NNUAL REPORT
982

BUREAU OF ECONOMIC GEOLOGY

W. L. FISHER, DIRECTOR • THE UNIVERSITY OF TEXAS AT AUSTIN
AUSTIN, TEXAS 78712

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. The Bureau Director is a member of the Texas Energy and Natural Resources Advisory Council, as well as several interagency committees. The Director represents Texas in the Association of American State Geologists.

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

The Bureau of Economic Geology publishes major reports in The University of Texas Publication series; it also has its own series of Reports of Investigations, Geologic Quadrangle Maps, Geologic Atlas Sheets, Environmental Geologic Atlases, Guidebooks, Handbooks, Geological Circulars, Mineral Resource Circulars, and several Special Publications. Publications are sold for a nominal price designed 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 programs and projects, publications, professional personnel activities, and special services in the area of Texas geology and resources available to agencies, industry, and all citizens of Texas. The Annual Report is available on request at no charge.

Cover illustrations: See explanation on inside back cover.

ANNUAL REPORT 1982

RESEARCH AND ADMINISTRATIVE OFFICES

Geology Building, Main Campus
University Station, Box X
Austin, Texas 78712
(512) 471-1534

Lavaca Offices
1300 Lavaca
University Station, Box X
Austin, Texas 78712
(512) 471-7721

Tri-Towers Offices
803 W. 24th
University Station, Box X
Austin, Texas 78712
(512) 471-1534

SPECIAL SERVICES LABORATORIES

Balcones Research Center
10100 Burnet Road
Austin, Texas 78758
(512) 835-3040 (MSL)
(512) 835-3042 (WSL)

BUREAU OF ECONOMIC GEOLOGY

W. L. FISHER, DIRECTOR • THE UNIVERSITY OF TEXAS AT AUSTIN
AUSTIN, TEXAS 78712

CONTENTS

RESEARCH

PUBLICATIONS

SERVICES

PERSONNEL

RESEARCH

Bureau research programs and projects are designed to address many of the State's major concerns in the areas of geologic, energy, mineral, land, and environmental resources. Through the years, an extensive research program in energy and mineral resources has been maintained. The Bureau's projects are directed toward comprehensive characterization of the State's resources, especially those with future potential, and toward solving both existing and future problems of resource utilization; the research programs incorporate geologic concepts that will build an understanding of a specific resource and its effect on human activities.

The diverse range of Bureau research programs is typified by the Federal National Waste Terminal Storage (NWTS) program. In-depth, comprehensive evaluations of subsurface hydrology, resource distribution, depositional systems, and land-surface configurations and denudation rates are required for this study. Such programs call for expertise in areas such as geomorphology, hydrology, basin analysis, tectonics, environmental geology, geochemistry, and rock physics. This research integrates complex geologic subdisciplines into a coordinated assessment of a critical problem needing scientific, objective review.

In 1982, Bureau research on energy resources was strengthened by Texas Energy and Natural Resources Advisory Council (TENRAC) support in two areas. First, a geological characterization of the larger oil reservoirs was completed toward development of models that may lead to more efficient advanced recovery techniques. Second, research on deep-basin lignite, occurrences between 200 and 2,000 ft in East Texas, led to a better measure of the resource and an improved definition of the associated hydrologic system. Numerous cores were successfully collected for chemical and petrological characterization.

Major efforts have continued in other energy and mineral areas as well. Engineering models were evaluated toward predicting migration and production of dispersed gas. An inventory of tight gas sands was completed. Further studies of enriched sulfides in Trans-Pecos volcanics and associated clastics continue as research sponsored by the Texas Mining and Mineral Resources Research Institute. A new inventory of Texas mineral producers has been reformatted for a computer printout that allows flexibility.

Work continues on land resources of the Texas submerged lands and of the lignite- and uranium-bearing lands of southwest Texas. Systematic geologic mapping, coastal studies, basin analyses, and investigations in other areas of economic geology further indicate the range of research programs carried forward in 1982.

ENERGY RESOURCES INVESTIGATIONS

HYDROLOGIC EVALUATION OF DEEP-BASIN LIGNITE

W. R. Kaiser, Project Director; Graham E. Fogg, Walter B. Ayers, Jr., Gary F. Collins, Colin M. Jones, Mary L. Ambrose, Mary L. W. Jackson, Gwendolyn L. Macpherson, Amy H. Lewis, Susan J. Tewalt, Dorothy L. Gower, Clara L. Ho, Cynthia A. Mahan, Steven J. Seni, and Peter R. Kremer; assisted by J. Nile Barnes, Paul E. Blanchard, Janet Boland, Rich E. Dobson, Greg J. Gilson, Thomas R. Laughery, David A. Prouty, David C. Reutter, and Thomas M. Simmons

This study, begun in September 1981 and funded by the Texas Energy and Natural Resources Advisory Council (TENRAC), is a 2-yr effort integrating geology and ground-water hydrology in the Wilcox Group of East Texas to identify areas of high potential for deep recovery of lignite. An integrated program of subsurface geologic, hydraulic gradient, hydrochemical, and resistivity mapping and ground-water modeling is under way along with a field program of drilling, logging, coring, and hydrologic testing. Work has been concentrated in two regions of the Wilcox: (1) the Sabine Uplift area, a 12-county area in far East Texas, centered on the semicircular Wilcox outcrop in Harrison, Panola, and Shelby Counties, including counties downdip of and ringing the outcrop and (2) east-central Texas, a 15-county area between the Neches and Colorado Rivers, extending along the outcrop and into adjoining downdip counties.

In the Sabine Uplift area, geologic mapping using approximately 1,100 oil and gas logs guided an associated field program of drilling, logging, and coring designed to test an evolving depositional model, facilitate lignite identification on oil and gas logs, and recover lignite for characterization. Lignite was operationally defined on oil and gas logs and its occurrence mapped. Maximum-sand mapping established a fluvial-deltaic origin for the lignite. Drilling locations were selected, using the lignite-occurrence and maximum-sand maps; 15 holes were drilled to depths of between 700 and 1,820 ft (213 and 555 m). All holes were extensively logged (natural gamma, density, neutron, 16-inch normal, focused resistivity, SP, and caliper); downhole data were digitally recorded for later computer manipulations of scale, curve format, and cross plotting for correlation with oil and gas logs and lithology (cuttings and core). Four holes were offset and cored, recovering 106 ft (32.3 m) of lignite, overburden, and underburden. Lignite is being extensively characterized, chemically and mineralogically. Chemical analyses include proximate, ultimate, Btu, forms of sulfur, major oxides, and major, minor, and trace elements on a whole-coal basis. In a cooperative program with Texas Tech University, mineral matter (low-temperature ash) is being examined by analytical electron microscopy. One-third of the core is being archived at 4°C in sealed PVC pipe.

Drilling has confirmed the stratigraphy of lignite occurrence in the lower and upper Wilcox, established in regional, subsurface mapping. Lignite can be identified on electric and induction logs, although distinguishing thin lignites from thin, hard streaks remains a problem. In effect, 15 wells were drilled to expand our data base by calibrating 1,100 logs for more efficient use in resource assessment. The

thickest (5 to 10 ft, 1.5 to 3.0 m), most laterally extensive lignite seams (10 to 15 mi, 16 to 24 km) occur in Shelby and Panola Counties in the lower 200 to 500 ft (61 to 152 m) of progradational Wilcox strata. Maximum-sand mapping was successfully tested, predicting range of sand thickness and lateral extent of lignite seams. Maximum- or major-sand maps, proven tools in basin analysis, can be made rapidly before or even during drilling to guide exploration.

Regional hydrogeologic data are being collected to elucidate the hydrology and to provide the framework necessary for interpreting site-specific hydrologic data in the assessment of mine sites or in situ gasifiers. Hydraulic-head data and water chemistry indicate that regional ground-water circulation in the Wilcox-Carrizo aquifer system closely follows topography in the outcrop. Elsewhere, correlation with topography is poorer owing to greater depths of the aquifer and hence greater confinement by overlying strata. Major recharge areas coincide with topographic highs or stream divides and sand hills in the outcrop, whereas major discharge areas coincide with major streams. Potential for downward flow is present everywhere, except beneath floodplains of major rivers and several of their tributaries. Discharge areas make up a small percent of the total area and potentially include intense, upward ground-water flow components. Surface-mine dewatering or depressurization might be more difficult in discharge than in recharge areas.

Areas of recharge and discharge were mapped by integrating data on aquifer hydraulics (head and pressure versus depth), ground-water chemistry, and sand-body geometry. Potentiometric-surface mapping has been completed; it is used to delineate regional flow in the horizontal plane and will help eliminate uncertainty about flow direction in the Wilcox (downdip, updip, or toward major rivers). Analysis of fluid pressure versus depth and mapping of the vertical hydraulic gradient ($\partial h/\partial z$) were used to delineate potential for and direction of the vertical component of flow. Values of the vertical hydraulic gradient were calculated for 7.5-minute quadrangles in the Sabine Uplift area by linear regression and mapped with 2 degrees of certainty. The resulting map can be used to evaluate mine or in situ gasifier sites with respect to potential for vertical flow and interconnection of sand bodies. Regionally consistent, non-zero values of $\partial h/\partial z$ indicate poor vertical interconnection, and anomalous zero values can indicate good interconnection vertically.

Regional trends in water chemistry are mappable (contourable) and vary in a predictable fashion as shown by hydrochemical mapping. Because the mapping of concentrations has proved difficult, ground-water evolution was linked to water-rock interaction through solution-mineral equilibria. Activity indices derived from reactions believed to play a role in the evolution of Wilcox-Carrizo waters were mapped. All maps reflect the same regional geochemical patterns; they show a positive correlation with areas of recharge and discharge identified in head mapping and outcrop geology. Recharge is defined by small log $[Na^+]^{.33}/[Ca^{2+}]^{.16}$ ratios and log $[Ca^{2+}]^{.3}$ $[Na^+]^{.7}$ products and large log $[H_4SiO_4^0]$ values and montmorillonite saturation indices. Hydrochemical mapping complements head mapping and helps to define recharge and discharge where head data are sparse or ambiguous, such as local recharge within regional discharge areas (for example, high alluvial terraces) or losing lakes (for example, Lake Cherokee). The framework has been provided for interpreting water-chemistry data at individual mines by establishing pre-mining conditions in the Wilcox. For example, typically basic, high HCO_3^- waters of the Wilcox will tend to neutralize acid mine waters. Moreover, in interchannel splay and overbank sands, the log $[Na^+]^{.33}/[Ca^{2+}]^{.16}$ ratio or log $[Ca^{2+}]^{.3}$ $[Na^+]^{.7}$ product should be higher, reflecting longer residence time. These activity indices may be effective tools for assessing the degree of interconnection with major channel sands, where ground-water circulation is active and the activity indices are smaller.

The role of sand-body geometry in controlling ground-water flow is poorly understood. Hydraulic conductivity (K), transmissivity (T), and advective dispersion of solutes are responsive to sand-body geometry. Channel-fill sands (maximum or major sands) focus ground-water flow and control average K of a stratigraphic interval. They are more permeable than surrounding Wilcox sediments by a factor of at least 10 to 100. Sand-body interconnectedness is a key factor affecting flow. Wilcox sands are seldom interconnected vertically. Equivalent vertical K is 1,000 to 10,000 times lower than equivalent horizontal K.

Because maximum or major sands reveal the framework elements of a depositional system as well as control ground-water flow, lithofacies and resistivity mapping is being focused on these sands. In east-central Texas, Anderson and Houston Counties were selected as a test area, and 10 maps were made. Resistivity reflects K in the shallow subsurface; therefore, thickness (b in meters) times resistivity (Ω-m^2/m) should reflect relative variations in transmissivity (T=Kb). Hence, a map of the resistivity-thickness product (units of Ω-m^2) was made to identify areas of high relative transmissivity and recharge. The map shows that recharge occurs at the outcrop and around salt domes, whereas flow is inferred to be downdip and, in Anderson County, toward the Neches and Trinity Rivers.

Empirical relations have been established for the Wilcox-Carrizo aquifer between formation resistivity and water chemistry to approximate water quality (total dissolved solids) from oil and gas logs. Regional salinity mapping indicates that deep-basin lignite in the lower Wilcox of the Sabine Uplift area occurs in intervals containing brackish or saline ground water, whereas upper Wilcox lignite occurs in the fresh-water interval. The base of fresh water is low near the outcrop and along the axes of major channel sand belts; it is high basinward or in interchannel areas. The Railroad Commission of Texas is using the curve relating resistivity to TDS to establish standards for enforcing plugging and abandonment regulations protecting drinking water.

An interim report summarizing these research results for year one of the project has been submitted to TENRAC; a Bureau Geological Circular will be published in 1983.

COMPUTERIZED CALCULATION OF LIGNITE RESOURCES IN TEXAS

W. R. Kaiser, Project Director; Susan J. Tewalt; assisted by Clayton H. Wilson

This ongoing project, funded by the U.S. Geological Survey, is calculating lignite resources according to criteria

of U.S. Geological Survey Bulletin 1450-B from a computerized data base. Near-surface lignites are identified on geophysical logs; seam depth and thickness data are coded and entered into the National Coal Resources Data System (NCRDS). Resources are calculated on an aggregate basis by stratigraphic unit and geographic region by Bureau of Economic Geology personnel using NCRDS programs on a Tektronix model 4054 graphics terminal. Point source of proprietary data remains confidential.

Remaining near-surface resources for the Wilcox Group in two geographic regions have been calculated. The tonnages are reported in three thickness categories of 2.5 to 5 ft, 5 to 10 ft, and greater than 10 ft for three degree-of-certainty categories (measured, indicated, and inferred). A revised method of data selection was initiated to decrease the unrealistically large inferred resource figures obtained early in the project. The new method includes all data points in each resource calculation; points with no coal seams or with seams thinner or thicker than the thickness category being considered are assigned zero total coal values. The additional data control results in improved resource figures by controlling the interpolation between points performed by the computer system.

Remaining near-surface resources for the Wilcox Group in east-central Texas (between the Colorado and Trinity Rivers) total 8,764 million short tons for all three thickness and degree-of-certainty categories. This total is comparable to resources of 8,641 million short tons calculated in Report of Investigations No. 104 for all seams greater than 2 ft thick.

The total resource figure for the Wilcox Group in northeast Texas (north of the Trinity River to Texarkana) was calculated to be 8,546 million short tons for all three thickness and degree-of-certainty categories, whereas the tonnage calculated in Report of Investigations No. 104 for seams greater than 2 ft thick is 8,359 million short tons. The NCRDS and Bureau of Economic Geology resource estimates are in close agreement; they are widely used by policy makers and planners.

Currently, Wilcox Group resources are being calculated in both geographic areas for two additional seam thickness categories relevant to economic surface mining in Texas: 2 to 3 ft and greater than 3 ft. These resource estimates will be directly comparable to previous estimates by the Bureau of Economic Geology. Upon completion of these calculations, we will begin resource estimation for the Wilcox Group in the Sabine Uplift area. Data for the Jackson Group in East Texas are currently being entered into the NCRDS.

GEOLOGICAL CHARACTERIZATION OF TEXAS OIL RESERVOIRS

William E. Galloway, Project Director; Noel Tyler, Chester M. Garrett, Jr., Thomas E. Ewing, Don G. Bebout, Ronee S. Reed, and Jan S. Posey; assisted by Madison T. Woodward III, William A. Ambrose, Victor J. Gavenda, and Karen Meador

Approximately 153 billion bbl of in-place oil have been discovered in Texas reservoirs; an estimated 61 billion bbl of this oil will be produced, largely by conventional primary and secondary recovery methods. The Bureau of Economic Geology, with partial funding from the Texas Energy and Natural Resources Advisory Council (TENRAC), has initiated a geologic characterization of the major oil-producing reservoirs of the State.

During the first phase of the study, larger reservoirs throughout the State were grouped into 47 families of geologically similar reservoirs, called plays. For each play and its component reservoirs, key geologic, engineering, and production information was tabulated and summarized largely from data in files of the Railroad Commission of Texas. From this initial characterization, groups of reservoirs possessing the greatest potential for significant reserve addition through infield drilling, improved secondary recovery practice, and tertiary recovery were identified, and the potential targets for such improvements were quantified. Results of the geologic characterization will be available through the Bureau in 1983 in a publication entitled *Atlas of Major Texas Oil Reservoirs*. This atlas will review the pertinent geologic and engineering data for each play and present selected maps, well logs, cross sections, and interpretive diagrams to illustrate the attributes defining representative reservoirs. A summary of the estimated target for reserve addition through infield drilling and enhanced secondary recovery is contained in a report to TENRAC.

The second phase of the research program, which is now under way, has as its objective a more detailed, site-specific facies and engineering characterization of typical reservoirs in plays having the largest potential for reserve additions. Descriptive, qualitative geologic models will be calibrated by integration of time-dependent well production data and other engineering data generated during reservoir development. Cooperation of field operators is critical to this analysis and is being actively solicited. Resultant integrated geologic facies and engineering performance models may suggest infield exploration strategies that can improve recovery efficiency from generic families of reservoirs.

GEOLOGIC INVESTIGATION OF LOW-PERMEABILITY GAS SANDSTONE RESERVOIRS

Robert J. Finley, Project Director; Jong H. Han, A. E. Saucier, and Noel Tyler; assisted by Stephen W. Speer, Mark Berlinger, and Gay Nell Gutierrez

An amount of natural gas equal to or up to three times more than current U.S. natural gas reserves may ultimately be recoverable from low-permeability reservoirs in the United States. These reservoirs include tight sandstones. Funded by the Gas Research Institute, this project has proceeded from a national review of blanket-geometry tight gas sandstones to an analysis of six stratigraphic units in Texas and the Rocky Mountain region. Ultimately, the Gas Research Institute will select two formations for major emphasis in a multiyear study of all aspects of blanket-geometry tight gas sandstones.

In the first half of 1982, a compilation of the geologic and engineering characteristics of over 30 formations in 16 sedimentary basins was completed. Only blanket-geometry tight gas sandstones were included; the West Virginia Geological Survey participated with the Bureau in reviewing sandstones of the Appalachian Basin. Emphasis was placed on the genetic depositional system of each

sandstone to develop groupings that might have overall similarities in reservoir characteristics. Deltaic and barrier-strandplain systems include the largest number of sandstones, and a few additional formations represent shelf systems. Overlap occurs between depositional systems; not all parts of all sandstones are tight, and the degree of current commercial development varies from extensive ("J" Sandstone, Denver Basin) to limited (Hartselle Sandstone, Black Warrior Basin).

From the initial survey, six sandstones were selected for more detailed study during late 1982 and early 1983: the Travis Peak and Olmos Formations in Texas, the Rollins-Corcoran-Cozette Sandstones and the Mancos "B" Shale in Colorado, and the Frontier Formation and upper Almond Formation in Wyoming. Close liaison is being maintained with the Colorado Geological Survey during this work, and a cooperative agreement has been made with the Geological Survey of Wyoming to participate in the research program. In early 1983, the Gas Research Institute will narrow the aforementioned group of sandstones to two stratigraphic units suitable for a detailed research effort. The Bureau will then conduct in-depth studies of external and internal reservoir geometry, reservoir petrography, diagenetic history, and relationship between all geologic parameters and engineering practices necessary to develop the tight gas resource, including reservoir stimulation by hydraulic fracturing.

GEOLOGIC FRAMEWORK AND ENERGY RESOURCE STUDIES, TEXAS CONTINENTAL SHELF

Robert A. Morton, Project Director; Lee A. Jirik and Nancy Banta; assisted by Mark A. Jarecki and Paul A. Hardwick

This 2-yr project, funded by the U.S. Geological Survey, will result in the construction of regional structural cross sections of the Texas offshore area, including both State and Federal waters. During 1982, electric logs, paleontological reports, and hydrocarbon information were obtained and plotted on base maps. Using the locations of available well control, nine dip sections and two strike sections were prepared, and preliminary stratigraphic subdivisions were selected for the Miocene and Plio-Pleistocene trends.

SPECIAL PROJECTS RESEARCH AND COORDINATION ASSISTANCE

Robert A. Morton, Project Director; Chester M. Garrett, Jr.

The purpose of this multifaceted project is to assist the U.S. Department of Energy in (1) selecting sites for testing geopressured geothermal resources and (2) analyzing geological and reservoir data from those tests. Other responsibilities include (3) integrating the test results in other ongoing research projects and (4) initiating studies of specific factors that are critical in evaluating geothermal resources.

In 1982, the Bureau of Economic Geology participated in reviews of geological and engineering characteristics and test results for design wells and wells of opportunity in Texas and Louisiana. Special projects work included oral presentations of Bureau research to professional and industrial groups interested in geothermal activities. In addition, well data, core samples, and research results were provided to individuals and corporations desiring information related to the geopressured geothermal research program.

SALINITY OF DEEP FORMATION WATERS, TEXAS GULF COAST

Robert A. Morton, Project Director; Jong H. Han and Jan S. Posey; assisted by Bryan R. Bracken and James F. O'Connell

This study is funded as part of the U.S. Department of Energy's geopressured geothermal research program. The study will provide information on the geographic and stratigraphic variations in the salinity of formation water produced from Tertiary geopressured sandstones, primarily of the Frio Formation of Texas. Knowing the chemical composition of subsurface fluids is important because salinity partly controls the solubility of methane in water and the scaling and corrosion of production equipment. Moreover, high-temperature brines may cause physical and chemical reactions with the clay minerals in shallow aquifers, thus adversely affecting brine injection.

During 1982, chemical analyses of waters produced from geopressured and hydropressured reservoirs were obtained from two primary sources: (1) data files of field operators and (2) water samples of South Texas fields collected specifically for this study and analyzed at the Bureau's Mineral Studies Laboratory. Values for total dissolved solids, major ions, and ion ratios for selected fields were plotted to depict lateral and vertical chemical variations and to delineate depth-dependent trends. Salinity values and concentrations of major rock-forming elements were also compared to temperature gradient, pressure gradient, sandstone thickness, thickness of surrounding shales, and proximity to salt. At year's end, regional maps depicting geographic variations in water chemistry of Frio and Vicksburg Formations were being prepared for publication.

RESOURCE ASSESSMENT AND SEISMIC STUDIES — GEOPRESSURED GEOTHERMAL ENERGY, TEXAS GULF COAST

Thomas E. Ewing, Project Director; assisted by Kathy Hubby and Olufemi Babalola

This project, funded by the U.S. Department of Energy, is a continuing effort to assess the distribution of producible geopressured geothermal energy on the Texas Gulf Coast. The current phase of this project focuses on the structural evolution of the successive Tertiary shelf margins that were responsible for creating geopressured reservoirs. Understanding the nature of shale-tectonic and salt-tectonic structures will lead to a definition of those areas where structures allow large geopressured reservoirs to be developed.

In 1982, two areas along the Frio growth fault trend, in the Corpus Christi and Port Arthur areas, were studied by subsurface geologic and seismic interpretive techniques. Together with the Blessing and Pleasant Bayou areas described in the 1981 BEG Annual Report and the McAllen area studied under the companion salinity project, a

comprehensive description of the nature and history of upper Oligocene structural activity has been assembled. Further work will concentrate on the Wilcox and other lesser geopressured trends and on quantification of significant parameters, such as fault-block size and geometry.

EXPLORATION AND PRODUCTION PROGRAM FOR LOCATING AND PRODUCING PROSPECTIVE AQUIFERS CONTAINING SOLUTION GAS AND FREE GAS—TEXAS GULF COAST

A. R. Gregory, Project Director; Zsay-Shing Lin, Ronee S. Reed, Thomas E. Ewing, and Robert A. Morton; assisted by Yueming Chen, Kwan Y. Lau, Wahiduzzaman Mirza, Victor Lombeida, Srikanta Mishra, and Richard G. Anderson

The objective of this project was to locate and evaluate a prospective watered-out gas reservoir that would be suitable for application of enhanced gas recovery (EGR) methods. Normally, gas reservoirs that water out under moderate to strong water drives are abandoned when the expenses associated with salt-water disposal make continued operations uneconomical. Under favorable conditions, however, watered-out reservoirs can continue to produce substantial quantities of gas at competitive prices.

The EGR method, which permits continued operations, involves the co-production of gas and water. Large volumes of water are produced to reduce reservoir pressure. The lower pressure causes expansion of free gas that was trapped in the water-invaded zone during the primary production period. Part of this free gas is mobilized and becomes producible. The economic evaluation of this producible gas is an important part of the project.

The first phase of the project, completed in 1981, consisted of establishing guidelines for screening and selecting a favorable prospect. The Port Arthur field, Jefferson County, Texas, was selected from over 150 gas fields that were screened. This field contains multiple watered-out gas sandstones, multiple thick aquifers, and gas stringer sandstones in the lower Hackberry (Frio) sandstone interval at depths of 10,850 to 11,700 ft. The field covers about 1,900 acres (3 mi^2) and originally produced gas condensate from an anticlinal closure on the downthrown side of a major fault. The fault separates the Port Arthur field from the Port Acres field lying to the west. Some of the lower Hackberry reservoirs are laterally extensive and have excellent reservoir characteristics. The average net-sandstone thickness is 350 ft. Core data and well log analyses show that porosities average 30 percent, and permeabilities average 60 md. Initial pressure gradients in the C reservoir average 0.76 psi/ft but fall to an average of 0.58 psi/ft at abandonment pressure. Salinities average 83,000 ppm NaCl, and the average methane solubility is 24 scf/bbl. Abundant shallow Miocene sands in the area are available for salt-water disposal.

In 1982, a detailed study of the Port Arthur field was made using various methods that are broadly classified as geological, reservoir engineering, geophysical, well log analysis, and economic analysis.

Available well logs were analyzed to determine formation characteristics of seven reservoir sandstones. Water saturations were calculated to help locate gas-water contacts. Hydrocarbon pore volume maps were prepared after evaluating reservoir porosity, gas sandstone thickness, and gas saturation. Comparison of the hydrocarbon pore volume maps with structure maps indicates that the gas accumulations are not controlled by structure alone but are influenced by other factors such as stratigraphy, sandstone quality (pore size), or both.

More than 31 mi of seismic data were acquired and reprocessed in an effort to (1) provide structural information to supplement geological interpretations, (2) locate boundaries of gas reservoirs and aquifers, and (3) evaluate seismic response to low saturations of free gas dispersed in water-invaded zones of watered-out gas reservoirs. Attainment of these objectives was severely limited by the very poor signal-to-noise ratio in the seismic data. The quality of data was adequate for structural interpretation but was not suitable for reservoir delineation or detection of gas zones. Modeling studies were done to show what kind of seismic response should be expected from known subsurface geology. The results were instructive in showing the possibilities of better reservoir delineation with increased bandwidth, improved signal-to-noise ratio, and a better knowledge of reservoir acoustic impedances. A basic question posed at the beginning of this study, whether dispersed free gas in a watered-out gas reservoir can be detected in seismic data, remains unanswered.

A computer reservoir simulation study was made of the C reservoir interval, located at an average depth of 11,132 ft; a three-dimensional two-phase model was used. History matches were performed, and a 10-yr shut-in period (1973 to 1982) was modeled, followed by an 8-yr production period from 1983 to 1990. Predicted production under natural flow conditions was 5.1 Bcf of gas, 51,000 bbl of condensate, and 8,940,000 bbl of water. Reservoir bottom-hole flowing pressure would decline from 6,632 to 4,309 psi during the production period. The gas flow rates would vary from 3,000 to 100 Mcf/d. The original gas in place (OGIP) was estimated to be 56.2 Bcf; 35 percent of the OGIP was recovered by primary production, and 14 percent of the gas remaining in the reservoir was the predicted recovery using the EGR co-production method. This prediction was made for a single well drilled to a depth of 11,650 ft and located on a site near the Meredith No. 2 Doornbos well.

Economic cash flow calculations show that the break-even gas price is $2.40/Mcf for a 15-percent rate of return after Federal income tax is paid. The net present worth of the investment is about $968,000 for a gas price of $3.00/Mcf and increases rapidly as gas prices rise. It is probable that production from the C reservoir will be commingled with production from other reservoirs in the field. If this occurs, the economic outlook for the prospect should be even better.

CONTINUITY OF GEOPRESSURED RESERVOIRS

Robert A. Morton, Project Director; Noel Tyler and Thomas E. Ewing; assisted by Ralph L. Kugler and Richard Farrand

Reservoir volumes and energy drives associated with Gulf Coast geopressured sandstones are being studied in

conjunction with the assessment of geopressured geothermal energy resources. This study, funded by the U.S. Department of Energy, investigated (1) the lateral and vertical distribution of porosity and permeability in both modern and ancient Gulf Coast sandstones and (2) the structural and stratigraphic hierarchy that limits the extent of the reservoir.

During 1982, measurements of porosity and permeability within several Frio reservoirs were assembled and plotted on electric log cross sections. The variations in pore properties shown on these sections are being evaluated in terms of the associated sedimentary facies interpreted from the log patterns and the general depositional setting established by regional geologic studies. Work planned for the future includes integration of core descriptions, core analyses, and log patterns to determine the inhomogeneities and potential barriers to flow in selected sandstone reservoirs.

RESOURCE EVALUATION OF LATE OLIGOCENE THROUGH MIOCENE MAJOR STRATIGRAPHIC UNITS, TEXAS GULF COAST BASIN

Jules R. DuBar, Project Director; assisted by Elizabeth M. Andrews

Work on the Frio (Oligocene) part of this project, funded in part by the U.S. Geological Survey, has been completed, and a Report of Investigations has been published (RI 122).

Objectives of the Miocene phase of the study are compilation of a geologic data base necessary for resource assessment of the productive Miocene major stratigraphic units; integration of the geologic framework analysis, historical indices of finding rate, and reservoir/source facies volumetrics as a basis for definition and quantitative resource evaluation of exploration production plays; and assessment of the potential undiscovered hydrocarbons within the Miocene major stratigraphic units.

During 1982, regional correlation of the subsurface Miocene section was essentially completed; facies-complex delineation and characterization is now in progress. A Pliocene-Miocene outcrop map was prepared, and preliminary correlations were made between surface and downdip subsurface units. Cuttings from selected coastal wells are being examined to help establish the Pliocene-Miocene contact and to facilitate correlation between onshore and offshore Miocene sections.

Data gathering necessary to compile net-sand, percent-sand, and isopach maps is in progress.

PREDICTING RESERVOIR QUALITY AND DIAGENETIC HISTORY IN THE FRIO FORMATION, TEXAS GULF COAST

W. R. Kaiser, Project Director; Robert J. Finley; assisted by James F. O'Connell, Susan L. Hallam, and Stephen W. Speer

This project, funded in part by the U.S. Department of Energy, is part of a larger program to evaluate geopressured geothermal resources in Texas. Solution-mineral equilibria are being used to analyze diagenesis in the Frio and to understand better the nature of the high-resistivity shale or cap rock that occurs near the top of the geopressured interval.

The role of brine chemistry in diagenesis is poorly understood and heretofore has not been an integral part of diagenetic studies. The objective is to relate water-rock interaction to sandstone diagenesis using equilibrium thermodynamics or solution-mineral equilibria by thermodynamically testing the relative stability of authigenic and detrital minerals with respect to formation waters. The use of solution-mineral equilibria as a predictor of reservoir quality was evaluated by thermodynamically comparing waters from regions with good and poor reservoir quality, the upper and lower Texas coast (South Texas), respectively. Comparison among waters from these regions was made on activity diagrams for 16 diagenetic reactions. Relative position of tested waters with respect to the stability field of authigenic minerals occluding permeability and porosity was used to predict reservoir quality. A total of 138 waters from 51 Frio oil and gas fields were thermodynamically tested, 102 from the geopressured interval (>0.465 psi/ft pore pressure gradient) and 36 from the hydropressured interval.

Carbonate equilibrium, chloritization, kaolinitization, cation exchange, and albitization reactions were written to test for relative mineral stability in Frio Formation waters. Almost all South Texas waters under subsurface conditions fall in the ferroan calcite stability field, that is, into the field of the mineral mainly responsible for occluding permeability and secondary porosity in South Texas. Chlorite is also an important inhibitor of reservoir quality in the deep Frio of South Texas. Higher temperature, pH, Mg^{2+} and Fe^{2+} activity, and volcanic-rich detritus promote chlorite formation in South Texas. As temperature and pressure increase, chlorite is stable relative to illite in most Frio waters; thus, chlorite is the layer silicate ultimately stable in deep Frio sandstones. Solution-mineral equilibria in hydropressured waters best reflect reservoir quality. Activity indices favoring chlorite and ferroan calcite stability and large log $[Ca^{2+}]^{-16}/[Na^{+}]^{-33}$ ratios are the best indicators of reservoir quality in deep Frio sandstones.

A correlation of uncertain geochemical significance exists between ionic strength (I), analytical molality, activity indices, and geopressuring. In geopressured waters, I uniformly increases with depth to approximately 14,000 ft (4,270 m), then apparently begins to decrease. Several mole ratios were plotted against depth to investigate the relation of molality to geopressuring. Variation in many of these ratios is largest between 8,000 and 11,000 ft (2,440 and 3,355 m), the transition zone between the hydropressured and geopressured intervals. The variation observed is attributed to more active water-rock interaction or diagenesis in the transition zone. Mineral transformations were correlated with geopressuring by plotting activity indices, derived from the diagenetic reaction pairs, against depth. Variation is largest in the transition zone and less in distinctly hydropressured or geopressured waters, suggesting again that most of the diagenesis occurs in the transition zone.

Solution-mineral equilibria were used to sharpen our perception of carbonate equilibrium, relative mineral stabilities, and timing of diagenetic events. Because pH generally decreases with depth in compactional and thermobaric waters, calcite precipitation should be expected early in diagenesis. Two stages of chlorite

formation are postulated, one early in the hydropressured interval at the expense of montmorillonite clay coats and another late in the geopressured interval at the expense of kaolinite. Albitization of feldspar is initiated in the hydropressured interval at less than 100°C.

The presence of cap rock has been linked to diagenesis and proposed as a potential indicator of deep secondary porosity; cap rock has been attributed to leaching of authigenic calcite (porosity enhancement) from underlying sandstones in the geopressured interval, upward migration of solutes, and subsequent reprecipitation of calcite at the top of geopressure. Analysis of sidewall cores and whole-core samples from the Frio Formation in Kenedy County, Texas, where cap rock is exceptionally well developed, did not show enrichment of calcite or total carbonate in the cap-rock interval. Instead, slight enrichment in total silica in cap rock was found, suggesting that release of silica during clay-mineral transformations such as smectite = illite and smectite = chlorite may be responsible for cap-rock development, where the latter reaction releases more silica than the former. Regionally, the abundance of chlorite is correlated with exceptional cap-rock development. Plots of smectite/illite content versus depth for wells analyzed as part of other geopressured-geothermal resource investigations show that cap-rock development closely coincides with the depth of the smectite-illite transformation. Activity index versus depth plots also indicate that clay-mineral transformation is favored at the top of geopressure. It is therefore concluded that high-resistivity cap-rock shale is not the result of precipitation of authigenic calcite and that the occurrence of cap rock is neither an indicator of superior reservoir quality at depth nor the result of calcite leaching.

An annual report summarizing these research results has been submitted to the U.S. Department of Energy. A Bureau Report of Investigations is planned to include, in addition, water analyses, salinity variations, and thermodynamic data.

GEOTHERMAL RESOURCE ASSESSMENT FOR THE STATE OF TEXAS

C. M. Woodruff, Jr., Project Director; Christine Gever and G. L. Macpherson; assisted by Edward A. Duncan, Laura Caprio Dwyer, Fred R. Snyder, and David R. Wuerch

This final phase of research on geothermal resources in Texas sponsored by the U.S. Department of Energy involves four tasks: completing a nontechnical map of statewide geothermal resources, continuing water temperature collection and compilation, producing a new statewide map showing geothermal gradients, and refining lithic and hydrologic data along the Balcones/Ouachita trend in Central Texas.

The public-oriented user map, to be published at a scale of 1:1,000,000 by the National Oceanic and Atmospheric Administration, shows the generalized extent of geothermal aquifers that have been recognized to date in Texas. The map also includes locations and tabular data for selected wells that have representative temperatures and water-quality attributes of the various aquifers. Publication of the map is expected in early 1983, and it will be distributed free of charge by the Bureau of Economic Geology.

The program of water temperature collection in the field is largely finished, although we continue to compile any newly acquired data. Some field work is still being done, however, to check questionable points. As these temperature data are acquired, the information is maintained in a computer file at the Bureau of Economic Geology. A magnetic tape containing selected data is also transferred to the U.S. Geological Survey, Menlo Park, California, where the information is incorporated into the USGS GEOTHERM file.

The new statewide depiction of geothermal gradients is a refinement of previous efforts to show areal changes in earth temperature conditions at depth. A major problem with existing maps showing geothermal gradient is their failure to distinguish areas of abrupt changes in thermal conductivity owing to different rock type. Since thermal conductivity is an inverse function of geothermal gradient, this failure may result in misleading interpretations. We have attempted to correct this by choosing a few rock units of consistent lithic properties (whenever possible, a limestone) and mapping geothermal gradients only for wells with a bottom-hole temperature in these specific horizons. This is being done for the Ellenburger Group west of the Balcones/Ouachita trend and for the Sligo/Pettet and Edwards Formations for part of the State east of this trend.

Geologic and hydrologic assessments are continuing along the Balcones/Ouachita trend in Central Texas because this region has the highest potential for economic use of low-temperature geothermal waters. Research indicates that four Cretaceous aquifers contain thermal waters along this trend. The geothermal well and a heat-exchange system are now operating at the Torbett-Hutchings-Smith Memorial Hospital at Marlin, where the basal Cretaceous Hosston Sand produces thermal water.

Ongoing work includes a new depiction of key subsurface structural horizons for the Central Texas region and comparisons of these structural data to geothermal gradients, measured temperatures of ground water, lineaments, and water quality trends. Our findings to date indicate that there is not anomalous heat flow along this trend, but instead, warm waters and anomalous geothermal gradients result from the upwelling of deep basinal fluids. Further work, however, is needed to substantiate this. The final phase of this project extends into 1983.

GEOLOGIC SETTING AND GEOCHEMISTRY OF THERMAL WATERS, HUECO TANKS AND PRESIDIO BOLSON AREAS, TRANS-PECOS TEXAS

Christopher D. Henry, Project Director

The Bureau has largely completed the geologic and hydrologic evaluations that compose this study. A report describing the geologic setting and geochemistry was published in 1981 (Geological Circular 81-1). At the request of the Texas Energy and Natural Resources Advisory Council, the Bureau continues to review the progress of geophysical studies of Trans-Pecos Texas geothermal resources done at The University of Texas at El Paso. The review consists of evaluating the results of thermal gradient studies, providing information about geology in study areas, and making recommendations for future research.

LAND AND ENVIRONMENTAL RESOURCES INVESTIGATIONS

ENVIRONMENTAL MONITORING—GEOPRESSURED GEOTHERMAL TEST WELL, BRAZORIA COUNTY

Thomas C. Gustavson, Project Director

The Bureau of Economic Geology, under contract to the U.S. Department of Energy, has undertaken management and coordination of environmental monitoring at the Brazoria County, Texas, geopressured geothermal test-well site. Effects on local ecosystem quality from the accidental release of geothermal brines and from the possible initiation of land-surface subsidence as a result of withdrawal of large volumes of geothermal fluids are the primary concerns of this project.

Baseline environmental studies include repeated analysis of air and water quality, a microseismicity survey, a first-order leveling survey, a liquid tilt-meter survey, an archeological resources survey, and a noise survey.

Microseismic monitoring near Pleasant Bayou No. 1 and No. 2 wells shows evidence of naturally occurring seismic activity of extremely small values within 4 km of the test-well site. Seismic activity of the same magnitude and distance from the test-well site, but which may have been induced by disposal of geothermal fluids or by other commercial-waste-fluid disposal in the vicinity, was also observed.

Air quality at the Pleasant Bayou test-well sites was monitored for particulates, methane, hydrogen sulfide, and sulfur oxide; results show that air from the test-well sites does not exceed national ambient air-quality standards for particulates or sulfur oxides.

Water chemistry of Chocolate Bayou, which is adjacent to the test well, is highly variable because mixing with marine waters of West Bay occurs in this part of the bayou. Water quality has not been affected by drilling and testing of the well.

Air- and water-quality studies and a long baseline tilt-meter survey were completed in 1981. Microseismic monitoring will continue through FY83.

SOUTHWEST TEXAS RIVER BASINS REGIONAL STUDY

E. G. Wermund and Thomas C. Gustavson, Project Directors; cartography by Richard L. Dillon and David Ridner

This long-term project is a comprehensive environmental geologic analysis of 30,558 mi² of the Nueces, San Antonio, Guadalupe, and Lavaca river basins of South Texas. The project was initiated in June 1972 under a contract with the Texas Water Development Board (now Texas Department of Water Resources). That contract continued through August 1975; thereafter, the Bureau of Economic Geology supported completion of all remaining work.

Results of this program include a series of maps, which were hand-colored on scribed plastic base maps. The bases are reproductions of the standard Army Map Service topographic maps (scale 1:250,000). The hand-colored series includes maps of (1) environmental geology, (2) physical properties, (3) active processes, (4) biologic assemblages, and (5) land use. Environmental geologic maps are compiled at a scale of 1:125,000; all other map types are presented at a scale of 1:250,000.

Maps of environmental geology and land use represent original mapping. The biologic assemblage map is also essentially original mapping because the biologic assemblages were identified in the field, and their boundaries were located in general conformity to environmental geologic boundaries. Maps of active processes and physical properties were directly derived from the environmental geologic map.

Environmental geologic units were mapped initially on standard topographic sheets (scale 1:24,000) or on black-and-white, controlled aerial photographic mosaics. Land use was interpreted from 1973 color-infrared aerial photographs (scale 1:120,000).

All the hand-colored maps prepared during the project are currently available for examination. Topographic maps (scale 1:24,000) and controlled photographic mosaics showing original compilation, which are on file at the Bureau of Economic Geology, are also available for study.

Over the next several years, the maps will be published in varied combinations of two or more colors at a scale of 1:250,000. Maps of the Seguin West and San Antonio East 1° Quadrangles are nearly completed for publication. A text, which explains the regional setting and methodology, is in preparation.

EVALUATION OF THE BASIN AND RANGE PROVINCE FOR THE SUITABILITY OF GEOLOGIC AND HYDROLOGIC ENVIRONMENTS FOR ISOLATION OF HIGH-LEVEL RADIOACTIVE WASTES

Christopher D. Henry, Project Director; assisted by Gail L. Fisher and Joseph P. Ash

In cooperation with the U.S. Geological Survey and states of the Basin and Range Province, the Bureau is doing a regional screening of the Basin and Range for possible waste isolation sites. The ultimate intent of the U.S. Geological Survey is to do a province-by-province study of the entire United States. The Basin and Range was chosen as a test area, not only to evaluate the province itself but also to develop methods of regional screening that could be used in other provinces. This project has focused on characterization of the geology and hydrology, including identification of or compilation of information on (1) surface distribution of potential host rocks as a first step to delineating their subsurface distribution, (2) ground-water flow systems and related hydrologic data, (3) tectonic conditions including Quaternary faults and volcanic centers and historic distribution of seismic activity, (4) distribution of natural resources, and (5) surficial processes and rates of erosion. A series of reports and maps of the foregoing characteristics, generated by the Bureau and by the U.S. Geological Survey, are being published by the USGS.

MINERAL RESOURCES INVESTIGATIONS

MINERAL PRODUCERS LIST

Mary W. McBride, Project Director; assisted by Audie L. Dobbs, Charles Johnson, and Jane Tingley

The Mineral Producers List, a computer-generated list of nonpetroleum mineral producers in Texas, is being revised and updated. The new list will be available in two forms: a printed booklet and a computer printout.

The booklet will contain three sections: an alphabetical list of companies with active production and their addresses and phone numbers; an alphabetical list of all actively produced commodities and the producing companies with county of operation; and an alphabetical list of counties showing the commodities produced and the companies operating within each county.

The new computer printout will be similar in format to our current offering, but it will contain brief remarks on the geology of many of the mines and will cite Bureau publications about the area. The printout will list over 2,100 sites and will include mines that produced in the past and sites of substantiated mineral occurrences as well as actively produced sites.

The revised Mineral Producers List is now undergoing final proofreading, and the new computer programs should be written in early 1983.

MINERALIZATION IN TRANS-PECOS TEXAS: ORE DEPOSITS IN CLASTIC SEDIMENTARY ROCKS

Jonathan G. Price, Project Director; Arthur G. Goldstein, Jan S. Posey, and Christopher D. Henry, geologists; Clara L. Ho, Steven W. Tweedy, Dorothy L. Gower, and Paul N. Williams, chemists; assisted by Allan R. Standen

Research on the origin of silver-copper-lead deposits in Trans-Pecos clastic rocks is continuing through funding from the Texas Mining and Mineral Resources Research Institute. Detailed mapping and structural measurements have indicated similar structural controls for deposits occurring within red-bed sequences of Precambrian, Permian, and Cretaceous age. Ores were probably deposited during Miocene or younger Basin and Range deformation, rather than during Oligocene igneous activity. Aspects of the geochemistry, mineralogy, structure, and origin of ores in Permian sandstones at the Plata Verde Mine were published in 1982 in Bureau of Economic Geology Mineral Resource Circular No. 70. Current research is focusing on the deposits in Precambrian sandstones and coarse siltstones and on those in Cretaceous conglomerates and sandstones.

MINERALIZATION IN TRANS-PECOS TEXAS: BASE AND PRECIOUS METALS IN VOLCANIC CENTERS

Christopher D. Henry, Project Director; Jonathan G. Price; assisted by Gail L. Fisher, Allan R. Standen, and Emil Bramson

This continuing project, funded by the Texas Mining and Mineral Resources Research Institute, is examining the relation among hydrothermal alteration, ore deposition, and Tertiary igneous activity. Ore deposits are associated with calderas in Trans-Pecos Texas and with individual intrusive centers. The study involves (1) detailed mapping of selected calderas and intrusions to determine their geology and the relations of ore deposition and hydrothermal alteration of the geology, (2) examination of known mineral occurrences to determine their origin, (3) geochemical analysis to determine which igneous centers are most favorable for ore deposits of particular elements, and (4) K-Ar dating to determine the relative timing of igneous activity and ore deposition. Work to date has focused on the Chinati Mountains and Infiernito calderas and mineralization associated with them, including Red Hill (Cu-Mo), West Chinati stock (Ag-Pb-Zn-Cu), and Ojo Bonito (Ag-Mo), Cave Peak and Marble Canyon stock (Mo), and the Bonanza Mine (Ag-Pb-Zn). Publications in press include a report on the geology of the Chinati Mountains caldera, an annotated compilation of all known mines and prospects in Trans-Pecos Texas, and a report on the geology of the Van Horn Mountains caldera. In addition, several abstracts have been published on the geology of some of the ore deposits.

IN SITU URANIUM LEACHING, GEOLOGICAL ASPECTS

Jonathan G. Price, Project Director; Patricia Bobeck, The University of Texas at Austin, Department of Geological Sciences

Geological, geochemical, and mineralogical aspects of research on in situ uranium leaching are being investigated in conjunction with the Department of Petroleum Engineering, The University of Texas at Austin. Samples of unleached cores and altered, leached cores from a South Texas uranium deposit in the Miocene Oakville Formation are being studied for mineralogical and geochemical changes resulting from bench-scale leaching experiments. Marcasite is clearly an important phase in controlling pH and Eh during leaching of this ore. Examination of electric logs from an in situ uranium mine in the Eocene Jackson Group of South Texas revealed that directions of problematic channelization of fluids during pilot tests are sedimentologically controlled.

BASIN STUDIES

GEOLOGIC AND GEOHYDROLOGIC INVESTIGATIONS IN THE TEXAS PANHANDLE

L. F. Brown, Jr., Project Director; T. C. Gustavson and C. W. Kreitler, Principal Investigators; Gilbert Arismendez, Randy L. Bassett, Robert W. Baumgardner, Jr., Ronald P. Brock, Roy T. Budnik, S. Christopher Caran, Edward W. Collins, Joseph A. Collins, Robert D. Conti, E. Dow Davidson, George A. Donaldson, James A. Doss, Jr., Alan R. Dutton,

Shirley P. Dutton, R. Stephen Fisher, Graham E. Fogg, Michael A. Fracasso, Steven A. Frishman, James K. Gluck, Arthur G. Goldstein, Thomas C. Greimel, Margaret J. Herron, Susan D. Hovorka, David A. Johns, Allan Kolker, Long-Cheng Liang, Marcie D. Machenberg, Douglas A. McGookey, Joseph H. McGowen, Mary K. McGowen, Francis W. O'Loughlin, Elizabeth D. Orr, Daniel H. Ortuño, Richard W. Ozment, Karen K. Ramming, Paul G. Randall, Douglas C. Ratcliff, Stephen C. Ruppel, William W. Simpkins, Dale A. Smith, D. Anderson Smith, Clarence C. Talley, Jr., Sterling F. Thomas, E. G. Wermund, Jr., and Prakob Wirojanagud; assisted by David G. Becker, Paul E. Blanchard, Patricia L. Brock, Jenny E. Burgen, David L. Carr, Pilar Castañeda, Ming Huen Chan, Wendy L. D'Attilio, Richard F. Davis, Rebecca A. Fountain, Debbie D. Fowler, Nancy E. Frank, Jaime Grana, Rosemary Guajardo, David D. Guetzow, Anne K. Harris, Virginia W. Henderson, John J. Hendler, Karen L. Herrington, Dana L. Hershberger, Patricia Hester, Richard D. Hunter, Cecil W. Irby, Jr., James K. Koga, Therese M. Lemmer, Stephen E. Lovell, Maria E. Lucas, Barbara A. Luneau, Maria M. Madiedo, Ronald G. McMurry, Kathleen R. Minahan, Greg G. Moore, Patricia M. Moseley, R. Matthew Myers, Paul R. H. Neville, David C. Noe, Wilbert I. Odem, Moduabuchuku C. Oluka, Kimberley A. Owens, Loren F. Phillips, Vicki J. P. Prestwood, Bruce A. Pridgen, David N. Purgason, Maria B. Ramsey, Bernd C. Richter, Frances E. Russell, Melissa A. Sandstrom, Rainer K. Senger, James R. Smits, Krishnamurthy Subramanian, Michael B. Tenbrook, Stephen C. Thomas, Jeffrey E. Thurwachter, Bright A. Tom-Quinn, Amy Wanamaker, Kelly O. Webb, Madison T. Woodward III, and John N. Wright

Since 1977, the Bureau of Economic Geology has conducted extensive geologic and hydrologic research in the Texas Panhandle, chiefly in the Palo Duro Basin. These research projects are being conducted under University contract with the U.S. Department of Energy as a part of the Department's nationwide investigation of potential nuclear waste repositories. Bureau research efforts are coordinated with the Texas Energy and Natural Resources Advisory Council, and results of research projects are made available to the public through Bureau publications.

The early program evolved through the following three phases: (1) 6 months of preliminary data collection and initiation of basic research tasks (late FY77); (2) 1 yr of intensive research to produce a basic stratigraphic/structural/facies framework for the basins and to initiate ongoing studies of surficial and near-surface processes that affect erosion, denudation, and salt solution (FY78); and (3) 1 yr of research aimed at initial analysis of deep cores, initiation of basin resource studies, calibration of subsurface logs (using cores), discrimination of general depth/salt/thickness fairways, initiation of deep-basin hydrologic studies, and continuation of surface and near-surface analyses of erosion, denudation, and salt solution rates (FY79).

Studies initiated in FY80 involved more specific discrimination and determination of salt character, natural resources potential, hydrologic integrity, host-rock properties, and surface and near-surface process rates, among others. The program in FY80 also passed into a more discriminating, intensified stage of evaluating priority items recognized during the earlier framework studies. The FY81 program was designed to continue to address dynamic aspects of salt dissolution, deep-basin fluid circulation/movement, and shallow aquifer hydrodynamics/hydrochemistry, as well as integration of these factors within the three-dimensional facies framework and resource potential of the basin. In addition, analyses of structural deformation, tectonic environment, and regional gravity anomalies were initiated.

The fifth year of investigation (FY82) was highlighted by analyses of faults, fault history, joint distribution, structural influences of Permian sedimentation, core, deep-basin hydrology, terrace stratigraphy, lineaments, and spring discharge. Reviews of natural resource production and Quaternary paleoclimatology were also completed. Important results of FY82 studies are summarized in the following.

Faults in and bounding the Palo Duro Basin were primarily active in Paleozoic time; however, post-Late Permian faulting displaced the Permian Clear Fork Formation 200 m (650 ft) in Oldham County, and the Triassic Dockum Group was downfaulted against Permian strata in Potter County. Additional minor post-Paleozoic faulting resulted from salt dissolution and collapse along fault zones. Detailed analyses of selected fault blocks within the basin indicate that fault movement began in the Ordovician, was most pronounced during the Early Pennsylvanian, and continued to influence sedimentation through the Late Pennsylvanian and Permian.

Zones of high fracture density have been recognized along the eastern Caprock Escarpment. That these zones of high fracture density have acted as preferred pathways for ground-water movement is indicated by the parallel orientations of fracture zones and orientations of long axes of dissolution-collapse basins.

Maps of structural and thickness variations in Mississippian and Ordovician strata have revealed that faults are common in the Palo Duro Basin. Mississippian strata are primarily carbonates and reflect predominantly shallow platform depositional environments. Lower Ordovician dolomites that underlie Mississippian strata were also deposited in shallow platform depositional environments.

Preliminary descriptions of core from the DOE Stone and Webster No. 1 Sawyer well (20 m to 1,464 m, 65 ft to 4,806 ft) have been completed. Highlights of the core analyses are recognition of collapse breccias resulting from dissolution of salt above the cycle 3 salt of the lower San Andres Formation, and high porosity in the cycle 4 dolomite of the lower San Andres Formation resulting from dissolution of salt contained in the dolomite.

Results of analyses of core and thin sections have confirmed that halite, gypsum, and anhydrite were deposited in brine pool environments and by displacive growth within sediments in the shallow subsurface. Early diagenetic modifications of both type of evaporites and associated limestone, dolomite, and terrigenous clastics include precipitation of halite cement in all porous zones, replacement of aragonite and gypsum with halite, dehydration of gypsum to anhydrite, and replacement of

halite by anhydrite and dolomite. Three separable dissolution events have been identified: syn-sedimentary dissolution in the halite precipitation environment, dissolution during major facies change at the top of cyclic salts, and post-Permian dissolution by ground waters. Low-salinity ground water penetrating into an evaporite section causes a sequence of alterations: recrystallization of halite, dissolution of halite and collapse of overlying beds, precipitation of gypsum cement, and hydration of anhydrite to gypsum. The resulting textures can be used to identify the former presence of anhydrite.

Results of continued studies of vitrinite reflectance of organic debris from cores and cuttings from the Palo Duro Basin suggest that strata within the basin are near their maximum temperature and depth of burial. Total organic carbon values from Wolfcampian shales from the DOE Stone and Webster No. 1 Sawyer well are more than 1.7 percent. Shales containing more than 0.5 percent TOC are generally considered potential hydrocarbon source beds. Several recent oil discoveries have been made in Pennsylvanian carbonates and granite wash of the Palo Duro Basin.

In addition to oil and gas, economic deposits of caliche, crushed stone, and sand and gravel are produced from the Texas Panhandle. Several other mineral resources have been identified, including clay, volcanic ash, gypsum, salt, and uranium, but none are being produced.

Estimates of permeability have been made from several stratigraphic units in the Palo Duro Basin from drill-stem tests, core analyses, and pumping tests. Measured permeability ranges from 0.04 to 1,600 md. Ranges of 1 to 10 md for Wolfcampian carbonates, 10 to 100 md for Pennsylvanian carbonates, 10 to 100 md for granite-wash facies, and 1 to 10 md for pre-Pennsylvanian carbonates are probably representative of average permeabilities in these deep-basin strata. An objective geostatistical method was used to map the potentiometric surface of the Wolfcampian aquifer. By using a geostatistical analysis of the hydraulic data (a two-dimensional spherical variogram) and kriging, an updated regional head map was prepared for the Wolfcampian aquifer.

Results of analysis of the regional ground-water flow system of the San Andres Formation indicate that the pattern of ground-water movement is controlled by recharge from the Pecos River on the west and by the distribution of evaporite facies. Chemical composition of San Andres water has evolved through solution of limestone and gypsum at shallow depths and through solution of halite by recharge of meteoric water around the perimeter of the Palo Duro Basin. A hybrid potentiometric map, based on a mixed data set of both original head values and kriged estimates, indicates that ground water in the San Andres Formation apparently moves from the northwest part of the area to the east and southeast across the Palo Duro Basin.

Analyses of spring water discharging from outcrops of the lateral equivalents of the upper San Andres and Seven Rivers Formations (Blaine and Whitehorse Formations) in the Rolling Plains have been completed. The Br/Cl ratios and the $\delta^{18}O + \delta^{2}H$ values of these saline waters indicate that they result from shallow meteoric ground water dissolving bedded Permian evaporites rather than from discharge of deep saline formation ground waters from beneath the evaporite section of the Palo Duro Basin.

A two-dimensional, east-west ground-water flow model simulating steady-state flow has been constructed for the basin.

Discharge rates of numerous springs along the eastern Caprock Escarpment and the Canadian Breaks of the Texas Panhandle have diminished markedly as a result of production of waters of the Ogallala aquifer for irrigation. Decreased spring discharge has reduced canyon development by slowing the rate of spring sapping and by reducing the rate of stream discharge in canyons and arroyos.

Lineament analyses have been completed for five representative drainage basins in the Texas Panhandle. For these basins, principal alignments are 310° to 320°, 0° to 10°, 30° to 40°, and 80° to 90°.

Results of analyses of terrace stratigraphy and radiocarbon dates indicate that terraces along the Little Red River were formed during a single, long-lived episode of downcutting that began less than 1,600 yr ago. Maximum rates of incision for this period of downcutting are 5.9 to 6.4 mm/yr (0.23 to 0.25 inches/yr).

A preliminary review of the literature pertaining to the Quaternary paleoclimatology of the Texas High Plains suggests an irregular, unstable climatic pattern characterized by episodic fluctuations of temperature and of both absolute and effective precipitation.

Studies in FY83 will continue to focus on salt character, natural resource potential, hydrologic integrity, host-rock properties, ground-water geochemistry, surface and near-surface process rates, tectonic environment, and basin seismicity.

GEOLOGIC AND GEOHYDROLOGIC INVESTIGATIONS IN THE EAST TEXAS BASIN

Charles W. Kreitler, Project Director; Steven J. Seni, Martin P. A. Jackson, H. Victor Wuerch, Edward W. Collins, Robert D. Conti, Shirley P. Dutton, Graham E. Fogg, and Debra H. Wood; assisted by Thomas M. Simmons, Steven M. Carlson, John Hultman, Jill O'Neal, Bernd C. Richter, and Rachel Burks

This research program, funded by the U.S. Department of Energy, investigated geologic and geohydrologic features critical to DOE's evaluation of the suitability of underground salt domes in the Gulf Coast Basin as possible sites for long-term isolation of nuclear wastes. Major considerations in this evaluation were the hydrologic and tectonic stability of the domes. To develop information related to these concerns, a Bureau research team began geologic, structural, stratigraphic, petrologic, and geochemical investigations of specific salt domes and also of the entire region in 1978. The resolution of these problems has provided approaches and solutions to questions concerning the suitability of any salt diapir being considered for long-term storage of chemical and nuclear wastes.

Hydrologic investigations included studies of ground-water flow around the domes in the shallow meteoric

aquifers and studies of ground-water flow in the deeper saline parts of the basin. These studies addressed the role of aquifer geochemistry in retarding potential nuclide migration away from a repository, the effect of permeability distribution on ground-water flow around domes, and the potential for upward leakage of saline waters from deeper aquifers. Results include the following:

A three-dimensional ground-water flow model was constructed for the Wilcox-Carrizo aquifer system near Oakwood Dome to elucidate the hydrogeology around salt domes of the Gulf-interior region and to evaluate the hydrologic suitability of Oakwood Dome for a high-level nuclear waste respository. The Wilcox is a multiple aquifer system, composed primarily of fluvial channel-fill sand bodies distributed complexly in a matrix of lower permeability interchannel sands and muds. Ground-water flow rates and directions are strongly influenced by the degree of interconnectedness between the channel-fill sands, which have predictable values of hydraulic conductivity. Lateral interconnectedness may depend largely on frequency distributions of channel-fill sands (that is, sand thickness-percent). Vertical interconnectedness is apparently poor, owing to the horizontally stratified sand/mud fabric. Because Oakwood Dome is surrounded by interchannel facies as a result of syndepositional dome growth, the dome may be essentially isolated from circulating Wilcox ground water. A possible exception is where channel-fill facies appear to touch or to be near the northeast flank, coinciding with a brackish-water plume that apparently results from salt or cap-rock dissolution. The northeast orientation of the plume seems to be caused by sand-body distribution and interconnection.

Water chemistry from the deep saline aquifers suggests that the brines result from salt dissolution. Salinity distribution in the Woodbine aquifer, however, does not show consistent increases of salinity near the domes. Dissolution of the domes in the deep aquifers may not be occurring.

Studies of cap rock and salt cores are nearing completion. Study of a single, non-oriented core from Oakwood Dome has revealed the presence of large, overturned, inclined folds within the salt stock together with major structural truncation by dissolution. Three-dimensional strain analysis and microstructural studies of halite indicate a complex interplay of dissolution, recrystallization, and flattening and constrictive strains induced by diapiric flow. These studies indicate that despite repeated dissolution of rock salt in the dome crest, the salt has closed and sealed dissolution cavities and extension fractures. The absolute timing of these events is unknown, but most of the Oakwood cap rock appears to have formed in the Cretaceous.

Strain analysis of the anhydrite cap rock indicates the existence of low strains induced by both vertical pure shear and lateral simple shear, probably caused by rise of the salt stock. These low strains suggest that either the anhydrite cap rock was strong enough to resist diapiric growth forces, or that it has largely recovered from strain by recrystallization. Both conclusions are favorable to the isolation of nuclear wastes in salt stocks.

Tectonic and stratigraphic studies were integrated to produce a comprehensive model of basin evolution from the time of initial formation in the Triassic to cessation of basin filling and the onset of regional erosion in the early Tertiary.

The East Texas Basin formed on thinned continental crust during breakup of Pangea and the opening of the Gulf of Mexico. It began as a simple graben in an extensional regime or a rhomb graben in a right-lateral shear regime.

The basin comprises four symmetrical provinces, each defined by characteristic salt structures and controlled by different initial thicknesses of Louann salt. The central salt-diapir province, which approximates the original graben, is encircled by provinces containing intermediate-amplitude salt pillows, low-amplitude salt pillows, and a salt wedge. Much of the central basin is inferred to be free of salt between diapirs.

Above a threshold thickness of approximately 600 m of salt, salt was mobilized by (a) loading beneath a carbonate wedge, (b) differential loading by prograding deltas, and (c) basin-edge tilting and consequent erosional breaching of pillows.

Net and gross growth rates and strain rates for all the East Texas diapirs have been calculated by three different methods. Caution must be exercised in applying these long-term rates (1 to 17 million yr) to much shorter durations envisaged for the life of a nuclear-waste repository. Nevertheless, these results indicate an extremely low probability of significant future domal growth. For example, Bethel Dome, which had the fastest growth of all in the early Tertiary (60 m per million yr), is currently growing much less than 15 m per 250,000 yr with respect to surrounding sediments, insufficient to expose a repository to erosion.

Variations in thickness and facies of near-dome strata induced by salt flow have been documented and incorporated in a comprehensive model. This enables not only the reconstruction of domal growth histories but also the prediction of subtle stratigraphic and structural traps for hydrocarbons. Such traps are generated during the growth of salt pillows, salt diapirs, turtle-structure anticlines, and residual saddle-like highs far from the diapirs responsible for their formation.

Seismicity studies have been evaluating the Elkhart-Mount Enterprise fault zone to determine whether any potential earthquake activity exisits. Results indicate the following:

At least eight probable earthquakes and hundreds of events of undetermined origin were recorded during the period from June 1981 to August 1982. Three of the earthquakes were felt by people in East Texas, specifically, two earthquakes at Jacksonville and one near Center. Four of the events were recorded at a sufficient number of stations to be located instrumentally. Two others can be recognized as aftershocks of the Jacksonville event. Two other events seem to have been earthquakes but were neither felt nor recorded at more than one station.

Results of Bureau research have shown the East Texas interior salt domes to be relatively less suitable for nuclear waste isolation repositories than other domes. Current Bureau research is generic in nature and chiefly for application to salt domes outside Texas.

UPPER PENNSYLVANIAN - LOWER PERMIAN DEPOSITIONAL SYSTEMS, EASTERN SHELF, WEST TEXAS BASIN

L. Frank Brown, Jr., Project Director; assisted by David A. Johns and Margaret J. Herron

Drafting is nearly complete on 22 regional stratigraphic cross sections of the Eastern Shelf of the Midland Basin. The sections include the Virgil (Cisco) and Wolfcamp Series within about 25 counties in north and west-central Texas. Produced by L. F. Brown, Jr., Raul Solis, and many assistants, these sections will be published late in 1983. The sections represent the basic stratigraphic framework developed over the last 10 yr to support the preparation of regional isolith and paleogeographic maps.

Late in 1982, the first of 35 isolith and paleogeographic maps of the lithogenetic sequences composing the Virgil (Cisco) and Wolfcamp Series (Upper Pennsylvanian and Lower Permian) was completed. During 1983, cartographic preparation of the maps will continue, leading to a published set of maps in early 1984.

GULF COAST STRATIGRAPHIC NOMENCLATURE

Thomas E. Ewing, Project Director; Jan S. Posey

The goal of this project is to compile a user-oriented packet of charts and supplementary text to summarize Texas Gulf Coast stratigraphy. This packet will include Cenozoic and Mesozoic time scales, correlation charts, and a lexicon of stratigraphic terms with suggested use.

Stratigraphic nomenclature in the Gulf Coast area has been confused and inconsistent. Major difficulties have arisen, both because of mixing of biostratigraphic, chronostratigraphic, and lithostratigraphic usages and because of poor correlations of surface and subsurface data. Recent genetic stratigraphic studies at the Bureau and elsewhere have often used informal nomenclature. This project will attempt to harmonize genetic stratigraphic units and formal nomenclature within the guidelines of the *North American Code of Stratigraphic Nomenclature*.

COASTAL STUDIES

STATE SUBMERGED LANDS OF TEXAS—SEDIMENTS, GEOCHEMISTRY, BENTHIC MACROINVERTEBRATES, AND ASSOCIATED WETLANDS

William A. White, Project Coordinator; Thomas R. Calnan (Chief Biologist), Robert A. Morton, Russell S. Kimble, Thomas G. Littleton, and H. Seay Nance; assisted by James A. DiGiulio and Janice L. Smith; Clara L. Ho, Dorothy Gower, Cynthia A. Mahan, and Steven W. Tweedy (Chemists)

This comprehensive inventory of Texas coastal submerged lands and associated wetlands continued through 1982 with grants under the Coastal Zone Management Act of 1972, as amended, administered by the Office of Coastal Zone Management, National Oceanic and Atmospheric Administration, U.S. Department of Commerce, through the Governor's Budget and Planning Office of the State of Texas. Research has been conducted in cooperation with the Marine Geology Branch of the U.S. Geological Survey and has been funded in part by the General Land Office of Texas.

A major goal of the submerged lands project is to produce a comprehensive data base for State-owned lands. During 1982, efforts were directed toward completing the analytical phase and preparing the first of seven atlases that will be published for the Texas Coastal Zone 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 (from the Gulf shoreline seaward for 10.36 statute mi) and from the bay-estuary-lagoon system of the Texas coast. Also in 1982, efforts continued toward providing updated regional maps of wetlands to complement the submerged lands inventory. In addition, a seasonal monitoring program was initiated in September 1982 in Espiritu Santo and Lavaca Bays. Multiple benthic grabs of sediments are taken monthly from 14 selected bay stations for macroinvertebrate and textural analyses.

The first submerged lands atlas, scheduled for publication in early 1983, will be of the Corpus Christi area. Atlases will consist of a text and a series of 17 maps including (1) 4 maps (scale 1:250,000) depicting various aspects of sediment distribution, (2) 12 maps (scale 1:250,000) depicting concentrations and distribution of selected trace, minor, and major elements, and (3) 1 full-color map (scale 1:125,000) depicting the distribution of benthic macroinvertebrate assemblages and species diversity in submerged lands as well as the distribution of coastal wetlands and associated environments.

Sediment analyses, conducted by the Bureau's Sedimentology Laboratory, are now complete for all areas of the Texas coast. Cartographic preparation of sediment distribution maps of the Corpus Christi area is complete and the maps have been approved for printing. Preliminary hand-colored maps depict the distribution of sediments in the six remaining map areas. Textural analyses of samples collected on a monthly basis in Espiritu Santo and Lavaca Bays are now in progress.

Additional geochemical analysis of selected sediments was conducted during 1982 by the Mineral Studies Laboratory of the Bureau. Included were approximately 70 samples from Laguna Madre in the Kingsville area. These data will supplement the previously completed geochemical data base. Geochemical maps of the Corpus Christi area are ready for printing. Approximately 150 sediment samples from the bay-estuary-lagoon environments in the Port Lavaca and Bay City - Freeport areas were selected for geochemical analysis (in progress at the end of 1982) to provide a better understanding of the sediment and geochemical relations in these areas.

Sedimentological and geochemical properties are being entered into computer files for statistical analyses; these analyses have been completed for the Corpus Christi and Galveston-Houston map areas.

Live benthic macroinvertebrates were identified and counted for approximately 300 samples in the Port Lavaca area and for 125 samples in the Kingsville area. Biological analyses are now complete for all map areas except for some additional sample analyses in the Kingsville, Brownsville, Port Lavaca, and Bay City - Freeport areas. Data were processed by computer for cluster analyses and species diversity, and the results were presented on hand-colored maps of each area. In addition, analyses of all benthic samples taken from Espiritu Santo and Lavaca Bays during September, October, and November have been completed. Among the eventual products of the biological analyses will be full-color maps, scale 1:125,000, showing the distribution of invertebrate assemblages and species diversity. The full-color map for the Corpus Christi area has been completed and is scheduled for publication in 1983.

Delineation of wetlands continued in 1982. The objective is to produce updated regional full-color maps of wetlands distribution; units will be patterned after the Bureau's Environmental Geologic Atlas of the Texas Coastal Zone series. Photographic interpretation and delineation of wetlands are almost complete for four (Corpus Christi, Galveston-Houston, Brownsville-Harlingen, and Beaumont - Port Arthur) of the seven map areas. The Corpus Christi area map has been completed and is ready for printing.

HISTORICAL MONITORING OF TEXAS BAY SHORELINES

Robert A. Morton, Project Director; Jeffrey G. Paine; assisted by Diane Robinson

This short-term pilot project was funded in part by the Texas Energy and Natural Resources Advisory Council (1) to establish techniques for documenting shoreline changes around the Texas coastal bays and lagoons, and (2) to develop site-specific data for Corpus Christi, Nueces, and Oso Bays near Corpus Christi. Shoreline changes in these bays that occurred between the mid-1800's and 1982 were determined by comparing topographic maps and aerial photographs and measuring the distances between sequential shoreline positions. Field observations and surveys were also used to distinguish between changes caused by natural processes and those caused primarily by human activities.

GEOLOGIC MAPPING

GEOLOGIC ATLAS OF TEXAS

Virgil E. Barnes, Project Director; Tucker Hentz; cartography by Richard L. Dillon, Thomas M. Byrd, and Margaret L. Evans

A geologic map of Texas showing the distribution of outcropping rock units is being published as a series of separate map sheets. Each sheet is printed in full color on a topographic base at a scale of 1:250,000 (1 inch equals approximately 4 mi). Map sheets are confined primarily to areas within 1 degree of latitude and 2 degrees of longitude, but some sheets include larger or smaller areas owing to cartographic presentation. When completed, the *Geologic Atlas of Texas* will consist of 38 map sheets depicting all of Texas and parts of New Mexico and Oklahoma.

During the year, the Fort Stockton Sheet was published, bringing to 35 the number of sheets in print. Three more sheets remain to be completed. The Tucumcari and Dalhart Sheets are in press and are scheduled to be published early in 1983. Tucker Hentz is field-checking the Wichita Falls - Lawton Sheet, the final sheet of the atlas series.

Revision and reprinting of atlas sheets continues. The Houston Sheet was completely revised and reprinted during the year. Color separation has been completed for extensive revision of the San Antonio, Beaumont, and Beeville - Bay City Sheets and publication of these sheets is scheduled for early 1983. The Dallas, Abilene, and Van Horn - El Paso Sheets have been revised and the copy is with cartography. These sheets are scheduled for reprinting in mid-1983. The Sherman Sheet has been revised, except for Permian rocks in the western part of the sheet. Mapping of these rocks will be revised by Tucker Hentz in connection with his field checking of the Wichita Falls - Lawton Sheet. The Palestine Sheet has also been revised, except for the northeast quarter of the sheet, for which U.S. Geological Survey 7.5-minute topographic quadrangle maps will not be available until 1984.

GEOLOGIC MAP OF TEXAS

Virgil E. Barnes, Project Director

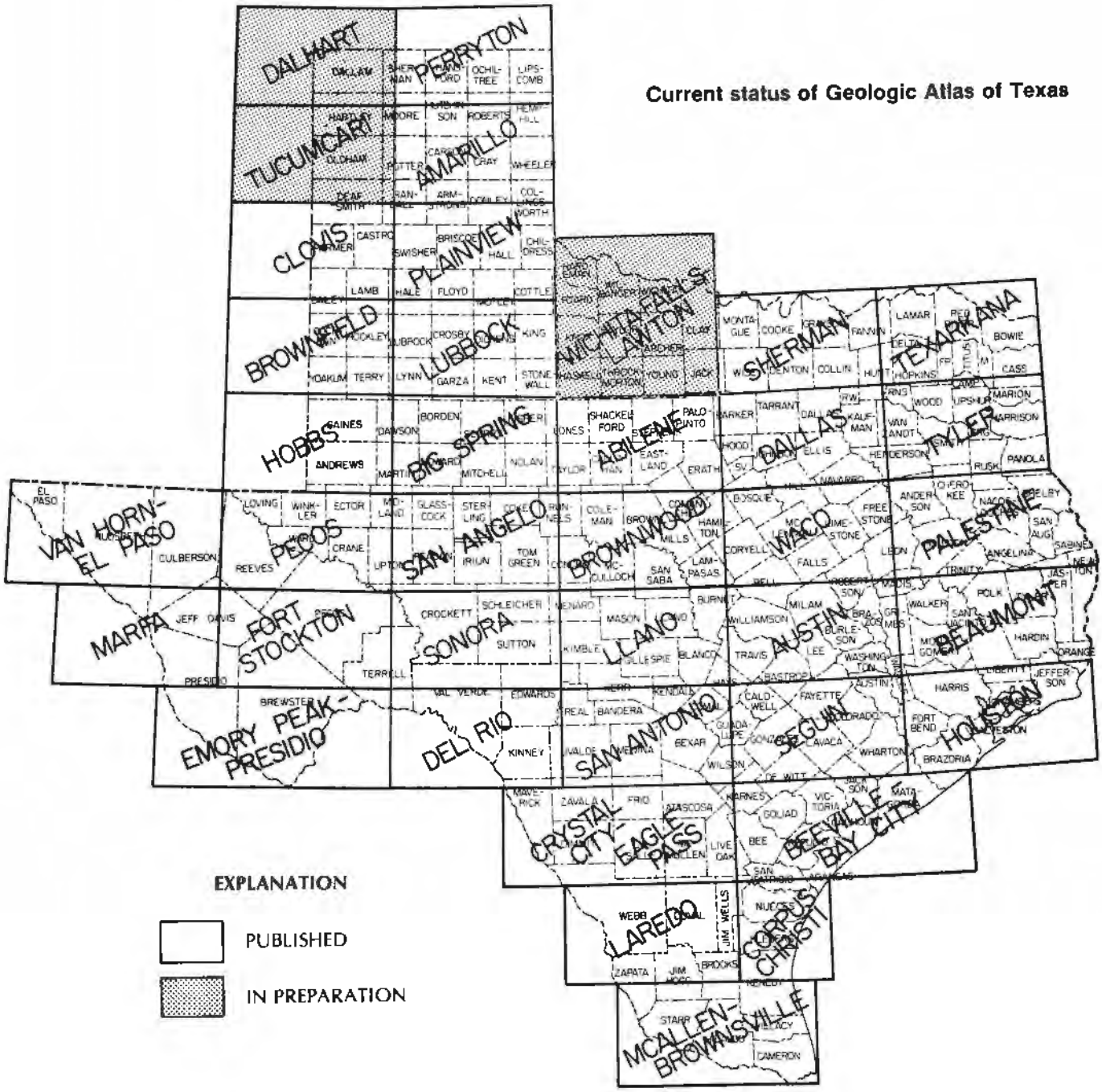
The preparation of a new geologic wall map of Texas began in May 1978. To be published in four quadrants at a scale smaller than 1:250,000, the new map will replace the 1937 U.S. Geological Survey *Geological Map of Texas*, which has been out of print for many years.

The new map is being derived from the *Geologic Atlas of Texas* map sheets (scale 1:250,000). A set of completed sheets of the *Geologic Atlas of Texas* has been marked for use in drafting the new map. Now that the Fort Stockton Sheet has been published, all except the northeastern quadrant of the State is ready for scribing. The date for scribing the northeast quadrant depends on the time of completion of the Wichita Falls - Lawton Sheet.

GEOLOGIC QUADRANGLE MAPPING IN CENTRAL TEXAS

Virgil E. Barnes, Project Director; Emilio Mutis-Duplat; cartography by Richard L. Dillon, Thomas M. Byrd, Margaret L. Evans, and David M. Ridner

Geologic mapping of 7.5-minute quadrangles in Central Texas was initiated in 1939 by Barnes to provide basic



geologic maps for use in economic, stratigraphic, structural, and geophysical investigation. All 37 of the geologic quadrangle maps have now been published. The final four maps of this series depict the geology of the Hammetts Crossing, Marble Falls, Pedernales Falls, and Spicewood Quadrangles.

In addition, the Purdy Hill Quadrangle in Mason County, mapped by Emilio Mutis-Duplat, was published. The field work for this map, done between 1968 and 1971, was for Mutis-Duplat's Ph.D. dissertation.

TECTONIC MAP OF TEXAS

Thomas E. Ewing, Project Director; Martin P. A. Jackson, Christopher D. Henry, and Charles M. Woodruff, Jr.; assisted by Stephen E. Lovell and Melissa A. Sandstrom; J. R. Garrison, consultant, Arlington, Texas; R. L. Nicholas, Shell Oil Co., Houston, Texas; and Arthur G. Goldstein, Colgate University, Hamilton, New York

The last systematic statewide compilation of structural and tectonic information was by 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 will incorporate these new data in a detailed display of surface and subsurface structural history for the State and adjoining areas of Mexico and the Gulf of Mexico at a scale smaller than 1:250,000. A companion illustrated text is also being compiled both to describe systematically and to synthesize the tectonic evolution of Texas from Proterozoic to Recent. The map and text will provide a valuable summary of Texas structural geology and suggest new approaches to the search for energy resources.

Contouring on significant subsurface horizons has been completed for much of the State, and the remainder will be completed in 1983. The text is now in outline form.

GRAVITY AND MAGNETIC MAPPING OF TEXAS

G. R. Keller, The University of Texas at El Paso, and C. L. V. Aitken, The University of Texas at Dallas, Project Directors

Gravity and magnetic maps of the State are being prepared at a scale of 1:250,000. The procedure for gravity mapping involves the merging of numerous different surveys, many available from the U.S. Department of Defense, onto one datum. Those data are then smoothed with a high-order polynomial surface. Magnetic maps are being prepared from National Uranium Resource Evaluation (NURE) aeromagnetic surveys. Both maps will be prepared as 1° by 2° quadrangles over the next several years. Project directors have scheduled El Paso, Van Horn, Marfa, Presidio, Pecos, Fort Stockton, and Emory Peak to be the first sheets for cartographic preparation in early 1983.

OTHER RESEARCH

CRETACEOUS VOLCANISM IN TEXAS

Thomas E. Ewing, Project Director; S. Christopher Caran

Middle to Late Cretaceous magmatism along the Balcones trend of South and Central Texas is an anomaly in the overall geologic history of the Texas Gulf Coast. The unusual petrology and distinctive eruptive styles of the volcanic rocks are coupled with significant stratigraphic anomalies. Important oil and gas reservoirs occur within, around, and over many of the 200-plus volcanic centers known in the area.

This project supplies a regional context for the distribution of Balcones igneous sites on the basis of integrated surface mapping, subsurface core description, and geophysical interpretation. Continued cooperation with the companies actively prospecting for volcano-related hydrocarbon reservoirs has allowed a much better understanding of models for Late Cretaceous volcanism. A discussion of these models was published in 1982.

COMPOSITION AND ORIGIN OF TEKTITES

Virgil E. Barnes, Project Director

This long-term study of tektites and meteorites began in 1935 and has resulted in 66 publications. The project during 1982 was mostly curatorial—furnishing material for other researchers, answering questions, reading manuscripts, and reviewing manuscripts for the periodical *Meteoritics*.

APPLICATION OF REMOTE SENSING TECHNOLOGY FOR RESOURCE EVALUATION IN TEXAS

Robert J. Finley, Project Director; Robert W. Baumgardner, Jr.

In cooperation with the Texas Natural Resources Information System (TNRIS), the Bureau of Economic Geology is applying remote sensing methods to natural resources studies. Mineralized zones in the Trans-Pecos region and irrigated croplands in the High Plains are currently under investigation.

In Trans-Pecos Texas, Landsat imagery continues to be used in analysis of Red Hill, a quartz porphyry intrusive with extensive supergene alteration. Preparations are being made to process airborne multispectral scanner data on TNRIS computer facilities, which will better define areas of limonite and jarosite surface staining.

Landsat imagery is being used in combination with contemporaneous aerial photography and field data to identify irrigated croplands in the High Plains of Texas. Band ratio techniques are used to differentiate between irrigated and unirrigated croplands. Measurements of total irrigated acreage in one county will be accomplished by using the Geographic Information System at TNRIS.

GEOLOGIC FEATURES OF MONAHANS SANDHILLS STATE PARK

Marcie D. Machenberg, Project Director

This project, which is being conducted in conjunction with the Texas Parks and Wildlife Department, will yield a guidebook to the eolian features of Monahans Sandhills State Park, which is located near the Ward-Winkler county line in West Texas. The active sandhills there formed approximately 40,000 B.P., when a drier-than-present climatic period caused ancestral Pecos River floodplain deposits to be blown eastward by paleowinds. The fine quartz sand that composes the Monahans Sandhills was concentrated in a northwest-southeast-trending belt against the base of the western Caprock Escarpment, a topographic barrier rising 90 m above the plain. Much of the dune belt is now stabilized by vegetation, but more than 1,600 hectares of active sand just east of Monahans have been preserved for recreational use and nature study.

The duneforms in the park are diverse and include dome-shaped coppice dunes stabilized by miniature shin-oak trees, wind-shadow dunes, parabolic dunes, transverse dunes, blowouts, and a type of complex parallel wavy dune called aklé dunes. Aklé dunes are mobile; dune crests shift

as much as 15 m within a 3-month period, but the complex trimodal wind regime of the area causes a seasonal reversal in the direction of dune movement. Overall yearly net migration of duneforms is negligible.

This study emphasizes the interrelationship among such variables as sand supply, precipitation, vegetation, wind regime, and human activities, all of which are responsible for the dynamic nature of this eolian system. A map of dune environments within the park is currently in preparation for release with the guidebook early in 1983.

THE PROVINCES OF TEXAS: THEIR REGIONAL AND ECONOMIC GEOLOGY

W. Keene Ferguson, Project Director

A general overview of the regional geology of the various physiographic provinces of Texas focuses on the geologic factors that account for their noticeable topographic features, such as fault scarps and collapse structures. Where significant, the effect of present-day geologic activity on land surfaces is noted, for example, along the coast. Also, attention is given to the relations among bedrock geology, soil development, and natural vegetation.

The history of mineral resources development within each province is discussed. Where a particular type of agriculture has been a distinctive feature of an area's development, such as in the lower Rio Grande Valley, its history is noted. For some areas, the human history has been a unique characteristic, as in that of the Germans on the Edwards Plateau. Some attention also is given to weather distribution and storms.

The product of the above syntheses will be tailored to nontechnical readers.

CONTRACTS AND GRANT SUPPORT

The Bureau of Economic Geology maintains formal and informal cooperative arrangements with several governmental entities. Parts of the Bureau's research program are conducted under university contracts and grants with State agencies, local units of government, Federal agencies, and other organizations.

Contract management personnel perform a variety of tasks associated with Bureau contract performance. Duties include preparing proposals and budgets, negotiating contracts, and monitoring expenditures. During the contract period, technical and financial reports are formatted and distributed at monthly, quarterly, and annual intervals.

In calendar year 1982, the following 22 contracts were active at the Bureau, each of which had reporting requirements:

Federal

A Study Designed to Identify Geohydrologic Environments Suitable for Isolation of High-Level Radioactive Waste from Man's Environment: supported by the U.S. Geological Survey.

Computerized Calculation of Lignite Resources in Texas: supported by the U.S. Geological Survey.

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

Consolidation of Geologic Studies of Geopressured Geothermal Resources in Texas: supported by the U.S. Department of Energy.

Evaluating the Potential of East Texas Interior Salt Domes as Areas for Isolation of Nuclear Waste: supported by the U.S. Department of Energy.

Evaluation of Basin and Range Province for Suitability of Geologic and Hydrologic Environments for Isolation of High-Level Radioactive Wastes: supported by the U.S. Geological Survey.

Geologic Framework and Energy Resource Studies, Texas Continental Shelf: supported by the U.S. Geological Survey.

Geothermal Resource Assessment for the State of Texas: supported by the U.S. Department of Energy.

Locating Field Confirmation Study Areas for Isolation of Nuclear Waste in the Texas Panhandle: supported by the U.S. Department of Energy.

Resource Evaluation of Late Oligocene through Miocene Major Stratigraphic Units, Texas Gulf Coast Basin: supported by the U.S. Geological Survey.

Rheology of Viscoelastic Fluids for Oil Recovery: supported by the U.S. Department of the Interior, Office of Surface Mining.

Texas Mining and Mineral Resources Research Institute–Fourth and Fifth Allotments, Scholarships and Fellowship Grants: supported by the U.S. Department of the Interior, Bureau of Mines.

State

An Analysis of Shoreline Changes in the Area of Corpus Christi Bay, Texas: supported by Texas Energy and Natural Resources Advisory Council.

Applied Coal Geoscience and the Electric Utilities: supported by the Electric Power Research Institute through the Texas Energy and Natural Resources Advisory Council.

Geologic and Hydrologic Evaluation of Deep-Basin Lignite: supported by the Texas Energy and Natural Resources Advisory Council.

Geologic Characterization of Texas Oil Reservoirs: supported by the Texas Energy and Natural Resources Advisory Council.

Geologic Setting and Geochemistry of Thermal Waters, Hueco Tanks and Presidio Bolson Areas, Trans-Pecos Texas: supported by Texas Energy and Natural Resources Advisory Council.

State Submerged Lands Study: supported by the Governor's Budget and Planning Office.

Other

Analysis of Low-Permeability Gas Sands Suitable for Future Research Programs: supported by the Gas Research Institute through the CER Corporation.

Exploration and Production Program for Locating and Producing Prospective Aquifers Containing Solution Gas and Free Gas--Texas Gulf Coast: supported by the Gas Research Institute.

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

Geology and Engineering Characteristics of Selected Low-Permeability Gas Sands: A Survey: supported by the Gas Research Institute through the CER Corporation.

CONTRACT AND GRANT REPORTS

A variety of reports are prepared annually under terms of grants and contracts with different sponsoring entities. Nearly all such reports are eventually published by the Bureau as part of its publication series. After acceptance by the sponsoring agency and until final publication, these reports are maintained on open file at the Bureau and may be consulted by interested persons.

Finley, R. J., 1982, Geology and engineering characteristics of selected low-permeability gas sands: a survey: prepared for CER Corporation and Gas Research Institute under Contract No. GRI-BEG-SC-111-81, 329 p., plus 35-p. addendum.

Finley, R. J., 1982, A preliminary assessment of high-resistivity cap rock shale in the Frio Formation of the Texas Gulf Coast: prepared for U.S. Department of Energy under Contract No. DE-AC08-79ET27111-6, 28 p.

Finley, R. J., and Han, J. H., 1982, Analysis of low-permeability gas sands suitable for future research programs: prepared for CER Corporation and Gas Research Institute under Contract No. GRI-BEG-SC-112-82, 53 p.

Galloway, W. E., Henry, C. D., and Smith, G. E., 1982, Predicting response of an aquifer system to uranium extraction, Oakville aquifer, Texas Coastal Plain: prepared for U.S. Environmental Protection Agency under Grant Nos. R805357010 and R805357020, 308 p.

Galloway, W. E., Garrett, C. M., Jr., Tyler, N., Ewing, T. E., and Posey, J. S., 1982, Geological characterization of Texas oil reservoirs: prepared for Texas Energy and Natural Resources Advisory Council under Interagency Contract No. (82-83)-0821, 96 p.

Gregory, A. R., Lin, Z. S., Reed, R. S., and Morton, R. A., 1982, Exploration and production program for locating and producing prospective aquifers containing solution gas and free gas—Texas Gulf Coast: prepared for Gas Research Institute under Contract No. 5080-321-0398, 170 p.

Gustavson, T. C., Howard, R. C., and McGookey, D. A., 1982, Environmental baseline monitoring in the area of General Crude Oil - Department of Energy Pleasant Bayou Number 2—a geopressured geothermal test well—1980: prepared for U.S. Department of Energy under Contract No. DE-AC08-79ET27111-7, 243 p.

Kreitler, C. W., Bracken, B., Collins, E. W., Conti, R., Dutton, S. P., Fogg, G. E., Jackson, M. P. A., McGowen, M. K., Pennington, W. D., Seni, S. J., Wilson, B., Wood, D. H., and Wuerch, H. V., 1982, Geology and geohydrology of the East Texas Basin—a report on the progress of nuclear waste isolation feasibility studies (1981): prepared for U.S. Department of Energy under Contract No. DE-AC97-80ET46617, 70 p.

Morton, R. A., Ewing, T. E., and Tyler, N., 1982, Continuity and internal properties of Gulf Coast sandstones and their implications for geopressured energy development: prepared for U.S. Department of Energy under Contract No. DE-AC08-79ET27111-4, 142 p.

Morton, R. A., Garrett, C. M., Jr., Posey, J. S., Han, J. H., and Jirik, L. A., 1982, Salinity variations and chemical compositions of waters in the Frio Formation, Texas Gulf Coast: prepared for U.S. Department of Energy under Contract No. DE-AC08-79ET27111-5, 96 p.

Schmedes, K. E., Baumgardner, R. W., Jr., and Finley, R. J., 1982, Remote sensing of the Coastal Applications Test Site—test site 1: economic and accuracy evaluation of mapping techniques: prepared for Texas Natural Resources Information System and National Aeronautics and Space Administration under Contract No. TDWR/TNRIS IAC No. (80-81)-1935, 107 p.

Teledyne Geotech (subcontractor), 1982, Microseismic monitoring of Chocolate Bayou, Texas, the Pleasant Bayou No. 2 geopressured/geothermal energy test well program: prepared for U.S. Department of Energy under Contract No. DE-AC08-79ET27111, 218 p.

Winker, C. D., Morton, R. A., Ewing, T. E., and Garcia, D. D., 1982, Depositional setting, structural style, and sandstone distribution in three geopressured geothermal areas, Texas Gulf Coast: prepared for U.S. Department of Energy under Contract No. DE-AC08-79ET27111-3, 132 p.

Woodruff, C. M., Jr., Caran, S. C., Gever, C. R., Henry, C. D., Macpherson, G. L., and McBride, M. W., 1982, Geothermal resource assessment for the State of Texas, status of progress, November 1980: prepared for U.S. Department of Energy under Contract No. DE-AS07-79ID12057, 248-p. text (1 vol.) and appendices (2 vols.).

PUBLICATIONS

In its role as a public geologic research unit, the Bureau of Economic Geology disseminates the results of research projects and programs primarily through its own publication series. During its 73-yr history, the Bureau has published more than 700 reports, bulletins, circulars, special publications, and maps covering major aspects of the geology and natural resources of Texas. In addition, more than 500 reports and maps are available to the public through open-file holdings at the Bureau. Publications are sold at nominal prices to recover printing or duplication costs. To date, more than 1 million publications have been distributed worldwide, mostly through direct sales. During 1982, approximately 45,500 volumes were distributed. The Bureau issued the following publications in 1982:

REPORTS OF INVESTIGATIONS

RI 113. Depositional Framework, Hydrostratigraphy, and Uranium Mineralization of the Oakville Sandstone (Miocene), Texas Coastal Plain, *by W. E. Galloway, C. D. Henry, and G. E. Smith. 51 p., 34 figs., 6 tables, 2 appendices ($2.50).*

The Oakville Formation of the Texas Coastal Plain has evolved as the single largest producer of uranium in Texas. Most of the uranium was recovered by in situ leaching. In addition, the Oakville serves as a major fresh-water aquifer, providing water for domestic and agricultural use. This report examines the geology, physical hydrology, and hydrochemistry of the Oakville aquifer, as well as the technology and potential effects of uranium extraction on the aquifer. It describes the physical stratigraphy and hydrostratigraphy of the Oakville fluvial system and presents new interpretations of its component facies. Hydrological and stratigraphic data are integrated to derive a regional transmissivity map of the aquifer. The report then synthesizes the geology and paragenesis of the major uranium districts and relates uranium occurrence to the hydrologic evolution of the Oakville.

RI 114. Formation of the Wink Sink, a Salt Dissolution and Collapse Feature, Winkler County, Texas, *by R. W. Baumgardner, Jr., A. D. Hoadley, and A. G. Goldstein. 38 p., 22 figs., 5 tables, 3 appendices ($1.50).*

Dissolution of halite in the Permian Salado Formation is inferred to have caused the Wink Sink to form. The Salado Formation near the sink contains dissolution zones at several levels, suggesting that water movement through the salt section is complex. Near the sinkhole, hydraulic heads of aquifers below the salt are at least as high as the salt but lower than the head of the near-surface Santa Rosa Formation. The potential for vertical water movement may be enhanced by abandoned oil and gas wells.

The sinkhole formed almost concentrically to an abandoned oil well, surrounded by other wells, in the 54-year-old Hendrick oil field. An abundant data base of geophysical logs and driller's logs from nearby wells is supplemented by a first-order leveling survey conducted over a 5-month period, a gravity survey of the immediate vicinity of the sinkhole, and a summary of the history of salt dissolution in the Delaware Basin. The geologic and hydrologic conditions pertinent to this case of catastrophic subsidence allow many plausible explanations of the cause of the sinkhole.

RI 115. Coastal Evaporite and Tidal-Flat Sediments of the Upper Clear Fork and Glorieta Formations, Texas Panhandle, *by M. W. Presley and K. A. McGillis. 50 p., 38 figs., 5 tables ($2.00).*

The association of red beds, carbonates, and evaporites in upper Clear Fork and Glorieta rocks seems to be a unique facies grouping, characteristic of desert-margin, coastal evaporite sedimentation in cratonic basins. Upper Clear Fork and Glorieta evaporite and carbonate facies were deposited in a range of shallow marine-shelf and intertidal to supratidal evaporite environments along an arid coastline. In inner-shelf environments, carbonates were deposited in upward-shoaling successions of subtidal, intertidal, and supratidal facies. Evaporites were deposited on a broad low-relief salt plain landward of shelf environments. The report discusses regional setting and stratigraphy and analyzes four major depositional systems: inner shelf, brine pan, salt flat, and mud flat. Temporal changes in distribution of these depositional systems are discussed.

RI 116. Genesis and Emplacement of Oil in the San Andres Formation, Northern Shelf of the Midland Basin, Texas, *by P. J. Ramondetta. 39 p., 28 figs., 7 tables ($2.00).*

San Andres oil production in the Northern Shelf of the Midland Basin constitutes nearly 13 percent of the total production in Texas. The San Andres and Clear Fork carbonate rocks of the Northern Shelf contain sufficient amounts of lipid-rich organic material to be considered potential petroleum source beds. Organic maturation of these rocks, however, is not sufficient to have initiated catagenesis.

San Andres oils have a common source, as evidenced by their remarkably uniform composition. Wolfcampian basinal clastics and dark argillaceous limestones of the northern Midland Basin are the most likely source rocks for this oil. Vertical expulsion of basinal oil through fractures into overlying shelf and shelf-margin carbonates has occurred along the Lower Permian Abo Reef trend. These oils have been biodegraded owing to their presence in relatively shallow, sulfate-rich reservoirs.

The trapping mechanism in the Northern Shelf combines structural and facies control. Good reservoir conditions exist in San Andres strata, which are draped and subsequently fractured over the subjacent shelf-margin buttress. Above the Abo Reef trend, a thick porous zone

exists in the lower San Andres and upper Clear Fork Formations; shelfward, this porous zone grades into discrete porous layers resulting from cyclic sedimentation in shallow inner-shelf and sabkha environments. These Upper Permian carbonates tend to lose porosity in a northward (updip) direction, where conditions were more evaporitic. This updip change from porous to nonporous facies provides the porosity pinch-out in the vast Levelland-Slaughter-Cato trend of Texas and eastern New Mexico.

RI 117. Wilcox Sandstone Reservoirs in the Deep Subsurface Along the Texas Gulf Coast, Their Potential for Production of Geopressured Geothermal Energy, *by D. G. Bebout, B. R. Weise, A. R. Gregory, and M. B. Edwards. 125 p., 135 figs., 4 tables, 2 appendices ($5.00).*

Wilcox reservoirs in the deep subsurface of the Texas Gulf Coast have long been targets for the production of hydrocarbons. The key to exploration for hydrocarbons in the Gulf Coast is understanding regional and local structure and sandstone and shale distribution. This also applies to exploration for geopressured geothermal reservoirs in the Wilcox.

Regional stratigraphic cross sections and maps were prepared for this report to identify geopressured geothermal fairways. Fairway studies using detailed stratigraphic and structural cross sections and net-sandstone maps helped locate prospects and test-well sites. Detailed sections and maps of fairways in Zapata, Duval, Live Oak, De Witt, Colorado, and Harris Counties are included, along with supporting studies of thermal gradients, shale-resistivity trends, pressure gradients including location of top of geopressure, porosity and permeability trends, and salinity changes with depth.

RI 118. Geochemistry of Ground Water in the Miocene Oakville Sandstone—A Major Aquifer and Uranium Host of the Texas Coastal Plain, *by C. D. Henry, W. E. Galloway, G. E. Smith, C. L. Ho, J. P. Morton, and J. K. Gluck. 63 p., 21 figs., 9 tables, 3 appendices ($2.50).*

The Oakville Sandstone of the Texas Coastal Plain is important economically because it is a major source of ground water for domestic and agricultural use and because it is the major source of uranium in the South Texas uranium mining district. This report focuses on the hydrochemistry—chemical composition—of Oakville ground water and discusses major ions, oxidation-reduction status, and concentrations of uranium and related, environmentally sensitive trace elements. Conclusions are directed toward exploration for uranium deposits and evaluation and avoidance of deleterious effects of uranium mining.

RI 119. Epigenetic Zonation and Fluid Flow History of Uranium-Bearing Fluvial Aquifer Systems, South Texas Uranium Province, *by W. E. Galloway. 31 p., 22 figs., 4 tables ($2.00).*

This report is the culmination of 4 years of research on the geologic setting and genesis of Texas uranium deposits. Using the Oakville Sandstone and its contained uranium deposits as a field laboratory, the report reviews the hydrogeologic framework of the Coastal Plain. Detailed geochemical and mineralogical characterization of typical uranium deposits of the two largest Oakville mining districts, Ray Point and George West, defines the common properties of South Texas roll-type mineralization fronts. Together with mapping of regional alteration patterns, the district studies outline four types of alteration events that may be superimposed in many combinations. Geochemical analysis, including use of sulfur isotopes, of various alteration products defined the composition of the ground waters responsible for alteration. In turn, examination of the hydrochemistry of various ground-water regimes of the shallow and deep Coastal Plain basin fill led to site-specific interpretation of the fluid fluxes responsible for uranium genesis.

RI 120. Lithology, Microstructures, Fluid Inclusions, and Geochemistry of Rock Salt and of the Cap-Rock Contact in Oakwood Dome, East Texas: Significance for Nuclear Waste Storage, *by O. R. Dix and M. P. A. Jackson. 59 p., 37 figs., 6 tables, appendix ($3.00).*

A well into Oakwood salt stock in Freestone County has yielded a continuous core through 137 m of anhydrite-calcite cap rock and 57 m of underlying diapiric rock salt. Layers of disseminated anhydrite constitute 1.3 ±0.7 percent of the salt core. Most of the salt core contains a strong deformation fabric, but the upper 2 m is unfoliated and rich in brine/gas inclusions. An abrupt, cavity-free contact separates rock salt from laminated cap rock consisting of fine-grained, compact anhydrite.

Microstructures and concentration gradients of fluid inclusions suggest that the unfoliated rock salt at the crest of the salt stock was formerly strongly foliated. This fabric was destroyed by solid-state recrystallization induced by brine descending from the cap-rock contact. Evidence is documented for repeated cycles of salt dissolution along this contact, followed by rise of salt to close the dissolution cavity. Much of the cap-rock lamination appears to have formed during these cycles. Despite repeated attrition and uplift of the Oakwood salt stock, this geologic system has offset these processes by self-sealing and recovery.

RI 121. San Andres Carbonates in the Texas Panhandle: Sedimentation and Diagenesis Associated with Magnesium-Calcium-Chloride Brines, *by Amos Bein and L. S. Land. 48 p., 27 figs., 9 tables, 2 appendices ($2.00).*

The Permian San Andres Formation in the Palo Duro Basin of the Texas Panhandle is a heterogeneous sedimentary system consisting of closely associated halite, anhydrite, dolomite, and mudstone and small amounts of calcite, quartz silt, celestite, chert, and organic matter. To the south, across the Northern Shelf of the Midland Basin, evaporites pinch out and carbonates predominate. Six lithofacies were differentiated in the Palo Duro and Northern Shelf carbonates: dolomudstone, pellet-oolite packstone-grainstone, filamentous (*Girvanella*-like) grainstone, sponge spicule packstone, wispy-laminated crinoid packstone, and skeletal packstone-grainstone. Facies distribution was controlled by water-body salinity, which increased from south to north.

Diagenesis of the San Andres carbonates occurred in contact with saline magnesium-calcium-chloride brines, which evolved from seawater by anhydrite and halite precipitation. Skeletal mold formation and subsequent anhydrite cementation, dolomitization, and high-strontium

calcite cementation associated with celestite precipitation are all cogenetic processes controlled by this brine-rock interaction.

This study provides details concerning the process by which the carbonate fabric was shaped and modified through time. Establishing diagenetic sequences in the carbonates intercalated with the salts may assist in answering two basic questions: namely, how hydrologically isolated the system is and how it relates to the prolific San Andres petroleum reservoirs along the northern margin of the Midland Basin.

RI 122. Frio Formation of the Texas Gulf Coast Basin—Depositional Systems, Structural Framework, and Hydrocarbon Origin, Migration, Distribution, and Exploration Potential, *by W. E. Galloway, D. K. Hobday, and Kinji Magara. 78 p., 76 figs., 15 tables, 19 pls. ($4.50).*

This synthesis of the depositional and structural framework of the Frio Formation of the Texas Gulf Coast Basin describes the spatial and geologic distribution of its contained hydrocarbons, reviews historical trends in discovery, and assesses the potential for further reserve additions. The Frio Formation has produced approximately 6 billion bbl of oil and 60 trillion ft³ of natural gas, making it one of the most productive stratigraphic units in North America.

This report culminates nearly 10 years of study of the Frio Formation by the Bureau. It defines and describes the principal depositional systems of the Frio Formation and discusses hydrocarbon source-rock distribution, maturation history, migration pathways, and trapping mechanisms. The report then attempts to explain known hydrocarbon productivity using modern concepts of petroleum genesis. Within this framework, seven principal Frio oil and gas plays are delineated and described. Unique to this report is the volumetric quantification of reservoir, source, and whole-rock productivity within each play. The report summarizes projections, determined by volumetric and historical methods, of undiscovered hydrocarbons in the Frio Formation. These projections emphasize the challenges facing explorationists in mature provinces such as the Gulf Coast Tertiary basin.

RI 123. Petroleum Potential of the Palo Duro Basin, Texas Panhandle, *by S. P. Dutton, A. G. Goldstein, and S. C. Ruppel. 87 p., 53 figs., 5 tables, 6 pls., appendix ($5.00).*

The Palo Duro Basin, an exploration frontier in the Texas Panhandle, seemingly has all the elements necessary for hydrocarbon generation and accumulation: reservoirs, traps, source rocks, and sufficient thermal maturity. Within the pre-Pennsylvanian section, porous facies in shallow marine carbonates of both Ordovician (Ellenburger Group) and Mississippian age have sufficient porosity and permeability for hydrocarbon accumulation. In the Pennsylvanian and Wolfcampian section, potential reservoirs are granite-wash sandstones, shelf-margin carbonates, and elongate-delta sandstones. Younger Permian dolomites in the Clear Fork (Leonardian) and the San Andres (Guadalupian) Formations are reservoirs along the Matador Arch. However, porosity in these units apparently pinches out to the north.

Both stratigraphic and structural trapping configurations exist in the basin. Major faults are associated with the Amarillo Uplift, and smaller faults have been identified in the deeper parts of the basin. Fracturing adjacent to some faults may have created fractured reservoirs.

This report presents the results of organic geochemical analyses of basin source rocks. Total organic carbon content indicates Pennsylvanian and Wolfcampian shales are fair to very good source rocks. Kerogen color and vitrinite reflectance, which measure thermal maturity, indicate that temperatures were sufficiently high to begin to generate hydrocarbons from lipid-rich organic matter. Recent oil discoveries in the Palo Duro Basin support this conclusion.

RI 124. Regional Hydrodynamics and Hydrochemistry of the Uranium-Bearing Oakville Aquifer (Miocene) of South Texas, *by G. E. Smith, W. E. Galloway, and C. D. Henry. 31 p., 26 figs., 1 table, appendix ($1.50).*

The Oakville Formation is both a major fresh-water aquifer used for domestic and agricultural purposes and the most productive uranium unit mined in Texas. This report examines aspects of geology and physical hydrology, hydrodynamics and hydrochemistry, and the technology and potential effects of uranium extraction on the Oakville aquifer.

This report defines ground-water recharge and discharge characteristics and temperature gradients along a 270-mi belt of Oakville outcrop that extends 15 to 45 mi downdip beneath coastal plain cover. Major components, electrochemical parameters, and trace metals within the area of Oakville aquifer usage are identified and synthesized within the context of regional geology and physical hydrology. Hydrochemical facies patterns shown in map format depict a normal downdip compositional evolutionary sequence locally modified by fault leakage of high-salinity, sulfidic waters from deeper stratigraphic horizons and a regional compositional influence caused by depositional lithofacies and lithic components in the rock matrix.

RI 125. Atoka Group (Lower to Middle Pennsylvanian), Northern Fort Worth Basin, Texas: Terrigenous Depositional Systems, Diagenesis, and Reservoir Distribution and Quality, *by D. M. Thompson. 62 p., 27 figs., 5 tables, 19 pls. ($2.50).*

The Atoka Group has a cumulative production history of more than 160 million bbl (oil plus gas equivalent). The group was deposited in the Middle Pennsylvanian (Atokan time) during the initial westward progradation of chert-rich terrigenous clastics derived both from the Ouachita Thrust Belt and locally from the Muenster Arch. Production and reservoir distribution and quality are facies controlled. Incorporating electric logs, core, and thin sections, this report delineates three packages of terrigenous deposits that reflect distinct depositional systems, determines the diagenetic history of the sandstone reservoirs, and plots the distribution of cumulative hydrocarbon production. It then relates depositional and diagenetic trends to current production and reservoir distribution and quality. This study, which concentrates on the northern half (9,500 mi²) of the Fort Worth Basin, will aid explora-

tionists in locating areas for production that were previously overlooked and will assist in effective production from all available horizons in the Atoka Group.

RI 126. Considerations in the Extraction of Uranium from a Fresh-Water Aquifer—Miocene Oakville Sandstone, South Texas, *by C. D. Henry, W. E. Galloway, and G. E. Smith. 36 p., 12 figs., 4 tables, appendix ($2.50).*

The Oakville Sandstone is the major uranium host of the South Texas uranium district and a major aquifer in the Gulf Coast. This report draws together the conclusions of a series of reports on the physical stratigraphy, hydrology, and aqueous geochemistry of the Oakville. It also gives additional information to assess the potential impact of mining on ground-water quantity and quality. It presents recommendations on baseline studies, determination of aquifer sensitivity, methods and goals of monitoring, and need for further research.

RI 127. Ground-Water Hydraulics and Hydrochemical Facies in Eocene Aquifers of the East Texas Basin, *by G. E. Fogg and C. W. Kreitler. 75 p., 44 figs., 6 tables, 2 appendices ($3.00).*

This report describes the regional hydrogeology of Eocene aquifers in the East Texas Basin in order to evaluate the suitability of salt domes in the basin for nuclear waste isolation. Eocene stratigraphic units in the East Texas Basin are composed of a thick (approximately 2,000 ft [600 m]) sedimentary sequence of fresh-water aquifers and aquitards. The aquifers are an important source of fresh water for domestic and industrial uses. This study is pertinent to predicting the hydrologic consequences of ongoing surface mining of Wilcox Group lignite deposits in the basin.

Three-dimensional analysis of abundant data on hydraulic head, pressure, and water chemistry from water wells tapping the Wilcox, Carrizo, and Queen City aquifers are used to reveal the regional ground-water circulation patterns, the locations and mechanisms of major recharge and discharge areas, and the evolution of ground-water chemistry along flow paths. This analysis concludes that structure and topography are major controls on ground-water circulation in the Eocene aquifers. Topographically controlled vertical leakage between the Queen City and Wilcox-Carrizo aquifer systems affects circulation in the Wilcox-Carrizo. Downward leakage occurs over most of the basin, and upward leakage occurs only beneath the Trinity and Sabine Rivers. Data show that as ground water flows from outcrop down the hydraulic gradient into the artesian part of the Wilcox-Carrizo aquifer, it is consistently altered chemically from an acidic, oxidized calcium-magnesium-bicarbonate-sulfate water to a basic, reduced sodium bicarbonate water. This change in the water chemistry can be used as a natural tracer for ground-water flow and is predominantly controlled by two reactions: calcite dissolution and cation exchange with montmorillonitic clays.

RI 128. Facies and Stratigraphy of the San Andres Formation, Northern and Northwestern Shelves of the Midland Basin, Texas and New Mexico, *by P. J. Ramondetta. 56 p., 41 figs., 3 tables ($2.50).*

An assessment of San Andres oil and gas potential in the Palo Duro Basin is important because San Andres salt deposits are being evaluated for possible storage of nuclear waste. This report describes and interprets the facies and stratigraphy of the San Andres Formation on the Northern and Northwestern Shelves of the Midland Basin in Texas and eastern New Mexico.

San Andres reservoirs of the Northern and Northwestern Shelves yielded 12.7 percent of the total oil production for the State of Texas in 1980. Maps, cross sections, and production data presented in this report document the nature of oil entrapment in this area, which is both structural and stratigraphic. Maps and cross sections for this report were made on the basis of approximately 3,000 well logs from the northern Midland Basin and the Palo Duro Basin in Texas and New Mexico.

RI 129. Environmental Geology of the Yegua-Jackson Lignite Belt, Southeast Texas, *by M. L. W. Jackson and L. E. Garner. 36 p., 15 figs., 4 tables, 5 pls. ($3.00).*

The Bureau has prepared five environmental geologic maps of the Yegua-Jackson lignite belt of southeast Texas and an accompanying text in response to renewed production of lignite in the State. This report is a companion study to RI 98, *Environmental Geology of the Wilcox Group Lignite Belt, East Texas,* and describes the regional setting, geology, geomorphology, climate, soils, vegetation, hydrology, structure, and lignite potential of the map area. The report explains mapping procedures, expands definitions of the environmental units given on the maps, and gives examples of how the maps can be used.

Mapping of the area, from Fayette County to the Texas-Louisiana border, involved interpretation of black-and-white, large-scale aerial photographs and extensive field work. The maps include 32 map units, defined in terms of substrate, soil, geomorphology, geologic processes, vegetation, and land use. The maps also identify active and abandoned lignite mines and lignite resource blocks.

GEOLOGICAL CIRCULARS

GC 82-1. Lineament Analysis and Inference of Geologic Structure—Examples from the Balcones/Ouachita Trend of Texas, *by S. C. Caran, C. M. Woodruff, Jr., and E. J. Thompson. 11 p., 4 figs., 3 tables (reprinted from Gulf Coast Association of Geological Societies Transactions, v. 31, p. 59-69) ($1.00).*

Lineaments perceived in Landsat satellite images are useful indicators of geologic structure. This study mapped more than 5,000 lineaments in 10 Landsat multispectral scanner images (band 5; 1:250,000 scale) in Central Texas between the Red River and Rio Grande, covering the buried Ouachita structural system and the Balcones, Luling, Mexia, and Talco fault zones. Distinct patterns of lineament density, lineament length, and angles of lineament intersection were found to correspond to structures. These structures (mainly faults and folds) controlled sedimentation, salt

tectonics, and the distribution of Late Cretaceous igneous features; they also affected the migration and entrapment of hydrocarbons, mineralizing fluids, and geothermal waters. Some of the structures are clearly expressed at the surface, whereas others (including those involving Precambrian and Paleozoic basement complexes) have subtle or anomalous expression. Correlation of readily detected lineaments with these structures provides a means for recognizing structural controls on mineral and water resources and is thus an exploration tool.

GC 82-2. Detailed Evaluation of Two Texas Lignite Deposits of Deltaic and Fluvial Origins, *by S. J. Tewalt, M. A. Bauer, and David Mathew. 12 p., 19 figs., 2 tables (reprinted from Gulf Coast Association of Geological Societies Transactions, v. 31, p. 201-212) ($1.00).*

Regional depositional systems of the Wilcox and Jackson Groups in East Texas are fluvial and deltaic, respectively. The geological occurrences of lignite deposits in both the Jackson and Wilcox outcrop areas in East Texas show positive correlations with the regional models. Using cross sections and isopach, isograde, and log-pattern maps, this study investigated seam continuity, areal distribution, quality, and relationships with associated sediments. These detailed evaluations revealed the local depositional setting of the lignite seams.

Lignite seams in the Jackson Group deposit reflect two processes of lower delta-plain deposition. Thin discontinuous seams apparently formed in small interdistributary areas that were frequently inundated by sediments during overbank flooding and crevassing. Thick coal seams were deposited on sand platforms during periods of delta-lobe abandonment. Lignite quality and seam characteristics indicate a change in position on the delta plain from stratigraphically older to younger seams.

Seams in the Wilcox Group deposit in East Texas are characteristic of an alluvial plain setting. Individual seams are lenticular and thick in the center and have abruptly thinning margins. Sand channels are normally parallel to the lignite bodies. Large mud-filled areas surround some lignite seams. Overall quality of lignites varies, but lignite is generally low in ash and high in heating value.

GC 82-3. Surficial Evidence of Tectonic Activity and Erosion Rates, Palestine, Keechi, and Oakwood Salt Domes, East Texas, *by E. W. Collins. 39 p., 24 figs., 2 tables ($1.75).*

Surficial geologic investigations at Palestine, Keechi, and Oakwood salt domes, East Texas, have provided information necessary for the evaluation of salt domes as nuclear waste repositories. Geologic and geomorphic studies essential for determining the stability of the salt domes showed that significant growth of the domes probably stopped before Pleistocene time, although subsidence during the Holocene may be evident. The methods of study used here can be applied to domes in other areas.

The report presents the general stratigraphy and geology at each dome and compares the geomorphology of the three domes through morphologic mapping. Terraces of the Trinity River were studied to evaluate long-term regional uplift and domal uplift. The potential for erosional breaching of the domes was determined through studies involving denudation rates in East Texas and entrenchment of the Trinity River. These studies established that erosional breaching of the domes is unlikely.

GC 82-4. Fault Tectonics of the East Texas Basin, *by M. P. A. Jackson. 31 p., 19 figs. ($1.50).*

This report describes the distribution, geometry, displacement history, and possible origins of the principal fault systems in the East Texas Basin. Regional fault systems are represented by the Mexia-Talco fault zone, the Elkhart Graben, the Mount Enterprise fault zone, and abundant subsurface faults in the central part of the basin. All the faults studied are of normal displacement and moved syndepositionally more than 120 million years ago. Some have listric shapes and associated rollover anticlines. The faults formed by processes associated with gravitationally induced creep of the Louann Salt, such as gliding over a salt décollement zone, crustal extension and collapse over salt pillows and turtle structures, and salt withdrawal from beneath downthrown blocks. None of the regional fault zones were caused directly by salt diapirism or marginal flexure of the basin, and there is little evidence of basement control. Available data suggest that none of these fault zones pose a seismic threat to a potential nuclear waste repository in the Gulf Coast area.

GC 82-5. Depositional Architecture of Cenozoic Gulf Coastal Plain Fluvial Systems, *by W. E. Galloway. 29 p., 24 figs., 1 table (reprinted from Society of Economic Paleontologists and Mineralogists Special Publication 31, p. 127-155) ($1.50).*

Studies of uranium deposits of the Oligocene and Miocene fluvial systems of the Texas Coastal Plain provide a unique opportunity for examination of the depositional architecture and evolution of alluvial deposits of the margin of a subsiding basin. This report examines the three-dimensional facies sequences of several major extrabasinal and smaller intrabasinal rivers. Contrasting channel types, ranging from perennial or seasonal braided, bed-load channels to sinuous, mixed-load channels, are documented and their characteristics outlined. Throughout the report, emphasis is on the recognition and mapping of fluvial facies and depositional elements using subsurface data. Sedimentology of time-equivalent and sequentially evolved fluvial axes is diverse, reflecting variations in texture and composition of sediment provided by the source area, paleoclimatic gradients and resultant discharge variability, and size of the individual drainage basin.

GC 82-6. Hydrocarbon Accumulation Patterns in the East Texas Salt Dome Province, *by D. H. Wood and A. B. Giles. 36 p., 18 figs., 4 tables ($1.50).*

This study evaluates the oil and gas resources of East Texas Basin salt domes to assess their suitability for nuclear waste isolation. It discusses salt movement in the central East Texas Basin and describes hydrocarbon production before 1979 in the context of stratigraphic occurrence and structural associations. Hydrocarbon accumulations are controlled by geologic history and by the present configuration of structures within the basin: namely, salt-cored anticlines, turtle-structure anticlines, and salt diapirs. Salt-cored anticlines have been most productive of hydrocarbons, and salt diapirs have been least productive.

Salt domes here could attract future drilling activity that might lead to breaching of a nuclear waste repository.

GC 82-7. Geology and Geohydrology of the Palo Duro Basin, Texas Panhandle: A Report on the Progress of Nuclear Waste Isolation Feasibility Studies (1981), *by T. C. Gustavson, R. L. Bassett, R. Budnik, R. J. Finley, A. G. Goldstein, J. H. McGowen, E. Roedder, S. C. Ruppel, R. W. Baumgardner, Jr., M. E. Bentley, S. P. Dutton, G. E. Fogg, S. D. Hovorka, D. A. McGookey, P. J. Ramondetta, W. W. Simpkins, D. Smith, D. A. Smith, E. A. Duncan, J. A. Griffin, R. M. Merritt, and E. R. Naiman. 212 p., 123 figs., 13 tables ($7.50).*

This report summarizes the Bureau's progress during 1981 in its long-term program to gather and analyze all geologic and hydrologic information needed for description and evaluation of the Palo Duro and Dalhart Basins as potential sites for nuclear waste isolation. The program was divided into five research tasks undertaken by a surficial analysis and shallow-stratigraphy group, a hydrology and geochemistry group, a basin analysis group, a host-rock analysis group, and a seismicity and tectonic environment group. The surficial analysis and shallow-stratigraphy group collected remotely sensed, surface and subsurface data to describe salt dissolution, surface processes, and geomorphic development. The hydrology and geochemistry group continued analysis of shallow and deep fluid circulation within the basins and rock and fluid geochemistry within various stratigraphic units. The basin analysis group characterized the major salt-bearing stratigraphic units, assessed the potential for generating and trapping hydrocarbons within the basins, and initiated studies of salt quality. Concurrently, the host-rock analysis group continued a study of cores from several drilling sites for analysis of salt and other lithologic units within the cores. The seismicity and tectonic environment group analyzed surface fracture systems and continued studies of regional gravity, deep-basement structure and tectonic development of the basin, and structural controls of sedimentation.

MINERAL RESOURCE CIRCULARS

MRC 70. Geology of the Plata Verde Mine, Hudspeth County, Texas, *by J. G. Price. 34 p., 13 figs., 4 tables, appendix ($2.50).*

Silver deposits in Permian sandstones occur in a Basin and Range horst at the Plata Verde Mine, which is located in the Van Horn Mountains of Trans-Pecos Texas. Mining from 1934 to 1943 produced small amounts of silver, copper, and lead from shallow orebodies rich in the secondary mineral bromargyrite. Surface mapping indicates that before secondary oxidation, the primary ore was restricted to reduced rocks within a dominantly oxidized section. Reduction resulted from a combination of early sedimentary-diagenetic processes and later introduction of sulfide-rich waters along Tertiary faults.

On the basis of observed structural and lithologic controls, geochemical characteristics, and metal zonation, a mode of formation similar to that of some red-bed copper deposits is proposed for the Plata Verde ores. Elsewhere in Trans-Pecos Texas, deposits of perhaps an analogous origin occur in Precambrian and Cretaceous sandstones. Additional orebodies are likely where red-bed sequences are cut by faults that transmitted aqueous sulfides.

MRC 71. The Mineral Industry of Texas in 1980, *by A. E. Ward. 19 p., 1 fig., 14 tables (free on request).*

A cooperative agreement between the U.S. Bureau of Mines and the Bureau of Economic Geology produces this annual summary of all the nonfuel minerals of Texas. This circular is a preprint of the chapter on Texas in the U.S. Bureau of Mines' *Minerals Yearbook 1980.*

GEOLOGIC QUADRANGLE MAPS

GQ 48. Geology of the Marble Falls Quadrangle, Burnet and Llano Counties, Texas, *by V. E. Barnes. Scale 1:24,000, in full color, 15-p. text ($2.50).*

A geologic map and accompanying text describe the surface and subsurface geology and mineral deposits within the Marble Falls 7.5-minute topographic quadrangle, located in the eastern part of the Llano region. The map area includes about 36 percent Precambrian granite, 3 percent Cambrian rocks, 28 percent Ordovician rocks, 17 percent Pennsylvanian rocks, 1 percent Cretaceous rocks, nearly 7 percent Quaternary deposits, small outcrops of Mississippian and Devonian rocks, and the only Silurian outcrop known in the Llano region. About 8 percent of the quadrangle is covered by water; all of Lake Marble Falls and parts of Lake Lyndon B. Johnson and Lake Travis are in the map area. The granite for the State Capitol was quarried in the north-central part of the quadrangle.

GQ 49. Geology of the Pedernales Falls Quadrangle, Blanco County, Texas, *by V. E. Barnes. Scale 1:24,000, in full color, 34-p. text ($2.50).*

A geologic map and accompanying text describe the surface and subsurface geology and mineral deposits within the Pedernales Falls 7.5-minute topographic quadrangle, located in the southeastern part of the Llano region. The map area includes about 0.5 percent Cambrian rocks, 30 percent Ordovician rocks, 4.5 percent Pennsylvanian rocks, 65 percent Cretaceous rocks, small outcrops of Devonian and Mississippian rocks, and small amounts of Quaternary deposits. The Pedernales

River flows through the quadrangle, and the rapids at the eastern side form the north edge of the Pedernales Falls State Park.

GQ 50. Geology of the Spicewood Quadrangle, Blanco, Burnet, and Travis Counties, Texas, *by V. E. Barnes. Scale 1:24,000, in full color, 15-p. text ($2.50).*

A geologic map and accompanying text describe the surface and subsurface geology and mineral deposits within the Spicewood 7.5-minute topographic quadrangle, located in the eastern part of the Llano region. The map area includes 8.1 percent Ordovician rocks, 0.7 percent Devonian and Mississippian rocks, 3.5 percent Pennsylvanian rocks, 84.2 percent Cretaceous rocks, and 2.4 percent Quaternary deposits. Lake Travis, in the northeastern part of the quadrangle, covers 1.1 percent of the map area .

GQ 51. Geology of the Hammetts Crossing Quadrangle, Blanco, Hays, and Travis Counties, Texas, *by V. E. Barnes. Scale 1:24,000, in full color, 11-p. text ($2.50).*

A geologic map and accompanying text describe the surface and subsurface geology and mineral deposits within the Hammetts Crossing 7.5-minute topographic quadrangle, located in the southeastern part of the Llano region. The map area is entirely Cretaceous rocks, except for a few small Quaternary deposits and two small outcrops of Pennsylvanian rocks at the foot of Pedernales Falls. The deeply entrenched, sinuous Pedernales River crosses the quadrangle, and headward erosion of tributaries has produced falls such as the one at Hamilton Pool near the eastern border of the quadrangle. The Pedernales River in its western 6.5 mi either borders or is encompassed by Pedernales Falls State Park.

GQ 52. Geology of the Purdy Hill Quadrangle, Mason County, Texas, *by Emilio Mutis-Duplat. Scale 1:24,000, in full color, topographic base, 22-p. text ($2.50).*

A geologic map and accompanying text describe the surface and subsurface geology and mineral deposits within the Purdy Hill 7.5-minute topographic quadrangle, located in the northwestern part of the Llano region. The map area includes about 90 percent Precambrian, Cambrian, and Pennsylvanian rocks, 10 percent Cretaceous rocks, and some Quaternary surficial deposits. The quadrangle lies mostly within the Llano River basin to the south; about 15 percent of the quadrangle lies within the San Saba River basin to the north.

GQ 53. Geology of the Carta Valley Fault Zone Area, Edwards, Kinney, and Val Verde Counties, Texas, *by R. E. Webster. Scale 1:96,000, in full color, topographic base, 23-p. text ($3.00).*

A geological study conducted in 1977 and 1978 identified and evaluated deformation in part of the southwest Edwards Plateau, Texas. This map and accompanying text review the geologic history of the area and name, describe, and deduce the origins of the prominent structural features. Several large-scale structural features are delineated within a 1,000-mi² area comprising the Devils Lake, Dry Devil, Carta Valley, and Flat Rock 15-minute topographic quadrangle maps. The most prominent structural feature is the Carta Valley Fault Zone, an east-west-trending zone at least 55 mi long and 1 to 2 mi wide.

GEOLOGIC ATLAS OF TEXAS

Geologic Atlas of Texas, Fort Stockton Sheet, *Charles Laurence Baker Memorial Edition, V. E. Barnes, project director. Scale 1:250,000, in full color, topographic base ($4.00).*

The Fort Stockton Sheet covers parts of Brewster, Pecos, Presidio, Jeff Davis, Reeves, Terrell, and Crockett Counties. Mapping was compiled and field checked by J. E. Anderson, Jr., J. B. Brown, J. C. Gries, E. M. P. Lovejoy, and Dawn McKalips using high-altitude aerial photographs. The map was reviewed by the West Texas Geological Society.

This sheet is a memorial edition honoring Charles Laurence Baker (1887-1979). Mr. Baker was a member of the Bureau from 1914 to 1917 and again in the early 1930's, when he described the major structural features of Trans-Pecos Texas in one of the Bureau's most prestigious publications: *The Geology of Texas,* vol. 2, pt. 2, 1934 (Bulletin 3401). Mr. Baker had an illustrious career as geologist and chief geologist of various oil companies, as well as head of the Department of Geology at Texas A&M University for 9 yr and as Geologist, State Geological Survey of South Dakota, for 8 yr.

PUBLICATIONS REPRINTED

Guidebook 11. Recent Sediments of Southeast Texas—A Field Guide to the Brazos Alluvial and Deltaic Plains and the Galveston Barrier Island Complex, *by H. A. Bernard, C. F. Major, Jr., B. S. Parrott, and R. J. LeBlanc, Sr., and [Appendix] Resume of the Quaternary Geology of the Northwestern Gulf of Mexico Province, by H. A. Bernard and R. J. LeBlanc, Sr. 132 p., 97 figs., 1970 (sixth printing, $6.00).*

Guidebook 14. Pennsylvanian Depositional Systems in North-Central Texas, A Guide for Interpreting Terrigenous Clastic Facies in a Cratonic Basin, *by L. F. Brown, Jr., A. W. Cleaves II, and A. W. Erxleben. 122 p., 79 figs., 1 table, 1 plate, 1973 (fourth printing, $4.00).*

Handbook 4. Bituminous Coal in Texas, *by T. J. Evans. 65 p., 18 figs., 9 tables, 1 plate, 1974 (second printing, $3.50).*

Geological Circular 67-4. Depositional Systems in the Wilcox Group of Texas and Their Relationship to Occurrence of Oil and Gas, *by W. L. Fisher and J. H. McGowen. 20 p., 10 figs. Reprinted from Transactions of the Gulf Coast Association of Geological Societies, v. 17, p. 105-125, 1967 (fifth printing, $1.50).*

Geological Circular 69-4. Geometry and Distribution of Fluvial and Deltaic Sandstones (Pennsylvanian and Permian), North-Central Texas, *by L. F. Brown, Jr. 15 p., 22 figs. Reprinted from Transactions of the Gulf Coast Association of Geological Societies, v. 19, p. 23-47, 1969 (fifth printing, $1.50).*

Geological Circular 72-3. Evaluation of Sanitary Landfill Sites, Texas Coastal Zone—Geologic and Engineering Criteria, *by L. F. Brown, Jr., W. L. Fisher, and J. F. Malina, Jr. 18 p., 3 figs., 4 tables, 1972 (second printing, $1.00).*

Geological Circular 74-1. Depositional-Episodes: Their Relationship to the Quaternary Stratigraphic Framework in the Northwestern Portion of the Gulf Basin, *by D. E. Frazier. 28 p., 18 figs., 3 tables, 1974 (second printing, $1.25).*

Geological Circular 76-3. Geothermal Resources--Frio Formation, Upper Texas Gulf Coast, *by D. G. Bebout, R. G. Loucks, S. C. Bosch, and M. H. Dorfman. 47 p., 52 figs., 1976 (second printing, $3.00).*

Geological Circular 78-6. Identification of Surface Faults by Horizontal Resistivity Profiles, *by C. W. Kreitler and D. G. McKalips. 29 p., 17 figs., 1978 (second printing, $1.50).*

Geological Circular 80-2. Importance of Secondary Leached Porosity in Lower Tertiary Sandstone Reservoirs along the Texas Gulf Coast, *by R. G. Loucks, M. M. Dodge, and W. E. Galloway. 8 p., 17 figs., 1980. Reprinted from Transactions of the Gulf Coast Association of Geological Societies, v. 29, p. 164-171, 1979 (second printing, $1.00).*

Geological Circular 80-3. Hydrology and Water Quality of the Eocene Wilcox Group: Significance for Lignite Development in East Texas, *by C. D. Henry, J. M. Basciano, and T. W. Duex. 9 p., 8 figs., 1980. Reprinted from Transactions of the Gulf Coast Association of Geological Societies, v. 29, p. 127-135, 1979 (second printing, $0.75).*

Geological Circular 80-5. Studies of the Suitability of Salt Domes in East Texas Basin for Geologic Isolation of Nuclear Wastes, *by C. W. Kreitler. 7 p., 3 figs., 1980. Reprinted from Transactions of the Gulf Coast Association of Geological Societies, v. 29, p. 157-163, 1979 (second printing, $0.75).*

Geological Circular 80-6. Distribution and Significance of Coarse Biogenic and Clastic Deposits on the Texas Inner Shelf, *by R. A. Morton and C. D. Winker. 15 p., 7 figs., 2 tables, 1980. Reprinted from Transactions of the Gulf Coast Association of Geological Societies, v. 29, p. 352-364, 1979 (second printing, $1.00).*

Report of Investigations No. 72. Van Horn Sandstone, West Texas: An Alluvial Fan Model for Mineral Exploration, *by J. H. McGowen and C. G. Groat. 57 p., 36 figs., 1971 (third printing, $2.50).*

Report of Investigations No. 73. Depositional Systems in the Woodbine Formation (Upper Cretaceous), Northeast Texas, *by W. B. Oliver. 28 p., 15 figs., 1971 (third printing, $2.00).*

Publication 6120. The Ouachita System, *by P. T. Flawn, A. Goldstein, Jr., P. B. King, and C. E. Weaver. 401 p., 13 figs., 2 maps in color, 15 pls., 1961 (fourth printing, $12.00).*

Special Publication. Delta Systems in the Exploration for Oil and Gas, *by W. L. Fisher, L. F. Brown, Jr., A. J. Scott, and J. H. McGowen. 212 p., 168 figs., 1969 (tenth printing, $6.00).*

Research Note 10. Lower Cretaceous Carbonate Tidal Facies of Central Texas, *by R. G. Loucks, A. J. Scott, D. G. Bebout, and P. A. Mench. 45 p., 1978. Reprint of a field trip guidebook prepared for the Gulf Coast Association of Geological Societies, 1977 (third printing, $1.50).*

Geologic Atlas of Texas: Houston Sheet, *Paul Weaver Memorial Edition, V. E. Barnes, Project Director. 1968 (second printing, $4.00).*

Geologic Atlas of Texas: San Antonio Sheet, *Robert Hamilton Cuyler Memorial Edition. 1974 (second printing, $4.00).*

OPEN-FILE MATERIAL

The Bureau of Economic Geology maintains open files of reports, maps, manuscripts, and various data. Some have been obtained from private and governmental sources; some are unpublished materials developed at the Bureau of Economic Geology. These files may be examined and copied at the Bureau offices.

The Bureau of Economic Geology is a repository for open-file reports of the U.S. Department of Energy (DOE), formerly U.S. Energy Research and Development Administration (ERDA). Because of limited space, only those reports pertaining to Texas, plus reports of special interest, are filed at the Bureau. Others are transferred to the Geology Library of The University of Texas at Austin. Information concerning DOE and ERDA open-file reports may be obtained from the Technical Library, Grand Junction Office, U.S. Department of Energy, Box 2567, Grand Junction, Colorado 81502 (telephone: 303-242-8621, ext. 279), and also from the Bureau of Economic Geology.

A limited number of open-file reports of the U.S. Geological Survey are also on file at the Bureau. Information concerning additional reports of that organization may be obtained from the Open-File Services Section (OFSS), Branch of Distribution, U.S. Geological Survey, Box 25425, Federal Center, Denver, Colorado 80225 (telephone: 303-234-5888).

SERVICES

COMPUTING

The computing staff continued to provide computer programming and hardware services in 1982 to support Bureau research and administrative needs. Approximately 50 computer projects were completed or in progress at year's end; among major projects completed or initiated were the personnel cost management data base with numerous reporting programs, an index of 15,000 well logs used in waste isolation studies, and a well core library system, as well as several new scientific programs, including a lineaments analysis and display system. Interactive support for scientific programming was enhanced by the addition of more terminal links to University computers at all Bureau locations. A major effort, stimulated by Quality Assurance requirements, is underway to create a software and documentation library, which should benefit the Bureau by increasing access to and quality of computing resources and by reducing duplication of efforts.

The staff level of five full-time members and one half-time member remained substantially constant over the year. The level of hardware support for graphics and other specialized requirements, which includes a 36-inch, three-color drum plotter and a 3 ft x 4 ft digitizing tablet, was also unchanged during the year.

PUBLIC INFORMATION

The Bureau of Economic Geology, functioning as an information center, a repository of geological materials, and a publisher of geological reports and maps, provides a variety of information services to the public.

Daily requests for information about Texas geological, energy, mineral, and land resources come to the Bureau from a wide spectrum of the public, including geologists, teachers, hobbyists, students, landowners, and other interested individuals, as well as representatives of companies, governmental agencies, and other organizations.

Much information is available in the Bureau's published reports and maps, which present data developed through Bureau research programs. The publication sales group, supervised by Bettye Blitch, responds to requests for Bureau publications. Staff members who, in addition to other duties, handle mail and telephone requests and assist visitors who wish to purchase publications include Cindy Ellis, Debbie Gandy, Harpreet Kang, Amy Kelly, Frances Kirkpatrick, Wanda LaPlante, Rosie Peterson, Natalie Potts, and Karen Ramming.

The Bureau also responds to requests for special information. Many members of the full-time research staff provide advisory and technical services, as requested, in their areas of expertise in mineral, land, and energy resources. In addition, Roselle Girard and Mary McBride handle many requests for information about general Texas geology, mineral resources, references, and Bureau programs and publications.

The Bureau's Reading Room, located on the fifth floor of the Geology Building, is open for public use from 8 a.m. to 5 p.m., Monday through Friday. It contains publications pertaining to Texas geology and mineral resources, various journals, and other publications.

Also of interest to the public is the Bureau's collection of open-file reports. Included in the collection are reports received from the U.S. Department of Energy and other sources and also an assortment of unpublished reports that have been prepared by the Bureau of Economic Geology. Bureau staffer Kay Forward maintains these open files and makes arrangements for copying specific reports requested by the public.

The Bureau of Economic Geology provides ongoing services to governmental agencies by participating in reviews (1) of environmental impact statements that are submitted to the Office of the Governor of Texas and (2) of permit applications that are submitted to the Surface Mining and Reclamation Division of the Railroad Commission of Texas.

MINERAL STUDIES LABORATORY

Activities at the Mineral Studies Laboratory (MSL) during 1982 were concentrated in the following areas:

(1) Coal characterization: The MSL is responsible for all methodology development and subsequent application of methods for coal characterization. Using new instruments, some purchased jointly by Texas Energy and Natural Resources Advisory Council (TENRAC) and The University of Texas at Austin, and the existing facilities, the MSL has developed and adopted the methods to be used for proximate and ultimate analyses, as well as for inorganic characterization. These methods include the following: proximate analysis by thermogravimetric analyzer (TGA); simultaneous determination of C, H, and N by an automatic CHN analyzer; analysis of total Btu by adiabatic Parr calorimeter; determination of total sulfur by a sulfur analyzer, using amperometric titration; identification of forms of sulfur by successive HCl and HNO_3 extractions, followed by measurement of SO_4 and ferric iron by turbidimetric and atomic absorption spectrophotometry (AAS), respectively; simultaneous determination of major oxides in ash, as well as major, minor, and trace elements in whole coal by inductively coupled plasma - atomic emission spectroscopy (ICP-AES); accurate determination of volatile and selected toxic trace elements (halides, Se, As,

U_3O_8, Ag, Hg, B) by oxygen bomb combustion and by subsequent measurements of each element by various methods established at the MSL; and identification of mineral constituents by X-ray diffraction, following low-temperature asher (LTA) treatment.

Advantages of the newly developed instrumental methods for coal analysis over those of the classical type include high sensitivity, reproducibility, and efficiency. Homogeneity of samples is achieved by proper splitting and pulverizing to less than 200 mesh particle size. The new capabilities of the MSL have not only enabled the Bureau to produce high-quality analytical results in tests on lignites but also to provide analytical services to other departments of The University of Texas at Austin and to citizens of Texas.

(2) New capabilities for projects: Research on improving analytical methodologies and stepped-up efforts in quality assurance have continued to be major goals of the MSL for all projects. These efforts have resulted in the following new developments: application of ICP-AES for simultaneous, precise, and accurate determination of major elements in silicate rocks, sediments, and rock salts; application of TGA for determination of H_2O^- and H_2O^+ in silicate rocks; application of CHN analyzer for determination of organic carbon and carbonate in conjunction with LTA treatment; determination of Ag and Au by graphite furnace AAS and determination of K for K/Ar dating; complete chemical and mineralogical characterization of rock salts by using various chemical and instrumental methods; and determination of occludent water in rock salts by soxhlet extraction/Karl Fischer titration for the West Texas Waste Isolation project.

Currently, the MSL has compiled about 80 different analytical procedures for the determination of various constituents in samples such as ores, rocks, coals, rock salts, and waters of various formations, as well as biological specimens.

(3) Contribution to other laboratories: The MSL is a member of the International Geostandards Working Group. C. L. Ho, Chemist-in-Charge, joined the American Society for Testing Materials (ASTM) subcommittees D-19 for water analysis and D-5 for coal analysis. The MSL is participating in national and international round-robin testing programs to analyze peats and coals (Grand Forks Energy Technology Center of the U.S. Department of Energy, Center for Energy Research Laboratory of Kentucky, National Bureau of Standards); in water analysis for ammonium (ASTM); in analysis of rocks for major, minor, and trace elements by ICP-AES (the Geological Survey of Canada and the Institute of Geological Sciences of London); and in revision of existing ASTM techniques for determining Kjeldahl nitrogen in coal.

(4) Renovation of existing MSL and planning of new quarters: All old fumehoods in the MSL facility were replaced with new ones in 1982.

During 1982, the MSL analyzed 8,378 samples (881 were coals; 2,528 were waters; 4,839 were rocks, sediments, and rock salts; and 130 were submitted by the public). In addition, 730 samples were analyzed by the Sedimentology Laboratory of the MSL.

WELL SAMPLE AND CORE LIBRARY

The Well Sample and Core Library (WSL), located at Balcones Research Center, is one of the Nation's largest public collections of subsurface geological materials. Authorized by the Texas Legislature in 1937, the WSL collection includes cores from more than 2,600 wells; driller's logs, representing approximately 500,000 wells; scout tickets for approximately 5,000 wells in West Texas; and a revised figure for drill cuttings of 55,000 wells. Driller's logs and scout tickets can be copied at the WSL. Cores and cuttings may be examined where binocular scopes and other equipment are available for visitor use. Cores and cuttings may also be checked out for study; the borrower pays shipping fees. Interested persons may visit the facilities from 8 a.m. to 5 p.m., Monday through Friday.

Approximately 155 non-Bureau persons visited the Well Sample and Core Library during 1982, in addition to a larger number of persons who used the WSL through phone orders. During this period, 355 cores and 457 sets of cuttings were checked out to non-Bureau persons. Bureau personnel examined 82 cores and 255 sets of well cuttings. Also during 1982, the WSL produced 730 thin sections.

Because cores and cuttings from BEG research projects and from donations continue to be received at the WSL and because existing space at Balcones Research Center is filled, an additional 4,850 ft^2 of warehouse space was leased this year. Temperature and humidity are controlled in 3,600 ft^2 of this space to conform to the U.S. Department of Energy policy regarding storage of salt cores used in the West Texas Nuclear Waste Isolation program. The rented space allows for shelving of everything that was previously placed on the floor. Potential donors are asked to retain cores until the new 92,500 ft^2 repository is completed in 1984. More information regarding donations can be obtained by calling the Well Sample Library at (512) 835-3042.

Donors of subsurface materials to the Well Sample Library in 1982 include Canus Petroleum, Chevron, Cities Service, Eason Oil, Mr. Gus K. Eifler, Jr., Elf Aquitaine Oil & Gas, Bendix Engineering, Energetics, Energy Fuel Corp., Evergreen Oil, GMW Corp., Gulf Oil, Henry Petroleum, Hilliard Oil & Gas, Kriti Exploration, Lear-Vaughn Petroleum, Mitchell Energy, Montgomery Stratigraphic Services, Oneok Petroleum, ONG Exploration, Reita Oil, Shell Oil, Stone Oil Co., Sunedco, Tenneco Oil & Gas, Triton Oil & Gas, Texas Uranium Operations, Tucker Drilling, the U.S. Geological Survey, and U.S. Steel.

An important activity at the WSL during 1982 included transport, slabbing, painting of permanent orientation marks, and boxing and sampling of West Texas Nuclear Waste Isolation project cores from Oldham, Deaf Smith, and Swisher Counties. A total of 10,349 ft of core from these counties was processed this year. Another major activity has been preparing to move into the new facility, which involves reboxing approximately 90 percent of the cores held at the WSL. This procedure allows the WSL staff to inventory each well and to slab any remaining whole core.

The job of entering all data from well cuttings into the University computer system was started in 1978 and is now being completed. Printouts should be available by March 1983.

The Well Sample and Core Library is supervised by George A. Donaldson, Curator-in-Charge. Full-time employees are Daniel Ortuño, Clarence Talley, Francis O'Loughlin, Joseph Collins, James Doss, and Ronald Brock. Student employees are Richard Hunter, John Hendler, James Koga, Douglas Falls, Sylvester Harris, Greg Moore, Kelly Webb, and Stephen Thomas.

PERSONNEL

STAFF ACTIVITIES AND HONORS

FISHER RECEIVED AAPG AWARD

The American Association of Petroleum Geologists held its annual convention in Calgary, Alberta, Canada, June 27 to 30, 1982. Dr. W. L. Fisher received the AAPG Distinguished Service Award.

FISHER NAMED TO ENERGY RESOURCES BOARD

Bureau Director W. L. Fisher was appointed to a 3-yr term on the Board of Mineral and Energy Resources of the National Research Council, the principal operating arm of the National Academy of Sciences.

Dr. Fisher has served on several NAS committees, most recently chairing the Committee on the Producibility of Oil and Gas.

BEST PAPER AWARD

Thomas E. Ewing and S. Christopher Caran received the A. I. Levorsen Memorial Award and the First Best Paper Award for their presentation of "Late Cretaceous volcanism in South and Central Texas—stratigraphic, structural, and seismic models" at the 32nd annual meeting of the Gulf Coast Association of Geological Societies. Their paper, presented in Houston, Texas, was printed in the *Transactions* of the GCAGS meeting.

FISHER ELECTED AUTHORITY CHAIRMAN

Bureau Director W. L. Fisher was elected chairman of the Texas Low-Level Radioactive Waste Disposal Authority. Governor Clements appointed him to the board, and the Board of Regents approved his appointment at its April 1982 meeting. The appointment is subject to confirmation by the Texas Senate.

UT REGENTS' ACTIONS CONCERNING BEG

In its June 1982 meeting at Port Aransas, the UT Board of Regents approved the appointments of Dr. W. L. Fisher to the Morgan J. Davis Centennial Professorship in Petroleum Geology, and of Dr. W. E. Galloway to the Leslie Bowling Professorship in Geological Sciences. Appointments were effective September 1, 1982.

BEBOUT VOTED PRESIDENT-ELECT OF GC/SEPM

Dr. Don G. Bebout was voted president-elect of the Gulf Coast Section of the Society of Economic Paleontologists and Mineralogists (GC/SEPM). Dr. Bebout is serving as assistant to the president during 1982-83 and then will be president during 1983-84. In addition to business activities, the president of the GC/SEPM is responsible for organizing committees for the annual GCAGS meeting, organizing the annual research conference, and selecting a site and a leader for the annual field trip.

Dr. Bebout rejoined the Bureau staff in July 1982 and has been assigned to the Reservoir Characterization project. He is currently working on identifying carbonate facies control on production in Paleozoic fields of West Texas. Dr. Bebout was also a Research Scientist with the Bureau from 1972-1979; his special interests at that time were in Cretaceous carbonates and geopressured geothermal energy exploration. Between his two tours with the Bureau, Don spent 3 yr with the Louisiana Geological Survey as Director of Research. He has also been a faculty member of The University of Texas at Austin Department of Geological Sciences and the Louisiana State University Geology Department; he taught graduate courses at both universities.

VISITORS

As always, the Bureau of Economic Geology hosted many visitors during the year. The following visits in 1982 illustrate the outside interest in Bureau research programs:

(1) Dr. Antonio Cendrero, University of Santander, Spain, to discuss environmental and hydrologic problems in volcanics;

(2) Dr. Robert Jordan, State Geologist, Delaware, to discuss stratigraphic interpretation of seismic records in relation to depositional systems and rifted passive continental margins;

(3) Murdiono Wongsowinoto, Chief of Environmental Geology Division, Geological Survey of Indonesia, to discuss environmental geologic research implemented by governmental planners.

RATCLIFF PROMOTED TO ASSOCIATE DIRECTOR

Upon recommendation by the Bureau Director, the UT Vice President for Academic Affairs and Research approved the promotion of Doug Ratcliff to Associate Director for Administration, effective January 1, 1982. Ratcliff was previously Assistant Director of the Bureau.

Hired as an administrative clerk at the Well Sample Library in 1974, Ratcliff was promoted to head of operations at the WSL; in 1977 he assumed the position of Assistant Director.

Ratcliff's duties include overseeing contract requirements, quality assurance programs, financial statements, student personnel, and equipment requests.

IN MEMORIAM: ELOISE HILL

Eloise Hill died in Austin, Texas, on May 1, 1982, after a long illness. She was a Bureau employee for 25 yr. Mrs. Hill began working at the Bureau in October 1956 as a clerk-typist. She had been the Bureau's Executive Assistant since September 1973.

Shortly after her death, UT President Peter T. Flawn presented The University of Texas at Austin's Excellence Award to Mrs. Hill's family in honor of her outstanding service to the University. Mrs. Hill had learned of her award in April when Dr. Flawn informed her that she was one of the 50 honorees chosen by a special committee from hundreds of nominees.

Bureau Director W. L. Fisher noted that the award for excellence recognized "what those of us who worked with Eloise have known for years. Mrs. Hill was truly exemplary of the kind of energy and dedication that make the Bureau the outstanding place it is; we miss her sorely because she was one of us in every way."

Photograph by David M. Stephens.

Eloise Hill (L) and Bettye Blitch (R) confer on administrative matters.

BETTYE BLITCH APPOINTED EXECUTIVE ASSISTANT

Bettye Blitch, who worked closely with Mrs. Hill as an administrative assistant, was appointed as the new Executive Assistant for the Bureau in May. Bettye joined the Bureau staff as an administrative secretary in 1975. This spring, she was presented a 10-yr service award by UT President Peter T. Flawn at the University's Annual Service Awards Program.

SUSAN ELLINGTON RECEIVED TRC MERIT AWARD

Bureau switchboard operator Susan Ellington was honored with a Merit Award Certificate from the State Employment of the Handicapped Awards Program, co-sponsored by the Office of the Governor and the Texas Rehabilitation Commission.

Brian Hicks of the Texas Rehabilitation Commission and Bureau Director W. L. Fisher made the presentation to Susan. Susan was nominated by the Bureau, where she has been employed for 2 yr.

The awards program is designed to honor handicapped State employees who demonstrate the capabilities of the handicapped, who render outstanding service to the State, and who have shown courage and initiative in overcoming handicaps, thereby serving as an inspiration to others.

The nomination from the Bureau noted that Susan had assisted in establishing and implementing procedures for the Bureau's 140-extension PBX system.

Photograph by James A. Morgan.

Susan Ellington receives TRC award from Brian Hicks.

NEW BUILDINGS

In 1982, plans were finished for new Bureau of Economic Geology buildings at the Balcones Research Center (BRC), about 8 mi northwest of campus. E. G. Wermund, R. L. Dillon, D. C. Ratcliff, and W. R. Kaiser of the Bureau worked on the design with architects Barnes, Landes, Goodman, and Youngblood of Austin during the year. The new Bureau buildings, currently scheduled for completion about September 1984, will be part of the nucleus for a new University of Texas research center, which will also include a building to house both the Center for Energy Studies and the Center for Electromechanics, a power plant, and a commons. The commons will provide facilities for conference space, mailing, library exchange, computer remote job entry, and a cafeteria.

At a north entry to the new BRC complex, the Bureau will occupy two buildings on opposite sides of a boulevard. A large core warehouse will be connected by forklift tracks to a two-story building. The lower story will house all support facilities for the Well Sample Library (WSL), including rooms for sawing, boxing, washing, thin-sectioning, and studying of core and cuttings. The second story will be for the Mineral Studies Laboratory (MSL). Separate areas will be maintained for sample preparation and analysis of organic and inorganic samples.

The warehouse will occupy 2.3 acres, which will allow space for nearly 50 linear mi of shelves. The combined WSL and MSL structure will be about 35,000 ft^2 gross, nearly equally divided.

A three-story research and administration building on the east side of the principal entrance boulevard will comprise 150,000 ft^2 gross. The first floor will house administrative offices, a conference room, a library, room for publication sales and storage, and offices for visiting scientists. The second floor will contain cartography, computing, editing, word processing, and several research modules. The research modules will contain both offices and open work space for larger research programs. Four research modules will occupy the third floor along with a microscope room.

The exterior of all buildings will be a combination of grayish-tan tilt-up concrete and olive-gray metal facing. The research and administration building will have one entrance wall of fossiliferous limestone.

NEW RESEARCH STAFF MEMBERS

Don G. Bebout

Don joined the Bureau, effective July 1982. He earned his Ph.D. in geology in 1961 from the University of Kansas; his master's degree is from the University of Wisconsin, and his bachelor's is from Mt. Union College. Don's dissertation is entitled "Desmoinesian Fusulinids of Missouri." A Research Scientist, Don brings to the BEG his internationally recognized capabilities in research on carbonate reservoirs. Don is also well known for his research in geothermal resources.

Roy T. Budnik

Roy began working at the Bureau in January 1982 as a Research Associate and is involved in basin analysis for the West Texas Waste Isolation program. A 1968 graduate in geology from Northern Illinois University, he also has a Ph.D. in geology from the University of California at Los Angeles. His dissertation concerns the sedimentary and tectonic history of a subduction complex in southern Alaska.

Jules R. DuBar

Jules joined the Bureau in July 1982 as a Research Scientist. He holds a master's degree in geology from Oregon State University and a Ph.D. in paleontology and stratigraphy from the University of Kansas. Jules' areas of interest are paleoecology, stratigraphy, coastal plain geology, and Appalachian Basin geology. At the Bureau, he is working on the project entitled "Resource Evaluation of Late Oligocene Through Miocene Major Stratigraphic Units, Texas Gulf Coast Basin."

Alan R. Dutton

Alan joined the Bureau in February 1982 as a Research Associate and is involved in the West Texas Waste Isolation program. Alan has a bachelor's degree in geology from the University of Rochester, Rochester, New York, and received his doctorate in geology from The University of Texas at Austin. His dissertation concerns the hydrogeology of the unsaturated zone at a lignite strip mine in East Texas. His primary areas of study are hydrogeology and water chemistry.

R. Stephen Fisher

Steve was added as a Research Associate in April 1982. He has a bachelor's degree and a master's degree in geology from Miami University, Ohio. He is finishing his Ph.D. in geology at The University of Texas at Austin. His dissertation topic is "Diagenetic History of Wilcox Sandstones and Formation Water, South-Central Texas." Areas of research interest include sedimentary and aqueous geochemistry.

Steve is working on the West Texas Waste Isolation project.

Michael A. Fracasso

Mike was added in November 1982 as a Research Associate at the Bureau, where he is involved with the West Texas Waste Isolation project. He has bachelor's degrees in geology and biology from Boston University and a master's degree in geology from Yale University. He has completed requirements for a Ph.D. in geology from Yale and expects to formally receive his degree in 1983. His dissertation is entitled "Cranial Osteology, Functional Morphology, and Systematics of *Limnoscelis paludis* Williston." Mike's areas of study include paleontology and stratigraphy, continental clastic depositional environments, Permo-Carboniferous stratigraphy, and vertebrate paleontology.

Steven A. Frishman

Steve was added in February 1982 as a Research Associate at the Bureau, where he is involved in technical coordination and documentation for the West Texas Waste Isolation project. Steve has a bachelor's degree in geology from Clark University, Worcester, Massachusetts, and a master's degree in geology from The University of Texas at Austin. His thesis is entitled "Geochemistry of Oolites, Baffin Bay, Texas." His areas of study include marine geology and marine sciences, geochemistry, and sedimentology.

Colin M. Jones

Colin joined the Bureau staff as a Research Associate in April 1982. He has a bachelor's degree and a Ph.D. from the University of Keele, Newcastle-under-Lyme, United Kingdom. His dissertation concerns sedimentology of Carboniferous fluvial and deltaic sequences in the United Kingdom. Colin's special research interests are clastic sedimentology, subsurface geology, and exploration. He is now involved in the Deep-Basin Lignite project at the Bureau.

Alva Eugene Saucier

Gene was added in October 1982 as a Research Associate at the Bureau, where he is involved in the Tight Gas Sands project. He has a bachelor's degree in geology from Louisiana State University and a master's degree in geology from the University of New Mexico. His thesis concerns the Morrison and related formations in the Gallup region of New Mexico. Gene's primary areas of study are stratigraphy, petroleum geology, uranium exploration, and sedimentology.

PAPERS AND ABSTRACTS BY BUREAU OF ECONOMIC GEOLOGY STAFF IN OUTSIDE (NON-BUREAU) PUBLICATIONS

PAPERS

Bebout, D. G., 1982, Regional and local geological setting of the Technadril - Fenix and Scisson - Department of Energy, Gladys McCall No. 1 well-site, *in* Wallace, R. H., Jr., ed., Geopressured-geothermal energy resource appraisal: hydrogeology and well testing determine producibility: Louisiana Geological Survey, Guidebook Series No. 2, p. 49-71.

Bebout, D. G., and Gutierrez, D. R., 1982, Regional cross sections—western Louisiana Gulf Coast: Louisiana Geological Survey Folio Series, 10 p.

Calnan, T. R., 1982, The distribution of *Lumbrineris verrilli* and *Lumbrineris ernesti* (Lumbrineridae: Polychaeta) in the bays and on the inner continental shelf in the Brownsville, Corpus Christi, and Beaumont - Port Arthur areas: Texas Academy of Science, Proceedings, Symposium on Recent Benthological Investigations in Texas and Adjacent States, p. 269-278.

Caran, S. C., Woodruff, C. M., Jr., and **Ewing, T. E.,** 1982, Lineament analysis as an exploration technique—examples from Central Texas: Fort Worth, Texas Christian University and Environmental Research Institute of Michigan, Second International Symposium on Remote Sensing of Environment, Summaries, p. 112-113.

Conti, R. D., 1982, Stratigraphic distribution of hydrocarbons with differing API gravities in the East Texas Basin: Gulf Coast Association of Geological Societies Transactions, v. 32, p. 199-204.

Dutton, S. P., 1982, Pennsylvanian fan-delta and carbonate deposition, Mobeetie Field, Texas Panhandle: American Association of Petroleum Geologists Bulletin, v. 66, no. 4, p. 389-407.

Dutton, S. P., Kreitler, C. W., and Bracken, B. R., 1982, Formation and diagenesis of salt-dome cap rock, Texas Gulf Coast, *in* Handford, C. R., Loucks, R. G., and Davies, G. R., eds., Depositional and diagenetic spectra of evaporites—a core workshop: Society of Economic Paleontologists and Mineralogists Core Workshop No. 3, p. 100-129.

Ewing, T. E., 1982, Geology of the Kamloops Group near Kamloops (notes). Geologic map of Tertiary rocks of the Afton-Tranquille area west of Kamloops, British Columbia: British Columbia Ministry of Energy, Mines, and Petroleum Resources, Preliminary Map 48 and notes, 19 p., scale 1:50,000.

Ewing, T. E., and **Caran, S. C.,** 1982, Late Cretaceous volcanism in South and Central Texas—stratigraphic, structural, and seismic models: Gulf Coast Association of Geological Societies Transactions, v. 32, p. 137-145. Abstract in American Association of Petroleum Geologists Bulletin, v. 66, no. 9, p. 1429, and in San Antonio Geophysical Society Newsletter, December 2, p. 2.

Fisher, W. L., 1982, Depositional systems and environments: *in* Encyclopedia of science and technology, 5th Edition, New York, McGraw-Hill, p. 104-108.

Fisher, W. L., 1982, Oil and gas finding rates in projections of future production: National Bureau of Standards Special Publication 631, Washington, D.C., p. 564-580.

Fisher, W. L., 1982, Reservoir anatomy and additional oil recovery, *in* Impact of geologic parameters on enhanced oil recovery: U.S. Department of Energy, BETC, Special Publication, p. 8-13.

Fisher, W. L., 1982, Statement on Outer Continental Shelf issues (on behalf of Governor of Texas): Committee Print, Subcommittee on the Panama Canal/Outer Continental Shelf, U.S. House of Representatives, Serial 97-36, OCS Oversight, pt. 3, p. 57-69.

Fisher, W. L., 1982, Tars and heavy crude in Texas, *in* National tar sands (heavy oil): Kentucky Geological Survey, Lexington, symposium, p. 67-87.

Galloway, W. E., 1982, Depositional architecture of Cenozoic Gulf coastal fluvial systems: Society of Economic Paleontologists and Mineralogists Special Publication 31, p. 127-155.

Galloway, W. E., Hobday, D. K., and Magara, K., 1982, Frio Formation of Texas Gulf Coastal Plain—depositional systems, structural framework, and hydrocarbon distribution: American Association of Petroleum Geologists Bulletin, v. 66, no. 6, p. 649-688.

Gustavson, T. C., and Boothroyd, J. C., 1982, Subglacial fluvial erosion: a major source of stratified drift, Malaspina Glacier, Alaska, *in* Davidson-Arnott, R., Nickling, W., and Fahey, B. D., eds., Research in glacio-fluvial and glacio-lacustrine systems: Proceedings, 6th Guelph Symposium on Geomorphology: Norwich, England, GEO Books, p. 93-116.

Gustavson, T. C., Simpkins, W. W., Alhades, Alan, and Hoadley, Ann, 1982, Evaporite dissolution and development of karst features on the Rolling Plains of the Texas Panhandle: Earth Surface Processes and Landforms, v. 7, p. 545-563.

Henry, C. D., and **Morton, R. A.,** 1982, Trans-boundary geothermal resources of Texas and Mexico: Albuquerque, University of New Mexico School of Law, Natural Resources Center, Natural Resources Journal, Proceedings, Anticipating Trans-boundary Resource Needs and Issues in the Mexico-U.S. Border Region, v. 22, p. 973-989.

Tankard, A. J., **Jackson, M. P. A.,** Eriksson, K. A., Hobday, D. K., Hunter, D. R., and Minter, W. E. L., 1982, Crustal evolution of southern Africa: 3.8 billion years of Earth history: New York, Springer-Verlag, 523 p.

Kaiser, W. R., 1982, Lignite depositional models, Texas Eocene: a regional approach to coal geology, *in* Schobert, H. H., compiler, Basic coal science workshop, Proceedings [1981], Houston: U.S. Department of Energy, Grand Forks Energy Technology Center, p. 9-67.

White, D. M., **Kaiser, W. R.,** and Groat, C. G., 1982, Status of Gulf Coast lignite activity, *in* Kube, W. R., Sondreal, E. A., and White, D. M., compilers, Technology and use of lignite: U.S. Department of Energy, Grand Forks Energy Technology Center, GFETC/IC-82/1 (DE82015926), p. 107-141.

Kimble, R. S., 1982, The distribution of the genus *Ampelisca* (Crustacea: Amphipoda) with respect to sediment and bathymetry on the Texas inner shelf: Texas Academy of Science, Proceedings, Symposium on Recent Benthological Investigations in Texas and Adjacent States, p. 249-256.

Kolker, Allan, 1982, Mineralogy and geochemistry of Fe-Ti oxide and apatite (nelsonite) deposits, and evaluation of the liquid immiscibility hypothesis: Economic Geology, v. 77, p. 1146-1158.

Littleton, T. G., 1982, A comparison of the distribution of two species of *Periploma* (Bivalvia: Periplomatidae) in Matagorda Bay, Texas: Texas Academy of Science, Proceedings, Symposium on Recent Benthological Investigations in Texas and Adjacent States, p. 257-267.

Masterson, A. R., 1982, The role of the information specialist in U.S. state geological surveys, *in* Kidd, C. M., ed., 2nd International Conference on Geological Information, Proceedings: Oklahoma Geological Survey Special Publication 82-4, v. 2, p. 258-274.

Ruppel, S. C., and Walker, K. R., 1982, Sedimentology and distinction of carbonate buildups: Middle Ordovician, East Tennessee: Journal of Sedimentary Petrology, v. 52, no. 4, p. 1055-1071.

Ethridge, F. G., Sunada, D. K., **Tyler, N.,** and Andrews, S., 1982, Field, model, and computer simulation of some aspects of the origin and distribution of Colorado plateau-type uranium deposits: U.S. Geological Survey Open-File Report 82-589, 47 p.

Tyler, N., and **Han, J. H.,** 1982, Elements of high-constructive deltaic sedimentation, lower Frio Formation, Brazoria County, Texas: Gulf Coast Association of Geological Societies Transactions, v. 32, p. 527-540.

Wermund, E. G., 1982, Communicating with planners: mapping in Texas: Episodes, v. 1982, no. 3, p. 24-30.

Wermund, E. G., 1982, Texas geology translated to land and water resources mapping for planning development of mineral and energy resources, *in* Nutalaya, P., Karasudhi, P., Thanasuthipitak, T., Kheoruenromne, I., and Sudhiprakarn, A., eds., 1st International Symposium on Soil, Geology, and Landforms, Proceedings: Impact on Land Use Planning in Developing Countries: Bangkok, Thailand, p. G4.1-G4.45.

Woodruff, C. M., Jr., 1982, Geothermal anomalies in Central Texas—Darcy's law versus the heat-flow equation, *in* Ruscetta, C. A., ed., Geothermal direct heat program, roundup technical conference, Proceedings, v. I: State-Coupled Resource Assessment Program, DOE/ID/12079-71, ESL-98, p. 228-239.

Woodruff, C. M., Jr., Dwyer, L. C., and **Gever, C.,** 1982, Geothermal resources of Texas: National Geophysical Data Center, National Oceanic and Atmospheric Administration, 1 p., scale 1:1,000,000.

ABSTRACTS

Ayers, W. B., Jr., and **Kaiser, W. R.,** 1982, Tongue River (Paleocene) depositional systems and the occurrence of coal in the Powder River Basin of Wyoming and Montana: International Association of Sedimentologists, 11th International Congress on Sedimentology, abstract volume, p. 56.

Bassett, R. L., and **Smith, D. A.,** 1982, Origin, composition, and migration of brines in the Palo Duro Basin, Texas: American Chemical Society, 183rd national meeting, Nuclear Chemistry Section, abstract no. 42.

Bassett, R. L., Smith, D. A., and **Roberts, M. P.,** 1982, Utility of computerized data bases of drill-stem-test information in hydrogeologic studies: American Association of Petroleum Geologists Bulletin, v. 66, no. 5, p. 546.

Bebout, D. G., 1982, Exploration along Lower Cretaceous shelf margin--Golden Lane, Mexico, to Louisiana: American Association of Petroleum Geologists Bulletin, v. 66, no. 5, p. 548.

Bebout, D. G., 1982, Hydrocarbon exploration along the Lower Cretaceous Stuart City trend, Texas, and Golden Lane and Poza Rica Trend, Mexico: Houston Geological Society Bulletin, v. 25, no. 2, p. 2.

Caran, S. C., 1982, Honey Creek geological studies: Texas Nature Conservancy, Texas Horizons, v. 7, no. 3, p. 5.

Caran, S. C., 1982, Hydrothermal mineralization within the Balcones and Luling Fault Zones of Texas: Gulf Coast Association of Geological Societies Transactions, v. 32, p. 218. *Also in* American Association of Petroleum Geologists Bulletin, v. 66, no. 9, p. 1426.

Caran, S. C., Metallogeny within the Balcones and Luling Fault Zones of Central Texas: Texas Academy of Science, 85th annual meeting, Abstracts, v. 34, no. 1, p. 11-12.

Collins, E. W., and **Kreitler, C. W.,** 1982, Field relationships of "false cap rock," Butler Salt Dome, East Texas: Geological Society of America, Abstracts with Programs, v. 14, no. 3, p. 108.

Dutton, A. R., 1982, Chloride in the unsaturated zone of interfluvial-mud facies in the Calvert Bluff Formation (Eocene) at the Big Brown lignite mine, East Texas: Geological Society of America, Abstracts with Programs, v. 14, no. 7, p. 480.

Dutton, S. P., 1982, Facies control of cementation and porosity in Pennsylvanian fan-delta sandstones, Texas Panhandle: American Association of Petroleum Geologists Bulletin, v. 66, no. 5, p. 565.

Ewing, T. E., 1982, Décollement zones for Texas Gulf Coast growth fault trends: Geological Society of America, Abstracts with Programs, v. 14, no. 7, p. 486.

Ewing, T. E., and **Caran, S. C.,** 1982, Late Cretaceous volcanism in Texas: Texas Academy of Science, 85th annual meeting, Abstracts, v. 34, no. 1, p. 21.

Finley, R. J., and Hallam, S. L., 1982, High-resistivity shale cap rock: an indicator of leached secondary porosity?: International Association of Sedimentologists, 11th International Congress on Sedimentology, abstract volume, p. 120.

Finley, R. J., Price, J. G., and **Henry, C. D.,** 1982, Detection and analysis of supergene alteration at Red Hill, Chinati Mountains, Trans-Pecos Texas, using Landsat data: Fort Worth, Texas Christian University and Environmental Research Institute of Michigan, International Symposium on Remote Sensing of Environment, Remote Sensing for Exploration Geology Conference, Summaries, p. 169-170.

Fisher, R. S., 1982, Origin and evolution of formation water from Eocene Wilcox sandstones, south-central Texas: Geological Society of America, Abstracts with Programs, v. 14, no. 7, p. 489.

Galloway, W. E., 1982, Geohydrologic regimes of sandstone diagenesis: International Association of Sedimentologists, 11th International Congress on Sedimentology, abstract volume, p. 119.

Hoel, H. D., and **Galloway, W. E.,** 1982, Goliad Formation of the South Texas Gulf Coastal Plain: regional genetic stratigraphy and uranium mineralization: American Institute of Mining, Metallurgical, and Petroleum Engineers, Program Abstracts.

Goldstein, A. G., 1982, Progressive microstructural development of high-temperature mylonite from the Lake Char fault, northeastern Connecticut: Geological Society of America, Abstracts with Programs, v. 14, nos. 1 and 2, p. 21.

Keller, G. R., Kruger, J. M., Schneider, R. V., Aiken, C. L. V., Lai, S. F., Nielsen, K. C., and **Goldstein, A. G.,** 1982, Regional geophysical studies of the southern Oklahoma aulacogen and Ouachita System: Geological Society of America, Abstracts with Programs, v. 14, no. 3, p. 115.

Goldstein, A. G., and **McGookey, D. A.,** 1982, Minor fault motions in relationship to the Late Paleozoic tectonics of the Wichita-Amarillo Uplift: Geological Society of America, Abstracts with Programs, v. 14, no. 3, p. 111-112. *Reprinted in* Oklahoma Geological Survey, Oklahoma Geology Notes, v. 42, no. 2, p. 96.

Gustavson, T. C., and **Finley, R. J.,** 1982, Geomorphic development of eastern New Mexico and the Texas Panhandle: a product of subsidence due to regional dissolution of Upper Permian salts: Geological Society of America, Abstracts with Programs, v. 14, no. 7, p. 504.

Han, J. H., and Scott, A. J., 1982, Effects of syndepositional structures on Lower Vicksburg (Oligocene), fluvial-deltaic sedimentation, McAllen Ranch field area, Hidalgo County, South Texas: Gulf Coast Association of Geological Societies Transactions, v. 32, p. 254.

Henry, C. D., and **Jackson, M. L. W.,** 1982, Application of environmental geology to lignite mining in Texas: American Institute of Mining, Metallurgical, and Petroleum Engineers, annual meeting, Technical Program, p. 118.

Henry, C. D., and McDowell, F. W., 1982, Timing, distribution, and estimates of volumes of silicic volcanism in Trans-Pecos Texas: Geological Society of America, Abstracts with Programs, v. 14, no. 3, p. 113.

Henry, C. D., McDowell, F. W., and **Price, J. G.,** 1982, Magmatism in West Texas and Chihuahua related to Tertiary subduction: Geological Society of America, Abstracts with Programs, v. 14, no. 7, p. 513.

Walton, A. W., and **Henry, C. D.,** 1982, A model of sedimentation in rhyolitic volcanic fields: the Oligocene of Trans-Pecos Texas: Geological Society of America, Abstracts with Programs, v. 14, no. 7, p. 641.

Jackson, M. L. W., 1982, Integration of environmental geologic maps and subsurface maps in the utilization of upper Eocene Jackson-Yegua lignite, East Texas: Geological Society of America, Abstracts with Programs, v. 14, no. 7, p. 521.

Eriksson, K. A., and **Jackson, M. P. A.,** 1982, Pre-3000 Ma earth surface processes: EOS, v. 63, no. 18, p. 366.

Jackson, M. P. A., 1982, Reassessment of the concept of Precambrian granite-greenstone terranes and high-grade terranes: EOS, v. 63, no. 18, p. 367.

Jackson, M. P. A., and **Seni, S. J.,** 1982, Geometry and structural evolution of salt diapirs in a marginal rift basin of the Gulf of Mexico: Geological Society of America, Abstracts with Programs, v. 14, no. 7, p. 521.

Jackson, M. P. A., Seni, S. J., and McGowen, M. K., 1982, Initiation of salt flow, East Texas Basin: American Association of Petroleum Geologists Bulletin, v. 66, no. 5, p. 584-585.

Kaiser, W. R., 1982, Predicting diagenetic history and reservoir quality in the Frio Formation (Oligocene) of Texas: International Association of Sedimentologists, 11th International Congress on Sedimentology, abstract volume, p. 119-120.

Boyd, F. M., and **Kreitler, C. W.,** 1982, Hydrogeology and geochemistry of the northern salt basin of West Texas and New Mexico: Geological Society of America, Abstracts with Programs, v. 14, no. 7, p. 449.

Littleton, T. G., 1982, The distribution, abundance, and ecology of the family Pyramidellidae in lower Laguna Madre, Texas: Bulletin of the American Malacological Union for 1981, p. 30.

Price, J. G., and **Henry, C. D.,** 1982, Infiernito caldera—petrologic characteristics and mineralization: Geological Society of America, Abstracts with Programs, v. 14, no. 3, p. 134.

Price, J. G., and **Henry, C. D.,** 1982, Porphyry copper-molybdenum deposit associated with the Chinati Mountains caldera, Trans-Pecos Texas: Geological Society of America, Abstracts with Programs, v. 14, no. 7, p. 593.

Ruppel, S. C., 1982, Depositional setting of the lower Carboniferous (Mississippian) in the Palo Duro Basin of the Texas Panhandle: Geological Society of America, Abstracts with Programs, v. 14, no. 7, p. 605.

Simpkins, W. W., Gustavson, T. C., and **Finley, R. J.,** 1982, Rates of erosion in a semi-arid environment: analysis of a two-year data record in the Texas Panhandle: Geological Society of America, Abstracts with Programs, v. 14, no. 3, p. 136.

Tewalt, S. J., Roberts, M. P., and Kim, N. H., 1982, Relating coal quality to geology through geostatistics: Geological Society of America, Abstracts with Programs, v. 14, no. 7, p. 630.

Ethridge, F. G., **Tyler, N.,** and Burns, L. K., 1982, Sedimentology of a Precambrian quartz-pebble conglomerate: southwest Colorado: International Association of Sedimentologists, 11th International Congress on Sedimentology, abstract volume, p. 52-53.

LECTURES AND PUBLIC ADDRESSES

Mary L. Ambrose

Mountain building: presented to a third-grade class, Austin Independent School District, Austin, Texas.

Robert W. Baumgardner, Jr.

Central Texas flood hazards, with examples from the May 24, 25, 1981, Austin flood: presented to a geologic

hazards class, Department of Geological Sciences, The University of Texas at Austin.

Don G. Bebout

Economic potential of the geopressured geothermal resource: presented at Conference on the Economic Future of the Central Gulf South, University of New Orleans, New Orleans, Louisiana.

Geopressured geothermal energy along the U.S. Gulf Coast: presented at Geothermal Resources Council, annual meeting, Houston, Texas.

Geopressured geothermal resources, Louisiana Gulf Coast: presented to American Planning Association (sponsored by Louisiana State University and State of Louisiana), Baton Rouge, Louisiana.

Lower Cretaceous shelf margin carbonates of the northern Gulf of Mexico: presented to Houston Geological Society, Houston, Texas.

L. F. Brown, Jr.

Seismic stratigraphic and depositional systems analyses: new exploration approaches applied to the Gulfo San Jorge Basin, Argentina: presented to the First National Hydrocarbon Congress, Buenos Aires, Argentina.

Seismic stratigraphy in petroleum exploration and stratigraphy of rift depositional systems: presented to Australian Bureau of Mineral Resources (Australian Geological Society), Canberra, A.C.T., Australia.

S. Christopher Caran

Geologic interpretation of remote images—effects of image type and quality, and of seasonal acquisition: presented to graduate and undergraduate classes in remote sensing (field trip to Honey Creek Preserve), Department of Geography, The University of Texas at Austin, Austin and Bulverde, Texas.

Geology and hydrology of Honey Creek Preserve, Comal County, Texas: presented at National Board of Governors, annual meeting, Nature Conservancy, Bulverde, Texas.

Geology of Ezell's Cave, Hays County, Texas: presented at Ezell's Cave National Natural Area (field trip), Texas Nature Conservancy, San Marcos, Texas.

Geology of the Zilker Nature Trail, Austin, Texas: presented to Austin Natural Science Center, nature trail advisory meeting, Austin, Texas.

Geology of Texas Nature Conservancy preserves: presented to Texas Nature Conservancy, first annual stewardship conference, Bulverde, Texas.

Inferring function from form—fundamentals of paleoecology: presented to Texas Memorial Museum, summer enrichment program for gifted science students, Austin, Texas.

Remote sensing and the San Antonio area: presented (with Charles Palmer and Raymond W. Neck) at Association of American Geographers, 1982 annual meeting field trip, San Antonio, Texas.

Edward W. Collins

Surficial geology studies for East Texas Waste Isolation: presented to geology students at Trinity University, San Antonio, Texas.

Susann Doenges

Editorial procedures at the Bureau of Economic Geology: presented to University editors, The University of Texas at Austin.

Alan R. Dutton

Mass transport through hydrogeologic facies in the unsaturated zone at Big Brown lignite mine, East Texas: presented to The University of Texas at Austin, Department of Geological Sciences, technical sessions.

Shirley P. Dutton

Meteoric water versus formation water origin of salt dome cap rock: presented to The University of Texas at Austin, Department of Geological Sciences, technical sessions.

Pennsylvanian fan-delta and carbonate deposition, Mobeetie Field, Texas Panhandle: presented at Fort Worth Geological Society meeting, Fort Worth, Texas.

R. Stephen Fisher

Diagenetic history of Eocene Wilcox sandstones and associated formation water, south-central Texas: presented to Department of Geological Sciences, The University of Texas at Austin, seminar.

W. L. Fisher

Activities in Texas lignite: presented to Beaumont Rotary Club, Beaumont, Texas.

Governmental role, free enterprise, and public values: presented to American Society of Real Estate Counselors, Symposium on Mineral Resources and Economic Security of the United States, Phoenix, Arizona.

Mining in Texas economy: presented to Texas Mining and Reclamation Association, Kerrville, Texas.

Natural gas in Texas: trends of the 1970's and future outlook: presented at TIPRO mid-winter meeting, Austin, Texas.

Oil in Texas: a perspective on the past and future: presented at Krost Symposium on Texas Oil Frontiers: Past, Present, and Future, Texas Lutheran College, Seguin, Texas.

Comments on trends in oil and gas exploration: presented at seminar on oil and gas exploration, Library of Congress, Congressional Research Service, Washington, D.C.

Potential for additional oil recovery in Texas: presented to Texas Petroleum Research Committee, Conference on Enhanced Oil Recovery, Austin, Texas.

Role of Outer Continental Shelf oil and gas resources in national security: presented to American Institute of Professional Geologists, annual meeting, Pasadena, California.

Tars and heavy crude in Texas: presented at National Tar Sands (Heavy Oil) Symposium, Lexington, Kentucky.

Texas and coal: a look into the future: presented to Texas Energy Forum, State of Texas Office of State-Federal Relations, Washington, D.C.

The U.S. position in mineral resources: presented at Arkansas Mining and Minerals Study Week Celebration, Russellville, Arkansas, banquet address.

Steven A. Frishman

Use of obsolete offshore production structures in artificial reef enhancement: presented at Gulf of Mexico Information Transfer Meeting, OCS Office, Minerals Management Service, U.S. Department of Interior, New Orleans, Louisiana.

William E. Galloway

Fluvial and deltaic petroleum reservoirs, Frio Formation, northern Gulf Coast: presented at Fifth Short Course on the Fluvial System, Colorado State University, Department of Earth Resources, Fort Collins, Colorado.

Fluvial deposits and uranium in Tertiary rocks of the Texas Coastal Plain: presented at Fifth Short Course on the Fluvial System, Colorado State University, Department of Earth Resources, Fort Collins, Colorado.

Frio Formation of the Texas Gulf Coastal Plain: depositional systems, structural framework, and hydrocarbon distribution: presented at Canadian Society of Petroleum Geologists luncheon, Calgary, Canada.

Geohydrologic regimes of sandstone diagenesis: 11th International Congress on Sedimentology, International Association of Sedimentologists, Hamilton, Ontario, Canada.

Paleohydrology of the uraniferous Oakville aquifer: presented at Penrose Conference, Hydrodynamics and Geochemistry of Ore Generation in Sedimentary Environments (sponsored by Geological Society of America), Lake of the Ozarks, Missouri.

Review of depositional environments of the Gulf Coast Tertiary: presented at Marathon Seminar Series, Southern Methodist University, Department of Geological Sciences, Dallas, Texas.

Roadside geology of New Zealand: presented at Austin Geological Society meeting, Austin, Texas.

Salt dissolution in the Palo Duro Basin, Texas: presented to Southern Methodist University, Department of Geology, Dallas, Texas.

Seismic and stratigraphic models of a depositional platform margin and case histories and field documentation of seismic reflection patterns: presented at American Association of Petroleum Geologists, Stratigraphic Interpretation of Seismic Data, short course, Irving, Texas.

Thomas C. Gustavson

Salt dissolution in the Texas Panhandle: presented at Southern Methodist University, Geology Department, technical session, Dallas, Texas.

Sedimentation in gravel streams: presented at Southern Methodist University, Geology Department, technical session, Dallas, Texas.

Christopher D. Henry

Application of environmental geology to lignite mining in Texas: presented at American Institute of Mining, Metallurgical, and Petroleum Engineers, national meeting, Dallas, Texas.

Mary L. W. Jackson

Fossils in Shoal Creek bed: presented at an Austin Recreation Center class, Austin, Texas.

Geology of the Audubon Sanctuary: presented at Travis Audubon Society field trip, Austin, Texas.

Summary of land resources studies: presented to Texas A&M University, Soil Survey and Land Resource Workshop, College Station, Texas.

M. P. A. Jackson

Determination of strain in diapiric rock salt: presented to The University of Texas at Austin, Department of Geological Sciences, structural geology class.

Reassessing the concept of Precambrian cratons and mobile belts: presented at Lunar and Planetary Institute, Houston, Texas.

Upward flow of diapiric rock salt and the formation of anhydrite cap rock in Oakwood Dome, East Texas: presented at The University of Texas at Dallas, Programs in Geosciences, open lecture/technical session.

W. R. Kaiser

Brines, clay minerals, and equilibrium: predicting diagenesis in the Frio Formation of Texas: presented at American Association of Petroleum Geologists, Role of Clay Minerals in Hydrocarbon Exploration, research conference, Santa Fe, New Mexico.

Allan Kolker

Petrology of Fe-Ti oxide and apatite (nelsonite) deposits: presented at The University of Texas at Austin, Department of Geological Sciences, noon seminar series.

Charles W. Kreitler

Hydrogeology of the aquifers surrounding the Gulf of Mexico: presented to The University of Texas at Austin, Department of Geological Sciences, class on the geology of the Gulf of Mexico.

Hydrologic evolution of Gulf Coast aquifers: presented at Penrose Conference, Hydrodynamics and Geochemistry of Ore Generation in Sedimentary Environments (sponsored by Geological Society of America), Lake of the Ozarks, Missouri.

Patterns of petroleum accumulation in East Texas salt dome province: presented at East Texas Association of Petroleum Landsmen, monthly meeting, Tyler, Texas.

Mary W. McBride

The Bureau of Economic Geology—a source of information for earth science teachers: presented to Austin Independent School District, Austin, Texas, in-service day meeting, and to Texas Advisory Committee on Environmental and Energy Education, semiannual meeting, Austin, Texas.

The geologic setting of East Texas iron ores—a cursory look (layman's field trip): presented to Texas Advisory Committee on Environmental and Energy Education, semiannual meeting, Longview, Texas.

Robert A. Morton

Coastal hazards and public policy: presented to The University of Texas at Austin, Department of Geological Sciences, geology class.

Effects of impermeable structures on shoreline stabilization and land loss—the Texas experience: presented at the Conference on Coastal Erosion and Wetlands Modification in Louisiana (sponsored by the Louisiana Universities Marine Consortium), Baton Rouge, Louisiana.

Mathematical prediction of beach dynamics: presented at Second Conference on Naval Special Warfare Technology, Applied Research Laboratory, Austin, Texas.

Methane entrained in Gulf Coast geopressured aquifers: presented at Houston Geological Society, monthly meeting, Houston, Texas.

Status of geopressured geothermal research and resource assessment in Texas: presented at Industry Forums (sponsored by the U.S. Department of Energy), New Orleans, Louisiana, and Houston, Texas.

Uncertainties of and incentives for developing geopressured geothermal energy: presented to The University of Texas at Austin, Department of Geological Sciences, geology class.

Jonathan G. Price

Geochemical characterization of unleached and leached ores: presented to The University of Texas at Austin, Department of Petroleum Engineering, In-Situ Uranium Leaching Advisory Panel.

Hydrothermal alteration in porphyry-type ore deposits: presented to The University of Texas at Austin, Department of Geological Sciences, geology class.

Principles of mineral exploration: porphyry copper, porphyry molybdenum, and skarn deposits: presented to The University of Texas at Austin, Department of Geological Sciences, geology class.

Steven J. Seni

Basin analysis, salt movement, and petroleum accumulation patterns—East Texas Basin: presented at North Texas Geological Society, monthly meeting, Wichita Falls, Texas.

History of salt movement in the East Texas Basin: presented at East Texas Geological Society, monthly meeting, Tyler, Texas.

Sedimentary record of Cretaceous and Tertiary salt movement, East Texas Basin—key to timing, rates, and volumes of salt flow: presented at The University of Texas at Dallas, Program in Geosciences, technical sessions.

Sedimentary record of salt movement in the East Texas Basin: presented to Placid Oil Company, San Antonio, Texas.

William W. Simpkins

Rocks: presented at Children's Discovery Center, Austin, Texas.

Water: presented to a fifth grade science class, Andrews Elementary School, Austin, Texas.

Water resources in the Austin area: presented to an earth science class, Anderson High School, Austin, Texas.

Susan J. Tewalt

What a geologist does: presented at Roy Bedichek Junior High School Career Fair, Austin, Texas.

E. G. Wermund

Bureau of Economic Geology — responsibilities and programs: presented to the Austin chapter of the American Statistics Association, Austin, Texas.

Geologic mapping in Texas: presented to cluster meeting of U.S. Geological Survey Central Division Geologists and Central State Geologists, Lake Ouachita, Arkansas.

Geologic research on deep geological burial of radioactive waste and its political sensitivity: presented to The University of Texas at Austin, Department of Geological Sciences, geology class.

History of Bureau of Economic Geology involvement in research on buried radioactive waste: presented to staff of Texas Senate Committee on Natural Resources, Austin, Texas.

Hurricane flooding and coastal processes: presented at Workshop on Earth-Science Data Applications to Land-Resource Planning (sponsored by U.S. Geological Survey and American Planning Association), Pan American University, Edinburg, Texas.

Mapping environmental geology and land resources for governmental planners: presented to The University of Texas at Austin, Department of Geological Sciences, geology class.

Recent developments of energy and mineral exploitation in Texas peripheral to Oklahoma: presented to the American Institute of Professional Geologists, Oklahoma Section, Tulsa, Oklahoma.

Texas involvement in National Waste Terminal Storage: presented to committee staff of U.S. House of Representatives, bill sponsored by R. L. Ottinger, Washington, D.C.

William A. White

Active processes and hazards along the Texas Coastal Zone: presented to The University of Texas at Austin, Department of Geological Sciences, geologic hazards class.

C. M. Woodruff, Jr.

Geology of Central Texas—an overview: presented to Travis County Archeological Society, Austin, Texas.

Geothermal gradient anomalies and remotely sensed lineaments along the Balcones/Ouachita trend, Central Texas: presented to Corpus Christi Geological Society, Corpus Christi, Texas.

Lineaments on Landsat—applications to resource exploration: presented at The University of Texas at Austin, Department of Government, Space and Society Symposium.

CONGRESSIONAL, LEGISLATIVE, AND SPECIAL TESTIMONY

U.S. Federal Energy Regulatory Commission, Washington, D.C. (on behalf of Governor of Texas)—W. L. Fisher (testimony given: "High-Cost Natural Gas Produced from Intermediate Deep Drilling").

U.S. House of Representatives, Subcommittee on Fossil and Synthetic Fuels, Hearings on Natural Gas Policy Act, Washington, D.C.—W. L. Fisher (with Mack Wallace and Walt Rostow, on behalf of Governor and Lt. Governor of Texas).

U.S. House of Representatives, Committee on the Outer Continental Shelf and Panama Canal: Oversight Hearings on OCS, Houston, Texas—W. L. Fisher (on behalf of Governor of Texas).

Texas Senate Committee on Natural Resources, Amarillo—W. L. Fisher (testimony given: "Bureau of Economic Geology: Role in DOE Nuclear Waste Disposal Site Activities in the Palo Duro Area, Texas").

Texas Energy and Natural Resources Advisory Council—W. L. Fisher, "Status of High-Level Waste Disposal Activities in Texas."

Texas Energy and Natural Resources Advisory Council—W. L. Fisher, "Projections of Lignite Production and Consumption to the Year 2000."

COMMITTEE SERVICES, OFFICES, AND OTHER PROFESSIONAL RESPONSIBILITIES

Robert W. Baumgardner, Jr.

Co-leader of field trip, "Geology of the Texas Panhandle," for Bureau of Economic Geology research staff.

Don G. Bebout

Chairman, Carbonate Research Group, 1981-1982, Society of Economic Paleontologists and Mineralogists.

Co-chairman, Program Advisory Committee, Gulf Coast Section, Society of Economic Paleontologists and Mineralogists Third Annual Research Conference, November 28 - December 1, 1982, Jurassic of the Gulf Rim, Baton Rouge, Louisiana.

Contributing author, Geological Society of America, Decade of North American Geology (DNAG), Gulf of Mexico volume.

Leader of field trip, "Ancient Carbonates, Central Texas," American Association of Petroleum Geologists.

Leader of field trip, "Lower Cretaceous Carbonates of Central Texas," Dallas Geological Society.

Member, Core Preservation Committee, American Association of Petroleum Geologists.

Member, Membership Committee, American Association of Petroleum Geologists.

Member, Publications Committee, Society of Economic Paleontologists and Mineralogists.

President Elect, Gulf Coast Section, Society of Economic Paleontologists and Mineralogists, 1982-1983.

Vice President/President Elect, Baton Rouge Geological Society, 1981-1982.

L. F. Brown, Jr.

Associate Editor, American Association of Petroleum Geologists Bulletin.

Continuing Education Lecturer, Seismic Stratigraphy Schools, American Association of Petroleum Geologists.

Continuing Education Lecturer, short courses in various aspects of basin analysis, American Association of Petroleum Geologists.

S. Christopher Caran

Chairman, 1982-1983, Earth Science Section, Texas Academy of Science.

Vice-chairman, 1981-1982, Earth Science Section, Texas Academy of Science.

Co-leader of field trip (with J. C. Grenda, W. J. Brown, and D. L. Lokke), "Permian and Cretaceous Stratigraphy, Tom Green County, Texas," Earth Science Section, Texas Academy of Science.

Shirley P. Dutton

Judge of presentations, Society of Economic Paleontologists and Mineralogists annual meeting, Calgary, Alberta, Canada.

Member, Committee on Midcontinent Province: United States, volume for the Decade of North American Geology, sponsored by the Geological Society of America.

Member, Committee on Stratigraphic Correlations, American Association of Petroleum Geologists.

Thomas E. Ewing

Delegate, American Association of Petroleum Geologists House of Delegates, representing Austin Geological Society, 1982-1985.

Publications Editor, Austin Geological Society, 1982-1983.

Secretary, Austin Geological Society, 1981-1982.

Robert J. Finley

Member (through January 1982), Citizens' Environmental Board, City of Austin.

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

W. L. Fisher

Associate Editor, American Association of Petroleum Geologists Bulletin.

Chairman, Committee on Producibility of Oil and Natural Gas, National Research Council, National Academy of Sciences.

Chairman, Energy Committee, Texas 2000 Commission.

Chairman, Executive Committee, Council on Energy Resources, The University of Texas at Austin.

Chairman, Geology and Resource Recovery Task Force, GURC.

Chairman, Nuclear Energy Committee, Texas Energy and Natural Resources Advisory Council.

Chairman, Conference on Natural Gas Resources Estimation, U.S. Department of Energy/RAND Corporation.

Chairman, Texas Low-Level Radioactive Waste Disposal Authority.

Commissioner, Texas 2000 Commission.

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

Member, Academic Liaison Committee, American Association of Petroleum Geologists.

Member, Advisory Board, Center for Energy Studies, The University of Texas at Austin.

Member, Advisory Committee, Institute for Latin American Studies, The University of Texas at Austin.

Member, Advisory Group, Southern Illinois University.

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

Member, Committee on Access to Public Lands, American Institute of Professional Geologists.

Member, Committee on Committees, Geological Society of America.

Member, Committee on Engineering Consideration for Deep Sea Drilling, National Research Council, Assembly of Engineering, Marine Board.

Member, Committee on Mineral Availability Program of U.S. Bureau of Mines, Association of American State Geologists.

Member, Environmental Geology Committee, American Institute of Professional Geologists.

Member, Executive Committee, Geology Foundation, The University of Texas at Austin.

Member, Governmental Liaison Committee, Association of American State Geologists.

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

Member, Natural Resources Committee, Texas Energy and Natural Resources Advisory Council.

Member, Policy Development Council, GURC.

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

Member, Program Development Council, GURC.

Member, Public Affairs Committee, Association of American State Geologists.

Member, Publications Committee, Society of Economic Geologists.

Member, Renewable Resources Committee, Southern States Energy Board.

Member, Research Committee, Interstate Oil Compact Commission.

Member, Resolution Committee, Interstate Mining Compact Commission.

Member, Technical Program Committee, American Association of Petroleum Geologists/Offshore Technology Conference.

Member, Texas Energy and Natural Resources Advisory Council.

Member, Texas Energy and Natural Resources Advisory Council, National Governor's Task Force for Federal Energy Regulatory Commission Inquiry.

Member, Texas Mapping Advisory Committee.

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

President, Association of American State Geologists.

Steven A. Frishman

Consultant (FY82), National Advisory Committee on Oceans and Atmosphere--Fisheries Task Force, National Ocean Goals and Objectives for the 1980's.

William E. Galloway

Session Co-chairman, technical symposium, International Association of Sedimentologists, 11th International Congress on Sedimentology.

Chester M. Garrett, Jr.

Delegate, 1981-1983, American Association of Petroleum Geologists, Austin Geological Society.

Chairman, 1982-1983, Finance Committee, Austin Geological Society.

Member, 1981-1982, Finance Committee, Austin Geological Society.

Arthur G. Goldstein

Co-leader of field trip, "Geology of the Texas Panhandle," for Bureau of Economic Geology research staff.

Thomas C. Gustavson

Co-chairman, Geomorphology session, South-Central Section, Geological Society of America.

Co-chairman, Geomorphology session, national meeting, Geological Society of America.

Co-leader of field trip, "Geology of the Texas Panhandle," for Bureau of Economic Geology research staff.

Christopher D. Henry

Chairman-Organizer, Symposium on Cenozoic volcanism in Trans-Pecos Texas: sponsored by the Geological Society of America, South-Central Section meeting.

Clara L. Ho

Member, American Society for Testing and Materials, Subcommittees D-19 (water) and D-5 (coal and coke).

Member, International Working Group of the Association Nationale de la Recherche Technique, Paris.

Mary L. W. Jackson

Treasurer, Austin Geological Society.

Allan Kolker

Co-leader of field trip, "Geology of the Texas Panhandle," for Bureau of Economic Geology research staff.

Charles W. Kreitler

Editor, Journal of Ground Water.

Mary W. McBride

Chairwoman, Publications Committee, Austin Geological Society.

Member, Evaluation of the Revised Science Curriculum Subcommittee of the Texas Advisory Committee on Environmental and Energy Education.

Robert A. Morton

Co-leader of field trip to sedimentary environments of the Louisiana-Texas coast, Geological Society of America.

Member, Academic Liaison Committee, Texas Section, American Institute of Professional Geologists.

Member, Well Review and Selection Committee, U.S. Department of Energy, Division of Geothermal Energy.

Douglas C. Ratcliff

Member, Membership Committee, American Association of Petroleum Geologists.

William W. Simpkins

Co-leader of field trip, "Geology of the Texas Panhandle," for Bureau of Economic Geology research staff.

Member, Technical Advisory Committee, North Rolling Plains Resource Conservation and Development Area.

E. G. Wermund

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

Member, Publications Committee, American Association of Petroleum Geologists.

Member, Publications Committee, Geological Society of America.

William A. White

Chairman, Field Trip Committee, Austin Geological Society.

C. M. Woodruff, Jr.

Chairman, Nominating Committee, Austin Geological Society.

Coordinator for Texas, Hydrothermal/Geothermal Resource Assessment Teams, U.S. Department of Energy, Division of Geothermal Energy.

Vice Chairman, City of Austin Environmental Board.

UNIVERSITY TEACHING/ CONTINUING EDUCATION

Don G. Bebout

Ancient Carbonate Facies and Depositional Environments (Geology 7939): Department of Geology, Louisiana State University, Baton Rouge, Louisiana.

(*with* Clyde Moore) Ancient Carbonates, Central Texas: Field Seminar for American Association of Petroleum Geologists, Central Texas area.

Carbonate Exploration School, subsurface logging exercise: American Association of Petroleum Geologists, Miami, Florida.

Subsurface Geological Basin Analysis (Geology 4131): Department of Geology, Louisiana State University, Baton Rouge.

L. F. Brown, Jr.

Depositional Systems and Seismic Stratigraphy in Basin Analysis: Australian Mineral Foundation and American Association of Petroleum Geologists, Adelaide, Australia.

Seismic Stratigraphy and Basin Analysis: American Association of Petroleum Geologists, Park City, Utah, and Dallas, Texas; and at Permian Basin Graduate Center, Midland, Texas; and to Department of Geological Sciences, The University of Texas at Austin; and to University of Tulsa advanced exploration school, Tulsa, Oklahoma.

Seismic Stratigraphy in Petroleum Exploration: presented to Institute of Technology, Department of Geology, Bandung, Java, Indonesia; and to Department of Geology, University of Gadjahmada, Jogjakarta, Java, Indonesia; and to Pertamina (Indonesian government oil company), Jakarta, Java, Indonesia.

Shirley P. Dutton

Formation and Diagenesis of Salt-Dome Cap Rock, Texas Gulf Coast: Society of Economic Paleontologists and Mineralogists Core Workshop on Depositional and Diagenetic Spectra of Evaporites, Calgary, Alberta, Canada.

Geology, Geophysics, and Hydrocarbon Potential of the Palo Duro Basin: Permian Basin Graduate Center, Midland, Texas.

W. L. Fisher

Depositional Systems in Oil and Gas Exploration: Canadian Society of Petroleum Geologists, Calgary, Canada.

Evaluating Federal Energy Policy, Policy Research Project (PA 882B): LBJ School of Public Affairs, The University of Texas at Austin.

Role of Facies Analysis in Seismic Stratigraphy: Oklahoma City Geological Society, Oklahoma City, Oklahoma.

William E. Galloway

Advanced Petroleum Geology of Terrigenous Clastic Depositional Systems: Earth Resources Foundation, University of Sydney, Sydney, New South Wales, Australia.

Basin and Trend Analysis in Exploration (Geology 379K): Department of Geological Sciences, The University of Texas at Austin.

Depositional Systems in the Exploration for Sandstone Stratigraphic Traps: Oklahoma City Geological Society/American Association of Petroleum Geologists, Continuing Education short course, Oklahoma City, Oklahoma.

Research in Sedimentary-Economic Geology (Geology 394): Department of Geological Sciences, The University of Texas at Austin.

Christopher D. Henry

Geology and Geochemistry of the Sinaloa Batholith, Western Mexico: presented to division seminar, Division of Earth and Physical Sciences, The University of Texas at San Antonio.

Geology, Timing, and Geochemistry of Magmatism in Trans-Pecos Texas: presented to graduate seminar, Department of Geology, Texas Christian University, Fort Worth, Texas.

M. P. A. Jackson

Guide to Oil and Gas Exploration in the East Texas Basin with Emphasis on Subtle Traps: Professional Seminar Group, Dallas, Texas.

W. R. Kaiser

Environments of Coal Deposition: seminar for Branch of Coal Resources, U.S. Geological Survey, Reston, Virginia.

Charles W. Kreitler

Investigation and Monitoring Procedures for Ground-Water Contamination Studies: U.S. Environmental Protection Agency, Dallas, Texas.

Formation and Diagenesis of Salt-Dome Cap Rock, Texas Gulf Coast: Society of Economic Paleontologists and Mineralogists Core Workshop on Depositional and Diagenetic Spectra of Evaporites, Calgary, Alberta, Canada.

Steven J. Seni

Guide to Oil and Gas Exploration in the East Texas Basin with Emphasis on Subtle Traps: Professional Seminar Group, Dallas, Texas.

SUPPORT STAFF

ADMINISTRATIVE/SECRETARIAL

The administrative/secretarial staff fulfills an important role in achieving the goals of the Bureau. These staff members are, in many respects, the Bureau's closest contact with the general public. In support of various research programs, staff members complete administrative, accounting, and secretarial tasks essential to the day-to-day operation of the Bureau. Mrs. Bettye Blitch, Executive Assistant, coordinates the work of the administrative/secretarial staff.

CARTOGRAPHY

Dan F. Scranton, Chief Cartographer, directs the work of the Cartography Section for the Bureau. Much of the Bureau's reputation in the areas of geologic and land resource mapping is a reflection of the excellent cartographic capability of these staff members. Besides the high-quality, full-color map products that are the hallmark of the Cartography Section, the present staff also produces a full range of other maps, text illustrations, slide copy, and display materials.

The staff also provides technical photographic support for the Bureau's publications, lectures and public addresses, and research projects. Most of the photographic work consists of slides and cover and text photographs.

PUBLICATIONS PREPARATION

A central part of the Bureau's function as a public geological research organization is to make available the results of its research programs. This is accomplished chiefly by means of its publications. Preparing Bureau reports for publication involves word processing and typesetting, editing, graphics design, and layout.

Lucille Harrell coordinates the work of the word processing and typesetting section. Susann Doenges directs the editorial staff, and Dan F. Scranton directs the design department.

BUREAU OF ECONOMIC GEOLOGY

Dr. W. L. Fisher, Director
Dr. L. F. Brown, Jr., Associate Director
Dr. Robert A. Morton, Associate Director
Dr. E. G. Wermund, Associate Director

Douglas C. Ratcliff, Associate Director for Administration
Eloise Hill, Executive Assistant
Bettye A. Blitch, Executive Assistant

RESEARCH SCIENTISTS

Dr. Virgil E. Barnes
Dr. Don G. Bebout
Dr. Jules R. DuBar
Dr. Robert J. Finley
Dr. William E. Galloway
A. Ray Gregory
Dr. Thomas C. Gustavson
Dr. Christopher D. Henry
Dr. Clara L. Ho
Dr. Martin P. A. Jackson
Dr. William R. Kaiser
Dr. Charles W. Kreitler
Dr. Charles M. Woodruff, Jr.

RESEARCH ASSOCIATES

Dr. Roy T. Budnik
Gary F. Collins
Dr. Alan R. Dutton
Shirley P. Dutton
Dr. Thomas E. Ewing
Dr. W. Keene Ferguson
Dr. R. Stephen Fisher
Dr. Michael A. Fracasso
Steven A. Frishman
Dr. Arthur G. Goldstein
Dr. Jong H. Han
Dr. Colin M. Jones
Dr. Zsay-Shing Lin
Dr. Jonathan G. Price
Dr. Stephen C. Ruppel
A. Eugene Saucier
Steven J. Seni
William W. Simpkins
Dr. Noel Tyler
William A. White

RESEARCH SCIENTIST ASSOCIATES

Mary L. Ambrose
Walter B. Ayers, Jr.
Nancy J. Banta
Robert W. Baumgardner, Jr.
Thomas R. Calnan
S. Christopher Caran
Eric S. Cheng
Edward W. Collins
Robert D. Conti
E. Dow Davidson, Jr.
Graham E. Fogg
Chester M. Garrett
Christine R. Gever
Roselle M. Girard
Dorothy L. Gower
Thomas C. Greimel
Tucker F. Hentz
Margaret J. Herron
Susan D. Hovorka
Mary L. W. Jackson
Lee A. Jirik
David A. Johns
Russell S. Kimble
Allan Kolker
Amy H. Lewis
Long-Cheng Liang
Thomas G. Littleton
Marcie D. Machenberg
Gwendolyn L. Macpherson
Mary W. McBride
Douglas A. McGookey
Elizabeth D. Orr
Jeffrey G. Paine
Jan S. Posey
Roneé S. Reed
D. Anderson Smith
Susan J. Tewalt
Sterling F. J. Thomas
Dr. Prakob Wirojanagud
Debra H. Wood
H. Victor Wuerch III

*Research Assistants

CARTOGRAPHIC STAFF

Dan F. Scranton
Chief Cartographer
John T. Ames
Mark T. Bentley
Thomas M. Byrd
Micheline R. Davis
Margaret R. Day
Richard L. Dillon
Margaret L. Evans
Richard P. Flores
Barbara M. Hartmann
Jamie S. Haynes
Jeff S. Horowitz
Jamie A. McClelland
James A. Morgan, Jr.
Richard M. Platt
David M. Ridner

ADMINISTRATIVE STAFF

Bettye A. Blitch
Executive Assistant
Eloise Hill
Executive Assistant
Lisa R. Berlinger
Michaela E. Clark
Ricardo DeLeon
Jillene M. Eliason
Cynthia G. Ellis
Susan Ellington
Daniel Feliciano
S. Kay Forward
Marcia J. Franklin
Debbie F. Gandy
Thomas M. Glimp
*Roger E. Harrell
Louise E. Harsey
Patrice J. Johnson
Harpreet Kang
Helen Kedzierski
Amy E. Kelly
Frances A. Kirkpatrick
Mary E. Koch
Wanda L. LaPlante
Shirlee M. Long
Nancy A. Miller
Rose M. Peterson
Natalie T. Potts
Karen K. Ramming
*Donald J. Ruisinger
*Jill C. Russell
Troy R. Salmon
Verna M. Speights
Doris J. Tyler
*J. David Ussery
M. Jean Wilke
Virginia C. Zeikus

EDITORIAL STAFF

Susann V. Doenges
Editor-in-Charge
Michelle C. Gilson
Jane Hedgepeth
Rebecca P. Lasley
R. Marie Littleton
Amanda R. Masterson
Susan H. Shaw
Laura A. Stalker
Jean M. Trimble

WORD PROCESSING/ TYPESETTING STAFF

Lucille C. Harrell
Administrative Assistant
Margaret T. Chastain
Phyllis J. Hopkins
Dorothy C. Johnson
Jana J. McFarland
Fannie M. Sellingsloh

MINERAL STUDIES LABORATORY

Dr. Clara L. Ho
Chemist-in-Charge
*James Nile Barnes
Karin Campbell
Dorothy L. Gower
Charles W. Kan
Cynthia A. Mahan
Eric Pfitzner
Wai-Ching Tam
Steven W. Tweedy
Paul N. Williams

WELL SAMPLE AND CORE LIBRARY

George A. Donaldson
Curator-in-Charge
Gilbert Arismendez
Ronald P. Brock
Joseph A. Collins
James A. Doss
Rosemary Guajardo
John J. Hendler
Richard D. Hunter
James K. Koga
Francis W. O'Loughlin
*Maduabuchuku C. Oluka
Daniel H. Ortuño
Paul G. Randall
Clarence C. Talley, Jr.

COMPUTING STAFF

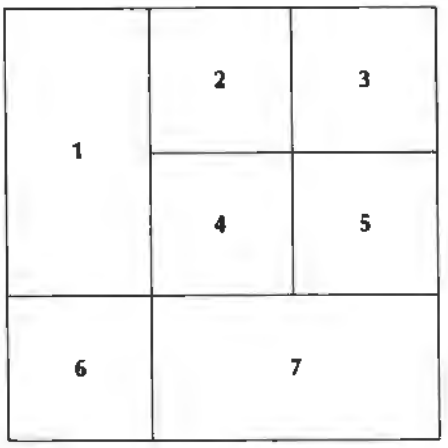
Michael P. Roberts, Manager
Dale V. Clark
Audie L. Dobbs
Richard W. Ozment
Jane D. Tingley
Thomas J. Wilmore

SEDIMENTOLOGY LABORATORY AND THIN SECTION SERVICES

Seay H. Nance
Research
Associate-in-Charge
Ethel E. Butler
Mary K. Plowman

RESEARCH ASSISTANTS

William A. Ambrose
Richard G. Anderson
E. M. Andrews-Goodman
Joseph P. Ash
Olufemi O. Babalola
David G. Becker
Mark J. Berlinger
Paul E. Blanchard
Janet C. Boland
Bryan R. Bracken
Emil Bramson
Patricia L. Brock
Jenny E. Burgen
Rachel J. Burks
Steven M. Carlson
Pilar Castañeda
Ming Huen Chan
Yueming Chen
Wendy L. D'Attilio
Richard F. Davis
James A. DiGiulio
Richard E. Dobson
Edward A. Duncan
Laura M. C. Dwyer
Douglas A. Falls
Richard B. Farrand
Guy A. Felton
Gail L. Fisher
Rebecca A. Fountain
Debbie D. Fowler
Nancy E. Frank
Victor J. Gavenda
Gregory J. Gilson
Steven M. Glimp
Jaime Grana
Rosemary Guajardo
David D. Guetzow
Gay Nell Gutierrez
Susan L. Hallam
Paul A. Hardwick
Anne K. Harris
Sylvester Harris
Virginia W. Henderson
John J. Hendler
Karen L. Herrington
Dana L. Hershberger
Patricia M. Hester
Katherine C. Hubby
John R. Hultman, Jr.
Richard D. Hunter
Cecil W. Irby, Jr.
Mark A. Jarecki
Charles G. Johnson
Beverly K. Johnston
Charles W. Kan
Phyllis A. Kapeller
Nae-Heon Kim
James K. Koga
Ralph L. Kugler
Kwan Yiu Lau
Thomas R. Laughery
Therese M. Lemmer
Peggy A. Loessberg
Victor H. Lombeida
Stephen E. Lovell
Maria E. Lucas
Barbara A. Luneau
Maria M. Madiedo
G. Scott Mather
Ronald G. McMurry
Karen J. Meador
Kathleen R. Minahan
Wahiduzzaman Mirza
Srikanta Mishra
Greg G. Moore
Patricia M. Moseley
R. Matthew Myers
Paul R. H. Neville
Ron B. Nickel
David C. Noe
James F. O'Connell
Wilbert I. Odem
Jill E. O'Neal
Kimberley A. Owens
Loren F. Phillips
Vicki J. Prestwood
Bruce A. Pridgen
David A. Prouty
David N. Purgason
Maria B. Ramsey
David C. Reutter
Bernd C. Richter
Diane E. Robinson
Frances E. Russell
Troy R. Salmon
Melissa A. Sandstrom
Rainer K. Senger
Thomas M. Simmons
Janice L. Smith
James R. Smits
Fred R. Snyder
Stephen W. Speer
Allan R. Standen
Krishnamurthy Subramanian
Wai-Ching Tam
Michael B. Tenbrook
Stephen C. Thomas
Jeffrey E. Thurwachter
Bright A. Tom-Quinn
Amy Wanamaker
Jeff B. Watson
Kelly O. Webb
Marcia D. Welch
Clayton H. Wilson
Steven G. Wilson
Geoffrey E. Wilwerding
Madison T. Woodward III
John N. Wright
David R. Wuerch



1. Tension fractures near the Wink Sink, Winkler County, Texas.
2. Photograph of thick section of anhydrite cap rock from Oakwood salt dome.
3. Regional structural setting of Palo Duro and Dalhart Basins.
4. Open-pit mining of uranium.
5. Photomicrograph of San Andres rocks.
6. Part of a stratigraphic strike section of the upper Wilcox, Lower Texas Gulf Coast.
7. Sand outcrop of the Yegua Formation.

BUREAU OF ECONOMIC GEOLOGY
The University of Texas at Austin
University Station, Box X
Austin, Texas 78712

Address correction requested

BOOKS

BOOKS