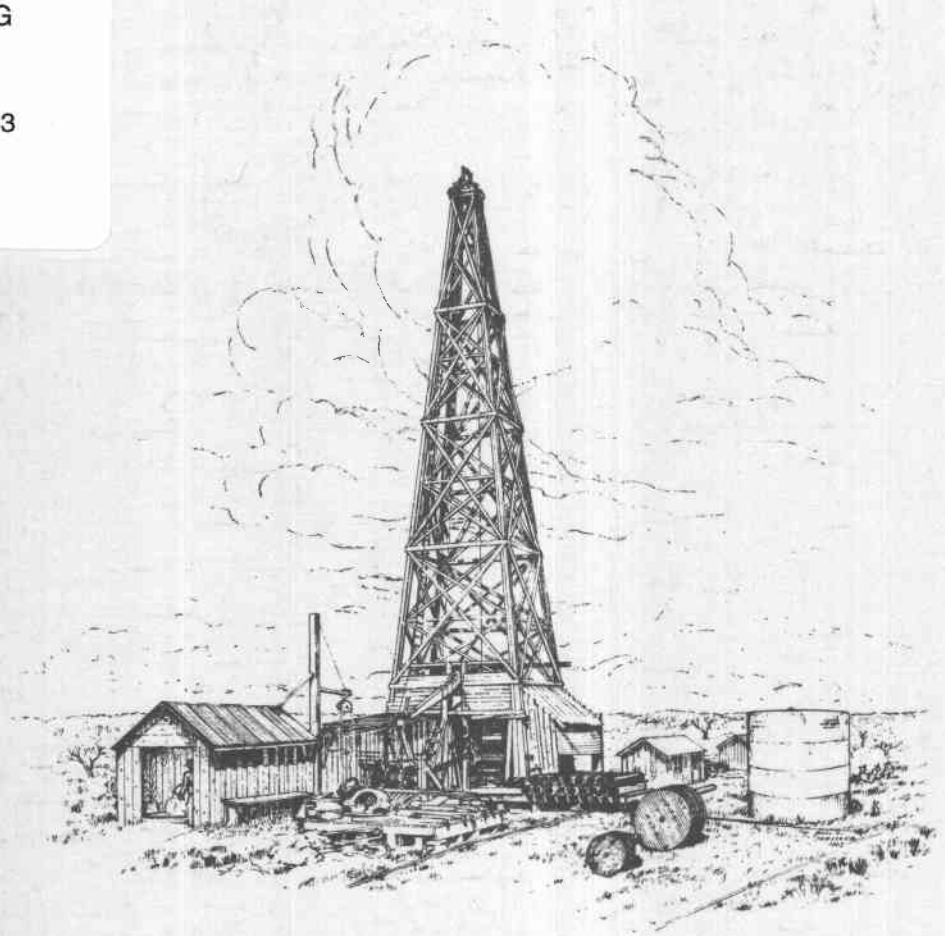


Centennial of The University of Texas at Austin, 1883-1983

ANNUAL REPORT 1983

Bureau of Economic Geology

W. L. Fisher, Director • The University of Texas at Austin • Austin, Texas 78712

FOREWORD

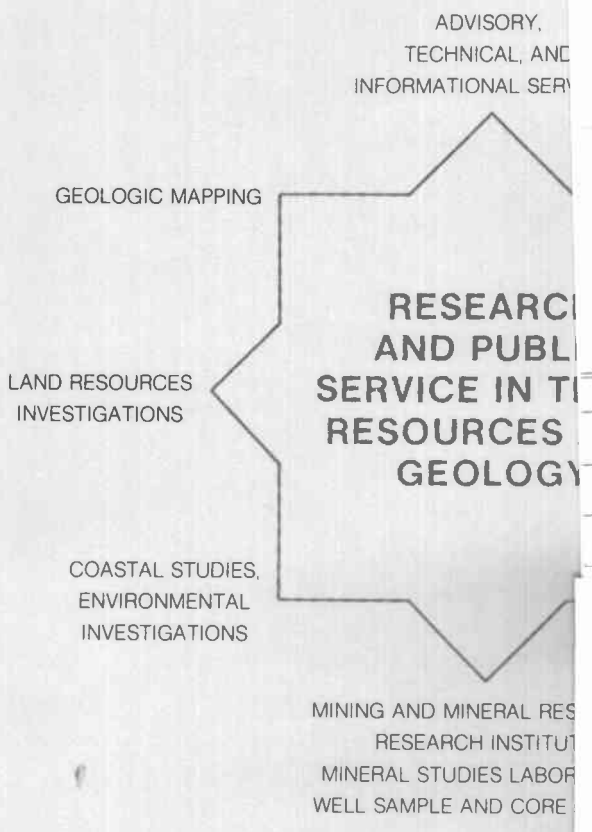
The Bureau of Economic Geology, established in 1909 as the successor to the Texas Geological Survey and the Texas Mineral Survey, is a research entity of The University of Texas at Austin. It also functions as the State Geological Survey, a quasi-State agency, and the Bureau Director represents Texas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

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

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

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

The Annual Report of the Bureau of Economic Geo
projects, publications, personnel activities, and servi
available to governmental agencies, industry, and th



On the cover: Santa Rita No. 1, which blew in at Big Lake field on May 28, 1923,
Texas land. In observance of the University's Centennial, 1883-1983, the Bureau
of its Special Publications series.

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CONTENTS

RESEARCH

In 1984, the Bureau of Economic Geology begins its 75th year of geological research in Texas. Since it was established, the Bureau has carried out projects designed to answer basic questions about the geology of the state and its myriad mineral, energy, and land resources. Bureau scientists have emphasized basic surface and subsurface research and its potential application for prudent and economical use of the state's mineral and energy resources. Programs have been started far ahead of application to determine the appropriate geological facts required for proper utilization. Such a research program has naturally developed an extensive knowledge not only of the resources and geology of Texas, but also of geological concepts having widespread applications. Today, Bureau research continues to address specific needs in the geologically diverse State of Texas. At the same time, it strives to develop broader, more fundamental geological concepts that may affect the long-range resource and environmental future of Texas, as well as the science of geology.

Research scientists address a variety of problems, ranging from energy and mineral resources to high-level nuclear waste isolation. Other areas include geopressured geothermal studies in the Gulf Basin, coastal geology, mineral resources of Trans-Pecos Texas, basic geologic mapping, and maintenance of a statewide data base of mineral statistics. Geological studies directed toward these areas of research focus on basin analysis, geochemistry, geohydrology, and geomorphology. About 75 professional staff scientists, including geologists, engineers, biologists, and chemists, work in a variety of team research programs to focus maximum expertise toward answering basic questions about the future of Texas' energy and natural resources.

During 1983, a major activity of the Bureau was the writing, drafting, editing, typesetting, and printing of the *Atlas of Major Texas Oil Reservoirs*. This report resulted from reservoir characterization studies done in 1982 and supported in part by the Texas Energy Development Fund. More detailed analysis of selected carbonate and clastic reservoirs continued during 1983.

Major multidisciplinary research in 1983 continued to evaluate the feasibility of Permian salt in the Texas Panhandle for safe isolation of high-level nuclear waste. Ongoing since mid-1977, this program sponsored by the U.S. Department of Energy (DOE) has required integrated research by a variety of specialists to evaluate hydrological and tectonic security, as well as to characterize repository stratigraphy, potential resources, and surface processes. Much of the 1983 effort was directed at analysis of cores and hydrological data derived from extensive drilling activities in 1982 and early 1983. Of critical national, State, and local concern, these studies require exceedingly sophisticated science and quality control.

Coring and hydrological testing of deep-basin Eocene lignite seams and associated complex sandstone aquifers in the East Texas Basin was a principal thrust in 1983. Funded in part by the Texas Energy Development Fund, the field testing program has permitted detailed chemical and petrographic characterization of Texas lignite, analysis of the geohydrology of Eocene fluvial and deltaic aquifers, and development of geophysical logging techniques needed to evaluate the feasibility for future in situ gasification programs. A critical resource for the 21st century, deep-basin lignite must be thoroughly researched before extensive deep-basin utilization can be successfully undertaken.

Other major ongoing research efforts include a study of low-permeability ("tight") gas resources in the Lower Cretaceous Travis Peak Formation in East Texas and adjacent Louisiana. The tight gas program, funded by the Gas Research Institute (GRI), addresses depositional systems, reservoir characteristics, and transferable procedures for optimum development. In 1983, onshore and offshore Miocene correlations, depositional systems, and initial play analysis progressed toward an integrated picture of these coastal and potential State and Federal shelf trends. Studies are designed to evaluate the potential for further development of onshore Miocene production and to assess similar development and further exploration in State and Federal waters. Researchers continue to analyze the potential for further production of free gas and solution gas from geopressured and associated hydropressured Tertiary reservoirs in the Gulf Coast Basin. Growing out of long-term geopressured geothermal studies sponsored by DOE, these more specific analyses continue with DOE and GRI funding. Structure, engineering, and reservoir continuity are aspects under investigation. Statewide computerized mineral producers data were updated in 1983 and an abridged list of mineral producers was published. An annotated bibliography (and maps) of mineral deposits in Trans-Pecos Texas was also compiled.

Research was completed and the first of seven area atlases of the Texas submerged lands was published in 1983. The atlas, titled *Submerged Lands of Texas, Corpus Christi Area: Sediments, Geochemistry, Benthic Macroinvertebrates, and Associated Wetlands*, established the format for the seven-volume series. Field work began in 1974 and laboratory analysis of almost 7,000 samples was completed in 1983. Atlases will be released during 1984 and 1985 as they are completed. Mapping was completed on the 20-year Geologic Atlas of Texas. Field checking of the Wichita Falls - Lawton sheet was finished and reached cartography in late 1983. This final atlas map will be incorporated into a 1:500,000-scale Texas geologic map that was in cartographic preparation during 1983. Statewide gravity and magnetic atlases at 1:250,000 scale went into cartographic processing in 1983. Compilation of a 1:750,000-scale tectonic map of Texas was completed and reviewed by regional geological societies during the year. Further details about these and other research highlights of 1983 are listed in the following summaries of Bureau research programs.

ENERGY RESOURCES INVESTIGATIONS

EVALUATING THE GEOLOGY AND GROUND-WATER HYDROLOGY OF DEEP-BASIN LIGNITE IN THE WILCOX GROUP OF EAST TEXAS

W. R. Kaiser, project director

This study, begun in September 1981 and funded by the Texas Energy and Natural Resources Advisory Council (TENRAC) and by legislative appropriation, is a continuing effort to evaluate deep-basin lignite in Texas. Work has been concentrated in the Sabine Uplift area and east-central Texas.

Geology

W. B. Ayers, Jr., Amy H. Lewis, Gary F. Collins, W. R. Kaiser, Colin M. Jones, Mary L. W. Jackson, D'Nese Y. Fly, and Mary L. Ambrose; assisted by Frank H. Bissett, Curtis W. Black, and Thomas R. Laughery

The Eocene Wilcox is the principal lignite host in Texas and a major fresh-water aquifer. Deep-surface mining and underground gasification pose questions about technology to maximize lignite recovery and to minimize environmental impacts. Thus, the regional hydrogeological framework for site selection, planning, and permitting of future deep surface mines and underground gasifiers is being developed by mapping lignite occurrence, sand-body (aquifer) geometry, and circulation and chemical evolution of ground water. TENRAC drilling, coordinated by the Bureau, tested lignite and evaluated aspects of the hydrology in the deep basin. Recovered lignite has undergone extensive chemical analysis.

In the Sabine Uplift area, a detailed subsurface study of the Trawick gas field, north-central Nacogdoches County, was completed during 1983. Sand-body geometry and depositional facies confirmed the regional trends and succession from deltaic to fluvial sedimentation. The most continuous lignites occur at the top of the deltaic lower Wilcox, whereas seams at the top of the upper Wilcox are laterally limited by channel sands. Lower Wilcox lignites probably evolved from interdistributary to blanket peats. Upper Wilcox lignites are assigned a backswamp origin.

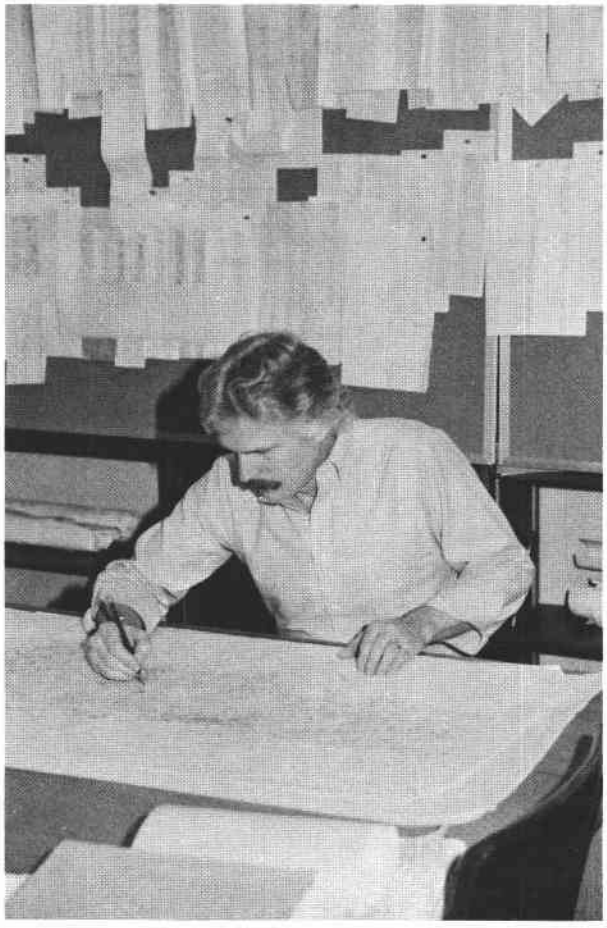
In east-central Texas, major- and maximum-sand maps based on 1,470 geophysical logs confirmed Wilcox deposition by ancient fluvial-deltaic systems sourced primarily to the northwest. A 75-mi-wide (120-km-wide) fluvial-deltaic complex entered the Eocene coastal plain in what is now Coryell County. Mapping of lignite occurrence and major sands in the Calvert Bluff Formation guided the location of 14 holes that were drilled to depths between 480 and 1,900 ft (146 and 579 m). Drilling, lignite-occurrence maps, and stratigraphic analysis define thick lignites in the lower Calvert Bluff southwest of the Navasota River and in the upper Calvert Bluff northeast of the Brazos River. Lignites at exploitable depths of less than 1,000 ft (305 m) occur in dip-elongate areas between channel sand belts. Major-sand maps were used to successfully predict regional trends in thickness but were less successful in predicting actual values.

Stratigraphic studies show that the Carrizo Sand, a major aquifer, and the upper Wilcox are distinct depositional systems separated by a regional marine transgressive unit. Deep-surface mining or underground gasification of upper Calvert Bluff lignites could be difficult in the presence of the Carrizo, especially where Carrizo and Wilcox sands are in direct stratigraphic and hydrologic contact.

Hydrogeology and Geochemistry

Graham E. Fogg, Mary L. Ambrose, W. R. Kaiser, W. B. Ayers, Jr., and Colin M. Jones; assisted by Paul E. Blanchard, Peter B. McMahon, and David A. Prouty

A limited hydrogeological drilling and testing program in the Sabine Uplift area has helped clarify Wilcox hydrology and identify constraints on underground coal gasification. Vertical hydraulic gradient and pressure data collected in Shelby, Panola, and Cherokee Counties show that small streams in the Wilcox outcrop do not necessarily induce upward ground-water flow and that deep flow is not necessarily downward beneath local topographic highs. Pressure gradients obtained in the field verify new vertical hydraulic gradient maps based on more deep data and moving averages. In northern Cherokee County, horizontal hydraulic gradients decrease with depth and actually reverse direction just below the transition from lower Wilcox to upper Wilcox strata. Consequently, optimal depths for underground gasifiers could be chosen to minimize ground-water contamination because of very slow flow rates. Lignites tested at depths of 400 and 690 ft (122 and 210 m) yielded values of hydraulic conductivity (0.27 and 0.059 ft/d [0.08 and 0.02 m/d]) suitable for underground gasification using wells linked by reverse combustion. However, the shallower lignite is hydraulically



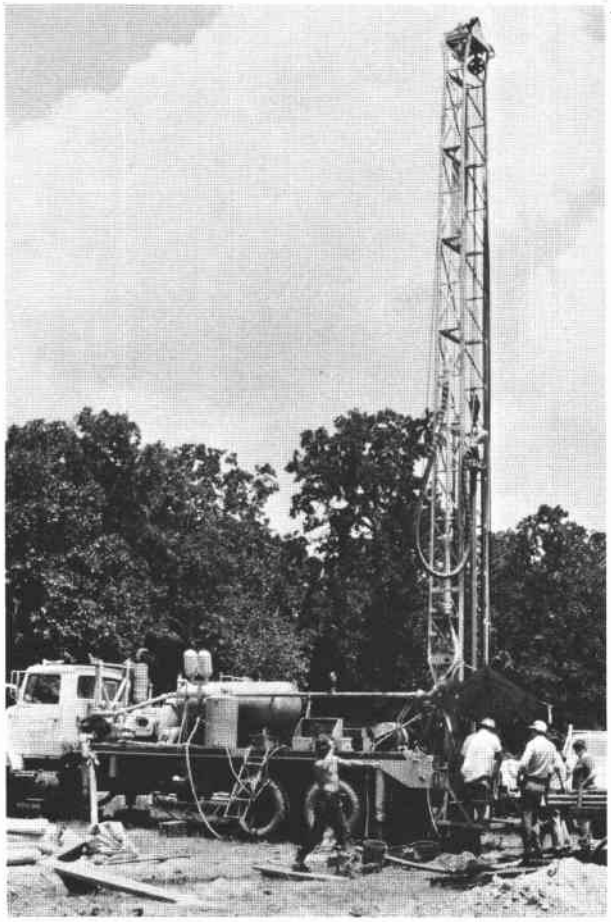
James A. Morgan

W. B. Ayers, Jr., prepares the map used to select deep-basin lignite drill sites.

connected to an underlying platform sand (crevasse splay) of the type that commonly underlies many Wilcox lignites.

Hydrochemical, resistivity, and hydraulic gradient mapping continues as part of the overall effort to elucidate patterns and rates of ground-water circulation and to place in perspective potential impacts of mine dewatering and depressurization on ground-water resources. Additional hydrochemical mapping has shown that trends in water composition can be mapped using either log activity or log molality indices. In the Sabine Uplift area, maps of log activity and log molality for Na^+, Na^+/Ca^{2+}, and HCO_3^- are similar to earlier maps, which had been made using log activity indices derived from reactions keyed to the chemical evolution of ground water, and show positive correlation with head mapping. The log ratio is more sensitive than are single ions. Water samples produced from the hydrological test wells confirm the trends predicted from hydrochemical mapping. In addition to indicating ground-water circulation patterns, the maps will provide regional water-quality data for assessing pre-mining conditions in the Wilcox.

Maps of resistivity and resistivity products indicate pathways of preferred ground-water movement. Belts of large resistivity product and ribbons of high resistivity extend deep into the subsurface (tens of miles) and coincide with the axes of major channel sands, illustrating the focusing of ground-water flow by thick framework sands. These maps should prove useful in the exploration for ground-water resources by identifying areas of good water quality (high resistivity) and high relative transmissivity (large resistivity products, or values of resistivity times thickness) in the shallow subsurface. In some cases, abrupt lowering of the base of fresh water coincides with major channel sand belts.



W. B. Ayers, Jr.

Bureau researchers monitor lignite-coring operation near Marquez in Leon County.

Chemical Characterization

Susan J. Tewalt, Clara L. Ho, Cynthia A. Mahan, Charlotte S. Holland, Steven W. Tweedy, and Daniel H. Ortuño; assisted by J. Nile Barnes

To recover lignite for characterization, 7 boreholes were offset and cored; lignite was recovered from 18 different seams and 5 stratigraphic horizons. A total of 85 deep-basin samples were analyzed chemically and mineralogically. Chemical analyses included proximate, ultimate, heating value, forms of sulfur, and ash oxides. On a whole-coal basis, major, minor, and trace elements were analyzed. On a dry, ash-free basis, the carbon content of the sampled seams indicates a coal rank borderline between lignite and subbituminous. Samples from the Sabine Uplift area are slightly richer in carbon (74.3 percent) than those of east-central Texas (71.3 percent) and of better quality (lower sulfur and ash and higher Btu). Overall, total sulfur content ranges from 1.3 to 1.5 percent (organic sulfur 75 percent), nitrogen 1.1 to 1.3 percent, and chlorine 96 to 104 ppm. Deep-basin, high-temperature ashes are markedly lower in SiO_2 and higher in Na_2O, SO_3, and CaO than are ashes from near-surface lignites. The most striking difference is in Na_2O content, which increases with depth and is correlated with Na^+ content in the ground water. Shelby and Panola County lignites are particularly rich in Na_2O, commonly exceeding 10 percent in deeper seams. Sodium is the major cause of fouling in pulverized-coal-fired boilers. In low-temperature ash, dominant minerals are kaolinite and quartz, with some pyrite and marcasite, minor illite, smectite, and chlorite, and trace amounts of several other minerals. Trace elements of greatest concern in coal are As, Pb, Se, B, Hg, Cd, and Mo. Among those in the Sabine Uplift area, only the mean of Se (10.2 ppm) exceeds that of the average for U.S. lignite (5.3 ppm), whereas As is lower (3.4 versus 6 ppm). Uranium averaged less than 1 ppm (0.8), compared with 2.5 ppm nationally. In east-central Texas, the means for Se, As, and U are 6.8, 9.0, and 1.4 ppm, respectively. Thus, Se is slightly lower and As and U slightly higher than in the Sabine Uplift samples. In both areas, the means for Pb, B, Hg, Cd, and Mo are similar to the averages for U.S. lignite.

A final report, a collection of 15 short papers summarizing results of the project's first 2 years, will be published in 1984 as a Bureau Geological Circular.

COMPUTERIZED CALCULATION OF LIGNITE RESOURCES IN TEXAS

W. R. Kaiser, project director; Susan J. Tewalt; assisted by Clayton H. Wilson and Curtis W. Black

Remaining near-surface lignite resources are being calculated for the State of Texas in this project funded by the U.S. Geological Survey (USGS). The National Coal Resources Data System (NCRDS) is being used to calculate resources according to criteria of USGS Circular 891. Seam depth, thickness, and location are coded from geophysical logs and entered into a computerized data base. The NCRDS uses an interactive graphics package to calculate resources and draw resource maps. Access to the system is through a Tektronix 4054 terminal at the Bureau. Resource estimates are reported by stratigraphic unit and by

geographic region. Point sources of proprietary data are kept confidential.

Remaining near-surface resources for the Wilcox Group in two geographic regions have been calculated. Tonnages have been reported for five seam-thickness categories. Three are standard USGS categories (2.5 to 5 ft, 5 to 10 ft, and greater than 10 ft [0.76 to 1.5 m, 1.5 to 3.0 m, and greater than 3.0 m]), and two are thickness categories used in previous resource estimates made by the Bureau. These two additional thickness categories, 2 to 3 ft and greater than 3 ft (0.61 to 0.91 m and greater than 0.91 m), are relevant to current surface-mining practices in Texas.

NCRDS resource estimates for the Wilcox Group in east-central Texas (between the Colorado and Trinity Rivers) total 8,764 million short tons (7,967 million t) in the three USGS categories of thickness and degree of certainty. The total NCRDS resource figure in the two Texas thickness categories is 10,370 million short tons (9,427 million t); this 18-percent increase resulted from including seams between 2 and 2.5 ft (0.61 and 0.76 m) thick. The estimate calculated in Bureau Report of Investigations No. 104 for all seams greater than 2 ft (0.61 m) thick was 8,641 million short tons (8,505 million t), smaller than both of the NCRDS estimates. This probably resulted because Report of Investigations No. 104 took a more conservative approach and also indirectly calculated resources in seams 2 to 3 ft (0.61 to 0.91 m) thick. Demonstrated resources calculated by NCRDS for the USGS and Texas thickness categories are 4,174 million short tons (3,795 million t) and 4,987 million short tons (4,534 million t), respectively.

The total estimate for the Wilcox Group in northeast Texas (north of the Trinity River to Texarkana) is 8,487 million short tons (8,353 million t). The NCRDS estimate of remaining resources for the Texas thickness categories is 11,519 million short tons (10,472 million t). The estimate reported in Report of Investigations No. 104 for seams greater than 2 ft (0.61 m) thick was 8,359 million short tons (7,599 million t). This is about 27 percent lower than the NCRDS estimate for the same seam thicknesses. The substantial difference in tonnages between the two NCRDS estimates for this region (8,487 and 11,519 million short tons [8,353 and 10,472 million t]) arises from the large number of seams between 2 and 2.5 ft (0.61 and 0.76 m) thick.

A progress report summarizing the regional resource maps and calculations was submitted to the USGS in 1983. Calculations for the Wilcox Group in the Sabine Uplift area are nearly completed. Data entry is underway for the Yegua Formation and Jackson Group in East Texas. Evaluation of the final region, the Wilcox and Jackson in South Texas, will complete the goals of the project.

GEOLOGICAL CHARACTERIZATION OF TEXAS OIL RESERVOIRS

William E. Galloway and Don G. Bebout, project directors; Noel Tyler, C. M. Garrett, Jr., and Eric S. Cheng; assisted by William A. Ambrose and Karen J. Meador

Approximately 153 billion barrels of in-place oil have been discovered in Texas reservoirs; an estimated 92 billion barrels of this oil will remain unrecovered, according to current extrapolations of recoverable reserves. The Bureau, with partial funding from the Texas Energy and Natural Resources Advisory Council, in 1982 began geological characterization of the major oil-producing reservoirs. Objectives of the 2-year program were to (1) define the geological and engineering parameters of the plays that host major oil reserves and (2) examine in detail classes of reservoirs that, with integrated analysis of genetic facies and engineering characteristics, might yield significant increases in recoverable reserves.

The first phase of the study culminated in 1983 with the publication of the *Atlas of Major Texas Oil Reservoirs*. This atlas groups nearly 450 of the state's most important reservoirs into genetically related plays. The petroleum geology and engineering characteristics of each play are described in a brief text and illustrated by more than 400 representative maps, cross sections, logs, and interpretative diagrams. A series of tables summarizes quantitative data for each reservoir included in the plays.

Following up on the overview of Texas reservoirs, two major plays were selected for site-specific reservoir studies. The San Andres Formation of the Central Basin Platform and Northern Shelf of the Midland Basin is the single largest oil-producing stratigraphic unit in the state. However, less than 30 percent of its oil in place is expected to be recovered. Subregional facies analysis of the San Andres has led to a geologically based grouping of San Andres reservoirs and identification of the specific productive facies. As a part of this effort, a set of regional cross sections for the Central Basin Platform has been produced and will be published in 1984. In addition, cores from 11 fields have been examined as part of the subregional analysis. Calibration of log response to specific productive facies and delineation of porosity and permeability distribution within representative fields are adding detail to the stratigraphic analysis.

The Frio Formation of the Gulf Coast is a second highly prolific producing unit. Two major fields representative of the Frio barrier/strandplain oil play of the Middle Coastal Plain, West Ranch field and Markham North - Bay City North field, have been subjects of integrated analysis of reservoir facies, engineering, and production history. Productive

James A. Morgan

Don G. Bebout works on detailed cross section of Dune field, Crane County.

attributes, comparative recovery efficiency, and petrophysical properties of individual reservoirs have been related to the complex facies mosaics of washover-fan, tidal-inlet, barrier-core, shoreface, strandplain, cuspate-delta, and chenier sand bodies. Publications reviewing this facet of the reservoir characterization program are in preparation.

James A. Morgan

William E. Galloway, director of reservoir characterization projects.

GEOLOGICAL CHARACTERIZATION OF ABANDONED TEXAS OIL RESERVOIRS

William E. Galloway, project director; Shirley P. Dutton and C. M. Garrett, Jr.

One target of nonconventional recovery in Texas is the oil that remains in abandoned fields. This target includes oil that has not been tapped by conventional field development because of reservoir heterogeneity and oil in reservoirs that have not been subjected to any secondary or tertiary recovery efforts. In 1980, the U.S. Department of Energy compiled a list of abandoned Texas oil fields (defined as having no oil production in 1977) that had individual cumulative production of more than 250,000 barrels. As part of the effort to characterize Texas oil reservoirs, the Bureau initiated a study in 1983 of the 312 abandoned fields having individual cumulative production greater than 500,000 barrels. Funding was provided by the Texas Energy and Natural Resources Advisory Council.

The fields were characterized by the same geological, engineering, and production parameters that were used in the *Atlas of Major Texas Oil Reservoirs*. Information on the fields comes largely from the files of the Railroad Commission of Texas. The 312 fields that were studied represent 46 percent of the total number of abandoned fields having cumulative production greater than 250,000 barrels. However, total production from these 312 fields is more than 75 percent of the total for all 676 fields listed. Some of the 312 fields produced oil in 1982, some had been reclassified and produced gas in 1982, and some had produced more than 10 million barrels and so were included in the earlier study of major Texas oil fields. Most of the remaining 219 fields fall into the same genetically related plays that characterize the largest Texas oil fields. However, some new plays were established for the abandoned fields. Of the fields that had no oil production in 1982, 134 were in Tertiary reservoirs of the Gulf Coast and 12 were in Mesozoic reservoirs in East Texas or south-central Texas. The remaining 73 abandoned fields had produced from Paleozoic reservoirs in West and North-Central Texas and the Panhandle. A Bureau Geological Circular characterizing abandoned reservoirs in Gulf Coast and East Texas fields is being prepared.

GEOLOGICAL INVESTIGATION OF LOW-PERMEABILITY GAS SANDSTONE RESERVOIRS

Robert J. Finley, project director; A. Eugene Saucier, Zsay-Shing Lin, Steven J. Seni, Jong H. Han, C. M. Garrett, Jr., and Noel Tyler; assisted by Gay Nell Gutierrez, Mark J. Berlinger, Janet L. Bader, Robert C. Murray, and William A. Ambrose

Recovery of natural gas from low-permeability sandstones is highly dependent on economic and technological factors. The objective of this project, funded by the Gas Research Institute, is to improve the geological understanding of blanket-geometry tight gas sandstones, thereby encouraging resource recovery using integrated and highly effective geological and engineering practices. Following a national review of more than 30 tight gas sandstones, the Travis Peak Formation in East Texas and North Louisiana and the Corcoran-Cozzette Sandstones in northwestern Colorado were selected for detailed study. The Travis Peak was chosen for its high potential resource, and the Corcoran-Cozzette because of expected transferability of research results to geologically similar units.

The Lower Cretaceous Travis Peak Formation is 500 to 2,500 ft (150 to 750 m) thick, and preliminary estimates of maximum recoverable gas in place in Texas alone range from 14 to 23 Tcf. The formation is sand-rich and contains no major laterally continuous markers; interpretation of the log facies of the Travis Peak has therefore been the primary means of defining framework sandstone packages. These include a progradational deltaic sequence in the lower Travis Peak, a fluvial facies interpreted to consist dominantly of braided alluvial facies in the middle Travis Peak, and a sequence of marginal marine sandstones, including a transition from clastic deposits to the carbonates of the overlying Pettet Limestone, in the upper Travis Peak. Most of the present Travis Peak production is from upper recessional facies, where permeabilities are often better than in the remaining parts of the formation, but the middle and lower subdivisions tend to be more sand-rich. Six new gas fields were discovered in the Travis Peak in East Texas during the first half of 1983, making it the unit having the second highest rate of exploration success in East Texas.

The Upper Cretaceous Corcoran and Cozzette Sandstones of the Piceance Creek Basin are typical of transgressive marginal marine sandstones deposited in the Cretaceous Seaway from New Mexico to Wyoming. Although the maximum recoverable gas in place in these units is estimated to be 4 Tcf, the technology used to exploit this resource will be applicable over a much larger area containing similar facies. These facies include shoreface, barrier foreshore, and a complex of facies in the upper part of each unit that includes bay-lagoon mudstones, the distributary-mouth-bar and distributary-channel sandstones of small deltas, and, locally, highly lenticular coals.

Interpretive description and mapping of the depositional systems and their component facies were begun in 1983 for both the Travis Peak and the Corcoran-Cozzette. The maximum concentration of net-sandstone

beds more than 50 ft (15 m) thick occurs in the middle braided facies of the Travis Peak, where thin intervening shales may present only weak barriers to containment of hydraulic fractures. In the Corcoran-Cozzette, the lower part of each unit shows an upward-coarsening shoreface sequence having a northeast trend that sharply defines the paleoshoreline. Sandstone geometry of tight gas reservoirs will affect the design and success of hydraulic fracture treatments, and the original detrital content of the sandstones partly affects the petrophysical properties of the reservoir. Clay content of tight gas reservoirs may, for example, be lower in certain high-energy environments, such as distributary mouth bar or barrier foreshore. However, the balance between authigenic and detrital clay in blanket sandstones remains to be evaluated, and the potential for greater cementation in originally more permeable sediments must be considered. Detailed analyses of depositional systems will continue in 1984, and diagenetic studies will be fully integrated into these analyses.

GEOLOGICAL FRAMEWORK AND ENERGY RESOURCE STUDIES, TEXAS CONTINENTAL SHELF

R. A. Morton, project director; Lee A. Jirik and Nancy J. Banta; assisted by Emil Bramson and Loren F. Phillips

The first phase of this multi-year project culminated in the construction of regional structural cross sections depicting the geology of offshore Texas. The nine dip cross sections tie with the onshore regional sections of the Tertiary formations and extend offshore to the present-day shelf edge. Two strike sections complete the set. The study is partly funded by and being conducted in cooperation with the U.S. Geological Survey and the Minerals Management Service.

During 1983, preliminary correlation of more than 1,000 electric logs (some with paleontology picks) allowed the stratigraphic subdivision of late Oligocene (Frio, Anahuac), Miocene, and Pliocene-Pleistocene sediments. An inventory of hydrocarbon production was also completed, and initial assignments were made to specific stratigraphic units. Future work will include preparation of regional structure and isopach maps of major stratigraphic units and analysis of hydrocarbon plays. Acquisition of recent seismic profiles for use in structural interpretation is anticipated by early 1984.

SALINITY OF DEEP FORMATION WATERS, TEXAS GULF COAST

R. A. Morton and W. R. Kaiser, project directors; assisted by James F. O'Connell

The chemical compositions and concentrations of brines produced from sandstone reservoirs beneath the Texas Coastal Plain vary greatly with depth and from one area to another. These hydrochemical variations reflect differences in deep-basin hydrology and in chemical evolution of the pore waters. This study, which is part of the U.S. Department of Energy's geopressured geothermal research program, is providing information on the geographic and stratigraphic variations in water primarily from the Frio and Vicksburg Formations. Preliminary interpretation of the chemical data shows two hydrochemical subregions in which hot brines originating deep in the basin have migrated upward and mixed with shallow connate waters. In other areas, relatively low salinity waters appear to be the product of shale dewatering and of clay-mineral transformations.

In 1983, regional maps and individual field plots were prepared of weight ratios (mg/L), mole ratios, and single ion concentrations, along with plots of total dissolved solids versus depth, temperature gradient, pressure gradient, and sandstone percent. In addition, Piper diagrams were used to show the lateral and vertical mixing of CaCl and NaCl waters in Hidalgo County, Texas.

A related study has been designed to compare sandstone and water composition with reservoir quality. Plots of activity indices, mole ratios, chloride concentration, and ionic strength versus depth are being evaluted for Alta Loma, Cedar Point, Donna, Portland, Red Fish Reef, and TCB fields and for four Louisiana wells of opportunity. Degrees of completeness vary among a total of 103 water analyses of samples taken from depths mainly between 3,000 and 13,000 ft (1 and 4 km). Most analyses include values for total Fe, Mg^{2+}, Na^{+}, Ca^{2+}, and pH; only 19 include SiO_2 values. Sixteen plots of activity indices (derived from diagenetic reaction pairs), 11 mole ratios, chloride concentration, and ionic strength versus depth have been completed. These plots are being compared with similar plots of the Frio regional data and with individual field plots. Analyses having SiO_2 values will be added to a suite of activity diagrams made from regional data and related to reservoir quality. Because the Louisiana well-of-opportunity samples come from areas of excellent reservoir quality and low geothermal gradients, comparison of their activity indices with those of Texas upper and lower coast waters is of particular interest; the upper coast waters come from areas of good reservoir quality, and the lower coast waters from areas of poor quality. Plotting of activity indices versus temperature and pressure gradients will help to elucidate the geochemical evolution of Frio brines.

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

T. E. Ewing, project director; assisted by Olufemi O. 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 1983, three areas (Katy, Fostoria, and Zapata) along the Wilcox growth-fault trend were studied using subsurface geological techniques and seismic interpretation. Study of these three areas, along with study of the Cuero and Live Oak areas reported elsewhere, permits a comprehensive description of the nature of Wilcox structural activity. Other work will concentrate on the quantification of parameters such as fault-block size and geometry.

INTEGRATION OF GEOLOGICAL AND FLUID DATA IN THE GEOPRESSURED GULF COAST BASIN

T. E. Ewing, project director; Noel Tyler, Malcolm P. R. Light, and A. R. Gregory; assisted by Victor H. Lombeida

Studies conducted by the Bureau related to geopressured geothermal resources on the Texas Gulf Coast have created a large amount of regional and subregional information on structural style, depositional systems, sandstone petrology and diagenesis, and fluid properties such as salinity, pressure, and temperature. In addition, the drilling of the Pleasant Bayou No. 2 test well led to a wide

variety of studies by many researchers on shale mineralogy, organic geochemistry, vitrinite reflectance, and reservoir continuity and diagenesis.

This project, begun in mid-1983 and funded by the U.S. Department of Energy, attempts to draw together all of the information available for the area surrounding the Pleasant Bayou test well, to analyze its limitations, and to integrate it into a comprehensive geological history. Particular attention is being paid to the history of fluid flow, to use of present fluid properties as indicators of fluid migration, and to the relationship between fluid properties, thermal history, and diagenetic modification in the development of the geopressured reservoirs.

PRODUCTION OF LIQUID HYDROCARBONS IN ASSOCIATION WITH THERMAL WATERS AND SOLUTION GAS

R. A. Morton, project director; Robert J. Finley and A. Eugene Saucier

Production of hot brines at high flow rates from overpressured aquifers is an integral part of the U.S. Department of Energy's Gulf Coast geopressured geothermal program. Several of the test wells have yielded minor quantities of liquid hydrocarbons in addition to geothermal water and dissolved methane. This study examines the preliminary test results to evaluate possible sources of the hydrocarbons, including (1) coning of nearby free hydrocarbons, (2) retrograde condensation within the reservoirs, (3) molecular dissolution of aromatic hydrocarbons at high temperatures and pressures, (4) residual accumulation of free hydrocarbons trapped by reservoir heterogeneities after primary migration, and (5) thermal maturation of organic matter in shales surrounding geopressured reservoirs.

In 1983, production of liquid hydrocarbons at two geopressured geothermal design wells and one well of opportunity was examined and compared with reservoir conditions and solubility of the recovered hydrocarbon species. The G. M. Koelemay No. 1 well (Jefferson County, Texas) apparently coned a free hydrocarbon phase into the well bore; recovery of natural gas liquids was up to 5.7 gal/Mcf during production testing. The brine reservoir was most likely in close contact with a gas-condensate accumulation. At the Pleasant Bayou No. 2 well (Brazoria County, Texas) and the Sweezy No. 1 well (Vermilion Parish, Louisiana), aromatic hydrocarbons (benzene, toluene, and xylene) were the major components of liquid hydrocarbon samples analyzed. These components have relatively high solubility in brine at reservoir conditions and, therefore, are probably common in geopressured geothermal fluids. Some samples recovered using surface separation equipment were characterized as oil or condensate. Production of these liquids is being investigated in relation to reservoir conditions, to possible local stratigraphic trapping, and to possible timing of the generation and migration of hydrocarbons.

GEOTHERMAL RESOURCE ASSESSMENT FOR THE STATE OF TEXAS

Charles M. Woodruff, Jr., project director; Christine R. Gever and G. L. Macpherson; assisted by David R. Wuerch

The final phase of this research on low-temperature geothermal resources in Texas, sponsored by the U.S. Department of Energy, involved 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 hydrological data that were collected on the Balcones/Ouachita trend in Central Texas.

The public-oriented user map was published at a scale of 1:1,000,000 by the National Oceanic and Atmospheric Administration and is available free of charge from the Bureau. The map 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 having temperatures and water-quality attributes that are representative of the various aquifers.

The program of collecting water temperatures from existing shallow wells was also completed. A magnetic tape containing selected data was transferred to the U.S. Geological Survey, Menlo Park, California, for incorporation 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 with depth. Earlier maps showing geothermal gradients did not distinguish areas of abrupt changes in thermal conductivity owing to different rock types. Because thermal conductivity is an inverse function of geothermal gradient, this may have resulted in misleading interpretations. We have attempted to correct this by choosing a few rock units of consistent lithic properties (whenever possible, limestones) and mapping geothermal gradients only for wells that have a bottom-hole temperature in these specific horizons. This was done for the Ellenburger Group west of the Balcones/Ouachita trend and for the Sligo/Pettet and Edwards Formations east of this trend.

Geological and hydrological assessments along the Balcones/Ouachita trend in Central Texas continued 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. A geothermal well and a heat-exchange system are now operating at the Torbett-Hutchings-Smith Memorial Hospital at Marlin, where the basal Cretaceous Hosston Sandstone produces thermal water.

IN SITU URANIUM LEACHING: GEOLOGICAL ASPECTS

Jonathan G. Price, project director; Patricia Bobeck, The University of Texas at Austin, Department of Geological Sciences; Long-Cheng Liang

Mineralogical, geochemical, and sedimentological-hydrological aspects of in situ leaching of uranium are being investigated as part of this project with the Department of Petroleum Engineering, The University of Texas at Austin. Successful pilot studies of new leaching technologies were conducted in the Miocene Oakville Formation of Live Oak County, Texas. In these studies, electron microscopy and microprobe analyses indicated that the main uranium phase in primary, reduced ore is a uranium-calcium silicate-phosphate. In an orebody in the Eocene Whitsett Formation of Karnes County, Texas, where recovery by in situ leaching has been generally low, two uranium-bearing phases were detected in primary ore: a uranium-calcium silicate-phosphate and uranium dispersed in or adsorbed by detrital organic matter. Bench-scale leaching experiments suggest that the uranium associated with organic matter is kinetically slower to extract than that from the other phase.

RESOURCE EVALUATION OF THE MIOCENE MAJOR STRATIGRAPHIC UNIT, TEXAS GULF COAST BASIN

Jules R. DuBar, project director; assisted by E. M. Andrews-Goodman, Katherine C. Hubby, and David C. Noe

Work on the onshore Miocene project, funded in part by the U.S. Geological Survey, is near completion. Objectives of the research are to compile a geological data base necessary for resource assessment of the productive Miocene operational units; to integrate the geological framework analysis, historical indices of finding rate, and reservoir/source facies volumetrics as a basis for defining and quantitatively evaluating resources of exploration-production plays; and to assess the potential undiscovered hydrocarbons of the Miocene major stratigraphic unit (MSU).

During 1983, data gathering and geological synthesis were essentially completed and preparation of the final report was begun. Maps of sand percent, sand isolith, isopach, structure, depositional systems, facies, and sand and shale units were completed for the two operational unit subdivisions of the Miocene MSU. Also completed were a Miocene production map depicting major oil and gas fields, an exploration-play map, a map of Miocene vertebrate distribution trends, a source-rock maturity map, and a structural subbasin map. Six strategically located stratigraphic dip sections depict relations between operational units, encasing units, facies distribution, structural character, and producing intervals.

Evaluation of ultimate hydrocarbon potential for Railroad Commission of Texas Districts 2, 3, and 4 were completed and similar evaluations for the 10 delineated exploration plays are in progress.

Miocene correlation studies have produced charts showing position of the Miocene MSU within the stratigraphic framework of the northwestern Gulf of Mexico. The correlations relate operational units to the standard North American mammalian zones, to northwestern Gulf benthic foraminifer zones, to interhemispherical planktonic foraminifer zones, to a standard chronometric scheme, and, in part, to worldwide eustatic cycles and magnetostratigraphic intervals.

LAND AND ENVIRONMENTAL RESOURCES INVESTIGATIONS

SOUTHWEST TEXAS RIVER BASINS REGIONAL STUDY

E. G. Wermund and Thomas C. Gustavson, project directors; Richard L. Dillon and David M. Ridner, cartographers

This long-term project is a comprehensive environmental geologic analysis of 30,558 mi² (79,145 km²) 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 has supported completion of all remaining work.

Results of this program include a series of maps that 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. For the biologic assemblage map, the 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 derived directly 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 photomosaics. Land use was interpreted from 1973 color-infrared aerial photographs (scale 1:120,000).

All the hand-colored maps, topographic maps (scale 1:24,000), and controlled photomosaics showing original compilation that were prepared during the project are on file at the Bureau and are available for study.

Over the next several years, the maps will be published in combinations of two or more colors. Maps of the Seguin West and San Antonio East 1° quadrangles are nearly completed. A text that explains the regional setting and methodology is in preparation.

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

Christopher D. Henry, project director; Jonathan G. Price; assisted by Rebecca C. Smyth

This study of the Basin and Range Province is being done in conjunction with the U.S. Geological Survey (USGS) and states of the Basin and Range. The purpose is regional screening of the province for potential high-level waste isolation sites. The project has focused on characterization of geology and hydrology in the Trans-Pecos region. Reports and maps from the project are being published by USGS, and subjects include (1) mineral resource areas, (2) distribution of potential host rocks, including intrusive rocks, tuffs, and basalts, (3) ground-water flow systems and regional hydrology, and (4) tectonic conditions. A series of regional cross sections in the Trans-Pecos area (scale 1:250,000) will be placed on open file at the Bureau. A summary report, to be published as a USGS Professional Paper, is in press; it will discuss the overall geological and hydrological characteristics of the Basin and Range in Trans-Pecos Texas as they bear on waste isolation.

MINERAL RESOURCES INVESTIGATIONS

NONPETROLEUM MINERAL PRODUCERS LIST

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

The revision of the list of Texas nonpetroleum mineral producers was completed during 1983, and the information is now available in two forms: a computer-generated printout and Mineral Resource Circular 74. The project, funded in part by the Texas Mining and Mineral Resources Research Institute and in part by the Minerals Information Location System of the U.S. Bureau of Mines, revised and updated data collected in the late 1970's. The entire data base, which will be updated from time to time, is available in computer printout form. Data indexed in Mineral Resource Circular 74 include names and addresses of active producers, commodities produced, and counties having active production.

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

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

Continuation of this study on the origin of silver-copper-lead deposits in red-bed sequences of the Trans-Pecos region is being funded by the Texas Mining and Mineral Resources Research Institute. The deposits, many of which are veins having east-northeast or northeast trends, occur in fluvial sandstones, coarse siltstones, and conglomerates of Precambrian, Permian, and Cretaceous ages. Historical production from the largest vein in the Precambrian Hazel Formation was about 4 million troy ounces of silver. Geographic positions, structural settings, vein and wall-rock mineralogy, and geochemistry indicate no direct links between these ores and Oligocene igneous activity in the region. The deposits probably formed during Miocene or younger Basin and Range extension.

Examination of fluid inclusions in barite, calcite, sphalerite, and rare quartz indicated that the ores were precipitated from saline aqueous fluids at temperatures between 120° and 170° C. Variation in salinity from 9 to 19 weight percent equivalent sodium chloride suggests that the chemical composition of the fluids changed rather drastically during ore formation, perhaps because of dilution of upward-moving saline fluids by shallow ground water.

C. D. Henry

Jonathan G. Price examines a silica-filled tension fracture at the south end of the Van Horn Mountains caldera, Trans-Pecos Texas.

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 project funded by the Texas Mining and Mineral Resources Research Institute is examining the relations between Tertiary igneous activity, hydrothermal alteration, and ore deposition. Recent Bureau publications include Report of Investigations No. 135, which contains a colored geologic map of the Chinati Mountains caldera (the site of several major ore deposits), and Mineral Resource Circular 73, an annotated bibliography of all mines and prospects in Trans-Pecos Texas. Reports on calderas of Trans-Pecos and stress orientations during Tertiary volcanism have been accepted for publication in various journals. In addition, several abstracts on volcanism and ore deposits and a report on the existence of the Rio Grande Rift in Texas have been published.

Work continues in several areas, including the origin of silver-lead-zinc veins in the Eagle Mountains; the origin of epithermal veins in the Ojo Bonito stock; the origin, mineralization, and petrogenesis of the related Marble Canyon and Cave Peak stocks, which contain molybdenum mineralization; and the structural and tectonic development of the Trans-Pecos area through time.

MINERAL RESOURCE EVALUATION, LOWER COLORADO RIVER AUTHORITY

L. F. Brown, Jr., project director; Gary F. Collins and Mary L. W. Jackson

This short-term project funded by the Lower Colorado River Authority identified natural resources along certain segments of the Colorado River and evaluated their economic potential. Lignite, uranium, sand, gravel, and petroleum were included in this 4-month evaluation. The program was completed at the end of 1983.

THE BARITE INDUSTRY AND RESOURCES OF TEXAS

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

Barite is used predominantly as a weighing agent in drilling fluids and also for the preparation of many industrial

barium chemicals. The United States is the world's largest producer and consumer of barite; deep well drilling programs in the Gulf Coast and elsewhere in Texas consume a substantial part of domestic and imported ores. This project, funded by the Texas Mining and Mineral Resources Research Institute, is examining the barite-processing industry and the geological setting and resource potential of barite in Texas. Texas has a strong barite-processing industry, but in-state primary production has been insignificant. The geological setting of several barite occurrences in Texas indicates the potential for substantial barite-rich ores. The major occurrences are in sedimentary terranes and include the late Paleozoic strata of the Marathon region, the Permian strata of the Delaware Basin, and the Gulf Coast salt-dome province. These Texas deposits appear to have originated from barium-rich formation waters in evolving sedimentary basins. Sulfur isotopic investigations of some deposits indicate the presence of isotopically heavy barites; this suggests a complex fractionation history involving selective partitioning of ^{32}S into reduced sulfur species, leaving the residual sulfate enriched in ^{34}S. Known barite deposits in Texas are too small and low grade to be commercial. The project will be completed in early 1984.

BASIN STUDIES

GEOLOGICAL AND GEOHYDROLOGICAL INVESTIGATIONS IN THE TEXAS PANHANDLE

E. G. Wermund, project director; Thomas C. Gustavson and Charles W. Kreitler, principal investigators

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

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

Studies begun in FY80 included more specific discrimination and determination of salt character, natural resources potential, hydrological integrity, host-rock properties, and rates of surface and near-surface processes. The program in FY80 also more intensely evaluated 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 and movement, and shallow-aquifer hydrodynamics and hydrochemistry, as well as to integrate 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 begun.

The fifth year of investigation (FY82) focused on 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.

The completion and testing by DOE of five stratigraphic test wells and two deep hydrological test wells in 1982-83 guided much FY83 research, which also included Quaternary and other surficial studies. Well tests were supplemented by 145 line mi (233 km) of DOE-contracted seismic reflection data and 580 line mi (933 km) of purchased proprietary seismic data originally collected for oil and gas exploration. Seismic surveys are critical to interpretation of tectonism and structural geology. Summaries of accomplishments from FY83 research follow.

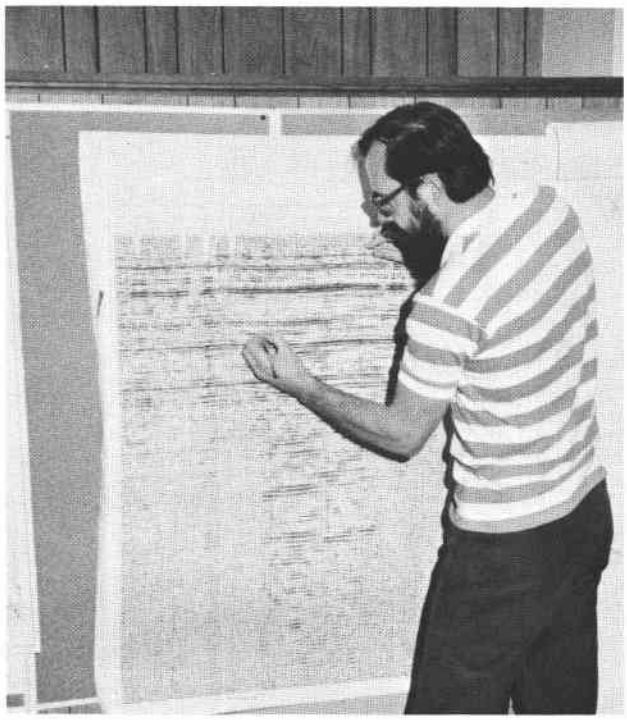
Structural Geology and Tectonics

Roy T. Budnik, E. W. Collins, and Douglas A. McGookey; assisted by Stephen E. Lovell, Melissa A. Sandstrom, and Thomas M. Simmons

Cenozoic structural deformation in the Texas Panhandle appears extensive and apparently resulted both from tectonic movements and from subsidence induced by dissolution of Permian bedded salt.

Cenozoic epeirogenic uplift greater than 3,000 ft (1,000 m) has occurred over parts of the Palo Duro Basin during both the Laramide orogeny and Basin and Range deformation. This uplift has induced fault reactivation and affected salt dissolution, as well as pre-Ogallala erosion, Ogallala deposition, and post-Ogallala erosion. Anomalous thickening of the Ogallala Formation (Neogene) in the Carson County basin appears to be related to Basin and Range extension to the west. Late Paleozoic, Mesozoic, and Neogene sediments thicken into the basin. The Carson County basin probably formed as a result of renewed strike-slip motion along preexisting faults.

Comparison of surface and basement structures in eastern Randall County, Texas, indicates that joint and fracture trends coincide with the dominant northwest- and northeast-trending basement faults. Clastic dikes cut strata throughout the Texas Panhandle, western Oklahoma Panhandle, and eastern New Mexico. The dikes tend to parallel regional joint trends and appear to have been formed by the filling of fractures or fissures from above. Subsidence caused by evaporite dissolution appears the most likely mechanism by which horizontal strain and extension opened the fractures or fissures. Folding of Permian strata above a salt-dissolution zone was identified in Caprock Canyons State Park, Texas Panhandle. Synclinal depressions were mapped in that area, and the association between the structural basins, joints, and veins suggests that systematic regional joints predating dissolution collapse have influenced salt dissolution. Fractures may have acted as preferred paths for fluid movement.



James A. Morgan

Roy T. Budnik interprets a seismic section from the Palo Duro Basin, Texas Panhandle.

Stratigraphy

Stephen C. Ruppel, Michael A. Fracasso, R. D. Conti, David A. Johns, Thomas C. Greimel, and Margaret J. Herron; assisted by Therese M. Lemmer, Loren F. Phillips, and Richard J. Stancliffe

Stratigraphic analyses have confirmed ages, depositional environments, and structural influences on deposition of various units. Conodont faunas were recovered from four wells in the Palo Duro Basin area. Correlation of these faunas with well-established zonations elsewhere in the midcontinent region suggests that (1) Early Mississippian (Osage) deposition was restricted to the area of the Anadarko Basin axis and (2) subsequent deposition (during the Meramecian) spread throughout the area as seas transgressed northward in response to the downwarping of the Ouachita geosyncline to the south.

Both unconformable and apparently conformable relations exist at the Pennsylvanian-Permian contact within the Palo Duro Basin. This is reasonable considering the nature of the Pennsylvanian-Permian contact in surrounding areas and the tectonic events of the region.

Systematic variations in the completeness of sedimentary cycles and in the vertical distribution of thin sheet siltstones in the San Andres Formation allow a subdivision into informal lower, middle, and upper genetic units. The fundamental mode of cyclicity is the same throughout, but the tempo differs among the three units. These differences may reflect changes in either structural control or frequency of eustatic sea-level change, or both.

Structural activity and orientation of structural trends have influenced deposition of lower San Andres strata in the Palo Duro Basin. Depositional facies, percent lithofacies, and lithofacies thickness of cycles 2, 3, and 4 have been affected.

Although the Quartermaster and Dewey Lake Formations in the Permian Basin have generally been considered Late Permian in age, the possibility of an Early to Middle Triassic age has also been raised. Radiometric dating of volcanic ash beds discovered in these formations in the Palo Duro Basin confirmed their age as Late Permian.

Core Analyses

Susan D. Hovorka, Allan Kolker, H. Seay Nance, and Sterling F. Thomas; assisted by Edward C. Cazier, Laura A. Elliott, Barbara A. Luneau, David C. Noe, David N. Purgason, and Clayton H. Wilson

Analyses of core from salt-bearing sections in the Palo Duro Basin have resulted in interpretations of depositional environments and insoluble residues resulting from dissolution.

Cores from two new wells, the DOE - Stone and Webster No. 1 Harman and the DOE - Stone and Webster No. 1 Zeeck, have allowed further examination of the stratigraphic column in Swisher County, Texas, including the base of the dissolution zone, the top of the salt, and the San Andres Formation. The No. 1 Zeeck core also contains parts of the Wichita and Wolfcampian shallow-water carbonates and Pennsylvanian starved-basin deposits.

Detailed logging of cores from three DOE stratigraphic test wells in Deaf Smith County, Texas, allowed correlation of zones of mudstone beds, clean halite, and anhydritic halite within the halite rock of units 4 and 5 of the San Andres Formation.

Cores from seven of the test wells drilled by DOE in the northern Palo Duro Basin were examined. All of the cores contain evidence that halite was once present above the current uppermost halite. Dissolution beneath the Southern High Plains appears to have been a non-catastrophic process in which rapid collapses did not occur. Two stages of diagenesis, probably accompanying two episodes of halite dissolution, were identified.

A classification of halite based on crystal size, crystal shape, amount and composition of impurities, distribution of fluid inclusions, and characteristic sedimentary structures was developed during examination of Palo Duro cores. The eight classes include a range of fabrics, from those originating as primary brine-pool precipitates to those

James A. Morgan

Patricia M. Hester logs core as part of the DOE-sponsored Texas Panhandle project.

formed during diagenesis. Partial and complete regressive sequences composed of a basal black mudstone, limestone, dolomite, nodular anhydrite, bedded anhydrite, and halite occur throughout most of the San Andres Formation. Even subtle fluctuations in sediment character can be traced over large distances within the Palo Duro Basin. The continuity of units reflects the extremely flat topography of the area during deposition and implies that similar sediments were forming at the same time in the area studied.

Thick bedded halite units of the San Andres Formation precipitated in shallow but regionally extensive brine pools, which were frequently and episodically flooded and subaerially exposed. Previously unrecognized subcycles 1 to 6 ft (0.3 to 1.8 m) thick within salt units are characterized by primary textures and bromide contents of about 70 ppm at the base, altered textures and variable bromide concentrations near the top, and a thin mudstone cap containing halite veins having high bromide contents (as much as 342 ppm).

Middle to Upper Permian clastic sediments in the Palo Duro Basin were primarily deposited in eolian dune, eolian flat, intermittent stream channel, wind-tidal(?) flat, shallow normal marine to hypersaline shelf, halite-influenced flat, and low-salinity pond environments. Source areas were probably granitic and medium-grade metamorphic terrains to the west and northwest of the Palo Duro Basin.

Clay minerals in clastic rocks, dolomite, anhydrite, and halite in the Palo Duro Basin consist of detrital illite, chlorite, diagenetic mixed-layered chlorite-vermiculite, chlorite-smectite, chlorite, swelling chlorite, and saponite. Illite dominates the detrital suite; the occurrence of mixed-layered clays is sensitive to geochemical conditions in the diagenetic environment.

Oil and Gas Potential

Shirley P. Dutton

Exploration for hydrocarbons in the Palo Duro Basin has been successful only along the northern and southern margins. However, recent analyses indicate that both basinal shales and carbonates have sufficient organic content and thermal maturity to have been hydrocarbon source rocks.

Analysis of organic matter content and thermal maturation of Mississippian and Lower Ordovician carbonates in the Palo Duro and Dalhart Basins indicates that these rocks may have acted as petroleum source rocks. Their source-rock potential is far less, however, than that of equivalent rocks in the oil-producing Hardeman Basin to the east.

Vitrinite reflectance of samples from Swisher and Oldham Counties, Texas, indicates that shales in the Palo Duro Basin below depths of about 7,000 ft (2,100 m) are mature source rocks. Pyrolysis data support the interpretation that Pennsylvanian basinal shales reached the oil-generation zone.

Pennsylvanian granite wash and carbonates are important oil reservoirs in the northwestern Palo Duro Basin. Fields are primarily controlled by structure, and traps are simple or faulted anticlines.

Geohydrology

Charles W. Kreitler, Alan R. Dutton, Prakob Wirojanagud, Elizabeth D. Orr, William W. Simpkins, and D. Anderson Smith; assisted by M. Saleem Akhter, Jenny B. Chapman, Patricia M. Moseley, Bernd C. Richter, and Krishnamurthy Subramanian

Basin hydrology studies included determinations of porosity from crossplots of geophysical logs, testing of deep-basin aquifer and dissolution zones, mapping of distributions of hydraulic head, analyses of pressure-depth relationships, and hydrological modeling.

James A. Morgan

William W. Simpkins uses a microcomputer to assist in hydrological research.

Study of Wolfcampian deep-basin aquifers has shown that neutron-density crossplotting is superior to neutron-sonic methods for quantitatively determining carbonate lithology and porosity. This is because the former method has proved more accurate at detecting secondary porosity and at determining lithology.

Quantitative estimates of porosity distributions in Wolfcampian strata of the Palo Duro Basin improved the resolution of porous zones, which can be applied to (1) constructing ground-water models, (2) delineating porous fairways for hydrocarbon exploration, and (3) determining changes in porosity along hydrological flow paths or within units that are locally or regionally correlatable.

Hydrogeological properties of the San Andres Formation within the Palo Duro Basin were measured for verification of a regional ground-water flow model. Six drill-stem tests and one pumping test provided estimates of hydraulic head and permeability in Deaf Smith, Randall, and Swisher Counties. A formation-water sample will be collected after cleanup of drilling contamination and analyzed to determine the flow path of ground water in the San Andres in the Palo Duro Basin.

Test wells were constructed in the Palo Duro Basin to provide data on the hydrogeology of the salt-dissolution zone. The bases of the test zones are within 7 to 49 ft (2 to 15 m) of the upper surface of bedded salt. The test zones in three of the four wells were drilled with an air-mist foam to reduce contamination of the strata to be tested. Hydrological and chemical analyses of water samples will be done to determine the source of ground water that dissolves the salt and the rate and timing of salt-dissolution processes.

The potentiometric surface of the Wolfcampian aquifer was updated using head data from the DOE - Stone and Webster No. 1 J. Friemel test well and using refined kriging parameters in the Palo Duro Basin area. An objective geostatistical method was employed to map the distribution of hydraulic heads measured in Upper Pennsylvanian rocks in the Palo Duro Basin and surrounding areas. Data variation was described using geostatistical analysis. Kriging was then used to estimate head values based on the available data having minimum estimate variance. The resulting estimates

were then contoured using CPS-1. Pressure-depth data from drill-stem tests indicate that the Deep-Basin Brine aquifer is underpressured. Potential exists for downward flow from shallow aquifers through the salt section and into the sub-salt brine aquifer. Within the Deep-Basin Brine aquifer, potential for vertical flow varies across the Palo Duro Basin. These variations may affect the lengths of potential flow paths to the biosphere.

Several factors determine the reliability of pressure-depth plots for hydrological interpretation in confined regional aquifers: the quality, quantity, and distribution of available data and variability in the components of the hydrogeological setting—namely, the potentiometric surface, the aquifer structure, and the surface topography. Failure to recognize the effects of these factors can result in misinterpretation of pressure-depth plots and inaccurate conclusions about the potential for vertical flow within the confined aquifer.

Ground waters in the Wolfcampian aquifer flow to the northeast toward the semi-impermeable granite Amarillo Uplift. The Wolfcampian potentiometric surface can be reasonably simulated only for areas where permeability of the granite wash that flanks the uplift is about 260 md. The best simulation results indicate a travel time across the basin of 1.2 to 2.0 million years. Total discharge through the Wolfcampian aquifer is about 550 acre-ft/yr (680,000 m^3/yr).

A cross-sectional ground-water flow model was used to simulate stream lines in addition to the hydraulic heads in the Palo Duro Basin. The model indicates that the spatial distribution of relatively permeable granite wash largely controls the ground-water flow pattern in the Deep-Basin Brine aquifer. Stream lines generally show downward flow into the basin in the center of the cross section. East of the basin, stratigraphically higher granite wash causes the stream lines to deflect upward and then run parallel to the predominantly horizontal formations. Potential discharge of deep basinal brines is indicated by upward-trending stream lines in the eastern Rolling Plains.

Extensive research on borehole sealing was done in response to the initial problems with the proposed nuclear waste repository site at Lyons, Kansas. Laboratory development and testing of grout plugs was emphasized. The Bell Canyon Test at the Waste Isolation Pilot Project (WIPP) site near Carlsbad, New Mexico, is the only major in situ test to date. Information from that test indicates that the steeper hydraulic gradient in the Palo Duro Basin will result in greater flow rates in boreholes there than at the WIPP site.

Geochemistry

R. Stephen Fisher, Clara L. Ho, Long-Cheng Liang, and Steven W. Tweedy; assisted by René V. Curtis and Gay Nell Gutierrez

Ground waters in the Texas Panhandle were analyzed for salinity and composition of deep-basin brines and for chemical and isotopic composition of shallow aquifers; water content of salt was also determined.

A standardized procedure of Soxhlet extraction in anhydrous methanol and Karl Fischer titration was established for the analysis of water content in salt. Values determined for more than 100 salt samples from the Palo Duro Basin range from less than 0.2 to greater than 15 weight percent. Clay-rich salts typically contain an order of magnitude more water than do samples having dolomite, anhydrite, or no impurities.

Highly saline sodium-chloride brines from aquifers below the San Andres Formation at three sites in the Texas Panhandle are capable of dissolving both halite and anhydrite. Although data are not yet sufficient for detailed evaluation of the chemical evolution of fluids along flow paths within specific units, results of analyses suggest that cross-formational mixing of brines may be significant.

The hydrogen (δD) and oxygen ($\delta^{18}O$) isotopic composition of shallow ground waters indicates the presence of typical meteoric water in the Palo Duro Basin area. The δD and $\delta^{18}O$ values range from -82 ‰ to -41 ‰ and -11.46 ‰ to -5.36 ‰, respectively, showing a general increase toward the east. This increase reflects the general decrease in altitude and the heavier isotopic composition of precipitation in the Gulf Coast area. The isotopic composition of ground water from the Dockum Formation in Swisher County suggests an origin farther to the west at higher elevations and the absence of significant mixing with isotopically heavier Ogallala water.

Chemical constituents and isotopic compositions of salt-spring and shallow subsurface brines in the Rolling Plains show characteristics typical of halite dissolution by meteoric ground water as well as discharge of deep-basin brine. The geographic distribution of different brine types correlates well with numerical modeling of ground-water flow.

Surficial and Geomorphic Studies

Thomas C. Gustavson, Robert W. Baumgardner, Jr., S. Christopher Caran, and Marcie D. Machenberg; assisted by Patricia L. Brock, Patricia M. Hester, Ronald G. McMurry, and R. Matthew Myers

Surface and Quaternary studies investigated the relation of structure to dissolution, Quaternary sedimentation and surface physiography, rates of erosion and deposition, and the late Quaternary - Holocene paleoclimate.

The vertical juxtaposition of structure, lithofacies, and dissolution and physiographic features, ranging in age from Paleozoic to Pliocene-Pleistocene, suggests control by the same structural elements in the central western part of the Texas Panhandle.

Quaternary alluvium as thick as 250 ft (76.2 m) covers an area of more than 3,000 mi^2 (7,800 km^2) on the western Rolling Plains. Neither the continuous extent nor the complex stratigraphy of these deposits had been recognized before the present study. Late Quaternary paleoclimatic and paleoenvironmental changes are reflected in this alluvial sequence. Deposition appears to have been structurally controlled in part, and the deposits themselves are faulted and downwarped locally. This new evidence of structural activity and effects on geomorphic processes during the late Pleistocene and Holocene Epochs may have implications for disposal of nuclear waste on the High Plains.

Downwarping and faulting of terrigenous sediment contemporaneous with deposition of late Quaternary beds are well exposed in southeastern Briscoe County, Texas. Deformation probably was caused by subsidence of the Permian subcrop owing to dissolution of bedded salt at depth. Fluvial sands and gravels and lacustrine clays filled the subsidence basin, producing a locally thickened Quaternary section. A well-developed paleosol above the lacustrine deposits was tilted and laterally truncated before modern eolian deposition at the site.

Hypsometric analysis of representative drainage basins indicates that when effects of salt dissolution are removed from long-term estimates of denudation, present rates of denudation are considerably greater than previously estimated rates for periods longer than 100,000 years.

Statistical analysis of erosion-pin measurements indicates significant differences and variability both within and between monitoring stations. The data are normally

distributed about a mean value of -0.135 cm. Field investigators confirmed the existence of differing levels of pin activity, consistent with the magnitude and frequency measurements implied by the normal distribution. Analyses also suggest that increasing the length of the data record or measurement interval will affect neither the frequency distribution of the data nor its validity.

A statistical study of amounts and rates of erosion and deposition from 1978 through 1982 indicates that although mean net erosion has increased over a 3-year period, the mean rate at which it proceeds has decreased. A probabilistic approach to rate projection provides an alternative to linear extrapolations of rates into the future. Geomorphic thresholds should be considered in any rate calculation.

Eolian processes have substantially modified the landscape on the Southern High Plains within historical time. The maximum inferred rate of deflation was 0.74 inch/yr (18.9 mm/yr) at a site in Bailey County, Texas, a region of loose, sandy soils and frequent seasonal dust storms. At least locally, agricultural practices have accelerated natural rates of erosion and deposition by winds. Eolian processes could adversely affect the surface facilities of a nuclear repository.

Preliminary data derived from six dust traps installed on the Southern High Plains show that dust deposition varies locally and seasonally in response to natural and man-induced factors. Monthly rates of dustfall at individual stations ranged from 1.3×10^{-4} lb/ft^2 (0.658 g/m^2) at Muleshoe to 2.8×10^{-3} lb/ft^2 (13.441 g/m^2) at Palo Duro Canyon. Dust deposition contributes greatly to the renewal of the High Plains surface.

Field studies, including drilling and seismic surveying, will be minimal during FY84. Activities will focus on integrating the large amounts of accumulated data into a holistic geology of the Palo Duro Basin.

GEOLOGICAL AND GEOHYDROLOGICAL INVESTIGATIONS IN THE EAST TEXAS BASIN

M. P. A. Jackson, project director; Steven J. Seni and Charles W. Kreitler

This research program, funded by the U.S. Department of Energy (DOE), investigated geological and geohydrological 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 waste. Major considerations in this evaluation were the hydrologic and tectonic stabilities of the domes. To develop information related to these concerns, a Bureau research team in 1978 began geological, structural, stratigraphic, petrological, and geochemical investigations of selected salt domes and also of the entire region. This research 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.

All Bureau geological and hydrological research in the basin from January 1978 through March 1983 was summarized in a contract report, which will be published as a Geological Circular. The report includes a comprehensive evaluation of Oakwood Dome as a potential repository; although it disqualifies Oakwood Dome for this purpose, it concludes that there is no characteristic of salt domes in general that precludes their use as repositories for nuclear waste.

Three papers on the geological aspects of salt flow in the basin were published in international journals and integrated as Report of Investigations No. 139 (in press). In addition, an atlas of all 15 shallow domes in the basin will be published by the Bureau and by the East Texas Geological Society.

Geology

M. P. A. Jackson and Steven J. Seni

Basin analysis during 1983 sought to determine the absolute and relative salt loss during basin evolution. Using five different geometric methods, the original mean thicknesses of Louann Salt were estimated as 1,610 ft (490 m) in the peripheral wedge province, 2,230 ft (680 m) in the pillow province, and 5,840 ft (1,780 m) in the central diapir province. Salt loss was calculated by comparing original thickness with present thickness. The diapir province has lost 540 mi^3 (2,250 km^3), or about 70 percent, of its original salt. Consideration of cap-rock volumes indicates that about 10 percent of this loss was due to subsurface dissolution, and about 90 percent was lost by surface extrusion and weathering. Only about 5 percent of the lost salt is still in solution; the balance has left the basin, presumably to the Gulf Coast Basin and Gulf of Mexico.

The results of the structural investigation of a salt core of the Oakwood Dome were submitted as a contract report. Current research on internal salt-dome structure is generic and designed to provide a reliable conceptual framework for researchers in other areas to apply to other salt bodies being considered as potential repositories. The dynamics of salt flow are being investigated by (1) comparative study of the internal structure of mined salt domes and salt structures exposed at surface, (2) a survey of all published experiments on model diapirs in Texas, Canada, Sweden, and West Germany, and (3) the development of a halokinetic theory that accommodates the rheologic and mechanical properties of rock salt and accords with field studies of natural salt structures.

Preliminary results of these studies suggest that several generations (F_n) of recumbent, tonguelike sheath folds form spontaneously in the horizontal source layer either where materials of slightly different viscosity are flowing laterally or where irregular roofs or floors bound the salt layer, as in salt glaciers (namakiers). In the stem of the diapir, these folds are refolded by F_{n+1} vertical folds; cross sections through these interference structures are crescent or mushroom shaped. If the diapir forms an overhanging cap, all older folds are refolded by an F_{n+2} generation of folds whose attitude varies from recumbent to upright. The F_{n+2} folds are either buckles highly flattened by transverse flow or shear folds formed by flow parallel to their axial surfaces. By deducing internal flow patterns, it is hoped that the distribution of in situ stresses can be at least partly inferred. The conditions under which deep folds of country rock penetrate the overhang region of a diapir are also being studied. If present, such indentations could threaten the hydrologic integrity of a hypothetical nuclear waste repository in a salt dome.

Geohydrology

Charles W. Kreitler

Hydrological investigations during 1983 were directed at the shallow meteoric aquifers around the domes and regional 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. Study of the hydrology of the deep saline aquifers in the East Texas Basin was completed and can be summarized as follows:

Ground waters in the deep aquifers (Nacatoch to Travis Peak) range in salinity from 20,000 to more than 200,000 mg/L. Their hydrogen and oxygen isotope compositions indicate that they were originally recharged as continental meteoric waters and probably were recharged during Cretaceous time. The waters therefore are very old. Both the water chemistry and the hydraulic pressures for the aquifers suggest that the basin can be subdivided into two major aquifer systems: (1) the Upper Cretaceous aquifers (Woodbine and shallower), which are hydrostatic to subhydrostatic, and (2) the Lower Cretaceous and deeper formations (Glen Rose, Travis Peak, and older units), which are slightly overpressured.

Major chemical reactions in the saline aquifers are dome dissolution, albitization, and dolomite dissolution. Salt-dome dissolution is considered to be the source of sodium and chloride in the saline waters. Albitization and dolomite dissolution occur only in the deeper formations. The high sodium concentration results in the alteration of plagioclase to albite and the release of calcium into solution. The increase in calcium should result in dolomite dissolution.

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

L. F. Brown, Jr., project director; David A. Johns and Margaret J. Herron

Drafting is complete and final proofing is underway on 24 regional dip and strike stratigraphic cross sections of the Virgilian and Wolfcampian Series in 25 counties of North-Central Texas. The cross sections provide a stratigraphic framework developed during the 1970's to support preparation of regional sandstone isolith and paleogeographic maps. It is anticipated that the cross sections and a brief text will be published late in 1984.

Cartographic preparation of regional sandstone isolith and paleogeographic maps of 16 lithostratigraphic sequences (Virgilian and Wolfcampian Series) covering 25,000 mi² (64,750 km²) was advanced in early 1984. These maps and a text should be completed during 1984.

GULF COAST STRATIGRAPHIC NOMENCLATURE

T. E. Ewing, project director

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 and suggested usage.

Stratigraphic nomenclature of 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 by the Bureau and other researchers have often used informal nomenclature. This project attempts to clarify formal nomenclature for genetic stratigraphic units within the guidelines of the North American Code of Stratigraphic Nomenclature.

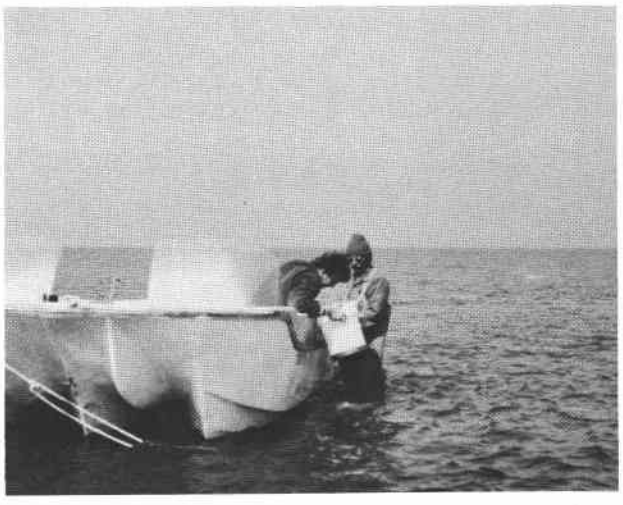
COASTAL STUDIES

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

E. G. Wermund, project coordinator; William A. White, principal investigator; Thomas R. Calnan, chief biologist; R. A. Morton, Russell S. Kimble, Thomas G. Littleton, and H. Seay Nance; assisted by James A. DiGiulio; Clara L. Ho, Charlotte S. Holland, Steven W. Tweedy, and Paul N. Williams, chemists; Barbara M. Hartmann, Mark T. Bentley, Richard L. Dillon, David M. Ridner, and Dan F. Scranton, cartographers

Work continued through 1983 on this long-term comprehensive inventory of Texas coastal submerged lands and associated wetlands. The project has been funded in part with grants under the Coastal Zone Management Act of 1972, as amended, which was administered by the Office of Coastal Zone Management, Coastal Energy Impact Program of the National Oceanic and Atmospheric Administration, through the Governor's Budget and Planning Office of the State of Texas, and with a recent grant from the Minerals Management Service, U.S. Department of the Interior.

This multiphase project is based on a completed sediment-sampling program of State-owned submerged lands during which more than 6,700 grab samples were collected for analyses of sediment types, associated geochemistry, and benthic macroinvertebrates. Grab samples were collected on 1-mi (1.6-km) centers from (1) the inner continental shelf extending from the Texas Gulf shoreline seaward for 10.36 statute mi (3 marine leagues) and from (2) the bay-estuary-lagoon system of the coastal zone from the Rio Grande to Sabine Lake. Another phase of the project uses color-infrared photographs to map the regional distribution of coastal wetlands, which will complement maps of submerged lands. Also, a seasonal monitoring program was begun in 1982 in Espiritu Santo and Lavaca Bays. Multiple benthic grabs of sediments were taken monthly from 14 selected bay stations for



W. A. White

Thomas R. Calnan and Thomas G. Littleton examine sediments collected with a grab sampler from Espiritu Santo Bay.

macroinvertebrate and textural analyses. This short-term study was completed in 1983.

Results of the State submerged lands project will be published in a series of seven atlases of the Texas coast. Map areas are similar to those used in the Bureau's Environmental Geologic Atlas of the Texas Coastal Zone series. Atlases will consist of a series of 17 maps, with accompanying text, depicting sediment distribution, concentrations and distribution of selected trace and major elements, and distribution of benthic macroinvertebrates and wetlands. The first submerged lands atlas—covering the Corpus Christi area—was published late in 1983. The next atlas to be published will be of the Galveston-Houston area.

During 1983, sediment analyses, conducted by the Bureau's Sedimentology Laboratory, were completed for the samples collected monthly in Espiritu Santo and Lavaca Bays. Also, textural analyses of about 100 samples previously collected from the inner continental shelf were begun to supplement previous analyses.

Geochemical analyses of more than 100 sediment samples from the bay-estuary-lagoon environments in the Port Lavaca and Bay City - Freeport areas were completed by the Mineral Studies Laboratory of the Bureau. These samples were selected to provide a better understanding of sediment and geochemical relations in these areas. Sedimentological and geochemical data are being entered into computer files for regression analyses; analyses were completed for the Brownsville-Harlingen map area.

Biological analyses are complete for all areas of the Texas coast. Data were processed by computer for cluster analyses and species diversity, and the results will be presented on hand-colored maps of each area. In addition, analyses of all benthic samples collected in Espiritu Santo and Lavaca Bays have been completed. Among the eventual products of the biological analyses will be full-color maps (scale 1:125,000) showing the distribution of macroinvertebrate assemblages and species diversity.

Delineation of wetlands continued in 1983. The objective is to produce full-color updated regional maps of wetlands distribution. Preliminary photographic interpretation and delineation of wetlands were begun for the Bay City - Freeport and Port Lavaca map areas. Cartographically scribed black-line prints depicting wetland unit boundaries were completed for the Galveston-Houston area and much of the Brownsville-Harlingen area. Scribing of wetland boundaries in the Beaumont - Port Arthur area was in progress. The initial hand-colored wetlands map of the Galveston-Houston area was completed.

HISTORICAL MONITORING OF TEXAS BAY SHORELINES

R. A. Morton, project director; Jeffrey G. Paine and William A. White; assisted by James A. DiGiulio and Diane E. Robinson

This project documents historical shoreline changes in some of the major Texas bays using techniques modified from those developed in the 1970's to monitor Gulf shoreline changes. The Texas Energy and Natural Resources Advisory Council partly funded a pilot project in the Corpus Christi Bay area in 1982 and the present studies of the Galveston and San Antonio Bay systems. Shoreline changes between the late 1800's and 1982 have been determined by comparing current shorelines with those shown on vintage topographic maps and aerial photographs dating from 1929. Sequential mapping has established shorelines as accreting, stable, or eroding and allowed the determination of rates of accretion or erosion.

In the Galveston Bay system (including Galveston, Trinity, East, and West Bays), most of the 1982 shoreline was landward of its position in the 1850's. The most widespread erosion occurred in Galveston Bay, where nearly 86 percent of the shoreline experienced erosion of 25 ft (8 m) or more. Erosion in the other bays was also extensive: 81 percent in West Bay, 78 percent in East Bay, and 67 percent in Trinity Bay. Typical erosion rates for the bay system were 1 to 5 ft/yr (0.3 to 1.5 m/yr), although higher rates were also common. Higher rates of erosion generally occurred in areas of great subsidence, areas of long northerly and southeasterly wave fetch, and along shorelines not protected by vegetation, bulkheads, or riprap. Appreciable accretion occurred only in Trinity Bay, with the progradation of the Trinity delta; areas of deltaic deposition accreted at high rates (10 to 40 ft/yr [3 to 13 m/yr]) before 1956. Subsidence, partial diversion of the Trinity River, and decreases in suspended-sediment concentration have resulted in considerable erosion along much of the Trinity delta since 1956.

In the San Antonio Bay system (Mission Lake and San Antonio, Espiritu Santo, Mesquite, and Guadalupe Bays), distances and directions of change between sequential shoreline positions were measured at approximately 190 stations spaced about 5,000 ft (1.5 km) apart. More than 70 percent of the stations recorded net shoreline erosion between the mid-1800's and 1982. Net long-term rates of erosion range from less than 1 ft/yr (less than 0.3 m/yr) to a high of about .11 ft/yr (3.5 m/yr). More recent short-term erosion rates along some shorelines exceed 11 ft/yr (3.5 m/yr). Highest rates of erosion were documented along Matagorda Island, along smaller islands on the mainland side of Espiritu Santo Bay, and along much of the shoreline of the Guadalupe delta at the head of San Antonio Bay. Retreat of this modern delta, which in some areas exceeds 8 ft/yr (2.5 m/yr), is occurring most rapidly along its southern boundary, where distributary channels are no longer active. Compactional subsidence of the delta has accelerated erosion. In the northern part of the delta, high rates of accretion or progradation have occurred at the mouths of distributaries fed by Traylor Cut (an artificial cut), which since its construction in 1935 has diverted most of the discharge of the Guadalupe River into shallow Mission Lake. Other human modifications that have affected shorelines in the San Antonio Bay system include the Intracoastal Waterway, Victoria Channel, and a variety of shoreline protection structures near Seadrift.

COASTAL CHANGES ASSOCIATED WITH HURRICANE ALICIA

R. A. Morton, project director; Jeffrey G. Paine; assisted by James A. DiGiulio

Although Hurricane Alicia was not an extreme event by meteorological standards, the storm caused substantial damage to private dwellings, eroded the beach, and caused retreat of the vegetation line along the upper Texas coast. Especially hard hit was west Galveston Island, where Alicia came ashore.

This study, partly funded by the Texas Office of the Attorney General, will provide measurements of the changes along the Gulf shoreline caused by the storm and an analysis of the physical processes that resulted in those changes. Primary data prepared for the study during 1983 include maps of the vegetation lines shown on aerial photographs before and after Alicia, as well as field observations and ground measurements. A second part of the study will deal with post-storm processes and the

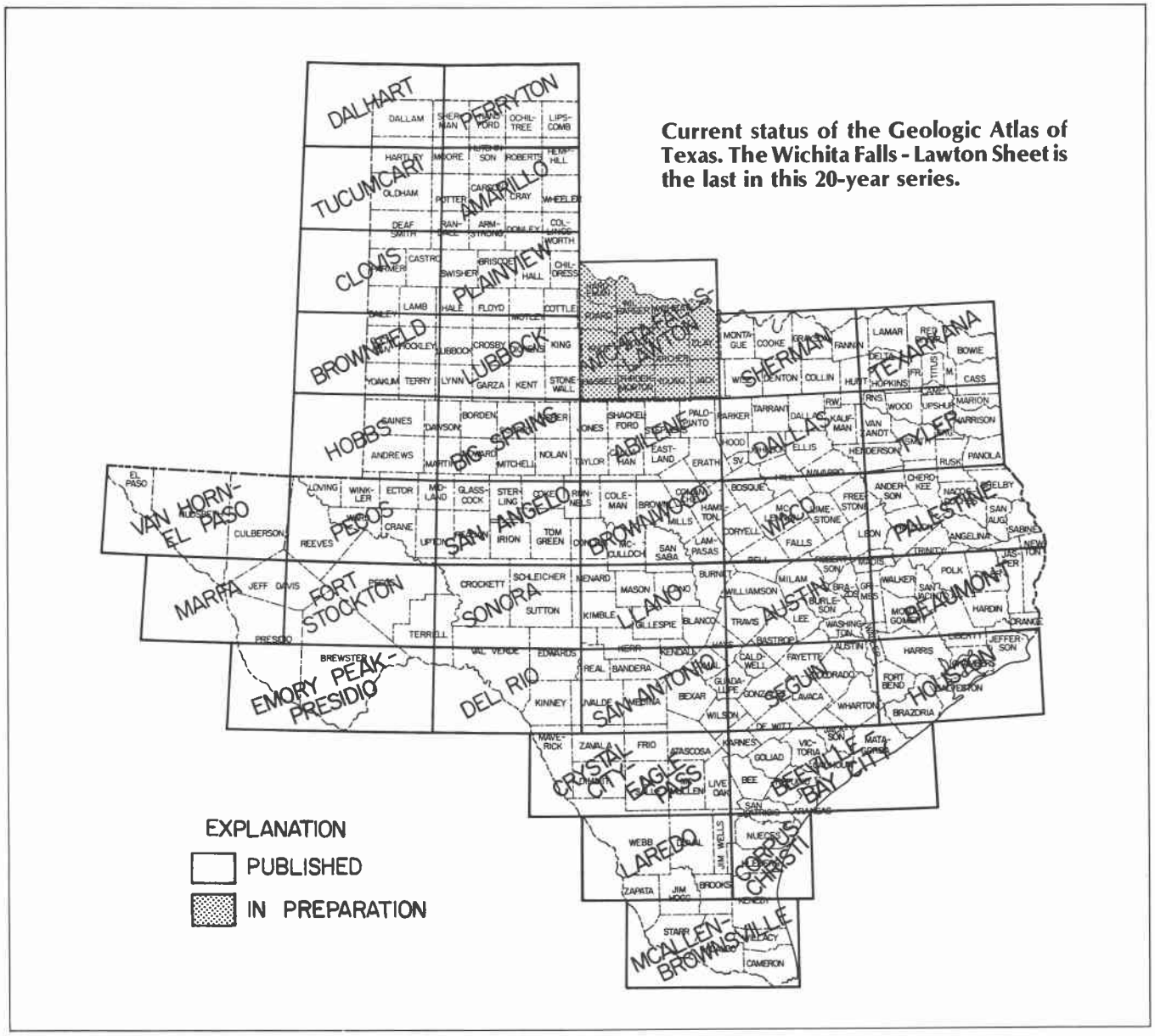
potential recovery of the beach and adjacent environs in both developed and undeveloped areas. Of particular interest is the magnitude and rate of natural recovery of the vegetation line following hurricanes in 1942 and 1961 and following Alicia. A better understanding of the rapid shifts in coextensive geological and legal boundaries will be achieved by studying beach response after major storms in Texas.

GEOLOGIC MAPPING

GEOLOGIC ATLAS OF TEXAS

Virgil E. Barnes, project director; L. F. Brown, Jr., and Tucker F. Hentz; Richard L. Dillon, Thomas M. Byrd, Margaret L. Evans, and Margaret R. Day, cartographers

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 about 4 mi). Most of the map sheets depict areas within 1 degree of latitude and 2 degrees of longitude, but some sheets cover larger or smaller areas to accommodate cartographic presentation. When completed, the Geologic Atlas of Texas will consist of 38 map sheets depicting all of Texas and parts of adjacent states.



James A. Morgan

Tucker F. Hentz uses a stereoscope to check field mapping for the Wichita Falls - Lawton Sheet.

The Tucumcari Sheet was published during 1983, bringing to 36 the number of sheets in print. The Dalhart Sheet is scheduled for publication early in 1984. Field checking of the final sheet of the series, the Wichita Falls - Lawton Sheet, will be completed by Tucker F. Hentz, under the supervision of L. F. Brown, Jr., by year's end.

Revision and reprinting of geologic atlas sheets continues. The extensively revised San Antonio Sheet and the slightly revised Van Horn - El Paso Sheet were reprinted during the year. The extensively revised Beaumont Sheet is ready to go to press, and the slightly revised Abilene Sheet will be ready by 1985. The moderately revised Beeville - Bay City Sheet will be reprinted when the current supply of maps nears exhaustion. The Perryton Sheet is being moderately revised, and extensive revision of the Lubbock Sheet, in part dependent on completion of the Wichita Falls - Lawton Sheet, is underway. Now that field work on the Wichita Falls - Lawton Sheet is complete and the unit has been traced onto the Sherman Sheet, the Sherman Sheet revision will soon go to cartography. All but the northeast quarter of the Palestine Sheet has been revised; revision will be completed when U.S. Geological Survey 7.5-minute topographic maps of the quarter are available.

GEOLOGIC MAP OF TEXAS

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

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

The new map is being derived from the Geologic Atlas of Texas map sheets (scale 1:250,000). A set of completed sheets of the Geologic Atlas of Texas has been marked for use in drafting the new map. Scribing is essentially complete for the southeast, northwest, and southwest quadrants of the map. Scribing is advanced for the northeast quadrant and will be completed as soon as copy for the Wichita Falls - Lawton Sheet is available.

TECTONIC MAP OF TEXAS

T. E. Ewing, project director; M. P. A. Jackson, Christopher D. Henry, Roy T. Budnik, Steven C. Ruppel, and Charles M. Woodruff, Jr.; assisted by Stephen E. Lovell and Melissa A. Sandstrom; William R. Muehlberger, The University of Texas at Austin, Department of Geological Sciences; J. R. Garrison, consultant, Arlington, Texas; R. L. Nicholas, Shell Oil Co., Houston, Texas; Arthur G. Goldstein, Colgate University, Hamilton, New York

The last systematic statewide compilation of structural and tectonic information was done by E. H. Sellards in the 1940's. Since then, much new surface and subsurface information has been acquired, and the concepts of tectonic mapping have advanced. This project will incorporate these new data in a detailed display of surface and subsurface structural history for the state and adjoining areas of New Mexico, Oklahoma, Mexico, and the Gulf of Mexico. The map will be in full color at a scale of 1:750,000. It will show exposed lithotectonic units in areas of surface structure and contours on selected deep horizons in areas of subsurface structure. Inset maps will show gravity, magnetics, basement terranes, and radiometric provinces. A companion illustrated text is also being compiled to systematically describe and synthesize the tectonic evolution of Texas from the Proterozoic to the Recent.

A preliminary review copy of the map was displayed at the American Association of Petroleum Geologists 1983 annual meeting in Dallas, Texas. Since then, all local geological societies in the state and adjoining areas have been asked to review the content and style of the map and to suggest improvements or revisions. Many oil and gas companies, as well as state geological surveys from adjoining states, have also been asked to review the map. The map will be published in 1985, with the companion text to follow.

GRAVITY AND MAGNETIC MAPPING OF TEXAS

G. R. Keller, The University of Texas at El Paso, and C. L. V. Aiken, The University of Texas at Dallas, project directors

Gravity and magnetic maps of Texas are being prepared at a scale of 1:250,000 to complement the surface-geology maps of the Geologic Atlas of Texas series. The project involves considerable computer reprocessing, compilation, and cartography. Gravity (Bouguer) maps are being prepared by combining the results of many different surveys, many of which have been provided by the U.S. Department of Defense, into a single datum. These gravity data are then smoothed with a high-order polynomial surface. Gravity maps in cartographic preparation in early 1984 included the following quadrangles: Clovis, Plainview, Amarillo, Tucumcari, Perryton, Dalhart, Brownfield, and Lubbock.

Magnetic maps are being prepared using National Uranium Resource Evaluation aeromagnetic surveys. The U.S. Department of Energy in Grand Junction, Colorado, is cooperating with the Texas program by reprocessing NURE data as required to develop integrated statewide contour maps. Individual maps will be published over the next several years as each is completed.

OTHER RESEARCH

CRETACEOUS VOLCANISM IN TEXAS

T. E. Ewing, project director; S. Christopher Caran

This project is using integrated surface mapping, subsurface core description, and geophysical interpretation to supply a regional context for the distribution of Middle to Late Cretaceous igneous rocks along the Balcones trend of South and Central Texas. The continued cooperation of oil companies and individuals currently prospecting for volcano-related hydrocarbon reservoirs has greatly assisted in construction of models of Late Cretaceous volcanism. A Bureau Geological Circular summarizing this research is in preparation.

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 1983 was mostly curatorial—furnishing material for other researchers, answering questions, and identifying specimens.

APPLICATION OF REMOTE-SENSING TECHNOLOGY TO RESOURCE EVALUATION IN TEXAS

Robert J. Finley, project director; Robert W. Baumgardner, Jr.; assisted by Robert Aanstoos and Charles Lancaster, Texas Natural Resources Information System

This project, which applies remote-sensing methods to natural resources studies, is being conducted in cooperation with the Texas Natural Resources Information System (TNRIS). Irrigated croplands in Parmer County, Texas, and mineralized zones in the Trans-Pecos region were investigated during 1983.

Landsat data, together with aerial photographs and field data, were used to delineate irrigated croplands in Parmer County. A ratio of Landsat data (band 7/band 5) was used to identify thick vegetation canopies, presumably resulting from irrigation. The Geographic Information System (GIS) of TNRIS was used (1) to smooth the data, removing small, anomalous areas from the map of irrigated acreage, and (2) to composite data from three dates during a single growing season. The GIS was then used to combine the map of irrigated croplands with a map of Parmer County showing major towns and roads. This method makes it possible to map changes in irrigated crops during a growing season or to make cumulative maps of irrigated land in a more timely fashion than is possible using present methods based on polls of farmers.

In Trans-Pecos Texas, Landsat band 5/band 4 ratio data were composited using a contrast-stretched band 5 density slice to show areas of limonite and jarosite surface staining at Red Hill, a quartz porphyry intrusive having extensive supergene alteration. The resulting image best placed the distribution of iron staining (based on ratio data) in the framework of the surface topography of the Chinati Mountains surrounding Red Hill (based on the density slice).

THE PROVINCES OF TEXAS: THEIR REGIONAL AND ECONOMIC GEOLOGY

W. Keene Ferguson, project director

The various physiographic provinces of Texas provide the framework for a synthesis of mineral and petroleum resources, general geology, and natural history. Provinces include the Gulf Coastal Plain, the Comanchean Uplands, the Great Plains, and the Trans-Pecos region. Drafts were complete by mid-1983 and review will continue during 1984.

DEPOSITIONAL SYSTEMS AND TAPHONOMY OF VERTEBRATE FOSSIL LOCALITIES IN THE WICHITA GROUP, NORTH-CENTRAL TEXAS

Michael A. Fracasso and Tucker F. Hentz

Vertebrate fossil sites in North-Central Texas offer the most complete record of tetrapod evolution known from the Lower Permian. This project entails interpreting the site-specific features of the depositional systems that produced these assemblages and locating each site in a precise lithostratigraphic and biostratigraphic framework.

CONTRACTS AND GRANT SUPPORT

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

Contract-management personnel prepare proposals and budgets, negotiate contracts, and monitor expenditures. During the contract period, technical and financial reports are distributed at monthly, quarterly, and annual intervals. In calendar year 1983, the following 23 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, U.S. Department of the Interior.

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

"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.

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

"Geologic Framework and Energy Resource Studies, Texas Continental Shelf (Phase I)": supported by the U.S. Geological Survey, U.S. Department of the Interior.

"Geologic Framework and Energy Resource Studies, Texas Continental Shelf (Phase II)": supported by the Minerals Management Service, U.S. Department of the Interior.

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

"Geothermal Resource Assessment for the State of Texas": 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, U.S. Department of the Interior.

"Studies Related to Continental Margins": supported by the Minerals Management Service, U.S. Department of the Interior.

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

State

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

"Analysis of Texas Salt Domes as Potential Sites for Permanent Storage of Toxic Chemical Wastes": supported by the Texas Department of Water Resources.

"Effects of Hurricane Alicia on the Texas Coast": supported by the Office of the Attorney General.

"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 the Texas Energy and Natural Resources Advisory Council.

"Mineral Resource Evaluation for the Lower Colorado River Authority": supported by the Lower Colorado River Authority.

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

Other

"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 the Gas Research Institute.

CONTRACT AND GRANT REPORTS

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

Finley, R. J., Garrett, C. M., Han, J. H., Lin, Z. S., Saucier, A. E., Seni, S. J., and Tyler, Noel, 1983, Geologic analysis of primary and secondary tight gas sand objectives, Phase A—Selective investigation of six stratigraphic units; Phase B—Initial studies: annual report prepared for the Gas Research Institute under contract no. 5082-211-0708, 334 p.

Finley, R. J., Price, J. G., and Henry, C. D., 1983, Remote sensing and mineral resource evaluation in Trans-Pecos Texas: prepared for the Texas Natural Resources Information System under contract no. IAC(80-81)-1935, 9 p.

Galloway, W. E., Tyler, Noel, Garrett, C. M., Jr., Bebout, D. G., Cheng, E. S., and Fisher, W. L., 1983, Geological characterization of Texas oil reservoirs: prepared for the Texas Energy and Natural Resources Advisory Council under contract no. IAC(82-83)-0821, 82 p.

Gregory, A. R., Lin, Z. S., Reed, R. S., Morton, R. A., and Ewing, T. E., 1983, Exploration and production program for locating and producing prospective aquifers containing solution gas and free gas—Texas Gulf Coast: prepared for the Gas Research Institute under contract no. 5080-321-0398, 197 p.

Kaiser, W. R., Ambrose, M. L., Ayers, W. B., Jr., Blanchard, P. E., Collins, G. F., Fogg, G. E., Gower, D. L., Ho, C. L., Jackson, M. L. W., Jones, C. M., Lewis, A. H., Mahan, C. A., Macpherson, G. L., Prouty, D. A., Tewalt, S. J., and Tweedy, S. W., 1983, Evaluating the geology and groundwater hydrology of deep-basin lignite in Texas: interim report prepared for the Texas Energy and Natural Resources Advisory Council under contract no. IAC(82-83)-0822, 130 p.

Morton, R. A., Ewing, T. E., Kaiser, W. R., and Finley, R. J., 1983, Consolidation of geologic studies of geopressured geothermal resources in Texas: prepared for the U.S. Department of Energy, Division of Geothermal Energy, under contract no. DE-AC08-79ET27111, 193 p.

Morton, R. A., and Paine, J. G., 1983, Historical monitoring of shoreline changes in Corpus Christi, Nueces, and Oso Bays: prepared for the Texas Energy and Natural Resources Advisory Council under contract no. IAC(82-83)-1342, 82 p.

Morton, R. A., Paine, J. G., and White, W. A., 1983, Historical shoreline changes in the Galveston Bay and San Antonio Bay systems, Texas Gulf Coast: prepared for the Texas Energy and Natural Resources Advisory Council, Division of Natural Resources, under contract no. IAC(82-83)-2025, 150 p.

Teledyne Geotech (subcontractor), 1983, Microseismic monitoring of Chocolate Bayou, Texas, the Pleasant Bayou No. 2 geopressured/geothermal energy test well program: annual report prepared for the U.S. Department of Energy under contract no. DE-AC08-79ET27111, 116 p.

The following Bureau publications served as final contract reports during 1983: Report of Investigations No. 129, contract no. 14-08-0001-G-642; Report of Investigations No. 133 and Geological Circular 83-1, DE-AC97-80ET46617; Report of Investigations No. 134, DE-AC08-79ET27111; Geological Circular 83-2, IAC(82-83)-0821; and Geological Circular 83-4, DE-AC97-83WM46651.

PUBLICATIONS

In its role as a public geological research unit, the Bureau disseminates the results of research projects and programs primarily through its own publication series. During its 74-year history, the Bureau has published nearly 1,000 reports, bulletins, circulars, special publications, and maps covering major aspects of the geology and natural resources of Texas. Publications are sold at nominal prices to recover printing or duplication costs. To date, about 1.5 million publications have been distributed worldwide, mostly through direct sales. During 1983, about 48,000 volumes were distributed. The Bureau issued the following publications in 1983:

SPECIAL PUBLICATIONS

Atlas of Major Texas Oil Reservoirs, by W. E. Galloway, T. E. Ewing, C. M. Garrett, N. Tyler, and D. G. Bebout. 139 p., 426 figs., 3 tables, 5 pls. ($40.00).

Fully illustrated compilation of geologic, engineering, and production data on the major oil reservoirs in Texas. This large-format atlas presents selected structure maps, cross sections, typical logs, and geological data for nearly 450 oil reservoirs in Texas that each have produced at least 10 million barrels of oil. These reservoirs together account for 70 percent of recorded production in the state through 1981. The authors grouped the reservoirs into 48 "plays," or families of reservoirs having the same depositional origin and, consequently, similar hydrocarbon source, reservoir, and trap characteristics. The plays are cataloged by geographic region: the Gulf Coast, East Texas, North-Central Texas, West Texas, and the Texas Panhandle. A brief descriptive text reviews the geological setting and production characteristics of each play. Detailed computer-generated tables list fluid, reserve, and production data on each reservoir. Most information in this atlas was compiled from unpublished sources, primarily hearing files of the Railroad Commission of Texas. Other sources of data included the Energy Information Agency of the U.S. Department of Energy and field studies published by regional geological societies, by the American Association of Petroleum Geologists, and by the Society of Petroleum Engineers of the American Institute of Mining, Metallurgical and Petroleum Engineers. Data were acquired and sorted over a period of nearly 2 years. The publication measures 17 by 22 inches and contains more than 400 maps and illustrations. Five full-color plates show lithology, genesis, stratigraphy, and trap and drive mechanisms of reservoirs across the state. This atlas was issued by the Bureau as a Centennial publication of The University of Texas at Austin.

Submerged Lands of Texas, Corpus Christi Area: Sediments, Geochemistry, Benthic Macroinvertebrates, and Associated Wetlands, by W. A. White, T. R. Calnan, R. A. Morton, R. S. Kimble, T. G. Littleton, J. H. McGowen, H. S. Nance, and K. E. Schmedes. 154 p., 60 figs., 21 tables, 6 pls., 4 appendices ($7.00).

Detailed inventory of submerged lands and associated wetlands in the Corpus Christi area of the Texas Coastal Zone. The primary aim of the Bureau's Submerged Lands of Texas Project, which was begun in 1975, is to provide comprehensive sedimentological, geochemical, and biological data needed to predict, measure, and manage the direct and indirect effects of coastal activities on the State-owned submerged lands of Texas. These lands encompass nearly 6,000 mi^2 (16,000 km^2) and extend 10.3 mi (17 km) from the Gulf shoreline on the inner continental shelf. This atlas, which focuses on the Corpus Christi area of the Coastal Zone, is the first in a series of atlases reporting the findings of the project. Researchers collected 6,700 surficial bottom samples across the submerged lands, from the Rio Grande to Sabine Lake, for the entire project. They performed detailed analyses to map and describe sediment distribution, concentrations of selected major and trace elements, and benthic macroinvertebrate populations of the submerged lands. Adjacent wetlands were delineated using stereoscopic, color-infrared positive transparencies taken by the National Aeronautics and Space Administration. Research was funded by the General Land Office and the Governor's Budget and Planning Office of the State of Texas through programs administered by the Office of Coastal Zone Management, National Oceanic and Atmospheric Administration. This new atlas series will complement the Bureau's Environmental Geologic Atlas series.

GEOLOGIC ATLAS OF TEXAS

Geologic Atlas of Texas, Tucumcari Sheet, Henryk Bronislaw Stenzel Memorial Edition, V. E. Barnes, project director. Scale 1:250,000, full color, topographic base ($4.00).

Geologic map sheet covering all of Oldham and parts of Hartley, Moore, Potter, Randall, and Deaf Smith Counties in Texas and parts of Quay, San Miguel, Harding, and Union Counties in New Mexico. The Tucumcari Sheet belongs to the Bureau's Geologic Atlas of Texas, a series of 38 map sheets showing the distribution of outcropping rock units in all of Texas and parts of adjacent states. Mapping for this sheet in Texas was compiled and field checked by G. K. Eifler, Jr., and in New Mexico by F. D. Trauger, Z. Spiegel, and J. W. Hawley using high-altitude aerial photographs. The map was reviewed by the Panhandle Geological Society. It is printed in full color on a topographic base at a scale of 1:250,000.

This sheet is a memorial edition honoring Henryk Bronislaw Stenzel (1899-1980). Dr. Stenzel was a member of the Bureau from 1934 to 1954 and a professor of geology at the University of Texas from 1947 to 1954. He emigrated to

the United States from Poland in 1925 and taught stratigraphy at Texas A&M University before he joined the Bureau. His training was in petrology and petrofabrics, which prompted his mapping of the Wolf Mountain phacolith in the Llano region. In deference to his A&M assignment, he changed his interest to soft-rock geology and became one of the foremost stratigraphers and paleontologists of the Tertiary of the Gulf Coast region. Following his work at the Bureau, he served as chairman of the Department of Geology at the University of Houston, as consultant for Shell Development Co., and as visiting professor of geology at Louisiana State University.

REPORTS OF INVESTIGATIONS

RI 130. Deep Brine Aquifers in the Palo Duro Basin: Regional Flow and Geochemical Constraints, by R. L. Bassett and M. E. Bentley. 59 p., 42 figs., 7 tables, 3 appendices ($2.50).

Investigation of the hydrogeology, flow system, chemical composition, and geochemical constraints on the brine environment of deep aquifers in the Palo Duro Basin of the Texas Panhandle. This report details the first phase of a comprehensive Bureau study of the hydrology of the Palo Duro and Dalhart Basins that will be used by the U.S. Department of Energy to evaluate the suitability of Permian salt formations for nuclear waste isolation. This phase focuses on Early Permian Wolfcamp carbonate aquifers in the Palo Duro Basin. Data sources include drill-stem tests, bottom-hole measurements, and chemical brine analyses conducted during wildcat drilling. In addition, the authors integrated two recently developed computer-modeling programs, AQ/SALT and SOLMNEQ, to evaluate the brine reaction state. The report concludes that the brines in deep aquifers of the Palo Duro and Dalhart Basins are moving eastward. The aquifers appear to be underpressured owing to a low-permeability evaporite barrier above transmissive carbonate and granite-wash facies; however, horizontal head gradients measured in the aquifers correspond to regional topographic slope. The authors found that salinity varies only slightly from the regional average and primarily results from dissolution of evaporites early in the flow path. Brines are in equilibrium with calcite in carbonate host rocks and also possibly with anhydrite in regions where sulfate reduction has not generated hydrogen sulfide.

RI 131. Origin and Diagenesis of Cap Rock, Gyp Hill and Oakwood Salt Domes, Texas, by C. W. Kreitler and S. P. Dutton. 58 p., 52 figs., 9 tables ($3.50).

Petrographic and geochemical comparison of cap rock in Gyp Hill and Oakwood salt domes of Texas. Some types of cap rock are thought to act as impermeable seals on salt stocks, preventing salt dissolution and thereby making the salt domes potentially more suitable as repositories for nuclear waste. This study, which was funded by the U.S. Department of Energy, delineates and contrasts the lithological, genetic, and hydrological characteristics of cap rock at Oakwood salt dome in East Texas, where cap rock appears to act as an effective barrier to salt dissolution, and at Gyp Hill salt dome in South Texas, where it apparently does not. The report contains more than 70 micro-photographs of cap-rock core from the two domes, as well as the results of detailed chemical and isotopic analyses. It also includes petrographic analyses of cap rock in four salt domes in Mississippi and Louisiana. The authors found that the genesis and diagenesis of cap rock at Gyp Hill and Oakwood salt domes occurred at different times and in different environments: Gyp Hill cap rock is now forming in a shallow meteoric aquifer, whereas Oakwood cap rock formed primarily during the Early Cretaceous in a deep saline aquifer. These different histories, the authors propose, account for the differences that were identified between the two cap rocks.

RI 132. Continuity and Internal Properties of Gulf Coast Sandstones and Their Implications for Geopressured Fluid Production, by R. A. Morton, T. E. Ewing, and N. Tyler. 70 p., 42 figs., 7 tables ($3.00).

Measurement and comparison of the geometries and inhomogeneities of sandstones representing the dominant depositional facies of geopressured geothermal aquifers and hydrocarbon reservoirs in the Texas Gulf Coast Basin. One aim of this study, which was funded by the U.S. Department of Energy, is to allow identification of the production potential of a sandstone reservoir on the basis of its facies type, lateral continuity, and diagenetic modifications. To compare the typical reservoir volumes and areal extents of Gulf Coast sandstones (fluvial, deltaic, barrier-strandplain, and shelf and slope), the authors classified sand bodies according to a four-level hierarchy: sand systems, fault blocks, individual sandstones within fault blocks, and isolated reservoirs. Measurement tools and data sources included published and unpublished studies of upper Quaternary and upper Tertiary sediments, planimetry of structure maps for more than 200 fault blocks in the Frio and Wilcox trends, estimates of the volumes of individual reservoirs calculated from geologic mapping and from engineering production data, and structure and stratigraphic maps of the areas surrounding three Gulf Coast wells of opportunity. In addition, the authors used sedimentary structures, electric log patterns, and more than 300 ft (90 m) of core from a Frio geopressured test well to identify six patterns of vertical variations in porosity and permeability. They ranked the production potential of the dominant facies types in the Gulf Coast Basin. The authors suggest that large and continuous reservoirs most likely occur where barrier-strandplain and delta-front sandstones parallel regional faults.

RI 133. Three-Dimensional Ground-Water Modeling in Depositional Systems, Wilcox Group, Oakwood Salt Dome Area, East Texas, by G. E. Fogg, S. J. Seni, and C. W. Kreitler. 55 p., 43 figs., 4 tables ($3.25).

Application of a three-dimensional numerical model to study ground-water flow in depositional systems of the Wilcox Group near Oakwood Dome in the East Texas Basin. This study presents a numerical model for testing hypotheses on ground-water circulation near salt domes. Funded by the U.S. Department of Energy, the report is part of the Bureau's evaluation of the hydrogeological suitability of salt domes for storing high-level nuclear waste. The authors used both lithofacies maps and field and laboratory measurements of hydraulic conductivity to characterize the geologically complex Wilcox aquifer. The model shows the relative importance and interaction of regional ground-water circulation patterns, vertical leakage across the Reklaw aquitard, recharge over Oakwood Dome, and large-

scale heterogeneity and anisotropy of the Wilcox-Carrizo aquifer system. To test the sensitivity of the model, the authors ran seven scenarios of flow conditions assuming various distributions of hydraulic conductivity of the Wilcox-Carrizo aquifer system and of the Reklaw aquitard. The study concludes that the interconnectedness of permeable channel-fill sands, which have predictable values of hydraulic conductivity, strongly influences the rate and direction of ground-water flow in the Wilcox. It also proposes that lateral interconnectedness may largely depend on the distribution and frequency of channel-fill sands and that vertical interconnectedness is apparently poor owing to horizontal stratification of sand and mud.

RI 134. Depositional Setting, Structural Style, and Sandstone Distribution in Three Geopressured Geothermal Areas, Texas Gulf Coast, by C. D. Winker, R. A. Morton, T. E. Ewing, and D. D. Garcia. 60 p., 49 figs., 8 tables ($2.50).

Interpretation of the depositional and structural histories of three areas on the Texas Gulf Coastal Plain and comparison of their potentials as exploration sites for geopressured geothermal reservoirs. Funded by the U.S. Department of Energy, this study is part of a regional evaluation of the feasibility of producing geothermal energy and methane from deep geopressured Tertiary sandstone aquifers beneath the Texas Coastal Plain. The authors integrated seismic reflection and well log data to predict reservoir size and continuity of the three areas chosen for investigation: the Cuero study area on the lower Wilcox (upper Paleocene) growth-fault trend and the Pleasant Bayou and Blessing study areas on the lower Frio (Oligocene) growth-fault trend. The authors found striking differences in structural style and sandstone distribution among the three geopressured geothermal areas. They conclude that the Pleasant Bayou area, because of its larger fault-block, greater thickness and lateral continuity of sandstones, and higher formation temperatures and pressures, has the best potential of the three for production of geothermal energy.

RI 135. Oligocene Volcanism and Multiple Caldera Formation in the Chinati Mountains, Presidio County, Texas, by J. C. Cepeda and C. D. Henry. 32 p., 15 figs., 3 tables, 2 pls. ($3.25).

Description of the stratigraphy, structure, economic geology, and geological history of the Chinati Mountains caldera in Trans-Pecos Texas. The Chinati Mountains area, a major Oligocene volcanic center, lies in the Basin and Range Province in the western part of Presidio County, Texas. The Chinati Mountains caldera is the largest caldera in Trans-Pecos Texas and is the source of the Mitchell Mesa Rhyolite, the largest and most extensive ash-flow tuff in the state. The caldera also contains several ore deposits and minor prospects, including the Shafter silver district, which has produced 31 million ounces of silver and minor amounts of lead and zinc. The authors' intensive study of this area relied on field data collected from 1975 through 1982, on petrographic analyses, and on K-Ar isotopic dating. This study was funded by the Texas Mining and Mineral Resources Research Institute, Bendix Engineering Corp., and the Geology Foundation of the Department of Geological Sciences at The University of Texas at Austin.

RI 136. Estimation of Coal Resources in Texas Gulf Coast, Ohio Northern Appalachian, and Wyoming Powder River Basins: A Comparison of Statistical Approaches, by S. J. Tewalt, M. A. Bauer, David Mathew, M. P. Roberts, W. B. Ayers, Jr., J. W. Barnes, and W. R. Kaiser. 137 p., 124 figs., 29 tables ($5.50).

Identification of the causes of uncertainty in coal resource estimation and statistical comparison of the variability of resource estimates for seams from different depositional environments. This report describes a project funded through the Electric Power Research Institute Supply Program, which assesses costs and conditions affecting the future availability of coal in the United States. The authors used several methods to estimate resources of four lignite deposits, each from a different depositional setting in the Wilcox and Jackson Groups, Texas Gulf Coast Basin. They compared variability among resource estimates for each deposit by employing classical statistics and Matheronian geostatistics. Of the four deposits studied, the alluvial plain setting exhibited the greatest variability in precise estimation of lignite resources. On a regional scale, the authors estimated near-surface resources of the Wilcox Group in east-central Texas and compared the variability of estimates obtained from both traditional and innovative statistical methods. They applied these regional methods to estimate resources in two other areas: the Tongue River Member of the Fort Union Formation in Wyoming and the Allegheny Formation in eastern Ohio.

RI 137. Depositional Systems in the Nacatoch Formation (Upper Cretaceous), Northeast Texas and Southwest Arkansas, by M. K. McGowen and C. M. Lopez. 59 p., 44 figs., 5 tables, 3 appendices ($2.00).

Investigation of the depositional facies and history, tectonics, and oil and gas production of the Nacatoch Formation in the East Texas Basin. The authors examined outcrop of the Nacatoch in northeast Texas and southwest Arkansas for this indepth study. They obtained subsurface data from electric logs from 1,500 wells throughout the East Texas Basin, along with well cuttings from 31 wells and sidewall cores from 3 wells. Five facies were identified in southwest Arkansas outcrop: tidal flat, tidal channel, tidal inlet associated, shoreface, and shelf. Two facies—deltaic and shelf—were identified in northeast Texas outcrop. In subsurface, nearshore and shelf deposits were found. Among this report's conclusions about the Nacatoch Formation in the East Texas Basin are (1) that tectonism controlled patterns of local sandstone distribution during deposition, (2) that the few sandstones that exist in the formation in the southern part of the basin do not threaten the hydrologic integrity of Oakwood and Keechi salt domes, and (3) that sandstones in the Nacatoch in the East Texas Basin are important shallow oil and gas reservoirs.

GEOLOGICAL CIRCULARS

GC 83-1. Oakwood Salt Dome, East Texas: Geologic Framework, Growth History, and Hydrocarbon Production, by A. B. Giles and D. H. Wood. 55 p., 31 figs., 5 tables, appendix ($2.50).

Description of the geometry, stratigraphic and structural setting, growth history, and hydrocarbon production of Oakwood salt dome in the East Texas Basin. Located 700 ft (210 m) beneath the boundary of Freestone and Leon

Counties, mushroom-shaped Oakwood salt dome is one of several salt structures evaluated by the Bureau for the U.S. Department of Energy as a potential nuclear waste repository. To assess the dome's hydrologic and tectonic stability, this study compiles data from a seismic profile, a gravity model, and 123 subsurface well logs obtained mostly during hydrocarbon exploration near the dome. The authors conclude that Oakwood salt dome, which is surrounded by Jurassic, Cretaceous, and Tertiary strata, probably remained near the depositional surface as it grew from a pillow (formed during the Late Jurassic) into a diapir structure (Late Jurassic - Early Cretaceous). The researchers used four methods to determine the vertical rise of the top of the salt and found that it has generally declined from approximately 230 ft/m.y. (0.07 mm/yr) during the Early Cretaceous to 5 ft/m.y. (0.002 mm/yr) since the Tertiary. The report also details hydrocarbon exploration at the dome and production of oil from Woodbine sandstones beneath the dome's overhang.

GC 83-2. Potential for Additional Oil Recovery in Texas, by W. L. Fisher and W. E. Galloway. 20 p., 6 figs., 1 table ($2.00).

Assessment of the technical and economic challenges to future recovery of oil in Texas. Of the nearly 156 billion barrels of oil in place discovered in Texas to date, a total of more than 100 billion barrels is now classed as unrecoverable by conventional means. The authors predict that the joint efforts of geologists and engineers will be needed to maximize recovery of this vast untapped resource. The study, which was funded partly by the Texas Energy and Natural Resources Advisory Council, evaluates trends in oil recovery in the State since discovery peaked in the 1930's; it also discusses the characteristics of oil termed nonconventional and some of the factors affecting its recovery. The authors describe the Bureau's regional characterization of major Texas oil reservoirs and categorization of geologically similar reservoirs into production plays according to depositional origin. They also discuss the usefulness of genetic reservoir models in improving the efficiency of oil recovery.

GC 83-3. Regional Aquifer Characterization for Deep-Basin Lignite Mining, Sabine Uplift Area, Northeast Texas, by G. E. Fogg, W. R. Kaiser, M. L. Ambrose, and G. L. Macpherson. 30 p., 11 figs. ($1.50).

Hydrogeological study of the Wilcox Group in the Sabine Uplift area of northeast Texas. Deep-basin lignite, or that between depths of 200 ft (61 m) and 2,000 ft (610 m), constitutes about 60 percent of the total lignite resources in Texas. However, because the state's principal host of deep-basin lignite, the Eocene Wilcox Group, also is a major fresh-water aquifer, questions are posed concerning hydrogeological feasibility and environmental impacts of deep-surface mining and underground gasification. This circular reports on the first phase of the Bureau's statewide study of the Wilcox Group, focusing on the Sabine Uplift region in northeast Texas. The authors describe hydrogeological characteristics of the region that are relevant to deep mining or gasifying, preparing and evaluating mine permits, exploring and selecting sites, and predicting lignite quality. Their integrated geological and hydrological approach included constructing maximum-sand, potentiometric surface, vertical hydraulic gradient, and hydrochemical maps.

GC 83-4. Geology and Geohydrology of the Palo Duro Basin, Texas Panhandle, a Report on the Progress of Nuclear Waste Isolation Feasibility Studies (1982), by T. C. Gustavson, C. W. Kreitler, R. L. Bassett, R. T. Budnik, S. C. Ruppel, R. W. Baumgardner, Jr., S. C. Caran, E. W. Collins, A. R. Dutton, S. P. Dutton, R. S. Fisher, G. E. Fogg, S. D. Hovorka, A. Kolker, D. A. McGookey, E. D. Orr, M. P. Roberts, R. K. Senger, Dale A. Smith, and D. Anderson Smith. 156 p., 91 figs., 12 tables, 2 pls. ($4.50).

Summary of progress made during fiscal year 1982 on study of the structure, tectonic history, physical stratigraphy, hydrogeology, geochemistry, natural resources, and geomorphology of the Palo Duro Basin in the Texas Panhandle. Since 1977, the Bureau has been gathering geological and hydrological information on salt-bearing and related strata in the Palo Duro Basin and vicinity to evaluate the basin as a potential site for isolation of nuclear waste. Funded by the U.S. Department of Energy, the research is part of the national nuclear waste repository program. This circular is made up of 24 papers, which report on four broad areas of research: surficial analysis and shallow stratigraphy, hydrology and geochemistry, basin analysis, and seismicity and tectonic environment. The authors use a variety of maps and illustrations to present their findings, including structure-contour, isopach, and mineral-occurrence maps, cross sections and seismic profiles, photomicrographs of thin sections and core from two stratigraphic test wells, and hydraulic head and potentiometric surface maps based on kriged estimates and drill-stem tests.

MINERAL RESOURCE CIRCULARS

MRC 72. The Mineral Industry of Texas in 1981, by A. E. Ward. 18 p., 1 fig., 13 tables (free on request).

Annual summary of all nonfuel minerals of Texas. This circular is a preprint of the chapter on Texas in the *Minerals Yearbook 1981* of the U.S. Bureau of Mines. It was produced through a cooperative agreement between the U.S. Bureau of Mines and the Bureau of Economic Geology.

MRC 73. Annotated Bibliography of Mineral Deposits in Trans-Pecos Texas, by J. G. Price, C. D. Henry, and A. R. Standen. 108 p., 31 figs., 1 table ($5.00).

Compilation and index of locations, references, and notes on mining activity, resources, and geological features of more than 300 mineral deposits in Trans-Pecos Texas. Although silver, mercury, sulfur, talc, and fluorspar are the dominant minerals that have been produced in Trans-Pecos Texas, many other commodities have been discovered and show promise for future development. This comprehensive bibliography groups localities into 49 geographic areas for which brief summaries are given. Locations of mineral deposits are shown on 30 topographic maps, which are keyed to a Cartesian grid of the region. The maps are at a scale of 1:250,000, the same as the Geologic Atlas of Texas.

Commodities are indexed by counties and topographic quadrangles, and the names of districts, mines, prospects, commodities, and host-rock formations are cross indexed. All active and abandoned mines, prospects, and noteworthy occurrences of metallic and nonmetallic minerals are included in this bibliography. Excluded are petroleum, geothermal, and ground-water resources, sand and gravel operations, quarries for crushed rock, and unexploited commodities that occur widely. Although the authors restricted this study to areas for which geological literature was available, they field checked and included several prospects and abandoned mines whose mineralogy, alteration, deposit type, or exact location previously had not been documented. Research for this project was funded by the Texas Mining and Mineral Resources Research Institute.

MRC 74. Nonpetroleum Mineral Producers in Texas - 1983, by M. W. McBride and A. L. Dobbs. 94 p., 4 figs. ($3.50).

Computer-generated directory of nonpetroleum mineral producers in Texas. Active nonpetroleum mineral producers in the state are indexed by name, mineral commodity, and county. In addition to files of the Bureau of Economic Geology, data sources include the U.S. Bureau of Mines, the Texas Department of Water Resources, the Texas Air Control Board, the Railroad Commission of Texas, the Texas Department of Highways and Public Transportation, the U.S. Environmental Protection Agency, the Bureau of Business Research of The University of Texas at Austin, and the Texas Mining and Reclamation Association. This circular was funded in part by the U.S. Bureau of Mines and the Texas Mining and Mineral Resources Research Institute.

OTHERS

Current Geologic Research in Texas: A Directory of University Faculty and Student Research, compiled by J. G. Price, T. E. Ewing, A. R. Masterson, S. C. Ruppel, and C. M. Woodruff, Jr. 29 p. ($3.30).

Survey of academic research on Texas geology now being done by geoscience departments in Texas and adjoining states and by selected institutions in other states. The Bureau compiled this directory from questionnaires returned by faculty and students at more than 30 universities now researching some aspect of Texas geology. A total of 185 projects are indexed by principal investigator, subject, and geographic area. Listings also include project coworkers, principal investigator's and coworkers' affiliations, project title, expected completion date, and expected place of publication. This is the first survey of this kind conducted by the Bureau. If sufficient interest is generated, the Bureau will repeat this survey annually.

Geothermal Resources of Texas, 1982, compiled by C. M. Woodruff, Jr., Laura Caprio Dwyer, and Christine Gever. Scale 1:1,000,000, full color ($1.00 handling charge for orders by mail; no charge if picked up in person).

Map depicting the 15 major low-temperature geothermal aquifers in the state. The map was constructed using data from published reports, files of State and Federal agencies, and field measurements. Schematic cross sections showing areal and vertical relations among the aquifers are included, along with measurements of depth, water temperature, water chemistry, and flow rates for selected wells. Areas noted either for past uses or for potential resource development are briefly discussed. The map was prepared by the National Oceanic and Atmospheric Administration, National Geophysical Data Center, for the U.S. Department of Energy, Geothermal and Hydropower Technologies Division.

SERVICES

COMPUTING

During 1983, the computing staff continued to provide services to the research staff and increasingly to administrative and support personnel. The staff of three programmers and two data-entry operators, directed by Michael P. Roberts, used time-sharing services provided by the University Computation Center. The Bureau's 19 time-sharing terminals include a graphics microcomputer with digitizing board and a three-color drum plotter.

The major thrust this year for the computing staff was participation in and support of the Office Automation Committee, which was investigating how automation could save time and increase capabilities of the Bureau at its new facilities at Balcones Research Center. The computing staff began two major studies to assist the committee, which is chaired by Associate Director Douglas C. Ratcliff: one study of the accounting function and the other of text preparation. The computing staff also investigated the current market offerings in office automation equipment, networks, and microcomputers.

Other new projects that were undertaken during the year included designing an inventory and check-out system for the Well Sample and Core Library, automating the Bureau mailing list, producing a laser-printed listing of Texas mineral producers, and tracking well core sampling activities. Several computer graphics projects for scientific use were completed, including a well-log-trace digitizing routine, a quick contouring program, and a rose-diagram generator. The Available Program Listing, which includes all Bureau-written programs for which source listings and user documentation exist, now has 57 entries.

PUBLIC INFORMATION

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

Many members of the full-time research staff provide advisory and technical services in their areas of expertise. In addition, Mary W. McBride, Research Scientist Associate, handles requests for information about Texas geology, mineral resources, references, and Bureau programs and publications.

READING ROOM AND OPEN FILES

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

The Bureau's collection of open-file reports and maps includes unpublished reports that have been prepared by the Bureau and materials received from the U.S. Department of Energy (DOE), formerly the Energy Research and Development Administration (ERDA), and other sources. Kay Forward maintains these open files and makes arrangements for copying reports requested by the public. 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).

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).

MINERAL STUDIES LABORATORY

The primary function of the Mineral Studies Laboratory is to support the Bureau's broad range of research projects. The MSL also provides services to other divisions of The University of Texas at Austin. Dr. Clara L. Ho, Research Scientist, directs the lab. Activities at the MSL during 1983 focused on coal characterization, support of the West Texas Waste Isolation project, participation in round-robin testing, and research and development.

Coal samples taken from cores drilled in six East Texas counties were analyzed for carbon, hydrogen, nitrogen, total sulfur, forms of sulfur, total Btu, major and minor oxides in coal ash, total inorganic elemental composition in whole coal, selected toxic trace elements in coal, and mineral constituents in LTA-treated coal. Proximate analysis also was performed.

In support of the West Texas Waste Isolation project, many techniques used for determining the chemical and mineralogical characteristics of rock salts and the chemical composition of brines were modified to improve sensitivity and accuracy. Water content in undisturbed core of rock salt was determined by Karl Fischer titration of the methanol extract of the salt. After the source of background water contamination was found, the extraction method was modified. The modified methanol extraction technique, using a large Soxhlet extractor, not only removes water from the salt but also preferentially dissolves the halides, leaving the non-halide mineral residue intact. Total mineralogy and clay mineralogy of the residue were identified by X-ray diffraction, and the chemical composition was determined by various methods. The residue was analyzed for SiO_2, Na, K, Mg, Ca, Al, Fe, Ti, Mn, Zn, Sr, Ba, Zr, P, SO_4^{2-}, and CO_3^{2-}. Brines were analyzed for Na, K, Mg, Ca, Sr, SO_4^{2-}, Cl^-, Br^-, I^-, and HCO_3^-. New spectrophotometric methods were developed for measuring trace amounts of Br^- and I^- in water-soluble fractions of the rock salts and in brines. All analyses were documented in accordance with quality assurance procedures for the WTWI project.

James A. Morgan

Steven W. Tweedy performs multi-element analysis by ICP-AES.

The MSL is an active member of the International Geostandards Working Group and the American Society for Testing and Materials (ASTM) subcommittee on coal analysis. During 1983, the MSL performed analyses on silicate whole rocks and iron ores for the round-robin testing programs conducted by the Geological Survey of Canada and by the Institute of Geological Sciences (London). The MSL also participated in testing of coals conducted by ASTM. The MSL's results compared favorably with those reported by other laboratories worldwide.

Research and development during the year included testing and simplification of the multiple-acid digestion procedure of Church, involving the use of HNO_3, $HClO_4$, HF, and HCl, for dissolution of geologic materials and ores to be analyzed for major, minor, and trace elements. New spectrophotometric methods for determination of Br^- and I^- were developed. Combined water (H_2O^+) in silicates was investigated, and preliminary results on certain types of samples were promising. A new method for concentration and subsequent determination of As by graphite furnace atomic absorption spectrophotometry (GFAA) using Pd as a matrix modification agent was developed. Use of the method for determination of As in geologic samples and brines remains to be validated. Techniques were evaluated for separation and concentration of other trace elements (Ag, Au, Pb, Co, and possibly Sn) in geologic samples for inductively coupled plasma - atomic emission spectrometer (ICP-AES) analysis or atomic absorption spectrophotometer (AAS) analysis. Techniques were also evaluated for improving the accuracy of iron determination in iron ores.

During 1983, the MSL analyzed a total of 7,827 samples (2,625 coals, 4,083 rock salts, rocks, sediments, and ores, and 901 waters; 159 coals and 59 rocks were submitted by the public). Various analyses were performed for the following departments of The University of Texas at Austin: Chemical Engineering, Petroleum Engineering, Geological Sciences, and Marine Studies.

WELL SAMPLE AND CORE LIBRARY

The Well Sample and Core Library provides information and services to geologists, students, and other persons interested in Texas geology. At present, the WSCL holds cores from approximately 2,950 wells, drill cuttings from more than 55,000 wells, driller's logs from about 500,000 wells, and scout tickets for about 5,000 wells in West Texas. Driller's logs and scout tickets may be copied at the WSCL. Cores and cuttings may be checked out for viewing; the borrower pays shipping costs. Authorization to sample cores and cuttings for thin sections or for destructive analysis is determined on a well-by-well basis. Patrons are asked to report the results of their analyses to the WSCL. If requested by the patron, the results will be held confidential for up to 18 months. Binocular scopes and other equipment are available for use at the WSCL.

Because of the slowdown in oil production and exploration, the number of non-Bureau patrons visiting the WSCL in 1983 dropped to 118, or three-fourths of last year's total. Checkouts of cores and cuttings by non-Bureau patrons totalled 178 and 116, respectively. Bureau personnel examined 180 cores and 19 sets of drill cuttings during the year.

Donors of subsurface materials to the WSCL during 1983 included Alamo Energy, Arco Exploration Co., Arkla Exploration Co., Buttes Resources, Cambe Exploration, Energy Reserves Group, Getty Oil Co., Goldking Production Co., Gulf Oil Corp., A. G. Hill, Hilliard Oil & Gas, B. J. Hughes, Inexco Oil Co., Kerr McGee Corp., John Kraak, Lear Petroleum, McCormick Oil & Gas, O. B. McKown, Midroc & Watkins, Mosbacher Production Co., Noranda Exploration, Inc., Placid Oil Co., Scandrill Co., Shell Oil Co., Sohio Petroleum Co., the Texas Department of Water Resources, Texas Gulf Production Co., Texas Gulf Sulphur, and the U.S. Geological Survey.

Activities during 1983 included transport, slabbing, application of orientation marks, and boxing of 6,895 ft of core from Swisher, Deaf Smith, and Randall Counties taken for examination and analysis for the West Texas Waste Isolation project. More than 3,062 samples were cut from West Texas cores for various analyses and thin sections. WSCL staff continued to rebox cores into standard-sized boxes that will fit the shelves of the new facility, which is to be located immediately west of the Bureau's new research and administration building. Of the cores that have been reboxed, more than 60 percent have had to be slabbed. A computerized listing of all cores and cuttings was completed in 1983. A printout of this data base, titled *Catalog of All Wells in Well Data File*, can be purchased from the Bureau.

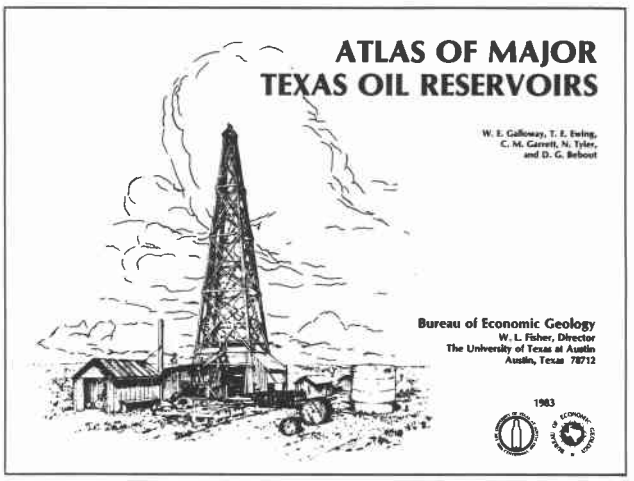
George A. Donaldson is curator of the WSCL. Interested persons may visit the facilities, located at Balcones Research Center, from 8 a.m. to 5 p.m. Monday through Friday. For information regarding holdings, policies, or computer listings, call 512-835-3042.

HIGHLIGHTS OF THE YEAR

ATLAS OF MAJOR TEXAS OIL RESERVOIRS

The Bureau dedicated the *Atlas of Major Texas Oil Reservoirs* to The University of Texas at Austin as part of its 1983 Centennial-year celebration. Oil has played a major role in the growth of The University of Texas at Austin, and it seems fitting that the first statewide oil atlas of Texas should be dedicated to the institution that has trained so many leaders in all areas of the State's petroleum industry.

The atlas was prepared with support of the Texas Energy Development Fund and with full cooperation of the Railroad Commission of Texas. Research involved the analysis of major Texas oil reservoirs that each will produce more than 10 million barrels in order to classify them into regional plays on the basis of reservoir genesis, trap, and drive. More than 450 oil fields were grouped into 48 regional plays that account for 70 percent of oil production in Texas through 1981. Relying principally on unpublished files of the Railroad Commission of Texas, authors W. E. Galloway, T. E. Ewing, C. M. Garrett, Jr., Noel Tyler, and D. G. Bebout prepared a 139-page atlas, which includes 426 maps, cross sections, and logs and five full-color plates, in a 17- by 22-inch format. Color maps depict reservoir lithologies and plays, reservoir genesis and major structural elements,



The Atlas of Major Texas Oil Reservoirs, *a Centennial publication of The University of Texas at Austin, was issued by the Bureau during 1983.*

producing stratigraphic units, trapping mechanisms, and drive mechanisms. Price of the atlas is $40.00, plus $3.25 handling charge for mail orders and $2.00 sales tax for Texas residents. It may be ordered from the Bureau of Economic Geology, The University of Texas at Austin, University Station, Box X, Austin, Texas 78712.

It is anticipated that the *Atlas of Major Texas Oil Reservoirs* will not only provide an integrated picture of Texas oil reservoirs needed for further exploration, but also will provide insight into future strategies aimed at recovering as much as possible of the 100 billion barrels of oil known but not now classed as recoverable. The future level of Texas oil production depends on successes in increasing recovery from existing reservoirs.

CONSTRUCTION OF NEW BUREAU QUARTERS UNDERWAY

At year's end, a new complex of Bureau buildings was being constructed at Balcones Research Center. The complex will include three buildings, each of which will house separate functions. One is dedicated to administration and research, including all the support activities leading to publication. A second building will hold both the Mineral Studies Laboratory and the Well Sample and Core Library facilities for processing and examining materials. A third building will hold cores and cuttings from exploration wells. Construction is scheduled to permit occupation of the administration and research building by September 1, 1984.

All buildings will be located at the north end of Balcones Research Center near the IBM properties. Access to the Bureau facilities will be provided by a north-south boulevard entered from a yet-to-be-constructed Braker Lane, which will run between Burnet Road and U.S. Highway 183 and will intersect a future extension of MoPac.

The gross area of the research and administration building approximates 150,000 ft², nearly equally distributed in three stories. The first floor will hold the Reading Room/Data Center, directoral and administrative offices, a conference room, and publications sales and storage areas. The second floor will be equally divided between research and the support activities of cartography and design, editing, word processing and typesetting, and computing. The top floor will contain research elements entirely. Research quarters on both floors will be organized around research program modules, which will consist of large, open, centralized work areas surrounded by offices.

The exterior of the building is being constructed of tilt-up concrete, metal, and glass. A three-story vertical panel of fossiliferous limestone will face the north and main entrance of the building. Special interior treatments will include a wall of polished granite in the conference room, a granite-faced reception desk, and mirrored exhibit cabinets in the entry and waiting areas.

The WSCL/MSL building will be two stories high and located immediately west of the research and administration building. The ground level will include rooms to house the records of the WSCL curator and to welcome visitors. Other rooms are designated for impregnating, sawing, polishing, and describing core, for washing and examining cuttings, and for preparing thin sections. Rooms designed for microprobe and electron microscope analyses, requiring a separate, isolated slab to prevent excessive vibrations and magnetic interferences, also will be on the first floor.

MSL operations will be housed on the second floor; this location is necessitated by the many vents required for hoods, furnaces, and plumbing. The rooms have been designed to accommodate the specific instruments required in multiple-element analyses of inorganic samples and lignite analyses. There will also be two wet laboratories, one for organic and the other for inorganic analyses.

Three new buildings are to be built near the Bureau complex: a Center for Energy and Electromagnetics, a Commons, and a Utilities structure. The Commons will include a theater, classrooms, exhibit area, a dining facility, outlets to campus library and computing facilities, and a recreational component. These buildings, along with the Bureau's new facilities, are the initial component of a larger center of the University dedicated to energy research. For example, Balcones Research Center will also house the new quarters of Microelectronics and Computer Technology Corp.(MCC), which are now in design.

James A. Morgan

Research and administration building viewed from northwest corner, December 1, 1983.

ROSELLE GIRARD RETIRES

Roselle M. Girard retired from the Bureau in 1983 after 32 years of service. Girard graduated from the University of Texas, Austin, in 1952 with a master's degree in geology. She had earlier worked as a junior geologist for the U.S. Geological Survey, as a lab technician for Shell Oil Co., and as an instructor of geology at UT Austin.

Candid Wedding Photographers, The Professional Image Company

Roselle M. Girard retired from the Bureau after 32 years of service.

She joined the Bureau in 1952 and spent the rest of her professional career at the University.

Girard was responsible for collecting mineral statistics for Texas as a part of the Bureau's cooperative program with the U.S. Bureau of Mines, and from 1960 to 1977 coauthored annual reports on the mineral industry of Texas. She also compiled bibliographies of Texas geology and resources and authored popular reports on Texas rocks and minerals.

In her years at the Bureau, Girard gained personal knowledge of practically all reports ever published on Texas geology and resources, from monographs to newspaper articles. She was a tremendous public resource, responding to several hundred inquiries each year. She received more letters of thanks from citizens for her help than any staff member in history, because of the efficient, thorough, and gracious way she handled all inquiries. Regardless of how difficult or obscure the inquiry might have been, Girard always managed to respond with some information of value.

We will miss Roselle Girard and her long, dedicated service to the Bureau, the University, and the citizens of the State. We wish her the best in her retirement years.

DILLON APPOINTED CHIEF CARTOGRAPHER

During 1983, Richard L. Dillon was appointed Chief Cartographer for the Bureau when Dan F. Scranton asked to return to the duties of Senior Cartographer. Dillon joined the Bureau in November 1968 and was serving as a Senior Cartographer when he assumed supervision of the Bureau's Cartography Section, which is composed of 14 staff members. Dillon is experienced in all phases of the Bureau's cartographic operations.

NEW RESEARCH STAFF MEMBERS

Malcolm P. R. Light

A recognized expert on subsurface geology and seismic exploration, Malcolm P. R. Light joined the Bureau in June 1983 as a Research Associate. He previously had coordinated the activities of a team of geologists and geophysicists exploring oil off the shore of South Africa. He also had served as a field geologist and mineralogist for the Geological Survey Department of Rhodesia. Light received a Ph.D. in geology from the University of Rhodesia in 1981 and a bachelor's degree (honors) from the University of Cape Town in 1971. The structure and metamorphism of the region east of Beitbridge, Zimbabwe, was the subject of his dissertation. In 1982, Light received a Specht Memorial Foundation Award for a paper titled "The Limpopo Belt—A Result of Continental Collision," which was published in *Tectonics*.

William F. Mullican III

William F. Mullican III, formerly an exploration geologist with the Texas Gulf Coast Division of Tenneco Oil Co., joined the Bureau staff as a Research Scientist Associate in December 1983. His areas of expertise include basin analysis, carbonate depositional systems, stratigraphy, and carbonate petrography. Mullican received a master's degree in geology from Texas Tech University in 1981 and bachelor's degree in science education from that university in 1978. His thesis examined the stratigraphy and diagenesis of the Lake Valley Formation in the San Andres Mountains of New Mexico.

Rainer K. Senger

Rainer K. Senger, a native of West Germany, was appointed to the post of Research Scientist Associate in February 1983. His interests include numerical modeling of ground-water flow, statistical interpretation of hydrological data, and contaminant transport problems. He currently is developing a model of ground-water flow in the Palo Duro Basin, Texas Panhandle, to provide information about subsalt aquifers. Senger received a master's degree in geology from The University of Texas at Austin in 1983 and a bachelor's degree from the University of Karlsruhe, West Germany, in 1976. His thesis was titled "Hydrogeology of Barton Springs, Austin, Texas."

GALLOWAY AND EWING RECEIVE BEST-PAPER AWARDS

William E. Galloway, Senior Research Scientist, and coauthors, former Bureau Research Scientists D. K. Hobday and Kinji Magara, received the Wallace Pratt Award for the best article in the *American Association of Petroleum Geologists Bulletin* in 1982. The paper, titled "Frio Formation of Texas Gulf Coastal Plain—Depositional Systems, Structural Framework, and Hydrocarbon Distribution," was published in Volume 66, Number 6, pages 649-688. The research was funded by the U.S. Geological Survey. The award will be presented in May 1984 at the AAPG annual meeting in San Antonio. The Bureau published a more comprehensive version of the report by the same authors (Report of Investigations No. 122).

A paper by Thomas E. Ewing, Research Associate, tied for Best Paper, Third Place Award, of the Gulf Coast Association of Petroleum Geologists at the 1983 annual meeting in Jackson, Mississippi, in October. Title of the paper was "Growth Faults and Salt Tectonics in the Houston Diapir Province—Relative Timing and Exploration Significance."

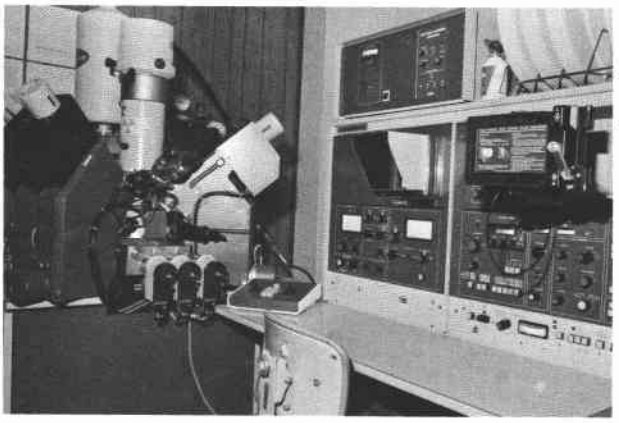
SEM AND ELECTRON MICROPROBE ADD TO ANALYTICAL CAPABILITIES

The Bureau acquired two sophisticated analytical instruments during the year: a JEOL JSM-T300 scanning electron microscope (SEM) and a CAMECA Camebax electron microprobe X-ray analysis system.

The SEM is capable of imaging both secondary and backscattered electrons. Images (including data) are recorded using a Polaroid photographic recording system. Magnifications of up to 200,000X can be achieved at a working distance of 48 mm.

The microprobe system is equipped with four automated wavelength dispersive spectrometers (WDS) and a Kevex 8000II energy dispersive X-ray microanalyzer system (EDS). The microprobe can be used to perform quantitative elemental analysis with both EDS and WDS. The WDS system is preferred for analytical work requiring high accuracy. Standards purchased from C. M. Taylor Co. enable the system to be calibrated on reference minerals, as well as pure elements, to ensure accurate analysis of geologic materials. Most elements on the periodic table ($5 \leq Z \leq 92$) can be measured. The microprobe system can also be used to perform standard SEM functions.

Steven W. Tweedy supervises the microprobe laboratory, Long-Cheng Liang is chief operator, and Eric Pfitzner maintains the instruments.



James A. Morgan

This sophisticated electron microprobe was installed at the Bureau's Mineral Studies Laboratory during 1983.

TEXAS MINING AND MINERAL RESOURCES RESEARCH INSTITUTE

The Texas Mining and Mineral Resources Research Institute (TMMRRI) is one of 31 State organizations funded and administered by the U.S. Bureau of Mines and dedicated to research and academic training in mineral science and technology. The Bureau of Economic Geology administers TMMRRI. The University of Texas at Austin, Texas A&M University, and Prairie View A&M are members of the Institute.

During the 1982-83 academic long terms and summer session, 10 fellowships and scholarships amounting to $44,750 were awarded to students at member universities. During the 1983-84 long terms, 11 were awarded for a total of $40,000. These funds supported undergraduate and graduate training in mineral-related fields of science and engineering.

The Institute also supported mineral resource research in Trans-Pecos Texas and compilation of statistics on Texas minerals and producers. In addition, it provided partial funding for deep-basin lignite research. Reports published by the Bureau during 1983 that were fully or partly funded by TMMRRI include Report of Investigations No. 135 and Mineral Resource Circulars 73 and 74.

RESEARCH STAFF ACTIVITIES AND PUBLICATIONS

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

PAPERS

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LECTURES AND PUBLIC ADDRESSES

W. B. Ayers, Jr.

"Tongue River (Paleocene) Depositional Systems and the Occurrence of Coal in the Powder River Basin of Wyoming and Montana": presented to The University of Texas at Austin, Department of Geological Sciences, technical session.

Virgil E. Barnes

"Geology and Its Application": presented to Kingston Elementary and Junior High School, fifth grade class, West Lafayette, Indiana.

S. Christopher Caran

"Mountain Building and Volcanism": presented to Williams Elementary School, third grade class, Austin, Texas.

R. D. Conti

"Stratigraphic Distribution of Hydrocarbons with Differing API Gravities in the East Texas Basin": presented to the Gulf Coast Association of Geological Societies, annual meeting, Houston, Texas.

Shirley P. Dutton

"Pennsylvanian Fan-Delta Deposition, Mobeetie Field, Texas Panhandle": presented to the Panhandle Geological Society, Amarillo, Texas.

"The Hercynian Foldbelt of Northwest Europe": presented to The University of Texas at Austin, Department of Geological Sciences, regional tectonics class.

T. E. Ewing

"Growth Faulting—Some Cases in Point": presented to the Austin Geological Society, Austin, Texas.

"Hackberry Oil and Gas Fields in Southeast Texas": presented to the Corpus Christi Geological Society, Corpus Christi, Texas, and to The University of Texas at Austin, University Students Geological Society.

"The Tectonic Map of Texas": talk and workshop presented to the Abilene Geological Society, the Corpus Christi Geological Society, the East Texas Geological Society, the El Paso Geological Society, the Houston Geological Society, the New Mexico Bureau of Mines, the New Mexico Geological Society, the North Texas Geological Society, the Oklahoma City Geological Society, the Oklahoma Geological Survey, the Panhandle Geological Society, the Roswell Geological Society, the San Angelo Geological Society, the South Texas Geological Society, the West Texas Geological Society, the Dallas Geological Society, and Texas A&M University.

R. Stephen Fisher

"Geochemistry of Diagenesis, Wilcox Sandstones, South-Central Texas": presented to The University of Texas at Austin, Department of Geological Sciences, research seminar.

W. L. Fisher

"Current Activities and Issues in Radioactive Waste Disposal": presented to the American Institute of Mining, Metallurgical and Petroleum Engineers, South Texas Minerals Section, Corpus Christi, Texas.

"Current Issues in Oil and Gas": *Texas Close-up* television interview, KTBC, Austin, Texas.

"Energy Resources of Texas": presented to the Texas Education Agency, seminar, Midland, Texas.

"Exploitation Strategy and Outlook for Oil and Gas in West Texas": presented to The University of Texas of the Permian Basin, Texas Technology Venturing.

"High-Level Radioactive Waste Disposal": radio interview, KUT, Austin, Texas.

"Major Current and Historical Issues in U.S. Public Lands Policy": presented to The University of Texas at Austin, Lyndon B. Johnson School of Public Affairs, Policy Research Project.

"Major Oil Fields of the Texas Gulf Coast Basin": presented to the Society of Economic Paleontologists and Mineralogists, Fourth Annual Research Conference, Houston, Texas.

"Oil and Gas: What Will the Price Be?": presented to the Railroad Commission of Texas, Oil and Gas Seminar, Austin, Texas.

"Outlook for the Energy Minerals": presented to the American Association of Petroleum Geologists, Energy Minerals Division, annual meeting, Dallas, Texas.

"Outlook for U.S. and Texas Energy Developments": presented to Southwest Texas State University, open lecture, San Marcos, Texas.

"Regulatory Impacts on Mineral Mining and Processing": presented to the Society of Mining Engineers, Dallas chapter, Dallas, Texas.

"Status of Low-Level Radioactive Waste Disposal in Texas": presented to the Nuclear Regulatory Commission, Arlington, Texas.

"Texas Oil and Gas Exploration Geostrategies in the 1980's": presented to the Society of Independent Professional Earth Scientists, annual meeting, San Antonio, Texas.

"The Current Energy Issues and Outlook": presented to the South Texas Geological Society, San Antonio, Texas.

"The U.S. Minerals Position": presented to the Interstate Mining Compact Commission, annual meeting, Little Rock, Arkansas.

Graham E. Fogg

"Ground-Water Modeling in the Tucson Basin and Near Oakwood Salt Dome: A Comparison of Traditional and Geologic Approaches": presented to The University of

Texas at Austin, Department of Geological Sciences, hydrogeology class.

"Hydrogeologic Issues for Lignite Development in Texas": presented to the Austin Geological Society, Austin, Texas.

Michael A. Fracasso

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

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

William E. Galloway

"Depositional Architecture and Reservoir Characterization of Late Paleozoic Submarine Slope and Basin Depositional Systems—Midland and Delaware Basins, Texas": presented to the American Association of Petroleum Geologists, annual meeting, Dallas, Texas.

"Geohydrologic Regimes of Sandstone Diagenesis": presented to the International Association of Sedimentologists, 11th International Congress, Hamilton, Ontario, Canada.

"Potential for Additional Oil Recovery in Texas: The 100-Billion-Barrel Target": presented to the South Texas Geological Society, San Antonio, Texas.

C. M. Garrett, Jr.

"The Bureau of Economic Geology—What It Is and What It Does": presented to the Austin Downtown Kiwanis Club, Austin, Texas.

Thomas C. Gustavson

"Technical Issues in Nuclear Waste Isolation, Palo Duro Basin": presented at the Energy Information Fair sponsored by Serious Texans Against Nuclear Dumping, Hereford, Texas, and presented to the Environmental Evaluation Group, Department of Health and the Environment, Santa Fe, New Mexico.

Christopher D. Henry

"Tectonic Setting of Volcanism in Trans-Pecos Texas": presented to the University of Houston, Department of Geology, seminar, Houston, Texas.

Clara L. Ho

"Chemical Properties in Lignite": presented at the University Methodist Church, open lecture sponsored by Interfirst Bank, Austin, Texas.

M. P. A. Jackson

"Role of Halokinesis in the Evolution of Sedimentary Basins": presented to Rice University, open lecture, Houston, Texas.

"Salt Domes of East Texas and the Gulf Coast": presented to The University of Texas at Austin, Department of Geological Sciences, graduate class.

W. R. Kaiser

"Lignite Geology, Quality, and Economics of Development": presented to the Austin Geological Society, Austin, Texas.

"Mining in Central Texas": presented to the Society of Mining Engineers of the American Institute of Mining, Metallurgical and Petroleum Engineers, South Texas Minerals Section, San Antonio, Texas.

Charles W. Kreitler

"Hydrodynamics of Saline Fluid Movement, East Texas Basin": presented to the East Texas Geological Society, Tyler, Texas.

"Origin and Diagenesis of Salt Dome Cap Rock": presented to Arizona State University, Geology Department, research colloquium, Tempe, Arizona, the U.S. Geological Survey, seminar, Reston, Virginia, and The University of Texas at El Paso, Geology Department.

"Origin and Evolution of Saline Waters, East Texas Basin": presented at the Friends of the Gulf seminar, sponsored by The University of Texas at Austin, Department of Geological Sciences, and presented to the U.S. Geological Survey, seminar, Reston, Virginia, and The University of Texas at El Paso, Geology Department.

Thomas G. Littleton

"From Confusion to Chaos—A Brief History of the Systematics of the Family Pyramidellidae (Mollusca: Gastropoda)": presented to the Texas Academy of Science, annual meeting, Nacogdoches, Texas.

Mary W. McBride

"An Introduction to the Geology of Austin": presented to the Austin Independent School District, elementary school principals, Austin, Texas.

"The Bureau of Economic Geology—Service and Research": presented to Naval Reserve Officers, Naval Research Unit, Austin, Texas.

"The Dynamic Earth—The Evidence in the Austin Area": presented to the Austin Independent School District, teachers' workshop, Austin, Texas.

R. A. Morton

"Geological and Environmental Significance of Sediment Transport During Storms": presented to the University of Virginia, Department of Environmental Sciences, seminar, Charlottesville, Virginia.

"Status of Geopressured Geothermal Research and Resource Assessment in Texas": presented at Industry Forums, sponsored by the U.S. Department of Energy, Houston, Texas.

Jonathan G. Price

"Energy and Mineral Mining Activity in Texas—1982": presented to the Texas Mining and Reclamation Association, annual meeting, Corpus Christi, Texas.

"Hobson Post Mortem: Geological Aspects of In Situ Uranium Mining": presented to The University of Texas at Austin, Department of Petroleum Engineering, In Situ Uranium Leaching Advisory Panel.

"Hydrothermal Alteration in Porphyry Copper and Molybdenum Deposits": presented to The University of Texas at Austin, Department of Geological Sciences, geology class.

"Uranium Deposits in Sedimentary Rocks": presented to The University of Texas at Austin, Department of Geological Sciences, geology class.

Stephen C. Ruppel

"Facies and Depositional Setting of Mississippian Rocks in the Palo Duro - Hardeman Basin Area": presented to the Society of Economic Paleontologists and Mineralogists, Permian Basin Section, Core Workshop No. 2, Midland, Texas.

Rainer K. Senger

"Hydrogeology of Barton Springs, Austin, Texas": presented to The University of Texas at Austin, Department of Geological Sciences, hydrogeology class.

Steven J. Seni

"Evolution and Salt Tectonics of the East Texas Basin": presented to the Fort Worth Geological Society, Fort Worth, Texas.

"Geologic Constraints on Disposal of Low-Level Nuclear Waste": presented to Texas Low-Level Radioactive Waste Disposal Authority, seminar and field trip, Austin, Texas.

"Geology, Salt Tectonics, and Petroleum Resources in the East Texas Basin": presented to the North Texas Geological Society, Wichita Falls, Texas.

Noel Tyler

"Anatomy of Texas Oil": presented to the West Texas Geological Society, Midland, Texas, and to the American Association of Petroleum Geologists, annual meeting, lecture and poster session, Dallas, Texas.

"Facies Control on Oil Accumulation and Production Trends in Major Texas Oil Reservoirs": presented to the University of the Witwatersrand, Economic Geology Research Unit, Johannesburg, South Africa.

"The Potential for Infield Oil Exploration in Cretaceous and Tertiary Plays of the Gulf Coast Basin": presented at the Southwest Energy Exposition, Alice, Texas.

E. G. Wermund

"A History of Bureau of Economic Geology Involvement in the National Waste Terminal Storage Program": presented to the High-Level Waste State Working Group, National Governors' Association, sponsored by the Office of Governor's Counsel, Austin, Texas.

"Future Directions for Remote Sensing in Texas State Government": presented to the Texas Natural Resources Information System, Applications System Verification and Transfer Project final review, Austin, Texas.

"Nuclear Waste Terminal Storage Program in the Texas Panhandle": presented to the Panhandle Geological Society, Amarillo, Texas.

"Status of High-Level Waste Studies in the U.S.": presented to the Lakeway Professional Breakfast Club, Lakeway, Texas.

William A. White

"Geologic Processes and Wetlands Along the Texas Coast": presented to the Travis Audubon Society, Austin, Texas

"State Submerged Lands of Texas—Sediments, Geochemistry, Benthic Macroinvertebrates, and Associated Wetlands": presented at Coastal Zone '83, Third Symposium on Coastal and Ocean Management, sponsored by the American Society of Civil Engineers and others, San Diego, California.

CONGRESSIONAL, LEGISLATIVE, AND SPECIAL TESTIMONY

W. L. Fisher

Analysis of Senate Bill 615, the Natural Gas Reform Act of 1983: given to the U.S. Senate, Committee on Energy and Natural Resources.

Analysis of House Resolution 626: given to the U.S. House of Representatives, Committee on Interior and Insular Affairs. (With Charles Mankin.)

"Coastal Impacts Associated with Offshore Oil and Gas Development": given on behalf of the Governor of Texas to the U.S. House of Representatives, Subcommittee on Outer Continental Shelf and Panama Canal.

Testimony at confirmation hearings on appointment to the Texas Low-Level Radioactive Waste Disposal Authority: given to the Texas Senate, Subcommittee on Nominations.

W. R. Kaiser and William E. Galloway

"Geologic and Hydrologic Setting—Cummins Creek Mine": given to the City of Austin, Electric Utility Commission.

R. A. Morton

"Position of Vegetation Line on Mustang Island and Galveston Island in Reference to the Texas Open Beaches Act": given to the Texas Attorney General's Office.

E. G. Wermund

"Technical Issues in Siting a High-Level Waste Repository in the Texas Panhandle": given to the Texas Joint House-Senate Committee on Hazardous Waste Disposal.

COMMITTEE SERVICES, OFFICES, AND OTHER PROFESSIONAL RESPONSIBILITIES

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Co-editor, Newsletter of the Austin Geological Society.

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

Member, Board of Directors, Travis Audubon Society.

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President, 1983-1984, Society of Economic Paleontologists and Mineralogists, Gulf Coast Section.

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

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

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

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

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

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

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Chairman, Ad Hoc Committee to Establish a Society of Geoscience Curators, Workshop on Core and Sample Curation for the National Continental Scientific Drilling Program, Los Alamos National Laboratory.

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

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

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

T. E. Ewing

Co-leader of field trip, "Volcanology, Structure, and Mineral Resources of Early Tertiary, South-Central British Columbia," Geological Association of Canada, annual meeting, field trip 1.

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

Publications Chairman, 1982-1983, Austin Geological Society.

Technical Programs Chairman, 1983-1984, Austin Geological Society.

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Alternate Representative, Task Force, Texas Natural Resources Information System.

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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, Continental Margin Committee, Association of American State Geologists.

Chairman, Nominating Committee, Association of American State Geologists.

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

Chairman, Geology and Resource Recovery Task Force, GURC.

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

Chairman, Texas Low-Level Radioactive Waste Disposal Authority.

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

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

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

Member, Ad Hoc Committee on Law of Sea Treaty, American Association of Petroleum Geologists.

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

Member, Committee on Committees, Geological Society of America.

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, Governmental Liaison Committee, Association of American State Geologists.

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

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

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

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

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

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

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

Member, Advisory Committee on Gas Proration and Ratable Take, Railroad Commission of Texas.

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

Member, Gas Analysis Group, The University of Texas at Austin.

Member, Geology Advisory Group, Southern Illinois University.

Member, Geology Associates Board, University of Kansas.

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

Member, Program Development Council, GURC.

Member, Research Committee, Interstate Oil Compact Commission.

Member, Resolution Committee, Interstate Mining Compact Commission.

Member, Texas Mapping Advisory Committee.

Past-President, Association of American State Geologists.

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

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Chairman, Finance Committee, Austin Geological Society.

Delegate (1982-1985) of Austin Geological Society to American Association of Petroleum Geologists.

Member, Nominating Committee, Austin Geological Society.

Christopher D. Henry

Co-chairman, Geochemistry-Petrology Session, Geological Society of America, South-Central Section, annual meeting.

Clara L. Ho

Fellow, American Institute of Chemists, Clay Mineral Society.

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

Member, Subcommittee for Coal Analysis, American Society for Testing and Materials.

Member, Subcommittee for Water Analysis, American Society for Testing and Materials.

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Treasurer, 1982-1983, Austin Geological Society.

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Member, Editorial Board for the volume *Precambrian Tectonics Illustrated,* Subcommission on Tectonics, International Union of Geological Sciences.

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Member, Editorial Board, *In Situ.*

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Field-Trip Coordinator, 1982-1983, Austin Geological Society.

Charles W. Kreitler

Editor, *Journal of Ground Water.*

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

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Treasurer, 1983-1984, Austin Geological Society.

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Co-chairperson, Directory Committee, Austin Geological Society.

Consultant, update of guide to the Texas Pecos Trail, Texas Department of Highways and Public Transportation.

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Member, Committee for the Third International Conference on Geological Information, Geoscience Information Society.

Member, Membership Committee, Association of Earth Science Editors.

Mary W. McBride

Member, Science Curriculum Review Committee, Texas Advisory Committee on Environmental and Energy Education.

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Chairman, Legislative and Governmental Committee, American Institute of Professional Geologists, Texas Section.

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

Co-leader of field trip, "Corpus Christi Area," Austin Geological Society.

Member, Review Committee, Geological Society of America, annual meeting.

Jonathan G. Price

Co-leader of field trip, "Geology of the Sierra Diablo and Southern Hueco Mountains, West Texas," Society of Economic Paleontologists and Mineralogists, Permian Basin Section.

Douglas C. Ratcliff

Vice-President, Austin Geological Society.

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

Susan J. Tewalt

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Texas Representative, Technical Workshop Review Group for Gulf of Mexico Outer Continental Shelf Leasing, U.S. Department of the Interior.

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

Member, Interagency Task Force, Texas Natural Resources Information System.

William A. White

Co-leader of field trip, "Corpus Christi Area," Austin Geological Society.

Charles M. Woodruff, Jr.

Chairman, Environmental Board, City of Austin.

Chairman, Nominating Committee, Austin Geological Society.

UNIVERSITY TEACHING/ CONTINUING EDUCATION

Don G. Bebout

Carbonate Exploration School: American Association of Petroleum Geologists, Austin, Texas.

Cretaceous Carbonate Field Seminar: American Association of Petroleum Geologists, San Antonio and Austin, Texas.

L. F. Brown, Jr.

"Research in Geology" (Geology 694): The University of Texas at Austin, Department of Geological Sciences.

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

"Seismic Stratigraphy and Basin Analysis": American Association of Petroleum Geologists, Las Vegas, Nevada, Colorado Springs, Colorado, and Geneva, Switzerland; Lafayette Geological Society, Lafayette, Louisiana; University of Houston, Geophysics School, Houston, Texas; and University of Tulsa, Advanced Exploration School, Tulsa, Oklahoma.

W. L. Fisher

"Depositional Systems and Facies Analysis": Federal Universidade de Ouro Prêto, short course, Ouro Prêto, Brazil.

William E. Galloway

"Basin Analysis in Exploration" (Geology 379K/391): The University of Texas at Austin, Department of Geological Sciences.

"Clastic Sedimentary Environments—Deltaic Systems" (Geoscience 5342): The University of Texas at Dallas, Programs in Geoscience, Visiting Professor.

"Exploration for Petroleum in Terrigenous Depositional Systems": University of Sydney, Sydney and Perth, Earth Resources Foundation, Australia.

"Fluvial Systems: Their Economic and Field Applications": American Association of Petroleum Geologists, Salt Lake City, Utah.

"Petroleum Geology of Fluvial and Deltaic Systems": Permian Basin Graduate Center, Midland, Texas.

"Seismic Stratigraphy": University of Sydney, Canberra, Earth Resources Foundation, Australia.

"Seismic Stratigraphy—Case Histories": Seismic Stratigraphy School, American Association of Petroleum Geologists, Dallas, Texas.

SUPPORT STAFF

ADMINISTRATIVE/SECRETARIAL

The administrative/secretarial staff is responsible for administrative, accounting, and secretarial work essential to day-to-day operation of the Bureau. These staff members are, in many respects, the Bureau's closest contact with the general public. They assist visitors who wish to purchase Bureau publications, and they also handle mail and telephone requests. Bettye A. Blitch, Executive Assistant, coordinates the work of the administrative/secretarial staff.

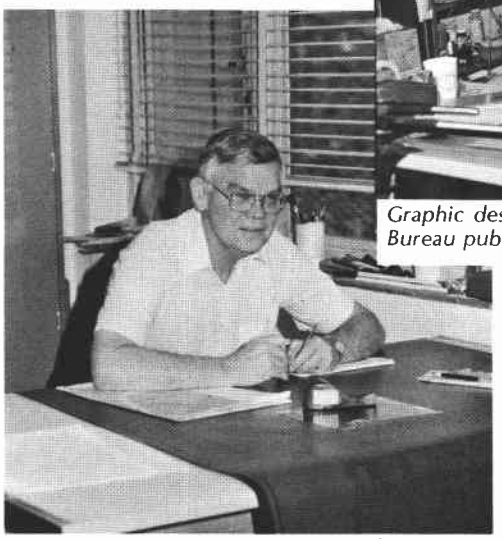
CARTOGRAPHY

Much of the Bureau's reputation in geologic and land resource mapping rests on the excellent capabilities of its cartography section. High-quality full-color maps are the hallmark of the cartography section. The staff also produces a wide range of other maps, cross sections, text illustrations, slide copy, and display materials. In addition, the staff provides cover and text photographs for the Bureau's publications, slides for lectures and public addresses, and negatives and color proofs of maps. Richard L. Dillon, Chief Cartographer, directs the work of the cartography section.

PUBLICATIONS PRODUCTION

A Bureau report undergoes many steps in the transformation from rough manuscript to final publication. Manuscripts are typed and typeset by the word processing/typesetting section, which is supervised by Lucille C. Harrell. The editorial staff, directed by Susann Doenges, edits and proofreads manuscripts and coordinates production throughout the publication process. Reports are designed and pasted up by the graphic design staff, which is supervised by Richard L. Dillon.

Graphic designer Jamie S. Haynes pastes up a page in a new Bureau publication.



Cartographer Dan F. Scranton scribes the Bureau's new geologic wall map of Texas.

Word-processing operator Dorothy C. Johnson revises a manuscript to be published as a Bureau report.

Photos/James A. Morgan

Paulo A. Mosmann fills an order for one of the Bureau's publications. The Bureau distributed 48,000 volumes during 1983.

Editor Michelle C. Gilson reviews galleys, one of various duties performed by the Bureau's editorial staff.

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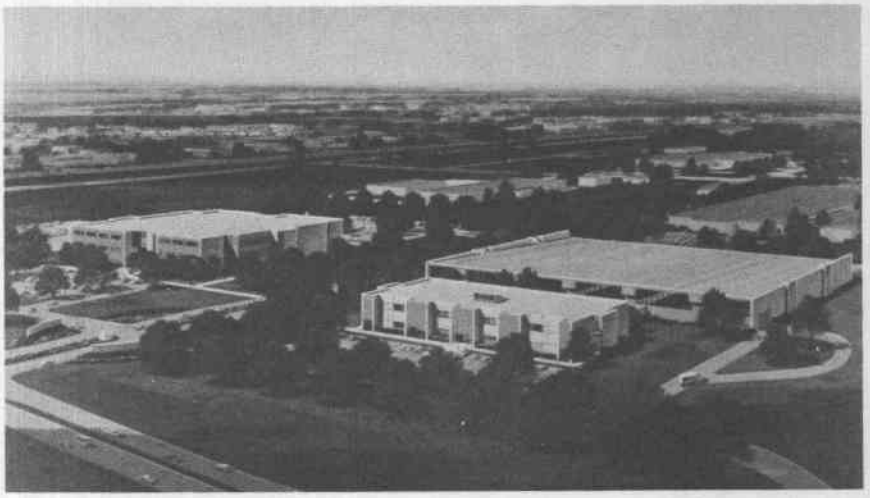
Clayton H. Wilson
Geoffrey E. Wilwerding
Kolleen M. Wilwerding
David R. Wuerch

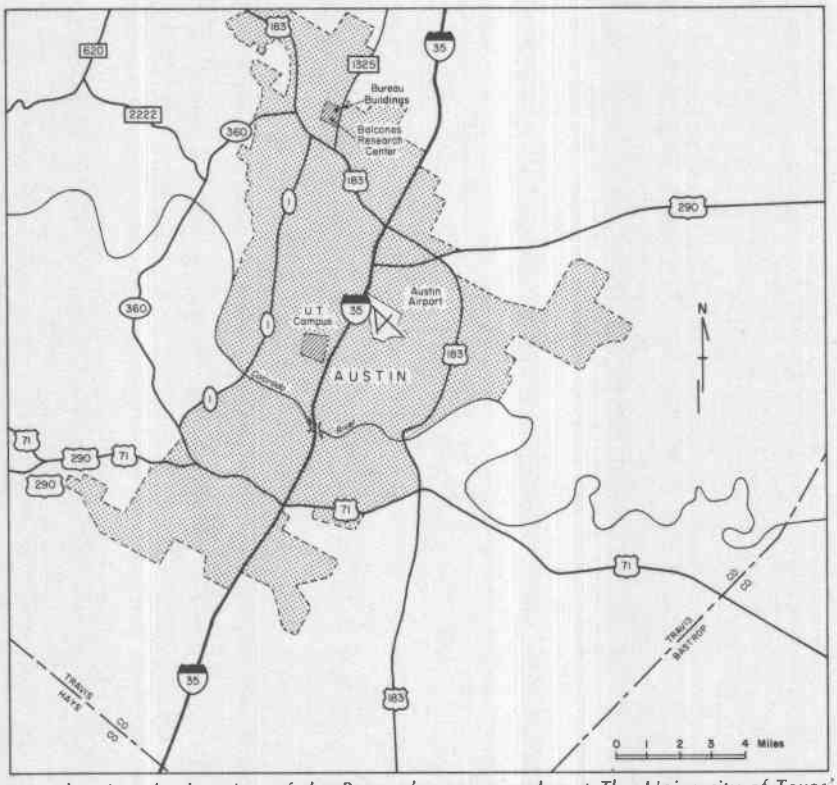
BUREAU TO BE LOCATED AT BALCONES RESEARCH CENTER AFTER SEPTEMBER 1984

After September 1984, those wishing to visit the Bureau of Economic Geology should come to our new complex at The University of Texas' Balcones Research Center. Artist's conception of the three-building facility shows a view looking to the southeast. The largest structure, a three-story, 150,000-square-foot research and administration building, is to the left. The two-story Well Sample and Core Library/Mineral Studies Laboratory, which is 35,600 square feet, is in the foreground. Behind and to the right is the 2.3-acre, 1½-story core repository.

FM 1325 →



Artist's conception of the Bureau's new three-building research complex.



Map showing the location of the Bureau's new complex at The University of Texas' Balcones Research Center, 10100 Burnet Road (FM 1325).

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Address correction requested

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