Bureau of Economic Geology

ANNUAL REPORT

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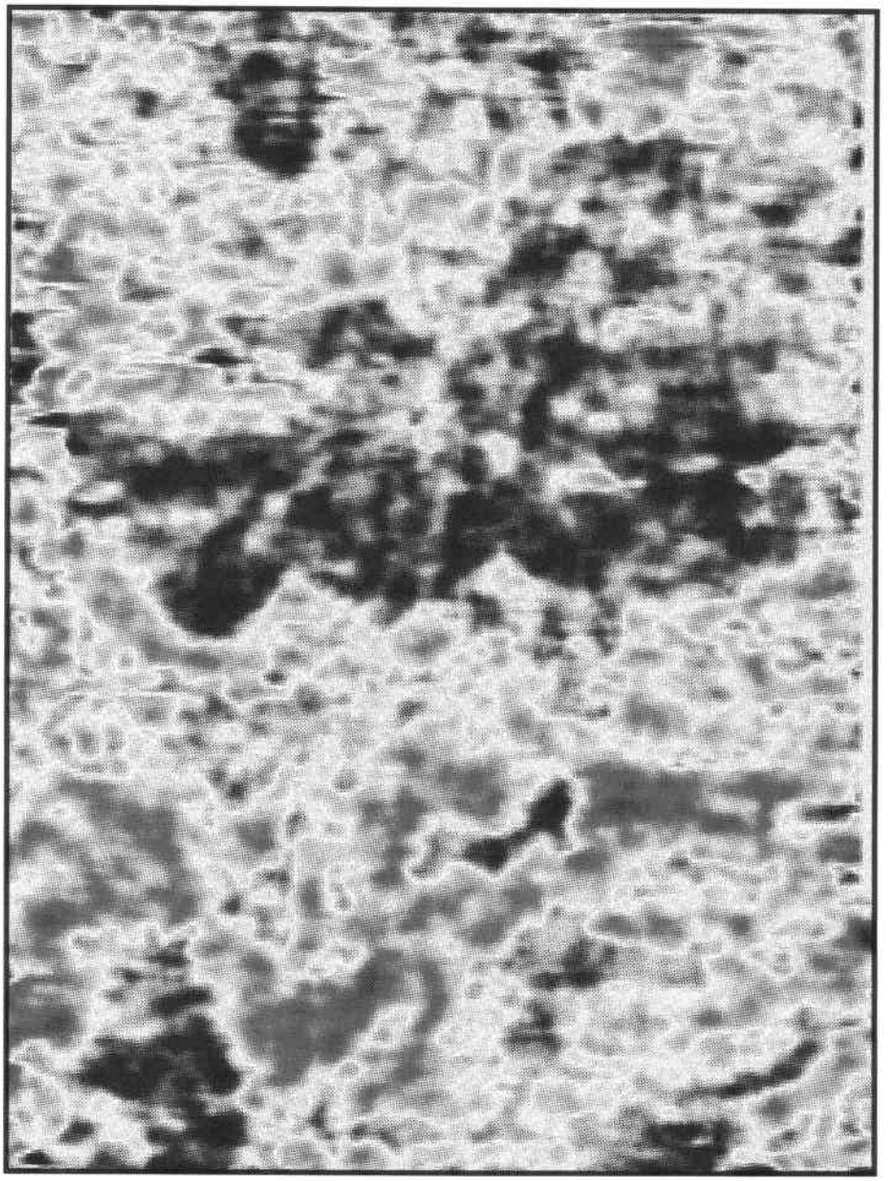


Seismic Sedimentology

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

Foreword

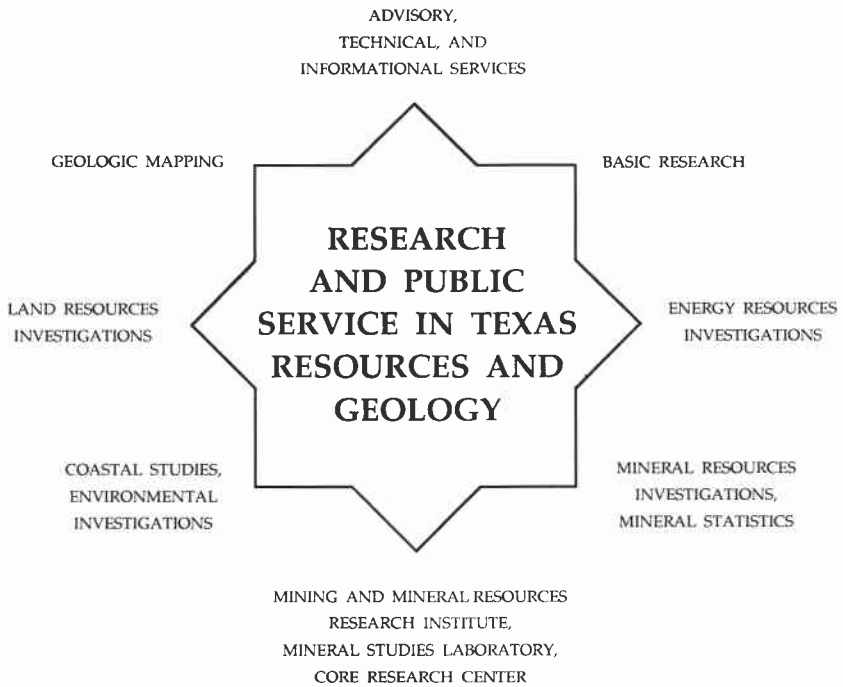
The Bureau of Economic Geology, established in 1909 as the successor to the Texas Geological Survey and the Texas Mineral Survey, is a research entity of The University of Texas at Austin. It also functions as the State Geological Survey, a quasi-State agency, and the Bureau Director represents Texas 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: An image of 7.5 mi² of a South Texas fluvial gas reservoir extracted from a three-dimensional seismic data volume recorded and processed with Bureau supervision and interpreted using the Bureau's geophysical workstation. The broad, east-west-trending red meanderbelt in the southern (lower) portion of the grid is interpreted as a system of several coalesced channels and splays. Arcuate channel geometries and accretionary topography can be inferred in a seismic sedimentologic interpretation of the image.

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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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W. L. Fisher, Director

The University of Texas at Austin • Austin, Texas 78713-7508

Contents

Research

The Bureau of Economic Geology continued to maintain a healthy and expanding research program during 1992. The Bureau's operating budget was approximately $15 million from line-item State appropriation and from 61 outside contracts and grants. Of these 61 funding sources, 21 were from interagency contracts with State and local government agencies and 12 were with the petroleum industry and private institutional foundations such as the Gas Research Institute (GRI). The remaining contracts and grants were with various agencies of the Federal government, such as the U.S. Department of Energy (DOE), the U.S. Geological Survey (USGS), and the Minerals Management Service (MMS).

In 1992, the Bureau conducted 48 research projects involving a range of geoscientific topics, including energy-resource, waste-isolation, hydrogeologic, experimental and applied-tectonic, coastal, mineral-resource, and mapping investigations. Sixteen new projects were initiated during the year. The new 1992 projects primarily address energy-resource and environmental topics, such as

(1) a multiyear study of the sequence-stratigraphic and petrophysical attributes of fluvial-deltaic reservoirs and their outcrop analogs,

(2) a 2-year study to generate new exploration plays in Paleozoic sediments in the Delaware Basin and Central Basin Platform of the Permian Basin,

(3) determination of areas of technology needs perceived by Texas independent petroleum producers and development of specific programs to augment existing programs in technology transfer,

(4) compilation of an oil and gas resource atlas of offshore northern Gulf of Mexico,

(5) study of the sources of saline water discharging into the Canadian River of the Texas Panhandle, and

(6) geochemical investigations to determine the geologic and chemical factors that lead to concentration of naturally occurring radioactive materials in oilfield brines and on oil- and gas-field equipment.

Several long-term projects of interest to the Texas public and to industry were successfully concluded during 1992. The *Atlas of Major Central and Eastern Gulf Coast Gas Reservoirs*, funded by GRI, has been completed and will be available from the Bureau in early 1993. The atlas synthesizes geologic, engineering, and current production data on major onshore natural gas plays and their component fields/reservoirs in Louisiana, Mississippi, Alabama, south Arkansas, and the western Florida panhandle. The new 1:500,000-scale *Geologic Map of Texas*, a four-quadrant map that has been several years in production, is now available for sale from the Bureau. This map supersedes the USGS's Texas geologic map, which was published in 1937 and has been out of print for many years. A recently concluded Bureau project estimated the recoverable resources of oil, natural gas, and geothermal energy in Texas and estimated long-term production in which either existing or advanced technology is used. Regional quantitative mapping and correlation of Plio-Pleistocene stratigraphic units in the West Cameron and western Garden Banks areas of the western Gulf Coast Basin may offer potential for both new field discoveries and reserve growth in this productive offshore area. A Bureau program of physical and seismic modeling of structural hydrocarbon traps in areas of extensional salt tectonics has yielded guidelines to improve the efficiency of petroleum exploration and development in such regions. Bureau researchers have also helped in developing a methodology to assess the risk that abandoned oil and gas wells in a given area pose to the underground sources of drinking water.

Energy-resource investigations make up the largest percentage of projects conducted by the Bureau during 1992. The Bureau's multiyear study of San Andres and Grayburg reservoirs received continued funding from industry sponsors during the year. The project involves the most detailed and comprehensive study ever conducted of the controls on San Andres and Grayburg carbonate-ramp reservoir development at all geologic scales (petrology/petrophysics to sequence stratigraphy). Continued focus on these reservoirs is warranted by the superb exposures of outcrop analogs in the Guadalupe Mountains, the extensive well-log data base of these units in the Permian Basin, and the vast potential for reserve growth in these reservoirs. Field and laboratory studies of two well-exposed fluvial-deltaic formations of the western United States have been designed to provide predictive models for improved oil and natural gas recovery from compartmentalized fluvial-deltaic reservoirs. Investigation of the Upper Cretaceous Ferron Sandstone of east-central Utah will ultimately enable prediction of the geometric distribution of flow units, baffles, and barriers to natural gas so that operators can optimize infill-drilling programs in mature Gulf Coast fluvial-deltaic gas reservoirs. As an outgrowth of the Ferron study, the Lower Cretaceous Dakota Sandstone (Fall River Formation) of eastern Wyoming and western South Dakota is similarly being studied as an outcrop analog of subsurface fluvial-deltaic reservoirs. The aim of this study is to determine (1) the three-dimensional architecture of depositional and diagenetic facies in the reservoirs and (2) the relation of these facies to the spatial distribution of petrophysical attributes that directly control fluid flow. In a new project begun in 1992, Bureau researchers are aiding Venezuelan geologists in maximizing secondary oil recovery from 10 lower Eocene deltaic reservoirs in the Misoa Formation in northeastern Lake Maracaibo. Misoa reservoirs have low recovery efficiencies and retain considerable volumes of unrecovered mobile oil; deciphering the geologic heterogeneity in these deltaic reservoirs is also a primary focus of this

project. Bureau scientists are studying the effects of paleotopography and structure on carbonate-platform facies/rock fabrics in the prolific Monahans Clear Fork reservoir of West Texas. This is one of several active projects that are designed to help improve production from Texas oil reservoirs.

As in past years, several projects funded by GRI constitute a significant portion of the Bureau's research in natural gas. An ongoing GRI/Bureau program continues to investigate factors controlling the porosity and permeability, fracture distribution, and state of stress in low-permeability natural gas reservoirs in Texas and Wyoming. A major accomplishment of this project in 1992 was the compilation and synthesis of data on the geologic and engineering attributes of 24 low-permeability sandstones in 13 U.S. sedimentary basins. In the Secondary Natural Gas Recovery (SGR) project, another multiyear endeavor supported by GRI and DOE, Bureau geologists and engineers are developing the necessary geologic and engineering knowledge to efficiently produce gas from mostly conventional permeability fluvial-deltaic reservoirs in the Gulf Coast Basin. In 1992, analysis of middle Frio Formation reservoirs of the Seeligson and Stratton fields and Wilcox reservoirs of the Lake Creek Unit was the major focus of project research. SGR project members conducted a series of 1-day Bureau/GRI short courses in several Texas cities and in New Orleans on infield reserve growth potential based on concepts and procedures developed during the project. These short courses were designed to assist exploration, production, and pipeline organizations in maximizing recovery of gas in existing fields by implementing cost-effective strategies during field development. The GRI-funded *Atlas of Major Midcontinent Gas Reservoirs*, which details major natural gas plays in Kansas, Oklahoma, and north Arkansas, is nearing completion and should be available from the Bureau by mid-1993. This compendium complements the *Atlas of Major Texas Gas Reservoirs*, which has been published, and the *Atlas of Major Central and Eastern Gulf Coast Gas Reservoirs*, which will be available in early 1993. During 1992, Bureau researchers also expanded a long-term study of the geologic and hydrologic controls on the production of coalbed methane by beginning examination of producing strata in the Greater Green River Basin of the western United States.

The Bureau's Applied Geodynamics Laboratory (AGL) conducts mathematical and physical scale modeling to generate new concepts, test hypotheses, and replicate specific geologic structures relevant to the location, origin, mechanics, and evolution of structural traps for oil and natural gas. In 1992, AGL researchers employed finite-element modeling of structural traps using GEOSIM-2D, a powerful computer program that simulates combinations of ductile and brittle deformation, large finite strains, faulting, sedimentation, and erosion. The Bureau's *Restore*© computer program for structurally restoring cross sections was further refined in 1992 by addition of capabilities for time-to-depth conversion, restoration to an arbitrary paleotopography, and interactive editing of fault-block boundaries. Experimental physical modeling focused on a wide range of gravity-driven tectonics involving diapirism, extension, contraction, and combinations of these structural styles.

Since the late 1960's, environmental and hydrogeologic investigations have grown and now constitute a significant portion of Bureau research. Twelve projects that address ground-water and environmental issues of importance to Texas and the nation were active at the Bureau during 1992. The Bureau continued a multiyear characterization of the overall geologic suitability of the proposed site for the Texas low-level radioactive waste repository in the Eagle Flat region of Hudspeth County, Texas. Site-specific work has focused on basin-fill sediments, near-surface geologic and vadose zone processes, and ground water in the vadose and saturated zones. Additional regional-scale studies of geologic and hydrologic systems are in progress. A multiyear investigation of the extent and hydrogeologic controls on contaminant migration at an inactive uranium-ore processing plant in Karnes County, Texas, was completed in 1992. Results of the study at this Uranium Mill Tailings Remedial Action (UMTRA) site will benefit both state regulators and those having responsibility for remedial actions. Another multiyear effort focuses on building a comprehensive account of the occurrence and movement of ground water in the vicinity of DOE's Superconducting Super Collider (SSC) in Ellis County, Texas. During 1992, work tasks to investigate vertical movement of ground water between surficial alluvium and Cretaceous bedrock and within the bedrock formations that will host the SSC were added to ongoing studies of hydrologic properties, controls on chemical composition of ground water and maintenance of artesian fluid pressures, and flow in fractures. Another added task is to develop and calibrate a model of ground-water resources in the regional aquifers that underlie the SSC site and that supply much of the region's water. Bureau researchers are halfway through a comprehensive 5-year hydrologic and geologic assessment of contaminant movement in and around DOE's Pantex plant, the nation's site for assembly, maintenance, and disassembly of nuclear weapons. Under the Bureau's leadership, using a multidisciplinary approach, scientists and engineers will provide an integrated view of the geologic framework and hydrologic processes involved in (1) ground-water recharge primarily from playas, (2) development of a perched aquifer, and (3) flow in the High Plains (Ogallala) aquifer. A Bureau investigation is evaluating the economic viability of using the known geopressured-geothermal resource in the deep Wilcox Group in South Texas as a reliable domestic source of alternative energy. The project is also determining the potential of using this geopressured-geothermal water for hot-water flooding of heavy-oil reservoirs.

Ongoing, multiyear coastal studies conducted by the Bureau in 1992 addressed the complex problems surrounding natural and humanly induced changes in sand-dominated Texas Gulf Coast shorelines and in the State's ecologically invaluable coastal wetlands. Bureau coastal geologists are assessing the commercial potential of mining sand, gravel, and heavy minerals from the Texas continental shelf. Sand deposits are used for beach nourishment, an ever-increasing necessity as the

combined effects of rising sea level and land subsidence are manifested as rapid beach erosion. Offshore sand extraction avoids the degradation of wetlands by eliminating the need for destructive onshore mining of sand. In a 5-year study of coastal erosion and wetland loss from Sabine Pass to Sargent Beach, the Bureau is developing the technical information and expertise to help ensure that economic development of the Texas coastal region is compatible with the dynamics of the coastal system. Toward this end, Bureau researchers are providing technical data on coastal erosion and land loss to coastal planners, predicting future rates of erosion by natural and humanly induced processes, and evaluating the impact of relative sea-level rise on coastal lands and communities.

The Texas Mining and Minerals 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, and undergraduate scholarships. For the 1991–92 academic year, four fellowships were awarded to support graduate research in ore deposition, mining engineering, and mineral economics.

Continuing mapping projects conducted by the Bureau in 1992 include (1) mapping of the mid-Tertiary volcanic field in the Big Bend Ranch State Natural Area and (2) 1:100,000-scale mapping of the New Braunfels, Texas, Quadrangle, an area of rapid development in Central Texas.

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

Energy Resources Investigations

Petroleum

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

F. Jerry Lucia, principal investigator; Charles Kerans, Fred P. Wang, and Rainer K. Senger; assisted by Andrew P. Czebieniak, Robin D. Dommisse, and Anil K. Mishra

The goal of the San Andres/Grayburg Reservoir Characterization Research Laboratory (RCRL) is to develop new generic methods for describing the three-dimensional distribution of petrophysical properties in carbonate-ramp reservoirs for the purpose of providing improved estimates of the quantity and location of remaining hydrocarbons. The research is funded by the RCRL Industral Associates Program composed of AGIP, Amoco, ARCO, BP, Chevron, Exxon, Fina, JNOC, Marathon, Mobil, Oxy, Phillips, Shell, Texaco, TOTAL, and UNOCAL. In addition, the program is supported by Silicon Graphics, Stratamodel, Radian, Halliburton, and Terra Science, companies that provide state-of-the-art software and seismic data.

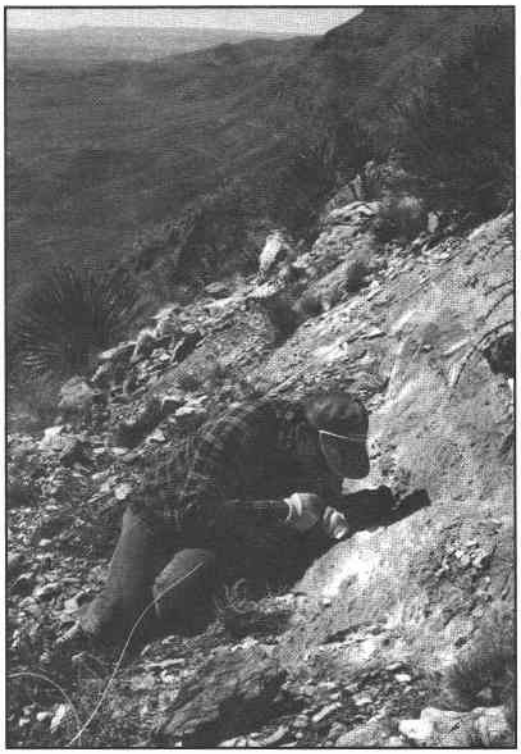
The approach is to combine the study of outcrop analogs of major reservoir types with subsurface reservoir studies. Detailed stratigraphic and petrophysical models can be described from well-exposed outcrops, and subsurface methods can be developed to apply these models to analogous reservoirs. Studies have focused on San Andres and Grayburg reservoirs because of (1) the vast resource of remaining oil in these reservoirs in the Permian Basin, (2) the carbonate-ramp setting of these reservoirs, which is common to many major carbonate reservoirs, and (3) the world-class outcrop of these formations in the Guadalupe Mountains, southeastern New Mexico.

Scaling factors are a key element of this research. Investigations consider a range of scales from regional sequence stratigraphy to depositional facies within individual genetic cycles. The distribution of petrophysical properties has been examined on scales ranging from inches to thousands of feet. The results indicate that (1) the smallest scale at which petrophysical parameters can be averaged is rock-fabric facies and (2) the stacking patterns and average properties of rock-fabric facies control production performance. A computer program that simulates reservoir conditions is used in this project to test the importance of outcrop results for predicting reservoir performance. The importance of describing the distribution of rock-fabric facies has been demonstrated by comparing the performance predictions using a rock-fabric facies model with performance predictions using routine reservoir methods. Routine reservoir methods typically predict significantly higher recovery than does the facies model.

Defining rock-fabric facies has been shown to be a key element in reservoir characterization. Rock-fabric facies include depositional and diagenetic textures. Three generic classes of depositional rock fabrics based on particle size and sorting have been established using outcrop and subsurface data. Diagenetic overprints that result in modification of depositional rock fabrics include the increase in particle size due to dolomitization and the addition of separate-vug porosity.

Detailed mapping of several outcrop windows at various positions within the regional sequence stratigraphic framework indicates that the stacking patterns and average properties of the rock-fabric facies can be correlated to large-scale sequence relationships. These relationships provide a basis for extrapolating the results of the detailed outcrop studies to the subsurface and have been transported to a portion of the Permian Basin using high-resolution reflection seismic data.

The outcrop results have been applied to the Seminole San Andres Unit on the Central Basin Platform. A subsurface rock-fabric facies framework that is similar to the outcrop model has been developed using cores and wireline logs. The framework has been quantified in terms



Bureau researcher taking permeability measurements using a minipermeameter on an outcrop of carbonate-ramp facies of the San Andres Formation, Algerita Escarpment, southeastern New Mexico. Characterization of petrophysical properties in outcrop is used to devise three-dimensional petrophysical models of equivalent reservoir rocks of the Central Basin Platform of the Permian Basin. Photograph by F. Jerry Lucia.

of porosity, permeability, and saturation using relationships among rock fabrics, porosity, permeability, and wireline log responses. The interwell area is described by extrapolating wellbore data using geostatistical methods developed from the outcrop study. The resulting reservoir model has been incorporated into a computer program that simulates reservoir conditions, and testing is currently in progress. Initial results are consistent with results from outcrop studies, indicating that a geologic framework at the level of genetic cycles quantified by averaging petrophysical properties over rock-fabric facies within genetic cycles is the fundamental scale of reservoir description.

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

This project, funded by the U.S. Department of Energy, was completed in March 1992. The purpose of the project was to develop improved methods for characterizing carbonate reservoirs by studying outcrop analogs of subsurface carbonate reservoirs. The study used a multidisciplinary approach, integrating geological, geostatistical, and engineering disciplines. Study concentrated on the clinoform facies of the San Andres (Permian) Formation exposed along the Algerita Escarpment, Guadalupe Mountains, southeastern New Mexico. Detailed geologic mapping of a window in the outcrop 800 ft wide and 120 ft high provided a detailed facies framework that was quantified using petrophysical data collected from core-plug samples from the various facies. The resulting reservoir model was input into a computer program that simulates reservoir conditions, and various waterflooding techniques were tested. The results indicate that (1) facies-averaged petrophysical parameters give adequate performance predictions, (2) recovery is related to the flood direction, and (3) distribution of remaining oil saturation is related to the stacking of facies.

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 R. Stephen Fisher, principal investigators; Mark D. Barton; assisted by Edward S. Angle and Samuel H. Epstein

Reservoir heterogeneity in fluvial-deltaic sandstones may critically limit the amount of natural gas that can be produced from established reservoirs along the Texas Gulf Coast. This project quantifies sandstone heterogeneity in outcrops of seaward- and landward-stepping units of the fluvial-deltaic Ferron Sandstone of east-central Utah. Field work is combined with petrologic and petrophysical analyses to develop a predictive approach for defining the geometric distribution of flow units, baffles, and barriers. Resulting knowledge of flow unit dimensions, permeability characteristics, and permeability correlation lengths can be used to optimize infill drilling programs in mature Gulf Coast sandstone gas reservoirs. The expected long-term benefit of this study is a predictive tool that can be used to increase incremental gas reserves from established fields in a more cost-efficient manner.

Objectives of this research are to (1) examine outcrop exposures of fluvial-deltaic sandstones in two different sequence stratigraphic settings to determine the distribution of flow units, baffles, and barriers to gas flow in sandstone reservoirs, (2) demonstrate that such information can be used to construct realistic reservoir models that can be used to guide infill drilling to maximize incremental gas reserve growth from established fields, and (3) establish general principles for such outcrop characterization studies that can be used by other researchers and field operators.

Sandstone geometry and permeability relations differ between landward- and seaward-stepping units of the Ferron Sandstone, largely because of differences in the amount and distribution of fine-grained silts and muds. A hierarchy of bounding elements that separate flow units has been recognized, and field permeability relations of bounding elements have been quantified. Within

sandstone facies, permeability correlation distances generally correlate with dimensions of major macroforms or stratal types. Sandstone compositions vary systematically between major facies. Framework grain and cement mineralogy and the type of intergranular material differ among fluvial, transgressive, delta-front, and distributary-channel sandstones. These differences affect pore structure, which is reflected in systematic differences in mean permeability of each facies. Petrophysical analyses of flow and mechanical properties have been completed on block samples from both seaward- and landward-stepping sandstones. Effects of grain size, detrital and diagenetic mineralogy on porosity, single-phase permeability, formation factor, and capillary pressure curves have been quantified. Preliminary data show good correlations between petrographic data and petrophysical properties.

Maximization of Petroleum Recovery Efficiency in West Texas

Stephen C. Ruppel, principal investigator; Mark H. Holtz; assisted by Robin D. Dommisse and Ronald A. Johns

This project, which is funded by the State of Texas under the Energy Research in Applications Program (ERAP), is a continuing 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. More than 30 scientists and engineers from 4 universities in the State are involved in the study.

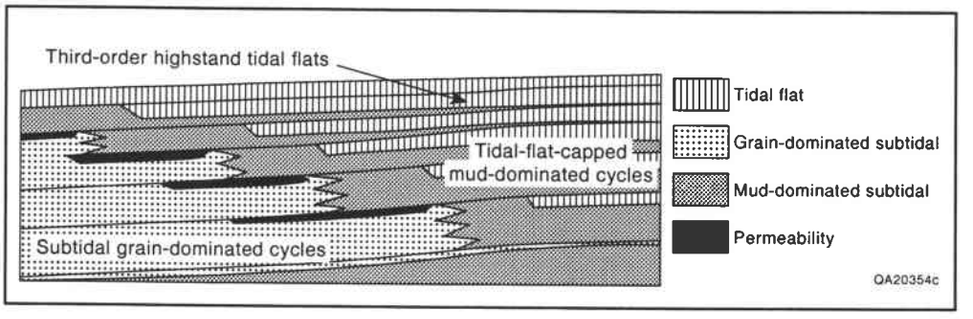
Research carried out at the Bureau has produced a geological model of the Monahans reservoir that interrelates multifrequency rise-fall cycles of relative sea level with depositional facies architecture, diagenesis, and the distribution of porosity and permeability. Facies patterns in this shallow-water carbonate platform reservoir are the direct result of the interaction of cyclic sea-level change and paleotopography. Tidal-flat deposits, for example, are most prevalent over paleotopographic highs, which in many cases are associated with current structural highs, whereas subtidal rocks are most abundant in paleotopographic or structural lows. Diagenesis of original depositional facies is primarily associated with sea-level fall and is thus concentrated at cycle tops. Porosity development is largely restricted to these diagenetically altered cycle tops. Because of facies variations across the field produced by the combined effects of sea-level cyclicity and paleotopography, porosity is developed in several facies types, including both tidal-flat and subtidal deposits. Permeability, however, is restricted to subtidal, grain-dominated rocks. Because of the relationships between facies/rock fabrics and paleotopography or structure, high porosities may be primarily encountered on structural highs, but high permeabilities may be largely restricted to structural lows. Successful mapping and modeling of these relationships is crucial for accurate flow unit modeling in Monahans and similar Clear Fork reservoirs.

Geological modeling and mapping of the reservoir is the basis for resource delineation studies also being conducted at the Bureau. These studies entail detailed analysis of production histories and trends and determination of petrophysical relationships based on analysis of core and wireline log data. The product of this research will be a better understanding of the original and present distribution of hydrocarbons in the Monahans reservoir and improved models for characterizing other low-recovery-efficiency Clear Fork reservoirs.

State Lands Energy Resources Optimization (SLERO) Project

Noel Tyler, director; Richard 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; assisted by Nina L. Baghai, Dieter K. Beike, Joseph C. Fiduk, Herbert Haubold, Thomas E. Hauk, Jun Liao, Ning Li, Amy K. Sapp, Mohammad A. Sattar, Quicheng Ye, and Hongliu Zeng

Project SLERO involves a five-university consortium for which the Bureau of Economic Geology serves as lead contractor. A multidisciplinary team of scientists and engineers, including geologists, geophysicists, and petroleum engineers from The University of Texas at Austin, Texas A&M University, The University of Houston, Texas Tech University, and Lamar University, is conducting integrated research designed to increase hydrocarbon recovery from existing Texas State Lands reservoirs. The project is funded by the Office of the



Research in the Monahans Clear Fork reservoir in West Texas for the ERAP project has identified high-frequency sea-level cyclicity and paleotopography as the primary controls on reservoir development. Permeability is concentrated at the tops of grain-dominated subtidal cycles that were deposited in topographic lows and subsequently altered by diagenesis with sea-level fall.

Governor of Texas and is being conducted in cooperation with the Texas General Land Office. Activities within this consortium study are divided into three parts: (1) play analysis and resource assessment, (2) reservoir characterization, and (3) advanced extraction technology.

Play Analysis and Resource Assessment

The purpose of play analysis is to place Texas State Lands reservoirs into geologically based plays or groups with similar geologic and engineering characteristics. The play context is used to identify individual fields for site-specific reservoir characterization and to establish key reservoir engineering parameters for resource assessment. Each geologically based play has characteristic engineering parameters, such as porosity, permeability, saturation, and pressure, which, along with cumulative production and field size, are used to calculate original oil in place, remaining mobile oil, and residual oil in all major State Lands reservoirs.

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

Reservoir Characterization

The second phase of the study, reservoir characterization, involves detailed site-specific studies of individual reservoirs, identified through play analysis as representative of a larger group of State Lands reservoirs. The object is to define styles of internal reservoir architecture and heterogeneity and to design strategies for maximizing recovery efficiency that may be applied to the entire representative group of reservoirs. Eight individual reservoirs and one subregional area have been selected for detailed study.

Keystone Field

The Keystone (Colby) reservoir, equivalent to the Queen Formation of Permian (Guadalupian) age, is located in Winkler County in the northwestern part of the Central Basin Platform of the Permian Basin, approximately 10 mi from the platform margin. The reservoir is composed of porous, very fine grained arkosic sandstones interbedded with low-porosity dolomite and anhydritic dolomite. Sandstones are interpreted to have been delivered to the shelf margin by eolian transport and reworked in shallow-water marine to peritidal environments.

The Keystone (Colby) reservoir is vertically divided into five sandstone-dominated units within the study area. Isopach maps of each of these five units and completion interval data indicate that large areas of thick sandstones are not open to wellbores. Conservative estimates based on porosities measured in cores and estimates of net-pay thickness and saturations indicate that approximately 4.6 MMbbl of mobile oil is not accessed by existing wellbores on State Lands.

The Keystone (San Andres) reservoir, which is approximately 400 ft thick, produces solution-gas-driven oil from a depth of 4,000 ft. Evaluation of logs and drill cuttings and comparison with cores from an analog reservoir provide the basis for a geologic description.

The reservoir is composed of an upward-shoaling sequence of subtidal grainstone/packstone that is thoroughly dolomitized and partially cemented with sulfates. The upward-shoaling sequence is capped by tidal-flat deposits, principally finely crystalline mudstone. Locally, postdepositional leaching has increased porosity and permeability and altered some anhydrite to gypsum. The combined effects of depositional environment and postdepositional leaching control rock properties used to define five reservoir flow units. Several opportunities for recompletion are present in an area surrounding the crest of the structure, where relatively few wells are in communication with proven productive reservoir zones.

Seventy-Six West Field

Seventy-Six West field, in Duval County, is one of 300 fields of the Jackson-Yegua Barrier/Strandplain Sandstone Play. Fields of this play produce oil from heterogeneous reservoirs consisting of a mosaic of strike-elongate barrier-bar sandstones, crosscutting channel facies, washover sandstones, and tidal inlet-fills. Geologic characterization of Seventy-Six West field has demonstrated compartmentalization of the reservoir caused by this complex facies arrangement and subsidiary structural complications. Several infill drilling locations were proposed to exploit zones containing mobile oil that are either inefficiently drained or uncontacted at the existing well spacing. Two wells have already been drilled and successfully completed as oil producers. A third well was selected as a prime location for water injection and will be incorporated in the ongoing waterflood design.

Colmena-Cedro Hill Field

Colmena-Cedro Hill field is representative of the Jackson-Yegua Barrier/Strandplain Sandstone Play, and provides comparison with the Seventy-Six West field, another Jackson-Yegua field in Duval County that was investigated in 1992. Just as at Seventy-Six West, the geologic characterization at Colmena-Cedro Hill demonstrated compartmentalization within the reservoir caused by the complex facies arrangement. In contrast to Seventy-Six West, however, structural elements at Colmena-Cedro Hill play a much more important role in production trends than does the facies architecture. Fault displacement, for example, determines whether the reservoir sandstones are gas-, or oil-, or water-saturated at Colmena-Cedro Hill field. Results of the study indicate zones within the reservoir that are either inefficiently drained or bypassed by the existing well spacing, and several infill drilling locations have been proposed to exploit these zones. Step-out drilling locations were also identified at Colmena-Cedro Hill field.

Delaware Mountain Group Subregional Study

The Delaware Mountain Group is approximately 3,300 ft thick and includes, in ascending stratigraphic order, the Brushy, Cherry and Bell Canyon Formations. Each approximately 1,000-ft-thick formation is characterized by a cyclically interbedded succession of sandstone, siltstone, and limestone. Oil and gas accumulations occur as multiple stratigraphic horizons in thin, laterally discontinuous sandstone reservoirs.

The Bureau of Economic Geology study indicates that the arrangement, distribution, and architecture of reservoir sandstones is best explained by an eolian-derived turbidite depositional model. Symmetric depositional cycles are characterized by 100- to 130-ft-thick eolian-derived turbidite successions that produce multiple discrete hydrocarbon reservoirs. The reservoir facies within these cycles are as much as 25 ft thick, laterally discontinuous, erosive-based lenticular sandstones. This style of sedimentation results from deposition of airborne silt and very fine grained sandstone that punctuates the normal background sedimentation. The eolian-turbidite depositional model suggests that multiple small-scale and short-lived channels produced a sheetlike sandstone distribution and that these sandstones are probably productive in the undrilled fairways between established production trends.

Screwbean Field

Screwbean field is located in Culberson and Reeves Counties and produces oil from a Delaware Mountain Group reservoir. Core description indicates that the Delaware Mountain Group at Screwbean is composed of five facies: (1) structureless sandstone (reservoir facies), (2) organic-rich siltstone, (3) very thinly laminated sandstone and siltstone, (4) thinly bedded ripple laminated sandstone and siltstone, and (5) nodular limestone with wispy siltstone laminae. Acoustic and gamma-ray log traces were calibrated to core data and plotted against facies to quantitatively define log facies. Core-calibrated log facies were extrapolated to uncored wells and mapped to establish facies diversity trends, lithology ratios, and the spatial distribution of reservoir and nonreservoir facies.

Cumulative production from the Screwbean study area was 1.2 MMbbl as of October 1991. Given the average 17 percent recovery efficiency from Delaware reservoirs, an estimated 7.5 MMbbl remains. The following development strategies, based on the eolian-derived turbidite model, are projected to provide an estimated 2 MMbbl in additional recoverable reserves: (1) recompletion of 16 percent of wells that perforated only one reservoir horizon but contain multiple pay horizons, (2) deepening of 18 percent of wells that penetrate only the upper 50 ft of the Bell Canyon Formation, and (3) infill drilling in a five-section undrilled fairway that contains multiple reservoir horizons productive in adjacent producing trends.

Powderhorn Field

Both oil and gas are produced from the lower Miocene Oakville Formation at Powderhorn field in Calhoun County. Powderhorn field is an example of the Miocene Barrier/Strandplain Sandstone Play. The 10 reservoir horizons were deposited in a variety of depositional environments, including fluvial channels and crevasse splays, bayhead deltas, tidal inlets, flood-tidal deltas, and washover fans. A geological-geophysical model for the field is being created using 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.

Corroborating the compartmentalized reservoir model developed for Powderhorn field are the six successful infill wells that have been completed by the field operator since the beginning of Project SLERO. The most outstanding of these wells is a top allowable producer that discovered a new, deeper reservoir zone, the first significant new discovery in the field in 30 years.

Las Tiendas Field

The Upper Cretaceous Olmos Formation reservoir at Las Tiendas field, in Webb and La Salle Counties, is part of the Upper Cretaceous Olmos Deltaic and Delta-Flank Sandstone Play. Gas reservoirs are located in strike-oriented sandstones formed in delta-front, lower shoreface, and transitional environments on a storm-dominated inner shelf. Porosity and permeability are preserved in the basal portions of individual sandstones, below the depth to which burrowing fauna intermix sandstone with the overlying silt and clay. High productivity occurs in wells that penetrate a few relatively thick, amalgamated storm deposits rather than many thinner sandstones. Results of this research suggest that interwell pressure communication is not a strong influence on production in many portions of this and adjacent fields. Areas where infill wells could reasonably expect near-original reservoir pressure have been mapped.

Lavaca Bay Field

Lavaca Bay field, located in Calhoun County, Texas, produces from the Downdip Frio Barrier/Strandplain Sandstone of the San Marcos Arch Play. The field contains 19 proven reservoirs that range in depth from 9,000 to 13,000 ft. Since discovery in 1964, the field has produced 70 million cubic feet (MMcf) of natural gas. The reservoir lithology is stacked sandstone beds, with thicknesses from a few to as much as 50 ft, separated by shales of comparable thicknesses. The sandstones are interpreted to have been deposited as proximal-to-distal shoreface beach ridges and swales within a progradational and aggradational barrier/strandplain system. The shales are interpreted to have been deposited as shelf muds. In addition to lateral heterogeneity within reservoirs caused by the ridge-and-swale depositional geometries, the reservoirs are broken by major growth faults and

associated minor faults, and sandstone thicknesses are affected by rollover subsidence associated with growth faulting. The result is an overlapping mosaic of separate reservoir compartments.

The gas-productive part of the Frio Formation is divided into 26 sandstone/shale units. Well log parameters, including spontaneous potential (SP), resistivity (R), and sandstone thickness (H), were measured for each of the sandstones. These values were contoured and, when integrated with structure maps, used to identify separate reservoir compartments and to estimate the fluid saturations in separate compartments. These reservoir compartments were evaluated with regard to well locations, completion intervals, and test and production history to identify potential infill and stepout well locations and recompletion opportunities. The results of this analysis are 10 proposed infill well locations, each of which individually targets from 2 to 8 separate reservoir compartments. Additionally, 30 prospective recompletion targets have been identified in existing wells.

Advanced Extraction Technology

The final phase of the project, advanced extraction technology, involves using the results of both play analysis and reservoir characterization to identify groups of State Lands reservoirs that will respond to specific development techniques. Designs of optimized waterflood programs for Seventy-Six West and Keystone (San Andres) fields are nearly complete and will soon be made available to field operators. SLERO researchers have also designed reservoir specific surfactant flood fluids and well stimulation procedures, and additional advanced extraction technologies will be available during the final phase of the project.

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

Robert J. Finley, principal investigator; Don G. Bebout, Robert A. Morton, Steven J. Seni, and Allan R. Standen

The Bureau of Economic Geology is currently developing a series of oil and gas atlases in collaboration with other State geological surveys and supported by GRI, DOE, and MMS. These atlases present compilations of trends of regional hydrocarbon resources. Atlases of large gas reservoirs in the central and eastern Gulf Coast and in the Midcontinent, are in press and in final preparation, respectively. In the fall of 1992, the Bureau received funding for an atlas series of oil and gas reservoirs in the Federal and State offshore waters of the Gulf of Mexico.

The need for an integrated analysis of hydrocarbon resources is underscored by the decline in domestic oil and gas production and the increasing dependence on foreign crude-oil imports. The shift in exploration emphasis in the lower 48 states from frontier areas to extended development in mature hydrocarbon provinces has fueled the need for compiled and collated reservoir data. Systematic synthesis of information on oil and gas resources on a reservoir play basis is required for the continued success of exploration and development activities for the offshore Gulf area. The Gulf of Mexico offshore region contains an estimated 17 and 26 percent, respectively, of the Nation's undiscovered conventional oil and gas resources. In Federal waters alone, more than 19,000 reservoirs in over 700 fields have produced an estimated 7.8 Bbbl of oil and about 89 Tcf of gas. The northern Gulf of Mexico is currently receiving much attention from the oil and gas industry for both field extension and infill drilling in mature areas of the basin as well as for promising targets for future petroleum discoveries in deeper waters across the outer shelf and slope. Major new field discoveries estimated to be in the 200 to 500 MMbbl class, representing a completely new hydrocarbon play, have been discovered recently in association with horizontal salt features along the lower continental slope.

Goals of the Gulf oil and gas atlas project include (1) classification and grouping of offshore oil and gas reservoirs into a series of geologically defined reservoir plays, (2) compilation of comprehensive reservoir play descriptions that include descriptive and quantitative summaries of play characteristics, cumulative production, reserves, original oil and gas in place, and various other engineering and geologic data, (3) development of detailed summaries of representative type reservoirs for each play, and (4) organization of computerized tables of reservoir engineering data in a geographic information system (GIS). The oil and gas atlas series for the Gulf of Mexico will provide a comprehensive index and data reference needed to more efficiently develop reservoirs, to extend field limits, and to better assess opportunities for intrafield exploration and development in a mature oil and gas province. This information will aid exploration and development efforts of offshore operators as well as local and national assessment efforts of State and Federal agencies. Since the 1980's, small independent oil and gas companies have been increasing their exploration efforts in the Gulf of Mexico; however, these small independents do not have large research staffs or the basinwide perspective of the major integrated companies. The atlases will help independent operators by providing an integrated regional reservoir play framework throughout the Gulf of Mexico.

Systematic compilation of Gulf of Mexico reserves and production data within a reservoir play-defined framework will help assess the most important combinations of trap types and producing facies. The data can be used to identify the areas of greatest potential with the highest concentration of remaining unrecovered hydrocarbons in existing fields and to guide frontier exploration in ultradeep water based on analysis of older submarine fan and slope-apron plays encountered beneath the shallower adjacent continental shelf. Thus, regional reservoir play analysis provides a logical basis for simultaneously evaluating both field reserve growth potential and opportunities for extension exploration in mature plays. In addition, synthesis of oil and gas

reservoirs will contribute to a better understanding of the history of the Gulf Coast Basin and will lead to better predictive capabilities with regard to future exploration and development opportunities in the basin.

Kinetic and Geochemical Aspects of Near-Surface Dolomitization

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

One of the greatest enigmas in sedimentary geology is how large bodies of dolomite are formed. Thirty-five percent of global carbonate sedimentary rock is dolomite, yet examples of Holocene dolomite occur as only partly dolomitized carbonate rock bodies generally containing 30 percent or less bulk volume of poorly ordered, metastable dolomite. This lack of a Holocene analog for thick, massive dolomite has been a major stumbling block in solving "the dolomite problem."

The Bureau of Economic Geology, with funding from the Texas Higher Education Coordinating Board's Advanced Research Program, has completed a study of young (Plio-Pleistocene) dolomite on the Island of Bonaire, Netherlands Antilles. These rocks are an ideal natural laboratory for investigation of the origin of dolomite for three reasons: (1) Bonaire dolomite is very young, (2) these rocks have never been deeply buried and therefore have never been exposed to elevated temperatures, and (3) the island is isolated from large continental landmasses and thus the possible sources of dolomitizing fluids are limited.

Dolomitized foreslope grainstone on Bonaire exhibits a progressive increase in unit cell dimensions, calcium content, and strontium content from updip low-porosity rocks to downdip high-porosity rocks, and microprobe data indicate that replacement dolomite is less stoichiometric and contains more strontium than does dolomite cement. Dolomite is in transitional contact with downdip limestone. These rocks are interpreted to have been dolomitized by marine-derived hypersaline brines that moved downdip from a superjacent sea-marginal lagoon or saline lake.

Mole-per-mole replacement of calcite by dolomite yields an approximately 12-percent increase in porosity because dolomite is denser than calcite. However, dolomitization of the Plio-Pleistocene rocks of Bonaire involved a net import of carbonate such that dolomitization resulted in porosity reduction. Rocks proximal to the source of dolomitizing fluids exhibit a greater amount of porosity occlusion than do more distal rocks. This observation indicates that dolomitization is a porosity-destroying process and that the degree of porosity destruction can be calibrated to the flow path of dolomitizing fluids. Porosity observed in Bonaire dolomite varies over a distance of hundreds of meters along fluid flow paths.

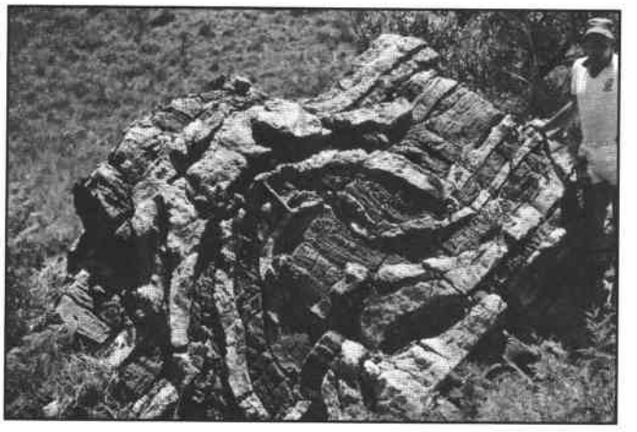
These geochemical tracers of dolomitizing fluid pathways may provide a means for predicting diagenetically controlled porosity trends in ancient rocks. Inasmuch as porosity trends are associated with significant changes in petrophysical characteristics and fluid storage capacity at a between-well scale, this interpretation scheme may facilitate mapping of flow units in hydrocarbon reservoirs and freshwater aquifers.

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

Noel Tyler, principal investigator; Richard P. Major and Roger Tyler

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

The Bureau of Economic Geology, under funding from the Texas Higher Education Coordinating Board's Advanced Research Program, has initiated a petrographic and geochemical study of Proterozoic carbonate rocks from the eastern Transvaal of South Africa. The purposes of this study are to track the nature of change in the composition of the atmosphere and to identify the effects of this major change in the ocean/atmosphere system on the precipitation of marine carbonate sediments. These carbonate rocks, which are completely dolomitized, may be examples of primary precipitation of this mineral (most younger dolomites are the product of altered calcite or



Stromatolite megadome in the Lower Proterozoic Eccles Formation of the eastern Transvaal, South Africa. These strata, which represent some of the oldest marine carbonate rocks that have not been severely deformed or metamorphosed, are being examined by Bureau researchers to decipher changes in the Earth's early atmosphere and their effects on the precipitation of marine carbonate sediments. Photograph by Noel Tyler.

aragonite sediments or rocks). The carbonate rocks of the eastern Transvaal provide a unique opportunity to study these phenomena because they are among the earliest examples of marine carbonate sediments that have not been severely deformed by tectonism or, as is the case for many Precambrian rocks, subjected to metamorphic temperatures and pressures.

During 6 weeks of field work in late April and early May 1992, approximately 3,000 m of core was logged, 2 1,000-m stratigraphic sections were traversed, and 250 dolomite and chert samples were collected. Samples were obtained both from cores made available by Rand Mines Ltd., South Africa, and from outcrops in and around the town of Pilgrim's Rest. Sample collection was designed to capture the full vertical extent of the stratigraphic sequence and to capture a range of early Proterozoic carbonate depositional textures. Petrographic and geochemical analyses of these samples, including cation and stable oxygen and carbon isotope analyses, are in progress.

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

Noel Tyler, principal investigator; Kenneth T. Barrow and Douglas B. Swift; assisted by Qing Fang

More than 1,600 large (>1 million barrels of oil equivalent) oil and gas fields containing an estimated 5.4 billion barrels of oil equivalent are thought to lie in the Permian Basin awaiting discovery. Most of these reservoirs will be found in subtle traps by explorationists having a detailed understanding of the complex interrelationships between hydrocarbon generation and migration, diagenesis, and trap formation. This 2-year project, funded by the Advanced Technology Program of the Texas Higher Education Coordinating Board, will produce an integrated geological, geophysical, and geochemical analysis documenting the timing and style of tectonic deformation, the origin and migration of hydrocarbons, and the depositional and diagenetic history of Paleozoic sediments in the Delaware Basin and on the adjacent Central Basin Uplift. Reprocessing and interpretation of older seismic data will be done at The University of Texas of the Permian Basin. Geochemical modeling will be conducted by the Petroleum Geology Branch of the U.S. Geological Survey in Denver, Colorado. Geologic interpretation and synthesis will be done by the Bureau of Economic Geology.

In 1992 records were compiled on all wells drilled into the pre-Permian section within the study area in Texas and New Mexico. Wells with anomalous sections (abnormally thickened or thinned, faulted, overturned, unusual lithology, etc.) were targeted for additional study. A well-log cross-section grid was created over the Central Basin Uplift and Delaware Basin and tied to the seismic grid being used in the project. All significant pre-Permian oil and gas reservoirs were identified, and some of these were selected for more detailed field studies.

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

Shirley P. Dutton and Noel Tyler, principal investigators; Michael H. Gardner; assisted by Christopher J. Collom, Widya Dharmasamadhi, and Amy K. Sapp

Significant amounts of oil and gas remain in many fields after conventional recovery operations reach maturity. Targeted infill drilling, waterflood optimization, and enhanced oil recovery programs will minimize production decline and add reserves, but many technical problems must be overcome before we can fully realize the potential of the remaining oil and gas resources in existing fields. One fundamental problem is determining the three-dimensional architecture of depositional and diagenetic facies in the reservoir and their relation to the spatial distribution of petrophysical attributes that directly control fluid flow in the reservoir. The purposes of this project, which developed as an outgrowth of the Ferron Sandstone study, are (1) determination of sequence stratigraphic controls on the anatomy of fluvio-deltaic sandstones, (2) outcrop quantification of the spatial distribution and scaling of petrophysical properties, (3) flow simulation of fluid through the reservoir analog, and (4) field-development optimization studies. Efforts will focus on fluvial-deltaic reservoirs because of the potential for incremental recovery through characterization of the pronounced reservoir heterogeneities that exemplify fluvially dominated deltaic reservoirs.

The project will focus on the Lower Cretaceous Dakota Sandstone (Fall River Formation), which has exposures of deltaic and incised-valley facies in outcrops in eastern Wyoming and western South Dakota. The Dakota provides an opportunity to study facies architecture in fluvial-deltaic reservoir sandstones that were deposited

Cliff face of fluvial sandstone from the Lower Cretaceous Dakota Sandstone (Fall River Formation) of the northern Black Hills, Crook County, Wyoming. The sandstone is part of an extensive incised valley system and is a direct outcrop analog to the Dakota Sandstone in the oil-producing Buck Draw field in the southern Powder River Basin. Photograph by Christopher J. Collum.

under stable conditions of low subsidence along the eastern margin of the Cretaceous seaway and compare them with the Ferron Sandstone, which was deposited in a rapidly subsiding foreland basin. Field work during the summer of 1992 focused on measuring sections, performing detailed outcrop characterization of facies architecture, and establishing the sequence stratigraphic framework of the deltaic systems tract. Through the use of sequence stratigraphy as an extrapolative tool, the geometric, volumetric, and facies attributes of Cretaceous Dakota deltas of the Western Interior can be extended to the Gulf Coast, Midcontinent, and Alaskan delta systems.

A direct subsurface reservoir analog to the sandstones studied in outcrop is the Dakota Sandstone in Buck Draw Field in the southern Powder River Basin. The study of an excellent suite of cores from Buck Draw field will allow us to compare the extent of diagenesis between the surface and subsurface Dakota sandstones. This comparison will enable us to perform petrophysical property transforms and thus use porosity and permeability data assembled on the outcrop in reservoir flow models.

This investigation of sandstone geometry and permeability structure is funded by a consortium of industrial associates comprising the following oil companies: Amoco Production Company, BP Exploration Operating Company Limited, Chevron Oil Field Research Company, Conoco, Inc., Societe Nationale Elf Aquitaine (Production), Exxon Production Research Company, Intevep S.A., Kerr-McGee Corporation, The Louisiana Land and Exploration Company, Mobil Research and Development Corporation, Occidental International Exploration and Production, Inc., and Oxy U.S.A., Inc., Oryx Energy Company, and Union Oil Company of California.

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

Noel Tyler, principal investigator; Eulise R. Ferrer, William A. Ambrose, Shirley P. Dutton, and H. Scott Hamlin; assisted by Pedro J. Gamboa and Mohan I. Javalagi

The goal of this 16-month project, which is funded by Lagoven S.A., an affiliate of Petroleos de Venezuela S.A., is to maximize secondary oil recovery from 10 lower Eocene deltaic reservoirs in the C–X members of the Misoa Formation in Lagunillas field, located in northeastern Lake Maracaibo. These heterogeneous reservoirs have a low recovery efficiency of 22 percent and contain considerable volumes of unrecovered mobile oil (more than 750 MMbbl) that have not been contacted at the current well spacing of approximately 160 acres. The Bureau of Economic Geology is conducting, in collaboration with Lagoven, an integrated study of Lagunillas field that includes a structural, stratigraphic, petrophysical, and production engineering analysis from well logs, cores, seismic, thin-section, and petroleum engineering data. The objectives of this study are to define (1) reservoir limits, (2) characteristics of rocks, reservoirs, and fluids, (3) volumes of oil originally in place, (4) hydrocarbon recovery factors, (5) recoverable oil reserves through primary production methods, and (6) volumetrics and potential for additional recovery.

The structural and stratigraphic framework of the 4,000-ft thick reservoir section in the Eocene Lagunillas field was established with a grid of more than 25 cross sections that collectively intersect more than 150 wells. Sandstones and shale beds in the most productive intervals in the lower Eocene (C-3-X and C-4-X members) were correlated to document the depositional geometry and lateral continuity of reservoir sandstones. Detailed core descriptions from the C-3-X and C-4-X members were integrated with the cross sections, and deltaic depositional facies in several transgressive and regressive parasequences were recognized. The project will be completed in 1993 with the targeting of selected reservoir zones in Lagunillas field for infill drilling, recompletion, or water injection to maximize secondary oil recovery.

Assessment of Oil, Natural Gas, and Geothermal Energy Production in Texas

William L. Fisher, principal investigator; Steven J. Seni

At the request of the Governor's Office and the Railroad Commission of Texas, the Bureau of Economic Geology made estimates of recoverable resources of oil, natural gas, and geothermal energy in Texas and provided estimates of long-term production paths for the State of Texas Energy Policy Partnership (STEPP).

With advanced technology and at prices of $20 to $25 per barrel (1990 dollars), 36 Bbbl of additional oil can be recovered in Texas, supporting a 2010 production of 575 MMbbl and a 2030 production level of 500 MMbbl. If technology is not advanced, recoverable resource volumes in Texas are estimated at 18 Bbbl.

The Bureau estimates 249 Tcf of additional natural gas can be recovered in Texas at prices up to $3 per Mcf (1990 dollars), and with advanced technology, supports a 5.0 Tcf production level in 2010 and a 3.6 Tcf level in 2030. With only existing technology, accessible resources in Texas amount to an estimated 162 Tcf and sharpened declines in long-term production.

The Bureau estimates 21 to 35 Tcf of methane potentially available from Texas geothermal waters but concludes that the volumes are not accessible at likely prices for competitive fuels. However, thermal uses of the resources for space heating, agriculture, and enhanced oil recovery are possible.

Estimation of the Oil Resource Base of the United States

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

The Bureau and the National Institute for Petroleum and Energy Research (NIPER) brought together a national panel of experts to provide an assessment of the oil resource base of the United States. The assessment was commissioned by the U.S. Department of Energy as part

of the research work for the National Energy Strategy. The Panel, chaired by William L. Fisher, consisted of 17 oil resource analysts representing a broad cross section of experts from major oil companies, independent oil companies, Federal government departments and agencies, State geological surveys, private foundations, and consulting firms. The Panel included representatives from all of the agencies or entities involved in previous resource estimates of the U.S. oil resource base.

The Panel met August 31 and September 1, 1992, at the Bureau to review and discuss the results of previous resource assessments. Bureau staff provided the Panel with the basic data, methodology, assumptions, and the results of resource assessments undertaken in the past 5 years. NIPER staff prepared an analysis of enhanced oil recovery potential. Resource estimates and perspectives were presented by representatives of the American Association of Petroleum Geologists, the Society of Petroleum Engineers, the Gas Research Institute, and ICF Resources Incorporated.

Four geographic areas were considered: the lower 48 states onshore, the lower 48 states offshore, Alaska onshore, and Alaska offshore. Estimates of reserve growth in existing fields and undiscovered resources were provided for two price scenarios ($20/bbl and $27/bbl in 1992 constant dollars) and two technology scenarios (existing technology and advanced technology). Individual estimates were made by the Panel members for what was considered to be the mean recoverable oil, given the specified price and technology assumptions.

The Panel concluded that the remaining, recoverable volume of crude oil in the United States ranges from 99 to 204 Bbbl, inclusive of 25 Bbbl of proved reserves. The estimate of 99 Bbbl assumes a stable oil price of $20/bbl (1992 constant dollars) with existing technology. The estimate of 204 Bbbl assumes a price of $27/bbl with advanced technology. This range in estimates of the remaining resource base is equivalent to 35 to 75 years of continued U.S. crude oil production at the current annual rate of 2.7 Bbbl.

In the Panel's estimation of recoverable resources, both price and technology are significant and they are almost equivalent in their impact. The average estimate for recoverable volumes (total undiscovered resources and reserve growth) at both price levels was approximately two-thirds greater with the assumption of advanced technology than with existing technology. Future potential was estimated by the Panel to be nearly equally divided between reserve growth from existing, already discovered fields, and new fields yet to be discovered. About two-thirds of the total remaining potential was estimated to be onshore in the lower 48 states, largely due to reserve growth from existing fields. About one-third of the total remaining potential was estimated to be in the offshore areas of the lower 48 states and onshore and offshore Alaska. Alaska and the lower 48 offshore areas were considered to hold nearly one-half of the future discovery potential and most of the potential for giant field discovery.

The Panel did not evaluate the impact of current access restrictions (for example, drilling restrictions in the Arctic National Wildlife Refuge and in various areas in the Federal offshore), premature abandonment of existing fields, downsizing of research and development efforts in the private sector, and regulatory constraints and environmental regulations. It was the judgment of the Panel that these factors could seriously limit the potential for recovery of the oil resources.

Technology Transfer

Bob A. Hardage, principal investigator; Sigrid J. Clift

The Bureau of Economic Geology is working closely with the Texas Independent Producers and Royalty Owners (TIPRO) and with regional associations of independent oil and gas operators to determine the technology areas where Texas independent producers need assistance in their efforts to achieve a higher level of technical utilization. More than 400 independent operators have discussed their technology needs with Bureau representatives in a series of forums held at Abilene, Amarillo, Corpus Christi, Dallas, Houston, Longview, Midland, and Wichita Falls. The information gathered in these statewide forums has been analyzed, and a prioritized list of technology training areas now exists. Current activity in the Bureau's technology transfer program is concentrated on performing the actual training, with the initial phase of the training program being a series of classes and demonstrations held at appropriate locations across the state of Texas. Bureau personnel organize and participate in these training sessions together with several non-Bureau people who have been recruited because of their demonstrated skills in lecturing and training. This phase of the technology transfer program is funded by the Department of Energy through their Bartlesville, Oklahoma, office and by the state-supported SLERO program.

Conodont Chemostratigraphy: Improvements in the Geologic Time Scale

Stephen C. Ruppel, principal investigator; Eric W. James; assisted by Nikolas A. Hazel, Terry L. Roark, and Kristen L. Staudenmayer

This new 2-year project, funded through the Advanced Research Program of the Texas Higher Education Coordinating Board, is directed toward developing and applying new techniques of relative and absolute dating of conodont microfossils in sedimentary rock successions. The absolute ages of most sedimentary rock sequences are poorly known. Chronologies are commonly based on faunal zonations that are only weakly tied to the chronostratigraphic record.

This project proposes to improve the geochnronological precision in Paleozoic sedimentary rock sequences through analysis of strontium and uranium-thorium-lead isotopes. Measurements of strontium isotope ratios ($^{87}Sr/^{86}Sr$) will refine relative age control of these sedimentary sequences by comparison to established secular changes in sea water strontium isotope ratios and at the same time improve the data on which these secular trends are

based. Uranium series isotopes offer the potential for absolute dating throughout the sedimentary rock record. Conodonts are uniquely appropriate for these studies because (1) they are more chemically inert than other materials available for study and are thus more likely to retain original sea water chemistries and (2) they are relatively widespread and common in Paleozoic sedimentary successions.

Initial stages of the research are directed toward obtaining conodonts and strontium isotope ratios from three important stratigraphic successions: the Silurian-Middle Devonian, the Upper Devonian–middle Mississippian, and the Permian. Of these, the latter is of particular importance because of its especially poorly constrained chronology and unresolved stratigraphic problems.

Gas

Geological Investigations of Low-Permeability Gas Sandstone Reservoirs

Stephen E. Laubach, principal investigator; M. Saleem Akhter, Sigrid J. Clift, Shirley P. Dutton, Douglas S. Hamilton, H. Scott Hamlin, and Tucker F. Hentz; assisted by Laura L. Brock and Barbara A. Marin; in cooperation with the Wyoming Geological Survey

Low-permeability formations contain an estimated minimum of 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. The Gas Research Institute (GRI) has supported investigations by the Bureau 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 1992, the Bureau's research had two major components: (1) 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 Geological Survey has been subcontracted for parts of the study of the Frontier Formation. (2) Conducting a screening of low-permeability formations to identify suitable locations for GRI-sponsored hydraulic fracture experiments, and researching and preparing a major summary of the geological and engineering attributes of low-permeability sandstones throughout the United States.

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. Among other findings, research in 1992 demonstrated that natural fractures are locally common in Canyon sandstones, and their occurrence can be predicted from the diagenetic character of the rock. A contract report was prepared that describes the completed stratigraphic, diagenetic, and structural studies of this formation.

Stratigraphic study of low-permeability sandstone in the Cleveland Formation in a seven-county (Hansford, Ochiltree, Lipscomb, Hutchinson, Roberts, Hemphill, and Wheeler) area of the Texas Panhandle was completed, and results were summarized in contract reports and Bureau publications. 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.

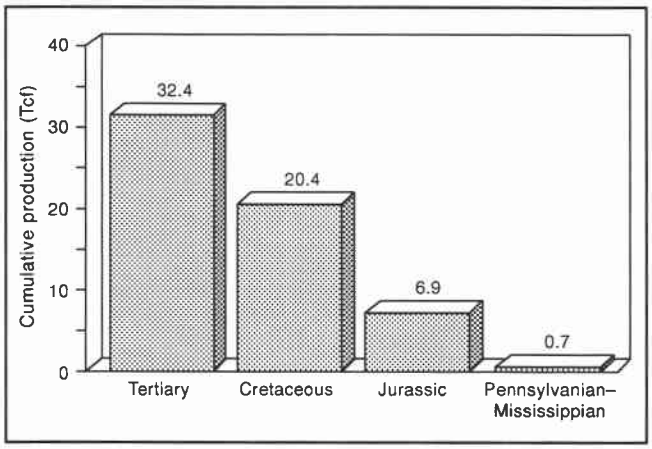
A summary geologic topical report was completed that details Frontier stratigraphy, diagenesis, and structure. Work in 1992 concentrated on analysis of natural fractures, in situ stress, and sequence stratigraphy of the Frontier Formation. Preliminary results of this work were reported in outside publications.

A major effort of this project in 1992 was the compilation and synthesis of data on the geological and engineering attributes of 25 low-permeability sandstones in 13 sedimentary basins across the lower 48 states. Emphasis was placed on the geologic characteristics that have the greatest impact on producibility of these low-permeability gas reservoirs, including depositional system, reservoir composition, orientation and abundance of natural fractures, and in situ stress. A major contract report summarizing the findings of this study was prepared.

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

Don G. Bebout, principal investigator; Chester M. Garrett, Jr., William A. White, and Tucker F. Hentz; assisted by John M. Mendenhall and Rick W. Reeves; subcontracts to Arkansas Geological Commission, Louisiana Geological Survey, Mississippi Department of Natural Resources; and to 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 Atlas of Major Central and Eastern Gulf Coast Gas Reservoirs is complete and is scheduled to be available in early 1993. Recorded total cumulative production of gas in this area is 152 Tcf; of this, 59 Tcf have been produced from the 1,357 reservoirs that have



Cumulative production totals by geologic age from natural gas plays of the central and eastern Gulf Coast.

produced more than 10 Bcf each and are included in this atlas. Louisiana has produced the most natural gas, with cumulative production of 49 Bcf from greater-than-10-Bcf reservoirs. The Louisiana data include only production from 1965 to 1990; production data prior to 1965 are not readily available. Tertiary reservoirs have produced the most gas, with cumulative production of 31 Tcf, the greater part of this from the Miocene. Cretaceous reservoirs are second, with cumulative production of 20 Tcf; most of the Cretaceous production is from the Upper Cretaceous Gas Rock play.

The Atlas of Major Midcontinent Gas Reservoirs will be available in mid-1993. Recorded total cumulative production from Midcontinent reservoirs is 103 Tcf; the 495 greater-than-10-Bcf reservoirs included in this atlas have produced 65 Tcf. Although 70 percent of the gas production is from Oklahoma, the largest play, Wolfcampian carbonates of the Hugoton Embayment, is shared by Kansas and Oklahoma.

The Bureau of Economic Geology has been the prime contractor for this gas atlas project funded by the Gas Research Institute. The Bureau issued subcontracts to the applicable state surveys for aid in gathering basic data on gas reservoirs and in preparing text and illustrations for the atlases.

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

Robert J. Finley, project director; Raymond A. Levey, principal investigator; Bob A. Hardage, Shirley P. Dutton, William A. Ambrose, Jeffry D. Grigsby, Richard P. Langford, Mark J. Burn, and Andrew R. Scott; assisted by Laura L. Brock, Traci A. Parks, Virginia M. Pendleton, Lisa E. Remington, Randy L. Remington, Asad M. Sattar, Robert S. Single, Beate K. Sterrenberg, Liangqing Xue, and Ran Zhou

The Secondary Natural Gas Recovery (SGR) project is funded by the Gas Research Institute (GRI), the U.S. Department of Energy (DOE), and the State of Texas. The Bureau is the lead technical contractor for this gas field-oriented research project, which is focused on identifying and documenting the impact of stratigraphic and diagenetic compartmentalization in fluvial-deltaic reservoirs of the Frio and Vicksburg Formations and the Wilcox Group in the Gulf Coast Basin. Achievements of this joint venture include (1) confirmation that incremental conventional gas resources represent a significant percentage of new gas reserves, (2) assessment of the distribution of incremental natural gas resources by depositional system, and (3) definition of cost-effective tools and strategies and testing of state-of-the-art techniques for achieving incremental recovery of natural gas in mature fields.

Reservoir modeling and engineering analysis is conducted by Research and Engineering Consultants of Englewood, Colorado. ResTech, Inc., of Houston conducts log interpretation and formation evaluation. Envirocorp Services and Technology of Houston has monitored drilling and completion activity and coordinated field-data acquisition in the gas fields investigated. In 1992 analysis of the middle Frio Formation was the major focus of project research. Completion of cooperative research of reserve growth at Seeligson field, with Oryx Energy, Mobil Exploration and Producing Company, and Mobil Research and Development Corporation, culminated with a GRI topical report documenting the degree of reservoir compartmentalization in laterally extensive fluvial-dominated reservoirs. Cooperative engineering testing in more than 60 gas wells at Stratton field operated by Union Pacific Resources Corporation (UPRC) formed the basis of defining reservoir groups that will allow geological characterization of the reservoirs to be merged with infield development scenarios to maximize the recovery of natural gas. Geophysical data acquisition included both conventional and slim-hole vertical seismic profiles to image interwell heterogeneities identified by pressure interference tests. A 7.5-mi^2 three-dimensional seismic survey designed to image multiple stacked thin-bed fluvial gas reservoirs was acquired across a study area within Stratton field where an extensive geological, engineering, and petrophysical data base has been analyzed. Implementation of the SGR approach for evaluating incremental gas resources was also demonstrated by conducting mini-evaluations in mature fields that were recently acquired by independent operators for infield development. Successful project identification of a bypassed reservoir perforated by one operator resulted in flow rates exceeding 1 MMcfg/d. Additional completions in additional surrounding wells also confirmed the existence of incremental gas.

Research into compartmentalization in Wilcox gas reservoirs was completed with the subsurface evaluation of depositional and diagenetic trends in Mobil's Lake Creek Unit of the Texas upper Gulf Coast. A log-based permeability model was successfully developed and calibrated to cores and production information. Integrated geologic and engineering evaluation of deltaic gas reservoirs confirmed the influence of depositional facies in the compartmentalization of distributary channel reservoirs compared to delta-front sandstones. Formation

evaluation, engineering and production history, and comparison of reservoir heterogeneities between subsurface gas reservoirs in the Wilcox and the surface parallel research efforts of the Bureau's GRI-supported research on outcrops of the Ferron Sandstone (Cretaceous) in central Utah and were documented in a GRI topical report.

A series of 1-day short courses on infield gas reserve growth potential were presented in Houston, Corpus Christi, Midland, San Antonio, Oklahoma City, and New Orleans. More than 350 participants from 100 companies and agencies attended these technology-transfer sessions designed to assist exploration, producing, and pipeline organizations in maximizing the recovery of gas in existing fields by implementing cost-effective strategies during field development. A PC-based, user friendly, computer program known as "Gas Wizard" (G-WIZ) was commercially released. This product, developed by the SGR project, was made available to the gas industry for detecting and evaluating multi-compartment behavior of gas reservoirs. The 1993 research effort will focus on final interpretation of integrated project testing, geophysics, and documentation of the results from this research project. Additional GRI topical reports and a DOE contract report will be available in the second quarter of 1993.

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

Robert J. Finley, principal investigator; Mary L. W. Jackson and Pedro J. Gamboa

The Macroeconomic Approaches project, a 1-year project funded by the Gas Research Institute (GRI), focused on analysis of gas reserve growth from infield drilling and recompletions 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 "macroeconomic 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 Macroeconomic Approaches project, reservoir completion intervals were examined on well logs to verify stratigraphic position of producing intervals defined in the EEA macroeconomic assessment. Well logs were grouped into two to seven completion sets within a 640-acre area and within a single reservoir. More than 400 completion sets were examined for geological continuity in the Frio, Vicksburg, Wilcox, and Miocene geologic units using depositional systems analysis and production information.

Four types of infield completions were identified: (1) completions in gas-cycled reservoirs (type 1), (2) completions reported to be in the same reservoir but interpreted not to be so, based on geologic analysis (type 2), (3) completions in a single reservoir with evidence of pressure communication (type 3), and (4) completions in a single reservoir with the infill completion pressure significantly above reservoir pressure in nearby wells (type 4).

In gas-cycled reservoirs (type 1), additional production may come from infield completions, but cycled gas is difficult to distinguish from new reserve additions. Type 2 infield completions, interpreted to be in two or more zones, may represent new pool additions. Infield completions in types 3 and 4 are in a single stratigraphic interval containing partially or totally isolated gas-filled compartments. Type 3 completions contact gas in pressure communication with existing wells and do not represent reserve growth, whereas type 4 completions represent within-reservoir reserve growth at pressures significantly above pressures in nearby wells.

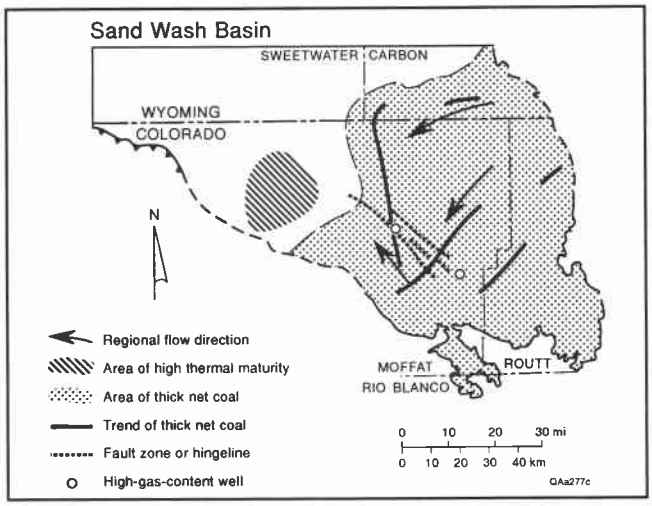
Across all permeability types, an estimated 78 percent of the initial EEA reserve growth estimate for South Texas was validated by this study. Volumes judged most appropriate for removal from the EEA estimate include the gas volume resulting from rate acceleration (type 3 completions) and from low-permeability Wilcox Lobo reservoirs where limited drainage radii lead to expected reserve growth and half of the gas volume from infield wells in gas-cycled reservoirs (type 1 completions). Gas volumes from shallower or deeper pools (type 2 completions), which may not represent reserve growth from the same reservoir as preceding completions in a group, nevertheless contribute to overall reserve growth.

In addition to validation of the EEA macroeconomic assessment analysis, this project provides a regional perspective for field-specific analyses performed in the Secondary Gas Recovery (SGR) project. The Macroeconomic 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 and Hydrologic Controls on Coalbed Methane Production

William R. Kaiser, principal investigator; Douglas S. Hamilton, Andrew R. Scott, and Roger Tyler; assisted by Ronald G. McMurry and Naijiang Zhou; in cooperation with the West Virginia Geological Survey and Colorado Geological Survey

The objective 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 is characterizing coalbed methane in western United States coal basins; the Colorado Geological Survey is subcontracted for data collection and logistical support; and the West Virginia Geological Survey (WVGS) is subcontracted to study the Northern Appalachian Coal Basin.



The Sand Wash Basin of Colorado and Wyoming is one of several basins of the western United States that produce commercial quantities of coalbed methane. In this and other basins of the western U.S., Bureau researchers are investigating major controls on coalbed methane production, such as basin hydrogeology, structure, coal trends, and thermal variations.

On the basis of a 1991 comparative study of the Greater Green River, Piceance, Powder River, and Raton Basins, the Greater Green River Basin was chosen for characterization of coalbed methane resources. Studies of coalbed methane in the greater basin have begun in the Sand Wash Basin, northwest Colorado. Geologic and hydrologic analysis of the Upper Cretaceous Mesaverde Group shows that the major controls on the production of coalbed methane are structural configuration, coal occurrence, thermal maturity (gas content), hydrodynamics, and water production. Details of the first year's work are summarized in an annual report to GRI that will be available in early 1993.

Steep structural dip (500 ft/mi) and coal occurrence limit economic exploration in the eastern and southeastern margins of the Sand Wash Basin. The thickest, most laterally continuous coal beds occur in the lower Williams Fork Formation (upper Mesaverde) in the eastern part of the basin. Individual coal beds are 10 to 20 ft thick; as many as 20 beds are present with an aggregate thickness of more than 100 ft.

Coals in the Sand Wash Basin have not reached the rank of maximum gas generation. Thus, large volumes of thermogenic gas may never have been generated. Most coal beds are high-volatile C to B bituminous rank and have gas contents of less than 200 ft^3/ton. Moreover, Williams Fork coals do not extend westward to the area of highest thermal maturity in the basin's structural center. Thus, they could not serve as conduits for updip, eastward, long-distance migration of gas for eventual resorption or conventional trapping.

Regionally, ground water flows westward from an eastern recharge area across an area of low thermal maturity up the coal-rank gradient. Consequently, only a relatively small volume of gas may be available to be swept basinward for conventional trapping. The most prospective areas lie basinward, northwest of Craig, Colorado, upflow of a major fault zone. Gas contents in some coal beds on the downthrown side of the fault exceed 400 ft^3/ton.

The Mesaverde is a thick, regionally interconnected aquifer system of high transmissivity, yielding large volumes of water. This is evident in a basinwide cumulative gas/water ratio of approximately 13 ft^3/bbl. In the Dixon and Craig Dome fields, coalbed methane wells produced water at an average rate of 500 to 700 bbl/d. It may not be possible to dewater (depressure) coal beds near the basin margins because of their proximity to the recharge area and high coalbed permeabilities of hundreds to thousands of millidarcys. Paradoxically, permeability may be too high for economic gas production. To date, high water production and low gas content at the basin margins have limited coalbed activity in the Sand Wash Basin.

In studies of coalbed methane in the Northern Appalachian Coal Basin, the WVGS has operationally defined the Middle Pennsylvanian Allegheny Formation, the major coal-bearing unit below the Pittsburgh coal, a prime target of coalbed methane exploration. The Allegheny is defined in outcrop by coals that are not easily recognized in the subsurface. The uppermost massive sandstone (First Salt, or Homewood, sandstone) of the underlying Pottsville Formation serves as the operational base of the Allegheny coal-bearing interval, and the Big Dunkard, or Mahoning, sandstone in the lower part of the Conemaugh Group serves as its operational top. The interval so defined contains the lowest Conemaugh and Allegheny coals. Among these, Allegheny coals are the thickest and most continuous.

Coal

Computerized Calculation of Lignite Resources in Texas

William R. Kaiser, principal investigator;
Mary L. W. Jackson; assisted by Scott C. Goode

This multiyear 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.

The resource calculation capabilities of the NCRDS are under revision and are still not fully operational. Therefore, no resources were calculated in 1992. However, the expanded computing and communications capabilities of the Bureau's Iris Indigo workstation, acquired for this project in 1991, have enabled us to correct calculations made previously. When resource calculation subprograms become available from the USGS next year, they will be incorporated into our version of the Geographic Resource Analysis Support System (GRASS), now installed on the Iris Indigo, and used to calculate lignite resources.

Experimental and Applied Tectonics Investigations

Applied Geodynamics Laboratory: Physical Tectonic Modeling

Martin P. A. Jackson, laboratory director;
Bruno C. Vendeville and Hemin Koyi;
assisted by Hongxing Ge and Shing-Tzong Lin

The Applied Geodynamics Laboratory (AGL) carries out physical scale-modeling to generate new concepts, test hypotheses, or occasionally to duplicate specific geologic structures relevant to the location, origin, mechanics, and evolution of structural traps for oil and gas. Research at AGL is funded by a consortium of industrial associates comprising the following oil companies: Agip S.p.A., Amoco Production Company, ARCO Oil and Gas Company, BP Exploration, Inc., Chevron O.F.R. Company and Chevron U.S.A., Inc., Conoco, Inc., EUROSIM Sarl, Exxon Production Research Company, Marathon Oil Company, Mobil Research and Development Corporation, Petroleo Brasileiro S.A., Phillips Petroleum Company, Shell Development Company, Société Nationale Elf Aquitaine Production, Texaco, Inc., and Total Minatome Corporation.

Most experiments were carried out in a normal gravity field. The deformation rig allows simulation of almost any structural style, including extension, shortening, wrenching, doming, and drape folding, or any combination of these styles. The rig is driven by two stepper motors controlled by two electronic indexers and a personal computer. A biaxial rig also allows experiments with simultaneous shortening or extension in two directions. 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. Other equipment built includes a highly accurate coaxial viscometer for measuring flow properties of modeling materials, a motorized sheet roller for manufacturing sheets of putty, and a slicing jig. 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 to 60 m 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 diapirism, extension, contraction, and combinations of these structural styles. Experiments covered the following main topics as well as other minor ones:

(1) Growth and lateral intrusion/extrusion mechanisms of salt tongues induced by progradation. This research examines the role of the prograding wedge in driving lateral flow of salt and how and when salt tongues break out from the source layer and cut upward across the stratigraphy.

(2) Control of basement block faulting on coeval diapirism and overburden faulting and folding. Some of the variables being examined are (a) the relative thickness of source layer and overburden compared with the throw of the basement fault and (b) the relative rates of extension and sedimentation.

(3) Extensional styles in anisotropic overburdens containing one or more décollements.

(4) Folding and thrusting above salt, shale, or other detachment layers. Of particular interest is the origin and evolution of blind thrusts and triangle zones in the front of thrust belts, a topic jointly studied with Dave Wilschko of the Center for Tectonophysics at Texas A&M University.

Applied Geodynamics Laboratory: Mathematical Tectonic Modeling

Martin P. A. Jackson, principal investigator;
Daniel D. Schultz-Ela

The Applied Geodynamics Laboratory (AGL) also carries out mathematical scale-modeling to generate new concepts or test hypotheses relevant to the formation of structural traps for oil and gas. Research at AGL is funded by a consortium of industrial associates comprising the following oil companies: Agip S.p.A., Amoco Production Company, ARCO Oil and Gas Company, BP Exploration, Inc., Chevron O.F.R. Company and Chevron U.S.A., Inc., Conoco, Inc., EUROSIM Sarl, Exxon Production Research Company, Marathon Oil Company, Mobil Research and Development Corporation, Petroleo Brasileiro S.A., Phillips Petroleum Company, Shell Development Company, Société Nationale Elf Aquitaine Production, Texaco, Inc., and Total Minatome Corporation.

Mathematical modeling uses several Macintoshes and digitizers, a Silicon Graphics Indigo workstation, and a variety of software, some of it developed at AGL. Most of the mathematical modeling involves numerical modeling, which comprises boundary-element modeling and finite-element modeling.

The finite-element modeling uses GEOSIM-2D, a program that can simulate combinations of viscous and plastic flow, large finite strains, faulting, sedimentation, and erosion. The program is jointly owned by EUROSIM Sarl and Total Compagnie Française des Pétroles. Dr. Jean-Pierre Bobineau of EUROSIM supplied training and produced many of the models created during the year. The topics being investigated are (a) reactive diapiric piercement of brittle overburden during regional extension; (b) the influence of extensional basement faulting on drape folding and associated diapirism, with and without ongoing sedimentation and erosion; (c) active piercement of a forceful intrusion through a brittle layer not undergoing regional extension; and (d) fracture formation in a compacting layer.

The boundary-element method incorporates discontinuities such as faults and fluid-pressurized cavities (including salt bodies). The modeling improves understanding of active piercement of diapirs through relatively thin roofs and the sequence of faulting during graben extension. The model predicts nucleation points of new faults, fault-propagation paths, and conditions necessary for continued slip on the faults.

The Macintosh-based *Restore*© computer program for structurally restoring cross sections was further refined by additional capabilities for time-to-depth conversion, for restoration to an arbitrary paleotopography, and for interactive editing of fault block boundaries.

Applied Geodynamics Laboratory: Structure of Upheaval Dome, Utah

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

Field mapping of Upheaval Dome was funded by Exxon Production Research Company. Other funds were supplied by the AGL Industrial Associates, comprising the following companies: Agip S.p.A., Amoco Production Company, ARCO Oil and Gas Company, BP Exploration, Inc., Chevron O.F.R. Company and Chevron U.S.A., Inc., Conoco, Inc., Exxon Production Research Company, Marathon Oil Company, Mobil Research and Development Corporation, Petroleo Brasileiro S.A., Phillips Petroleum Company, Shell Development Company, Société Nationale Elf Aquitaine Production, Texaco, Inc., and Total Minatome Corporation.

Upheaval Dome is a breached, subcircular Mesozoic dome underlain by Permian Paradox evaporites. Three-dimensional exposures suggest that Upheaval Dome may represent the pinched-off stem of a salt dome. The overhanging diapiric bulb or salt extrusion postulated to have overlain the stem would have been removed by erosion during elevation of the Colorado Plateau. Pinched-off, pancake-shaped diapirs are common in the subsurface Gulf of Mexico. Diapiric necking in fluid overburdens has been modeled extensively. However, necking of viscous salt in a brittle overburden, which is much more relevant to salt tectonics, has never been investigated. Upheaval Dome presents a potential opportunity to examine at the surface the three-dimensional brittle response to diapiric pinch off.

Our structural and stratigraphic mapping around Upheaval Dome has focused on (1) gathering evidence for a protracted growth history, which would support its origin as a salt dome, and (2) determining the development of this structure by linked fault systems in the overburden. Erosional channels, depositional onlaps, and primary thickness changes in several formations indicate the developing structure affected depositional patterns over a long period of time prior to reaching its present state. The dome is rimmed by a monoclinal kink where the negligible regional dip abruptly steepens into a prominent rim syncline. The inner limb of the rim syncline dips outward at ≤60°. Overall, dips increase inward from the synclinal trace, elevating strata above regional datum. In both limbs of the rim syncline, circumferential extensional faults thin strata. These axisymmetric, ramp-flat extensional faults dip mostly inward but also outward. Nearer the center, the Kayenta is thickened into centripetal thrust duplexes and circumferential folds. These circumferential extensional and contractional fault systems are consistent with necking of a diapiric stem. However, further mapping is required to determine whether or not Upheaval Dome is actually a pinched-off salt structure.

Upheaval Dome, Utah, is a breached Mesozoic dome underlain by Permian Paradox evaporites. Field investigations of this salt structure by Bureau researchers complement ongoing physical and mathematical modeling of similar structures formed by salt tectonics.

Land, Water, and Environmental Resources Investigations

Environmental, Geologic, and Hydrogeologic Studies

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

Jay A. Raney, principal investigator; Edward W. Collins, Alan R. Dutton, L. Edwin Garner, Mary L. W. Jackson, Richard P. Langford, William F. Mullican III, Jeffrey G. Paine, Bernd C. Richter, Bridget R. Scanlon, Steven J. Seni, Allan R. Standen, G. Stephen Stubbs, Steven W. Tweedy, E. G. Wermund, and Jiannan Xiang; assisted by Bruce K. Darling, Richard S. Goldsmith, Randall K. Hill, Shin-Chuang Jeng, Jun Liao, Ravi Nigudkar, Kristine L. Scherff, and Jin-Ru Yen

The Texas Low-Level Radioactive Waste Disposal Authority is, at the direction of the Texas Legislature, attempting to locate a suitable site for the Texas low-level radioactive waste repository in southern Hudspeth County, Texas. During 1992, the State of Texas acquired the Faskin Ranch, east of Sierra Blanca, Texas, and named a proposed site on the northern side of the ranch. The Bureau of Economic Geology is conducting geologic and hydrogeologic studies to characterize the proposed site and the surrounding region. Results of these investigations will be used to assess the suitability of the proposed site and will provide data for use in performance assessment, design of the facility, and licensing.

The proposed site is located in a desert basin with more than 150 ft of basin-fill sediments overlying Cretaceous bedrock. Depth to ground water is more than 650 ft. Site-specific work has focused on characterization of the basin-fill sediments, collection of baseline data on near-surface geologic and vadose zone processes, and establishing locations for monitoring ground water in the vadose and saturated zones. The Bureau has had 19 boreholes drilled as part of this project, including 4 deep monitoring wells. The Bureau has also collected almost 4 line miles of high-resolution seismic data across the site. Analysis of the geophysical data and paleomagnetic studies of basin-fill sediments are being jointly conducted with scientists from The University of Texas at El Paso. Mapping of the surface, description and analysis of samples acquired from the drilling program, and additional drilling and surface excavations are in progress.

Regional geologic and hydrologic studies are being conducted because of and in accordance with licensing requirements and because the geologic and hydrologic systems are regional in scale. Regional studies of lineaments, natural resources, geology, neotectonics, and the saturated zone were well advanced during 1992. The initial lineament and natural resource (mineral and geothermal) evaluations were completed. Interpretations of aerial photographs and field studies were undertaken as part of the regional assessment of Quaternary faulting, and bedrock geologic maps of the Eagle Flat area were compiled. Most of the sampling for the regional hydrochemistry study was completed, and data for compilation of a regional potentiometric surface were acquired. This information is now being synthesized and interpreted. Results from many of these studies will be used in geohydrologic models of the site and region.

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

Charles W. Kreitler, principal investigator; Timothy J. Jackson, Jonathan G. Blount, and Jay A. Raney; assisted by Patricia W. Dickerson

The Falls City UMTRA site is an inactive uranium ore processing site in western Karnes County, Texas. Leaching of the mill tailings has resulted in contamination of the ground water in the Deweesville and Conquista sands and clays. Anomalous levels of uranium, radium, chloride, sodium, aluminum, and sulfate and low pH values are present in the ground water.

The Bureau has conducted a study to characterize the geologic, hydrologic, and hydrochemical setting of the Falls City UMTRA site. The investigation has described the hydrogeologic conditions of each aquifer (Conquista, Deweesville, and Dilworth), mapped the ground-water flow system in each aquifer, delineated the major contaminated plumes, described the chemistry of the tailings solutions and their geochemical reactions with the host rock, and characterized the chemical composition of the ground water. Although some problems remain to be addressed, the results of these studies are important to the UMTRA project as the work proceeds from surface stabilization to ground-water remediation.

Evaluation of Ground-Water Availability in Gulf Coastal Plain Aquifers

Alan R. Dutton, principal investigator; M. Saleem Akhter; assisted by Ganesh P. S. Rao

Ground water across the Gulf Coastal Plain supplies a large amount of the total water used in the counties near the Colorado River. This study, which began in late 1990 with support from the Lower Colorado River Authority (LCRA), developed 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 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.

The numerical model had been built based on geologic and hydrologic data. The model consists of different layers

representing aquifers in the Eocene Queen City and Sparta Formations and Jackson Group, and the Miocene Catahoula and Oakville Formations in an approximately 9,800 mi^2 area of Bastrop, Colorado, and Fayette Counties. The flow model is being implemented using the finite-difference code MODFLOW. 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 pinch-out of thick sand deposits.

Work tasks during 1992 focused on model calibration and sensitivity analysis. Steady-state simulations were performed for calibration and sensitivity analyses, and transient (historical) runs were made for determining recharge and cross-formational water flow rates. Simulations conducted over a 90-year data period indicate that due to recharge rates and small historical depletion of water in storage, aquifers in the Sparta and Queen City Formations possess potential for future development of water resources.

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

Steven J. Seni and Robert J. Finley, principal investigators

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 geopressured-geothermal water as a reliable, domestic source of alternative energy. 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 necessary for enhanced oil recovery by steam or hot-water flooding. In 1991, research concentrated on evaluating the potential of using geopressured-geothermal water for hot-water flooding of heavy-oil reservoirs.

In South Texas, the location of geothermal resources below heavy-oil reservoirs and the thickness and lateral continuity of heavy-oil and geothermal-energy resources suggest that thermally enhanced oil recovery may be economically viable. A valuable resource is an inventory of deep abandoned gas wells that penetrate potential hot-water reservoirs in the Wilcox. At least 60 deep abandoned wells have been identified that could be cost-effective geothermal production wells.

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 typically leave 70 percent of the original oil remaining in place.

Geologic and Hydrologic Characterization of Pantex Plant

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

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.

The Department of Energy is required by applicable Federal and State regulations to remediate and monitor areas of contamination at the Pantex facility. The Bureau of Economic Geology and its subcontractors are conducting investigations on and off the Pantex plant to enable the State to independently assess DOE's cleanup efforts. Under the Bureau's leadership, using an multidisciplinary approach, scientists and engineers are describing 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, 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-lake 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 Battelle/Pantex, will provide an integrated view of the geologic framework and hydrologic processes involved in ground-water recharge (primarily from playas), development of a perched aquifer, and flow in the Ogallala aquifer.

Multidisciplinary studies at the Pantex plant are designed to determine transport mechanisms, transport rates, and the fate of potential contaminants that include gasoline, solvents, and high explosives and their derivatives. Research objectives are to determine

- the rates and processes by which runoff is collected in playa basins and recharged through the unsaturated zone to an extensive perched aquifer and eventually to the Ogallala aquifer,

- the chemical evolution of contaminants as they pass through playa biota and underlying sediments,
- the hydrology and water chemistry of the Ogallala and perched aquifers, and
- the depositional systems of the Ogallala and Blackwater Draw Formations and playa sediments.

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 40 km of high-resolution reflection seismic data were collected. Ogallala ground-water and subsurface stratigraphic data bases were assembled for the Pantex plant and surrounding region. Preliminary hydrologic modeling of the the unsaturated zone was initiated.

The second year of investigations at the Pantex plant was highlighted by the completion of two stratigraphic test wells on the plant, and by acquisition of approximately 20 km of shallow high-resolution seismic data south of the plant. The stratigraphic test wells were completed as ground-water monitoring wells for the perched aquifer and for the Ogallala aquifer. Twenty additional shallow wells designed to provide core from the Blackwater Draw Formation and hydrologic data from the unsaturated zone were also completed.

Preliminary interpretation of hydrologic and stratigraphic data indicates that recharge to aquifers on the High Plains occurs primarily from runoff collected in playa basins. In addition, a large perched aquifer is present beneath much of the Pantex plant at a depth of about 250 ft. Waters in the perched aquifer contain tritium, which was derived from atmospheric testing of atomic weapons, suggesting that these waters were recharged from the surface within the last 40 years. The apex of the broadly cone-shaped perched aquifer is located beneath playa 1, which is the discharge point for surface drainage ditches at the Pantex plant.

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

Alan R. Dutton, principal investigator; M. Saleem Akhter, Arten J. Avakian, and Fred P. Wang

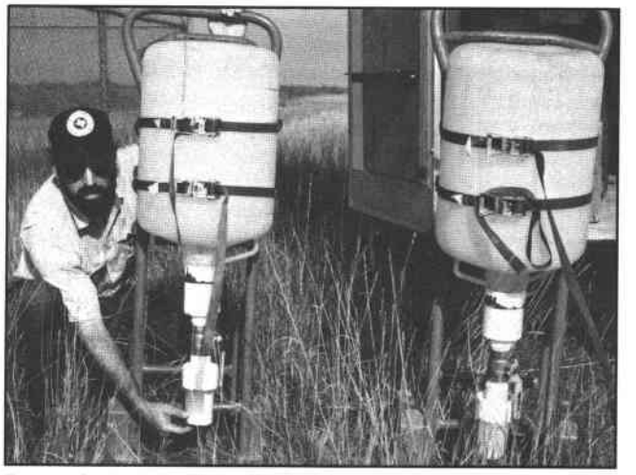
The Oligocene Frio Formation and its numerous subunits constitute very productive hydrocarbon reservoirs in the upper Texas Gulf Coast. Geologically, these formations are thick and laterally extensive, and they are characterized by numerous growth faults that developed during the deposition and burial of the Texas Gulf Coast Tertiary sediments. Growth faults have divided the sand units into isolated compartments. Geologic and hydrologic characteristics are commonly discontinuous across the faults.

This study, initiated in 1991 and funded by the Texas Higher Education Coordinating Board, described the geologic and hydrologic factors influencing the compartmentalized reservoirs in the Chocolate Bayou field in eastern Brazoria County. Additionally, the gas resource base, cumulative production, and estimates of potential incremental recovery from undrained sections of the reservoirs were determined using available engineering methods. Geology and pressure and production histories of seven gas-bearing sands in the middle to lower Frio Formation were examined. The investigations show that reservoir sands are internally continuous within the major fault blocks, but discontinuous across the growth faults, where sands are placed against shales. The pressure and production data and depletion trends in wells suggest that nearly 44 percent (750 Bcf) of the original estimated gas in place still remains to be produced. A major part of this resource can be produced effectively by reducing the well spacing through infill completions.

Paleohydrology of the Non-Glaciated Great Plains: Climatic and Geomorphologic Implications

Alan R. Dutton, principal investigator

This research, funded by the U.S. Geological Survey (USGS) as part of its Water Resources Research Section 105 Grant Program, is designed to determine the origin and age of ground water in confined and unconfined aquifers beneath the High Plains. Previous hydrogeologic studies showed that confined ground waters have δD and $\delta^{18}O$ values that are isotopically lighter than those of ground water in the overlying unconfined High Plains aquifer. During 1991 water samples were collected from



Bureau hydrogeologist collecting inorganic carbon dissolved in ground water for carbon-14 age dating at a well on the Texas High Plains. The dissolved carbon is precipitated as the white-colored strontium carbonate ($SrCO_3$) salt. The 2-wheel hand trucks were modified to hold the inverted carboys containing 13 gallons (~98 lb) of ground water while the $SrCO_3$ powder settles into ordinary glass canning jars. The field technique is being used in the USGS Paleohydrology, DOE Pantex, and Texas Low-Level Radioactive Waste Disposal projects at the Bureau. Photograph by Alan E. Fryar.

confined and unconfined aquifers in the Texas Panhandle, eastern New Mexico, southwestern Kansas, southeastern Wyoming, and western Nebraska. During 1992, additional water samples were collected from the High Plains aquifer in the Texas Panhandle. Isotopic and age data have been received from analytic laboratories and mapped and graphed to test various interpretations.

Ground-water ages are being studied using ^{3}H, ^{14}C, and ^{36}Cl radioactive isotopes. Ground-water ages in the unconfined High Plains aquifer appear markedly younger than ages in the confined aquifers beneath the central and northern Great Plains, based on ^{3}H and ^{14}C data. Estimated ages range from a few decades to several thousand years. Ground waters in the confined aquifers appear to be as old as 15,000 to more than 39,000 yr based on ^{14}C data. These results are sensitive to correction factors that account for solution of carbonate minerals. $^{36}Cl/Cl$ isotopic ratios are used for comparison with the ^{14}C ages. Samples with very high $^{36}Cl/Cl$ isotopic ratios, as great as $1{,}393 \bullet 10^{-15}$, have low concentrations of dissolved chloride, less than 100 mg/L, and occur at up-gradient positions along flow paths beneath the central and northern Great Plains. Samples with low $^{36}Cl/Cl$ isotopic ratios, less than $100 \bullet 10^{-15}$, have equal or greater chloride concentrations of approximately 25 to 400 mg/L and occur at down-gradient positions along the inferred flow paths. One possible geochemical model being considered for interpreting $^{36}Cl/Cl$ isotopic ratios involves mixing of meteoric, ^{36}Cl-enriched waters in the subsurface with chloride-rich waters that have attained a secular equilibrium between ^{36}Cl production by neutron capture and ^{36}Cl decay.

Once the complete set of geochemical data is available, we will determine the differences in isotopic composition between the unconfined and confined aquifers and relate vertical differences to ground-water ages, possible flow paths for recharge water, and ground-water residence time and flow velocity. Geomorphological effects will be taken into account. Paleoclimatologic model interpretations will be studied to evaluate how sensitive the isotopic composition of precipitation might have been to paleoclimatic conditions in the central and northern Great Plains. Quantitative estimates of ground-water flow rates in confined aquifers will be based on numerical modeling of ground-water flow. Flow models will track pathlines through the aquifer systems to test whether sources of isotopically depleted water can effectively supply the observed water in the confined aquifers beneath the southern Great Plains. The model results will be calibrated with the results of ground-water age dating.

Hydrogeologic Studies in Support of the Superconducting Super Collider (SSC)

Alan R. Dutton, principal investigator; Don G. Bebout, Alan J. Cherepon, Edward W. Collins, Susan D. Hovorka, Ian C. Jones, Stephen E. Laubach, Robert E. Mace, H. Seay Nance, and Rainer K. Senger; assisted by Sreevathsa Ramachandra and Ganesh P. S. Rao

The purpose of this study, supported through the Texas National Research Laboratory Commission (TNRLC), is to develop a comprehensive account of the occurrence and movement of ground water in the vicinity of the Superconducting Super Collider (SSC) in Ellis County. Subsurface facilities of the SSC will be constructed in the Cretaceous Eagle Ford Shale, Austin Chalk, and Taylor Marl. Work during 1992 included collection and interpretation of hydrogeologic data in these formations and testing of hypotheses. We completed an inventory of 1,038 public and private water wells in the vicinity of the SSC ring to document well locations for the SSC project and to characterize the use of ground-water resources. To map seasonal changes in the water table and to document base-line water-level fluctuations, water levels have been monitored monthly and hourly in the 37 monitoring wells operated by the Superconducting Super Collider Laboratory (SSCL) and in approximately 80 of the privately owned wells. Samples have been collected for analyses of water chemical composition from the SSC monitoring wells and from approximately 30 private wells. Chemical composition of ground water is being studied to interpret the age of ground water and the rate 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. Fracture density is highest in the upper and lower parts of the Austin Chalk. More ductile behavior of the middle chalk is related to authigenic clay derived from diagenesis of volcanic ash. Hydrologic attributes of fracture systems have been interpreted and are being used to simulate local ground-water flow in fractured bedrock. Other ground-water flow modeling addresses the effect of stratification and weathering of the bedrock formations on depth of circulation of ground water, the effect of topography in controlling recharge and discharge patterns, and the hydrologic explanation of artesian water levels in monitoring wells on the east side of the SSC ring.

Since the mid-20th century, withdrawal of ground water, particularly in the Dallas–Fort Worth area, from deep regional aquifers in the Woodbine, Paluxy, and Twin Mountains Formations that underlie the SSC have caused major declines in water levels. Future water-level decline is of concern because ground water will be needed to meet a significant part of future increased water demand owing to population and economic growth, regardless of whether there is any direct use of ground water by the SSC project.

Water-level decline in the regional aquifers will be calculated using a numerical model of regional and local ground-water flow. For valid predictions, best practice requires that the numerical model include accurate hydrogeologic characteristics of the aquifer, particularly aquifer thickness, transmissivity, and storativity. Areal distribution of transmissivity and storativity will be estimated from reported hydrologic tests and from geologic maps describing the stratigraphy and depositional facies of the aquifer units. Stratigraphic studies of the regional aquifers began in 1992. Model parameters will be calibrated based on historic potentiometric surfaces and changes in water levels. The completed and tested model will be made available to agencies responsible for assessing future water-resource availability.

Using Nitrogen Isotopes to Trace Non-Point Source Contamination

R. Stephen Fisher, principal investigator

According to the U.S. Environmental Protection Agency, non-point source pollution is the largest single category of water contamination affecting the nation's waters. This project, initiated in the fall of 1992, is part of a national pilot program to evaluate land use and land management methods of the agricultural production and livestock industries and their impact on water quality. First-year activities at the Bureau focused on developing the capability to measure stable nitrogen isotope ratios of ammonium and nitrate in soil and water samples. Subsequent work will apply nitrogen isotopic analyses to identify sources of contamination and to trace contaminant movement in the shallow subsurface.

Environmental Surveys of Texas National Guard Training Sites

E. G. Wermund, principal investigator

In late 1992, the Texas Adjutant General (Texas National Guard) began supporting Bureau research to document the environmental status of their training sites. The Bureau will (1) assess the status of the flora and fauna, the soil and bedrock, and the shallow ground water, (2) reconstruct post-1950 trends for environmental change from historical records and aerial photographs, and (3) outline an environmental management plan for future uses of the training sites.

Using Electromagnetic Geophysical Surveys to Locate Non-Point Sources of Natural Salt Water Pollution of the Canadian River, Texas and New Mexico

Thomas C. Gustavson, principal investigator; Arten J. Avakian, Susan D. Hovorka, Jeffrey G. Paine, and Bernd C. Richter

The Canadian River carries approximately 53,000 metric tons of dissolved halite (NaCl) annually and nearly an equal amount of gypsum ($CaSO_4$). These high-total dissolved solid (TDS) waters discharge into Lake Meredith, which is the primary source of drinking water for most municipalities on the Texas High Plains from Amarillo on the north to Lubbock and Brownfield on the south. The salinity of Lake Meredith has increased dramatically over the last 10 yr, from approximately 200 ppm to over 400 ppm, and must be diluted with Ogallala water to reduce its salinity enough to meet EPA drinking water standards (250 ppm). For all of these communities, production of large volumes of water from the Ogallala aquifer for blending with Lake Meredith waters is expensive. Furthermore, Ogallala ground-water levels are declining because rates of water use for domestic, agricultural, and industrial purposes exceeds recharge rates.

The objective of part I of this study was to assist the Canadian River Municipal Water Authority in determining the sources of saline water being discharged into the Canadian River. The Bureau completed a conductivity survey and collected and analyzed water samples to identify segments of the Canadian River that were receiving saline waters. The Bureau also prepared detailed cross sections identifying areas of halite and gypsum dissolution along the northwestern margin of the Palo Duro Basin near the Ute Reservoir. The areas of primary concern are along the Canadian River in New Mexico 12 to 20 km downstream of the Ute Reservoir; near the Texas–New Mexico border 30 to 60 km downstream of the Ute Reservoir; and near Lahey Creek north of Amarillo, Texas. This research was funded by the Canadian River Municipal Water Authority.

Part II of this study will use conductivity surveys (EM surveys), a noninvasive geophysical technique, to locate saline ground-water plumes in alluvium or bedrock in the floor of the Canadian River Valley. EM systems consist of a transmitter coil and a receiver coil. Electric current flowing in the transmitter coil creates a primary magnetic field. A secondary magnetic field is created by current induced to flow in the subsurface by the primary magnetic field. For shallow surveys, induced currents flow mostly in fluids filling pores in subsurface strata. Conductivity of the pore fluid increases almost linearly with increases in salinity of the fluid; changes in the primary magnetic field caused by subsurface current flow are detected by the receiver coil. Once sources of high-TDS waters are identified, engineered remediation work could begin. Remediation will likely require installation of production wells, pumping contaminated ground water to draw down the local ground-water table and reduce or eliminate discharge of contaminants to the Canadian River, and reinjection of these waters into deep subsurface strata. Part II of this research is funded by the Texas Water Development Board.

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

R. Stephen Fisher, principal investigator; assisted by Bernd C. Richter

Oil-field brines and scale formed in oil- and gas-field equipment contain variable amounts of naturally occurring radioactive materials (NORM), ranging from background concentrations to the significant levels found in uranium-mill tailings. High concentrations must be identified because they pose a health threat to those exposed to contaminated equipment. Measuring radiation levels at each well or facility is time-consuming and expensive, particularly for small operators. This project seeks to develop screening criteria that will facilitate identification of oil- and gas-fields that have high potential for producing NORM.

Our first activities included conducting a literature search to identify oil and gas fields that produce significant quantities of NORM and communicating with field operators to arrange sampling visits from all major reservoir types in Texas. Subsequent research will

include geochemical investigations to determine the geologic and chemical factors that lead to NORM production. Results of this work will help determine where NORM wastes are likely to occur, on the basis of reservoir type and geologic setting. This information will greatly reduce the number of wells that need to be tested for NORM production, providing economic relief to small operators.

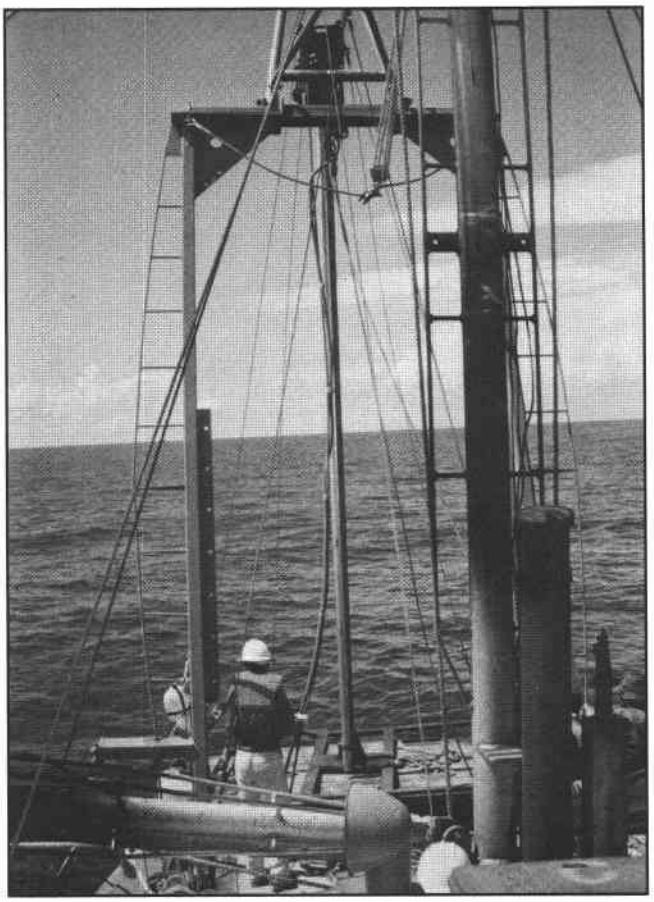
Coastal Studies

Physical and Environmental Assessment of Sand Resources—Texas Continental Shelf

Robert A. Morton, principal invesigator; James C. Gibeaut; assisted by Cynthia A. Jennings

A recent inventory of nonfuel minerals in the Gulf of Mexico demonstrated that potentially economic deposits of sand, gravel, and heavy minerals occur on the Texas continental shelf. Particularly promising for commercialization in the near term are nearshore deposits of sand. These sand deposits may be suitable for beach nourishment if sediment textures are compatible with beach sand. Furthermore, offshore sand extraction may become more attractive if onshore sources of sand with compatible properties are volumetrically limited and potential degradation of wetlands can be avoided by eliminating onshore mining of beach sand. Demand for beach nourishment sand along the northwestern Gulf of Mexico is increasing as the combined effects of rising sea level and land subsidence are manifested as rapid beach erosion. In Texas, Heald and Sabine Banks are two offshore sand deposits that have the greatest economic potential for near-term exploitation because they are (1) likely to be suitable for beach nourishment, (2) the largest sand deposits located offshore of some of the most rapidly eroding developed shores, and (3) relatively close to potential markets in both southeastern Texas and western Louisiana. The purpose of this study, funded by the Minerals Management Service Office of International Activities and Marine Minerals, is to evaluate the potential for leasing and mining sand from Heald and Sabine Banks.

Efforts during 1992 were directed toward assessing the quality and volume of Sabine and Heald Bank sediments and evaluating the composition and thickness of any overburden materials. To accomplish this, the banks were cored, sediment textures and mineralogy were determined, and volumes of the sand deposits were estimated using seismic and lithologic information. An additional task investigated the subregional lateral extent of sand deposits away from the Banks. This was accomplished by constructing cross sections of foundation borings, integrating the foundation borings and high-resolution seismic profiles, and mapping the distribution of sand in the shallow subsurface. All the pertinent Texas offshore sand resources information are being incorporated into a geographic information system.



Shipboard vibracoring rig at Sabine Bank near Port Arthur, Texas. The rig is being used by Bureau researchers to determine the quality and quantity of nearshore sand resources in Texas coastal waters for potential use in beach nourishment along the Texas Gulf Coast.

Monitoring the Beach and Vegetation Line on Galveston Island

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

In August 1983 Hurricane Alicia crossed the Texas coast, causing substantial beach erosion and extensive damage to houses near the shoreline. Scouring action by storm waves and currents undermined many homes, destroyed bulkheads, and caused landward retreat of natural vegetation. The purpose of this study 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.

In 1992, an experimental beach survey was conducted at Galveston Island State Park using Global Positioning System (GPS) technology. The purpose of the survey was to test the accuracy and repeatability of GPS measurements and to compare them with conventional beach profiles surveyed using a theodolite. Results of the experiment showed that (1) GPS surveys can be repeated with centimeter-level accuracy, (2) beaches can be monitored more rapidly and efficiently with GPS methods than with conventional surveys, and (3) alongshore changes in beach morphology can be observed using GPS technology that cannot be detected with conventional shore-normal beach profiles.

Characterization of Sand Bodies within Seismic Sequences—Texas Continental Margin

Robert A. Morton, principal investigator; assisted by Cynthia A. Jennings

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.

In 1992, additional 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 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. 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.

Four seismic sequences (pre-Wisconsin, Early Wisconsin, Late Wisconsin, and Holocene/Modern) were identified, and the following maps were prepared for each sequence: total thickness, net sand, percent sand, and depositional systems. At year end, a final contract report was being prepared that summarized the geologic history of the study area and emphasized the influence of sea-level fluctuations and salt mobilization on sequence development and deposition of sand bodies within sequences.

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 Thomas A. Tremblay

The Bureau and the USFWS have been cooperating on a 30-month study to interpret losses and/or gains in wetland and seagrass habitats from the 1950's and 1979 to 1989 in the Galveston Bay system. The work was funded by the Texas Water Commission in support of the Galveston Bay National Estuary Program (GBNEP). The first 21 months of the study were devoted to field descriptions of the habitats by the Bureau and interpretations of the habitats on aerial photographs by the USFWS for 30 7.5-minute quadrangles composing the Galveston Bay system. Interpretations of the aerial photographs were converted to digital line graph presentation.

In 1992, the Bureau interpreted trends of gains and/or losses of wetland habitats employing an ARC/INFO PC geographic information system. Between the 1950's and 1989 there has been a loss of 15 to 20 percent in estuarine emergent wetlands from the system. The major loss has been to encroachment of bay waters from relative sea-level rise, the major component of which is land-surface subsidence. Other losses resulted from agricultural practices, drainage alteration, impoundments, dredging and filling, and commercial and residential construction.

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

Robert A. Morton, principal investigator; William A. White and Diane M. Spinney; assisted by Joan M. Drinkwin

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. During 1992, the first year of the study, we identified the regional coastal issues, compiled and assembled existing data and information, updated shoreline-change maps, established priorities for the 5-year investigation, and coordinated 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 resulted 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.

Coastal Mapping and Shoreline Monitoring Projects

Robert A. Morton, principal investigator

In 1992, the Bureau of Economic Geology served in an advisory capacity to the Beach and Dune Task Force of the town of South Padre Island. Technical assistance involved identifying the optimum zone for reestablishing and protecting fore-island dunes, updating recent maps of shoreline movement, and developing a program to monitor the beaches and dunes of South Padre Island.

Bureau coastal scientists also conducted work for the U.S. Environmental Protection Agency as part of its activities for the Gulf of Mexico Program, Coastal and Shoreline Erosion Subcommittee. 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 were (1) a list of references and sources of information regarding coastal erosion in Texas, (2) a brief summary of the recent geologic history of the Texas Gulf shoreline, (3) an explanation of the shoreline changes illustrated on the map, and (4) an explanation of the factors causing coastal erosion in Texas.

Mineral Resources Investigations

Texas Mining and Mineral Resources Research Institute

Christopher D. Henry, director; Eric W. James; assisted by Linda L. Davis

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; academic affiliates include The University of Texas at Austin, Texas A&M University, and Prairie View A&M College. TMMRRI awards competitive graduate fellowships, postdoctoral research positions, research assistantships, and undergraduate scholarships. For the 1992–1993 academic year, four fellowships were awarded to support graduate research in ore deposition, mining engineering, and mineral economics.

Research under TMMRRI focuses on the relationship between ore formation and contemporaneous igneous and tectonic activity using field mapping, geochemical analysis, detailed petrography, isotopic dating, and computer modeling of hydrothermal processes. Two broad topics have been of continuing interest: (1) rare metal resources in Trans-Pecos Texas and (2) the sources of metals for ore deposits.

A belt of alkalic, rhyolitic intrusions, and related fluorite deposits that trends through New Mexico, Texas, and northern Mexico constitute known and potential resources of beryllium, rare earth elements, and other rare metals. The fluorite deposits develop by reaction of fluorine-rich, hydrothermal solutions, derived from the rhyolites, with Cretaceous limestone. The hydrothermal solutions extract the rare metals from the rhyolite and carry them as fluoride complexes; precipitation of fluorite leads to precipitation of the metals. TMMRRI research has included geologic mapping and geochemical studies of the rhyolites and deposits. Major occurrences in Texas include what may be the world's largest beryllium deposits at Sierra Blanca and similar deposits containing beryllium, molybdenum, thorium, and uranium in the Christmas Mountains. The research has shown that many economically important metals, commonly considered immobile in most hydrothermal or igneous systems, are highly mobile in fluorine-rich solutions. Results of these investigations apply not only to exploration in this region but also to understanding rare-metal enrichment and mineralization in alkalic intrusions worldwide.

TMMRRI research has used Pb isotopic tracers to identify both the source of metals in ore deposits and the origin of related igneous rocks. Metals in ore deposits in Texas represent a mix of igneous, basement, and sedimentary sources. For example, some of the rare-metal-enriched alkalic rocks are melts of lower crust; the metals probably also come from the crust. Vein and porphyry-type Mo prospects appear to derive their Pb from igneous rocks of the associated volcanic center. In contrast, red-bed-hosted Ag-Cu deposits with no apparent igneous source of fluids appear to have extracted Pb from the host sediments. High-temperature carbonate-hosted Ag-Pb-Zn deposits contain variable mixtures of Pb from mid-Tertiary igneous rocks and from sedimentary wall rocks. For example, Pb in deposits at Shafter, Texas, comes mostly from associated igneous rocks and underlying old crust. Similar, but larger, deposits at Santa Eulalia, Chihuahua, contain a larger proportion of Pb from sedimentary sources and a smaller contribution from Precambrian basement. These data suggest that contributions of metals from sedimentary sources may be necessary to develop large Ag-Pb-Zn deposits.

Mapping Investigations

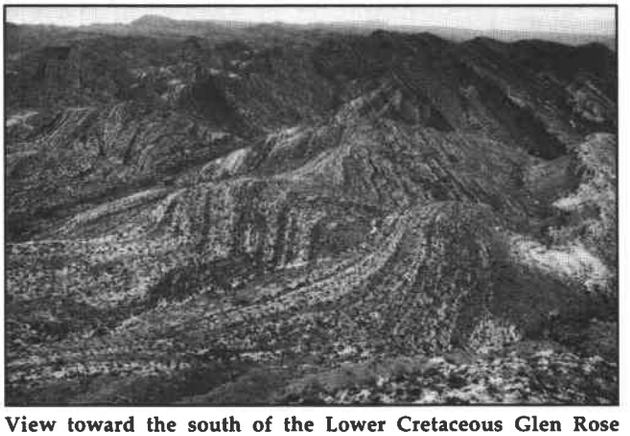
Geologic Studies of the Big Bend Ranch State Natural Area

Christopher D. Henry; William R. Muehlberger (Department of Geological Sciences); Larry McCormick (Long Island University, New York); 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 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, were mapped during the first year. A comprehensive report about the Solitario is in progress.

The second year of the project focused on the Bofecillos Mountains in the central part of the Natural Area. The Bofecillos Mountains are a volcanic highland built up over several million years by a complex series of volcanoes. Major activity began about 32 Ma ago with eruption of mostly trachyte lavas from the "Fresno" volcano in the south-central Bofecillos Mountains. Most of the volcanic rocks erupted rapidly about 27.1 Ma ago as a series of distinct events from both a large central vent and from numerous satellitic vents and fissures around its flanks. This "Rawls" volcano produced basalts through rhyolites and numerous intrusions and domes. Final volcanism in the Bofecillos Mountains consisted of widespread but volumetrically minor alkalic basalts. These basalts erupted between 24 and 17 Ma ago, contemporaneous with Basin and Range faulting, and commonly carry xenoliths from the mantle and lower crust.



View toward the south of the Lower Cretaceous Glen Rose Formation exposed along the western rim of the Solitario in the Big Bend Ranch State Natural Area, Trans-Pecos Texas. Beds of the Glen Rose and of the complete Lower Cretaceous section are tilted up along the flanks of the Solitario because of structural doming related to laccolithic intrusion. Photograph by Christopher D. Henry.

The study, which is being coordinated with Parks and Wildlife personnel examining the biological, archeological, and cultural resources of the area, will produce a detailed geologic map and report of the entire Natural Area. It is assisting Parks and Wildlife to preserve the Natural Area, to develop it for public visitation, and to provide information and education about the natural history of the area to 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.

Geologic Atlas of Texas

Virgil E. Barnes, principal investigator

Geologic atlas sheets have been published for the entire state, so new work focuses on revision and reprinting of older maps as they go out of print. The Beaumont and Plainview sheets were revised and reprinted this year. The San Antonio and Dallas sheets were reprinted without changes.

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

Christopher D. Henry, principal investigator; Edward W. Collins; William P. Elder (U.S. Geological Survey, Menlo Park)

This multiyear project concerns mapping the geology of the 1:100,000-scale New Braunfels, Texas, Quadrangle. The map area covers a rapidly developing part of Central Texas that includes Wimberley, Canyon Lake, Guadalupe River State Park, New Braunfels, northern San Antonio, Lake Medina, Boerne, and Comfort. This 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. 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 geology is being mapped on 1:24,000-scale 7.5-minute quadrangles, and a composite map will be published using the new USGS 1:100,000-scale topographic map of the area as a base.

The second year of this project focused on completing the mapping of the northeast quarter of the 1:100,000-scale New Braunfels, Texas, Quadrangle. Draft geologic maps of the eight 7.5-minute quadrangles composing this area near Wimberley, Canyon Lake, and Guadalupe River State Park have been completed. The completed maps are the Anhalt,

Devils Backbone, Fischer, Hunt, Sattler, Spring Branch, and Wimberley Quadrangles. Units that occur in this area are mostly Cretaceous limestone, marl, and shale that crop out along the Balcones Fault Zone. Lower Cretaceous units are the Cow Creek Limestone, Hensel Formation, Glen Rose Formation, Walnut Formation, Kainer and Person Formations of the Edwards Group, and Georgetown Formation. Upper Cretaceous units include the Del Rio Formation, Buda Formation, Eagle Ford Group, Austin Group, and Taylor Group. In this area, normal faults of the Balcones Fault Zone mostly strike N40°–70°E, and the composite stratigraphic displacement across the zone is about 1,600 to 1,800 ft. Mapping of the southeast quarter of the 1:100,000-scale New Braunfels, Texas, Quadrangle is projected to be completed during 1993.

Other Geologic Investigations

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

Don G. Bebout and Charles Kerans, principal investigators

A geological trail guide for the Permian Reef Geology Trail, McKittrick Canyon, Guadalupe Mountains National Park, is being prepared by a team of geologists from the Bureau of Economic Geology and the Department of Geological Sciences, The University of Texas at Austin, and industry. In addition to the principal investigators, participants include Robert G. Loucks and Alton Brown, ARCO; P. M. Harris, Chevron; Brenda Kirkland, Department of Geological Sciences, The University of Texas at Austin; Denise Mruk, Marathon; and Emily Stoudt and Susan Longacre, Texaco. The 30 stops described in detail in this guide are located in toe-of-slope, slope, reef, and outer-shelf and shelf-crest depositional environments. Permanently installed 100-ft elevation markers provide assistance in locating trail stops.

The objective of this guide is to provide documentation of the features encountered along this trail for the large number of geologists who either individually or as part of university and industry groups traverse this Permian platform-margin reef complex. This trail guide will be available in mid-1993.

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 1992, the following 61 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.

"Analysis of the United States Oil Resource Base": supported by the U.S. Department of Energy through the National Institute for Petroleum and Energy Research.

"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 (Completion) and Jackson-Yegua Trend, East Texas (Revision)": supported by the U.S. Geological Survey, U.S. Department of the Interior.

"Conducting Technology Transfer Seminars": supported by the U.S. Department of Energy through the National Institute for Petroleum and Energy Research.

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

"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 (two contracts).

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

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

"Mining and Mineral Resources Research Institute Fellowships": supported by the Bureau of Mines, U.S. Department of the Interior.

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

"Paleohydrology of the Nonglaciated Great 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.

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

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

"Studies Related to Continental Margins (years 3 through 9)": supported by the Minerals Management Service, U.S. Department of the Interior (seven contracts).

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

State and Local

"Beach and Dune Work Plan, South Padre Island": supported by the town of South Padre Island.

"Determination of Canadian River Salinity": supported by the Canadian River Municipal Water Authority.

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

"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.

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

"Development and Application of the Nitrogen Isotope Tracer in Evaluating Hydrogeologic Controls on Abatement of Non-Point Source Pollution from Livestock Confined Feeding Areas and Other Agricultural Operations": supported by Tarleton State University.

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

"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).

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

"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.

"Investigation of Saline Water Contamination in the Canadian River and Lake Meredith": supported by the Texas Water Development Board.

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

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

"Planning Environmental Management of the Texas National Guard Training Areas": supported by the Texas Adjutant General's Department.

"Quality Assurance Assistance to the Texas Low-Level Radioactive Waste Disposal Authority": 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.

"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).

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

Private

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

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

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

"Characterization of Eocene Reservoirs: LL-652 Area, Lake Maracaibo, Venezuela": supported by Lagoven S. A.

"Characterization of Heterogeneity Style and Permeability Structure in a Sequence Stratigraphic Framework in Fluvio-Deltaic Reservoirs": supported by Conoco, Inc., Oryx Energy Company, Occidental International Exploration and Production Company, Exxon Production Research Company, Intevep, UNOCAL, Amoco Production Company, Mobil Exploration and Production, BP International, Ltd., Societe Nationale Elf Aquitane (Production), and Chevron Oil Field Research Company.

"Characterization of San Andres and Grayburg Reservoirs": supported by Amoco Production Company, Mobil Exploration & Producing U.S., Inc., UNOCAL, ARCO Oil and Gas Company, Exxon Production Research Company, Marathon Oil Company, Shell Oil Company, Japan National Oil Corporation, OXY U.S.A., Inc., Phillips Petroleum Company, Compagnie Française Des Petroles, Texaco Services, Inc., Exxon Company, U.S.A., Fina Oil and Chemical Company, BP International, Ltd., and Agip S.p.A.

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

"Geologic and Hydrologic Controls on Coalbed Methane Production": supported by the Gas Research Institute.

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

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

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 82-year history, the Bureau has published nearly 2,250 reports, bulletins, circulars, special publications, and maps covering major aspects of the geology and natural resources of Texas. 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 1992, about 30,000 volumes were distributed. The Bureau issued the following publications in 1992:

Reports of Investigations

RI 205. Hydrogeologic Investigations of Deep Ground-Water Flow in the Chihuahuan Desert, Texas

by William F. Mullican III and Rainer K. Senger. 60 p., 28 figs., 4 tables, $5.00

Conducted as part of investigations for siting a low-level radioactive waste repository in Trans-Pecos Texas, this study evaluates ground-water resources and characterizes ground-water systems in an area near El Paso. This area comprises three aquifers, the Diablo Plateau aquifer, Hueco Bolson silt and sand aquifer, and Rio Grande alluvium aquifer, whose hydrologic properties were largely unknown until this study. By evaluating local ground-water resources, determining ground-water flow paths and velocities, and testing hydrologic hypotheses using ground-water flow models, the authors were able to characterize the physical hydrogeology of the saturated zone. Evaluation of local ground-water resources involved drilling new wells and locating existing water wells for measuring water levels and discharge rates. Sixteen water wells and one spring producing from saturated sections were located, tested, and sampled. Twelve aquifer tests were completed in order to determine the transmissivities of aquifers in bolson and Cretaceous strata: aquifer transmissivities were found to range from 0.19 to 290.0 ft^2/day. Ground-water systems were characterized by delineating the water-bearing units, measuring representative transmissivities, and modeling local and regional ground-water flow patterns. A planar ground-water flow model was constructed to ascertain controls on regional flow patterns, and these data were corroborated by water-chemistry data on tritium, carbon-14, and TDS. The authors conclude that local ground-water resources are constrained by two controls: the cost of drilling and completing wells and of producing water at depths greater than 400 ft and (2) very low productivity of aquifers. Future efforts to explore for further sources of usable ground water are therefore unlikely.

RI 206. Geology of the Infiernito Caldera and Magmatic Evolution of the Chinati Mountains, Trans-Pecos Texas

by Christopher D. Henry, J. G. Price, T. W. Duex, and Eric W. James. 56 p., 29 figs., 5 tables, 1 full-color plate in pocket, $12.50

One of the largest volcanic centers in Texas, the Infiernito caldera lies in the northern Chinati Mountains, 35 km (20 mi) southwest of Marfa and 25 km (15 mi) east of the Rio Grande. About 37 Ma ago, the caldera underwent a complex sequence of tuff and lava eruption, caldera collapse, and intrusion. Igneous activity continued for about 5 m.y. and culminated in the formation of the 32-Ma Chinati Mountains caldera. This area is of interest because it typifies the intense mid-Cenozoic volcanism that occurred in Trans-Pecos Texas. The Infiernito and Chinati Mountains calderas represent some of the most voluminous and persistent magmatism in Texas. Also, numerous mineral deposits of silver, lead, iron, molybdenum, and copper in the area are genetically related to the igneous activity. The authors describe in detail the volcanic stratigraphy, caldera development, geochemistry, and economic geology of the area and conclude with a summary of the history of volcanism in the Chinati Mountains area. A 1:24,000-scale, full-color geologic map of the Infiernito caldera accompanies the report.

RI 207. Environmental and Applied Tracers as Indicators of Liquid and Vapor Transport in the Chihuahuan Desert, Texas

by Bridget R. Scanlon. 51 p., 27 figs., 5 tables, $5.00

In a 40 km^2 area of the Chihuahuan Desert in Texas, unsaturated flow processes were examined using chemical and hydraulic approaches. Chloride mass balance data suggest low downward liquid fluxes that are reduced to less than 1 mm yr^{-1} below the top meter of the soil. Deeper penetration of bomb ^3H, which is volatile, relative to that of bomb ^{36}Cl, which is nonvolatile, is attributed to enhanced downward movement of ^3H in the vapor phase. This conclusion is corroborated by short-term numerical simulations of nonisothermal liquid and vapor flow that suggest an annual net downward vapor flux. In this report, the author's integration of chemical and hydraulic methods provides a comprehensive delineation of unsaturated zone processes in desert soils.

RI 208. Characterization of a Karsted, High-Energy, Ramp-Margin Carbonate Reservoir: Taylor-Link West San Andres Unit, Pecos County, Texas

by F. Jerry Lucia, Charles Kerans, and G. W. Vander Stoep. 46 p., 37 figs., 3 tables, $3.50

The Taylor-Link West San Andres unit, on the south margin of the Central Basin Platform, Pecos County, was

discovered in 1928. It is a prime example of the importance of integrating geological and engineering information to develop strategies for improving hydrocarbon production. It represents a class of San Andres reservoirs that are affected by various karst-related dissolution and brecciation processes. The authors present a detailed geologic characterization of the Taylor-Link West, then quantify this description in an engineering model using core description and analysis and capillary pressure measurements. A mobile oil isopach map of the field was constructed that shows 21.8 MMbbl of mobile oil remaining, only 1.5 MMbbl of which will be produced under current production practices. This publication is of special interest to carbonate reservoir geologists interested in San Andres reservoirs, and in karsting in general, and to petrophysicists who use core data to determine original oil saturations and to distinguish between fracture and matrix permeability.

RI 209. The Rise and Fall of Diapirs during Thin-Skinned Extension

by Bruno C. Vendeville and Martin P. A. Jackson. 60 p., 51 figs., $4.50

Grabens overlying diapirs are commonly ascribed to intrusion, withdrawal, or dissolution of salt. Using dynamically scaled physical modeling, the authors propose, in contrast, that many grabens or half grabens above diapirs form by regional thin-skinned extension of a brittle overburden. This regional extension can initiate and promote piercement of diapiric walls through thick overburdens, regardless of overburden density. The same regional extension that effects the rise of diapirs can also make diapirs fall. Turtle-structure anticlines with keystone grabens form between subsiding walls. During extreme extension, diapirs subside until they are fragmented by crestal grabens. These grabens can eventually ground onto basement and invert to form mock turtle anticlines. This report is intended to give field geologists and seismic interpreters new insights into geometry and deformation history of rock diapirs and associated faults.

RI 210. Plio-Pleistocene Genetic Sequences of the Southwestern Louisiana Continental Shelf and Slope: Geologic Framework, Sedimentary Facies, and Hydrocarbon Distribution

by Robert A. Morton and W. B. Ayers, Jr. 74 p., 35 figs., 1 table, 1 appendix, $7.00

This research was conducted (1) to describe the structural and stratigraphic frameworks of Plio-Pleistocene strata in southwestern offshore Louisiana, (2) determine the relationships between hydrocarbon reservoirs, genetic sequences, and depositional systems tracts, and (3) evaluate the remaining exploration potential of the region. In this report the authors accomplished these tasks by extending interpreted cross sections from the High Island and East Breaks Areas into the West Cameron and western Garden Banks Areas, mapping the principal Plio-Pleistocene genetic stratigraphic sequences and related depositional systems, interpreting geologic histories, and assessing the associated hydrocarbon plays. The authors used a data base of approximately 270 electric logs of wells penetrating all or part of the Plio-Pleistocene section, paleontological reports for nearly 180 of the wells, and seismic data covering more than 1,550 linear miles of the study area. About 100 fields have been discovered in the western Louisiana section of the Plio-Pleistocene trend, most of which are small, but a few contain more than 100 MMboe. Fields producing from Plio-Pleistocene strata are divided into six exploration plays on the basis of structural style, reservoir facies, and hydrocarbon composition. All six offer some potential for new field discoveries and reserve growth. Three oversized structural cross sections accompany the report.

Geological Circulars

GC 92-1. Core and Log Analyses 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

Edited by Raymond A. Levey, assisted by Jeffry D. Grigsby. 56 p., 52 figs., 3 tables, $3.50

A three-part publication, this volume discusses the Frio Formation, Vicksburg Formation, and Wilcox Group, and the Stratton/Seeligson, McAllen Ranch, and Lake Creek fields. Each section presents a brief introduction to the gas play and field, the depositional system and facies architecture, and reservoir properties. The focus of each section narrows from play to field scale by emphasizing the relation between core and log data and the scale of depositional system and facies architecture. A concluding section by the senior editor summarizes the implications of these findings for incremental gas recovery within these reservoirs.

GC 92-2. Surface Fissures in the Hueco Bolson and Adjacent Basins, West Texas

by Robert W. Baumgardner, Jr., and Bridget R. Scanlon. 44 p., 19 figs., 2 tables, $3.50

Surface fissures exist in many desert basins in the western United States; this report describes fissures common to the Hueco Bolson of Trans-Pecos Texas. The term "fissure" refers to the alignment of surface collapse features, and these fissures are generally underlain by subsurface tension fractures. Three surface fissures, ranging from 20.5 to 140 m long, were found in the study area, all in topographic lows, which indicates that overland flow is important in their development. Geomorphic features associated with the fissures are outlined. Subsurface fractures provide conduits for preferential water movement, as indicated by low chloride

concentration. Fissures in the study area differ from those in many areas of the desert Southwest in that there has been no significant ground-water pumping in the study area. The source of tensional stress that formed the subsurface fractures may have been related to natural lowering of ground-water levels over geologic time caused by incision of the Rio Grande, change to warmer, drier climate, fault movement, and preferential drainage of gravel lenses beneath the site. Bedrock irregularities may have been important in generating tensional stress. The authors also examine other fissures in the region, and they conclude that fissure development appears to be a natural geomorphic phenomenon in arid desert basins that have undergone climate change and ground-water lowering since the Quaternary.

Other Publications

Atlas of Major Central and Eastern Gulf Coast Gas Reservoirs

Edited by Don G. Bebout, William A. White, Chester M. Garrett, Jr., and Tucker F. Hentz. 88 p., 457 figs., 34 tables, 4 plates in pocket. $38.00

In collaboration with other State geological surveys and supported by the Gas Research Institute, Bureau researchers have compiled and edited this atlas of large gas reservoirs in the central and eastern Gulf Coast. The atlas groups United States onshore gas reservoirs into a series of geologically defined plays and presents comprehensive play descriptions, including summaries of play characteristics, cumulative production, and various other engineering and geologic data. Also included are detailed summaries of representative type reservoirs for each play. The oversize format (22 x 17 inches) permits the inclusion of numerous field maps, cross sections, and logs in addition to regional maps showing play boundaries. Thus, it serves as a reference tool for operators to more efficiently develop reservoirs, to extend field limits, and to better assess opportunities for intrafield exploration and development in this mature oil and gas province. This information will aid exploration and development efforts of operators as well as local and national assessment efforts of State and Federal agencies. This atlas and the previously published Texas gas atlas will provide an integrated regional play framework throughout the U.S. Gulf of Mexico. In addition, this synthesis of gas reservoirs contributes to a better understanding of the history of the Gulf Coast Basin and indicates future exploration and development opportunities in the basin.

Technology Transfer Needs and Requirements for Independent Oil and Gas Producers

by Marcus E. Milling, Bob A. Hardage, and A. L. Gilliland (TIPRO). 33 p., 11 figs., $3.00

In 1991, a series of forums was convened by the Bureau and the Texas Independent Producers and Royalty Owners Association (TIPRO) in Abilene, Amarillo, Corpus Christi, Dallas, Houston, Longview, Midland, and Wichita Falls. At these forums more than 400 attendees collectively determined areas in which Texas independent producers need assistance in their efforts to achieve a higher level of technical competence. According to the responses of the forum participants, the five highest priority areas for technology transfer are (1) improved exploration strategies for discovering remaining oil and gas resources, (2) advanced formation evaluation techniques for improved assessment and development of oil and gas reservoirs, (3) completion technology to improve reservoir stimulation and wellbore cleanup, (4) cost-effective access to advanced seismic imaging techniques to reduce exploration risk and optimize field development, and (5) improved characterization of oil and gas reservoirs so uncontacted and bypassed resources can be recognized and developed. Other topics of concern were technologies for reservoir performance prediction, oil and gas data bases, advanced enhanced oil recovery, and production operations. The convenors of the forums and the authors of this overview obtained these results as the first phase of a three-phase project designed to transfer technology to independent producers, and thus assist them in continuing to develop domestic oil and natural gas resources.

Mineral Resource Circulars

MRC 82. The Dimension Stone Industry of Texas

by L. Edwin Garner. 16 p., 15 figs., $3.00

Dimension stone is a natural rock that is quarried for production of blocks, slabs, or other shapes in specific dimensions. Dimension stones produced in Texas include mainly granite and limestone and some sandstone and marble. Although the Texas dimension stone industry has been active since the late 1880's, Texas accounts for a relatively small part of the total dimension stone produced in the United States. Texas has increased its share of the U.S. market from less than 3 percent in the late 1970's to almost 7 percent in 1987. Statewide dimension stone production in 1987 totaled more than 75,000 short tons valued at about $10 million.

This circular analyzes the Texas dimension stone industry and illustrates its ability to compete on national and international levels. Dimension stone resources are evaluated on the basis of current market value and historical production and pricing trends. Finally, the economic importance of the Texas dimension stone industry is compared with that of national and foreign industries. The author concludes that if a reduction in imported dimension stone occurred, a substantial increase in U.S. production would result. In this event, effective marketing practices and modern production techniques could markedly increase dimension stone production in Texas.

MRC 83. Texas Portland Cement Industry and Cement Resources

by Mary W. McBride, T. S. Patty, and R. D. Sharpe. 72 p., 42 figs., 14 tables, 4 appendices, $6.00

As a cement producer, Texas is now second only to California. Rapid population growth and industrial expansion of the state in 1975 through 1985 created a strong market for cement, and the abundance of limestone and other raw materials used in cement production, as well as reliable energy supplies, made the siting of cement plants in Texas economically feasible. From 1970 through 1980, Texas consumed an average of 7.3 million tons of cement annually. Economic problems in the late 1980's have meant decreased production and lowered profits for the cement industry recently, and older, less efficient wet-cement plants have been closed. Many plants now have new capital, as a result of investment by European and Asian companies, however, and the cement industry of Texas is ready to renew maximum production should additional output be required. In this case, the authors predict that Texas may assume preeminence as a cement-producing state before the end of the century.

Maps

Geologic Map of Texas

Virgil E. Barnes, compiler; Barbara M. Hartmann, and Dan F. Scranton, cartographers. 4 full-color sheets, 1:500,000-scale, $22.50

This map supersedes the U.S. Geological Survey's "Geologic Map of Texas," which was published in 1937 and has been out of print for many years. The new map is shipped unfolded and consists of four sheets (quadrants), each of which measures 3.6 × 4.3 ft; the entire map is 7.2 × 8.6 ft. The map contains more than 350 lithostratigraphic units ranging in age from Precambrian to Quaternary. The map also incorporates many stratigraphic revisions that are now found on recently revised (post-1987) GAT sheets, and thus it represents the latest knowledge of the geology of Texas. In addition to the bedrock and unconsolidated surficial units, the map shows all major cultural features, such as county boundaries, cities, state and federal highways, and railroad lines.

See the full description under "Highlights," page 45.

Geology of Texas Map

Page-sized map, in full color, scale 1 inch = 100 miles, $0.25

This concise and colorful summary of the geology of Texas consists of a page-sized four-color map on one side of the page and a descriptive narrative text on the other. Amenable to laminating, framing, or other display or reference uses, this map is an excellent overview for students or laypeople. Discounts for bulk orders are available.

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

Papers

Ayers, W. B., Jr., and **Kaiser, W. R.**, 1992, Coalbed methane in the San Juan Basin of the western United States: controls on reservoir properties and gas production, *in* Beamish, B. B., and Gamson, P. D., eds., Symposium on coalbed methane research and development in Australia: James Cook University of North Queensland, Australia, Coalseam Gas Research Institute, v. 1, p. 1–30.

Ayers, W. B., Jr., and **Kaiser, W. R.**, 1992, Coalbed methane occurrence and producibility, Fruitland Formation, Navajo Lake Area, San Juan Basin, New Mexico, *in* Ryan, Barry, and Cunningham, John, eds., Proceedings, The Canadian Coal and Methane Geoscience Forum: Alberta Geological Survey, Alberta Research Council, p. 4–20.

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Services

Core Research Center

The Core Research Center (CRC) houses the largest public collection of subsurface geological materials in the United States and is open from 7:00 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 George Bush, Curator, at (512) 471-1534, ext. 401. A brochure describing the CRC is available upon request.

Approximately 9,500 cores and drill cuttings from 56,500 wells are available for study at the CRC and may be viewed on-site or checked out for a period of 6 weeks. Patrons are asked to provide results of analyses of borrowed material, which then become part of the center's reference material. Information regarding wells is stored in a relational data base, and customized data base searches may be purchased.

During 1992, 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 16,000 boxes of core (24 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 more than 2,000 thin sections for Bureau and non-Bureau patrons. More than 2,000 photographs were taken of geologic materials during 1992.

New acquisitions in 1992 totaled more than 2,400 new cores (more than 152,000 linear feet of core) and drill cuttings from more than 1,400 wells. Donations were received from American Exploration, Arco Oil and Gas, Ashland Exploration, B-1 Industries, Ballard Exploration, Beard Oil, Brazos River Authority, Chevron, Clayton Williams, Jr., CNG Producing, Cockrell Oil, Department of Geological Sciences (The University of Texas at Austin), Exxon, GLG Energy, Kerr-McGee, Lagoven S.A., Lewis Petroleum Properties, Louisiana Land and Exploration, Maguire Oil, Maxus Energy, Meridian Oil, Oxidental Petroleum, Northern Illinois Gas, Oryx, Phillips/Bell, Placer Dome, Plains Petroleum, Quintana Resources, Reservoirs, Inc., Samedan, Shell, Target Oilfield Supply, Telegraph Exploration, Texaco, Texas A&M University, Texstar North American, Tuskar Oil, U.S. Exploration, and the U.S. Geological Survey.

Mineral Studies Laboratory

The Mineral Studies Laboratory (MSL) serves as the Bureau's analytical geochemistry facility. Located in approximately 18,000 ft^2 of laboratory space adjacent to the Bureau's Research and Administrative Office, the MSL can provide near-complete geochemical, mineralogical, and textural characterization of most geological materials. The MSL is currently staffed by Chief Chemist Steven W. Tweedy along with other professional analytical staff. 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 have also been performed at the MSL.

Many Bureau projects were supported by MSL services during 1992. Among these were the Paleohydrology of the Non-Glaciated Plains, Texas Advanced Research–Bonaire Dolomite, Gas Research Institute–Ferron Sandstone, Pantex, Texas Low-Level Radioactive Waste Disposal Authority, Superconducting Super Collider, Uranium Mine Tailing Recovery Act, and Tight Gas Sandstone 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, UT's Mechanical Engineering department, and Sandia National Laboratories.

The MSL has continued to develop Quality Assurance procedures for its services, now being required by many projects. The laboratory continues to participate 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, 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 1992, 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.

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 the 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; drillers' logs for about 400,000 Texas wells; and completion cards for more than 300,000 Texas wells and more than 150,000 wells in adjacent states.

The Reading Room staff cataloged, indexed, shelved, and entered into a computer data base more than 1,800 items. More than 1,000 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 1992, the facility had accumulated approximately 80,000 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

Bureau Geophysical Program

Use of three-dimensional seismic data played a prominent role in the Bureau's 1992 research program. A three-dimensional seismic survey covering 7.5 mi^2 of Stratton field was designed by Bureau personnel, who also supervised the field work and data processing. The migrated data were interpreted with the Bureau's Sierra software and DEC 5000 workstation, and the seismic sedimentology patterns revealed in the seismic images were critical in defining reservoir compartment boundaries. A second three-dimensional data volume recorded at Seeligson field in late 1990 and processed and interpreted by contractors in 1991 was reinterpreted at the Bureau to obtain more precise imaging of the fluvial Frio reservoirs in this field. The objective of all applications in Stratton and Seeligson fields to date has been to define depositional variability at the interwell scale, which is critical to incremental recovery of natural gas. An increased level of three-dimensional seismic activity is planned for 1993 research programs. To support this expanding geophysical program, Advance Geophysical's ProMAX software was installed at the Bureau in 1992 so that seismic data processing can be done when necessary to enhance stratigraphic imaging, and negotiations were initiated to add a Landmark workstation to the Bureau's seismic interpretation resources.

One of the most effective geophysical techniques used in the Bureau's environmental projects is shallow seismic reflection profiling. This technique has been used extensively by the Bureau at the U.S. Department of Energy's Pantex plant near Amarillo, Texas, to map key subsurface interfaces such as the top and base of the Ogallala aquifer and the probable lateral continuity of a fine-grained stratum that perches downgoing ground water before it reaches the Ogallala. The Bureau has also used reflection profiling to determine the depth to the bedrock/basin fill contact at a proposed low-level radioactive waste repository site east of El Paso, Texas. The strengths of this method are that it (1) employs a surface seismic source and ground-motion detectors and is thus noninvasive, (2) can be scaled to provide profiles of the subsurface from depths of about 15 to 300 m, and (3) generally produces data that are readily interpretable geologically. Inferences about important physical parameters such as seismic velocity, porosity, and permeability can also be made from seismic data.

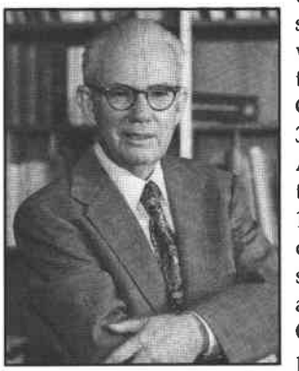
Bureau Takes Lead in Study of the National Oil Resource Base

On October 21, 1992, the U.S. Department of Energy held a press conference in Washington, D.C., to release a study prepared jointly by the Bureau and the National Institute for Petroleum and Energy Research (NIPER). The study, "An Assessment of the Oil Resource Base of the United States," was based on estimates of oil resource potential prepared by a national panel of 17 oil analysts representing a broad cross section of experts from major oil companies, independent oil companies, Federal government departments and agencies, State geological surveys, private foundations, and consulting firms. The Panel, chaired by Bureau Director W. L. Fisher, met August 31 and September 1, 1992, at the Bureau to review and discuss the results of previous resource assessments.

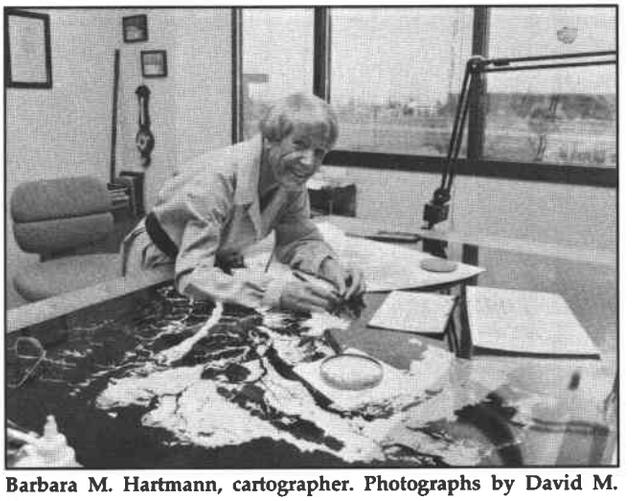
Geologic Map of Texas Published by the Bureau

Virgil E. Barnes, compiler; Barbara M. Hartmann and Dan F. Scranton, cartographers

A new, full-color, 1:500,000-scale geologic map of Texas was published in 1992 and is now available. This map supersedes the U.S. Geological Survey's "Geologic Map of Texas," which was published in 1937 and has been out of print for many years. The new map is shipped unfolded and consists of four sheets (quadrants), each of which measures 3.6 × 4.3 ft; the entire map is 7.2 × 8.6 ft. Compiled largely from the 38 1:250,000-scale "Geologic Atlas of Texas" (GAT) sheets that were published between 1965 and 1987, the map contains more than 350 lithostratigraphic units ranging in age from Precambrian to Quaternary. The map also incorporates many new stratigraphic



Virgil E. Barnes, map compiler.



Barbara M. Hartmann, cartographer. Photographs by David M. Stephens.

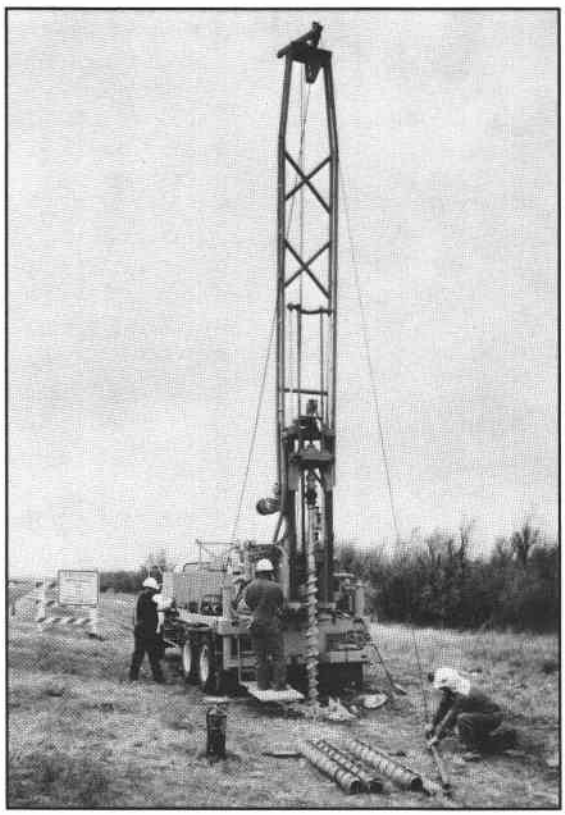
revisions now shown on recently revised (post-1987) GAT sheets, and thus it represents the latest knowledge of the geology of Texas. In addition to the bedrock and unconsolidated surficial units, the map shows all major cultural features, such as county boundaries, cities, state and federal highways, and railroad lines. Virgil E. Barnes, who has had more than 50 years' experience in field mapping and studying Texas geology, was the map compiler; Barbara M. Hartmann, an award-winning Bureau cartographer, conducted the color-separation procedures; and Dan F. Scranton did the scribing.

Bureau Acquires New Drilling Rig

In August, the Bureau acquired a new Central Mining Equipment Model 75 drilling rig. The new rig has greatly increased the drilling capabilities of the Bureau, especially in the area of environmentally related research, which has been steadily expanding at the Bureau in the last several years. When choosing the model of rig to purchase, special emphasis was placed on its capability to employ multiple drilling techniques including hollow- and solid-stem augering, continuous coring, and rotary drilling with both mud and air circulation systems.

The drilling rig was purchased for the Pantex project, for which extensive drilling is required to characterize Ogallala aquifer and Blackwater Draw sediments and to install an assortment of hydrological monitoring equipment. Initial drilling has already produced a significant amount of continuous core that is reshaping current views of the geologic and hydrologic controls in the Texas High Plains area.

The rig is operated by a crew of Bureau personnel from the Core Research Center. Currently, Jordan Forman, Bill Doneghy, and Alex Colunga are ably overseeing the operation of the rig. Future research efforts that may be enhanced by use of the new rig include coastal studies, desert ground-water investigations, and commercial rock and mineral surveys.



New drilling rig acquired by the Bureau to augment subsurface analysis capabilities. Photograph by David M. Stephens.

Bureau Hosts Continental Margins Symposium

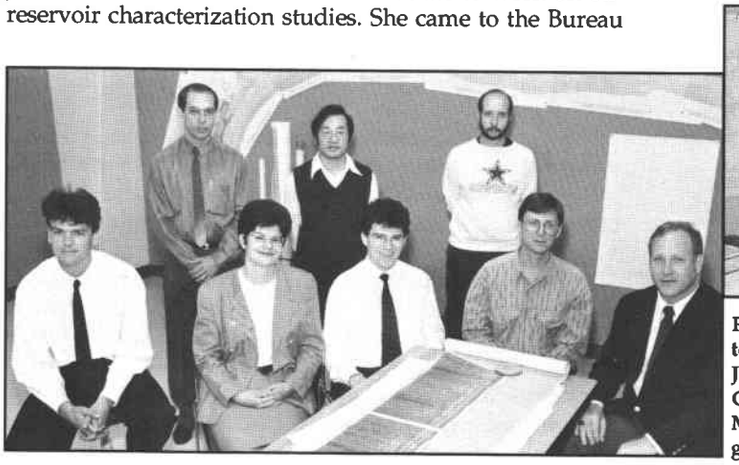
In November 1992 the Bureau organized and hosted the third Symposium on Studies Related to Continental Margins, which was sponsored by the Minerals Management Service of the U.S. Department of the Interior. Invited attendees included Minerals Management Service personnel, the President of the Association of American State Geologists, investigators who have participated in the Continental Margins Program, and invited speakers from industry and government. The goals of the symposium were to (1) discuss and disseminate research results from years five and six of the Continental Margins Program, (2) illustrate and evaluate promising research efforts conducted by the coastal states, (3) provide an overview of the program, (4) encourage discussion of future research directions for the program, and (5) provide a representative sampling of industry activities in particular coastal and offshore areas.

Awards and Honors

Alan R. Dutton was elected a Geological Society of America Fellow. **W. L. Fisher** was elected President-Elect of the Gulf Coast Association of Geological Societies (GCAGS). A paper presented at the 1992 annual meeting of the Southwest Section of the American Association of Petroleum Geologists by **Stephen C. Ruppel,** titled "Styles of Deposition and Diagenesis in the Monahans Clear Fork Reservoir: Implications for Improved Characterization of Leonard Reservoirs on the Central Basin Platform," was chosen to be presented in the "Best of AAPG for SPE" session at the annual meeting of the Society of Petroleum Engineers in Washington, D.C. **J. Ulises Ricoy** received an honorable mention award from GCAGS for his poster presentation titled "Stratigraphic-Structural Interpretation and Reservoir Characterization of Lavaca Bay Field, Calhoun County, Texas," which was given at the 1991 GCAGS meeting in Houston. **Andrew R. Scott** and **William A. Ambrose** won the Energy Minerals Division Certificate of Excellence in Presentation for their paper titled "Thermal Maturity and Coalbed Methane Potential of the Greater Green River, Piceance, Powder River, and Raton Basins," which was presented at the 1992 AAPG meeting in Calgary, Alberta, Canada.

New Research Staff

Roger J. Barnaby joined the Bureau as a Research Fellow to work on the State Lands Energy Resource Optimization (SLERO) project. Barnaby received a Ph.D. from Virginia Polytechnic Institute, where he studied the stratigraphy and diagenesis of a Lower Cambrian carbonate platform. Before coming to the Bureau, Barnaby worked at BP Exploration, Inc., as an exploration geologist on projects in the Gulf of Mexico and in Alaska. **Mark J. Burn**, a native of England, joined the Bureau to work on the Secondary Gas Recovery project. Burn received his Ph.D. from Oxford Polytechnic and has previous research experience with K.S.E.P.L. (Shell Research, The Netherlands). His primary research interests are the architecture and external geometry of potential fluvial-deltaic sandstone reservoirs within a sequence-stratigraphic framework. **Eulise R. Ferrer** comes to the Bureau as a visiting Research Fellow with extensive industry experience with Lagoven S.A. in Venezuela to participate in an ongoing Bureau project of geological characterization of Eocene reservoirs in Lake Maracaibo, western Venezuela. **Alan E. Fryar**, who received his Ph.D. from the University of Alberta in Edmonton, Canada, joined the Bureau to study the chemical evolution and flow of ground water for the Pantex project. Fryar's primary research interests include the geochemical and hydraulic evolution of reaction fronts in sediments. **James C. Gibeaut**, a coastal geologist, came to the Bureau to work on the Sand Resources and Coastal Erosion projects. Gibeaut received his Ph.D. in marine science from the University of South Florida. Prior to coming to the Bureau, he was a Visiting Assistant Professor in Geology at the University of South Florida. Gibeaut also served as the head of science and data management for the State of Alaska's Exxon *Valdez* Oil Spill Response Center in 1990–91. **Barry J. Hibbs**, who examined the hydrodynamic, hydrochemical, and hydrothermal bank storage effects in the Colorado River alluvial aquifer in Central Texas for his Ph.D. dissertation at The University of Texas at Austin, joined the Bureau to work on hydrogeologic studies of the saturated zone at the potential low-level radioactive waste repository at Eagle Flat, Trans-Pecos Texas. Hibbs' other research interests include regulatory and water-resource-policy issues. **Lee E. McRae**, who received her Ph.D. from Dartmouth College, joined the Bureau as a Research Associate to work on oil-reservoir characterization studies. She came to the Bureau from Amoco Production Company's Worldwide Exploration Group, where she was most recently assigned to clastic reservoir studies of Tertiary strata in northern Burma. **Carol L. Ruthven**, who received her Ph.D. from Queen's University in Kingston, Ontario, Canada, joined the Bureau as a Research Associate to work as an energy analyst. Her research experience includes the study of energy and trade policy, pipeline tolls and tariffs, and oil and gas regulations. Prior to joining the Bureau, she worked as a Senior Energy Analyst for the Department of Energy, Government of Alberta. **Douglas B. Swift**, based in the Bureau's office at the Center for Energy and Economic Diversification in Midland, acts as a Bureau liaison to the Permian Basin oil community. He is also involved in Bureau research on the origin and migration of hydrocarbons in the Delaware Basin and Central Basin Platform. Swift comes to the Bureau with 20 years of professional geological experience both in industry and as a geological consultant in the greater Permian Basin region. **Thomas A. Tremblay** received his B.A. in geology at The University of Texas at Austin and then worked as a Bureau research assistant while completing his Master's in geography. His research involved a geographic information systems (GIS) pilot study of the wetlands of the Virginia Point quadrangle in Galveston County, Texas. During the past 2 years he has continued his work on the Galveston Bay estuary system project and has maintained the GIS data base for the SLERO project. He recently joined the Low-Level Radioactive Waste Disposal project, for which he will analyze digital elevation models of the study area. **Bruce N. Turbeville**, who received his Ph.D. from The University of Texas at Austin, joined the staff of the Mineral Studies Laboratory to oversee operation of the stable isotope mass spectrometer and associated laboratory equipment. Turbeville is an igneous petrologist and clastic sedimen-tologist who has conducted research in Mexico, Trans-Pecos Texas, Italy, and the Cape Verde Archipelago. **Jiannan Xiang** received his Ph.D. from Pennsylvania State University and worked in the hydrology and environmental groups at the University of California, Riverside. Xiang's research interests include aquifer and vadose-zone test techniques and theories, mathematical modeling of subsurface water flow, and numerical code development and evaluation of problems in subsurface flow and transport. Xiang is working on the Eagle Flat and Pantex projects at the Bureau.



Research staff who joined the Bureau during 1992 (from left to right): Mark J. Burn, Eulise R. Ferrer, Carol L. Ruthven, Jiannan Xiang, Alan E. Fryar, Bruce N. Turbeville, James C. Gibeaut, and Douglas B. Swift. Shown above are Lee E. McRae, Thomas A. Tremblay, and Roger J. Barnaby. Photographs by David M. Stephens. Not shown is Barry J. Hibbs.

Research Staff Activities

Lectures and Public Addresses

Arten J. Avakian

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

Kenneth T. Barrow

"Project SLERO and reservoir characterization of the Powderhorn (Miocene) field, Calhoun County, Texas": presented to the Gulf Coast Seismic and Sequence Stratigraphy Project 1992 spring meeting, College Station, Texas.

"Las Tiendas (Olmos) field reservoir characterization": presented at the State Lands Energy Resource Optimization (SLERO) Project, 1992 annual review meeting, Houston, Texas.

"Powderhorn (Miocene) field reservoir characterization": presented at the State Lands Energy Resource Optimization (SLERO) Project, 1992 annual internal review meeting, Houston, Texas, and the State Lands Energy Resource Optimization (SLERO) Project review meeting hosted by the Texas General Land Office, Austin, Texas.

"Tectonics, sedimentation, and sequence stratigraphic models of intracratonic basins": presented to The University of Texas at Austin, Department of Geological Sciences (Geology 391), Austin, Texas.

"Sedimentation and stratal architecture on clastic continental shelves": presented to The University of Texas at Austin, Department of Geological Sciences (Geology 391), Austin, Texas.

Don G. Bebout

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

Kenneth M. Duncan

"Evolving standards for the systems manager of the 90's": presented to The University of Texas at Austin, Department of Management Science and Information Systems (MIS 374), Austin, Texas.

"Using AppleEvents, Apple's Object Model, and scripting user applications with Frontier": presented to the Austin Macintosh Developers Association, Austin, Texas.

"GIS at BEG: past, present, and future capabilities": presented to The University of Texas at Austin, Bureau of Economic Geology, Austin, Texas.

Alan R. Dutton

"Overview of regional hydrogeologic investigations, Superconducting Super Collider site, Ellis County, Texas": presented to The University of Texas at Austin, Department of Geological Sciences, Austin, Texas.

"Simulation of ground-water particle paths in an alluvial aquifer overlying the Superconducting Super Collider (SSC) site, Texas": presented to The University of Southwestern Louisiana, Department of Geology, Lafayette, Louisiana.

"Paleohydrology of the non-glaciated Great Plains: an isotopic and age-dating study": presented to the University of South Louisiana, Department of Geological Sciences, Lafayette, Louisiana, and to The University of Texas at Austin, Department of Geography, Austin, Texas.

"Paleohydrology of the non-glaciated Great Plains: ^{14}C and ^{36}C age-dating of confined and unconfined aquifers": presented to The University of Texas at Austin, Department of Geological Sciences, Austin, Texas.

"Hydrogeologic investigations of regional ground-water flow and ground-water resources, Ellis County area, North Texas": project briefing presented to Texas National Resources Laboratory Commission and SSC Laboratory, De Soto, Texas.

Shirley P. Dutton

"Overview of tight gas sands geological characterizations": presented to the Gas Research Institute, Natural Gas Supply Project Advisors Meeting, Tight Gas Sands Project area, Albuquerque, New Mexico.

"Geologic controls on reservoir properties of low-permeability sandstone, Travis Peak Formation, East Texas": presented to the Shreveport Geological Society, Shreveport, Louisiana.

Robert J. Finley

"Natural gas reserve replacement via infield reserve growth: an example from Stratton field, onshore Texas Gulf Coast Basin": presented to the Third International Reservoir Characterization Technical Conference, ITT Research Institute, National Institute for Petroleum and Energy Research, and U.S. Department of Energy, Tulsa, Oklahoma.

"Geological examples of current improved recovery technologies": presented to the Texas Independent Producers and Royalty Owners Association Forum on Improved Oil and Gas Recovery, Houston, Texas.

"Integrated geological and geophysical characterization of Gulf Coast reservoirs for incremental natural gas recovery": presented to the Joint Meeting of the Geophysical Society of Houston and the Houston Geological Society, Houston, Texas.

"Briefing on current and prospective natural gas recovery technologies": presented to Congressional staff members attending Natural Gas Fact-Finding Meeting, Enserch Corporation, Dallas, Texas.

"Incremental natural gas resources through infield reserve growth/secondary natural gas recovery": presented to the Natural Gas Research and Development Contractors Review Meeting, U.S. Department of Energy, Morgantown, West Virginia.

"Extrapolation of gas reserve growth potential: development of examples from macro approaches": presented to the 1992 Project Advisor Group Meeting, Gas Research Institute, Golden, Colorado.

"Infield natural gas reserve growth joint venture (secondary gas recovery)": presented to the 1992 Project Advisor Group Meeting, Gas Research Institute, Golden, Colorado.

"Integrated geological, petrophysical, geophysical, and engineering approach to evaluating the potential for infield natural gas reserve growth: examples from South Texas": presented to the Houston Geological Society, Houston, Texas.

"Improved oil and gas recovery: a symposium preview": presented to the 1992 Annual Meeting of the Texas Independent Producers and Royalty Owners Association, Fort Worth, Texas.

"A positive assessment of U.S. natural gas supply": presented to The University of Texas at Austin, Bureau of Business Research conference on the role of natural gas in environmental policy, Austin, Texas.

R. Stephen Fisher

"Relations between petrography and permeability in a fluvio-deltaic reservoir analog, Ferron Sandstone, Utah": presented as part of the field trip "Architecture and Permeability Structure of Fluvial-Deltaic Sandstones, Ferron Sandstone, East-Central Utah" held in conjunction with the SEPM 1992 Theme Meeting on the Mesozoic of the Western Interior.

"Detrital and diagenetic mineralogy of the Ferron Sandstone, central Utah": presented as part of the field trip "Architecture and Permeability Structure of Fluvial-Deltaic Sandstones, Ferron Sandstone, East-Central Utah" held in conjunction with the SEPM 1992 Theme Meeting on the Mesozoic of the Western Interior.

"Sandstone architecture, geometry, mineralogy, and permeability in a sequence stratigraphic setting": presented to the 1992 Gas Research Institute Geoscience Contractors Review Meeting, Houston, Texas.

William L. Fisher

"Exploration and exploitation trends in domestic oil and gas": luncheon address presented to the Corpus Christi Geological Society, Corpus Christi, Texas.

"Role of technologies in oil and gas development; with emphasis on trends in natural gas": presented to the International Association of Energy Economists, Houston Chapter, Houston, Texas.

"Future geologic issues in Texas—energy, environment, and water": presented to the Society of Independent Professional Earth Scientists, Austin Chapter, Austin, Texas.

"Introduction to the McKelvey Forum": presented to the U.S. Geological Survey Conference, Houston, Texas.

"Oil and gas in the nineties—a look at the fundamentals": luncheon address presented to the Division of Professional Affairs, American Association of Petroleum Geologists, Southwest Section Meeting, Midland, Texas.

"Projection and outlook for oil, natural gas, and geothermal resources in Texas": presented to the State of Texas Energy Policy Partnership, Austin, Texas.

"Emerging technologies in oil and gas exploration and recovery": presented to the National Technology Initiative Conference, DOE, DOT, DOC/The University of Texas at Austin, Austin, Texas.

"Production economics of oil and gas in marginal fields": presented to the OCS Policy Committee, U.S. Department of the Interior, Houston, Texas.

"Issues in U.S. gas supply": presented to First Chicago Bank's Spring Energy Panel, Chicago, Illinois.

"Surviving the meltdown": presented to the East Texas Geological Society, Tyler, Texas.

"The coming crises in preserving petroleum and geologic data": presented to the Association of Records Managers and Administrators, Petroleum Industry Action Committee, Austin, Texas.

"Changing dynamics in U.S. oil and gas": presented to the Society of Professional Independent Earth Scientists, Houston Chapter, Houston, Texas.

"U.S. energy policy: Do we care anymore?": presented to The University of Texas at Arlington, Arlington, Texas.

"Roles of technologies and efficiencies in U.S. oil and gas": presented to the South Texas oil show, Corpus Christi, Texas.

"Reservoir characterization technologies and reserve growth": presented to the Reservoir Characterization Forum, convened by Schlumberger-Doll Research, Ridgefield, Connecticut.

"U.S. oil and gas recovery and advancing technology": presented to the Society of Exploration Geophysicists, annual meeting, Development and Production luncheon, New Orleans, Louisiana.

"Trends in the U.S. oil and gas industry": briefing presented to the Canadian National Energy Board and staff, Calgary, Alberta, Canada.

"Analysis of oil and natural gas policies in the National Energy Strategy": presented to The University of Texas at Austin Committee, State of Texas Energy Policy Partnership, Austin, Texas.

"Oil, gas, and the birds: the dodo or the phoenix?": presented to Texas Tech University, Lubbock, Texas.

"Geology and the domestic petroleum industry": presented to the Department of Geology, University of Kentucky Centennial Celebration Symposium on "The Next Ten Years: the Geological Sciences in 2002," Lexington, Kentucky.

"Natural gas supply and demand: reaching equilibrium at last": presented to the Third Annual Conference on Moving Gas on Texas Intrastates, Houston, Texas.

"Technologic trends in oil and gas discovery and recovery": presented to the Sociedad Internacional de Ingenieros Petroleos, Santa Cruz, Bolivia.

"Outlook for the domestic oil and gas industry": presented to the Petroleum Engineering Club, Dallas, Texas.

"Activities in professional affairs," presented to the American Institute of Professional Geologists, Texas Chapter, annual meeting, Austin, Texas.

"Natural gas futures in U.S. and Mexico": presented to the North American Free Trade Association Conference, Monterey, Mexico.

Robert L. Folk

"Hot springs of Viterbo, Italy, and the importance of bacteria in carbonate sediments and rocks": presented to The University of Texas at Austin, Hydrogeology Seminar, Austin, Texas; the New Mexico School of Mines, Socorro, New Mexico; the University of New Mexico, Albuquerque, New Mexico; the Alabama Geological Survey, Tuscaloosa, Alabama; and Wichita State University, Wichita, Kansas.

"Egyptian pyramids: geopolymer concrete or real limestone?": presented to the New Mexico School of Mines, Socorro, New Mexico; the University of New Mexico, Albuquerque, New Mexico; and Wichita State University, Wichita, Kansas.

Alan E. Fryar

"Experimental modeling of contaminant-induced diagenesis": presented to The University of Texas at Austin, Department of Geological Sciences, Austin, Texas.

"Characterizing ground-water flow at a U.S. nuclear site": presented to the University of Alberta, Department of Geology, Edmonton, Alberta, Canada.

William E. Galloway

"Depositional and structural style of the Cenozoic fill, NW Gulf of Mexico Basin": presented to Baylor University, Department of Geology, Waco, Texas.

"Sediment supply—primary control on development of siliclastic depositional systems and sequences": presented to the Dallas Geological Society, Dallas, Texas.

"Sediment supply, tectonism, and siliciclastic depositional system and sequences": keynote address presented to the Eleventh Australian Geological Congress, Ballarat, Australia.

"Sequence stratigraphic framework of the Cenozoic fill, Central and Northern North Sea Basin": presented at the Fourth Conference on Petroleum Geology of NW Europe, Barbican Centre, London, U.K.

"Evacuation and filling of large submarine canyons": presented to The University of Houston, Department of Geosciences, Houston, Texas.

Michael H. Gardner

"Changes in shallow marine facies architecture related to sediment volume partitioning: examples from the Ferron Sandstone (Cretaceous), Utah": presented to the Chevron Oil Field Research Laboratory, La Habra, California.

"Changes in distributary channel-belt architecture related to base-level change: examples from the Ferron Sandstone (Cretaceous), Utah": presented to the Chevron Oil Field Research Laboratory, La Habra, California.

"Reservoir characterization of Screwbean field, Delaware Mountain Group, West Texas": presented at State Lands Energy Resource Optimization (SLERO) Project annual review meeting, Houston, Texas.

"Reservoir characterization of the Delaware Mountain Group": presented at Texas General Land Office Review Meeting, Austin, Texas.

"The role of genetic stratigraphy in reservoir characterization: examples from the Ferron Sandstone (Cretaceous), Utah": presented to the UNOCAL exploration science technology seminar, Los Angeles, California.

"Genetic stratigraphy of the Ferron Sandstone (Cretaceous), Utah": presented to The University of Texas at Austin, Department of Geological Sciences, Austin, Texas.

James C. Gibeaut

"Natural and unnatural evolution of tidal inlets": presented to the U.S. Army Corps of Engineers, Jacksonville, Florida.

Thomas C. Gustavson

"Age and development of the Ogallala Caprock calcrete, Southern High Plains, northwestern Texas and eastern New Mexico": presented to the Soil Survey and Land Resource Workshop, College Station, Texas.

"Depositional systems, paleosols, and paleoclimate: Ogallala and Blackwater Draw Formations, Texas and New Mexico": presented to the Panhandle Geological Society, Amarillo, Texas.

"Hydrologic and geologic site characterization of DOE's Pantex plant, Texas Panhandle": presented to the Texas Alliance of Groundwater Districts at DOE's Pantex plant, Amarillo, Texas.

Douglas S. Hamilton

"Reservoir characterization of Seventy-Six West and Colmena-Cedro Hill fields": presented to the State Lands Energy Resource Optimization (SLERO) Project 1992 annual internal review meeting, Houston, Texas, and to the Texas General Land Office, Austin, Texas.

"Deeper pay potential in the Duval County Ranch Corporation area": presented to the State Lands Energy Resource Optimization (SLERO) Project 1992 annual internal review meeting, Houston, Texas, and to the Texas General Land Office, Austin, Texas.

"Geology and hydrology of coalbed methane in the Sand Wash Basin": presented to the Gas Research Institute, Chicago, Illinois, and to the Gas Research Institute, National Gas Supply Project Advisors Group, Colorado Springs, Colorado.

Bob A. Hardage

"Imaging thin Frio gas reservoirs": presented to the Society of Exploration Geophysicists Development and Production Forum, Big Sky, Montana.

"Technology transfer program for independent oil and gas operators": presented at Texas Independent Producers and Royalty Owners meetings, Fort Worth and Los Colinas, Texas.

"Principles of crosswell reflection imaging": presented to the Geophysical Society of Tulsa, Tulsa, Oklahoma.

"Status of seismic activity at Stratton fields": presented to Union Pacific Resources, Fort Worth and Bishop, Texas.

"3-D seismic technology": presented to Mitchell Energy, The Woodlands, Texas; to Cross Timbers Oil Company, Fort Worth, Texas; and to Occidental Petroleum, Midland, Texas.

Rodney Heathcott

"Macintosh basics, Excel, Word, and Cricket Graph": presented to The University of Texas at Austin, Bureau of Economic Geology, Austin, Texas.

Christopher D. Henry

"Beryllium and other rare metals in Trans-Pecos Texas": presented to SEPM (Society for Sedimentary Geology), Permian Basin Section, and West Texas Geological Society, Midland, Texas, and to the Big Bend Geological Society and Sul Ross State University, Alpine, Texas.

"Tectonic and geochemical evolution of Tertiary magmatism in Trans-Pecos Texas": presented to The University of Houston, Department of Geosciences, Houston, Texas.

Tucker F. Hentz

"Bone beds of the Permian red beds, North-Central Texas": presented to the Central Texas Paleontological Society, Austin, Texas.

Mark H. Holtz

"Porosity and permeability characteristics in a mixed carbonate/siliciclastic sequence: an example from the upper Guadalupian (Permian)": presented to the Roswell Geological Society, Roswell, New Mexico.

"Facies controls on porosity, permeability, and oil production in McFarland/Magutex (Queen) reservoirs, Permian Basin, Texas": presented to the New Mexico Technical Institute, Petroleum Recovery Research Center, Socorro, New Mexico.

"Petrophysical characteristics of mixed carbonate-siliciclastic lithologic sequences": presented to The University of Texas at Austin, Department of Petroleum Engineering (PEN 369), Austin, Texas.

"An assessment of electric utility CO_2 emissions for enhanced oil recovery: the potential in Texas": presented at the 14th Annual North American Conference of the International Association of Energy Economics, New Orleans, Louisiana.

"Modeling of 3-D rock property distribution within depositionally and diagenetically controlled flow units: a carbonate reservoir example" presented at the 2d Annual Symposium on 3-D Reservoir Characterization, Texaco, Inc., Exploration and Production Technology Department, Houston, Texas.

"Geologic and engineering characteristics of the Upper Guadalupian mixed carbonate-siliciclastic reservoirs of the Permian Basin, West Texas and New Mexico": presented to the New Mexico Bureau of Mines and Mineral Resources and the Petroleum Recovery Research Center, Socorro, New Mexico.

"Hydrocarbon resource assessment integrating geologic and petroleum engineering characteristics": presented to representatives of the Hungarian Mining and Geologic Survey, Austin, Texas.

"Hydrocarbon resources on state lands": presented to the General Land Office, Austin, Texas.

"SLERO progress report on play analysis and resource assessment": presented at the State Lands Energy Resource Optimization (SLERO) project 1992 annual internal review meeting, Houston, Texas.

"Reserve growth potential of oil and gas on State of Texas lands": presented to the General Land Office, Austin, Texas.

"Petrophysical and production characteristics of Leonardian restricted-platform carbonate reservoirs, Permian Basin, West Texas": presented at the ERAP 1992 annual review meeting, Austin, Texas.

"Assessment of hydrocarbon resources on University of Texas Lands: future reserve growth potential": presented at the 1992 West Texas Geological Society Fall Symposium, Midland, Texas.

Susan D. Hovorka

"Microfabric influence on fracture intensity, Austin Chalk, shallow subsurface, Ellis County, Texas": poster session presented to the Natural Fracture Workshop, The University of Texas at Austin, Bureau of Economic Geology, Austin, Texas.

Martin P. A. Jackson

"The rise and fall of diapirs during thin-skinned extension": AAPG Distinguished Lecture presented to Michigan Technological University, Houghton, Michigan; University of Missouri, Rolla, Missouri; University of New Orleans, New Orleans, Louisiana; and the North Texas Geological Society, Wichita Falls, Texas.

"The rise and fall of diapirs during thin-skinned extension": presented to AGIP S.p.A, Milan, Italy.

"Introduction to salt tectonics": presented to the Ministry of Oil and Mineral Resources, Sanaa, Republic of Yemen.

"Contractional and basement-involved salt tectonics": presented to British Petroleum Exploration Operating Company, Ltd., Sanaa, Republic of Yemen.

"The outer structure of Upheaval Dome, Utah": presented to Exxon Production Research, Houston, Texas.

"Structural geology of Upheaval Dome, Utah": presented to Exxon Production Research, Houston, Texas.

"Overview of Applied Geodynamics Laboratory Research for 1992": presented to The University of Texas at Austin, Bureau of Economic Geology, Industrial Associates of the Applied Geodynamics Laboratory, Austin, Texas.

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

"Upheaval Dome, a possible pinched-off diapir": presented to The University of Texas at Austin, Bureau of Economic Geology, Industrial Associates of the Applied Geodynamics Laboratory, Austin, Texas.

"AGL research directions for 1993": presented to The University of Texas at Austin, Bureau of Economic Geology, Industrial Associates of the Applied Geodynamics Laboratory, Austin, Texas.

Mary L. W. Jackson

"Industrial minerals mined lands inventory, South and East Texas": presented to the Central Texas Mining Section, Society of Mining Engineers, American Institute of Mining, Metallurgical, and Petroleum Engineers, San Marcos, Texas.

"Structural history of the Sabine Arch and its relation to hydrocarbon traps": presented to the East Texas Geological Society, Tyler, Texas.

Eric W. James

"Tectonostratigraphic terranes in Texas (!): lead isotopic evidence": presented to The University of Texas at Austin, Department of Geological Sciences, Hard Rock Seminar, Austin, Texas.

"Isotopic terranes in Texas and their place in the isotopic zonation of North America": presented to The University of Texas at Austin, Institute for Geophysics, Austin, Texas.

William R. Kaiser

"Geology and hydrology of coalbed methane in the Sand Wash Basin": presented to the Gas Research Institute, Natural Gas Supply Project Advisors Group, Colorado Springs, Colorado.

"Texas lignite: resource calculations using geologic models and the NCRDS": presented to Hungarian mining delegation, Austin, Texas.

"Coalbed methane in the Greater Green River Basin, Wyoming and Colorado": presented to Greater Green River Natural Gas Technology Workshop, Denver, Colorado.

Charles Kerans

"Modeling of carbonate reservoirs using outcrop analogs—quantification of petrophysical attributes within a sequence stratigraphic framework": presented to the Reservoir Characterization Forum, Schlumberger-Doll Research Center, Ridgefield, Connecticut.

"The sequence framework of the San Andres in outcrop and subsurface: implications for reservoir characterization": presented to North and South Permian Basin business units, Amoco Production Company, Houston, Texas.

"Integrated characterization of San Andres and Grayburg reservoirs: insights from outcrop studies": presented to the Society of Independent Professional Earth Scientists, Midland Branch, Midland, Texas.

"Sequence framework for the San Andres Formation: implications for improved reservoir characterization and exploration": presented to SEPM (Society for Sedimentary Geology), Permian Basin Section, Midland, Texas.

"Sequence stratigraphy in a mixed carbonate-clastic system: Guadalupian of the Guadalupe Mountains": presented to the Sequence Stratigraphy Working Group, Amoco Production Company, Houston, Texas.

"The role of computers in resource assessment and reservoir characterization and modeling at the Bureau of Economic Geology": presented to an NCR training group, Houston, Texas.

"Guadalupian sequence stratigraphy: a snapshot in time": presented to The University of Texas at Austin, Department of Geological Sciences Technical Sessions, Austin, Texas.

"Advances in sequence stratigraphy of the Guadalupian of the Guadalupe Mountains: the rest of the story": presented to the San Andres-Grayburg Reservoir Characterization Research Laboratory, Industrial Associates Group, Carlsbad, New Mexico.

"Impact of advanced geological characterization studies on Ellenburger reserve growth: current activities and future directions": presented to The University of Texas System University Lands Review meeting, Midland, Texas.

"Role of intermediate (3rd, 4th) and high-order cyclicity in San Andres sequence interpretation and reservoir characterization: How much detail is enough?": presented to Mobil Producing and Development Company, Dallas, Texas.

"Integrated geologic and engineering characterization of carbonate ramp reservoirs: outcrop models and application to the subsurface": presented to The University of Tulsa, Department of Geological Sciences, Tulsa, Oklahoma.

"High-resolution sequence framework of Guadalupian strata in the Guadalupe Mountains, New Mexico and Texas": presented in conjunction with the Fina field trip, Carlsbad, New Mexico.

"Quantitative analysis of grainstone body geometries within a sequence framework, the potential for predictive reservoir characterization": presented to the San Andres-Grayburg Reservoir Characterization Research Laboratory, Industrial Associates Group, Carlsbad, New Mexico.

"High-resolution sequence stratigraphy of a mixed siliciclastic/carbonate system, Leonardian/Guadalupian of the Guadalupe Mountains": presented to The University of Colorado at Boulder, Department of Geological Sciences, Boulder, Colorado.

Hemin Koyi

"Centrifuge modeling of segmentation and emplacement of salt sheets": presented at the Gulf Coast Section Society of Economic Paleontologists and Mineralogists Foundation, 13th Annual Research Conference, Houston, Texas.

"Basement faulting: a complementary triggering mechanism for diapirism": presented at the Gulf Coast Section Society of Economic Paleontologists and Mineralogists Foundation, 13th Annual Research Conference, Houston, Texas.

"Effect of differential compaction and loading upon diapirism": presented at the Gulf Coast Section Society of Economic Paleontologists and Mineralogists Foundation, 13th Annual Research Conference, Houston, Texas.

"Sealing risk in the Nordkapp Basin, Norwegian Barents Sea": presented at Saga Petroleum, Oslo, Norway.

"Modelling segmentation and emplacement of salt sheets using anisotropic overburdens": presented at the Institute of Geology, Uppsala, Sweden.

Stephen E. Laubach

"Fracture patterns in reservoir rocks": presented to the Fort Worth Geological Society, Fort Worth, Texas.

"Frontier Formation stratigraphy, diagenesis, and natural fractures": presented to the Gas Research Institute/Society of Petroleum Engineers workshop on Conclusions of Research in the Frontier Formation, Casper, Wyoming.

"Regional state of stress and hydraulic fracture azimuth in the western Green River Basin": presented to the Gas Research Institute/Society of Petroleum Engineers workshop on Conclusions of Research in the Frontier Formation, Casper, Wyoming.

"Summary of BEG geologic studies of Canyon Sandstone, Texas, and Frontier Formation, Wyoming": presented to the Gas Research Institute Project Advisors Group Meeting, Albuquerque, New Mexico.

"Problems associated with interpreting fracture patterns in coal": presented to the Gas Research Institute/Bureau of Economic Geology Natural Fracture Workshop, Austin, Texas.

"Fractures in sedimentary rocks": presented to Lawrence Berkeley National Laboratory Earth Science Division, Berkeley, California.

"Natural fractures: profiting from a widespread reservoir element": presented to Department of Energy/Gas Research Institute, Greater Green River Basin Gas Technology Workshop, Denver, Colorado.

"Opportunities for horizontal drilling in fractured low-permeability sandstones, United States": presented to Horizontal Drilling Symposium, Denver, Colorado.

Raymond A. Levey

"Infield gas reserve growth: an integral part of the natural gas resource base": presented to the Fort Worth Geological Society, Fort Worth, Texas.

"Reservoir characterization for infield reserve growth in natural gas reservoirs": presented to the Gas Research Institute, Project Advisors meeting, Denver, Colorado.

"Integrated geologic and engineering analysis for identifying secondary gas in Stratton field": presented to Union Pacific Resources, Fort Worth, Texas.

"Results of the Secondary Natural Gas Recovery project": presented to Maxus Exploration Company, Amarillo, Texas.

"Secondary natural gas recovery: targeted technology applications for infield reserve growth": presented to the Gas Research Institute/U.S. Department of Energy Technical Advisory Committee meeting, Houston and Austin, Texas.

"Applications of secondary gas research in a mature gas field": presented to Pintas Creek Oil Company, Corpus Christi, Texas.

"Results of the Secondary Natural Gas Recovery project: targeted technology applications for infield reserve growth": presented to Union Pacific Resources, Bishop, Texas.

"Historical example of infield natural gas reserve growth": presented to Canadian Hunter Exploration, Ltd., Austin, Texas.

"The Secondary Natural Gas Recovery project: targeted technology applications for infield reserve growth": presented to the Electric Power Research Institute, Austin, Texas.

"Evidence and strategies for infield reserve growth": presented to the International Gas Research Conference, Orlando, Florida.

"Stratigraphic compartmentalization within gas reservoirs: examples from fluvial-deltaic reservoirs of the Texas Gulf Coast": presented to the 33rd annual meeting of the Gulf Coast Association of Geological Societies, Jackson, Mississippi.

F. Jerry Lucia

"Quantification and simulation of carbonate-ramp reservoirs, Algerita Escarpment and Seminole field": presented to Amoco Oil and Gas Company, Houston, Texas.

"An outcrop reservoir model of San Andres clinoform facies, Irabarne Tank, Algerita Escarpment, Guadalupe Mountains, New Mexico": presented to the annual fall meeting of the San Andres-Grayburg Reservoir Characterization Research Laboratory Industrial Associates Group, Carlsbad, New Mexico.

"New approach to describing carbonate reservoirs for input into reservoir simulators for improved recovery planning": presented at the Archie Conference, Galveston, Texas.

"Scales of heterogeneity and fluid flow response in carbonate ramp reservoirs, San Andres outcrop, Algerita Escarpment, New Mexico": presented to the Society of Petroleum Engineers Permian Basin Study Group, Houston, Texas.

"Archie-type petrophysics: the key to integrated multidisciplinary characterization of carbonate reservoirs": presented to the Permian Basin Section of the Society of Professional Well Log Analysts, Midland, Texas.

"Stratigraphic framework and quantification of San Andres outcrop reservoir model": presented to Mobil Research Laboratory, Dallas, Texas.

"What a development geologist contributes to petroleum engineering": presented to The University of Texas at Austin, Department of Petroleum Engineering (PEN 102), Austin, Texas.

"Facies control on multiphase fluid flow in nonfractured carbonate formations": presented to the Austin Geological Society, Austin, Texas.

Richard P. Major

"Reservoir characterization of Keystone field": presented to the State Lands Operators and the Texas General Land Office, Austin, Texas, and to the State Lands Energy Resource Optimization (SLERO) Project review meeting, Houston, Texas.

"Review of The University of Texas at Austin, Bureau of Economic Geology Research Programs": presented to the Texas General Land Office Legal Services Division, Austin, Texas.

"Review of the State Lands Energy Resource Optimization (SLERO) Project": presented to the Texas General Land Office Legal Services Division, Austin, Texas.

"Depositionally and diagenetically controlled reservoir heterogeneity, Jordan (San Andres) field, Ector and Crane Counties, Texas": presented to the University Lands Seminar, Midland, Texas.

Auburn L. Mitchell

"Uses of geophysical devices to assess effects of former brine disposal pits": presented to the Railroad Commission of Texas, Sterling City, Texas.

Robert A. Morton

"Response of Holocene depositional systems tracts to sediment influx, northern Gulf of Mexico": presented to the TAMU-UTIG Gulf of Mexico Synthesis project meeting, Austin, Texas.

"Nearshore studies of the Texas Coast conducted by the Bureau of Economic Geology": presented to The University of Texas at Austin, Marine Science Institute Seminar, Port Aransas, Texas.

"Contrasting styles of deep-water sandstone deposition, offshore Texas": presented to the Minerals Management Service, Third Symposium on Studies Related to Continental Margins—A Summary of Year-Five and Year-Six Activities, Austin, Texas.

Jeffrey G. Paine

"Shallow seismic methods in environmental and hydrogeological studies": presented to The University of Texas at Austin, Department of Geological Sciences, Austin, Texas.

Virginia M. Pendleton

(with **Rick D. Edson** and **Bob A. Hardage**)

"Interpretation of a fluvial depositional system using 3-D seismic horizon amplitude images": presented to Sierra Geophysics, Inc., Seventh Annual Software Users Meeting, Houston, Texas.

Jay A. Raney

"Geologic setting and site characterization of the Texas Low-Level Radioactive Waste Repository, Trans-Pecos Texas": presented to State of Vermont legislators and state officials, Montpelier, Vermont.

"Update and progress report, on site characterization activities, Hudspeth County, Texas": presented to Board of Directors, Texas Low-Level Radioactive Waste Disposal Authority, Sierra Blanca, Texas.

"Geology of earth fissures, Trans-Pecos Texas": presented to the U.S. Department of Energy, Vadose Zone Forum, Austin, Texas.

"Earthquakes and recent tectonics, Trans-Pecos Texas": presented to the Texas Low-Level Radioactive Waste Disposal Authority, Citizens Advisory Committee, Sierra Blanca, Texas.

"Geologic and hydrologic setting of the proposed Texas site for a low-level radioactive waste repository, Hudspeth County, Texas": presented to the Texas Low-Level Radioactive Waste Disposal Authority and State Geologist of Vermont, Austin, Texas.

"Site characterization studies and geologic and hydrogeologic framework of the proposed Texas site for a low-level radioactive waste repository, Hudspeth County, Texas": presented to the Vermont Agency of Natural Resources, the Vermont Attorney General's Office, and Vermont legislators, Montpelier, Vermont.

Stephen C. Ruppel

"Controls on reservoir development in Silurian and Devonian carbonates in West Texas with an example from the Three Bar field": presented to the University Lands Seminar, Midland, Texas.

Bridget R. Scanlon

"Numerical simulations of unsaturated flow in semiarid systems": presented to The University of Arizona at Tucson, Department of Hydrology, Tucson, Arizona.

"Evaluation of moisture flux in semiarid soils": presented to The University of Nevada at Reno, Department of Geology, Reno, Nevada.

"Preferential flow in fissured sediments related to site characterization of a low-level radioactive waste disposal facility in Texas": presented at the INTRAVAL workshop, Las Cruces, New Mexico.

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

Daniel D. Schultz-Ela

"Evidence for early salt deformation of Upheaval Dome, Utah": presented to Exxon Production Research, Houston, Texas.

"Structural geology of Upheaval Dome, Utah": presented to Exxon Production Research, Houston, Texas.

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

"Introduction to GEOSIM-2D numerical modeling": presented to The University of Texas at Austin, Bureau of Economic Geology, Industrial Associates of the Applied Geodynamics Laboratory, Austin, Texas.

"Initiation of grabens triggering reactive diapirs": presented to The University of Texas at Austin, Bureau of Economic Geology, Industrial Associates of the Applied Geodynamics Laboratory, Austin, Texas.

"Reactive piercement of diapirs during extension": presented to The University of Texas at Austin, Bureau of Economic Geology, Industrial Associates of the Applied Geodynamics Laboratory, Austin, Texas.

"Transition from reactive to active diapirism": presented to The University of Texas at Austin, Bureau of Economic Geology, Industrial Associates of the Applied Geodynamics Laboratory, Austin, Texas.

"Finite element modeling of concurrent brittle and ductile deformation": presented to The University of Texas at Austin, Department of Geological Sciences (Geology 380C), Austin, Texas.

Steven J. Seni

"Colocation of geothermal and heavy-oil resources in South Texas": presented to U.S. Department of Energy, Salt Lake City, Utah.

Diane M. Spinney

"Geographic Information System at BEG: past, present, and future capabilities": presented to The University of Texas at Austin, Bureau of Economic Geology, Austin, Texas.

Douglas B. Swift

"Consulting as an alternative for the recently unemployed: data bases, services, contracts, ethics, and responsibilities": presented to The University of Texas of the Permian Basin, Center for Energy and Economic Diversification, Midland, Texas.

Noel Tyler

"Potential for reserve growth through detailed reservoir characterization—examples from outcrops and subsurface in Texas": presented to Intevep, Caracas, Venezuela.

"Outcrop quantification of permeability structure in seaward stepping deltaic systems": presented to Intevep, Caracas, Venezuela.

"Outcrop characterization of deltaic reservoir heterogeneity, Ferron Sandstone, Utah, U.S.A.": presented to Petrobras Research Center, Rio de Janeiro, Brazil.

"Comparative permeability structure in seaward versus landward stepping delta systems, Ferron Sandstone, Utah": presented to UNOCAL Exploration Science Technology Seminar, Brea, California.

"Reservoir geology, reserve growth, and recovery efficiency: new case studies from the Permian Basin and Gulf Coast": presented to the U.S. Geological Survey petroleum geology seminar, Denver, Colorado.

"Oil reserve growth": presented to the Texas Independent Producers and Royalty Owners Association annual meeting, Fort Worth, Texas.

"Characterization of sandstone reservoirs": presented to Santos, Ltd., Adelaide, Australia.

"Architecture and permeability structure in retrogradational deltaic systems: implications for reserve growth in Lake Maracaibo reservoirs": presented to Intevep, Caracas, Venezuela.

"Assessing risk in infill drilling in deltaic reservoirs": presented to the 1992 Gas Research Institute Geoscience Contractors review meeting, Houston, Texas.

Roger Tyler

"Cyclic sedimentation in the Malmani Dolomite Subgroup, Eastern Transvaal, South Africa": presented to

The University of Texas at Austin, Bureau of Economic Geology, Carbonate Rock Colloquium, Austin, Texas.

Bruno C. Vendeville

"Kinematics and dynamics of extensional salt diapirs": presented to The University of Texas at Austin, Institute for Geophysics, Gulf of Mexico Structural and Stratigraphic Synthesis Project, Austin, Texas.

"The rise and fall of diapirs during thin-skinned extension": presented to Texas A&M University, Center for Tectonophysics, College Station, Texas.

"Five short stories about experimental salt tectonics": presented to Shell Offshore, Inc., New Orleans, Louisiana.

"Control on welding and rates of passive diapirism": presented to The University of Texas at Austin, Bureau of Economic Geology, Industrial Associates of the Applied Geodynamics Laboratory, Austin, Texas.

"Mechanics of salt flow during basement faulting": presented to The University of Texas at Austin, Bureau of Economic Geology, Industrial Associates of the Applied Geodynamics Laboratory, Austin, Texas.

"Critical roof thickness over active diapirs": presented to The University of Texas at Austin, Bureau of Economic Geology, Industrial Associates of the Applied Geodynamics Laboratory, Austin, Texas.

"Kinematic analysis of listric normal faults": presented to The University of Texas at Austin, Bureau of Economic Geology, Industrial Associates of the Applied Geodynamics Laboratory, Austin, Texas.

E. G. Wermund

"The Bureau of Economic Geology Geophysical Log Library": presented to the Petroleum Industry Action Committee and the Association of Records Managers and Administrators, Austin, Texas.

"The Bureau of Economic Geology": presented to managers from the Hungary Department of Mining and Economics, Austin, Texas.

"Bureau of Economic Geology resources for teachers": presented to Round Rock Independent School District science teachers (K through 12), Austin, Texas.

Bureau of Economic Geology Seminars

M. Saleem Akhter

(and **Arten J. Avakian**) "Attempts to locate reservoir compartments using geology and production data, Chocolate Bayou field—Texas Gulf Coast"

William A. Ambrose

(and **Roger Tyler**) "Structural and stratigraphic controls of coalbed methane in the Greater Green River, Piceance, Powder River, and Raton Basins"

Arten J. Avakian

(and **M. Saleem Akhter**) "Attempts to locate reservoir compartments using geology and production data, Chocolate Bayou field—Texas Gulf Coast"

Don G. Bebout

"Carbonate facies along the Permian Reef Geology Trail, McKittrick Canyon, Guadalupe Mountains National Park, West Texas"

Mark J. Burn

"Controls on the anisotropy and variability of fluvial reservoir analogues from the Pennsylvanian of eastern Kentucky"

Sigrid J. Clift

(and **Stephen E. Laubach**) "Advancements in sandstone analysis through axial point-load testing"

Alan R. Dutton

"Paleohydrology of the nonglaciated Great Plains: isotopic evidence and age dating"

"Summary of ground-water investigations at the Superconducting Super Collider (SSC) Site, North Texas"

Shirley P. Dutton

"Influence of provenance and burial history on diagenesis of the Frontier Formation, Green River Basin, Wyoming"

Robert L. Folk

"Bacterial precipitation of carbonate in hot springs, oolites, ancient limestones, and sandstone cements"

Alan E. Fryar

"The geochemical and hydraulic evolution of reaction fronts in sand columns"

Michael H. Gardner

"Sequence stratigraphy of eolian-derived turbidites: patterns of deep-water sedimentation along an arid carbonate platform, Permian (Guadalupian) Delaware Mountain Group, West Texas"

L. Edwin Garner

"Status of the Geophysical Log Facility"

James C. Gibeaut

"Morphodynamic classification, evolution, and modeling of unstructured inlets in west-central Florida"

"Beach and nearshore pollution from the Exxon *Valdez* oil spill—two and three years after"

Thomas C. Gustavson

"Tertiary and Quaternary stratigraphy and paleoclimate of the Southern Great Plains, Texas and New Mexico"

Douglas S. Hamilton

(and Carl Fiduk) "Assessment of Paleocene and Eocene strata in the Duval County Ranch area, South Texas, using integrated geologic and geophysical methods—discovery of new oil and gas potential"

Tucker F. Hentz

"Evidence for eustatic and tectonic control on the sequence stratigraphy of the Upper Pennsylvanian Cleveland Formation, western Anadarko Basin"

Susan D. Hovorka

"Cyclic sedimentation in deep-water shelf facies of the Austin Chalk"

Mary L. W. Jackson
"Gas reserve growth potential from infield drilling in Tertiary reservoirs, South Texas"

William R. Kaiser
(and **Andrew R. Scott**) "Hydrology of coalbed gases and thermal maturity of coals in the western United States"

Richard P. Langford
"Architecture of Middle Frio fluvial deposits"

Stephen E. Laubach
(and **Sigrid J. Clift**) "Advancements in analysis of subsurface fractures through point-load testing"

Raymond A. Levey
"Clues, techniques, and strategies for maximizing infield reserve growth of natural gas reservoirs"

F. Jerry Lucia
"Cause and control for location of remaining mobile oil in carbonate ramp reservoirs"

Robert E. Mace
"Hydrology of the near-surface Austin Chalk and Taylor Marl in the vicinity of the Superconducting Super Collider (SSC) site"

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

J. Ulises Ricoy
"Relationships between well log and production parameters: an efficient approach for reservoir flow characterization: Lavaca Bay field"

Daniel D. Schultz-Ela
"Numbers and nature: finite element modeling of geologic structures"

Andrew R. Scott
(and **William R. Kaiser**) "Hydrology of coalbed gases and thermal maturity of coals in the western United States"

Roger Tyler
(and **William A. Ambrose**) "Structural and stratigraphic controls of coalbed methane in the Greater Green River, Piceance, Powder River, and Raton Basins"

Congressional, Legislative, and Special Testimony

William L. Fisher
"Statement on President's economic plan and tax proposals": presented to the Finance Committee, Lloyd Bentsen, Chairman, U.S. Senate, Washington, D.C.

"Statement to Committee on Applied Research Needs Relative to Extraction and Processing of Oil and Gas": presented to the National Research Council, Dallas, Texas.

Committee Services, Offices, and Other Professional Responsibilities

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

Edward W. Collins
Co-leader of field trip: "Faults and fractures of the Balcones Fault Zone, Central Texas," Symposium on Studies Related to Continental Margins, Austin, Texas.

Kenneth M. Duncan
Board of Directors, Austin Macintosh Developers Association.
Member, Base Map Requirements Definition Team, GIS Planning Council.

Alan R. Dutton
Editor, *The Hydrogeologist*.

Shirley P. Dutton
Chairman, Program Committee, Gulf Coast Association of Geological Societies 1994 Annual Meeting.
Member, Grants-in-Aid Committee, American Association of Petroleum Geologists.
Member, Joint Technical Program Committee, Geological Society of America.
Member, Nominating Committee, SEPM (Society for Sedimentary Geology).
Member, Steering Committee, Gulf Coast Association of Geological Societies.

Robert J. Finley
Chairman, Technology Realization Subcommittee, Outlook Committee, State of Texas Energy Policy Partnership (STEPP), Railroad Commission of Texas.
Member, Committee on Development Geology, American Association of Petroleum Geologists.
Member, Source and Supply Task Group, Natural Gas Study, National Petroleum Council.
Member, Reserve Appreciation Subgroup, Source and Supply Task Group, Natural Gas Study, National Petroleum Council.
Member, Technology Subgroup, Source and Supply Task Group, Natural Gas Study, National Petroleum Council.
Member, Historical Review Group, Source and Supply Task Group, Natural Gas Study, National Petroleum Council.
Member, Committee on Publications, American Association of Petroleum Geologists.

R. Stephen Fisher
Member, Committee on Hydrogeology and Environmental Geology, SEPM (Society for Sedimentary Geology).
Co-leader of two field trips, "Architecture and Permeability Structure of Fluvial-Deltaic Sandstones" and "Ferron Sandstone, East-Central Utah."

William L. Fisher
Director, Geology Foundation, The University of Texas at Austin.

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

President-Elect, American Institute of Professional Geologists.

Vice President, Gulf Coast Association of Geological Societies.

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

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

Chairman, Oil Resources Panel, U.S. Department of Energy.

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

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

Chairman, Audit Committee, Geological Society of America.

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

Chairman, Advisory Council, American Institute of Professional Geologists.

Councilor, Geological Society of America.

Representative to the International Union of Geological Sciences, American Association of Petroleum Geologists.

Foundation Trustee, American Geological Institute.

Trustee, Southwest Research Institute.

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.

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, Natural Gas 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 and Gas Compact Commission.

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, Secretary of Energy Advisory Board, U.S. Department of Energy.

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

Member, Editorial Advisory Board, Offshore.

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

Member, State of Texas Energy Policy Partnership, Co-chairman, Outlook Committee.

Member, Potential Resources Committee, Independent Petroleum Association of America.

William E. Galloway

Graduate advisor, Department of Geological Sciences, The University of Texas at Austin.

Michael H. Gardner

Co-chairman, poster sessions, "Mesozoic of the Western Interior" theme meeting, SEPM (Society for Sedimentary Geology), central Utah and Fort Collins, Colorado.

Co-leader of field trip, "Architecture and permeability structure of fluvial-deltaic sandstones within a sequence stratigraphic framework," Bureau of Economic Geology Industrial Associates, central Utah.

Co-leader of field trip, "Architecture and permeability structure of fluvial-deltaic sandstones within a sequence stratigraphic framework," SEPM (Society for Sedimentary Geology) theme meeting, "Mesozoic of the Western Interior," central Utah.

Co-leader of field trip, "Architecture and permeability structure of fluvial-deltaic sandstones within a sequence stratigraphic framework," Statoil, Norsk Hydro, and Saga Oil, central Utah.

Chester M. Garrett, Jr.

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

Member, Ad Hoc Nominating Committee, Austin Geological Society.

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

Thomas C. Gustavson

Co-chairman, Geomorphology session, Geological Society of America National Meeting, Cincinnati, Ohio.

Douglas S. Hamilton

Chairman, Membership Committee, Austin Geological Society.

H. Scott Hamlin

Co-leader of field trip, "Fractures in Frontier Formation," Wyoming Geological Association/American Association of Petroleum Geologists, Southwestern Wyoming.

Bob A. Hardage

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

Member, Organizing Committee, Society of Exploration Geophysicists Research Forum.

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

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

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

Member, Visiting Committee, Department of Petroleum Engineering, The University of Texas at Austin.

Mark H. Holtz

Member, Computer Applications Committee, Society of Petroleum Engineers.

Martin P. A. Jackson

Associate Editor, Geological Society of America *Bulletin*.

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

Member, International Union of Geological Sciences Commission on Tectonics.

Mary L. W. Jackson

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

Judge, Poster and Core Session, Gulf Coast Association of Geological Societies Convention, Jackson, Mississippi.

Charles Kerans

Co-leader of field trip, "High-resolution sequence stratigraphy and reservoir characterization of ramp-crest to inner ramp facies tracts, San Andres sequences 4 and 5," San Andres-Grayburg Reservoir Characterization Research Laboratory, Carlsbad, New Mexico.

Leader of field trip, "Carbonate sequence stratigraphy and depositional facies, Guadalupian of the Guadalupe Mountains," Fina Oil and Chemical Company, New Mexico and Texas.

Stephen E. Laubach

Co-convenor, Gas Research Institute/Bureau of Economic Geology Natural Fracture Workshop.

Member, Local Organizing Committee and Program Committee, 35th U.S. Symposium on Rock Mechanics.

Member, Program Committee, Society of Petroleum Engineers Joint Rocky Mountain Regional and Low-Permeability Reservoir Symposium.

Co-leader of field trip, "Fractures in Frontier Formation," Wyoming Geological Association/American Association of Petroleum Geologists, southwestern Wyoming.

Co-leader of field trip, "Faults and fractures in the Balcones fault zone, Austin region, Central Texas," Continental Margins Symposium, Austin, Texas.

Raymond A. Levey

Co-convenor, Core, log, and Reservoir workshop, Society of Professional Well Log Analysts, 33rd annual meeting.

F. Jerry Lucia

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

Co-leader of field trip, "Paleokarst, Karst-Related Diagenesis, and Reservoir Development: Examples from Ordovician-Devonian Age Strata of West Texas and the Mid-Continent," Permian Basin Section, SEPM (Society for Sedimentary Geology).

Richard P. Major

President, Austin Geological Society.

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

Associate Editor for Book Reviews, American Association of Petroleum Geologists.

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

Judge, Evolution of Pore Systems of Carbonate Rocks with Progressive Burial session, SEPM (Society for Sedimentary Geology), American Association of Petroleum Geologists, 1992 annual meeting.

Amanda R. Masterson

Publications Manager, Geoscience Information Society.

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, Meetings Policy Committee, SEPM (Society for Sedimentary Geology).

Member, Committee on Conventions, American Association of Petroleum Geologists (SEPM representative).

Member, Louisiana Coastal Land Loss Classification Committee, Louisiana Geological Survey in cooperation with the U.S. Geological Survey and Argonne National Laboratory.

Leader of field trip, "Coastal land loss and public policy: examples from Galveston Island," U.S. Department of the Interior, Minerals Management Service OCS Public Policy Committee, Galveston, Texas.

Jay A. Raney

Leader of field trip, "Tectonic development, stratigraphy, and regional setting of southern Hudspeth County, Texas," agencies of the State of Vermont: Low-Level Radioactive Waste Disposal Authority, Agency of Natural Resources, and Attorney General's Office, Hudspeth County, Texas.

Co-leader of field trip, "Earth fissures of the Fort Hancock-Sierra Blanca area, Hudspeth County, Texas," INTRAVAL meeting, Las Cruces, New Mexico.

Co-leader of field trip, "Geologic setting of the proposed Texas site of a low-level radioactive waste repository, Hudspeth County, Texas," U.S. Department of Energy, Vadose Zone Forum, Hudspeth County, Texas.

Texas representative, U.S. Department of Energy State and Tribal Government Working Group, Dallas, Texas; Denver, Colorado; and San Francisco, California.

Texas representative, U.S. Department of Energy, RCRA Workshop.

Member, Technology Transfer Committee, U.S. Department of Energy State and Tribal Government Working Group.

Stephen C. Ruppel

Chairman, Publications Committee, Austin Geological Society.

Carol L. Ruthven

Member, Outlook Committee, State of Texas Energy Policy Partnership (STEPP), Railroad Commission of Texas.

Steven J. Seni

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

Chairman, Field Trip Committee, Austin Geological Society.

Diane M. Spinney

Member, Base Map Requirements Definition Team, GIS Planning Council.

Douglas B. Swift

Chairman, Reprint Series Committee, West Texas Geological Society.

Chairman, West Texas–New Mexico Future Reserves Evaluation Committee, American Association of Petroleum Geologists.

Judge, Technical Papers, 1992 annual meeting, Southwest Section, American Association of Petroleum Geologists.

Member, Stratigraphic Problems Committee, West Texas Geological Society.

Member, Environmental Issues Committee, Division of Environmental Geosciences, American Association of Petroleum Geologists.

Noel Tyler

Member, Delphi Panel Assessment of U.S. Oil Resources, Austin, Texas.

Co-leader of field trip, "Architecture and permeability structure of fluvial-deltaic sandstones within a sequence stratigraphic framework," Bureau of Economic Geology Industrial Associates, central Utah.

Co-leader of field trip, "Architecture and permeability structure of fluvial-deltaic sandstones within a sequence stratigraphic framework," SEPM (Society for Sedimentary Geology) theme meeting, "Mesozoic of the Western Interior," central Utah.

Co-convenor, American Association of Petroleum Geologists Eastern Section Symposium, "Advances in Reservoir Characterization," Champaign, Illinois.

Convenor, Oil Reserve Growth Technology Transfer School, Texas Independent Producers and Royalty Owners Association, Austin, Texas.

Member, Graduate Admissions Committee, Department of Geological Sciences, The University of Texas at Austin.

Member, External Advisory Committee, Center for Research on Parallel Computation, Rice University, Houston, Texas.

Roger Tyler

Coordinator and co-convenor, Gas Research Institute/ Bureau of Economic Geology Natural Fracture Workshop.

Coordinator, Carbonate Rock Sampling Field Excursion, Eastern Transvaal, South Africa.

Bruno C. Vendeville

Chairman, Fault Mechanics and Structural Development Poster Session, American Geophysical Union, 1992 Spring meeting.

Member, Editorial Board, *Tectonophysics*.

E. G. Wermund

Chairman, Core and Sample Committee, Association of American State Geologists.

Chairman, Operations Review Committee, Texas Natural Resources Information System Task Force.

Chairman, Physical Habitat and Living Resources Subcommittee, Scientific and Technical Advisory Committee, Galveston Bay National Estuary Program.

Co-chairman and Representative for Texas, Gulf of Mexico Regional Technical Working Group, Minerals Management Service, U.S. Department of the Interior.

Vice-Chairman, Texas Natural Resources Information System Task Force.

Member, Texas Mapping Advisory Committee.

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

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

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

Member, Committee to Draft a Geographic Information System Data Dictionary, Texas General Land Office and Department of Information Resources.

Member, Membership Committee, Geological Society of America.

Member, UCAR Committee, The University of Texas at Austin.

William A. White

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

Member, Coastal Dredging Policy Subcommittee, Coastal Coordination Executive Committee.

University Teaching/ Continuing Education

Don G. Bebout

"Carbonate field seminar—Lower Cretaceous platform carbonates, Central Texas—surface to subsurface": co-lecturer of short course presented to American Association of Petroleum Geologists, Field Seminar Series, San Antonio and Austin, Texas.

"Contrasting depositional styles in Grayburg reservoirs: Dune field (Central Basin Platform) and Farmer field (Ozona Arch) and implications for future development": presented in the continuing education seminar "Strategies for Advanced Oil Recovery in the Permian Basin: Targeting the Remaining Resource," Midland, Texas.

Robert J. Finley

"Gas reserve growth": presented to the Texas Independent Producers and Royalty Owners Association Technology Transfer School, Austin, Texas.

William E. Galloway

"Depositional systems and sequences": two-day short course given at 11th Australian Geological Congress, Ballarat, Australia.

"Depositional systems and sequences": two-day lecture series given at School of Earth Sciences, Stanford University, Stanford, California.

Jeffry D. Grigsby

"Reservoir properties from core and log analysis of Gulf Coast sandstones": co-lecturer of short course presented to the Society of Professional Well Log Analysts, Oklahoma City, Oklahoma.

"Infield gas reserve growth potential: Gulf Coast sandstone reservoirs": co-lecturer of short course presented to the Houston Geological Society, Houston, Texas, and the Corpus Christi Geological Society, Corpus Christi, Texas.

H. Scott Hamlin

"Geology of the Canyon sands tight gas reservoirs, Val Verde Basin": co-lecturer of short course presented to the

Gas Research Institute and the Society of Petroleum Engineers, Canyon Sands Workshop, Midland, Texas.

"Stratigraphy and diagenesis of Frontier Sandstone, Moxa Arch, western Green River Basin": co-lecturer of short course presented to the Gas Research Institute and the Society of Petroleum Engineers, Frontier Formation Workshop, Casper, Wyoming.

Bob A. Hardage

"Exploration strategies": short course presented to Texas independent operators, Austin, Texas.

"Geophysical techniques for imaging heterogeneous Frio gas reservoirs": GRI-sponsored short course presented at Houston, Midland, Corpus Christi, and San Antonio, Texas, and New Orleans, Louisiana.

Mark H. Holtz

"Assessment of hydrocarbon resources on University Lands: future reserve growth potential": presented in the continuing education seminar "Strategies for Advanced Oil Recovery in the Permian Basin: Targeting the Remaining Resource," Midland, Texas.

"Geologic facies and lithology controls on porosity, permeability, and oil production in McFarland/Magutex (Queen) reservoirs, University Lands, West Texas": presented in the continuing education seminar "Strategies for Advanced Oil Recovery in the Permian Basin: Targeting the Remaining Resource," Midland, Texas.

Martin P. A. Jackson

"Advanced salt tectonics": short course presented to the New Orleans Geological Society, New Orleans, Louisiana; AGIP S.p.A, Milan, Italy; and British Petroleum Exploration, Houston, Texas.

"Structural and depositional styles of Gulf Coast Cenozoic continental margins": co-lecturer of short course presented to Texaco, Inc., New Orleans, Louisiana.

William R. Kaiser

"Coalbed methane: depositional, hydrologic, and petrologic controls on reservoir characteristics of coal beds": co-lecturer of short course presented to the American Association of Petroleum Geologists, Energy Minerals Division, 1992 annual convention, Calgary, Alberta, Canada.

Charles Kerans

"High-frequency sequence and cycle stratigraphy for description of Clearfork, San Andres, and Grayburg carbonate reservoirs": short course presented (with Stephen C. Ruppel) to the Permian Basin Graduate Center, Midland, Texas.

"Recognition and correlation of high-frequency cyclicity in mixed clastic-carbonate sequences": short course presented to the San Andres-Grayburg Reservoir Characterization Research Laboratory, Industrial Associates Group, Carlsbad, New Mexico.

"Impact of advanced geological characterization studies on Ellenburger reserve growth: current activities and future directions": presented in the continuing education seminar "Strategies for Advanced Oil Recovery in the Permian Basin: Targeting the Remaining Resource," Midland, Texas.

Richard P. Langford

"Reservoir properties from core and log analysis of Gulf Coast sandstone reservoirs": co-lecturer of short course presented to the Society of Professional Well Log Analysts, Oklahoma City, Oklahoma.

Raymond A. Levey

"Reservoir properties from core and log analysis of Gulf Coast sandstone reservoirs": co-lecturer of short course presented to the Society of Professional Well Log Analysts, Oklahoma City, Oklahoma.

"Infield gas reserve growth potential: Gulf Coast sandstone reservoirs": co-lecturer of short course presented to the Houston Geological Society, Houston, Texas; the Corpus Christi Geological Society, Corpus Christi, Texas; Oxy, U.S.A., and the West Texas Geological Society, Midland, Texas; the South Texas Geological Society, San Antonio, Texas; and the New Orleans Geological Society, New Orleans, Louisiana.

F. Jerry Lucia

"Use of geological/petrophysical reservoir descriptions to avoid financial hardship: Taylor Link (San Andres) field": presented in the continuing education seminar "Strategies for Advanced Oil Recovery in the Permian Basin: Targeting the Remaining Resource," Midland, Texas.

"Carbonate reservoir geology": short course presented to the Southwest Section, American Association of Petroleum Geologists, Midland, Texas.

Richard P. Major

"Depositionally and diagenetically controlled reservoir heterogeneity, Jordan (San Andres) field, Ector and Crane Counties, Texas": presented in the continuing education seminar "Strategies for Advanced Oil Recovery in the Permian Basin: Targeting the Remaining Resource," Midland, Texas.

Robert A. Morton

"Coastal land loss": co-lecturer of short course presented to the Maine Geological Society, Portland, Maine.

"Exploring a barrier island system": 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

"High-frequency sequence and cycle stratigraphy for description of Clear Fork, San Andres, and Grayburg carbonate reservoirs": short course presented (with Charles Kerans) to the Permian Basin Graduate Center, Midland, Texas.

"Characterization of Silurian and Devonian reservoirs on University Lands with an example from Three Bar Field": presented in the continuing education seminar "Strategies for Advanced Oil Recovery in the Permian Basin: Targeting the Remaining Resource," Midland, Texas.

Noel Tyler

"Oil reserve growth": presented to the Texas Independent Producers and Royalty Owners Association Technology Transfer School, Austin, Texas.

"Characterization of heterogeneous reservoirs": presented to the Federal University of Ouro Preto, Ouro Preto, Brazil.

"Unraveling the architecture of heterogeneous reservoirs—problems and promise for increased hydrocarbon recovery": presented to The University of Texas at Austin, Department of Petroleum Engineering, Graduate Seminar, Austin, Texas.

Support Staff

Administrative/Secretarial

The general administration of the Bureau, including personnel, accounting, publication sales, purchasing and vouchering, travel, reception/switchboard, 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 3,610 appointment forms each year to properly allocate staff time among funding sources. In addition, this section controls more than $5 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 a good reputation for producing high-quality products but is best known for the full-color maps produced in support of Bureau projects.

The section's 14-person full-time staff, directed by Richard L. Dillon, chief cartographer, produced 5 black-and-white plates, 14 full-color maps, 2,100 text figures, and 1,800 visual aids in 1992. All items produced by this staff are published in Bureau publications, as contract reports and articles in professional journals, or used in presentations at local and national 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 at the Bureau. Currently, one DOS-based PC is used to produce slides and five Macintoshes are used to produce posters, slides, and text figures. We are adding a VXT 19-inch X-Terminal that is connected to a DECstation 5000 workstation that will run ARC/INFO software in a UNIX environment for producing digital maps. Training and the acquisition of a digitizing table will be coming soon.

Computer Resources

The Computer Resources staff provides three types of service to research, administrative, and support personnel: system services (facilities and hardware, operations and software), user education and consulting, and systems analysis and programming. The section supports programming and data base applications on Bureau computers (a VAX-VMS cluster, two ULTRIX workstations, three UNIX workstations, more than 80 networked personal computers, and 20 high-quality output devices), the University's IBM computers, and the Center for High Performance Computing Cray system.

In 1992, under the supervision of Kenneth M. Duncan, manager of this section, the Computer Resources staff added a new DECstation 5000, an SGI IRIS Indigo workstation, and an SGI Indigo ELAN workstation. The DECstation's primary function is to expand the Bureau's Geographic Information System (GIS) capabilities. New GIS capabilities also include ARC/INFO and ArcView software. The Indigo workstation is primarily dedicated to numerical modeling. The Indigo ELAN workstation is used for reservoir modeling and visualization. Three new 486 PC-based workstations were added to support computer mapping and digitizing, geophysical modeling, and oil simulation. The staff continued to upgrade, improve, and market *Restore*©, a Macintosh program that enables geoscientists to sequentially backstrip and balance cross sections from extensional terranes. The staff completed a publication sales and inventory system and ChargeBack©, a Macintosh-based chargeback system for personal computers. Significant progress was also made on (1) implementation of an inventory control data base and (2) expansion of networking capabilities.

Publications

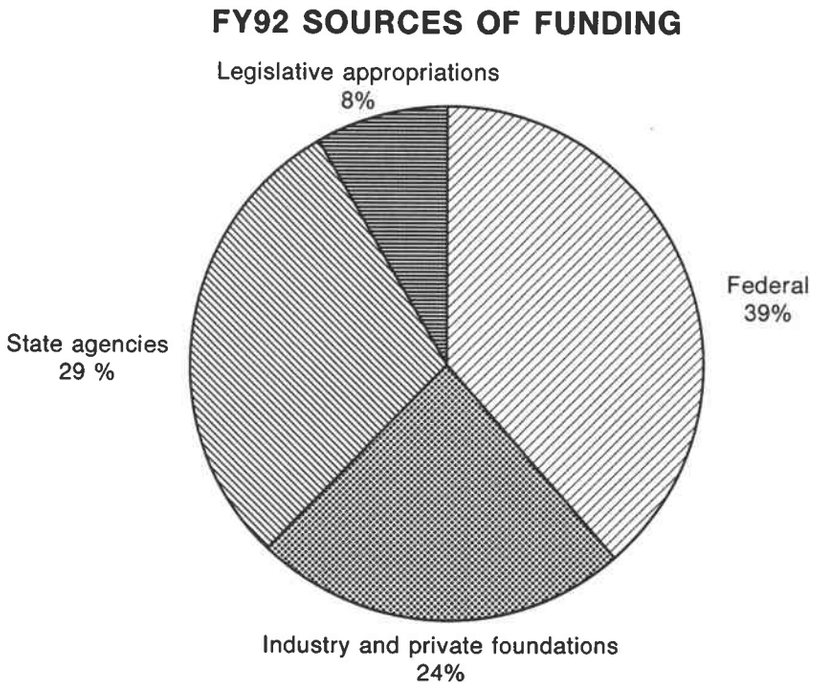
The Publications staff, consisting of word processor/typesetter operators, proofreaders, editors, and designers, produces a variety of printed materials for the Bureau. Susann Doenges, Editor-in-Charge, supervised the section until her promotion to Assistant Director in September, at which time Amanda Masterson became Editor-in-Charge. In addition to producing Bureau publications, the staff also prepares contract reports, papers and abstracts, and various documents in support of research projects. Most reports published by the Bureau are now produced through desktop publishing technology. Manuscripts are revised electronically, and pages are prepared for the printer through layout programs. This year 14 new publications were issued by the Bureau. Twenty-four contract reports were also completed, and 218 papers and abstracts by Bureau authors were published by professional journals and publishers.

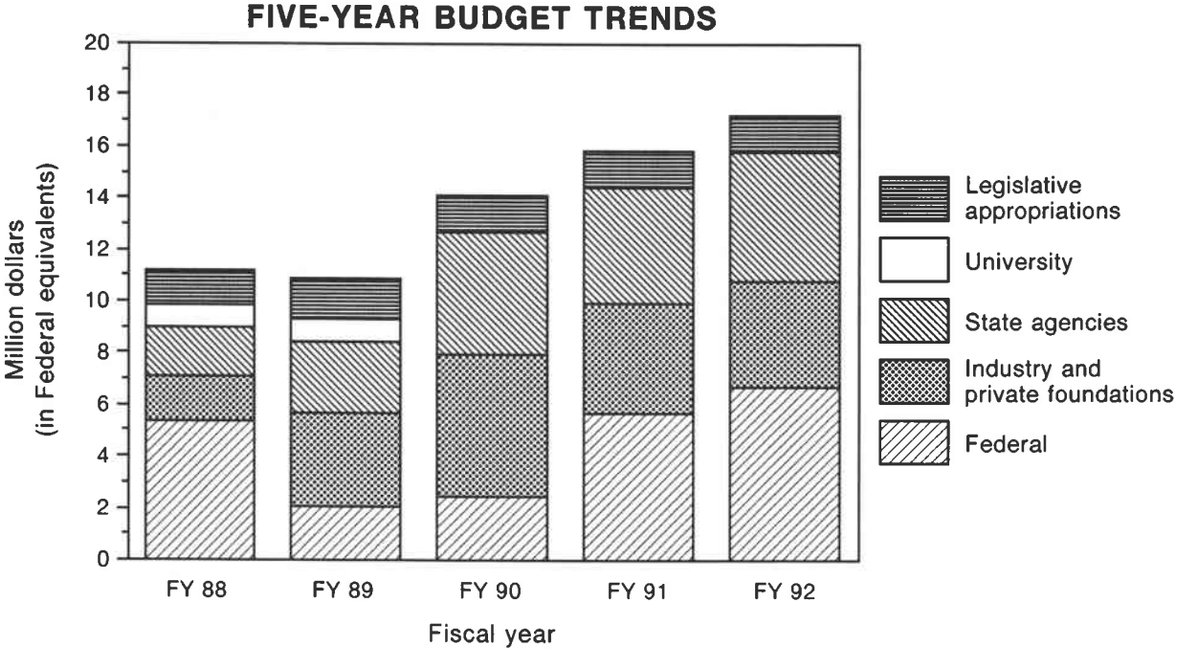
Quality Assurance

The Bureau of Economic Geology has maintained a formal quality assurance program since 1979. The program is documented in written instructions that address research activities, analytical procedures, and methods for verifying and documenting the achievement of quality. The Bureau's quality assurance program conforms to requirements and standards contained in the Texas Constitution, Article XVI, Section 59(a); 10 CFR Part 50, Appendix B; 10 CFR Part 61; ANSI/ASME NQA-1; NUREG-0856; NUREG-1199; NUREG-1293; and NUREG-1383. The program also meets requirements promulgated by the U.S. Department of Energy and U.S. Environmental Protection Agency.

During 1992, quality assurance personnel participated in four Bureau research projects: Geologic Studies of West Texas Bedded Salt Deposits; Geologic and Hydrologic Studies of the Eagle Flat Area–Phase II; Comprehensive Hydrogeologic Investigations of Regional Ground-Water Flow and Ground-Water Resources, Ellis County Area, North Texas; and Geologic and Hydrologic Characterization of the Pantex plant. The Bureau's quality assurance manager also assisted the Texas Low-Level Radioactive Waste Disposal Authority in developing and implementing their quality assurance program.

Sources of Funding and Budget Trends





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