Annual Report 1986

Bureau of Economic Geology

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Foreword

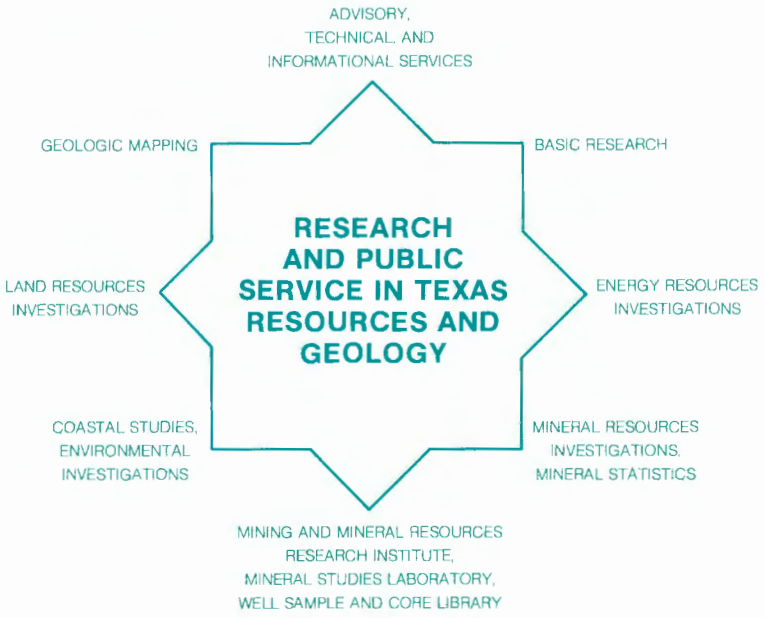
The Bureau of Economic Geology, established in 1909 as the successor to the Texas Geological Survey and the Texas Mineral Survey, is a research entity of The University of Texas at Austin. It also functions as the State Geological Survey, a quasi-State agency, and the Bureau Director represents Texas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

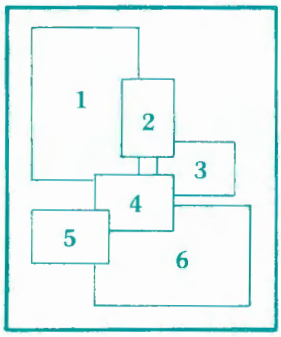
Extensive advisory, technical, and informational services relating to the resources and geology of Texas are provided by the Bureau. In addition, the Bureau conducts basic and applied research projects in energy resources, mineral resources and statistics, coastal and environmental studies, land resources, 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 Special 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.





On the cover—From field work to publication, an example from the hydrogeology of the Dockum aquifer in the Texas Panhandle: 1. Dockum sandstone overlying mudstone is exposed in Tierra Blanca Creek. 2. Water samples are obtained from pumping well. 3. Eh and pH are measured at the well site. 4. Chemical and isotopic compositions of water are determined in the laboratory. 5. Interpretive cross section shows hydrostratigraphic distribution of isotopic values. 6. The final product is a report on the hydrogeochemistry and water resources of the Triassic Lower Dockum Group.

Cover design by Margaret L. Evans; photographs by William W. Simpkins (1, 2), Alan R. Dutton (3), James A. Morgan (4), and Raquelle Smalley Keegan (6).

Annual Report

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Research

Bureau of Economic Geology research is aimed chiefly at near- and intermediate-term concerns in the area of natural resources. Probably the two most critical areas for an industrial state and nation are the safe and secure disposal of waste products and the means of realizing sufficient production of energy resources. Of the 38 research programs pursued in 1986, 8 dealt with isolation and disposal of waste products and 15 concerned energy resources, especially oil and gas.

The total number of Bureau research projects conducted in 1986 rose to 38 compared with 35 reported in 1985. A new project was added to petroleum research, replacing one that was completed in 1985. Another research project was added to studies of conventional gas. One new program was added to research into the aspects of waste disposal. For the first time in several years the Bureau added a new areal mapping program. Furthermore, a major research initiative to drill a 40,000-ft borehole for continental crust research was proposed in 1986.

The newest addition to petroleum-related research is a reservoir characterization research laboratory committed to improving recovery from poorly productive West Texas reservoirs. Advanced reservoir characterizations will originate from recently completed genetic stratigraphic studies of the very fine grained sandstone reservoirs of the Spraberry Trend of the Midland Basin. Sponsors of this industrial associates research program are ARCO, Exxon, Mobil, Standard Oil, and Texaco.

Preparation of an atlas of major Texas gas reservoirs and analysis of gas reservoir heterogeneity were initiated under a project jointly funded by the Bureau and the Gas Research Institute. The gas atlas will define the contribution of various types of reservoirs to current production and will group these reservoirs into genetically related plays, provide a baseline for future trends in reserve additions and reserve growth, and extend to gas some of the methodologies for resource analysis that were initiated with the Bureau's *Atlas of Major Texas Oil Reservoirs*.

A new project, funded by the Texas Water Development Board, is a geologic and hydrologic study of the Edwards aquifer along the Balcones Fault Zone in the vicinity of Georgetown, Texas. Assessing the potential for water pollution in the poorly defined recharge zone of the aquifer requires detailed mapping of the formations, measuring of the faults and fractures, and advanced holistic analysis of the hydrology.

Geologic mapping of the Christmas Mountains and Hen Egg Mountain quadrangles is a new program supported by the U.S. Geological Survey. A detailed study of the area was undertaken because it is one of the most poorly understood parts of the Trans-Pecos igneous province and because available information suggests the potential for significant deposits of beryllium, fluorite, mercury, and molybdenum. The 1986 announcement by Cabot Corporation of an economic deposit of beryllium-bearing fluorspar in a geologic setting in Hudspeth County that is similar to that of the Christmas Mountains reinforced the value of further study in the area.

The last new research program to be reported for 1986, the depositional framework and genesis of Eocene submarine gorges in the northwest Gulf Coast region, is funded by the National Science Foundation. The primary result of this proposed four-dimensional analysis of one family of Tertiary gorge fills will be a critical reexamination of causal relationships between large-scale erosion at continental margins and depositional setting, eustatic sea-level cycles, and local depositional and structural events.

Further descriptions of Bureau research projects are provided on the following pages. Several programs have grown substantially beyond their initial coverage of a year ago.

Energy Resources Investigations

Petroleum

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

Robert A. Morton, project director; W. B. Ayers, Jr., and Lee A. Jirik; assisted by Nancy Banta, Denise Hanna, and Richard Sams

This long-term industry-sponsored research program is focused on the regional genetic stratigraphy, structure, and energy resources of the Texas portion of the continental shelf and upper slope. The primary data base, which has been gathered during the past 4 years, includes more than 1,700 conventional well logs, numerous paleontologic reports, scout tickets, and production records. In 1985, an industrial associates group was organized to maintain the research effort and to increase the exchange of information with potential users. Participants in the industrial associates program during 1986 were Amoco, ARCO, Conoco, Louisiana Land and Exploration, Mobil, Pennzoil, Phillips, Standard Oil, Tenneco, Texaco, and the U.S. Geological Survey.

In 1986, correlation and quantitative mapping of the middle and upper Miocene stratigraphic units were completed, and a series of maps depicting structural trends and sandstone distribution was prepared. Featured in the middle and upper Miocene map series are isopach maps of net sand and percent sand for six stratigraphic units and maps illustrating the principal depositional features, structural elements, and hydrocarbon plays. By yearend the project was directed toward completing the Miocene maps and facies interpretations that have been integrated with results of earlier studies of the equivalent onshore section to produce a regional synthesis and report of the depositional systems, structural framework, and petroleum resources of the middle and upper Miocene depositional sequences.

A second phase of the project was initiated in 1986 involving correlating well logs in the Plio-Pleistocene trend (Galveston South, High Island South, West Cameron South, and East Breaks areas) and integrating the lithostratigraphic and biostratigraphic correlations into a regional grid of seismic lines. Scheduled for 1987 are a series of structural cross sections and maps of the Plio-Pleistocene sediments similar to those prepared for the Miocene section.

Studies Related to Continental Margins

Steven J. Seni, project director; H. Scott Hamlin

Under Douglas C. Ratcliff's direction, the Bureau coordinates a multidisciplinary program of the Continental Margins Committee of the Association of American State Geologists. Geological surveys of coastal states are funded by the U.S. Minerals Management Service to conduct studies relevant to the needs of the individual states and of the Department of the Interior's offshore leasing program. The Bureau's research for the third year of the program concentrated on defining factors affecting the distribution of hydrocarbon resources beneath the Texas Outer Continental Shelf. The downdip portion of the distal Frio Formation was examined with emphasis on extension of productive trends in State waters into Federal Outer Continental Shelf leases. Distal Frio field size distributions and discovery histories were tabulated for all offshore fields and for fields within individual hydrocarbon plays. The short productive life of the highly productive gas fields in the distal Frio trend indicates that new large fields must be found to offset production declines from the older fields.

Petroleum Resource Assessment of State-Owned Lands

Steven J. Seni, project director; H. Scott Hamlin

State-owned lands along the Texas coast include all normally submerged lands extending offshore to the 3-league (approximately 10-mi) line. Significant oil and gas resources are recovered from State tracts offshore and in rivers, bays, and lagoons. The General Land Office of Texas (GLO) is the State agency charged with managing State lands. GLO must have reliable subsurface geologic data and historical production data to evaluate effectively bids for leasing oil and gas drilling rights on State tracts. Accordingly, GLO has granted a 2-year contract to the Bureau to assist in assessment of oil and gas potential of State-owned lands along the Texas coast. With an improved subsurface geologic data base GLO can manage State resources more effectively and institute a geologic-based system for economic evaluation of State lease tracts.

Most production from State lands is from Miocene and Frio reservoirs. Large-scale regional maps (scale 1 inch = 16,000 ft) of structure, net- and percent-sand maps, and oil field distributions of these productive units have been completed along with a computerized data base of well logs, production histories, and State tracts.

Geological Characterization of Texas Oil Reservoirs (Sandstone Reservoir Studies)

Noel Tyler, project director; Edgar H. Guevara; assisted by J. Crispin Gholston

Ongoing characterization studies of sandstone reservoirs continued to focus on the low-recovery (6 percent of original oil in place) submarine fan pools of the Permian Spraberry Trend in West Texas. Three waterflood units in the trend, Preston, Shackelford, and

Driver, were selected for detailed study in 1985; efforts continued to focus on these units in 1986.

The main producing zones are two sand-rich intervals at the base and top of the Spraberry. The sand-rich intervals are the product of multiple depositional events on the mid-to-lower fan and are thus highly stratified. They are characterized by dip-elongate channel axes bounded by interchannel areas. Internally along the channel axes are channel sandstones and siltstones that grade laterally into levee sandstones, siltstones, and mudstones. Interchannel-axis areas may also contain minor channel deposits. Comparison of production data with the sedimentary architecture of Spraberry reservoirs shows that superior wells are located on channel axes; wells completed in interaxial deposits are poor producers. Facies changes within individual reservoir strata and between wells indicate a strong success potential for selective infill drilling in channel axes and reperforation of existing wells in interaxial areas. Results of these studies will be published in two Bureau reports in 1987.

James A. Morgan

Left: Research Scientist Bob Morton (standing) and Research Assistant Dick Sams interpret well logs and seismic lines from the offshore Plio-Pleistocene depocenter as part of the industrial associates-sponsored research program. Right: Research Associate Rick Major examines cored reservoir rock from Penwell field, which produces oil from University lands in West Texas.

Geological Characterization of Reservoirs on University Lands

Don Bebout, project director; Graham E. Fogg, Chester M. Garrett, Jr., Edgar H. Guevara, Claude R. Hocott, Charles Kerans, F. Jerry Lucia, R. P. Major, Stephen C. Ruppel, and Gary W. Vander Stoep; assisted by Syrous Bouzari, Harris Cander, Karen Herrington, Mark Holtz, Matthew Parsley, Timothy Walter, and John Worrell

The University Lands project, funded by The University of Texas System, is a multidisciplinary project that includes reservoir geology, reservoir engineering, petrophysics, and computer simulation and modeling. The objective of the project is to provide information to operators of fields on University lands that could lead to increased oil recovery through modification and extension of existing development programs.

Cumulative production from reservoirs on University lands amounts to 1.5 billion barrels of oil; 200 million barrels of conventional reserves remain in these reservoirs. However, an additional 1.5 billion barrels of mobile (nonresidual) oil remain trapped by reservoir heterogeneities in these complex carbonate and sandstone pools. This untapped mobile oil is the target for reserve growth through extended conventional recovery.

By far, the largest volume of currently uncontacted mobile oil (922 million barrels) is in pervasively dolomitized lower Guadalupian San Andres and Grayburg platform carbonate reservoirs; consequently these formations have been emphasized in ongoing studies. San Andres and Grayburg reservoirs now being studied are Dune (operated by Mobil), Emma (ARCO), Penwell (Fina), and Taylor-Link West (Taylor-Link Operating, formerly Mid America). Another 440 million barrels of potentially recoverable mobile oil lies in Silurian/Devonian and Ellenburger reservoirs. Spraberry sandstone reservoirs (potential reserves for extended conventional recovery of 100 million barrels) are also being studied in the Benedum field (Marathon Oil Company), the southern part of which is on University lands.

Studies of facies, diagenesis, petrophysics, and production characteristics of Dune field have been completed, and computer-assisted reservoir modeling and simulation studies are under way. The trap at Dune field is dominantly stratigraphic. Porosity is best developed in dolomitized subtidal and intertidal pellet grainstones that grade updip into nonporous supratidal anhydrite and pisolite facies. These supratidal facies also prograded across the porous facies to seal the reservoir. Calibration of rock fabric recognized in core with geophysical logs delineated the lateral and vertical distribution of porosity and permeability, which when used with well-completion, production, and injection data provides guidance for future field development. Aided by geological and petrophysical interpretations made by the Bureau, Mobil plans to modify existing field operations in part of their University Unit 15/16.

The quality of the San Andres reservoir in Emma field is also strongly controlled by the original depositional facies. Permeability and porosity are best developed in skeletal grainstone facies. Geochemical investigations reveal four generations of dolomite; however, the major dolomitization event occurred at shallow depths during the late Guadalupian by descending brines, which originated from evaporation of seawater. Anhydrite, which occludes porosity in much of the field, was emplaced after dolomitization. Subsequent leaching of anhydrite has locally enhanced reservoir porosity and permeability.

Penwell field is being studied in close cooperation with Fina Oil and Chemical Company. The San Andres Formation, the reservoir section, is composed of an upward-shoaling suite of dolomitized sediments. Production is primarily from intercrystalline (enhanced

by a late-stage diagenetic event), interpellet, and intergranular porosity, all in subtidal facies; however, thin zones of fenestral and sheet-crack porosity in supratidal facies are also productive. The lower part of the reservoir is subtidal fusulinid wackestones and pellet-fusulinid packstones to grainstones. These facies were deposited as quiet-water, pelleted carbonate mud. The pellet facies are overlain by grainstones composed partly of dasycladacian algae and are capped by supratidal mudstone to pisolitic grainstones characterized by abundant fenestrae and sheet cracks and by interbedded siltstone. Diagenesis included two episodes of dolomitization and cementation by anhydrite and minor kaolinite.

Geologic characterization of the Taylor-Link West San Andres Unit was begun in May 1986 and has involved detailed core logging and construction of facies maps and cross sections. A general geologic model for the field indicates that the main pay interval is a thick porous grainstone unit at the top of the San Andres. The high degree of reservoir heterogeneity is attributed to secondary porosity development associated with subaerial ex-

Lyn Conine and Bill Black of the Taylor-Link Operating Company (second and third from left) and Bureau researchers (from left) Charlie Kerans, Don Bebout, Claude Hocott, and Jerry Lucia gather in front of a pump jack in Taylor-Link West San Andres reservoir that is being used in a new waterflood project under study by the University lands reservoir characterization group.

posure and solution. The karst porosity network is being studied in detail to aid the ongoing waterflood program.

Spraberry reservoirs of the Driver and Benedum Units are naturally fractured, very fine grained sandstones and siltstones that represent outer-fan peripheral channels and associated facies of mixed-sediment submarine fans. This facies architecture results in highly heterogeneous reservoirs. Oil accumulations are stratified or multilayered and isolated vertically by shale and carbonate mudstone. Within each oil-producing interval, the best reservoirs occur in dip-oriented belts of sand-filled channels and are thus laterally isolated. Areas of higher oil production generally correlate with trends of greater net sandstone and siltstone, indicating that reservoir stratigraphy influences oil distribution and recovery. Additional oil could be recovered by infill drilling and well recompletions in partly drained or untapped reservoir compartments.

Reservoir Characterization Research Laboratory

Noel Tyler, project director; Edgar H. Guevara; assisted by J. Crispin Gholston, John Farrelly, John Worrell, and Timothy Walter

Using recently completed genetic stratigraphic studies as a foundation for advanced reservoir characterization, this industry-funded program is committed to improving recovery from poorly productive West Texas reservoirs. Participants in this industrial associates research project are ARCO, Exxon, Mobil, Standard Oil, and Texaco.

The subjects of current research are the naturally fractured, deep-water, very fine grained sandstone reservoirs of the Spraberry Trend of the Midland Basin. The main objectives of these studies are (1) to identify oil-saturated intervals and natural fractures using modern well logs; (2) to evaluate matrix porosity, especially the influence of diagenesis on porosity enhancement or destruction, and the relation between reservoir petrology and well log response; and (3) to determine the relation between oil recovery and the sedimentological character of reservoir rocks in the Spraberry Formation in the Midland Basin in general and in the central Spraberry Trend in particular for exploration and extended development. Completion intervals in the Spraberry Formation have commonly been selected on the basis of gamma-ray correlation with nearby oil-producing sandstones. The information to be acquired will help in the detection of poorly drained or bypassed oil zones for completion or recompletion.

Gas

Geological Investigations of Low-Permeability Gas Sandstone Reservoirs

Robert J. Finley, project director; Robert W. Baumgardner, Jr., Shirley P. Dutton, Michael A. Fracasso, Karen Herrington, Mary L. W. Jackson, and Stephen E. Laubach; assisted by Bruce C. Gates, Peter Hennings, Alice Spencer, and John Wilson

Since 1982, the Gas Research Institute (GRI) has supported geological investigations designed to develop knowledge necessary to exploit effectively low-permeability, gas-bearing sandstone. As part of that program, the Bureau has been conducting research on the Lower Cretaceous Travis Peak (Hosston) Formation, a low-permeability sandstone that underlies East Texas, North Louisiana, and southern Mississippi, and on the Upper Cretaceous Corcoran and Cozzette Sandstone Members of the Price River Formation (Mesaverde Group) in the Piceance Creek Basin of Colorado. This effort is part of a broader program designed to increase the understanding and ultimate utilization of unconventional gas resources through integration of multiple disciplines

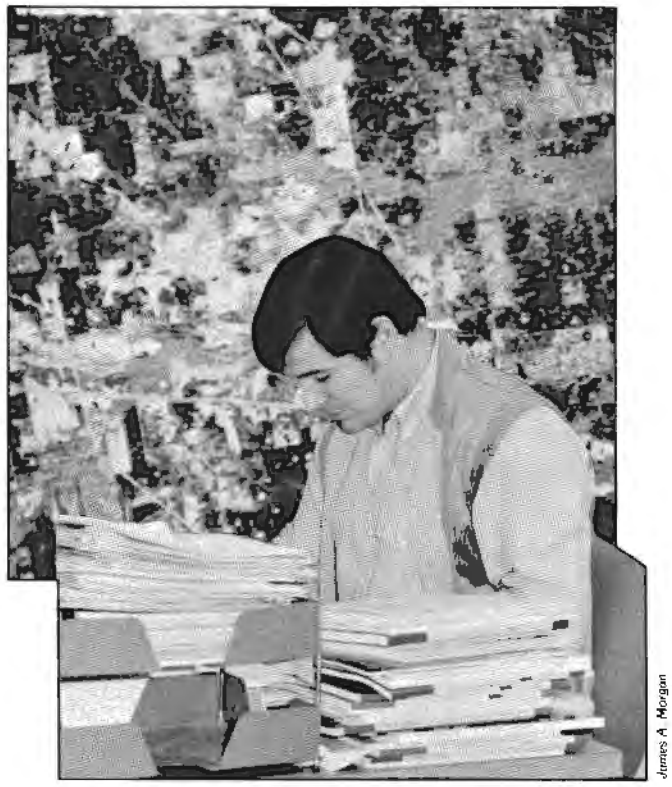
involved in tight gas resource development, particularly geology, log analysis, and reservoir engineering. At present, many tight gas sandstones are not being efficiently evaluated, hydraulically fractured, or produced because of a lack of appropriate technology to stimulate development of the tight gas resource at competitive prices.

The research effort for 1986 focused on the Travis Peak Formation and the drilling of a GRI-operated test well in East Texas. Research on the Corcoran and Cozzette sandstones received lower priority because operator activity in the Piceance Basin has declined during the current gas surplus. Geological research objectives for the Travis Peak study included identifying play areas suitable for drilling a Staged Field Experiment (SFE) well, developing an understanding of the depositional systems of the reservoirs, determining the diagenetic and burial history of Travis Peak sandstone, and defining the maturation and migration history of hydrocarbons. Another objective is definition of structural influences on gas production, including distribution of natural fractures and state of stress of reservoir rocks. Geological results are being integrated with geophysical well logging and reservoir engineering research conducted by other contractors to the Gas Research Institute.

Geological characterization of Bethany, Belle Bower, and Waskom fields in eastern Harrison and Panola Counties, Texas, was undertaken to locate a site for GRI's first SFE well. Criteria including depth to the reservoir zone, proximity to existing low-permeability reservoirs, thickness and lateral continuity of the reservoir zone, proximity of the reservoir zone to potential fracture barriers, and lateral continuity of potential fracture barriers were used to evaluate the three alternative fields. Consideration of these factors resulted in selection of the Waskom field, Harrison County, as the site for the first SFE well. The well was drilled and cased through the Travis Peak Formation to a total depth of 7,900 ft, and 469 ft of core from two producing zones was recovered. Cased-hole experiments and completion of this research well will continue into 1987.

Core from the SFE well and two cooperative wells from Waskom field (450 ft of core) and closely spaced electric logs were used to interpret the depositional systems of the reservoir zones. Reservoir sandstones of the upper Travis Peak in Waskom field are upward-fining channel facies whose upper mudstone members exhibit features characteristic of overbank deposition in swampy floodplain environments. The lower Travis Peak producing zone is characterized by blocky and upward-fining sandstones with multilateral architecture. The sandstones appear to be transitional braided to meandering channels with partial reservoir continuity established by crosscutting relations.

Petrographic and diagenetic studies were conducted using 2,325 ft of core from 18 wells, including almost 1,200 ft of new core processed by the Bureau's Core Research Center in 1986. Permeability in much of the Travis Peak in the six-county study area has been reduced to less than 0.1 md by compaction, minor pressure solution, and extensive precipitation of authigenic minerals, particularly quartz. Inorganic diagenesis ended during the Cretaceous when oil migrated into Travis Peak reservoirs from Jurassic source rocks. Later, deasphalting of the oil by solution of large volumes of gas filled much of the remaining porosity with reservoir bitumen (a solid hydrocarbon residue) in some zones near the top of the formation.



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Research Associate Mike Fracasso analyzes data pertaining to Travis Peak low-permeability gas sandstones in Waskom field. In the background is an example of Landsat Thematic Mapper data. Area shown is environs of Waskom, Texas, near the Texas-Louisiana border.

Ongoing remote sensing and structural studies of the East Texas Basin were designed to determine structural history of the basin and probable propagation direction of hydraulic fractures in the tight sandstones of the Travis Peak. A detailed structural study of the Travis Peak and younger formations in East Texas was undertaken to confirm the timing of movement of the Sabine Uplift and to help define mechanisms for structural growth. Structure and isopach maps based on 811 well logs show that the Sabine Uplift was part of a large basinal area in the Late Jurassic and Early Cretaceous, and movement on the uplift postdated Travis Peak deposition. Timing, orientation, and magnitude of arching indicate that the Sabine Uplift may have been produced by northeast-directed tectonic events related to orogenic activity in the

southern North American Cordillera and the Sierra Madre Oriental in Mexico.

A goal of the structural studies is to develop models of natural and artificially induced fracture systems that will permit improved prediction of induced hydraulic fracture propagation direction and fracture containment. The project provides a unique opportunity to approach these goals through a combination of high-resolution structural mapping and the analysis of macrostructures and microstructures in oriented whole core. Structural observations are being integrated with the results of a wide range of in situ geophysical and engineering experiments. Petrographic analysis of healed microfractures and finite strain measurement are two new techniques being developed as part of this project. Microfractures may prove useful for defining natural fracture trends from core because the use of microfractures permits more systematic and reproducible data collection than can be accomplished by sampling widely spaced macrofractures by coring. Compaction is an important parameter in many types of basin studies, and compaction in Travis Peak sandstone has been quantified using a computerized version of the center-to-center strain analysis technique. The technique promises to be useful for studying the relationship between sediment burial, diagenesis, and regional stresses.

Remote sensing efforts also yielded information about probable fracture propagation direction in Travis Peak sandstones. Work progressed from a regional study based on 1:250,000-scale Landsat images to subregional studies over the Sabine Uplift based on 1:100,000-scale synthetic aperture radar (SAR) data. Regional lineament trends significant at the 99-percent confidence level have azimuths of 325° and 21°. The northwest trend is parallel to the mean azimuth of wellbore elongations in the Jurassic Schuler Formation in 50 wells throughout East Texas. In addition, this trend is subparallel to wellbore elongations (342°) from a cooperative well cored by GRI in Waskom field. In the East Texas Basin, the northeast trend of Landsat lineaments (16°) is subparallel and statistically equivalent to the trend of underlying elongate salt structures (29°). These results suggest that lineaments and subsurface structures result from like-oriented stresses.

Tight gas research in 1986 included continued testing and analysis of information from the Holditch Howell No. 5 SFE well. In addition, geologic characterization of new play areas will identify potential sites for a second Travis Peak SFE well to be drilled in 1987. Local depositional systems studies will contribute to development of a comprehensive model of regional depositional systems and reservoir potential of the Travis Peak Formation in East Texas. Structural studies will be a major component of tight gas research in 1987 as techniques used to analyze the natural fracture system and regional state of stress are refined. Petrographic and diagenetic work will explore the relationship between petrophysical properties and petrographic parameters such as clay content, cementation, and grain size.

The Atlas of Major Texas Gas Reservoirs and Analysis of Gas Reservoir Heterogeneity

Robert J. Finley and Noel Tyler, project directors; Chester M. Garrett, Jr., and Elisabeth C. Kosters; assisted by William Schramm and James Reistroffer

This program, funded jointly by the Gas Research Institute and the Bureau of Economic Geology, is designed to produce an atlas of the most significant gas reservoirs in Texas as a companion to the Bureau's *Atlas of Major Texas Oil Reservoirs*. Texas gas production accounts for about one-third of the U.S. domestic supply, yet there is no comprehensive publication that contains key information on the character and distribution of the Texas natural gas resource. The gas atlas will define the contribution of various types of reservoirs to current production and group those reservoirs into genetically related plays, provide a baseline for future trends in reserve additions and reserve growth, and extend to gas some of the methodologies for resource analysis that were initiated with the oil atlas. Definition of major gas-producing trends is the first step toward reservoir heterogeneity studies that will be initiated with later phases of gas atlas development.

Using a screening parameter of cumulative gas production of 10 billion cubic feet (the equivalent of 1.6 million barrels of oil), researchers have identified 2,000 reservoirs for inclusion in the atlas. Two-thirds of these reservoirs lie in Mesozoic and Tertiary sediments of the Gulf Coast and East Texas provinces. The remaining reservoirs are Paleozoic and extend across the Texas Panhandle, West Texas, and North-Central Texas.

Reservoir data are derived from multiple sources including hearing files of the Railroad Commission of Texas, field files of the Department of Energy (Energy Information Administration, Dallas Field Office), and commercially available data bases. Information to be included in the atlas will be specific to the reservoir rather than the field. The atlas will comprise general reservoir information, petrophysical data, and reservoir volumetrics together with representative illustrations.

Data collection and synthesis will be completed by mid-1987; publication of the atlas is scheduled for June 1988.

Geological, Geochemical, and Engineering Research Support for Gulf Coast Co-production Program

Robert J. Finley, project director; Noel Tyler, Malcolm P. R. Light, and David W. Koppenaal; assisted by James Reistroffer and Javier Meneses-Rocha

The Bureau of Economic Geology and the Center for Energy Studies are conducting joint investigations for the Gulf Coast Co-production Program. The purpose of this project, funded by the Gas Research Institute, is to investigate the mechanisms of, and to improve the hydrocarbon production from, gas reservoirs that have been

abandoned or are beginning to water out. Activities in 1986 were focused on the geology of the Port Arthur and Northeast Hitchcock fields.

Geology of the Port Arthur Field

Noel Tyler; assisted by James Reistroffer

Detailed reexamination of the sedimentary architecture of Hackberry (Oligocene) reservoir sandstones at Port Arthur field suggests the presence of several free-gas-bearing zones in the upper parts of the Hackberry. Detection of these zones and an estimation of the potential resource for secondary gas recovery were the main research thrusts during 1986 Port Arthur field studies. In this era of depressed gas prices these untapped zones could provide additional financial returns and incentive for initiation of more co-production projects.

The Hackberry sequence contains onlapping thick, massive, proximal canyon-fill deposits that grade vertically into more distal submarine fan sediments exhibiting a pronounced distinction between channel and overbank deposits. Although the upper units of the Hackberry are more continuous than the lower units, the internal architecture of the upper units is more variable and complex. Channel facies form the framework around which overbank deposits are arranged. Channel deposits have consistently higher porosities and permeability values and are thicker than associated overbank facies. However, overbank deposits have the greatest potential for selective recompletion for production of bypassed gas. More than 10 zones have been mapped and inferred to have high potential for recompletion; also present are several other zones of lower potential. In contrast, the necessity for optimum permeability and thicker sand development dictates that wells designed expressly for co-production be completed in the channel sands. The two completion philosophies are not mutually exclusive; superposed reservoir sands would permit multiple completions in a design well.

Two further avenues of research are geological constraints and fluid incompatibilities that may affect injection of the produced water into shallower Miocene disposal sands. In the Port Arthur area these sands are strongly strike parallel and are probably of wave-dominated delta/strandplain origin. As such they are highly favorable for disposal because these systems characteristically display excellent lateral continuity. Four sands are primary targets for disposal, but many other units in the Miocene could also receive injected brines.

The equilibrium of fluids in Hackberry and Miocene sands and the different mixes of these formation waters have been investigated at surface in situ temperatures and pH values. Twenty-five SOLMNEQ computer programs were run. SOLMNEQ calculates the equilibrium distribution of inorganic aqueous species in natural waters from the results of chemical analyses. Hackberry fluids from the 1-6 well were analyzed by the Bureau's Mineral Studies Laboratory. Published results of chemical analyses for Miocene waters were obtained from an area slightly east of Port Arthur in Louisiana.

Both Hackberry and Miocene waters are sodium chloride brines, but Miocene waters are twice as saline as Hackberry waters. SOLMNEQ data indicate that mixing of Hackberry and Miocene waters will lead to the development of scale in the Miocene disposal reservoirs. Scaling should also occur in surface production equipment because of changes in temperature and pH. This is an important finding since brine disposal is one of the most serious problems in co-production.

Geology of the Northeast Hitchcock Field

Malcolm P. R. Light and David W. Koppenaal; assisted by Javier Meneses-Rocha

During 1986, investigations continued to define the source of the formation fluids at the Northeast Hitchcock field using the results of major, trace, and rare-earth element analyses of formation waters and rocks. Detailed interpretations of the results of gas chromatographic and mass spectrometry analyses are under way, but petrographic investigations of the Frio A sandstones have been completed.

Twenty-five major, trace, and rare-earth element analyses were completed for deltaic and fluvial sandstones, shales, limestones, and coals from the Northeast Hitchcock field area. Major and trace element concentrations were determined early in this project by the Bureau's Mineral Studies Laboratory. An extended delay in completing rare-earth element analyses resulted from problems in stabilizing the new inductively coupled plasma mass spectrometer. The rare-earth element content of formation waters from the Northeast Hitchcock field is still to be determined and must be available before an interpretation can be made of the source of the waters.

Distribution of rare-earth elements is distinctly different in the Frio sandstone/shale reservoir section and deeper limestone/red-bed sequences. Distribution of rare-earth elements in fluids could, therefore, show whether fluids were locally derived from shale dewatering or were derived from deeper levels.

Cogeneration Issues in Texas

Robert J. Finley, project director; Mary L. W. Jackson; assisted by Bruce C. Gates

As part of a study of the present and future status of cogeneration in Texas, the Bureau completed a review of fuel supplies and prices for the period 1985 through 2000. Oil, gas, and coal were considered in this review, but major emphasis was placed on present and future supplies of natural gas, the primary fuel for cogeneration in Texas. The potential supply of cogenerated electricity in Texas is larger than for any other state, reaching

3,024 megawatts at the end of 1985. Most of this capability was located in the Gulf Coast region, which accounted for 37 percent of Texas gas production in 1985.

Development of the gas resource is less mature than for oil, but already more gas reserves are derived from reserve growth, or continued development of existing fields, than are added through new-field exploration. Extensions and new-pool discoveries were the primary categories of gas reserve additions in the major non-associated-gas-producing areas of Texas, especially in Railroad Commission district 4 in South Texas, the leading gas-producing district. Historical trends in reserve additions and well completions show the effects of producer incentives under the Natural Gas Policy Act from 1979 to 1982, followed by the effects of excess gas supply from 1985 through 1986, when gas prices steadily eroded. Concerns were raised for future gas deliverability under continued low prices that do not provide adequate incentives to producers and under future regulatory uncertainties. Some results of the gas supply analysis were published in Geological Circular 86-4, *Recent Production Trends and Outlook for Future Oil and Gas Supplies in Texas.*

Consolidation of Geologic Studies of Geopressured Geothermal Resources in Texas

Robert J. Finley, project director; Malcolm P. R. Light

This Department of Energy-funded program has been separated into two tasks: (1) special projects research and coordination assistance and (2) mesoscopic and microscopic analyses of rock samples utilized in rock mechanics studies.

Special Projects Research and Coordination Assistance

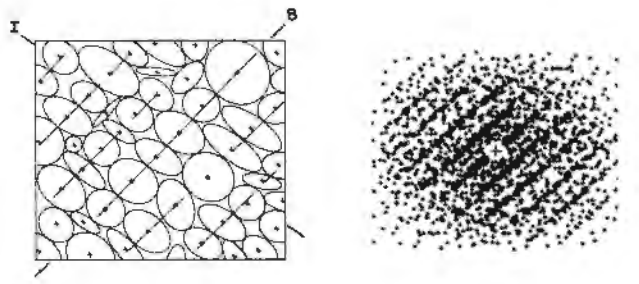
Malcolm P. R. Light

The Bureau provided representatives of government, industry, and university research laboratories with rock samples, assistance, and information on topics related to geopressured energy. Publications on the geology of the Texas Gulf Coast by Bureau staff were made available to researchers.

Mesoscopic and Microscopic Analyses of Rock Samples Utilized in Rock Mechanics Studies

Malcolm P. R. Light

This project was designed to complement detailed studies of rock mechanics being conducted at The University of Texas at Austin on Frio A reservoir sandstones from the Northeast Hitchcock field, Galveston County. The fabric and movement of undeformed and experimentally deformed deltaic sandstones were to be determined by mesoscopic, transmission (universal stage), and scanning electron microscopic (SEM) analyses of oriented core samples.



Stacking of imbricated ellipses (I) in foreset beds (B) produces steeply dipping interference banding on a Fry diagram (right). Similar banding is visible in Fry diagrams of Frio delta sandstones.

Limited funding and the very mixed and deformed initial mineralogy in the Frio A sandstones precluded universal stage and SEM work. Instead, a method of graphical fabric analysis was used because it is faster and yields a more complete analysis than the universal stage method. The orientation of long axes of grains in vertical rock sections was determined and plotted on rose diagrams.

Sandstone petrography and porosity reduction measurements were carried out by point-counting 18 oriented rock sections to estimate the shortening that sandstones had undergone during experimental compaction. Rounded to irregular and elongate grains of quartz, feldspar, rock fragments, chlorite, shale clasts, and cements form the main constituents. Skeletal and vacuolized feldspars compose about 2 percent of the sandstones. Grains are imbricated in sandstones in shallowly to steeply dipping crossbeds. Steeply dipping interference banding on Fry diagrams for distributary-mouth-bar sandstones results from foreset bedding.

Results of point-count analyses indicate that porosity was reduced 42 to 62 percent by experimental compaction. Collapse of skeletal and vacuolized feldspars accounts for 7 to 10 percent porosity reduction, and further compaction results from deformation of ductile grains. A linear relationship exists between percent porosity reduction and content of ductile grains and cements in Frio A sandstones. Ductile grains and cements have deformed and lubricated grain margins, facilitating grain rotation and intergranular movement.

Vertical extension fractures and shears inclined at 16° to 45° in the direction of maximum stress were developed in the sandstones during experimental compaction. Horizontal and irregular vertical expansion fractures formed simultaneously during post-compaction decompression of cores. The development of crosscutting compaction shears in the clean distributary-mouth-bar sandstones, surrounded by a 3- to 5-mm-wide zone in which the precompaction porosity is largely retained, has implications for the maintenance of large production rates in geopressured and co-production reservoirs. These compaction shears are fluid channels and may preferentially open during hydraulic fracturing to form conduits for increased fluid flow to the well bore.

Coal

North-Central Texas Bituminous Coal

W. B. Ayers, Jr.

Study of the depositional settings of bituminous coals in the Harpersville Formation of North-Central Texas continued for a 16-county (12,000-mi^2) area that extends from Stephens County west into Scurry County and south through McCulloch County. Lithofacies, isopach, structure, and coal occurrence maps of four intervals are being checked for internal consistency, and a manuscript to accompany the maps will be written in 1987.

Preliminary analysis indicated that the Harpersville Formation records a history of clastic and carbonate deposition on a prograding shelf. The formation thickens basinward (westward) from outcrop to the Harpersville shelf margin, which prograded 10 to 20 mi basinward during Harpersville deposition. Dip-elongate fluvial-deltaic sediments dominate in the shallow subsurface; sediment input was greatest in the southern half of the study area. Strike-elongate carbonates that prevail on the western one-third of the shelf are broken by dip-elongate passes, through which fluvial systems fed sediments to shelf-margin deltas or submarine canyons. In the subsurface, coal is most abundant in the northern area, where it formed in upper Harpersville delta-flank and interdeltaic settings.

E. C. Kosters

Research Associate Walt Ayers examines Wilcox strata in the Sandow lignite mine near Rockdale, Texas.

Geology and Ground-Water Hydrology of Deep-Basin Lignite in the Wilcox Group of East Texas

W. R. Kaiser, project director; Graham E. Fogg

This study is a continuing effort to evaluate the Wilcox Group. Major effort in 1986 centered on manuscript preparation for publication of three geological and hydrological folios: (1) *The Wilcox Group and Carrizo Sand in the Sabine Uplift Area, Texas: Ground-Water Hydraulics and Hydrochemistry* (24 pls. and 28 figs.), (2) *The Wilcox Group (Paleocene-Eocene) in the Sabine Uplift Area, Texas: Depositional Systems and Deep-Basin Lignite* (17 pls. and 11 figs.), and (3) *The Wilcox Group and Carrizo Sand in East-Central Texas: Ground-Water Hydraulics and Hydrochemistry* (in preparation).

Folios will feature maps (scale: 1 inch = 6 mi), regional cross sections, and tabulated supporting data (microfiche appendix), along with a short interpretive text. The first geological folio, *The Wilcox Group and Carrizo Sand (Paleogene) in East-Central Texas: Depositional Systems and Deep-Basin Lignite* (30 pls. and 4 figs.), was published in 1985. The Sabine Uplift hydrological folio will be published next. Unpublished maps, cross sections, and supporting data for all folios are available for use at the Bureau.

Computerized Calculation of Lignite Resources in Texas

W. R. Kaiser, project director; Mary L. W. Jackson

This ongoing project, funded by the U.S. Geological Survey (USGS) and begun in 1979, provides estimates of remaining near-surface lignite resources (those under less than 500 ft of cover) in Texas. The computerized data base and graphics software of the National Coal Resources Data System (NCRDS) are used to calculate resources according to criteria of USGS Circular 891. NCRDS is accessed at the Bureau through a Digital VT220 terminal, and a Tektronix 4054 terminal is used for plotting resource maps. Seam thickness, depth, and data locations are coded from geophysical logs and entered into the data base; point sources of proprietary data remain confidential.

Resources are calculated by stratigraphic unit in five seam categories—three standard USGS categories for lignite (2.5 to 5, 5 to 10, and greater than 10 ft) and two that reflect current mining practice in Texas (2 to 3 and greater than 3 ft)—and reported on an aggregate basis by geographic region. Resources in the Wilcox Group (Paleocene-Eocene) of East Texas have been calculated for three geographic regions, representing approximately 68 percent of available data. Data entry and validation for the Jackson/Yegua trend in East Texas (24 percent of data) are in progress and about 80 percent complete; digitization of point-source data delivered to the USGS in July 1984 is pending. Eight percent of the data remain for entry and occur in the Wilcox and Jackson Groups of South Texas. Completion of resource calculation in remaining areas depends on timely digitization.

Evaluation of Hydrocarbon Generation and Depositional Environment of Texas Eocene Coal Deposits Using Organic Petrography and Geochemistry

P. K. Mukhopadhyay (Organic geochemical work done partly in collaboration with James R. Gormly, Mobil Research and Development Corp., Dallas, Texas, and John Zumberge, Steve Martin, and Douglas King, Ruska Laboratories, Houston, Texas)

This ongoing project, funded primarily by the U.S. Geological Survey (USGS), was begun in 1985 and continues to evaluate the depositional setting of peat-forming environments and hydrocarbon generation of coals from the Wilcox, Claiborne, and Jackson Groups by maceral composition, Rock-Eval pyrolysis, elemental composition, bitumen extract/gas chromatography, and anhydrous/hydrous pyrolysis-gas chromatography.

Organic facies indicative of different peat-forming environments were evaluated using a maceral composition ternary diagram. Accordingly, the presence of high ulminite, fusinite/semifusinite, and resinite in near-surface Wilcox coals in the northeast Texas and Sabine Uplift area indicates that they accumulated in an alluvial plain swamp from arboreal vegetation. Sesquiterpanes and diterpanes in the saturate fraction of the extract suggest that the main lipid fraction of the coal was generated from resinite maceral occurring within texto-ulminite. However, macerals rich in humodetrinite, liptodetrinite, and sporinite in near-surface and deep-basin Wilcox coals in east-central Texas indicate that they accumulated in a reed-marsh environmental complex lower on the paleoslope, possibly within the interdistributary basins of the upper delta plain. Wax-alkanes are the main component in the saturate fraction of the gas chromatographs. High pyrite, organic sulfur, humodetrinite and liptodetrinite, amorphous liptinite, and a few dinoflagellates in Jackson coals from central and South Texas indicate that they accumulated under more aquatic anoxic conditions on the lower delta plain or in a barrier-bar environment. On a hydrogen-index versus oxygen-index plot, the Jackson coals lie within type II and III kerogen maturation paths. They are classified as humic, mixed, and sapropelic coals and are correlated with maceral composition and peat-forming environments.

Hydrocarbons generated by hydrous and anhydrous pyrolysis of humic, mixed, and sapropelic coals from the Wilcox, Claiborne, and Jackson Groups have different geochemical fingerprints, which may be useful in correlating crude oils with coal extracts. Hydrous pyrolysis of mixed coals generates heavy crude oil that has a bimodal n-alkane distribution pattern. The low-molecular-weight compounds are assumed to be derived from liptodetrinite macerals of algal affinity. Amounts and variability of hydrocarbons generated by anhydrous pyrolysis are similar to the products obtained from hydrous pyrolysis of each type of coal. Activation energies for hydrocarbon generation are calculated by anhydrous pyrolysis for different types of coal, which shows a lower activation energy and frequency factor for mixed coal than for sapropelic coal.

These results, together with microscopic analysis, suggest a modified concept of primary hydrocarbon migration from coals whereby hydrocarbons flow in narrow networks between maceral and mineral constituents. This concept indicates that mixed coal is a richer source rock than humic coal and that more effective migration avenues occur in mixed coal than in humic or sapropelic coal. Pyrolysis of these coals is used to characterize the hydrocarbons that would be generated during liquefaction.

Land, Water, and Environmental Resources Investigations

Waste Isolation Studies

Geological and Hydrogeological Evaluations of the Texas Panhandle for a Potential High-Level Waste Repository

The West Texas Waste Isolation project continued to investigate the geologic and hydrologic environments of the Texas Panhandle, where a site in Deaf Smith County has been proposed by the U.S. Department of Energy for a repository for high-level nuclear wastes. Work during 1986 included investigations in the disciplines of stratigraphy, hydrology, aqueous and rock geochemistry, geomorphology, structural geology, and paleoclimatology. The results of these studies were reported to DOE and to the scientific community in a series of publications and presentations. For two consecutive months in 1986 the cover illustrations on the bulletin of the Geological Society of America were from articles by Bureau research staff on the West Texas project.

Surficial and Geomorphic Studies

Jay A. Raney, Thomas C. Gustavson, and S. Christopher Caran; assisted by Michael Blum and Henry Eby

Erosion, deposition, and associated climatic conditions were monitored at five remote locations on the Southern High Plains and Caprock Escarpment. Results of previous extensive field investigations,

particularly in the Rolling Plains, were evaluated in terms of indicated rates of landscape evolution. Paleoclimatic conditions during the latest Pleistocene and Holocene were reconstructed, providing a partial basis for inferring rates of geomorphic processes operating in the past.

Continuing studies of the late Tertiary Ogallala and Quaternary Blackwater Draw Formations suggest that deposition of basal Ogallala fluvial sediments was controlled by topography on the underlying middle Tertiary erosional surface. Paleovalley-fill sequences consist of gravelly- and sandy-braided stream deposits. Both paleovalley fills and paleo-upland areas are overlain by eolian sediments deposited as sand sheets and loess. Ground-water calcretes are extensively developed in the Ogallala fluvial sediments. Pedogenic calcretes occur primarily in the eolian sediments of the upper Ogallala and the overlying Blackwater Draw. The processes of pedogenesis and eolian deposition and deflation have occurred from Ogallala time to the present. Although the Blackwater Draw Formation was originally assigned an Illinoisan age, interbedded volcanic ash beds dated at 1.4 m.y. (Guaje ash) and 0.6 m.y. (Lava Creek "B" ash) and radiocarbon dates suggest that deposition occurred throughout the Quaternary.

Stratigraphy and Sedimentology

Jay A. Raney, Robert D. Conti, Susan D. Hovorka, and David A. Johns; assisted by Susan Ide, Joseph Ramage, Patricia M. Granger, Michael Rosen, and Franz Hiebert

A basinwide fence diagram of the Triassic Dockum Group was constructed to show the three-dimensional distribution of sandstone, sandstone-mudstone, and mudstone lithofacies so that changes in depositional environments and paleogeography through the Late Triassic could be interpreted. Results indicate that there was an overall expansion and deepening of the lacustrine basin and that water-level fluctuations were common but decreased in magnitude through time.

Investigations of the Permian Artesia Group focused on the relationships between tectonic patterns and depositional environments interpreted from core and geophysical well log studies. Prior to the late Guadalupian, tectonism along the Matador Arch influenced bathymetry. The arch was periodically the location of shelf-edge deposition or of the transition zone between marine conditions to the south and evaporitic conditions to the north. During deposition of the Artesia Group, subsidence of tectonic elements along the Matador Arch diminished until sedimentation matched subsidence, thus allowing the Permian shelf edge to prograde southward. Regional marine transgressions that initially produced basinwide evaporite deposits were followed by development of isolated brine pans both north and south of the emergent Matador Arch.

Stratigraphic correlations of individual genetic cycles between the San Andres Formation in the subsurface of the Palo Duro Basin and the outcrop of the Pease River Group (Flowerpot, Blaine, and Dog Creek Formations) in the Rolling Plains established the equivalence of these units. Evaporite strata thin and clastic units thicken eastward, reflecting an eastern source for the clastics. Halite has been dissolved from near-surface environments, but its former geometry can be reconstructed by recognition of the remaining insoluble residues.

Hydrostratigraphic studies of the Wolfcamp Series were extended to include analysis of the depositional systems and events that marked the transition from open-marine to evaporitic sedimentation in the Palo Duro Basin. The uppermost Wolfcamp diagenetic facies, a high-porosity dolomite, underlies the first occurrence of low-porosity Wichita anhydritic dolomite; maps of the high-porosity dolomite suggest that it is continuous throughout the basin.

Structural Geology and Tectonics

Jay A. Raney, Roy T. Budnik, and Edward W. Collins

Structural and tectonic studies of the Palo Duro Basin region continued during 1986 and resulted in several publications. Much of this work concentrated on the tectonic history of the Amarillo Uplift that defined the northern margin of the Palo Duro Basin during the Pennsylvanian Period. Current studies suggest that this tectonic boundary may have been a zone of significant strike-slip faulting. More recent structural features at the base of the Ogallala Formation indicate possible tectonic reactivation during the Tertiary. Additional studies are planned to investigate the possibility of very recent faulting that may be analogous to that associated with the Meers fault in Oklahoma.

Hydrogeology

Charles W. Kreitler, Alan R. Dutton, Ronit Nativ, Rainer K. Senger, and D. Anderson Smith; assisted by Arten Avakian, Gay Nell Gutierrez, Deborah Pfeiffer, and Michael Vecchio

Analysis of hydrochemical data for the Ogallala aquifer led to a better understanding of recharge processes and rates. Previous estimates of recharge rates to the Ogallala aquifer vary by two orders of magnitude, primarily because the relative proportions of recharge from rainfall and recharge from playa lakes were not well known. Recharge to the Ogallala aquifer was investigated by combining meteorological and geochemical information. Rainwater sampled at five stations across the Southern High Plains during 1 year was analyzed for $\delta^{18}O$, δD, and tritium. The presence of tritium in the ground water and of $\delta^{18}O$ and δD relative to values observed in rainwater suggests that the Ogallala aquifer was recharged by focused percolation of partly evaporated playa lake water.

A hydrogeologic study of sandstones of the Triassic Dockum Group indicates that topographically controlled ground-water-basin divides, established in the

Pleistocene by erosion of the Pecos and Canadian River valleys, prevent ground-water recharge from entering the confined part of the aquifer beneath the Southern High Plains. Ground water may have been recharged during the Pleistocene before thick Dockum sandstones were removed by erosion of the Pecos River valley. The confined Dockum aquifer appears to be separated from the overlying, heavily pumped High Plains aquifer by thick mudstones in the upper part of the Dockum Group. Chemical composition of Dockum ground water is controlled by reactions between water and feldspar, kaolinite, smectite, chert, calcite, dolomite, and pyrite and by ionic exchange between water and clays. Brackish to saline, sodium sulfate and sodium chloride hydrochemical facies were derived by mixing of recharged water with ground water containing dissolved gypsum and halite derived from underlying Permian strata.

Dissolution of Permian halite and gypsum at the top of the confined deep-basin aquifer is influenced by flow of ground water downward from the Dockum aquifer. Studies completed at two hydrologic test wells drilled into salt-dissolution zones 33 to 48 ft above bedded halite indicate that 10,000- to 20,000-year-old ground water is saturated with respect to gypsum and undersaturated with respect to halite and consequently has a potential for further halite dissolution. At a third well drilled into a salt-dissolution zone beneath the Southern High Plains, ground water is near equilibrium with respect to halite and anhydrite, which suggests that rates of ground-water flow and salt dissolution in that area are slower than around the margin of the Southern High Plains.

Cross-sectional modeling of ground-water flow in the Palo Duro Basin was used to investigate the effects of erosional decompaction associated with the westward retreat of the Eastern Caprock Escarpment by simulating local subhydrostatic conditions within the Evaporite aquitard near the Caprock Escarpment. Interval transit times from geophysical logs indicated abnormally high porosities within the aquitard east of the escarpment, supporting the modeling results.

The hydrologic, three-dimensional continuity of porous lithofacies of the Wolfcampian Brown Dolomite of the Deep-Basin Brine aquifer was determined through facies studies. Geophysical log and core analyses of porous Wolfcamp carbonates revealed the relative importance of primary and secondary porosity.

Host Rock Geochemistry

R. Stephen Fisher, David A. Johns, W. R. Kaiser, Harry H. Posey, and Susan D. Hovorka; assisted by Jonathan Blount, Mark E. Erwin, Franz Hiebert, Susan Ide, Joseph Ramage, and Michael Rosen

Mineralogical and geochemical analyses of Dockum sandstones were conducted to investigate the depositional and diagenetic history of the rocks as well as relations between the sandstone composition and hydrogeologic properties. The detrital and diagenetic mineralogy of the sandstones reflects both the original depositional environment and the modern hydrologic setting. Smectite, illite, and mixed layer chlorite-smectite clays were identified. A diagenetic sequence includes quartz precipitation as overgrowths, calcite cementation, feldspar dissolution, formation of authigenic kaolinite, albitization(?), and formation of authigenic illite and smectite. Studies to determine the timing of cementation events and to evaluate the extent of albitization are in progress.

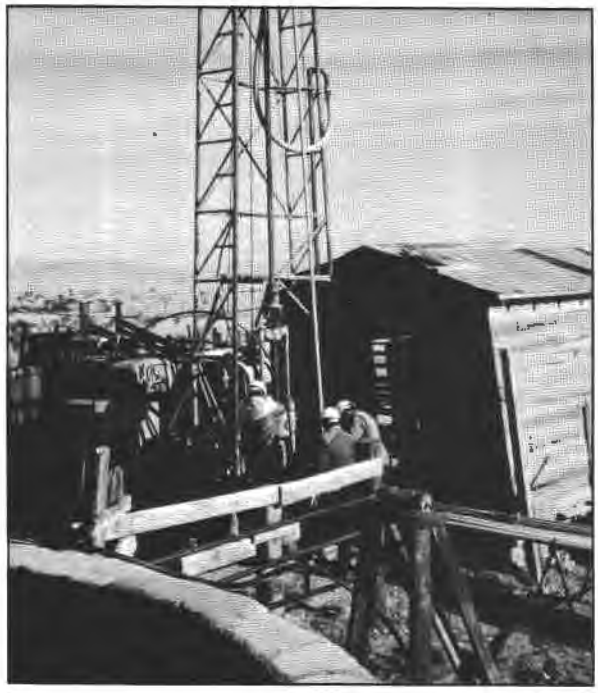
Stable and radiogenic isotopic compositions were used to investigate the stratigraphy and diagenesis of dolomite and anhydrite in upper Wolfcamp and lower Leonard (Wichita) strata. Age estimates based on the chronostratigraphic strontium isotope curve suggest that the Wolfcamp/Leonard boundary may be younger than previously thought. Eight different types of anhydrite across the Wolfcamp/Leonard boundary were identified and analyzed for chemical and isotopic compositions. The results indicate complex effects of brine reflux, sulfate reduction, and meteoric-water invasion during the deposition of these strata and the overlying evaporites. Continuing investigations are designed to determine the specific timing of anhydrite formation and alteration and to investigate the mechanisms of dolomitization.

Investigation of the diagenesis of halite in the Permian evaporites continues as a cooperative effort between the Bureau and researchers at Arizona State University. Integration of investigations of the sedimentology, trace element composition of halite, and stable isotopic compositions of fluid inclusions in bedded halite reveals three general types of halite in the Palo Duro Basin. Bedded salt of San Andres units 4 and 5 precipitated in a marine evaporite environment. Higher in the section bedded salt of the Artesia Group appears to be evaporite strata that precipitated because of evaporative concentration of mixed meteoric-marine brines. Halite samples from Tansill and Seven Rivers strata, the highest salts in the section, are interpreted to be second-cycle halite produced by meteoric water dissolution of preexisting salt and subsequent precipitation. A general depositional model for bedded halite in the Palo Duro Basin has been constructed on the basis of these three types of data.

Low-Level Radioactive Waste Disposal

Charles W. Kreitler and Jay A. Raney, coordinators; William F. Mullican III, Edward W. Collins, Ronit Nativ, Thomas C. Gustavson, Christopher D. Henry, S. Christopher Caran, and D. Anderson Smith; assisted by Arten Avakian, Henry Eby, and Gay Nell Gutierrez

The Bureau conducted preliminary geologic and hydrologic investigations of four areas in Trans-Pecos Texas at the request of the Texas Low-Level Radioactive



Research Scientist Associate Bill Mullican pump-tests water well on the Diablo Plateau as part of the site-selection investigations for a repository of low-level radioactive waste.

Waste Disposal Authority. The results of these investigations will assist the Authority in their selection of areas for more detailed evaluations, leading to selection of a site for a repository of low-level radioactive waste produced within the state of Texas. Some of these studies were conducted in conjunction with the Institute for Geophysics and the Department of Civil Engineering of The University of Texas at Austin.

Five areas in Hudspeth and Culberson Counties were investigated to provide an initial data base on the surface and subsurface geologic setting, stratigraphy, structural geology, hydrology, and hydrochemistry. The areas were mapped geologically, and rock characteristics that may affect porosity and permeability, such as faults, fracture systems, karst features, and lithologies, were described in support of the hydrologic investigations. Hydrologic concerns at each site were depth to water table, permeability of potential host sediments and rocks, mechanisms and rates of recharge, and rates and direction of ground-water flow. Drilling was conducted to provide stratigraphic control and to provide test boreholes for hydrologic investigations.

The two areas investigated in Culberson County are underlain by the Permian Castile and Bell Canyon Formations. The Castile Formation displays evidence of solution and collapse and appears to contain a complex system of underground solution channels. Chemical and isotopic compositions of ground water indicate active recharge through the thin unsaturated zone that mixes with older waters flowing from west to east. Residence time of ground water in the aquifer is relatively short, and many springs discharge from the shallow ground-water table.

Another study area lies 11 mi northeast of Fort Hancock in Hudspeth County. It is underlain by Tertiary and Quaternary deposits composed of alluvial sands and gravels overlying a thick sequence of interbedded clays, silts, and fine sands of the Hueco Bolson. Cretaceous bedrock underlies the unsaturated bolson deposits. In the site area, the water table was encountered by drilling at a depth of 478 ft in probable Cretaceous carbonates. Waters from the Cretaceous aquifer are isotopically old and show only minor evidence of active recharge. Two other aquifers were encountered in this area in fine-grained bolson deposits and in Rio Grande alluvial sediments, but they do not occur at the site.

Two sites located on the Diablo Plateau in Hudspeth County, about 25 mi southwest of Dell City, were also investigated. The northern site is underlain by fractured Precambrian rhyolite porphyry, and the southern site is underlain by Cretaceous and Permian carbonates and clastics. Two aquifers are present in the Diablo Plateau area: a shallow aquifer in the southwest area with depths to water generally less than 200 ft and a deeper aquifer underlying most of the region with depths to water as great as 700 ft. Modern recharge was found to occur over the entire study area, a probable result of flooding within the numerous arroyos that dissect the Diablo Plateau. It is being investigated whether recharge occurs at the sites.

Hydrogeology of Saline Ground Water in Texas Gulf Coast Formations Used for Deep-Well Injection of Chemical Wastes

Charles W. Kreitler and M. Saleem Akhter; assisted by Audrea M. Sutley and Warren T. Wood

Three to four billion gallons of chemical wastes have been injected annually into the saline sandstone sections of the Frio, Yegua, Catahoula, Oakville, Wilcox, and undifferentiated Miocene units in the Texas Gulf Coast. The U.S. Environmental Protection Agency (EPA) is evaluating the suitability of this disposal method. One critical concern is the long-term fate of these wastes; that is, Will they ever migrate back to the biosphere?

EPA has funded a 2-year program for the Bureau to characterize the regional hydrogeology of the injection zone to determine whether waste fluids could migrate and pollute potable waters. The first year's effort has been directed toward constructing potentiometric surfaces of these saline formations so that rates and directions of flow can be determined. A data base of about 30,000 pressure measurements has been constructed from Petroleum Information, Inc., files. Fresh-water-equivalent potentiometric surface maps are being constructed with these data. In the second year the chemical composition of the brines in these formations will be evaluated to improve the understanding of Gulf Coast Basin hydrodynamics.

Geochemistry of Saline Ground Water in Texas Gulf Coast Formations Used for Deep-Well Injection of Chemical Wastes

Charles W. Kreitler and Bernd C. Richter

The chemical compositions of waters within saline formations beneath the Texas Gulf Coast that are used for the disposal of chemical wastes by deep-well injection are being determined for the U.S. Environmental Protection Agency (EPA). Results of about 1,300 chemical analyses from all available sources have been computerized to provide a data base. Most waters within injection zones (4,000 to 7,000 ft) are the NaCl type and have salinity values that range from 30,000 to 80,000 mg/L. Salt-dome regions have higher salinities. Some South Texas waters have high calcium concentrations (up to 40,000 mg/L). This data base will be used in other EPA programs to determine whether the liquid wastes are chemically compatible with water and minerals in the formations used for injection and to evaluate the overall hydrology of saline formations in the Texas Gulf Coast that are used for deep-well injection of chemical wastes.

Sources of Salt-Water Pollution in Western Tom Green County

Charles W. Kreitler and Alan R. Dutton; assisted by Deborah Pfeiffer

This investigation was designed to characterize chemically and isotopically specific sources of brines that have a potential to pollute shallow ground water in Tom Green and eastern Irion Counties. This study followed a previous pilot study that indicated that brines from oil fields and natural ground-water discharge are most likely contributing to the overall poor quality of ground water in the Concho River drainage basin. Salinity and hydrochemical facies of shallow ground waters in Tom Green and eastern Irion Counties are generally controlled by reactions between meteoric water and minerals in the aquifers. The poor quality of ground water in Permian formations that subcrop beneath alluvium in the Concho River valley appears to be caused by natural discharge of briny ground water flowing eastward across the Eastern Shelf of the Midland Basin. Brines from different oil fields and oil-bearing formations can be broadly distinguished by acetate, Cl/SO_4 ratio, and stable isotopic compositions. Brines from fields at shallow depths in the San Angelo and San Andres Formations more closely resemble shallow ground waters in Tom Green and eastern Irion Counties than do brines from deeper fields producing from Canyon and Strawn rocks. This study will be completed with (1) testing of residual salt-water content beneath abandoned oil field brine disposal pits, (2) further sampling of oil field brines to improve resolution of chemical differences between fields, and (3) sampling of poor-quality ground water in wells that are erratically distributed within good-quality aquifer areas to determine local sources of salt-water pollution.

Research Associate Alan Dutton tests alkalinity and pH of an oil field brine near San Angelo as part of an investigation for the Railroad Commission of Texas to determine sources of salt-water pollution in western Tom Green County.

Geology and Ground-Water Hydrology of the Edwards Aquifer Recharge Zone, Williamson County

Christopher D. Henry and Charles W. Kreitler, project directors; Edward W. Collins and Rainer K. Senger

This project, funded by the Texas Water Development Board, involves geologic and hydrologic study of the Edwards aquifer along the Balcones Fault Zone in the vicinity of Georgetown, Texas. Geologic and structural mapping is intended to help delineate recharge areas of the aquifer. Detailed mapping to distinguish Cretaceous bedrock, including the Comanche Peak, Edwards, Georgetown, Del Rio, Buda, Eagle Ford, and Austin Formations, and Quaternary cover units, as well as faults and fractures associated with the Balcones Fault Zone, is being done to understand the distribution of permeability and porosity. The Edwards Limestone is the dominant part of the aquifer, but associated limestones in the Comanche Peak and Georgetown Formations may also be part of the aquifer. Limestone in the latter two formations is generally not as porous as limestone in the Edwards, but fracturing associated with faults may have created localized areas of greater porosity and recharge potential.

The hydrology of recharge to the aquifer is being studied in cooperation with the U.S. Geological Survey and the Texas Water Commission. In the first phase of the study, existing precipitation data, information on water levels, and water-chemistry data were analyzed to identify spatial and temporal distribution of hydrologic

E. W. Collins

Samples are taken from springs, such as Knight's Springs (above) in Williamson County, to identify chemical characteristics of ground water at natural discharge points from the Edwards aquifer.

and hydrochemical parameters. Further, continuous water-level recorders were installed at several wells in the area to identify the effects of individual recharge events on water levels in different areas of the aquifer. The second phase of the study will involve analysis of the hydrochemical characteristics of surface and ground water and the ways they vary with recharge events.

Coastal Studies

State Submerged Lands of Texas—Sediments, Geochemistry, Benthic Macroinvertebrates, and Associated Wetlands

William A. White, Thomas R. Calnan, Robert A. Morton, and H. S. Nance; assisted by James Miller; David W. Koppenaal and Steven W. Tweedy (chemists); Daniel H. Ortuño (sedimentology lab technician)

Work continued through 1986 on this long-term comprehensive inventory of Texas coastal submerged lands and associated wetlands. During the first part of the year, partial funding was provided by the Minerals Management Service, U.S. Department of the Interior, as part of a concluding 2-year contract. A major objective of the study is to produce an extensive data base characterizing submerged lands and wetlands along the entire Texas coast from Sabine Lake to the Rio Grande. The submerged lands study is based on textural, geochemical, and benthic macroinvertebrate analyses of selected sediment samples that were collected on 1-mi centers from the inner continental shelf and from the bay-estuary-lagoon systems. Coastal wetlands are being mapped and described using color-infrared photographs and field surveys.

The submerged lands atlas of the Brownsville-Harlingen area, third in the series of seven that will cover the entire Texas coast, was ready for publication at the end of 1986. The Corpus Christi and Galveston-Houston volumes have been published. Other atlas areas (listed in order of priority for publication) are Beaumont-Port Arthur, Bay City-Freeport, Port Lavaca, and Kingsville. Draft reports and hand-colored maps have been completed for all the areas. The atlases consist of a text and a series of 17 maps: (1) 4 maps (scale 1:250,000) depicting the distribution of sediment textures, (2) 12 maps (scale 1:250,000) depicting concentrations and distributions of selected trace, minor, and major elements in sediments, and (3) 1 full-color map (scale 1:125,000) depicting the distribution of coastal wetlands and associated environments as well as the distribution of benthic macroinvertebrate assemblages and species diversity in submerged lands.

The use of standardized analytical methods for different areas of the coast has allowed a comparison of parameters such as trace-metal concentrations from one bay or shelf area to another. In addition, normalization of elemental concentrations using percent mud has proved to be an effective method for characterizing and defining bay and shelf sediment trace-metal content. Anomalous occurrences of trace metals have been identified in several areas along the Texas coast; high concentrations in some sediments are apparently related to anthropogenic contributions of trace metals to the system.

Benthic macroinvertebrates found in bay-estuary-lagoon and inner shelf sediments are primarily polychaetes, bivalves, gastropods, and crustaceans. Polychaetes are dominant in most sediments. On the inner shelf, stations having higher percentages of sand generally have more benthic species. This positive correlation between percent sand and number of species is lower in the bays than on the inner shelf. Diversity on the inner shelf is generally high to very high. Cluster analysis was used to delineate benthic communities in all bays and on the inner shelf. Cluster analysis of data from stations in the bay-estuary-lagoon system generally yielded less well defined station groupings and assemblages than data from stations on the inner shelf. This was expected because of greater hydrographic and sediment variability in the bays.

Delineation of coastal wetlands and associated environments continued in 1986. One objective of the study is to produce updated regional full-color maps of wetlands; units are patterned after the Bureau's *Environmental Geologic Atlas of the Texas Coastal Zone* series. With the completion of the Kingsville area in 1986, wetlands have now been interpreted and delineated on photographs in all areas of the coast. Wetland maps of the Beaumont-Port Arthur, Bay City-Freeport, Port Lavaca, and Kingsville areas are in various stages of hand-coloring, editing, and cartographic preparation. Comparison of the distribution of wetlands mapped on photographs taken in 1979 as part of the Submerged Lands project with those mapped for the *Environmental Geologic Atlas* on mid-1950's photographs indicates significant local changes in wetland distribution in some areas such as Galveston-Houston and Beaumont-Port Arthur. Many changes, which include the replacement of marshes by open water, are related to land-surface subsidence and surface faulting.

Shoreline and Vegetation-Line Changes along the Texas Coast

Jeffrey G. Paine, Robert A. Morton, and William A. White

Monitoring of nearshore changes in geological and legal boundaries along the Texas coast comprised two efforts during 1986. The first effort, long-term bay shoreline monitoring, involved comparison of bay shorelines depicted on late 1800's topographic charts with shorelines mapped on aerial photographs taken between 1930 and 1982. In addition to quantifying shoreline changes, a major objective of the project was to examine processes leading to those changes. Results of the Galveston Bay study were published in 1986 in Geological Circular 86-3, and results of the San Antonio Bay study will be published in a 1987 Geological Circular.

The second effort was to investigate short-term (intervals of less than 10 years) coastal changes between Sabine Pass and the Rio Grande. Changes in position of the Gulf shoreline and vegetation line between the mid-1800's and mid-1970's were published as a series of Geological Circulars between 1974 and 1977. Since the original study, the availability of recent photographs, occurrences of hurricanes after 1975, evidence of rapid coastal changes, and refinements to shoreline monitoring techniques have led to the need for updating the earlier reports.

Gulf shoreline and vegetation-line changes between 1974 and 1982 were documented at more than 300 sites spaced approximately 5,000 ft apart, and rates of change were calculated for these sites. Compared with generally high erosion rates documented for the late 1960's and early 1970's, 1974 to 1982 changes are less erosional and are locally accretionary. Investigations into the possible causes of the reduction in erosion rate have centered on a decrease in the relative rate of sea-level rise observed at most Texas tide gauges between 1974 and 1982. Tide data since 1982 show that rates of relative sea-level rise are again increasing, implying a return to widespread erosion. Results of this study are scheduled to be published in late 1987.

Mineral Resources Investigations

Assessment of the Hard-Mineral Resource Potential of State-Owned Lands

Jonathan G. Price, project director; Tucker F. Hentz and Gay Nell Gutierrez

A project jointly funded by the General Land Office and the Texas Mining and Mineral Resources Research Institute is assessing the potential for future production of nonpetroleum mineral commodities on certain State-owned lands. The project, which is scheduled for completion early in 1987, is focusing on two sulfur districts in Trans-Pecos Texas, the Rustler Springs district in Culberson and Reeves Counties and the Fort Stockton district in Pecos County. In both districts sulfur has been produced from Permian evaporite sequences. Pennzoil's Culberson mine is one of the largest Frasch-type sulfur mines in the world.

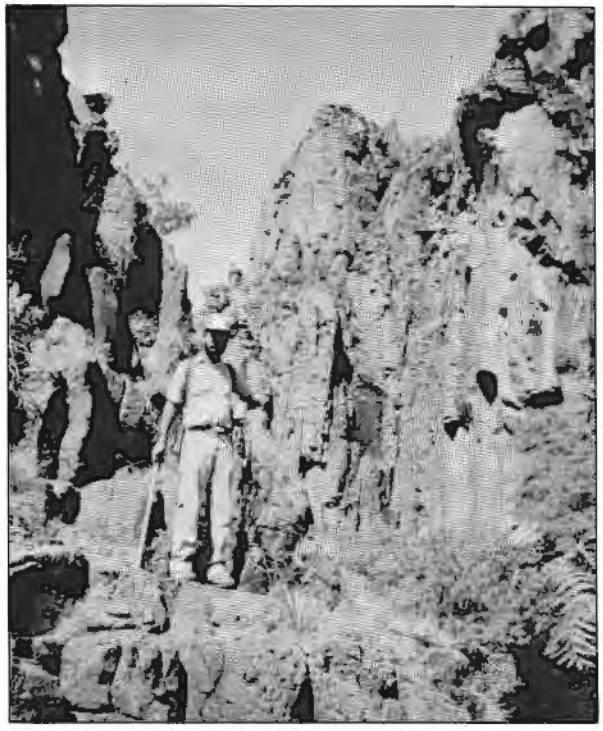
Resource assessments are being made by analyzing data from several sources. Because the sulfur probably formed by a complex process involving bacterial digestion of hydrocarbons and reduction of sulfur in anhydrite or gypsum to form hydrogen sulfide, then oxidation by ground waters to form native sulfur, various lithologic, hydrologic, and structural factors contributed to the localization of sulfur deposits. Gamma, neutron, and lithologic logs for approximately 1,500 drillholes have been used to construct stratigraphic cross sections and structure contour maps of the tops of several Permian formations. Additional computer-generated maps derived from log data show the depths and thicknesses of sulfur occurrences, drilling densities, and total depths of exploratory wells. Surface expressions of faults, joints, and prominent solution features have been identified and mapped from low-altitude aerial photographs in the Rustler Springs district. Maps showing oil and gas fields in Permian and older rocks are also incorporated into the study.

Results of the sulfur study will be published in a Bureau Mineral Resource Circular, and a computer data base will be housed in the General Land Office. The data base will include digitized locations of property corners, drillholes, prospects, and mines; stratigraphic and sulfur-occurrence data used in map drawing; and a tract-by-tract assessment of the sulfur resource potential.

Magma Generation, Magma Evolution, Caldera Development, and Ore Deposition, Trans-Pecos Texas

Christopher D. Henry, project director; Jonathan G. Price; assisted by Jeffrey N. Rubin and James H. Wittke

Many Trans-Pecos mineral deposits, such as those of molybdenum, tin, tungsten, fluorine, and beryllium, were clearly derived during Tertiary igneous activity. It is important to understand the chemical evolution of the magmas, including trace elements, from their origins in the mantle or crust to their extrusion or intrusion in the shallow crust. Heat supplied by ascending magma also induces hydrothermal circulation, which is often enhanced by structures formed by calderas, large volcanic collapse features. This igneous-induced hydrothermal



J. G. Price

Research Scientist Chris Henry examines columnar jointing in the Bracks Rhyolite, one of several enigmatic silicic volcanic units with textural characteristics of lava flows but areal distributions of ash flow tuffs.

circulation may be a requirement for the origin of some metallic ores, such as large deposits of silver and mercury in Texas.

Fundamental petrologic questions about the origin of igneous rocks in Trans-Pecos Texas are being addressed by field mapping, geochemical analyses of rocks and individual minerals, potassium-argon dating, computer modeling of magmatic processes, and thermodynamic calculations. Research is funded by the Texas Mining and Mineral Resources Research Institute.

Studies in 1986 emphasized petrogenesis in three igneous centers, all of which have significant potential for ore deposits. Modeling of magma evolution at Marble Canyon-Cave Peak, which hosts a molybdenum deposit, indicates a combination of fractional crystallization and crustal assimilation gave rise to the spectrum of igneous rocks present. Magma evolution in the Infiernito caldera, however, was dominated by fractional crystallization; mixing between different magmas and crustal assimilation were minor but measurable processes. Preliminary studies of the rhyolitic intrusions at Sierra Blanca, a potentially major beryllium deposit, suggest they were highly differentiated magmas mineralogically resembling granite pegmatites. The intrusions contain cryolite, Na_3AlF_6, and are enriched in Be, F, Y, Zr, Nb, Sn, REE, and Th.

Several publications resulting from these studies were released in 1986. The Bureau's Guidebook 23, *Igneous Geology of Trans-Pecos Texas*, was prepared as part of a field trip connected with the national meeting of the Geological Society of America in San Antonio. Other related Bureau publications include Report of Investigations No. 151 on caldera development in the Van Horn Mountains and Geologic Circular 86-2, a compilation of potassium-argon age determinations of Tertiary igneous rocks in Trans-Pecos. An article titled "Alkalic Rocks of Contrasting Tectonic Settings in Trans-Pecos Texas" was accepted for publication in a GSA Special Paper on alkalic rocks. Two manuscripts on magma evolution and geothermometry in the Infiernito caldera magma system have been prepared for publication in *Contributions to Mineralogy and Petrology*.

State of Stress with Time and Relation to Ore Deposition

Christopher D. Henry, project director; Jonathan G. Price

Understanding the relationship between ore deposits and tectonic stress during the Tertiary Period requires knowledge of the state of stress with time. Potassium-argon dating of dikes has been used to determine paleostress orientations and studies of vein orientations and sizes as a function of time throughout western North America. Unlike most large epithermal precious metal veins in the world, which formed in environments of crustal extension, those in Trans-Pecos Texas formed chiefly in a compressional environment. These types of deposits formed during the peak of Trans-Pecos igneous activity, between 38 and 32 mya, when the region was under a state of mild compression residual from early Tertiary Laramide folding and thrusting. These observations may explain the small size of most igneous-related veins in Texas.

Field work and isotopic dating this year have confirmed that a change from compression to extension occurred about 31 mya. Dating has revealed that 24- to 18-m.y.-old alkali basalt dikes are widespread, although volumetrically minor compared with earlier igneous rocks in Texas. These dikes were preferentially injected into north-northwest-striking fractures and are part of a general trend observed throughout the Basin and Range province at that time.

Results of these studies published or accepted for publication in 1986 include an article on the Basin and Range dikes in a special issue of the *Journal of Geophysical Research* and a summary of dike orientations and stress relations, which will appear in a Geological Society of America field guide for the Decade of North American Geology series. An invited presentation on the relationships between stress orientations–tectonic setting and magmatism was given at the national GSA meeting in San Antonio. An abstract titled "Tectonic Controls on Orientation and Size of Epithermal Veins" was submitted to a conference on the tectonic control of ore deposits.

Texas Portland Cement Industry and Cement Resources

Mary W. McBride, Tom S. Patty (consultant, Erlin, Hime Associates, Division of WJE, Austin, Texas), and Roger D. Sharpe (United States Gypsum Co., Chicago, Illinois)

Texas is the leading cement-producing state in the nation and is now in its second century of cement manufacture. A manuscript describing the Texas industry and delineating geologic occurrence of current and potential resources, funded in part by the Texas Mining and Mineral Resources Research Institute, has been reviewed by members of the cement industry and by Bureau staff.

The report is designed to give the professional in the cement industry an appreciation of the vast supply of cement raw materials available in Texas and to acquaint the lay reader with an industry that produced products valued at $550 million in 1985.

The Barite Industry and Resources of Texas

J. Richard Kyle (The University of Texas at Austin, Department of Geological Sciences), principal investigator

The Texas Mining and Mineral Resources Research Institute funded this study of the geology of barite resources and the economics of the barite industry. Most known barite deposits in Texas are too small and low grade to compete commercially with present domestic and foreign sources for the oil well drilling industry. The geologic setting of some barite occurrences in Texas suggests substantial potential, particularly for chemical and glass grade barite. A manuscript summarizing this project is in review for publication by the Bureau as a Mineral Resource Circular.

Mapping Investigations

Geologic Atlas of Texas

Virgil E. Barnes, project director; L. F. Brown, Jr., and Tucker F. Hentz; Richard L. Dillon, Dan F. Scranton, Margaret D. Koenig, and John T. Ames, cartographers

The Bureau's *Geologic Atlas of Texas*, a series of 38 separate map sheets, was completed at the end of the year with the color separation of the Wichita Falls-Lawton Sheet. That sheet will be printed in early 1987. The full-color map series shows the distribution of the outcropping rock units in Texas and parts of adjacent states on a topographic base at a scale of 1:250,000 (1 inch = 4 mi). Most of the sheets depict areas within 1 degree of latitude and 2 degrees of longitude.

With the publication of the last sheet in the series, the atlas project will shift from new mapping to revising maps that have gone out of print. The Brownwood and Llano Sheets were reprinted without revision in 1986, and the Emory Peak-Presidio Sheet will be reprinted from original plates in spring 1987. Revised versions of the Dallas, Beeville-Bay City, and Beaumont Sheets are in various stages of color separation and will be reissued when completed. The Abilene, Lubbock, Palestine, and Sherman Sheets are temporarily out of print and will be reissued as they are revised.

Geologic Map of Texas

Virgil E. Barnes, project director; Dan F. Scranton, cartographer

Preparation of a new geologic wall map of Texas began in May 1978. This map will be published in four quadrants at a scale of 1:500,000 and will replace the U.S. Geological Survey's *Geologic Map of Texas*, which was published in 1937 and has been out of print for many years.

The new map is being derived from the *Geologic Atlas of Texas* map sheets (scale 1:250,000). Initial scribing of all four quadrants was completed in 1986. Review of the explanation, which includes 352 geologic units, is completed. Review of scribing for the northeast and southwest quadrants of the geologic map is completed and is in progress for the northwest and southeast quadrants.

Tectonic Map of Texas

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

The last statewide compilation of structural and tectonic information was by E. H. Sellards in the 1940's. Since then, much new surface and subsurface information has been acquired, and the concepts of tectonic mapping have advanced. This project incorporates new data to provide a display of surface and subsurface structure of the state and adjoining parts of New Mexico, Oklahoma, Mexico, and the Gulf of Mexico. The map will be published in full color at a scale of 1:750,000 and will depict exposed lithotectonic units and contours of selected deep subsurface horizons. Inset maps summarize gravity, magnetics, and basement terranes or isotopic-age provinces or both. An illustrated text will describe and synthesize the tectonic evolution of Texas.

Geologic Mapping of the Christmas Mountains and Hen Egg Mountain 7.5-Minute Quadrangles, Christmas Mountains Intrusive Province, Trans-Pecos Texas

Christopher D. Henry, project director; Jonathan G. Price; assisted by Don Miser

This project is supported by the U.S. Geological Survey's Cooperative Geologic Mapping Program (COGEOMAP). A detailed study of the area was undertaken because it is one of the most poorly understood parts of the Trans-Pecos igneous province and because available information suggests the potential for significant deposits of beryllium, fluorite, mercury, and molybdenum. Detailed mapping shows that the geology consists of abundant small, shallow intrusions emplaced into Cretaceous sedimentary rocks. The intrusions range in composition from nepheline-normative basalt to peralkaline rhyolite and occur in two distinct, silica-undersaturated and silica-oversaturated compositional trends. A previously unrecognized caldera formed as a result of eruption of a peralkaline quartz trachyte. Potassium-argon dating as part of the project shows that most of the magmatism occurred during several episodes between 47 and 41 mya but that some magmatism is as young as 28 and 24 m.y. Most ore deposits consist of contact replacement fluorite at the contact of rhyolites, commonly peralkaline varieties, with Cretaceous limestones. The deposits are irregularly but potentially significantly enriched in beryllium, uranium, thorium, molybdenum, zirconium, lead, and zinc. Results of the mapping will be used to revise the Emory Peak-Presidio Sheet of the *Geologic Atlas of Texas*.

Gravity and Magnetic Mapping of Texas

G. R. Keller (The University of Texas at El Paso, Department of Geological Sciences) and C. L. V. Aiken (The University of Texas at Dallas, Department of Geological Sciences), project directors; cartography by John T. Ames and Richard M. Platt

Gravity and magnetic maps of Texas are being prepared at a scale of 1:250,000 to complement the surface-geology maps of the *Geologic Atlas of Texas* series. The project involves considerable computer reprocessing, compilation, and cartography. Gravity (Bouguer) maps are prepared by combining many different surveys using a single datum. Gravity data are then smoothed with a high-order polynomial surface. To date, the Amarillo, Big Spring, Brownfield, Clovis, Dalhart, Hobbs, Lubbock, Perryton, Plainview, and Tucumcari Sheets have been published.

Magnetic maps are being prepared using National Uranium Resource Evaluation (NURE) aeromagnetic surveys. Much of the data have been provided by the U.S. Department of Defense. In 1986, scribing was under way on the 10 sheets for which gravity maps have been published.

Other Geologic Investigations

Experimental Modeling of Salt Domes

M. P. A. Jackson, project director; Reinold R. Cornelius, Christopher J. Talbot (University of Uppsala, Sweden), and Claire Craig (The University of Texas at Austin, Institute for Geophysics)

Modeling of salt diapirs in 1986 focused on simulating the diapirs exposed in the Great Kavir of north-central Iran. From a mechanical viewpoint, these diapirs have several unusual features: (1) two distinct buoyant source layers of Tertiary age are juxtaposed in the diapirs; (2) although the exposed diapirs are among the world's broadest, their spacing is anomalously close; and (3) gravitational overturn has advanced to an extremely mature stage of canopy formation (described in the previous article). Explanation of these unusual features would provide new mechanical insights into the natural deformation of salt.

Computer modeling at the Institute for Geophysics using linear analytical theory has been used to study diapiric spacing in two dimensions, based on the structure and stratigraphy of the Great Kavir salt basin. Provisional results suggest that diapirs pierced their overburden relatively late and that the close clustering of the diapirs is due to the presence of the double source layer. The results have been compared with the spacing of Great Kavir salt pillows to the east of the diapir province and of Hormuz diapirs in the Zagros foldbelt to the southwest.

Experiments at the Hans Ramberg Tectonic Laboratory of the University of Uppsala at the end of 1986 successfully simulated in three dimensions the formation of both discrete mushroom-shaped diapirs and multidiapir canopies, scaled to the mechanical stratigraphy of the Great Kavir. Data from these experiments will be analyzed in 1987.

Great Kavir Salt Dome: A Generic Study of Diapiric Structure and Mechanics

M. P. A. Jackson, project director; Reinold R. Cornelius, Augusto Gansser (Swiss Federal Institute of Technology), and Jovan Stöcklin (Seuzach, Switzerland)

More than 50 Tertiary salt diapirs are exposed in the Great Kavir (Dasht-e-Kavir), an extensive salt desert in north-central Iran. Study of the diapirs began in 1985, funded by the U.S. Department of Energy, based pri-

A. Gansser

Oblique aerial photograph shows composite salt diapir exposed in the Great Kavir of Iran. White Eocene salt, covered by residual gypsum crust, makes up the core and is surrounded by prominently layered Miocene mixed evaporites.

marily on aerial photographs (1:29,000 and 1:58,000 scales) and Landsat images (1:250,000 scale). Several unusual geologic features combine to provide an unparalleled opportunity for the mapping and structural analysis of diapirs to yield new information on the natural deformation of salt: (1) superb exposure of complete domes at varying structural levels, (2) consistent stratigraphy within the diapirs for structural correlation, and (3) prominent compositional layering in diapirs and country rock that clearly delineates folds, faults, and shear zones.

In 1985 the internal structure of 30 diapirs was mapped from aerial photographs. Interpretation of the maps was aided by previous study of the kinematics of diapirism in centrifuge experiments. The salt domes were classified into six basic map patterns, which can be interpreted as representing exposures of six different structural levels of salt domes having the same basic geometry. This complex geometry is mushroom shaped: a stalk is surmounted by an overhanging bulb with downward-facing, pendant peripheral lobes. Tilting and asymmetry cause additional complexities. A full range of salt structures has been recognized: salt pillow, salt anticline, salt stock, and salt canopy. The latter structure is a 40-km-wide allochthonous salt layer formed by lateral fusion of 12 diapiric bulbs connected by diapiric stems to a deep source layer of salt. Similar structures may be present in the northwestern Gulf of Mexico.

Studies in 1986, which will be continued in 1987, integrate the local strains due to diapiric intrusion with the regional folding and thrusting. Geologic and structural maps and cross sections are being prepared at scales of 1:250,000, 1:160,000, and 1:50,000. Landsat images provided an undistorted, digitized base map onto which data from the aerial photographs were plotted. Data derived photogeologically are checked against and combined with field data collected over two decades. Elevations were determined in the field and by photogrammetric parallax measurements with sufficient accuracy to map 20-m contour intervals. Mapping of surficial deposits provides information on neotectonics.

A provisional interpretation is that the Great Kavir basin was shortened by regional folding and pierced by salt diapirs within a remarkably short geologic timespan—probably in the last 5 m.y. About half of the diapirs are still actively extruding. The area is also noteworthy for the paucity of faults resulting from diapirism and the high degree of ductile strain in the country rocks, which are also salt bearing.

Stratigraphy of Upper Pennsylvanian and Lower Permian Sequences in North-Central Texas

L. F. Brown, Jr., project director; Raul Salis and David A. Johns

This long-term project involves interpretation of the lithogenetic stratigraphy and depositional systems of the Virgilian and Wolfcampian Series in 25,000 mi^2 of the Eastern Shelf and adjacent Midland Basin. In 1986, a manuscript titled "Regional Stratigraphic Cross Sections, Upper Pennsylvanian and Lower Permian Strata (Virgilian and Wolfcampian Series), North-Central Texas" was approved for publication. At the end of the year, the report was in typesetting preparation and final drafting. The report will include a text, 23 cross sections covering 2,000 mi, and other plates and figures.

At the end of the year a manuscript for a second report titled "Regional Depositional Systems and Paleogeography, Upper Pennsylvanian and Lower Permian, North-Central Texas" was nearing review. This report will include paleogeographic maps of 16 terrigenous clastic sequences composing the Virgilian and Wolfcampian cyclothems on the Eastern Shelf and adjacent Midland Basin. Included will be plates illustrating the depositional models that operated during deposition of the sequences.

Initial review of geophysical logs was begun late in the year to evaluate inferred sea-level changes and their effect on the depositional sequences, including the distribution of marine condensed sections and inferred low-stand delta/slope systems.

Depositional Framework and Genesis of Tertiary Submarine Gorges, Eocene, Northwest Gulf Coast

William E. Galloway, project director; assisted by W. F. Dingus and R. E. Paige

Large erosional gorges cut into paralic sediments are prominent stratigraphic features of many depositionally

active deltaic (offlap) continental margins. Increasingly, and without critical examination of the underlying premise, origination of such features is being equated with local or eustatic falls in sea level. The primary result of this proposed four-dimensional analysis of one family of Tertiary gorge fills will be a critical reexamination of causal relationships between depositional setting, eustatic sea-level cycles, and local depositional or structural events and large-scale erosion at continental margins.

Tasks to be completed in this study are to (1) describe the three-dimensional geometry and stratigraphic setting of Eocene gorges on the Northwest Shelf of the Gulf Basin within the closely constrained framework of bounding depositional systems and contemporaneous structural growth, (2) interpret the depositional architecture and origin of gorges and their fill, and (3) assess the temporal relationship of gorge incision and filling to inferred worldwide eustatic cycles. Delineation of gorge morphology, syndepositional structural framework, paleogeographic setting, and position within Wilcox depositional cycles will rely on analysis of well and geophysical data. Core and sample data from wells will be used for age dating and lithologic interpretation of gorge fill and bounding facies. Graphical decompaction procedures will enhance reconstruction of original gorge morphology.

The project ends on June 1, and final reports will be submitted to the National Science Foundation and for publication.

Facies and Diagenesis of Organic Matter from Sapropel Layers of the Tyrrhenian Basin, Ocean Drilling Program, Leg 107

P. K. Mukhopadhyay

This project included shipboard participation (through an invitation from the Ocean Drilling Program, Texas A&M University) as an organic geochemist on the cruise of Leg 107 in the Tyrrhenian Sea (between Corsica and Italy in the Mediterranean Sea) between December 28, 1985, and January 22, 1986. After the cruise, selected samples of the saturate fraction of the extracts of 14 black shales from different sites of Leg 107 were analyzed by organic petrography, Rock-Eval pyrolysis, and gas chromatography.

Preliminary postcruise studies indicate that so-called sapropel layers have wide variations in organic carbon content (between 0.42 and 8.86 percent total organic carbon [TOC]) and in the nature of the organic matter (type I to type IV kerogens). Data suggest that high organic carbon-rich black shale (8.86 percent TOC; hydrogen index [HI]: 934) contains lacustrine-derived lamellar alginite having unimodal n-alkane distribution. Moderate organic carbon-rich sediments (2.14 to 5.49 percent TOC; HI between 185 and 295) had both partially oxidized and fecal-pellet-associated biodegraded alginite and a mixture of marine (biodegraded diatom or dinoflagellates) and terrestrial (sporinite and cutinite) liptinite. Mixed marine and terrestrial organic matters show a bimodal distribution of n-alkanes. Organic-poor black to gray shales (0.42 to 0.72 percent TOC; HI between 38 and 93) contain either totally oxidized algal-derived amorphous macerals or typical primary inertinites (fusinite, macrinite, etc.) and generate a broad n-alkane distribution without any peak. This differentiation in organic facies suggests that various phases of black shale deposition occurred during the syndrift and postrift periods of the Tyrrhenian Basin, which may be comparable to the modern East African rift system.

Huminite/vitrinite reflectance and T_{max}(°C) suggest a high maturity trend (0.24 percent R_o at 25 m with T_{max} 411°; 0.66 percent R_o at 600 m with T_{max} 435°). The projected maturity at 700 m (maximum drilled depth) was 0.73 percent R_o, suggesting that kerogens below 500 m were mature enough to generate an appreciable amount of liquid hydrocarbons.

Contract and Grant Reports

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

Ewing, T. E., Light, M. P. R., Tyler, N., and **Morton, R. A.,** 1986, Consolidation of geologic studies of geopressured geothermal resources in Texas: The University of Texas at Austin, Bureau of Economic Geology, 1984 annual report prepared for the U.S. Department of Energy under contract no. DE-AC08-79ET27111, 97 p.

Fisher, R. S., 1986, Clay mineralogy in evaporite host rocks, Palo Duro Basin, Texas Panhandle: The University of Texas at Austin, Bureau of Economic Geology, final report prepared for the U.S. Department of Energy, Salt Repository Project Office, under contract no. DE-AC97-83WM46651, Open-File Report OF-WTWI-1985-45, Revision 01, 25 p.

Hovorka, S. D., and McCrary, M. M., 1986, Petrography of the Artesia Group: interim report, volume 1 and volume 2: The University of Texas at Austin, Bureau of Economic Geology, final report prepared for the U.S. Department of Energy, Salt Repository Project Office, under contract no. DE-AC97-83WM46651, Open-File Report OF-WTWI-1985-42, Revision 01, unpaginated.

Kreitler, C. W., Raney, J. A., Mullican, W. F., III, Collins, E. W., and **Nativ, Ronit,** 1986, Preliminary geologic and hydrologic studies of sites HU1A and HU1B in Hudspeth County, Texas: The University of Texas at Austin, Bureau of Economic Geology, final report prepared for the Texas Low-Level Radioactive Waste Disposal Authority under contract no. IAC(86-87)-1061, 104 p.

Kreitler, C. W., Raney, J. A., Nativ, Ronit, Collins, E. W., Mullican, W. F., III, Gustavson, T. C., and **Henry, C. D.,** 1986, Preliminary geologic and hydrologic studies of selected areas in Culberson and Hudspeth Counties, Texas: The University of Texas at Austin, Bureau of Economic Geology, final report prepared for the Texas Low-Level Radioactive Waste Disposal Authority under contract no. IAC(86-87)-0828, 184 p.

Kreitler, C. W., and **Richter, B. C.,** 1986, Hydrochemical characterization of saline aquifers of the Texas Gulf Coast used for disposal of industrial waste: The University of Texas at Austin, Bureau of Economic Geology, final report prepared for the U.S. Environmental Protection Agency under contract no. R-812785-01-0, 164 p.

Light, M. P. R., Jackson, M. L. W., and **Ayers, W. B., Jr.,** 1986, Coordination of geological and engineering research in support of Gulf Coast co-production program: The University of Texas at Austin, Bureau of Economic Geology, annual report prepared for the Gas Research Institute under contract no. 5084-212-0924, 267 p.

Lin, Z. S., and **Finley, R. J.,** 1986, Comparative engineering field studies and gas resources of the Travis Peak Formation, East Texas Basin: The University of Texas at Austin, Bureau of Economic Geology, topical report prepared for the Gas Research Institute under contract no. 5082-211-0708, 96 p.

The following Bureau publications served as final contract reports during 1986:

Ewing, T. E., 1986, Structural styles of the Wilcox and Frio growth-fault trends in Texas: constraints on geopressured reservoirs: The University of Texas at Austin, Bureau of Economic Geology Report of Investigations No. 154, 86 p.
Prepared for the U.S. Department of Energy, Division of Geothermal Energy, under contract no. DE-AC08-79ET27111.

Fracasso, M. A., and **Hovorka, S. D.,** 1986, Cyclicity in the middle Permian San Andres Formation, Palo Duro Basin, Texas Panhandle: The University of Texas at Austin, Bureau of Economic Geology Report of Investigations No. 156, 48 p.
Prepared for the U.S. Department of Energy, Salt Repository Project Office, under contract no. DE-AC97-83WM46651.

Galloway, W. E., 1986, Depositional and structural framework of the distal Frio Formation, Texas: The University of Texas at Austin, Bureau of Economic Geology Geological Circular 86-8, 16 p.
Prepared for the Minerals Management Service, U.S. Department of the Interior, under agreement no. 14-12-0001-30115.

Galloway, W. E., Jirik, L. A., Morton, R. A., and **DuBar, J. R.,** 1986, Lower Miocene (Fleming) depositional episode of the Texas Coastal Plain and continental shelf: structural framework, facies, and hydrocarbon resources: The University of Texas at Austin, Bureau of Economic Geology Report of Investigations No. 150, 50 p.
Prepared for the Minerals Management Service, U.S. Department of the Interior, under agreement nos. 14-12-0001-30115 and 14-12-0002-40029.

Richter, B. C., and **Kreitler, C. W.,** 1986, Geochemistry of salt-spring and shallow subsurface brines in the Rolling Plains of Texas and southwestern Oklahoma: The University of Texas at Austin, Bureau of Economic Geology Report of Investigations No. 155, 47 p.
Prepared for the U.S. Department of Energy, Salt Repository Project Office, under contract no. DE-AC97-83WM46651.

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White, W. A., Calnan, T. R., Morton, R. A., Kimble, R. S., Littleton, T. G., McGowen, J. H., **Nance, H. S.,** and Schmedes, K. E., 1986, Submerged lands of Texas, Brownsville-Harlingen area: sediments, geochemistry, benthic macroinvertebrates, and associated wetlands: The University of Texas at Austin, Bureau of Economic Geology Special Publication, 138 p.
Financial assistance was provided in part by (1) the General Land Office of Texas, with funding in accordance with section 305 of the Coastal Zone Management Act for Coastal Zone Management Program (CZMP), (2) the Governor's Budget and Planning Office, with grants in accordance with section 308 of the same act for the Coastal Energy Impact Program (CEIP); CZMP and CEIP funding was administered by the National Oceanic and Atmospheric Administration of the U.S. Department of Commerce, and (3) the Minerals Management Service of the U.S. Department of the Interior; parts of the study were conducted in cooperation with the U.S. Geological Survey. Contract numbers with the General Land Office were IAC(80-81)-1201, IAC(78-79)-1910, IAC(78-79)-0539, IAC(76-77)-1244, and IAC(76-77)-0833. Contract numbers with the Governor's Budget and Planning Office were CZ80M935019, IAC(80-81)-0865, and IAC(78-79)-1210. The contract number with the Minerals Management Service is 14-12-0001-30070.

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 1986, the following 30 contracts, each of which had reporting requirements, were active at the Bureau:

Federal

"Computerized Calculation and Characterization of Lignite Resources in Texas": supported by the U.S. Geological Survey, U.S. Department of the Interior (two contracts).

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

"Depositional Framework and Genesis of Tertiary Submarine Gorges, Eocene, Northwest Gulf Coast": supported by the National Science Foundation.

"Environmental Geologic Atlas of the Texas Coastal Zone": supported by the Minerals Management Service, U.S. Department of the Interior.

"Geochemical Characterization of Saline Formations in the Texas Gulf Coast that are used for Deep-Well Injection of Chemical Wastes": supported by the U.S. Environmental Protection Agency.

"Geologic Mapping of the Christmas Mountains and Hen Egg Mountain 7.5-Minute Quadrangles, Christmas Mountains Intrusive Province, Trans-Pecos Texas": supported by the U.S. Geological Survey, U.S. Department of the Interior.

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

"Printing Environmental Maps of Texas": supported by the U.S. Geological Survey, U.S. Department of the Interior.

"Regional Hydrologic Characterization of Saline Formations in the Texas Gulf Coast that are used for Deep-Well Injection of Chemical Wastes": supported by the U.S. Environmental Protection Agency.

"Studies Related to Continental Margins" (years 1 through 4): supported by the Minerals Management Service, U.S. Department of the Interior (three contracts).

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

State

"Assessment of the Hard-Mineral Resource Potential of State-Owned Lands": supported by the General Land Office of Texas.

"Development of Ground-Water Data Management Systems": supported by the Texas Water Commission.

"Geologic and Fluid Behavior Characteristics of Oil Reservoirs on University Lands": supported by The University of Texas System.

"Geology and Ground-Water Hydrology of the Edwards Aquifer Recharge Zone, Williamson County, Texas": supported by the Texas Water Development Board.

"Leg 107 of the Ocean Drilling Program": supported by the Texas A&M Research Foundation.

"A Preliminary Data Base on the Geology of Two Sites for a Low-Level Nuclear Waste Repository": supported by Texas Low-Level Radioactive Waste Disposal Authority.

"Preparation of a Petroleum Resource Data Base for Texas State Submerged Lands": supported by the General Land Office of Texas.

"Reconnaissance Data Base on the Geology of Hudspeth Sites 1A and 1B": supported by the Texas Low-Level Radioactive Waste Disposal Authority.

"Sources of Salt-Water Pollution in Western Tom Green County": supported by the Railroad Commission of Texas.

Private

"Cogeneration Issues in Texas: The Policy Choices": supported by Houston Natural Gas.

"Development of an Atlas of Major Texas Gas Reservoirs": supported by the Gas Research Institute.

"Genetic Stratigraphy, Depositional Systems, Structural Evolution, and Petroleum Exploration Potential: Northwest Gulf of Mexico Continental Shelf": supported by industry and the Minerals Management Service, U.S. Department of the Interior.

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

"Geological, Geochemical, and Engineering Research in Support of Gulf Coast Co-Production Program": supported by the Gas Research Institute.

"Reservoir Characterization Research Laboratory": supported by industry.

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 77-year history, the Bureau has published nearly 1,700 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, about 1.66 million publications have been distributed worldwide, mostly through direct sales. During 1986, about 40,000 volumes were distributed. The Bureau issued the following publications in 1986:

Special Publications

Geology and Ground-Water Hydrology of Deep-Basin Lignite in the Wilcox Group of East Texas, *by W. R. Kaiser, M. L. Ambrose, W. B. Ayers, Jr., P. E. Blanchard, G. F. Collins, G. E. Fogg, D. L. Gower, C. L. Ho, C. S. Holland, M. L. W. Jackson, C. M. Jones, A. H. Lewis, G. L. Macpherson, C. A. Mahan, A. H. Mullin, D. A. Prouty, S. J. Tewalt, and S. W. Tweedy. 182 p., 80 figs., 29 tables, 2 appendices ($7.00).*

Regional integration of subsurface geology, aquifer hydraulics, ground-water chemistry, and the occurrence and composition of deep lignite.

The Wilcox Group is both a principal host of lignite and a major fresh-water aquifer. The thickest and most laterally extensive deep lignite seams occur in Shelby, Panola, Robertson, Milam, Burleson, and Lee Counties. Their presence and identification on electric and induction logs were confirmed in an associated drilling and coring program that tested an evolving depositional model and recovered lignite for chemical analysis. Regional ground-water flow patterns and aquifer (sand) trends were mapped by integrating data on aquifer hydraulics and ground-water chemistry with data on aquifer (sand-body) geometry and sand content. These data provide the regional framework to facilitate interpretation of site-specific hydrologic and hydrochemical data at lignite mines, municipal well fields, and waste disposal sites. Deep lignite is borderline subbituminous in rank and enriched in sodium. Chemical constituents, except for sodium, should present no major obstacles to the utilization of deep lignite.

Submerged Lands of Texas, Brownsville-Harlingen Area: Sediments, Geochemistry, Benthic Macroinvertebrates, and Associated Wetlands, *by W. A. White, T. R. Calnan, R. A. Morton, R. S. Kimble, T. G. Littleton, J. H. McGowen, H. S. Nance, and K. E. Schmedes. 138 p., 60 figs., 16 tables, 6 pls., 3 appendices ($12.50).*

Detailed inventory of submerged lands and associated wetlands in the Brownsville-Harlingen area of the Texas Coastal Zone.

State-owned submerged lands of Texas encompass nearly 6,000 mi^2 and extend 10.3 mi from the Gulf shoreline on the inner continental shelf. This atlas, which focuses on the Brownsville-Harlingen area of the Coastal Zone, is the third in a series of submerged lands atlases to provide comprehensive sedimentological, geochemical, and biological data for management of coastal areas. Researchers collected and analyzed 6,700 surficial bottom samples across the submerged lands, from the Rio Grande to Sabine Lake, to map and describe sediment distribution, concentrations of selected major and trace elements, and benthic macroinvertebrate populations. Adjacent wetlands were delineated using stereoscopic, color-infrared positive transparencies provided by the National Aeronautics and Space Administration and are depicted on a full-color map along with the distribution of benthic macroinvertebrate assemblages and species diversities in submerged lands.

Reports of Investigations

RI 149. Controls on Porosity and Permeability of Hydrocarbon Reservoirs in Lower Tertiary Sandstones along the Texas Gulf Coast, *by R. G. Loucks, M. M. Dodge, and W. E. Galloway. 78 p., 71 figs., 3 tables, 5 pls., appendix ($3.00).*

Description and interpretation of the formation, preservation, and distribution of sandstone porosity and permeability in the Wilcox Group and Yegua, Vicksburg, and Frio Formations of the Texas Gulf Coast.

Although much has been written on the structure, stratigraphy, and depositional systems of this highly drilled area, only in the last decade have systematic data become available on diagenesis and reservoir quality. An earlier report, Report of Investigations No. 111, addressed specific questions on the topic. This publication presents the regional data base assembled for the northwestern Gulf of Mexico basin and includes whole cores and core plugs from 179 wells, core-plug porosity and permeability analyses from 253 wells, and acoustic logs from 86 wells. Trends in reservoir quality, sandstone composition, and diagenetic features are defined. The text includes four black-and-white plates showing criteria used for recognition of secondary porosity and a color centerfold plate illustrating the generalized sandstone consolidation sequence with depth. The authors report that porosity and permeability in sandstones shallower than 3,050 m are generally adequate for hydrocarbon production; however, below that depth, reservoir quality is highly variable. The producing fairways within the coastal plain are further subdivided by patterns in deep reservoir quality.

RI 150. Lower Miocene (Fleming) Depositional Episode of the Texas Coastal Plain and Continental Shelf: Structural Framework, Facies, and Hydrocarbon Resources, *by W. E. Galloway, L. A. Jirik, R. A. Morton, and J. R. DuBar. 50 p., 20 figs., 4 tables, 7 pls., appendix ($4.50).*

Delineation of major structural features, interpretation of depositional systems and structural styles, and discussion of the hydrocarbon distribution and potential of the lower Miocene Fleming Group and its subsurface equivalents.

The authors synthesized several hundred geophysical logs to establish a genetic stratigraphic framework for lower Miocene sediments and resources. Their interpretations are presented in three structural cross sections and in numerous quantitative lithofacies maps and interpretive drawings. Paleontologic summaries of more than 60 wells aided definition of chronostratigraphic relationships and paleobathymetric zones. Quantitative facies maps clearly define the presence of three major depositional regimes within the lower Miocene section—the subaerial coastal plain, the coastline, and the submerged shelf and slope. Six principal depositional systems are delineated and discussed in detail. In the second half of the text, the authors discuss the origin and distribution of hydrocarbons within the lower Miocene sequence. A comprehensive table summarizes the geologic characteristics and remaining potential of the nine identified lower Miocene oil and gas plays. The authors conclude that the Miocene has significant remaining exploration potential; they note, however, that production within the Miocene has typically been limited to numerous small gas fields.

RI 151. The Van Horn Mountains Caldera, Trans-Pecos Texas: Geology and Development of a Small (10-km^2) Ash-Flow Caldera, *by C. D. Henry and J. G. Price. 46 p., 31 figs., 3 tables, 1 pl., appendix ($5.00).*

Investigation into the stratigraphy, structure, geochemistry, and economic geology of the Van Horn Mountains caldera of the Trans-Pecos volcanic province.

This report is part of a broader study to understand the origin and evolution of the igneous rocks of Trans-Pecos Texas, their regional tectonic setting, and the relationship between igneous processes and settings in Trans-Pecos Texas that give rise to ore deposits. The geology of the caldera area is presented in a full-color, 1:24,000-scale map. Text discussion includes the overall stratigraphy, geologic history, geochemistry, and structural development of the caldera. Detailed geologic mapping of the area originally studied by P. C. Twiss in the 1950's revealed a caldera 3 to 4 km in diameter. Although the caldera is small, data collected by the authors indicate it underwent an extensive history of initial ash-flow eruption and caldera collapse, post-ash-flow volcanism, resurgent intrusion, and eruption of a second ash-flow tuff. Rocks in the caldera show a compositional progression from high-silica rhyolite through trachyte to basalt that suggests eruption from a zoned magma chamber and is similar to compositional evolution in other calderas of Trans-Pecos Texas. Although no known ore deposits are associated with the caldera, geochemical analyses indicate that a rhyolite porphyry intrusion has undergone considerable hydrothermal alteration of a type characteristic of porphyry molybdenum systems. The authors conclude by comparing the formation and evolution of the caldera with published general caldera models.

RI 152. Depositional Systems and Oil and Gas Plays in the Cretaceous Olmos Formation, South Texas, *by Noel Tyler and W. A. Ambrose. 42 p., 33 figs., 7 tables, 1 pl. ($3.00).*

Comprehensive study of the origin, formation, and regional distribution of depositional systems and resulting oil and gas plays in the Upper Cretaceous Olmos Formation in South Texas.

The Olmos Formation is an economically important oil- and gas-bearing unit. Although the formation has been actively drilled since the mid-1920's, little has been published about the origin and regional distribution of Olmos sandstones. This study covers an eight-county area and includes almost the entire subsurface extent of the formation from outcrop in Maverick County to the Cretaceous shelf edge in Webb and La Salle Counties. The authors trace the development and depositional environments of the Catarina and Big Foot delta systems and the Rocky Creek barrier/strandplain system and discuss the seven oil and gas plays in the Olmos Formation, including active downdip oil, gas, and condensate-rich plays along the Lower Cretaceous shelf edge in La Salle and McMullen Counties. Recent developments in Olmos trends suggest that the best years of production may lie ahead. Youthful shelf-edge gas, condensate, and oil plays are highly productive and, together with wildcat prospects further basinward, offer the best potential for continued high-level production from this mature province.

RI 153. Genetic Stratigraphy and Oil Recovery in an Upper Cretaceous Wave-Dominated Deltaic Reservoir, Big Wells (San Miguel) Field, South Texas, *by Noel Tyler, J. C. Gholston, and W. A. Ambrose. 38 p., 33 figs., 1 table ($2.50).*

Detailed study of the geologic setting and engineering and production characteristics of Big Wells (San Miguel) field in Dimmit and Zavala Counties, South Texas.

The Big Wells (San Miguel) field was selected for detailed study as a part of a long-term project to investigate the potential for oil field reexploration to increase oil recovery in Texas. The study is based on analysis of the geologic setting and petrophysical and production characteristics of the Upper Cretaceous Big Wells (San Miguel) wave-dominated deltaic reservoir. Diagenetic overprint and a weak drive mechanism are major causes of poor recovery from the Big Wells pool. The principal concern of the study was to determine whether reservoir heterogeneities further hindered production and trapped conventionally recoverable oil in isolated compartments in the reservoir. The authors found that well-to-well heterogeneity has played a minor role in affecting oil production from the reservoir. Rather, fieldwide variability exerts a strong influence on oil recovery. The authors conclude that wave-dominated deltaic reservoirs are characterized by minimal well-to-well heterogeneity, excellent internal strike continuity, and, consequently, maximum efficiency of mobile-oil recovery.

RI 154. Structural Styles of the Wilcox and Frio Growth-Fault Trends in Texas: Constraints on Geopressured Reservoirs, *by T. E. Ewing. 86 p., 61 figs., 2 tables ($4.00).*

Subsurface geological and seismic study of structural styles in the Wilcox and Frio growth-fault trends in selected areas of the Texas Gulf Coast.

Structural variability is a key determinant of the size of geopressured aquifers in the deep subsurface. Discovery of large geothermal reservoirs in the geopressured zone depends on the favorable intersection of large-volume, high-quality sandstone bodies and large-area fault compartments. In this report the wide variability in structural styles within the growth-faulted, geopressured trends of the Texas Gulf Coast is illustrated by detailed structural maps of Wilcox and Frio growth-fault trends and quantified by statistical analysis of fault compartment geometries. Within the Frio growth-fault trend the Sarita, Corpus Christi, and Port Arthur areas, together with the previously studied Blessing and Pleasant Bayou prospects, span nearly the entire range of Frio depositional systems. The Frio and Wilcox growth-fault trends show distinct differences. The author concludes that Wilcox sandstones tend to be dip-elongate, whereas fault compartments are highly strike-elongate; the probability of large reservoirs is consequently low. Frio sandstones are of mixed geometry, and fault compartments are larger and more equant, suggesting an increased chance of finding large reservoirs.

RI 155. Geochemistry of Salt-Spring and Shallow Subsurface Brines in the Rolling Plains of Texas and Southwestern Oklahoma, *by B. C. Richter and C. W. Kreitler. 47 p., 25 figs., 6 tables, appendix ($3.00).*

Investigation into the occurrence of salt-discharge areas and the sources and types of brines within the Rolling Plains.

Natural salt springs and salt seeps in the Permian Rolling Plains discharge more than 25,000 tons of sodium chloride per day, degrading water quality for hundreds of miles downstream from salt-discharge sites. Understanding whether salinity results from local halite dissolution or as discharge from deep-basin brine aquifers is fundamental to controlling naturally occurring salt-water pollution. Objectives of this report were to review the occurrence of salt-discharge areas in the Rolling Plains, to characterize the chemistry and types of brines and their geographic distribution, and to determine the controls on the source of salinity. The authors' conclusions are based on geological, hydrological, geochemical,

and isotopic data from various published sources as well as field data collected and analyzed for the study. Brines derived from dissolution of halite by fresh, locally recharged, shallow ground water are chemically and isotopically distinct from brine derived from deep-basin brine aquifers. The authors also note that different brine types are distributed in different geographic areas. They conclude that the pervasive presence of brine, underlying the Rolling Plains at relatively shallow depths and with artesian heads in places above land surface, makes natural salt pollution-control difficult; they suggest that injection of brine into deep-basin brine aquifers may be a reasonable method of disposal.

RI 156. Cyclicity in the Middle Permian San Andres Formation, Palo Duro Basin, Texas Panhandle, *by M. A. Fracasso and S. D. Hovorka. 48 p., 40 figs., 4 pls. ($4.50).*

Analysis of cyclic vertical lithofacies sequences within the San Andres Formation of the Palo Duro Basin.

The San Andres Formation is largely composed of cyclic sequences of carbonate, anhydrite, and halite. Using geophysical log data, the authors traced these cycles across the entire Palo Duro Basin; four oversized plates reproduce cross sections that document the correlations. Cores recovered from 10 Department of Energy stratigraphic test wells were studied, and at least one cored well was incorporated in each cross section for precise lithologic control. Core photographs, showing typical textures of evaporite rocks and associated facies, are reproduced in the text. The authors discuss depositional systems, propose extrabasinal correlations of the San Andres Formation cycles, document lateral facies relationships and variations in the style of cyclicity, and note structural influences on sedimentation in the formation. The authors conclude that the entire suite of evaporitic cyclic facies reflects predominantly shallow-water marine deposition in contrast to previously proposed sabkha-like models of deposition. Systematic changes in thickness and completeness of the cycles allow the authors to divide the San Andres into three informal genetic sequences. These sequences share a similar cyclic mode but are characterized by differences in tempo of cyclicity, reflecting changes in regional basin subsidence rate or frequency of sea-level change or both.

RI 157. Hydrogeology and Hydrochemical Facies of the San Andres Formation in Eastern New Mexico and the Texas Panhandle, *by A. R. Dutton and E. D. Orr. 58 p., 13 figs., 3 tables, 3 appendices ($3.50).*

Discussion of the origin and flow potential of water in low-permeability carbonate rocks in the San Andres Formation in the Palo Duro Basin.

Data on fluid pressure, permeability, ground-water flow patterns, and chemical and isotopic composition of ground water were studied by the authors to reconcile conflicting previous interpretations of origin and movement of brine within the formation. Hydraulic-head data and numerical models indicated that ground water flows downward through the evaporite confining system in the Palo Duro Basin; however, evidence derived from study of chemical and isotopic composition of brine from two test wells indicated that ground-water movement in the San Andres in the Palo Duro Basin is negligible. The hydraulic-head data base consisted of detailed measurements at 7 wells, water levels at 103 wells, drill-stem tests at 378 wells, and several estimates of head at springs and seeps. An extensive appendix details hydraulic tests at six wells for analyzing permeability and fluid pressure in the low-permeability carbonate rock. Chemical data were obtained from sampling at two test wells, from published reports, and from field surveys done by industry. The authors suggest that chemical and isotopic composition is more readily explained by preservation of connate brine than by reaction of meteoric water with rock and that ground-water flow downward across the evaporite confining system to date has not greatly influenced water composition.

RI 158. Hydrogeology of a Gypsum Playa, Northern Salt Basin, Texas, *by F. M. Boyd and C. W. Kreitler. 37 p., 24 figs., 4 tables, appendix ($2.50).*

Hydrogeologic study of the formation processes of salt flats in the northern Salt Basin, Trans-Pecos Texas.

The Salt Basin is one of the most prominent intermontane valleys of the Trans-Pecos region. The northern Salt Basin is a closed hydrologic system in which discharge of ground water occurs in a series of playas, or salt flats. The broad expanses of dry salt flats are interesting features from hydrogeologic, aesthetic, and historic standpoints. Pore waters in the salt flats are Na-Mg-SO_4-Cl brines. The formation of these brines is considered to be related to ground-water movement, evaporative concentration, and mineral precipitation; they are not considered to be residual brine from Pleistocene lake deposits, as argued in earlier studies. The authors characterize the geology of the source rocks, geomorphology of the playa surfaces, shallow subsurface stratigraphy and mineralogy of the salt flats, ground-water movement, and geochemistry of the waters in the basin and relate these phenomena to the origin and evolution of the brines and to the processes and rates of gypsum precipitation. A history of salt mining at the salt lakes is included in an appendix.

RI 159. Numerical Modeling of Regional Ground-Water Flow in the Deep-Basin Brine Aquifer of the Palo Duro Basin, Texas Panhandle, *by Prakob Wirojanagud, C. W. Kreitler, and D. A. Smith. 68 p., 46 figs., 6 tables, 3 appendices ($3.50).*

Investigation of ground-water flow in the Palo Duro Basin using a two-dimensional finite element model.

Bedded Permian-age evaporite sequences in the Palo Duro Basin are being considered for a permanent nuclear waste repository by the U.S. Department of Energy. The purpose of this modeling study is to provide an understanding of regional ground-water flow in the formations beneath the Permian evaporite section. From this understanding, more detailed, smaller scale studies can be designed. This study is also intended to provide a better understanding of the boundary conditions and permeabilities of the aquifer and aquitard system as well as provide estimates of ground-water travel times across the basin. Numerical simulations were made of the Wolfcamp aquifer modeled as a single layer and of the entire Deep-Basin Brine aquifer system, including the Wolfcamp aquifer, modeled as a single layer. The two-dimensional finite element model incorporates different lithologies and permeabilities of the aquifer system and incorporates downward leakage through the Evaporite aquitard. Input to the models is primarily geologic data from detailed Bureau studies and hydrologic data from petroleum exploration test wells.

RI 160. Hydrogeochemistry of the Vadose Zone in Unmined and Reclaimed Deposits at Big Brown Lignite Mine, East Texas, *by A. R. Dutton. 37 p., 23 figs., 7 tables, appendix ($2.50).*

Evaluation of the hydrochemical evolution of water in the vadose, or unsaturated, zone in different sedimentary facies and in reclaimed lignite-mining spoil at the Big Brown lignite mine to assess how lignite surface mining affects hydrogeology.

Six sampling stations in the vadose zone—one in unmined mud, three in unmined sand, and two in reclaimed mud deposits—were operated from August 1979 to May 1981. The extent of seasonal variation in vadose-water content and in water chemical composition was studied by repeated sampling in each facies. Lithology, vadose-zone hydrology, and hydrochemistry were investigated by thin-section petrography, exchangeable-cation analysis, neutron-moisture geophysical logging, and water sampling using suction lysimeters. The author states that hydrogeochemistry of the vadose zone appears to be controlled by recharge rate, mineralogy, and history of each site. He concludes that low-permeability argillaceous deposits in the Calvert Bluff Formation most likely function as confining beds that retard vadose-water flow from reclaimed land to juxtaposed aquifers, thus limiting the impact of mining on ground-water quality.

RI 161. Hydrogeochemistry and Water Resources of the Triassic Lower Dockum Group in the Texas Panhandle and Eastern New Mexico, *by A. R. Dutton and W. W. Simpkins. 51 p., 19 figs., 4 tables, 2 appendices ($3.00).*

Documentation of how aquifer lithology, regional ground-water flow patterns, and chemical reactions between ground water and minerals control the quality and location of ground-water resources in the Lower Dockum Group.

The authors determined the potentiometric surface, hydrochemical facies, and stable isotope composition of Dockum Group ground water. Records of water levels in 258 wells were reviewed. Chemical analyses of ground-water samples in the Lower Dockum Group were obtained from 365 wells. Twenty-one ground-water samples were collected and analyzed by the authors. The authors reviewed ground-water use, specific capacity tests, and water-well drilling records to better predict future use of Dockum Group ground water. They also discuss the hydrogeologic relationship between water quality and well yield. The authors note that the shape of the potentiometric surface and the location of ground-water-basin divides are controlled by topography and stratigraphy. They conclude that chemical composition of Dockum Group ground water was largely derived from reactions of minerals with ground water that was recharged before the Holocene Epoch.

Geological Circulars

GC 86-1. Chemical Characterization of Texas Lignite, *by S. J. Tewalt. 54 p., 21 figs., 22 tables, 2 appendices (on microfiche) ($3.00).*

Statistical analysis of lignite chemical data from the Paleocene-Eocene Wilcox Group and the Eocene Yegua Formation and Jackson Group.

Chemical data from several hundred analyses of near-surface lignites were obtained from industry, mining permit applications, and government publications. Eighty-five Wilcox deep-basin lignite samples were collected and characterized from 24 seams in 8 deep East Texas coreholes. The author ranks Wilcox lignite as the best quality lignite, followed by Yegua and Jackson lignite. Some Wilcox deposits, particularly in the east-central and Sabine Uplift areas, are ranked as borderline subbituminous. Results of sulfur, high-temperature-ash, and trace element analyses indicate no major obstacles to utilization. The publicly available chemical data collected are presented on microfiche.

GC 86-2. Compilation of Potassium-Argon Ages of Tertiary Igneous Rocks, Trans-Pecos Texas, *by C. D. Henry, F. W. McDowell, J. G. Price, and R. C. Smyth. 34 p., 1 table ($3.00).*

Tabular listing of all published isotopic ages, as well as many unpublished ages, of the Tertiary igneous rocks of the Trans-Pecos region.

Arranged in geologically related groups, the table expands upon an earlier summary by McDowell and includes all known K-Ar ages through 1986. The table lists available rock type, analytical data, location, and references. Where appropriate, the authors have briefly discussed the significance of the ages, especially to point out obviously unreasonable ages. This compilation is the basis for an extended discussion of the geochronology of the region by Henry and McDowell in Guidebook 23.

GC 86-3. Historical Shoreline Changes in Trinity, Galveston, West, and East Bays, Texas Gulf Coast, *by J. G. Paine and R. A. Morton. 58 p., 30 figs., 2 tables, 3 appendices ($3.00).*

Documentation of extensive shoreline changes within the Galveston Bay system since the 1850's and discussion of the physical processes that cause shoreline movement.

Observed long-term changes in shoreline position provide estimates of the relative stability of shorelines and allow comparisons of shoreline changes before and after human modifications became significant. Analysis of shoreline movement in the Galveston Bay system included comparing topographic charts (dated 1850 to 1852) with aerial photographs (taken in 1930, 1956, 1974, and 1982), measuring shoreline movement, calculating the rates of change for particular time periods (1850-52 to 1930, 1930 to 1982, and 1850-52 to 1982), and summarizing in tables and on maps the magnitude and rate of shoreline changes. The authors report that, despite the widespread use of shoreline protection measures, which date back to 1930 in some areas, approximately 78 percent of the shorelines within the Galveston Bay system retreated an average of 2.2 ft/yr between the early 1850's and 1982. They predict that unprotected shorelines in the system will continue to retreat in response to natural erosional conditions that have been augmented by human activities.

GC 86-4. Recent Production Trends and Outlook for Future Oil and Gas Supplies in Texas, *by W. L. Fisher and R. J. Finley. 31 p., 17 figs., 9 tables, appendix ($2.00).*

Discussion of future oil and gas exploration and production in Texas based on analysis of industry trends of the past 10 to 15 years.

Although oil and gas production in Texas peaked in 1972, the State still contributed 28 percent of oil production and 33 percent of gas production in the United States in 1984. The authors provide a historical perspective on oil and gas production trends for the last decade and a half and suggest that the remaining hydrocarbon resource base is substantial. For oil, the authors report that the price structure prevailing from 1980 to 1985 resulted in substantial moderation of production decline rates. Recent reserve additions are shown to be largely from existing fields rather than new-field exploration. Rates of oil reserve growth in different regions of Texas are reviewed and show that mobile oil reserve growth has been concentrated in the Permian Basin. For gas, the authors define reserve distribution, note the effects of Natural Gas Policy Act price incentives and of gas oversupply, and consider gas price and supply interactions. Gas production, reserves, and well completions are reviewed by Railroad Commission of Texas districts. The authors conclude that capability to pursue remaining Texas hydrocarbon resources will require increased geological and engineering understanding of oil and gas reservoirs as well as favorable economic incentives and public policy.

GC 86-5. Organic Geochemistry of the Pennsylvanian and Lower Permian, Palo Duro Basin, Texas, *by S. P. Dutton. 28 p., 13 figs., 3 tables, 2 appendices ($2.00).*

Determination of source-rock quality and thermal maturity of potential hydrocarbon source rocks from five deep stratigraphic test wells in the Palo Duro Basin.

The author estimated source-rock quality by TOC analysis and thermal maturity through analyses of kerogen color, vitrinite reflectance, and pyrolysis. Samples for TOC analysis were collected from both cuttings and cores. Kerogen type was identified microscopically in all of the samples that contained more than 0.5 percent TOC, and five basic kinds of kerogen were distinguished—algal, amorphous, herbaceous, woody (vitrinite), and coaly (inert). Kerogen color in the same samples was evaluated using a thermal alteration index, which standardizes alteration colors from colorless (immature stage of maturation) to black (totally metamorphosed). Vitrinite reflectance was determined in all samples with more than 0.5 percent TOC. Several samples were sent to three laboratories to compare the different vitrinite assessments. Finally, pyrolysis was performed on selected samples to determine the type and maturity of kerogen. All of the data gave generally similar results for shales in the basin, indicating that some Pennsylvanian and lower Wolfcampian shales have reached temperatures high enough to generate oil from Types I and II (hydrogen-rich) organic matter. However, the pyrolysis data indicate that much of the organic matter in the Palo Duro Basin is Type III (vitrinite) and that temperatures have not been been high enough to generate oil or gas from it.

GC 86-6. Fracture Analyses of the Palo Duro Basin Area, Texas Panhandle and Eastern New Mexico, *by E. W. Collins and B. A. Luneau. 39 p., 34 figs. ($2.50).*

Investigation of the occurrence and characteristics of fractures within the Palo Duro Basin area through field studies and core analysis.

The U.S. Department of Energy is evaluating bedded Permian salt deposits of the basin as potential sites for the storage of high-level nuclear wastes; understanding the distribution and characteristics of fractures in rocks of the region is a necessary part of the evaluation. The purpose of the report is to define regional fracture patterns, compare fracture patterns of different ages of strata, and describe characteristics of the fractures. The authors determined regional fracture patterns by measuring joint strikes in outcrop and possible fracture orientations from fracture identification logs. Field studies of joints in Permian and Triassic strata were conducted in various areas of the Panhandle to determine the relationship between joint spacing and bed thickness, the vertical and horizontal variability of joint orientations throughout the strata, and the potential influence that joint spacing may have on dissolution processes. Where outcrops do not exist, fracture identification logs were used to evaluate possible fracture orientations. Core was used to identify veins and evaluate the diagenetic and structural history of vein-bearing strata; photographs and microphotographs illustrate vein characteristics.

GC 86-7. Mississippian Conodonts from the Southern Texas Panhandle, *by S. C. Ruppel and T. M. Lemmer. 36 p., 13 figs., 4 tables, 2 pls. ($2.50).*

Report on occurrence, description, and significance of the first conodonts to be documented from subsurface Mississippian rocks in the Southern Midcontinent.

A total of 451 identifiable conodonts were recovered from 4 cores in the Palo Duro Basin and Hardeman Basin areas of the southern Texas Panhandle. Although specimens were mostly fragmented, 18 species representing 8 genera and indeterminate specimens of 4 additional genera were identified. The authors report that *Cavusgnathus, Gnathodus, Hindeodella,* and *Taphrognathus* are the most common genera, constituting more than 50 percent of the fauna. A new species, *Apatognathus pinnata,* is described. Two black-and-white plates depict the most significant species. Faunas recovered from the cores are primarily middle to late Meramecian in age. On the basis of these biostratigraphic data the authors conclude that Mississippian deposition in much of the area did not commence until that time. Conodont color was recorded for all conodont elements. The authors report significant discrepancies between levels of thermal maturity implied by conodont color and other indices, indicating that previous calibrations of conodont color alteration index (CAI) with thermal maturity may need to be reevaluated.

GC 86-8. Depositional and Structural Framework of the Distal Frio Formation, Texas Coastal Zone and Shelf, *by W. E. Galloway. 16 p., 7 figs., 1 table, 3 pls. ($2.50).*

Synthesis of new well data and earlier Bureau research on the Frio Formation providing a more definitive description of the downdip fringe of the Frio depositional sequence.

Deep drilling and public release of well logs have added significantly to the data base used in a previous study of this prolific hydrocarbon producer, particularly along the downdip fringe where data have been sparse. This study focuses on a belt ranging from 25 to 50 mi wide along the downdip limits of well control. The expanded data base includes logs from the deepest wells, numerous paleontologic reports, and sparse core descriptions. The author first incorporated new wells in the regional Frio correlation grid established by Galloway and others in Report of Investigations No. 122. Next, a generalized structural map for the top of the Frio Formation was synthesized from well data and published data to show the principal structural features affecting the downdip Frio section. A series of quantitative lithofacies maps were then prepared using all cross-section and infill wells. Net-sandstone and percent-sandstone maps for each of three operational units identified in the Frio are the basis for interpretation of downdip Frio depositional facies and history. Oversized plates depict structural features, lithofacies, and interpretive cross sections. The author concludes with a discussion of the hydrocarbon potential of the distal Frio. He notes that the most productive facies thus far are the distal shoreface and inner-shelf sandstones deposited on the northern margin of the Norias delta system. This delta system extends well into the Federal Outer Continental Shelf waters, and recent discoveries of commercial hydrocarbons in deeply buried distal shoreface sandstones lie directly along strike.

Guidebooks

GB 22. Geomorphology and Quaternary Stratigraphy of the Rolling Plains, Texas Panhandle, *T. C. Gustavson, ed. 97 p., 48 figs., 6 tables, appendix ($4.00).*

An illustrated guidebook describing 18 sites of geologic and archeologic interest that highlight the geomorphic processes, Quaternary stratigraphy, and cultural history of the Texas Panhandle.

Field stops, primarily in Hall and Briscoe Counties, describe phenomena widespread in the eastern Texas Panhandle. Nine stops emphasize the effect that dissolution of evaporites, primarily salt, and collapse of overlying strata have had on landscape development and Quaternary stratigraphy. Six other stops describe a newly recognized, as yet unnamed Quaternary stratigraphic unit. At three other stops, the authors describe deposition and incision of unpaired terraces along the Little Red River, recent hillslope erosion rates, and effects of eolian processes. Two final stops illustrate the archeological resources of the Lake Mackenzie area and vertebrate remains from the Tule Formation. Figures include ground and aerial photographs of the sites, topographic maps, geologic maps, measured sections, and stratigraphic sections. An appendix lists radiocarbon dates of the various sites.

GB 23. Igneous Geology of Trans-Pecos Texas, *J. G. Price, C. D. Henry, D. F. Parker, and D. S. Barker, eds. 360 p. ($12.00).*

Detailed field trip road log of points of geologic interest from El Paso to Big Bend National Park and 16 articles of current research into the igneous geology of Trans-Pecos Texas.

Detailed stop descriptions highlight caldera structures, field relations of pyroclastic rocks, rheology of peralkaline ash-flow tuffs and lava flows, magma mixing within intrusions, and petrogenesis of silica-undersaturated and silica-oversaturated magmas. The authors used the road log for a 3-day field trip held as part of the annual meeting of the Geological Society of America. The research articles cover topics mentioned above as well as geochemical and petrologic aspects of igneous rocks in Trans-Pecos Texas and adjacent Mexico, geochronology of the region, and sedimentology of volcaniclastic rocks.

Maps

Bouguer Gravity Atlas of Texas, Amarillo, Big Spring, Brownfield, Dalhart, Hobbs, Lubbock, Perryton, Plainview, and Tucumcari Sheets, *G. R. Keller (The University of Texas at El Paso) and C. L. V. Aiken (The University of Texas at Dallas), project directors. 1:250,000 scale ($2.00 each).*

1° by 2° Bouguer gravity maps covering areas of the Texas Panhandle and eastern New Mexico.

These transparent maps are at the same scale as the *Geologic Atlas of Texas* sheets and can be superimposed on them to compare gravity information with surface geology. The Bouguer maps, which eventually will cover the entire state, are being prepared by combining the results of numerous surveys, many of them provided by the U.S. Department of Defense, into a single datum. These gravity data are then smoothed with a high-order polynomial surface.

Mineral Resource Circular

MRC 78. The Mineral Industry of Texas in 1984, *by J. P. Ohl and M. W. McBride. 24 p., 2 figs., 12 tables (free on request).*

Annual summary of all nonfuel minerals of Texas.

This circular is a preprint of the chapter on Texas in the *Minerals Yearbook 1984* of the U.S. Bureau of Mines. It was produced through a cooperative agreement between the U.S. Bureau of Mines and the Bureau of Economic Geology.

Services

Public Information

Requests for information about Texas geology, energy, mineral, and land resources come to the Bureau from a wide spectrum of the public, including geologists, engineers, educators, students, landowners, and other interested individuals, as well as companies, governmental agencies, and other organizations.

Extensive data and information from the Bureau's Reading Room/Data Center and from files in the office of the Public Information Geologist regarding mineral resources (both energy and nonenergy minerals) and general geology of specific areas of the state (both surface and subsurface) are adapted to answer the specific requests.

During 1986, more than 1,300 such requests were handled by the Public Information Geologist. In addition, members of the research staff provide advisory and technical services in their areas of expertise.

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 Reading Room/Data Center, supervised by Jeffrey Thurwachter, is open for public use from 8 a.m. to 5 p.m., Monday through Friday. All materials are available to the public for reference use only. Arrangements can be made for photocopying noncopyrighted materials.

The Reading Room houses a collection of about 10,000 titles and 50 periodicals pertaining to the geology, water resources, and mineral resources of Texas and adjacent states. Included in the collection are extensive reports and open-file materials received from the U.S. Bureau of Mines, the U.S. Geological Survey, and the U.S. Department of Energy, as well as unpublished open-file reports and contract reports prepared by the Bureau for various contracting agencies.

The Data Center houses an extensive collection of surface and subsurface geologic data pertaining to Texas. Original cross sections, maps, and other work data used in preparing many of the Bureau's publications are placed on open file for staff and public use. Large collections of topographic maps, geologic maps, Texas aerial photographs, and Landsat images are also on file. The Data Center also holds well logs for more than 45,000 wells in Texas and 8,000 wells in adjacent states; microfiche copies of well logs for more than 40,000 wells in West Texas, New Mexico, and Oklahoma; scout tickets and well records for more than 200,000 Texas wells and 30,000 New Mexico wells; driller's logs for about 400,000 Texas wells; and completion cards for more than 300,000 wells in Texas and more than 150,000 wells in adjacent states.

Major efforts in the Reading Room/Data Center in 1986 were organizing and indexing various data items. More than 2,800 books were cataloged, indexed, and entered into the title/subject catalog data base on the Bureau's VAX 11/780. Staff members can search this data base to ascertain Reading Room holdings from their offices. More than 5,000 donated well logs were received and added to the Bureau's holdings. Another VAX data base now contains header information from more than 15,000 Gulf Coast well logs and 20,000 East and West Texas Waste Isolation well logs in the Bureau's holdings.

Mineral Studies Laboratory

The Bureau has an excellent geochemical analysis capability in its Mineral Studies Laboratory (MSL). The MSL, comprising 18,500 ft^2 of laboratory space and a staff of analytical chemists and geochemists, is capable of near-complete geochemical characterization of geological materials. Major analytical instruments available include an ARL 35000 inductively coupled plasma optical emission spectrometer, a VG PlasmaQuad inductively coupled plasma mass spectrometer, a VG SIRA 12 stable isotope mass spectrometer, a Cameca Camebax electron microprobe, a Jeol SEM/EDXRF microscope, a Dionex 2001 ion chromatograph, and a Phillips X-ray diffractometer. Complete wet chemical analysis, coal analysis, sample comminution, and fire assay capabilities also exist or await installation. The MSL uses these capabilities to provide analytical support services as well as methods development/application research. These services are available to the Texas geological community but are primarily applied in Bureau research programs. The MSL is directed by Chief Chemist David W. Koppenaal.

The primary technical activities of the MSL in 1986 included various geochemical characterization efforts for Bureau research projects, such as the West Texas Waste Isolation, Reservoir Characterization, and Texas Mining and Mineral Resources Research Institute programs. MSL research activities focused on the development of a helium inductively coupled plasma/mass spectrometry technique (first demonstrated at the MSL) for the determination of halogens in halites and brines, and the search for a more sensitive and accurate technique for the determination of water in rocks and minerals.

The MSL continued its participation in several professional societies and associations devoted to standardizing and developing analytical methods. The MSL is a member of the International Geostandards Working Group and participates in the work of several committees of the American Society for Testing and Materials, including subcommittees on Coal and Coke, Hazardous Wastes, and Water. These activities help the MSL maintain high standards and stay abreast of new developments in the analysis of geological materials.

During the latter part of 1986, Zvi Sofer joined the Bureau's MSL group, where he will be working to establish an isotope geochemistry laboratory as well as assisting in the future development of the MSL's organic geochemistry capabilities. The addition of Sofer to the staff and the development of these capabilities will greatly strengthen the MSL's role in the application of geochemical analysis to the solution of geological problems.

Core Research Center

The Core Research Center (CRC) and adjacent repository are open from 8 a.m. to 5 p.m., Monday through Friday. Information on holdings, policies, or computer listings may be obtained by calling Michael S. Cosper, Curator, at (512) 471-1534.

The CRC has two core examination rooms equipped with 14 examination tables, binocular microscopes, and supporting equipment available on request. The CRC also has a drill cuttings examination room with 16 individual compartments, each with exhaust ports to remove acidic fumes. Another room is dedicated to X-ray radiography of whole or slabbed core. A core saw room is equipped with two Ray Tech automatic saws capable of slabbing 300 ft of whole core per day, two Target masonry saws, and a Felker trim saw for cutting thin section stubs.

The repository houses nearly 50 linear miles of shelves to hold both core and samples. The shelves are designed to hold 180 linear feet of slabbed core per foot of shelf on pallets. About 10 percent of the repository is isolated and climate controlled to hold destructible core lithologies like salt. A loading dock with a mechanical lift allows fork lifts to drive directly into delivery trucks to off-load pallets. Fork lifts also deliver pallets directly to CRC rooms through covered galleries.

Cores and cuttings may be checked out in person for study on site or for use outside the Bureau. Samples sent outside may be held for 6 weeks; extensions are considered. To take samples or thin sections from cores or cuttings requires approval by the curator. Patrons are requested to provide results of analyses to the CRC to become part of the center's reference material.

The Core Research Center was visited by 358 non-Bureau patrons during 1986. Non-Bureau patrons and Bureau geologists examined core from 539 wells and cuttings from 227 wells. Cores from 197 wells were slabbed, reboxed, and filed in the new repository. The thin section lab produced 829 slides requested by Bureau and non-Bureau geologists.

During 1986, cores and cuttings were donated by ARCO; Argent Petroleum; ARKLA Exploration Company; Bass Enterprises; Bell Labs; Braham Resources, Inc.; Braswell Oil; Billy Caldwell; Coalinga Corporation; Coates Energy Trust; Thomas D. Coffman; Corum Production Company; Edco Petroleum; Exxon; Jack Frost; Graham Resources; Albert Haertlein; Inexco Oil Company; International Oil and Gas; Jordan Oil Company; Robert Linsey; Louisiana Land and Exploration; MEG Petroleum Corporation; Mobil Oil; Murexco; Pan Canadian Petroleum Company; Pennzoil; Phillips Petroleum; Pogo Production Company; Primary Fuels, Inc.; Reservoirs, Inc.; Rutherford Oil Company; Shell; Sohio Petroleum Company; Sonat Exploration; Taubert, Steed, Gunn and Medders; Texaco; Texas Department of Water Resources; Texas Low-Level Waste Disposal Authority; Trinity Engineering Corporation; U.S. Borax; and Wainco.

Geophysical Log Facility

The Bureau's Geophysical Log Facility was established as a result of legislation that went into effect in September 1985 that requires all operators of oil, gas, or geothermal wells to 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. In the 16-month period from September 1, 1985, to December 31, 1986, the facility received more than 17,000 new well logs and 4,000 older logs.

The Railroad Commission provides paper or microfiche copies of the well logs as well as microfiche copies of three different cumulative indexes to the logs to the Bureau. The logs are filed by district number, then by API number. Use of these numbers is the most efficient way to request logs. The primary means of examining and duplicating logs is through use of the microfiche copy.

The Geophysical Log Facility allows the public, the petroleum industry, and commercial well log service companies to examine and duplicate well logs. The facility is equipped with several microfiche readers, a microfiche duplicator, and a continuous printer that makes paper copies from microfiche. Requests for logs and information can be made in person or by telephone. Hours of operation are 8:30 a.m. to 4:30 p.m., Monday through Friday. The facility is located in the Bureau's Research and Administration Building at Balcones Research Center.

Highlights of the Year

Activities of the Director

William L. Fisher, Director of the Bureau of Economic Geology, was named to the Leonidas T. Barrow Chair in Mineral Resources by The University of Texas System Board of Regents in June. Fisher has served as Chairman of the Department of Geological Sciences, The University of Texas at Austin, since 1984. The department now includes 40 faculty, 190 graduate students, and 215 undergraduates. In 1986 Fisher was also awarded an honorary Doctor of Science degree from Southern Illinois University at Carbondale. Fisher delivered the spring commencement address to the university's College of Science.

In August Fisher began a 3-year term on the Advisory Council of the Gas Research Institute. He received the appointment at GRI's annual Board of Directors Advisory Council meeting in Napa, California. GRI supports a substantial volume of Bureau research, including co-production, reservoir heterogeneities, and gas in tight sands, as well as work on the gas atlas.

At the annual American Association of Petroleum Geologists convention in Atlanta, Fisher delivered the AAPG Presidential Address, titled "The Aggressive Pursuit of Marginal Resources." Fisher served as AAPG president during the 1985–86 term. At the 36th annual Gulf Coast Association of Geological Societies meeting in Baton Rouge, Fisher received an honorary GCAGS membership, the organization's highest honor.

New Research Staff Members

Elisabeth C. Kosters

Elisabeth C. Kosters, originally from The Netherlands, joined the Bureau in August as a Research Associate on the Gas Atlas project. Kosters has a bachelor's degree in geology from the University of Groningen, a master's degree in geomorphology and sedimentology from the University of Amsterdam, and a Ph.D. in marine sciences from Louisiana State University at Baton Rouge. Her dissertation concerned peat formation in the Mississippi Delta Plain. Before joining the Bureau, Kosters was a Research Associate for 5 years with the Louisiana Geological Survey. She is a member of the Society of Economic Paleontologists and Mineralogists and the International Association of Sedimentologists.

Stephen E. Laubach

Stephen E. Laubach joined the Bureau in June as a Research Associate on the project to study gas in low-permeability sandstone reservoirs. Originally from Lyme, Connecticut, Laubach has a bachelor's degree from Tufts University and a master's degree and Ph.D. from the University of Illinois at Urbana, all in geology. His dissertation concerned polyphase deformation, thrust-induced strain and metamorphism, and Mesozoic stratigraphy of the Granite Wash Mountains in west-central Arizona. Before joining the Bureau, Laubach was a lecturer at Lehigh University. He is a member of the American Association of Petroleum Geologists, the Geological Society of America, the American Geophysical Union, and the Mineralogical Society of America.

James A. Morgan

Researchers Elisabeth Kosters, Zvi Sofer, and Stephen Laubach joined the Bureau staff in 1986.

Zvi Sofer

Zvi Sofer, originally from Israel, joined the Bureau's Mineral Studies Laboratory as a Research Scientist in October. He is in charge of setting up a laboratory for MSL's stable isotope mass spectrometer. Sofer has a bachelor's degree in chemistry and a master's degree in inorganic chemistry from Hebrew University, Jerusalem, and a Ph.D. in isotope geochemistry from the Feinberg Graduate School of the Weizmann Institute of Science, Rehovot, Israel. His dissertation concerned the isotopic composition of hydration water in gypsum. Sofer was previously employed as a Senior Research Geochemist with Cities Service Oil and Gas Corporation in Tulsa, Oklahoma. He is a member of the Geochemical Society and the American Association of Petroleum Geologists.

Promotions

Malcolm P. R. Light

Malcolm P. R. Light, who has been with the Bureau for 3½ years, was promoted from Research Associate to Research Scientist in September. Light works on the Co-production and Geopressured Geothermal projects. For the Co-production project Light's duties involve mapping and interpretation of co-production reservoirs and studying formation water, hydrocarbons, and shale to determine sources of produced fluids. His duties for the Geopressured Geothermal project involve studies of compositional formation waters and geologic structures to determine the primary reasons for the large size of geopressured reservoirs.

Stephen C. Ruppel

Stephen C. Ruppel was promoted to Research Scientist in September. He was formerly a Research Associate and has been with the Bureau for 5 years. Ruppel works on the University Lands project, and his duties involve geological characterization of oil reservoirs on University lands. A current focus of his research is the study of the timing and nature of dolomitization in Permian rocks in West Texas using petrographic and geochemical techniques.

Ph.D. Completions

Shirley P. Dutton

Shirley P. Dutton, Research Associate studying gas in low-permeability sandstone reservoirs, received a doctoral degree in geology from The University of Texas at Austin in December. Dutton's dissertation concerned diagenesis and burial history of the Lower Cretaceous Travis Peak Formation in East Texas. Dutton's supervisor was Lynton S. Land of UT's Department of Geological Sciences.

James A. Morgan

Shirley Dutton and Graham Fogg completed doctoral degrees in geology.

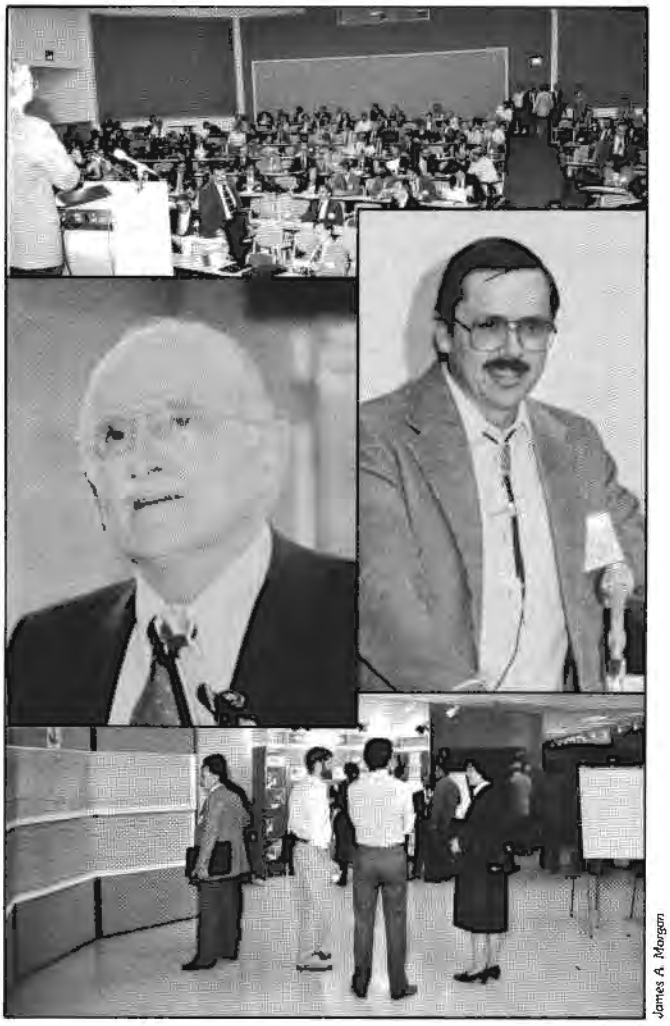
Graham E. Fogg

Graham E. Fogg, Research Associate on the University Lands project, received a doctoral degree in geology from The University of Texas at Austin in December. Fogg's dissertation concerned stochastic analysis of aquifer interconnectedness, with a test case in the Wilcox Group of East Texas. Fogg's supervisor was Charles W. Kreitler of the Bureau.

Bureau Hosts Project GUIDE Workshop

A proposal development workshop for Project GUIDE, Gulf Investigations and Deep Exploration, was hosted by the Bureau at Balcones Research Center in October. Project GUIDE is a proposal to DOSECC, Inc., to drill an ultradeep borehole to 40,000 ft on the San Marcos Arch, De Witt County, Texas. DOSECC is a group established by the National Science Foundation, the U.S. Geological Survey, the Department of Energy, and a consortium of 33 universities to manage drilling and scientific investigations of the Earth's continental crust. More than 150 scientists, engineers, administrators, and dignitaries from the United States and Europe gathered to discuss the scientific objectives associated with the proposed research hole.

The areas of potential investigation discussed during the workshop included a wide range of geological, geophysical, geochemical, hydrological, and engineering topics. Academic, industry, and government researchers were enthusiastic about the scientific data that can be obtained from an ultradeep borehole in an actively forming basin with a long and complex history. Insight into processes of passive continental margins, such as formation of transitional crust, generation of hydro-



James A. Morgan

Scientists from the U.S. and other countries gathered at Balcones Research Center for the Project GUIDE workshop. Featured above (center) are former UT President Peter T. Flawn (left), who served as Bureau Director from 1960 to 1970, and Senior Research Scientist William E. Galloway (right) and scenes from the workshop.

carbons, and greenschist metamorphism, would have broad scientific and economic importance. Both the scientific and the technological knowledge gained from this drillhole could be applied to many basins and continental margins throughout the world, including the host basins of most of the world's major hydrocarbon reserves.

Bureau research and support staff were responsible for much of the success of the workshop. They participated in the organization and logistics of the workshop and in scientific discussions. The results of the workshop were included in a 225-page project proposal that was "fine-tuned" and printed within 4 days of the meeting's conclusion and then sent to DOSECC for review. Initial response to the Project GUIDE proposal has been very favorable, and researchers are hopeful that some initial work leading to final selection of a specific drill site can begin in the next few years.

Awards and Honors

Doss Receives UT Excellence Award

James Doss was chosen from hundreds of University of Texas at Austin nominees to receive a UT Excellence Award. The awards are given annually to about 50 recipients and signify the University's recognition of "consistent, high-level performance." Doss received a $500 check and the personal congratulations of UT President William H. Cunningham at the 25th Annual Staff Recognition Program and President's Reception in May. Doss was also honored by Director William L. Fisher and fellow employees at a Bureau awards presentation.

Doss, a Senior Administrative Clerk, joined the Bureau in 1982. His duties have included operating the Bureau drilling rig, maintaining Bureau vehicles, and overseeing a staff of six Lab Research Assistants involved in facility and vehicle operation.

James A. Morgan

James Doss (left), recipient of a UT Excellence Award, is congratulated by Bureau Director William L. Fisher.

"There is no member of the Bureau who shows more dedication than James," said Fisher of Doss' honor. "He is always positive and will help anywhere and any way he is needed."

Long-time staffer Eloise Hill, who died in 1982, was the only other Bureau employee to receive the UT Excellence Award since its inception.

Bureau Staff Receive Service Awards

Seven Bureau staff members were among those honored at the 25th Annual Staff Recognition Program and President's Reception in May. Associate Director for Administration Douglas C. Ratcliff was honored for 15 years of service to the University. Honored for 10 years of service were Technical Staff Assistant Ethel E. Butler, Researchers Thomas R. Calnan, Robert J. Finley, and Steven J. Seni, Cartographer Margaret D. Koenig, and Editor Amanda R. Masterson.

Research Staff Receive Awards for Papers, Poster Session

Shirley P. Dutton received the A. I. Levorsen Memorial Award and the First Place Best Paper Award for a paper she presented at the 36th annual Gulf Coast Association of Geological Societies meeting in Baton Rouge. The Levorsen award is given to "the best paper with particular emphasis on creative thinking toward new ideas in exploration." Dutton's paper, "Petrography and Diagenesis of Lower Cretaceous Travis Peak (Hosston) Formation, East Texas," is based on her research on gas in low-permeability sandstone reservoirs, funded by the Gas Research Institute.

H. Seay Nance was awarded honorable mention for a paper he presented at the Society of Economic Paleontologists and Mineralogists midyear meeting in Golden, Colorado. Nance's paper, "Depositional Setting and Facies Relations in Upper Permian Red Beds of the Palo Duro Basin, Texas Panhandle," is the result of his work on the West Texas Waste Isolation project, funded by the U.S. Department of Energy.

Harry H. Posey and Malcom P. R. Light, along with two other authors, received an SEPM Excellence of Presentation Award for a poster session they delivered at the annual American Association of Petroleum Geologists meeting in Atlanta. Posey, Light, J. Richard Kyle (Department of Geological Sciences, The University of Texas at Austin), and Peter E. Price (Marathon Oil Company) received the award for the presentation titled, "Thermal Model for Salt Dome Cap Rocks and Mineral Deposits." Cartographers Annie Kubert-Kearns and Richard M. Platt did the drafting for the display.

Budnik and Tyler Invited to Speak

Roy T. Budnik was an invited speaker at the Penrose Conference in Oklahoma in March. The topic of the conference, held at Quartz Mountain Lodge in the Wichita Mountains of southwestern Oklahoma, was

James A. Morgan

Bureau staff awarded honors for papers and various research activities are (from left) Harry Posey, Malcolm Light, Noel Tyler, Shirley Dutton, Graham Fogg, and Seay Nance.

"The Southern Oklahoma Aulacogen." Budnik spoke on "Seismic Reflection Studies of Proterozoic Volcanics," "Left-Lateral Intraplate Deformation along the Ancestral Rocky Mountains," and "Basin and Range-Age Deformation along the Amarillo Uplift."

Noel Tyler was an invited participant in the Society of Petroleum Engineers Forum series on "Use of Reservoir Simulators," held in Jackson Hole, Wyoming, in August. Tyler was a discussion leader of the session on heterogeneous reservoirs and presented a paper titled "The Critical Role of the Geologist in Simulation of Heterogeneous Reservoirs."

Hocott Named Distinguished Lecturer

Claude R. Hocott was selected as Distinguished Lecturer Emeritus for 1986–87 by the Society of Petroleum Engineers. He was also named EOR Pioneer by SPE.

Fogg Named to Editorial Board

Graham E. Fogg was selected to serve a 3-year term on the editorial board of *Ground Water*, the research journal of the Association of Ground Water Scientists and Engineers. The Association is a division of the National Water Well Association. *Ground Water* is published bimonthly.

GSA *Bulletin* Features Bureau Illustrations

Two consecutive covers of the Geological Society of America *Bulletin* featured illustrations from articles by Bureau researchers in 1986. A diagram of salt structures that accompanied an article coauthored by Martin P. A. Jackson appeared on the March cover of the GSA *Bulletin*. Jackson's article, coauthored with C. J. Talbot (Institute of Geology, University of Uppsala, Sweden), is titled "External Shapes, Strain Rates, and Dynamics of Salt Structures." The April cover featured Thomas C. Gustavson's figure of regional structural elements in the Texas Panhandle and eastern New Mexico. The figure accompanied Gustavson's article titled, "Geomorphic Development of the Canadian River Valley, Texas Panhandle: An Example of Regional Salt Dissolution and Subsidence." GSA's choice of these two illustrations is a compliment to both the researchers and the Bureau cartographic staff.

Price Collection Donated to Bureau

A major contribution to the Reading Room/Data Center was made in 1986 when W. Armstrong Price, Jr., a geologist who has been called "the father of coastal studies in Texas," donated his personal library to the Bureau. The Price collection, which was appraised as having a fair market value of more than $119,000 is a comprehensive gathering of research materials relating primarily to coastal and marine geology, but also including other branches of earth sciences such as oceanography, soil science, climatology, archaeology, and vegetational geography. Plans are currently under way to archive the collection in the Reading Room.

Bebout Co-chairs Reservoir Conference

Senior Research Scientist Don G. Bebout of the University Lands project and Paul M. Harris of Chevron Oil Field Research Company were co-chairmen of a research conference on reservoir characterization held in Midland, Texas, in October. The title of the conference, sponsored by the Bureau and the Permian Basin Section of the Society of Economic Paleontologists and Mineralogists, was "Hydrocarbon Reservoir Studies—San Andres/Grayburg Formations, Permian Basin."

Twenty-four speakers from industry and the Bureau presented geological and engineering papers on 14 San Andres/Grayburg reservoirs located in an area bounded on the north by the Northern Shelf and on the south by the southern tip of the Central Basin Platform. Cores from 13 fields were displayed at the evening core workshops. Other highlights of the evening sessions were a demonstration of epifluorescence and a display of a regional cross section along the Central Basin Platform.

Other Bureau scientists participating in the conference were Chester M. Garrett, Jr., Claude R. Hocott, Charles Kerans, F. Jerry Lucia, Richard P. Major, and Stephen C. Ruppel. Lucia was also co-leader of a post-conference field trip to San Andres and Grayburg exposures in the Guadalupe Mountains. Bureau scientists who attended the conference included Robert J. Finley, Graham E. Fogg, and Gary W. Vander Stoep.

Distinguished Speakers Visit Bureau

Phillip Playford, Assistant Director of Mines, Australia, visited the Bureau in February. He gave a special seminar on "Modern Stromatolites at Shark Bay, Australia." Playford is an internationally known specialist in the study of modern and Devonian carbonate environments.

Janos L. Urai, of the Department of Structural and Applied Geology, University of Utrecht, The

Netherlands, visited the Bureau in April. Urai gave a series of four lectures on "Recent Developments in Evaporite Deformation Studies." Urai's work has important implications for the storage of nuclear waste in salt. The lecture series was attended by representatives from the U.S. Department of Energy's Office of Nuclear Waste Isolation, RE/SPEC Inc., Texas A&M University, Stone and Webster Engineering Corporation, and Lawrence Berkeley Laboratory. Urai also demonstrated preparation techniques for microstructural analysis in the Bureau's Mineral Studies Laboratory.

John Geissman, of the Department of Geology, University of New Mexico, Albuquerque, also visited the Bureau in April. Geissman delivered two lectures, titled "Applications of Paleomagnetism and Rock Magnetism to Problems in Stratigraphy and Diagenesis: Past, Present, and Future" and "Paleomagnetic and Rock Magnetic Techniques as Significant Aids in Structural Geology and Tectonics, from Quadrangle to Craton." Geissman discussed with Bureau staff members the specific application of paleomagnetic and rock magnetic techniques to various areas of Bureau research.

Hans Machel from the Basin Research Institute at Louisiana State University presented a talk at the Bureau in November. He spoke on "Aspects of Sulfate-Hydrocarbon Redox-Reactions, or Why Rocks May Smell Even Worse."

Bureau's Industrial Associates Program Expands into Reservoir Development

The Bureau began a new research program in 1985 that allowed sponsoring companies to participate in geological studies that directly benefit the petroleum industry. Efforts are directed toward assessing the structural and stratigraphic framework of the Texas offshore region to provide an exploration tool for companies engaged in the search for hydrocarbons beneath State and Federal waters.

In mid-1986 a sister industrial associates program, the Reservoir Characterization Research Laboratory (RCRL), was developed under the direction of Noel Tyler. In contrast to the offshore program, which is exploration oriented, research in the RCRL is focused on methodologies to detect and recover the vast volumes of unrecovered mobile oil that remain trapped in geologically complex reservoirs at abandonment. The RCRL attempts to bridge the divide between the exploration geologist and the production engineer by integrating analyses of reservoir architecture, state-of-the-art well logs, and engineering and production data.

Initial industrial participants in the RCRL were ARCO, Mobil, Standard Oil, and Texaco. The program continues to grow with the addition of Exxon as a sponsor midway through the first year and several other companies, including independents, showing considerable interest.

The subject of the first year of study has been the supergiant Spraberry Trend area field, which, with 9.4 billion barrels of original in-place oil, is the single largest accumulation of oil in Texas. However, recovery efficiencies of the low-permeability submarine reservoirs are the lowest of all Texas reservoirs: less than 6 percent of the original oil in place will be recovered at current technology levels. The target for extended conventional recovery through strategic infill drilling implemented by the RCRL's improved reservoir description is more than 4 billion barrels of unrecovered mobile oil.

Topics of study in the Spraberry range from microscopic to well log analysis of modern logs, to areally intensive reservoir studies, to regional detection in 26 counties of the depositional axes of the Spraberry that are the fundamental causes of sweet-spot production. Future RCRL studies will continue to focus on the huge resource of unproduced movable oil remaining in Permian Basin reservoirs in West Texas.

Texas Mining and Mineral Resources Research Institute

The Texas Mining and Mineral Resources Research Institute (TMMRRI) is one of 32 State organizations funded and administered by the U.S. Bureau of Mines and dedicated to research and academic training in mineral resources and technology. The Bureau of Economic Geology administers the Institute, which is directed by Jonathan G. Price. The University of Texas at Austin, Texas A&M University, and Prairie View A&M College, a subdivision of Texas A&M University, are academic members of the Institute.

The Institute supports training and education of mining personnel through graduate fellowships, research assistantships, and undergraduate scholarships. The advisory board for TMMRRI is composed of the President of The University of Texas at Austin, the Vice-Chancellor and Dean of Engineering at Texas A&M University, and a senior member of the Railroad Commission of Texas. Representatives of the advisory board plus two members of the Texas mining industry serve on the TMMRRI Fellowship Committee. During the 1986–87 academic year, five graduate fellowships were awarded. Areas of TMMRRI-supported graduate research include rock mechanics, metallic ore deposits, and mineral economics. During 1986, four other students received support through research assistantships on Institute-funded mineral resource projects. These students are given the opportunity to participate in organized research that is often broader in scope than that for a dissertation or thesis.

Reports published by the Bureau in 1986 that were fully or partly funded by TMMRRI include Report of Investigations No. 151 on the geology of the Van Horn Mountains caldera, Guidebook 23 on the igneous geology of Trans-Pecos Texas, Geological Circular 86-1 on chemical characterization of Texas lignites, and Geological Circular 86-2 on potassium-argon dating of Trans-Pecos igneous rocks.

Research Staff Publications and Activities

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

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Abstracts

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Lectures and Public Addresses

W. B. Ayers, Jr.

"Status and Future of Lignite Mining in Texas": presented to Lower Colorado River Authority, Fuels Workshop, Austin, Texas.

Edward C. Bingler

"Ash-Flow Stratigraphy of the Hartford Hill Rhyolite": presented to The University of Texas at Austin, Department of Geological Sciences, structure-petrology seminar.

"BEG Research for High-Level Radioactive Waste Disposal": presented to Christian Science Monitor, national radio interview.

"BEG Research on Ground Water and Underground Injection Control Research": presented to staff of the U.S. House Government Operations Subcommittee, Austin, Texas.

"DOE-sponsored High-Level Radioactive Waste Programs at the Bureau of Economic Geology": presented to Chief, Office of Civilian Radioactive Waste Disposal, briefing, Washington, D.C.

"DOE-sponsored High-Level Radioactive Waste Repository Program": presented to Representative J. J. Pickle, briefing, The University of Texas at Austin.

"Federally Sponsored Research at the Bureau of Economic Geology": presented to staff of Representative J. J. Pickle, briefing, The University of Texas at Austin, and Washington, D.C.

"Federally Sponsored Research Programs at the Bureau of Economic Geology": presented to Office of the Chancellor, The University of Texas System, briefing, Austin, Texas.

"A Gulf Coast Deep Drilling Research Initiative": presented to Baton Rouge Geological Society, monthly meeting, Baton Rouge, Louisiana.

"High-Level Radioactive Waste Management Research": presented to Chief, U.S. Department of Energy/OCRWM and Washington, D.C. headquarters staff, Austin, Texas.

"Project GUIDE: A Deep Drilling Initiative in the Gulf Coast Region": presented to James Coleman, Office of Basin Energy Studies, U.S. Department of Energy, College Station, Texas.

"Project GUIDE: A Gulf Coast Initiative in the National Continental Scientific Drilling Program": presented to the Houston Geological Society, monthly meeting, Houston, Texas.

"Project GUIDE: A Gulf of Mexico Deep Drilling Research Initiative": presented to the Science Advisory Committee, Deep Observation and Sampling of the Earth's Continental Crust, Inc. (DOSECC), DOSECC program review meeting, Denver, Colorado.

"Research Programs of the Bureau of Economic Geology": presented to Standard & Poor's/Moody's Investor Service, briefing sponsored by the President's Office, The University of Texas at Austin.

"Reservoir Characterization Research at the Bureau of Economic Geology": presented to Director of Energy Studies, World Bank, and to Energy Research Directorate, USAID, Washington, D.C.

L. F. Brown, Jr.

"Seismic Stratigraphy": presented to The University of Texas at Austin, Department of Geological Sciences, undergraduate class in geophysics.

Thomas R. Calnan

"Benthic Macroinvertebrates of Texas Submerged Lands": presented to Texas A&M University, Sea Grant College Program, Workshop on Estuaries and Wetlands of the Texas Coast, College Station, Texas.

S. Christopher Caran

"Geology of Westcave Preserve, Travis County, Texas": presented to Westcave Preserve Tour, Annual Patrons' Day, Austin, Texas.

"Geology of Wild Basin Wilderness Preserve, Travis County, Texas": presented to Wild Basin Wilderness Preserve Tour, Austin, Texas.

"Quaternary Stratigraphy of the Western Rolling Plains, Texas: the Late Pleistocene-Holocene Lingos Formation—Enhancement of Continental Sedimentation by Karstic Subsidence": presented to Texas A&M University, Department of Geological Sciences, faculty and graduate student seminars, College Station, Texas.

Alan R. Dutton

"Instantaneous Profile Method for Hydraulic Conductivity": presented to The University of Texas at Austin, Department of Geological Sciences, class on field methods in ground-water hydrology.

"Introduction to Hydrogeology": presented to The University of Texas at Austin, Department of Geological Sciences, minority recruitment program in geological sciences and geophysics.

Shirley P. Dutton

"Diagenesis and Burial History of the Lower Cretaceous Travis Peak Formation, East Texas": presented to The University of Texas at Austin, Department of Geological Sciences, technical sessions.

Robert J. Finley

"Energy—to the Year 2000": presented to Texas Environmental Balancing Bureau, annual meeting, San Antonio, Texas.

R. Stephen Fisher

"Chemical Evolution of Hypersaline, Deep-Basin Brines": presented to University of Houston, Department of Geosciences, geology seminar.

W. L. Fisher

"The Aggressive Pursuit of Marginal Resources": presented to American Association of Petroleum

Geologists, annual meeting, presidential address, Atlanta, Georgia.

"Efficiencies in Pursuing Marginal Resource Bases": presented to Houston Geotech 86, Houston, Texas.

"Future of Texas Oil and Gas: an Update": presented to Texas Ex-Students Association, Alumni College 1986, Austin, Texas.

"Future Opportunities in Academic and Public Service": presented to Texas Section, American Institute of Petroleum Geologists, Dallas, Texas.

"Impact of Oil Prices on Outer Continental Shelf Development": presented to Department of the Interior OCS Policy Advisory Board, Norfolk, Virginia.

"Oil Prices and the Future of the Domestic Industry": presented to Pioneer Oil Prospector Society, Houston, Texas.

"Outlook for Oil Prices": presented to General Land Office of Texas, Texas Business Editors, Austin, Texas.

"Petroleum Economics and the Decline in Exploration": session chairman and speaker, Southern Methodist University, Conference on Impacts of Price Declines on Oil Exploration, Development, and Financing, Dallas, Texas.

"Petroleum Geology: Is There a Future?": presented to The University of Texas at Arlington.

"Petroleum Prices and Their Impacts": presented to IBM Latin American Advisory Board, Austin, Texas.

"A Producer State View": presented to Gas Research Institute, Energy Seminar on Impact of Lower World Oil Prices on U.S. Natural Gas Supply and Prices, Napa, California.

"Reserve Growth of Reservoirs: the Magnitude of the Geologic Opportunity"; "Facies Architecture and Depositional Modeling in Predicting Reservoir Heterogeneity"; and "Oil Recovery Mind Sets and Institutional Barriers": presented to 1986 National Conference on Earth Science, Geology, and Reservoir Management, University of Alberta and Canadian Society of Petroleum Geologists, Banff.

"Small Field Exploration and Large Field Re-exploration: the Future of Petroleum Geology in the U.S.": presented to Abilene Geological Society, Abilene, Texas; Corpus Christi Geological Society, Corpus Christi, Texas; Lafayette Geological Society, Lafayette, Louisiana; Tulsa Geological Society, Bartlesville, Oklahoma; New Orleans Geological Society, New Orleans, Louisiana; West Texas Geological Society, Midland, Texas; Pacific Section, American Association of Petroleum Geologists, Bakersfield, California; Lamar University, Beaumont, Texas; Baton Rouge Geological Society, Baton Rouge, Louisiana; Institute for Geophysics and Department of Geological Sciences, The University of Texas at Austin.

"Small Field Exploration and Large Field Re-exploration: the Unconventional Conventional Gas Resource": presented to Gas Research Institute, annual meeting, Chicago, Illinois.

"Some Possible Paths for Oil Prices": presented to Lakeway Men's Club, Lakeway, Texas.

"Substituting Knowledge": presented to Southern Illinois University, College of Science, commencement address, Carbondale, Illinois.

"Trends in Oil and Gas Exploration and Exploitation": presented at American Association of Petroleum Geologists Day, Tulsa, Oklahoma.

"U.S. Oil and Gas Supplies": session chairman and speaker, Electric Power Research Institute, 1986 Fuel Supply Seminar, San Diego, California.

"U.S. Oil Production Capability in Jeopardy": presented to National Academy of Sciences, Board on Mineral and Energy Resources, Washington, D.C.

"What Is Happening with Oil Prices": presented to the John Gray Institute, Beaumont, Texas.

Graham E. Fogg

"A Geostatistical Method of Estimating Aquifer or Reservoir Interconnectedness": presented to The University of Texas at Austin, Department of Geological Sciences, technical sessions.

"Reservoir Modeling Approaches": presented to prospective contributors to industrial associates program, sponsored by the Bureau of Economic Geology, Austin, Texas.

Michael A. Fracasso

"Hunting for Dinosaurs": presented to Highland Park Elementary School and Boone Elementary School, kindergarten and third grade classes, Austin, Texas.

"Origin of Reptiles: *Limnoscelis paludis*, Cladistics, and Temporal Morphologies": presented to The University of Texas at Austin, Department of Geological Sciences, seminar.

William E. Galloway

"Depositional and Structural Architecture of Prograding Clastic Continental Margins—Tectonic Influence on Patterns of Basin Filling": presented to Geological Society of Norway, Tectonics and Structural Geology Study Group, Fourth Annual Meeting on Tectonics and Deposition in Sedimentary Basins, Stavanger, Norway.

Edgar H. Guevara

"Geological Characterization of Submarine Fan Reservoirs and Opportunities for Additional Oil Recovery in the Central Spraberry Trend, Midland Basin, Texas": presented to Permian Basin Section, Society of Economic Paleontologists and Mineralogists, monthly meeting, Midland, Texas.

"Submarine Fan Oil Reservoirs of the Central Spraberry Trend": presented to the Austin Geological Society, monthly meeting, Austin, Texas.

Thomas C. Gustavson

"Physiographic Evolution of the Southern High Plains: an Example of the Effects of Regional Dissolution of Permian Bedded Salts": presented to Panhandle Geological Society, Amarillo, Texas; University of Houston, Department of Geosciences, Houston, Texas.

Christopher D. Henry

"Magma Evolution in the Infiernito Caldera, Trans-Pecos Texas": presented to The University of Texas at Austin, Department of Geological Sciences, hard rock seminar.

"Origin of Chemical and Thermal Zonation in the Infiernito Magma System, Trans-Pecos Texas": presented to University of Houston, Department of Geosciences, Houston, Texas.

Claude R. Hocott

"High Tech Comes to the Oil Patch": presented to Society of Petroleum Engineers, Local Section, Abu Dhabi, United Arab Emirates; Cairo, Egypt; Dhahran, Saudi Arabia; Doha, Qatar; Midland, Texas; Salt Lake City, Utah; Victoria, Texas.

"Vignettes of Early EOR History": presented to Society of Petroleum Engineers/Department of Energy, EOR Symposium, awards luncheon, Tulsa, Oklahoma.

M. P. A. Jackson

"Centrifuge Modeling of the Effects of Sedimentary Loading on the Growth of Salt Structures": presented at Shell Development Company's Bellaire Research Laboratories, Shell Distinguished Lecturer Series, Houston, Texas.

"Interpretation of Diapir Growth Histories": presented to The University of Texas at Austin, Department of Geological Sciences, graduate class on seismic stratigraphy of the North Sea.

"Problems of Rayleigh-Taylor Instability in the Great Kavir of Iran": presented to University of Uppsala, Institute of Geology, faculty and graduate students, Uppsala, Sweden.

David W. Koppenaal

"Inductively Coupled Plasmas as Ion Sources for Mass Spectrometry": presented to Austin Mass Spectrometry Society, monthly meeting, Austin, Texas.

Charles W. Kreitler

"Deep Well Injection in Texas": presented to The University of Texas at Austin, Department of Civil Engineering.

"Diagenesis of Salt and Associated Evaporites": presented to Office of Nuclear Waste Isolation, joint meeting of Engineering Review Group and Geologic Review Group, Columbus, Ohio.

"Hydrogeologic-Geochemical Problems Associated with Disposal of High-Level Nuclear Waste in Texas Panhandle": presented to Amarillo Chamber of Commerce, Amarillo, Texas; Hereford Chamber of Commerce, Hereford, Texas.

"Hydrogeology of Gulf Coast Sedimentary Basin as It Relates to Deep Well Injection of Chemical Waste": presented to U.S. Environmental Protection Agency, Kerr Research Laboratory, Ada, Oklahoma.

"Hydrogeology of the East Texas Basin": presented to Shreveport Geological Society, Shreveport, Louisiana; University of Colorado, Geology Department, Boulder, Colorado; The University of Texas at Austin, Department of Geological Sciences, hydrogeology seminar.

"Hydrogeology of the Palo Duro Basin": presented to Amarillo Chamber of Commerce, Amarillo, Texas; Hereford Chamber of Commerce, Hereford, Texas.

"Underground Injection of Chemical Wastes in Texas": presented to Underground Injection Council Advisory Board, U.S. Environmental Protection Agency, Kerr Research Laboratory, Ada, Oklahoma.

Stephen E. Laubach

"Polyphase Deformation and Thrust-Induced Strain, Maria Foldbelt, Western Arizona": presented to University of Illinois, Geology Department, Urbana, Illinois.

"Shear Heating and Fault Dynamics": presented to Lehigh University, Department of Geology, colloquium, Bethlehem, Pennsylvania.

M. P. R. Light

"Coordination of Geological and Engineering Research in Support of Gulf Coast Co-production" and "Pleasant Bayou Geology Review": presented to the Gas Research Institute and U.S. Department of Energy representatives, GRI Forum, Houston, Texas.

"Integrated Hydrothermal Model for Proposed Deep Crustal Borehole on the Texas Gulf Coast—Origins of Geopressured Brines and Lead-Zinc, Uranium, Hydrocarbon, and Cap-Rock Deposits": presented to Cornell University, Program for the Study of the Continents, Ithaca, New York.

F. Jerry Lucia

"Origin and Distribution of Collapse Brecciation in the Lower Ordovician of West Texas": presented to Permian Basin Section, Society of Economic Paleontologists and Mineralogists, monthly meeting, Midland, Texas.

"West Texas Carbonate Reservoirs: Reservoir Parameters": presented to potential industrial sponsors of Reservoir Characterization Research Laboratory, The University of Texas at Austin, Bureau of Economic Geology.

Mary W. McBride

"The Cement Industry and Cement Raw Materials in Texas": presented to 22d Forum on Geology of Industrial Minerals, Little Rock, Arkansas.

Robert A. Morton

"Consequences of Shoreline Changes along the Texas Gulf Coast": presented to the Brazoria County Dune Protection Committee, Lake Jackson, Texas.

"Genetic Stratigraphy, Depositional Systems, Structural Evolution, and Petroleum Exploration of the Texas Continental Shelf": presented to Academic Research Review, sponsored by Texaco, New Orleans, Louisiana.

"Shoreline Changes and Coastal Development, Are They Compatible?": presented to the Lone Star Chapter of the Sierra Club, Port Isabel, Texas.

P. K. Mukhopadhyay

"Characterization of Kerogens by Microscopy under the Aspects of Maturation and Hydrocarbon Generation"; "Different Types of Resinites in Coal and Kerogen—a Potential Source of Liquid Hydrocarbons"; "Fluorescence Microscopy of Crude Oil, Condensate, Bitumen, and Kerogen"; and "Organofacies Variation in Cretaceous Deep Sea Sediments from the Atlantic Ocean": presented to Research Institute of Petroleum, special seminar sponsored by Ministry of Petroleum, People's Republic of China, Beijing, China; and "Separation of Kerogens from Total Organic Matter—Its Problems and Implications" and "Vitrinite Reflectance—Its Application and Problems": presented to Shengli Oil Field Research Center, Geo-

chemistry Group, Research and Development, sponsored by Ministry of Petroleum, People's Republic of China, Shengli, Shandung, China.

"Characterization of Tertiary Coals from Texas Based on Organic Petrography and Geochemistry": presented to U.S. Geological Survey, special seminar, Reston, Virginia.

"Classification of Kerogens Based on Organic Petrography and Pyrolysis-Gas Chromatography": presented to Texas Tech University, Department of Geology and Department of Physics, joint seminar, Lubbock, Texas.

"Generation of Hydrocarbons from the Tertiary Coals of Texas": presented to the Southern Regional Organic Geochemistry Conference, College Station, Texas.

William F. Mullican III

"Subsidence and Collapse over Texas Salt Domes": presented to The University of Texas at Austin, Department of Geological Sciences, hydrogeology seminar.

Ronit Nativ

"Characterization of the Ogallala Aquifer": presented to The University of Texas at Austin, Department of Geological Sciences, seminar.

Jeffrey G. Paine

"Late Quaternary Evolution of the Texas Coast": presented to Third Texas Coastal Bend Archeological Palaver, Corpus Christi, Texas.

Harry H. Posey

"Diagenesis of Permian Carbonate and Anhydrite, Palo Duro Basin, Texas": presented to University of California, Davis, Geology Department, seminar.

"Perspectives on Gulf Coast Basin Diagenesis from Isotopic Studies of Salt Domes": presented to University of California, Davis, Geology Department, seminar.

Jonathan G. Price

"Gold in Texas": presented to Uvalde Rotary Club, Uvalde, Texas.

"Gold in Texas, or Lack Thereof": presented to Rice University, Department of Geology, Houston, Texas.

"Magma Mixing in a Zoned Alkalic Intrusion": presented to Rice University, Department of Geology, Houston, Texas.

"Mineralization Associated with Alkaline Rocks of Trans-Pecos Texas": presented to U.S. Geological Survey, Friends of Ore Deposits Seminar, Reston, Virginia.

"Tectonics and Magmatism, Trans-Pecos Texas": presented to University of New Orleans, Department of Geology and Geophysics, graduate seminar, New Orleans, Louisiana.

"Tertiary Tectonics and Magmatism in Trans-Pecos Texas": presented to Rice University, Department of Geology, Houston, Texas.

"Texas Mineral Potential": presented to Texas Mining and Reclamation Association, annual meeting, Dallas, Texas.

Jay A. Raney

"Geology of the Texas Panhandle": presented to Amarillo Chamber of Commerce, select committee, Amarillo, Texas; Deaf Smith County Chamber of Commerce, Hereford, Texas.

Douglas C. Ratcliff

"Energy Resources of Texas": presented to 26th Texas Energy Science Symposium, sponsored by Texas Atomic Energy Research Foundation and The University of Texas at Austin, Austin, Texas.

M. P. Roberts

"The Software Prototyping Concept": presented to The University of Texas at Austin, Bureau of Economic Geology staff.

Rainer K. Senger

"Basin Hydrodynamics Using the Palo Duro Basin as an Example": presented to The University of Texas at Austin, Department of Geological Sciences, hydrogeology seminar.

Steven J. Seni

"Natural Resources of Salt Domes in Texas": presented to Austin Geological Society, Austin, Texas.

Steven W. Tweedy

"Determination of H_2O+ in Rocks Using a Carbon Dioxide Coulometric Analyzer": presented to American Chemical Society, regional meeting, Houston, Texas.

Noel Tyler

"Character and Economic Significance of Early Proterozoic Fluvial Sediments, South Africa": presented to The University of Texas at Austin, Department of Geological Sciences, graduate class in depositional systems.

"Depositional Systems and Oil and Gas Plays in the Cretaceous Olmos Formation, South Texas": presented to Austin Geological Society, Austin, Texas; Dallas Geological Society, Dallas, Texas; Houston Geological Society, Houston, Texas.

"Facies Architecture and Reservoir Heterogeneity in Submarine Fan Reservoirs, Permian Spraberry Trend, West Texas": presented to Shell Research Laboratory, Houston, Texas.

"The Role of the Geologist in Reservoir Simulation": presented to Society of Petroleum Engineers Forum on Reservoir Simulation, Jackson Hole, Wyoming.

E. G. Wermund

"Bureau of Economic Geology Core Facilities—a Significant Texas Resource": presented to Austin Kiwanis Club, Austin, Texas.

"Bureau of Economic Geology Map Sales—How Many and Who Buys": presented to U.S. Geological Survey, Central Region cluster meeting, Lawrence, Kansas.

"MMS Coastal Margins Programs with State Geological Surveys": presented to Minerals Management Service, Regional Technical Working Group, Ternary Session, Metairie, Louisiana.

"Overview of the Bureau of Economic Geology's High-Level Waste Program in the Texas Panhandle": presented to the Hereford Chamber of Commerce, Hereford, Texas.

"Texas Bureau of Economic Geology—Programs and Resources": presented to Georgetown Rotary Club, Georgetown, Texas.

William A. White

"The Bureau's Submerged Lands and Wetlands Studies of the Galveston-Trinity Bay System": presented to Sea Grant College Program, Galveston Bay Workshop, sponsored by Texas Water Commission and Texas A&M University, College Station, Texas.

"Geologic Processes and Their Relationship to Wetlands along the Texas Coast": presented to Austin Community College, class on ecosystems, Austin, Texas.

"Recent and Ongoing Coastal Studies of the Bureau of Economic Geology": presented to Texas A&M University, Sea Grant College Program, Workshop on Estuaries and Wetlands of the Texas Coast, College Station, Texas.

Bureau of Economic Geology Seminars

The Bureau holds weekly seminars during the spring and fall to promote communication among scientists, to encourage guidance and peer review of Bureau research, and to foster professional development of junior staff. Lectures given during 1986 follow:

Robert W. Baumgardner, Jr.

"Analysis of Subsurface Structure via Lineament Study, East Texas and Northwest Louisiana."

S. Christopher Caran

"Ground-Water Lakes—Pleistocene and Modern Examples from New Mexico and Texas."

Robert D. Conti

"Oomoldic Porosity in a Wolfcampian Shoaling-Upward Sequence (Palo Duro Basin): Petrophysical Implications."

Reinold R. Cornelius

"Centrifuge Modeling of Syndepositional Salt Diapirs: Downbuilding and Sidebuilding by Differential Loading."

Shirley P. Dutton

"Diagenesis and Burial History of Travis Peak Sandstones."

Graham E. Fogg

"A Geostatistical Method of Estimating Aquifer or Reservoir Interconnectedness."

Chester M. Garrett, Jr.

"Oil Reservoirs in the Permian."

Edgar H. Guevara

"Submarine Fan Reservoirs of the Benedum (Spraberry) Field, Upton County, Texas."

H. Scott Hamlin

"Hydrogeology of Barbers Hill Salt Dome, Texas Coastal Plain."

Tucker F. Hentz

"Lithostratigraphy and Depositional Environments of Lower Permian Red Beds, North-Central Texas."

Susan D. Hovorka

"Depositional Systems of Evaporites of the Palo Duro Basin."

M. P. A. Jackson

"Centrifuge Modeling of Syndepositional Salt Diapirs: Upbuilding and Downbuilding under Uniform Loading."

David A. Johns

"Diagenesis of the Dockum Group Strata."

Charles Kerans

"Profile of a 1.2-Billion-Year-Old Carbonate Platform, Dismal Lakes Group, Northwest Territories, Canada."

Stephen E. Laubach

"Geologic Setting of Mesozoic Metamorphism in Western Arizona."

M. P. R. Light

"Integrated Hydrothermal Model for Proposed Deep Crustal Borehole on the Texas Gulf Coast—Origins of Geopressured Brines and Lead-Zinc, Uranium, Hydrocarbon, and Cap-Rock Deposits."

F. Jerry Lucia

"Carbonate Reservoir Geology."

P. K. Mukhopadhyay

"Diagenesis of Organic Matter and Hydrocarbon Gases from Tyrrhenian Sea, Ocean Drilling Program, Leg 107."

H. S. Nance

"Issues in Upper Permian Stratigraphy along the Matador Arch, Texas."

Ronit Nativ

"Characterization of the Ogallala Aquifer."

Jonathan G. Price

"Heavy Rare Earth Elements, Beryllium, and Other Exotic Commodities in Trans-Pecos Texas."

M. P. Roberts

"BEG Computing Patterns."

Stephen C. Ruppel

"San Andres Facies and Porosity Development: Emma Field, West Texas."

Congressional, Legislative, and Special Testimony

Edward C. Bingler

Letter of purpose for Project GUIDE: drafted for William H. Cunningham, President, The University of Texas at Austin, for transmittal to Texas congressional delegation.

Written statement sponsoring Senate Bill 1026, the National Continental Scientific Drilling Program: drafted for

Senator Lloyd Bentsen for delivery to the U.S. Senate, Subcommittee on Energy Resources and Production.

Written statement in support of enactment of Senate Bill 1026: drafted for Bureau Director William L. Fisher and given to U.S. Senate, Subcommittee on Energy Resources and Production.

Robert J. Finley and William L. Fisher

"Future Trends in Texas Oil and Gas": given to Texas House of Representatives, Committee on Energy.

William L. Fisher

"The Continental Scientific Deep-Drilling Program, S.1026": given to the U.S. Senate, Subcommittee on Energy Development and Production, Committee on Energy and Natural Resources.

"The High Cost of Low Oil Prices": given to Governors' Summit Conference on Energy.

"The Impact of Today's Low Oil Prices on Tomorrow's": given to U.S. House of Representatives, Committee on Energy and Commerce, Subcommittee on Fossil and Synthetic Fuels.

"Production Impacts on the Independent Operator": given to U.S. House of Representatives, Committee on Small Business.

"Production Impacts and National Security": given (with Commissioner Mack Wallace, Railroad Commission of Texas) to U.S. House of Representatives, Budget Committee.

"The Variable Import Tariff": given (with Commissioner Mack Wallace, Railroad Commission of Texas) to U.S. Senate, Committee on Energy and Natural Resources.

Charles W. Kreitler and Steven J. Seni

"Geology of Keechi Salt Dome and Implications for Chemical Waste Disposal": technical witnesses (with W. Klemt and B. K. Knape, Texas Water Commission) to Texas House of Representatives, Subcommittee on Environmental Affairs.

Robert A. Morton

Technical witness to Texas Senate, Special Committee on Coastline Rehabilitation.

Cooperated with the Brazoria County Sand Dune Protection Committee.

Cooperated with the Texas Antiquities Committee regarding possible locations of shipwrecks near Galveston.

Cooperated with the Texas Attorney General's Office regarding State-owned coastal property (*Alvenus* litigation, Packery Channel, Boca Chica Park).

Cooperated with the Texas Parks and Wildlife Department regarding planned activities at Cedar Bayou and Packery Channel.

Jonathan G. Price

"Access to State Lands": given to Texas House of Representatives, Committee on Energy, for the General Land Office of Texas and the Bureau of Economic Geology.

Committee Services, Offices, and Other Professional Responsibilities

W. B. Ayers, Jr.

Co-leader of field trip, "Geology of Gulf Coast Lignites," Geological Society of America, annual meeting.

Robert W. Baumgardner, Jr.

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

Co-leader of field trip, "Quaternary Geology and Geomorphology of the Rolling Plains, Texas Panhandle," Geological Society of America, annual meeting.

Don Bebout

Chairman, Technical Program, Society of Economic Paleontologists and Mineralogists, 1987 midyear meeting.

Co-chairman of research conference, "Hydrocarbon Reservoir Studies, San Andres/Grayburg Formations, Permian Basin," Society of Economic Paleontologists and Mineralogists, Permian Basin Section.

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

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

Member, Publication Committee, American Association of Petroleum Geologists.

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

Edward C. Bingler

Chairman, Policy Coordinating Council, Bureau of Economic Geology, The University of Texas at Austin.

Chairman, Subcommittee on International Trade, Industry-Legislative Task Force.

Co-chairman, Technical Program Committee, Austin Geological Society.

Coordinator, Project GUIDE—Deep Observation and Sampling of the Earth's Continental Crust, Inc.

General Chairman, Project GUIDE Workshop.

Member, Texas Industry-Legislative Task Force.

L. F. Brown, Jr.

Member, Continuing Education Program, American Association of Petroleum Geologists.

S. Christopher Caran

Co-leader of field trip, "Quaternary Geology and Geomorphology of the Rolling Plains, Texas Panhandle," Geological Society of America, annual meeting.

Co-leader of field trip, "Upper Cretaceous Volcanic Centers of South and Central Texas," Geological Society of America, annual meeting.

Edward W. Collins

Co-leader of field trip, "Quaternary Geology and Geomorphology of the Rolling Plains, Texas Panhandle," Geological Society of America, annual meeting.

Carolyn E. Condon

Member, Finance Committee, Society of Economic Paleontologists and Mineralogists, 1987 midyear meeting.

Member, Technical Program Committee, Society of Economic Paleontologists and Mineralogists, 1987 midyear meeting.

E. Dow Davidson, Jr.

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

Richard L. Dillon

Member, Technical Working Group on Digital Mapping, Texas Natural Resources Information System.

Susann Doenges

Editor, *Blueline*, Newsletter of the Association of Earth Science Editors.

Jules R. DuBar

Representative to Geological Society of America, for Bureau of Economic Geology, The University of Texas at Austin.

Alan R. Dutton

Co-presider, Technical Session, Hydrogeology II, Geological Society of America, 1986 annual meeting.

Shirley P. Dutton

Chairman, Awards and Judging Committee, Society of Economic Paleontologists and Mineralogists, 1987 midyear meeting.

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

Member, Committee for "Sedimentary Cover of the Craton: U.S." volume of the Decade of North American Geology series, Geological Society of America.

Secretary, Mid-Continent Section, Society of Economic Paleontologists and Mineralogists.

Robert J. Finley

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

Chairman, Geology Session, Society of Petroleum Engineers, Unconventional Gas Technology Symposium.

Member, Program Committee, Society of Petroleum Engineers, Unconventional Gas Technology Symposium.

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

R. Steven Fisher

Member, Planning Committee, Society of Economic Paleontologists and Mineralogists, 1987 midyear meeting.

William L. Fisher

Chairman, Advisory Council, American Association of Petroleum Geologists.

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

Chairman, Subcommittee on National Energy Policy, Office of Technology Assessment, U.S. Congress.

Co-director, Energy and Natural Resources Division, Policy Research Institute, The University of Texas at Austin, Lyndon B. Johnson School of Public Affairs.

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

Liaison, to American Association of Petroleum Geologists, Association of American State Geologists.

Member, Advisory Council, Gas Research Institute.

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

Member, Board on Mineral and Energy Resources, National Research Council, National Academy of Sciences.

Member, Committee on Continental Scientific Drilling, National Research Council, National Academy of Sciences.

Member, Coordinating Committee, U.S. Oil and Gas Outlook, National Petroleum Council.

Member, Geology Advisory Group, Southern Illinois University.

Member, Geology Associates Advisory Board, University of Kansas.

Member, Governing Board, American Geological Institute.

Member, High-Level Nuclear Waste Disposal Committee, Association of American State Geologists.

Member, Policy Advisory Board, Outer Continental Shelf, U.S. Department of the Interior.

Member, Research Committee, Interstate Mining Compact Commission.

Member, Research Committee, Interstate Oil Compact Commission.

Member, Texas Mapping Advisory Committee.

Member, Texas Senate-House of Representatives Joint Special Committee on Cogeneration.

Member, Town and Gown.

Member, U.S. National Committee on Geology, National Academy of Sciences and U.S. Department of the Interior.

Moderator, Workshop on Effects of Low Oil Prices on Domestic Crude Oil Production, Office of Technology Assessment, U.S. Congress.

President, American Association of Petroleum Geologists.

Vice President, Institutional Participation, Bureau of Organizing Committee, 28th International Geology Congress.

Graham E. Fogg

Manuscript Reviewer, *Ground Water*, Journal of the Association of Ground-Water Scientists and Engineers.

Member, Ground-Water Committee, American Geophysical Union.

Michael A. Fracasso

Chairman, Publicity Committee, Society of Economic Paleontologists and Mineralogists, 1987 midyear meeting.

William E. Galloway

Editor, *Uranium*.

Member, Committee for "Gulf of Mexico" volume of the Decade of North American Geology series, Geological Society of America.

Member, Project GUIDE Steering Committee, Deep Observation and Sampling of the Earth's Continental Crust, Inc.

Session Chairman, Project GUIDE Workshop, Scientific Program of Ultradeep Drilling in the Gulf of Mexico Basin, Deep Observation and Sampling of the Earth's Continental Crust, Inc.

Working Group Leader, Gulf Coast Working Group, EDGE Workshop, Houston Area Research Center, Geotechnology Research Institute.

Chester M. Garrett, Jr.

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

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

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

Member, Public Information Committee, American Association of Petroleum Geologists.

President-Elect (1986-87), Austin Geological Society.

Treasurer (1985-86), Austin Geological Society.

Thomas C. Gustavson

Co-chairman, Institute for Tertiary and Quaternary Studies (TER-QUA), annual meeting.

Co-leader of field trip, "Quaternary Geology and Geomorphology of the Rolling Plains, Texas Panhandle," Geological Society of America, annual meeting.

Member, Kirk Bryan Award Committee, Quaternary Geology and Geomorphology Division, Geological Society of America.

Member, Panel on Quaternary Geology and Geomorphology, Geological Society of America.

Christopher D. Henry

Co-leader of field trip, "Igneous Geology of Trans-Pecos Texas," Geological Society of America, annual meeting.

Member, Atlas Editorial Board, Rio Grande Rift Consortium.

Claude R. Hocott

Member, Engineering Development Committee, National Science Foundation, International Ocean Drilling Program.

Member, Long-Range Planning Committee, Society of Petroleum Engineers.

Member, Research Committee, Interstate Oil Compact Commission.

M. P. A. Jackson

Associate Editor, American Association of Petroleum Geologists Bulletin.

Member, Subcommittee on Structural Geology, Committee for Education, American Association of Petroleum Geologists.

Mary L. W. Jackson

Delegate, Audubon Council of Texas, for Travis Audubon Society.

Member, Membership Committee, Austin Geological Society.

Member, Technical Services Committee, Society of Economic Paleontologists and Mineralogists, 1987 midyear meeting.

David A. Johns

Co-chairman, Audio-Visual Committee, Society of Economic Paleontologists and Mineralogists, 1987 midyear meeting.

Member, Newsletter Committee, Austin Geological Society.

W. R. Kaiser

Member, Editorial Board, *In Situ*.

Charles Kerans

Chairman, Field Trip Committee, Society of Economic Paleontologists and Mineralogists, 1987 midyear meeting.

Co-leader of field trip, "Devonian Reef Complexes of the Canning Basin, Western Australia," International Sedimentologic Congress.

David W. Koppenaal

Chairman, Subcommittee D.05.29.03, Task Group on Ion Chromatographic Methods, American Society for Testing and Materials.

Secretary, Subcommittee D.05.29.02, X-ray Fluorescence Methods, American Society for Testing and Materials.

Secretary, Technical Committee TC27/WG14, Trace Elements in Coal, International Standards Organization.

U.S.A. Delegate, Technical Committee TC27/WG13, Major and Minor Elements in Coal, International Standards Organization.

U.S.A. Delegate, Technical Committee TC27/WG14, Trace Elements in Coal, International Standards Organization.

Elisabeth C. Kosters

Vice Chairman, Gulf Coast Section, Society of Economic Paleontologists and Mineralogists Convention Committee, 1986 annual meeting.

Charles W. Kreitler

Chairman, Selection Committee, Birdsall Lectureship, Geological Society of America, Hydrogeology Division.

Convenor of symposium, "Hydrogeology of Sedimentary Basins," Geological Society of America, Hydrogeology Division, annual meeting.

Member, Selection Committee, O. E. Meinzer Award in Hydrogeology, Geological Society of America.

Panelist for the U.S. Environmental Protection Agency committee to develop technical guidelines for the 1986 Safe Drinking Water Act Amendments, EPA Well Head Protection Program, and the Sole Source Aquifer Protection Program.

Reviewer of hydrogeology abstracts for general hydrogeology sessions, Geological Society of America, annual meeting.

F. Jerry Lucia

Co-leader of field trip, "San Andres/Grayburg Formations, Guadalupe Mountains, New Mexico and Texas," Permian Basin Section, Society of Economic Paleontologists and Mineralogists.

Member, Publications Committee, American Association of Petroleum Geologists.

R. P. Major

Judge, Society of Economic Paleontologists and Mineralogists Excellence of Presentation Award, American Association of Petroleum Geologists, annual meeting.

Member, Awards and Judging Committee, Society of Economic Paleontologists and Mineralogists, 1987 midyear meeting.

Mary W. McBride

Chairman, Technical Services Committee, Society of Economic Paleontologists and Mineralogists, 1987 midyear meeting.

Secretary, Austin Geological Society.

Robert A. Morton

Co-convenor, Gulf Coast Section, Society of Economic Paleontologists and Mineralogists, 1986 Research Conference on shelf sandstones.

Co-leader of field trip, "Holocene Environments of the Central Texas Coast," Gulf Coast Section, Society of Economic Paleontologists and Mineralogists.

General Chairman, Society of Economic Paleontologists and Mineralogists, 1987 midyear meeting.

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

Member, Nominating Committee, Texas Section, American Institute of Professional Geologists.

P. K. Mukhopadhyay

Chairman, Nominating Committee, Society of Organic Petrology.

Member, Dispersed Organic Matter Group, International Committee for Coal Petrology.

William F. Mullican III

Co-chairman, Technical Program Committee, Austin Geological Society.

H. S. Nance

Member, Technical Services Committee, Society of Economic Paleontologists and Mineralogists, 1987 midyear meeting.

Jeffrey G. Paine

Member, Standing Advisory Committee, Southern Coastal Corridor Cultural Resource Planning Region.

Harry H. Posey

Reviewer of abstracts, Economic Geology Section, Society of Economic Geologists, Geological Society of America, annual meeting.

Jonathan G. Price

Co-leader of field trip, "Igneous Geology of Trans-Pecos Texas," Geological Society of America, annual meeting.

Leader of field trip, "Llano Area Granite and Graphite," Central Texas Mining Section, Society of Mining Engineers.

Member, Energy and Mineral Resources Graduate Studies Committee, The University of Texas at Austin.

Member, Nomination Committee, Austin Geological Society.

Reviewer of abstracts, Geological Society of America, annual meeting.

Vice Chairman, Central Texas Mining Section, Society of Mining Engineers.

Jay A. Raney

Chairman, Last plenary session of Project GUIDE Workshop, Deep Observation and Sampling of the Earth's Continental Crust, Inc.: The University of Texas at Austin.

Member, Project GUIDE Steering Committee, Deep Observation and Sampling of the Earth's Continental Crust, Inc.

Douglas C. Ratcliff

Chairman, Finance Committee, Society of Economic Paleontologists and Mineralogists, 1987 midyear meeting.

Member, Finance Committee, Gulf Coast Association of Geological Societies.

Member, Membership Committee, American Association of Petroleum Geologists.

M. P. Roberts

Member, Technical Working Group on Digital Mapping, Texas Natural Resources Information System.

Stephen C. Ruppel

Member, Technical Program Committee, Society of Economic Paleontologists and Mineralogists, 1987 midyear meeting.

Zvi Sofer

Discussion Leader, Session on Stable Isotopes in Organic Matter, Gordon Research Conference on Organic Geochemistry.

Member, Committee for the selection of the Organic Geochemistry Division best paper, Geological Society of America.

Jeffrey E. Thurwachter

Chairman, Newsletter Committee, Austin Geological Society.

Noel Tyler

Chairman, Entertainment Committee, Society of Economic Paleontologists and Mineralogists, 1987 midyear meeting.

Invited Discussion Leader, Society of Petroleum Engineers Forum on Reservoir Simulation.

Member, Reservoir Development Committee, American Association of Petroleum Geologists.

E. G. Wermund

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

Chairman, Field Trips Committee, Geological Society of America, annual meeting.

Judge, Awards and Judging Committee, American Association of Petroleum Geologists, annual meeting.

Judge, Poster Sessions, Geological Society of America, annual meeting.

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

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

Past President, Executive Committee, Gulf Coast Association of Geological Societies.

University Teaching/ Continuing Education

Don Bebout

Lectures and field trips on carbonate facies and depositional environments: School on Fundamentals of Petroleum Engineering for employees of Schlumberger, sponsored by The University of Texas at Austin, Department of Petroleum Engineering.

L. F. Brown, Jr.

"Seismic Stratigraphy" (Geology 380N): The University of Texas at Austin, Department of Geological Sciences.

"Seismic Stratigraphy in the Exploration for Petroleum": American Association of Petroleum Geologists Seismic Stratigraphy School, Houston, Texas; San Diego, California; Jakarta, Indonesia.

Shirley P. Dutton and Robert J. Finley

Core Workshop: Travis Peak (Hosston) Formation, East Texas: School on Fundamentals of Petroleum Engineering for employees of Schlumberger, sponsored by The University of Texas at Austin, Department of Petroleum Engineering.

Robert J. Finley

"Tight Gas Sandstones": School on Fundamentals of Petroleum Engineering for employees of Schlumberger, sponsored by The University of Texas at Austin, Department of Petroleum Engineering.

William E. Galloway

"Application of Geology to Energy Resources" (Geology 368N): The University of Texas at Austin, Department of Geological Sciences.

"Terrigenous Clastic Depositional Systems" (Geology 383): The University of Texas at Austin, Department of Geological Sciences.

"Topics in Sedimentary Basin Analysis" (Geology 391): The University of Texas at Austin, Department of Geological Sciences.

Claude R. Hocott

"Petroleum Engineering" (PEN 320): The University of Texas at Austin, Department of Petroleum Engineering.

Charles Kerans

"Carbonate Platform Depositional Models and Application to Petroleum Exploration": School on Fundamentals of Petroleum Engineering for employees of Schlumberger, sponsored by The University of Texas at Austin, Department of Petroleum Engineering.

F. Jerry Lucia

"Petrophysical Characteristics of Carbonates": School on Fundamentals of Petroleum Engineering for employees of Schlumberger, sponsored by The University of Texas at Austin, Department of Petroleum Engineering.

R. P. Major

"Principles of Carbonate Diagenesis": School on Fundamentals of Petroleum Engineering for employees of Schlumberger, sponsored by The University of Texas at Austin, Department of Petroleum Engineering.

Jonathan G. Price

"Activity-Composition Relations of Rock-Forming Minerals, Recalculating Microprobe Analyses, and Geothermometry": Rice University, Department of Geology, short course, Houston, Texas.

Support Staff

Administrative/Secretarial

The administrative/secretarial staff is responsible for administrative, personnel, accounting, purchasing, payroll, and secretarial work essential to day-to-day operation of the Bureau. Responsible for publication sales, they assist visitors who wish to purchase publications directly from our sales section at Balcones Research Center as well as those who place orders by phone or mail. Bettye A. Blitch, Executive Assistant, coordinates the work of the administrative/secretarial staff.

Cartography

The cartography department has done much over the years to enhance the Bureau's reputation in geologic and land resource mapping. Perhaps best known for its high-quality, full-color maps, the cartography section also produces a wide range of other maps, cross sections, text illustrations, slide copy, posters, and display materials. Within the department, a publication design section prepares all covers, designs publication formats, and pastes up camera-ready copy. A photography section provides cover and text photographs for Bureau publications, slides for lectures and public addresses, and negatives and color proofs for maps. Richard L. Dillon, Chief Cartographer, directs the work of the cartography department.

Productivity of the department is best shown in the lists of publications by scientists in 1986. In support of that work the cartographers and draftspersons completed 1,275 black-and-white illustrations, 697 pieces of colored slide copy or poster art, 65 black-and-white maps or cross sections, and 2 full-color maps.

Computing

The computing staff provides three types of services to research, administrative, and support personnel: system services (facilities and operations), user education and consultancy, and programming services. Educational services include conducting classes for users and preparing fact sheets and bulletins.

The Bureau's in-house computing system consists of a VAX 11/780 computer with 8 megabytes of memory, an asynchronous network of more than 120 terminals and 60 peripherals that include 6 microcomputers, 3 pen plotters, an electrostatic plotter, 3 laser printers, and a 4- by 3-ft digitizing station. In 1986, installation was completed, and the system was brought into full production. Software runs under VMS and includes fourth-generation data-base tools, a statistical package, a full-function word processing package, and a contour plotting system.

The computing section supports programming applications on the University's Cyber and IBM computers and performs routine operating services such as plot production and data entry. Another service is data-base maintenance and administration. The computing staff also administers software Quality Assurance procedures to satisfy Federal contract requirements. Substantial programming effort during 1986 was dedicated to new capabilities in oil and gas data bases, image processing of satellite scenes, and automated reporting of core holdings.

The staff, under the direction of Michael P. Roberts, consists of a systems analyst who is also the VAX system manager, two programmers, a system development hardware specialist, and an administrative assistant.

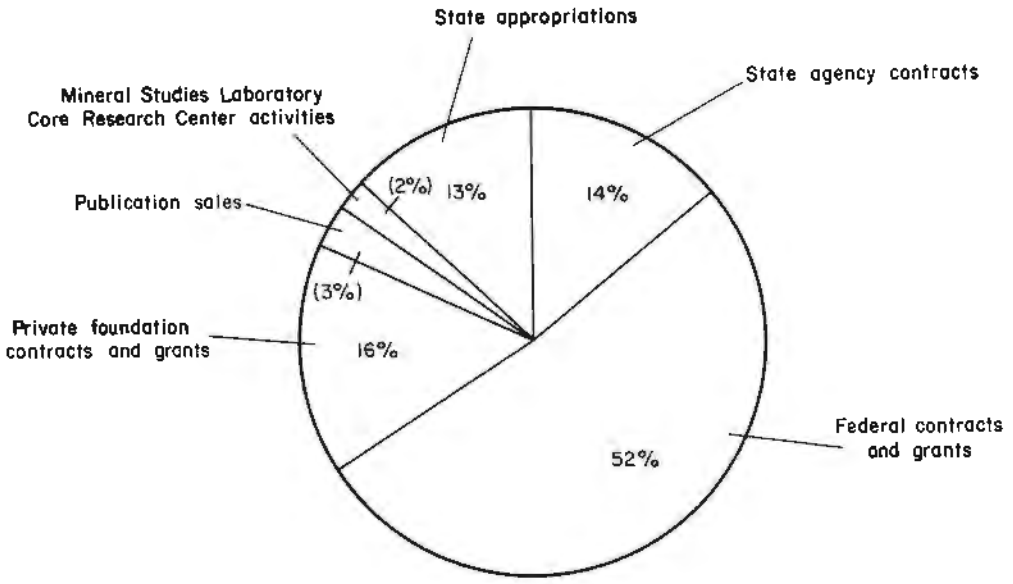
Editing

The editing section, supervised by Susann Doenges, Editor-in-Charge, includes editors and proofreaders. The staff edits and proofreads manuscripts for Bureau publications and contract reports as well as papers and abstracts that are submitted to professional journals. A monthly newsletter, distributed to all Bureau staff, is also prepared by Editing. During 1986, the publications staff issued a record 35 new Bureau reports, 7 of which also served as final contract reports, and 8 independent final contract reports. Nearly 20,000 pages of text were proofread, and more than 4,500 pages of text were edited.

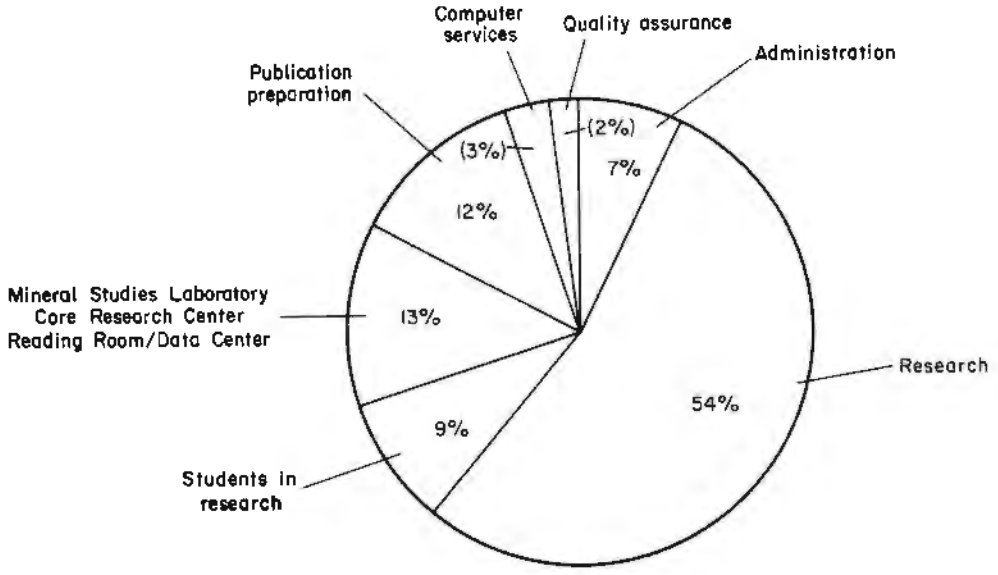
Word Processing/Typesetting

The word processing/typesetting staff includes several word processing and typesetting operators who are supervised by Lucille C. Harrell. Refining the process of communication between the word processing system and the typesetting system continued during 1986. Most of the research staff now type first drafts of their manuscripts on the VAX computer, and the word processing staff then transfers the manuscripts to the dedicated word processing system. This process allows the word processing staff to merge text from several authors into one document and reformat documents into a consistent Bureau style before they are typeset. Similarly, the typesetting staff can transfer manuscripts from the VAX computer directly to the typesetter for the final steps in the publication process. During the year, 41,556 pages of text and tables were processed by the word processing/typesetting staff.

Sources of Funding



Uses of Funding



1985-86

BUREAU OF ECONOMIC GEOLOGY

Dr. William L. Fisher, Director

Dr. Edward C. Bingler, Deputy Director
Dr. E. G. Wermund, Associate Director for Operations, Assistant to the Director
Douglas C. Ratcliff, Associate Director for Administration
Bettye A. Blitch, Executive Assistant

Senior Research Scientists

Dr. Virgil E. Barnes
Dr. Don G. Bebout
Dr. L. F. Brown, Jr.
Dr. William E. Galloway

Research Scientists

Dr. Jules R. DuBar
Dr. Robert J. Finley
Dr. Thomas C. Gustavson
Dr. Christopher D. Henry
Dr. Claude R. Hocott
Dr. Martin P. A. Jackson
Dr. William R. Kaiser
Dr. David W. Koppenaal
Dr. Charles W. Kreitler
Dr. Malcolm P. R. Light
Dr. Robert A. Morton
Dr. Jonathan G. Price
Dr. Jay A. Raney
Dr. Stephen C. Ruppel
Dr. Zvi Sofer
Dr. Noel Tyler

Research Associates

Dr. Walter B. Ayers, Jr.
Dr. Roy T. Budnik
Edward W. Collins
Dr. Alan R. Dutton
Dr. Shirley P. Dutton
Dr. R. Stephen Fisher
Dr. Graham E. Fogg
Dr. Michael A. Fracasso
Dr. Edgar H. Guevara
Dr. Charles Kerans
Dr. Elisabeth C. Kosters
Dr. Stephen E. Laubach
Dr. Richard P. Major
Dr. Prasanta K. Mukhopadhyay
Dr. Ronit Nativ
Steven J. Seni
William A. White
Dr. James H. Wittke

Research Scientist Associates

M. Saleem Akhter
Mark Andreason
Robert W. Baumgardner, Jr.
Thomas R. Calnan
S. Christopher Caran
Carolyn E. Condon
Robert D. Conti
Reinold R. Cornelius
E. Dow Davidson, Jr.
Chester M. Garrett, Jr.
H. Scott Hamlin
Rodney Heathcott
Tucker F. Hentz
Susan D. Hovorka
Mary L. W. Jackson
Lee A. Jirik
David A. Johns
Christopher C. Lewis
Mary W. McBride
William F. Mullican III
H. Seay Nance
Jeffrey G. Paine
Thomas Pinkston
Bernd C. Richter
Jeffrey N. Rubin
Rainer K. Senger
Gary W. Vander Stoep

Senior Research Fellow

F. Jerry Lucia

Research Fellow

Harry H. Posey

Administrative Staff

Bettye A. Blitch
Executive Assistant
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