Agency.

Member, Technical Advisory Panel, Joint Special Committee on the Edwards Aquifer, Texas State Legislature.

Stephen E. Laubach

Co-chairman (with W. B. Ayers, Jr.), Coalbed Methane in the San Juan Basin Symposium, Geological Society of America, Rocky Mountain/South-Central Sections combined meeting.

Raymond A. Levey

Leader of field trip, "Core and log analysis of depositional systems and reservoir properties of Gulf Coast natural gas reservoirs: an integrated approach to infield reserve growth in Frio, Vicksburg, and Wilcox sandstones," Gulf Coast Association of Geological Societies, 1991 annual meeting.

F. Jerry Lucia

Associate Editor, *Journal of Petroleum Technology*, Society of Petroleum Engineers.

Member, Nominating Committee, SEPM (Society for Sedimentary Geology).

R. P. Major

President-Elect, Austin Geological Society.

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

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

Judge, Recent Advances in Carbonate Diagenesis Technical Session, Society of Economic Paleontologists and Mineralogists, American Association of Petroleum Geologists, 1991 annual meeting.

Amanda R. Masterson

Chair, Editorial Review Board, Geoscience Information Society.

Publications Manager, Geoscience Information Society.

Marcus E. Milling

Chairman, Human Resources Advisory Committee, American Geological Institute.

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

Chairman, Advisory Board, Department of Geology, The University of Iowa.

Vice-Chairman, Foundation Board of Trustees, American Geological Institute.

Member, Petroleum Research Liaison Committee, Industry Recovery Research Forum.

Robert A. Morton

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

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

Member, Convention Policy Committee, SEPM (Society for Sedimentary Geology).

Member, Committee on Conventions, American Association of Petroleum Geologists (SEPM [Society for Sedimentary Geology] representative).

Member, Coastal Erosion Subcommittee, Environmental Protection Agency, Gulf of Mexico Program.

Member, Program Committee, Gulf Coast Section, SEPM (Society for Sedimentary Geology), Twelfth Annual Research Conference.

Member, Coastal Land Loss Classification Committee, Louisiana State University.

H. Seay Nance

Co-leader of field trip, "Sequence stratigraphy, facies, and reservoir geometries of the San Andres, Grayburg, and Queen Formations, Guadalupe Mountains, New Mexico and Texas," American Association of Petroleum Geologists, 1991 annual meeting.

Jay A. Raney

Leader of field trip, "Field trip to Eagle Flat region, Hudspeth County, Texas," Texas Low-Level

Radioactive Waste Disposal Authority, Hudspeth County, Texas.

Leader of field trip, "Geologic and hydrologic investigations and field trip to the Eagle Flat region, Hudspeth County, Texas," Governor's staff, State of Texas, and Board of Directors, Texas Low-Level Radioactive Waste Disposal Authority, Hudspeth County, Texas.

Texas representative, U.S. Department of Energy State and Tribal Government Working Group, Yakima, Washington.

Texas representative, U.S. Department of Energy State and Tribal Government Working Group, Denver, Colorado.

Douglas C. Ratcliff

Member, University Parking and Traffic Policy Committee, The University of Texas at Austin.

John G. Sclater

Chairman, Ocean Studies Board of the National Academy of Sciences.

Steven J. Seni

Member, Technical Advisory Group for Salt Cavern Waste Disposal, Texas Water Commission.

Allan R. Standen

Co-chairman, Youth Activities meeting, American Association of Petroleum Geologists 1991 annual meeting, Dallas, Texas.

Member, American Association of Petroleum Geologists Core Curation Committee.

Member, Gemological Institute of America, Alumni.

Noel Tyler

Member, External Advisory Committee, Geosciences Parallel Computation Project, Rice University.

Member, Awards and Support Committee, The University of Texas at Austin, Department of Geological Sciences.

Member, Public Lands Committee, Interstate Oil Compact Commission.

Convenor and co-leader of field trips, "Architecture and permeability structure of fluvial-deltaic sandstones, Ferron Sandstone, Utah."

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.

Bruno C. Vendeville

Co-chairman, Structural geology session III: fold and thrust belts, Geological Society of America 1991 annual meeting, San Diego, California.

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, Texas Natural Resources Information System Task Force.

~~Member, Texas Mapping Advisory Committee.~~

Member, Texas Water Commission Technical Advisory Committee on Nueces Bay Freshwater Inflow.

Member, Policy Committee on Texas Geographic Information Systems, Texas Department of Information Resources.

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

Member, Environmental Geology Committee, American Association of Petroleum Geologists.

Vice Chairman, Task Force guiding policies of the Texas Natural Resources Information System.

~~Member, Texas Mapping Advisory Committee recommending priorities to the U.S. Geological Survey~~ National Mapping Division.

Member, Texas Water Commission Technical Advisory Committee advising rules for freshwater inflows to Nueces Bay from the Choke Canyon and Lake Corpus Christi Dams System.

Member, Department of Information Resources, Policy Committee on Texas Geographic Information Systems.

Member, Committee to explore development of an Institute for Environmental Studies, College of Natural Sciences, The University of Texas at Austin.

William A. White

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

University Teaching/ Continuing Education

Don G. Bebout

"Carbonate core-logging exercise": student core workshop presented to the Society of Economic Paleontologists and Mineralogists, 1991 annual meeting, Dallas, Texas.

"Carbonate field seminar": co-lecturer of short course presented to the American Association of Petroleum Geologists, Field Seminar Series, San Antonio and Austin, Texas.

"Carbonate core workshop": short course presented to the Permian Basin Graduate Center, Midland, Texas.

Robert J. Finley

"Infield gas reserve growth potential: Gulf Coast reservoirs": short course presented to gas operators, Houston, Texas.

"Opportunities and strategies for incremental recovery in mature oil and gas reservoirs": tutorial presented to the Third International Reservoirs Characterization Technical Conference, Tulsa, Oklahoma.

Jeffry D. Grigsby

"Infield gas reserve growth potential: Gulf Coast sandstone reservoirs (Frio, Vicksburg, Wilcox)": co-lecturer of short course presented to the Gas Research Institute Gas Reservoir Workshop, Houston, Texas.

H. Scott Hamlin

"Geological overview of the Frontier Formation at the Enron South Hogsback cooperative well": co-lecturer of short course presented to the Gas Research Institute and the Society of Petroleum Engineers, Frontier Formation Workshop, Denver, Colorado.

Bob A. Hardage

"Vertical seismic profiling": short course presented on behalf of Geophysical Press, Nice, France.

"Geophysics for engineers": short course presented to the Louisiana Land & Exploration Company, Houma, Louisiana.

"Seismic exploration": short course presented to The University of Tulsa 28th Advanced Petroleum Geology Short Course session, Tulsa, Oklahoma.

"Reservoir geophysics": seminar presented to the Permian Basin Geophysical Society, Midland, Texas.

"Seismic stratigraphy and reflection amplitudes": short course presented to the Geophysical Society of Houston, Houston, Texas.

Susan D. Hovorka

"Evaporite sedimentology": core exercise presented to The University of Texas at Austin, Department of Geological Sciences (Geology 391), Austin, Texas.

Charles W. Kreitler

"Wellhead protection strategies for confined aquifer settings": short course presented to the U.S. Environmental Protection Agency, San Juan, Puerto Rico.

Raymond A. Levey

"Infield gas reserve growth potential: Gulf Coast reservoirs": short course presented to gas operators, Houston, Texas.

Stephen E. Laubach

"Identifying and interpreting fractures": co-lecturer of short course presented to the Houston Geological Society, Houston, Texas.

Robert A. Morton

"Exploring a barrier island system": principal lecturer of short course presented to The University of Texas at Austin, Department of Continuing Education, and the Marine Science Institute, Port Aransas, Texas.

Stephen C. Ruppel

"Patterns of facies and reservoir development in Silurian and Devonian rocks in the Permian Basin": short course presented to the Permian Basin Graduate Center, Midland, Texas.

Noel Tyler

"Opportunities and strategies for incremental recovery in mature oil and gas reservoirs": tutorial presented to the Third International Reservoirs Characterization Technical Conference, Tulsa, Oklahoma.

Support Staff

Administrative/Secretarial

The general administration of the Bureau, including personnel matters, accounting, publication sales, purchasing and vouchering, travel, reception/switchboard area, and preparation of correspondence, is handled by the Administrative staff. The Bureau's involvement in numerous contracts and research projects requires the Administrative staff to process more than 3,500 appointment forms each year to properly allocate staff time among funding sources. In addition, this section controls more than $4 million in purchases and subcontracts and handles publication sales in excess of $150,000 per year. Wanda LaPlante, Executive Assistant, supervises this section.

Cartography

The Cartographic section has done much over the years to enhance the Bureau's reputation in geologic and land-resources mapping. Perhaps best known for its high-quality, full-color maps, the Cartographic section also produces a wide range of other maps, cross sections, text illustrations, slides, posters, and display materials. A full-time professional photographer was hired in 1991 to provide cover and text photographs for Bureau publications, slides for lectures and public addresses, and negatives and color proofs for maps. Richard L. Dillon, Chief Cartographer, directs the work of the Cartographic section.

The section's 14-person full-time staff produced 35 black-and-white plates, 3 full-color maps, 1,800 text figures, and 1,600 visual aids in 1991. All items produced by this staff are published in Bureau publications or as contract reports or articles in journals or used in presentations at professional meetings. Because these materials are used publicly, high cartographic standards must be maintained.

The use of computers to produce visual aids and text figures continues to expand. Currently two DOS-based PC's are used to produce slides and four Macintoshes are used to produce posters, slides, and text figures.

Computer Resources

The Computer Resources staff provides three types of service to Bureau 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, one ULTRIX workstation, two UNIX workstations, more than 60 networked PC's, and 20 high-quality output devices), the University's IBM computers, and the Center for High Performance Computing Cray system.

In 1991, under the supervision of Kenneth M. Duncan, Manager, the Computer Resources staff added a new VAX 4000, a DECstation 5000, an SGI IRIS INDIGO workstation, and a ZYPLEX terminal server. The VAX 4000 provides the operating system and resource sharing capabilities for VMS satellite nodes. The DECstation is dedicated to geophysical data analysis and modeling. The INDIGO workstation is primarily dedicated as a GIS-GRASS system and is used for graphical analysis, image processing, map display and data input. With the terminal server, all Bureau computers (both VMS and UNIX) are available to users from their terminals (Macintoshes or PC's). Three new 486 and two 386 personal-computer-based workstations were added to support a geographic information system, computer mapping and digitizing, geophysical modeling, and oil simulation. The staff continued to upgrade, improve, and market *Restore*©, a program that enables geoscientists to sequentially backstrip and balance cross sections from extensional terranes. The staff completed the Core Research Center's computerized data base for tracking holdings and transactions. Significant progress was also made on the implementation of (1) a charge-back system for personal computer use and (2) a publication sales and inventory system.

Publications

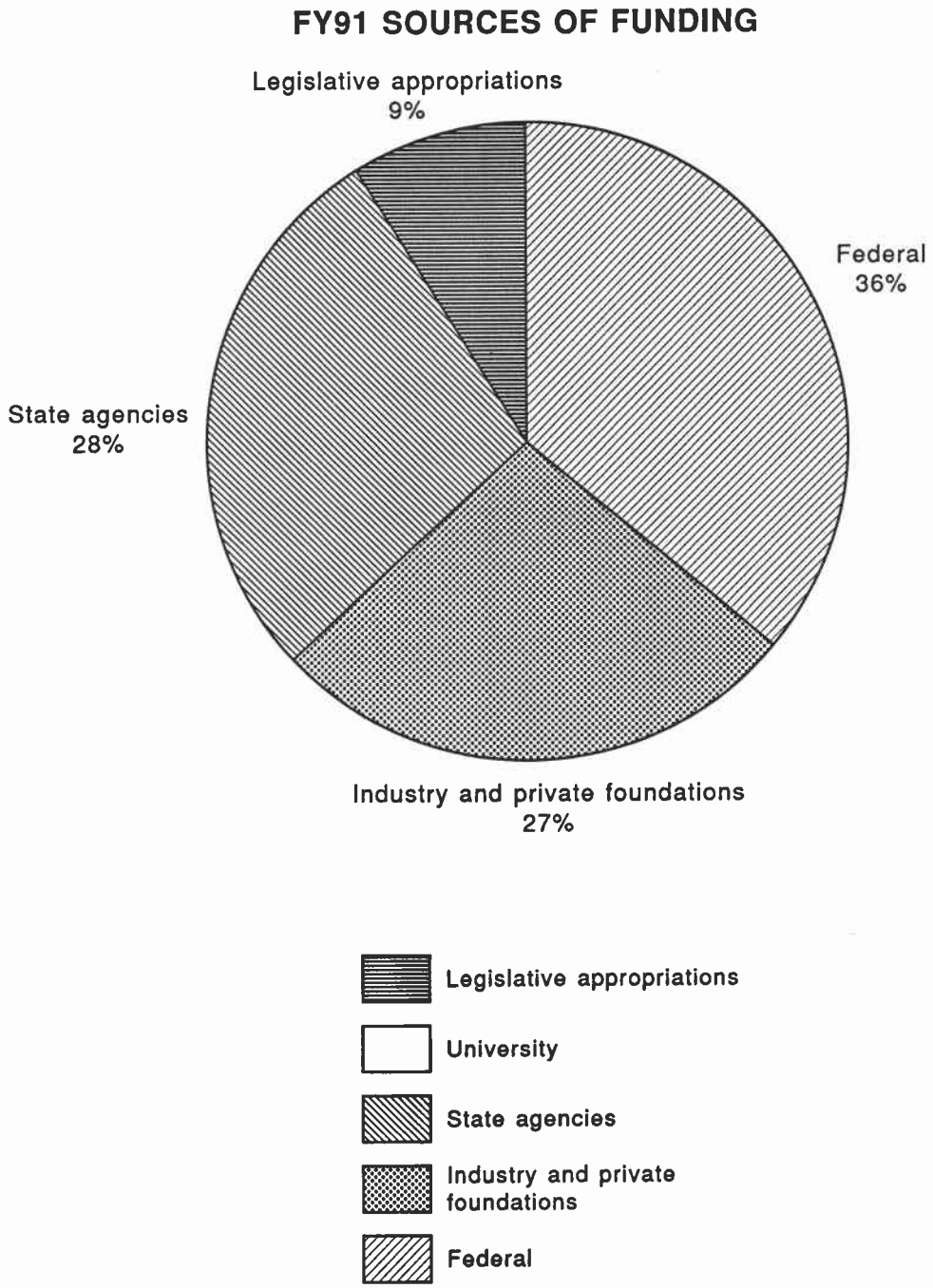
The Publications staff, consisting of word processor/typesetter operators, proofreaders, editors, and designers, produces a variety of printed materials for the Bureau. Susann Doenges, Editor-in-Chief, supervises the section. In addition to producing Bureau publications, the staff also prepares contract reports, papers and abstracts, and documents in support of research projects. Most reports published by the Bureau are now produced through desktop publishing. Manuscripts are revised electronically, and pages are prepared for the printer through layout programs. This year 14 new publications and 18 contract reports were issued by the Bureau. More than 160 papers and abstracts by Bureau authors were published by professional journals and publishers.

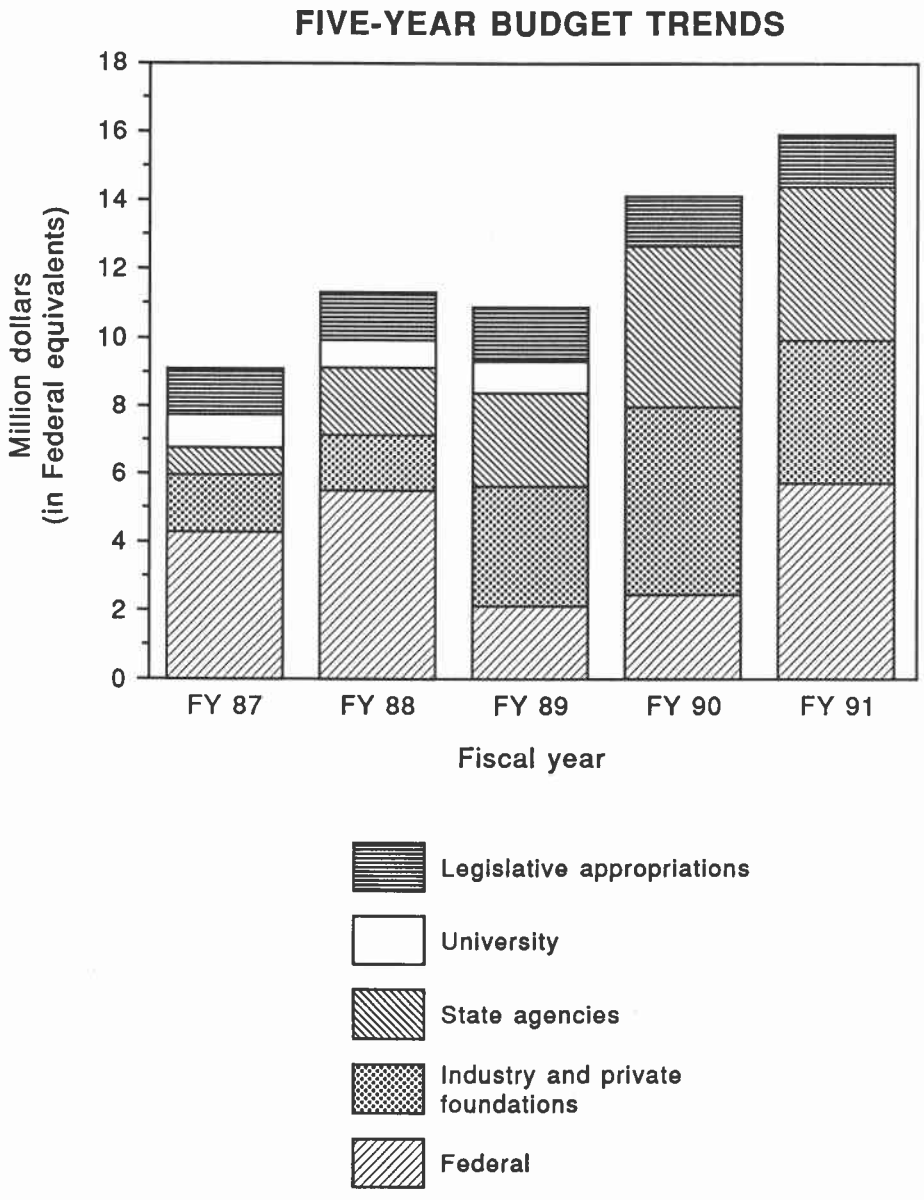
Quality Assurance

The Quality Assurance Group develops and monitors the Bureau's quality assurance program. The group directly supports scientific research and administration activities by interpreting regulatory and contractual requirements and preparing and issuing quality assurance procedures to ensure compliance with the requirements. The staff consists of the Quality Assurance Manager and trained lead auditors who conduct audits of implementation of the quality assurance program.

In 1991, the Quality Assurance Group assisted with hydrologic studies of the Superconducting Super Collider site, characterization of the Pantex site, and investigations of the potential Texas low-level radioactive waste disposal site. The Quality Assurance Manager also assisted the Texas Low-Level Radioactive Waste Disposal Authority in preparing their quality assurance program.

Sources of Funding and Budget Trends




FIVE-YEAR BUDGET TRENDS
Million dollars
(in Federal equivalents)
18
16
14
12
10
8
6
4
2
0
FY 87
FY 88
FY 89
FY 90
FY 91
Fiscal year
Legislative appropriations
University
State agencies
Industry and private foundations
Federal

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Douglas C. Ratcliff, Associate Director for Administration • Wanda L. LaPlante, Executive Assistant

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Land and Marine Resources
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Environmental Resources and Minerals
Dr. Noel Tyler
Oil Resources
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Dr. Claude R. Hocott
Dr. Martin P. A. Jackson
Dr. Charles W. Kreitler
Dr. Robert A. Morton

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Dr. Alan R. Dutton
Dr. Shirley P. Dutton
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Dr. Edgar H. Guevara
Dr. William R. Kaiser
Dr. Charles Kerans
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Dr. Raymond A. Levey
Dr. Richard P. Major
Dr. Jay A. Raney
Dr. Stephen C. Ruppel
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Dr. Noel Tyler
Dr. E. G. Wermund

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L. Edwin Garner
Dr. Jeffry D. Grigsby
H. Scott Hamlin
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Auburn L. Mitchell
Dr. Jeffrey G. Paine
Dr. Daniel D. Schultz-Ela
Dr. Rainer K. Senger
Dr. Steven J. Seni
Dr. Bruno C. Vendeville
William A. White

Research Scientist Associates

William A. Ambrose
Arten J. Avakian
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Donald A. Bowen*
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Sigrid J. Clift
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Roselle M. Girard
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Robert E. Mace
William F. Mullican III
H. Seay Nance
Bernd C. Richter
Andrew R. Scott
Kathleen M. Strub
Roger Tyler
Joseph Yeh

Senior Research Fellow

F. Jerry Lucia

Research Fellows

Dr. Peter R. Cobbold
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Dr. Eric W. James
Hemin Koyi
Dr. J. Ulises Ricoy
Dr. Fred P. Wang

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Publications

Susann V. Doenges
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Chief Designer
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Computer Resources

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Sharon A. Bierschenk
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Steven W. Tweedy
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Raul Herrera

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Robert A. Sanchez
Eldon S. Trunnell*

Cartography

Richard L. Dillon
Chief Cartographer
John T. Ames
Edwin B. Banks
Barbara M. Hartmann
Margaret D. Koenig*
Susan N. Krepps
Anne I. Kubert
Michele L. LaHaye
Joel L. Lardon
Yves H. Oberlin
Patrice A. Porter
Kerza A. Prewitt
Jana S. Robinson
Maria E. Saenz
David M. Stephens
Teresa L. Weaver

Quality Assurance/ Geophysical Log Facility

Carolyn E. Condon
Quality Assurance Officer
Daniel H. Ortuño

Student Research Assistants

Jennifer Aguirre
Edward S. Angle
Nina L. Baghai
Angela B. Baker
Mark D. Barton
Dieter K. Beike
Craig E. Bennett
Wade S. Bickham
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Chih-Peng Yu
Hongliu Zeng
Naijiung Zhou

*Temporary staff

THE UNIVERSITY OF TEXAS AT AUSTIN
Bureau of Economic Geology
University Station, Box X
Austin, Texas 78713-7508

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