1994-1995 ANNUAL REPORT

The Kentucky Geological Survey has conducted research on the mineral and water resources of the state of Kentucky for the past 156 years. This report provides a summary of the KGS activities during the fiscal year of July 1, 1994, through June 30, 1995.

University of Kentucky, Lexington

1994–1995

ANNUAL REPORT

KENTUCKY GEOLOGICAL SURVEY
UNIVERSITY OF KENTUCKY
LEXINGTON, KENTUCKY

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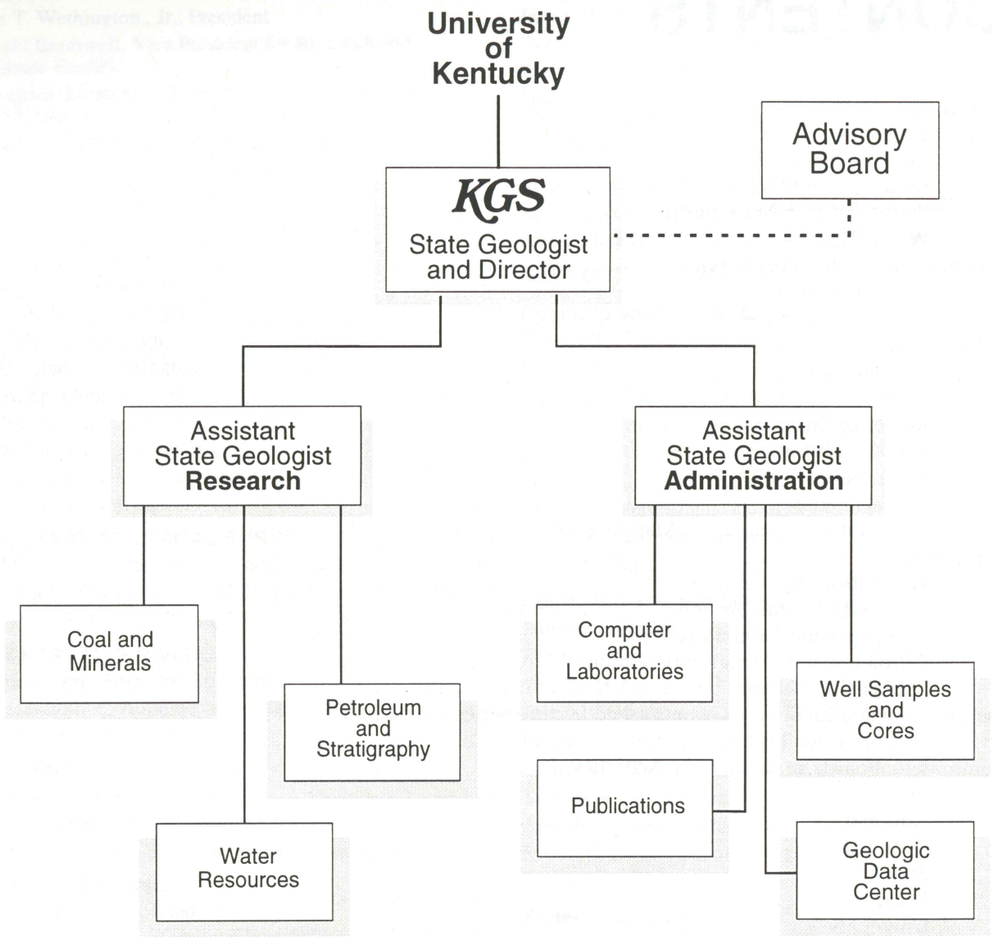


FOREWORD

The Kentucky Geological Survey has conducted research on the mineral and water resources of Kentucky for the past 157 years. These efforts have resulted in topographic and geologic map coverage for Kentucky that has not been matched by any other state in the United States, and public data bases on energy, mineral, and water resources that are used by thousands of citizens, private industry, and government agencies each year. Virtually every sector of modern society requires information about the earth: its resources, hazards, and environments. Society's needs for geologic and resource information change, and therefore the job of characterizing Kentucky's geology and resources also changes. The Kentucky Geological Survey has continued to build its public data bases and perform basic research to satisfy the changing needs of the Commonwealth.

KGS provides technical support to a large number of State and Federal agencies. In addition, the Survey places great emphasis on public-service activities. Members of the Survey staff are actively involved in special committees and public-service groups dealing with coal, water, oil and gas, industrial minerals, and geologic hazards. In particular, Dr. Donald C. Haney, State Geologist and Director of the Kentucky Geological Survey, currently serves on the Board on Earth Sciences and Resources of the National Research Council, which is the principal operating agency of the National Academy of Sciences. The Board on Earth Sciences and Resources coordinates the National Research Council's recommendations to the Federal government on earth-science issues, ranging from basic research, through application, to assistance in policy formulation. The Board is responsible for conducting studies and preparing reports on fundamental issues in the earth sciences and on the directions that disciplines of the earth sciences should be taking, as well as issues relating to the energy and mineral resources of the nation. Dr. Haney will serve on the board through 1995. Dr. Haney also serves on the National Committee to Research Programs of the U.S. Bureau of Mines, the Secretary of the Interior's National Geologic Mapping Advisory Committee, the Association of American State Geologists National Geologic Mapping Committee, the Geological Society of America National and Southeastern Section Committees on Geology and Public Policy, and serves as Chairman of the Kentucky River Authority.

The objective of this annual report is to provide a brief summary of the activities of the Kentucky Geological Survey during the past fiscal year (July 1, 1994–June 30, 1995). A complete summary of the Director's public-service activities, as well as those of other KGS personnel, can be found under the *Public Services* and *Committees, Boards, and Advisory Activities* sections of this report.

RESEARCH ACTIVITIES

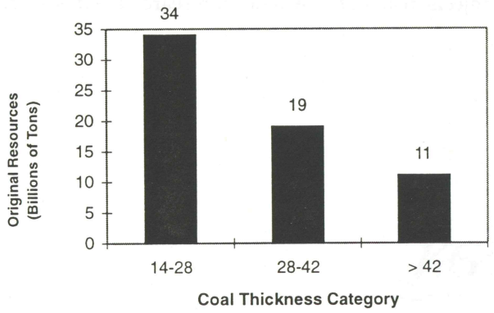
Basic research in geology and hydrology has formed the cornerstone of the Kentucky Geological Survey since its inception. The Kentucky Geological Survey maintains a diversified and comprehensive research program into the fields of coal geology, industrial and metallic minerals, oil and gas, and hydrology. In addition, a number of special projects are funded by grants or contracts. Projects in all of these areas of research are described in greater detail in the following sections.

Coal

Throughout this century coal has been Kentucky's leading mineral industry in terms of revenues generated and employment. A total of 7.2 billion tons of coal has been produced from Kentucky's coal fields. Kentucky has a large resource of remaining coal, but much of the remaining coal is thinner than what is currently being produced. In order to maintain current production levels into the next century, new reserves will have to be discovered, new extraction technologies will have to be developed, and the available resources will have to be used more efficiently. The Kentucky Geological Survey is conducting research to provide information on Kentucky's coal resources that will be utilized in the future.

The bulk of Kentucky's substantial remaining coal resources is only 14 to 42 inches thick, occurs below drainage, or is of poorer quality than what is currently mined. The next generation of mining will most likely be in deeper parts of the coal basins than are presently mined. KGS is conducting research to determine the resource potential of below-drainage coal in both the Western and Eastern Kentucky Coal Fields. The quality of the remaining reserves, especially in regard to sulfur and trace elements, must also be characterized.

More efficient use of the available resources should also extend the use of Kentucky resources. Increased cooperation among mining companies could result in more efficient use of the resource. Also, new mines will either target smaller reserves of above-drainage coal or will locate below-drainage, deep reserves. A significant resource of surface-mineable coal exists in the Eastern Kentucky Coal Field, amounting to an estimated 6.9 billion tons. However, part of this coal is restricted from mining because of the legal liability associated with re-mining unclaimed land. New mining must deal with environmental liabilities associated with the old surface mines. However, one new technology already available, thin-seam mining, may reduce the costs of extracting coal under thick overburden and may make these resources desirable for development. Technology that can economically produce coal from seams 14 to 42 inches thick would certainly open up resources for development in both the Eastern and Western Kentucky Coal Fields.



Eastern Kentucky original resources.

KGS has recently resumed research on coal-bed methane. Coal-bed methane gas is produced in association with coal in many states, but little has been done in Kentucky to explore this energy option, although the potential for coal-bed methane exists in parts of the Eastern and Western Kentucky Coal Fields.

Coal-bed methane was produced in the 1950's in the Eastern Kentucky Coal Field from gas wells. The gas was mistakenly identified as conventional gas at first, but analysis of drilling records suggested the gas was produced from coal beds. This past year a gas company working in cooperation with several coal companies produced gas from coal-bed methane wells in eastern Kentucky, and a pipeline was reported to have been connected to these wells.

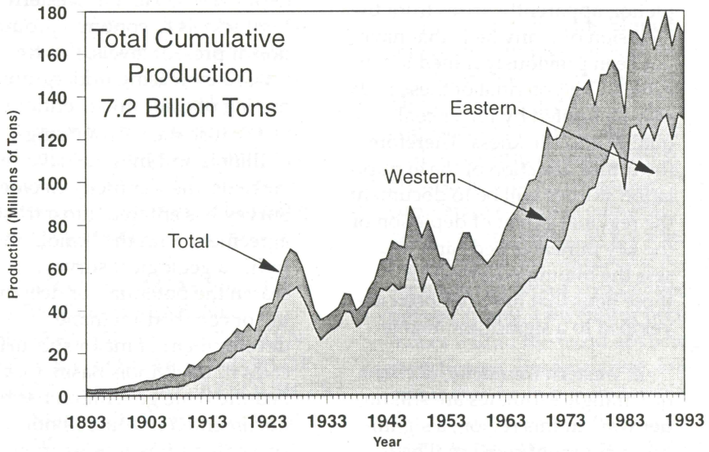
During the coalification process, large amounts of gas are produced—more gas than the coal can hold. Some of this gas escapes and is stored in other rocks or escapes into the atmosphere; and some of the gas remains in the coal. At first, coal appears to be nonporous and rather densely packed, but it is actually the least dense rock in the coal fields. Because the gas is stored in the coal, coal can hold more gas than an equal volume of more conventional reservoir rock such as sandstone. Generally, a coal's gas content increases with depth (below drainage) and rank of the coal.

The technology for discovering and producing coal-bed methane

differs from that for conventional gas. Permeability in coals is created by naturally occurring fractures, called cleats. Coal is frequently an aquifer because its cleats are commonly saturated with water. Coal-bed methane is locked in coal by the water in cleats, and is usually undetectable using conventional gas-well technology. For methane to be produced from coal, water must first be pumped from the seam.

In the Eastern Kentucky Coal Field, where past mining has been largely above drainage, most of the gas in these coals has escaped to the atmosphere over periods of thousands of years, as the water content of the coals changed with changing climate. Accordingly, most of the drift mines in coals well above valley bottoms have not had a persistent methane problem. The history of valley-bottom and below-drainage coals is different. Numerous mine-gas problems have been associated with the Lower Elkhorn (Pond Creek, Path Fork) and Upper Elkhorn coals in eastern Kentucky and from several seams in shaft mines in western Kentucky. As the above-drainage coal resources of Kentucky are depleted, more future mining will have to come from coals situated below drainage, and below-drainage mines may be faced with methane-control problems. One potential solution to methane control is the production of the gas ahead of mining. Another is controlled extraction of the methane. Capturing methane as a marketable resource could benefit the coal industry in Kentucky. Gas can be accumulated locally and used to generate power for the coal company, or put in a pipeline (depending upon quality and quantity of the gas).

One of many ways to develop coal-bed methane fields is to simply drill a gas well to the coal, perhaps fracture the coal, pump out the water, extract the gas, and connect the well to a gas pipeline. Coordinating the drilling with mining of the coal has also been successful: gas wells are drilled down to the coal bed (or just above it), the coal is mined out, and the roof collapses, creating a large void of collapsed rock (called gob) that may intersect coal beds above the main bed. Gas accumulates in the gob and is pumped out by the existing gas wells. A variation of this post-mining gas extraction is drilling gas wells into abandoned underground mines. Many old underground mines fill with methane and other gases, which blend with the air already in the mine. This gas can be produced, but is generally of lower concentration because it is mixed with other gases.



Total coal production in Kentucky, 1893–1993.

Many issues must be faced before coal-bed methane can be extracted. Perhaps the most controversial issue is ownership of the gas. In Kentucky, ownership of coal and gas may be held separately. Owners of the coal rights may contend that the coal-bed gas belongs to them, while owners of the gas rights hold that the gas is theirs. Some states have settled the issue by court actions or legislation. Unfortunately, Kentucky has not yet made a decision on ownership of coal-bed gas. Federal regulations allowing extraction of gas will become effective in October 1995. They will call for forced pooling of those who own the gas, but do not wish to participate in its production. In other words, if owners are against the production of their gas, it can still be produced, but an escrow account will be set up and administered by a review board, which will protect the interests of the mineral and gas owners.

Coal companies have a vested interest in coal-bed methane extraction because they are concerned about encountering explosive gas during the mining process. They would also be interested in the effect of coal-bed methane production on the mining of the coal. Gas companies, on the other hand, have the expertise for developing and producing gas, a potentially dangerous product. Cooperative ventures be-

tween coal companies and gas companies would sidestep the legal problem of ownership and would benefit both parties.

Another methane-related issue is the disposal of water pumped from coal during methane production. Little is known about the quality of this water. Can it simply be pumped into existing streams (surface discharge), or should it be pumped back into the ground (underground injection)?

The projects described in the following sections are designed to answer questions about coal resources. These projects cover coal-resource assessment, coal-mining geology, and coal quality and petrology. Coal-related information generated by these projects is made available through the Kentucky Coal Resources Information System (KCRIS), which is one of the largest publicly available coal data bases in the United States. KCRIS contains descriptions of coal beds, coal-thickness measurements, coal-quality analyses, and borehole descriptions. Most of this information is in electronic form and is continually updated. The Kentucky Geological Survey also promotes technology transfer through workshops and publications.

Coal-Resource Assessment

AVAILABLE COAL RESOURCES IN EASTERN AND WESTERN KENTUCKY

Gerald A. Weisenfluh and Robert E. Andrews

In 1983, detailed coal-resource estimates were completed for the Eastern and Western Kentucky Coal Fields. The results of this work indicated that, for beds greater than 14 inches in thickness, 57 billion and 38 billion short tons remained in eastern and western Kentucky, respectively. While these estimates of the total resources suggest future mining potential on the order of hundreds of years, it is evident that this potential may be greatly reduced if land-use and technological restrictions to mining are considered. Coal Availability for Economic Development is an ongoing national research program supported by the U.S. Geological Survey to quantify the kinds and magnitudes of restrictions to mining in order to plan the development of energy resources.

In eastern Kentucky, detailed coal-availability estimates have been prepared for nine of the 200 quadrangles in the region. These data are currently being extrapolated to the remainder of the region. The detailed studies have shown that average mined-out tonnages are low (10 to 12 percent) relative to original resource estimates. However, they also indicate that key coal beds, such as the Fire Clay and Pond Creek, which represent a significant proportion of current annual coal production, have been extensively mined. The low average depletion apparently arises from the inclusion of many beds that have not been previously mined to any extent. The potential of these beds may be limited by lower coal quality and thickness. Therefore, the future direction of the extrapolation studies will be to document the regional extent of depletion of the key mineable beds and to assess the mining potential for those beds that have not been developed to a significant degree.

In western Kentucky, detailed quadrangle estimates are still under way. In this region, a significant amount of some coal beds has been rendered unmineable because overlying or underlying coal beds have been underground mined. Also, as in eastern Kentucky, some coals have been extensively mined out. Currently, regional information is being compiled to assist in the extrapolation studies. In order to accomplish these goals, a significant effort has been undertaken to computerize available drill-hole information from throughout the coal field.

DEEP COAL AND ENERGY RESOURCES OF THE WESTERN KENTUCKY COAL FIELD

David A. Williams and Stephen F. Greb

For most of the history of the Western Kentucky Coal Field, mining has concentrated on a few near-surface coal beds. In many counties the near-surface reserves are rapidly becoming depleted or have already been depleted. In the past decade, deep mines have become increasingly important. In 1994, approximately 23 million tons of coal was underground mined in western Kentucky, compared to 15 million tons surface mined. One deep mine in Union County extracted coal from a depth of 1,000 feet. If western Kentucky is to continue production at present levels, this trend toward increasing underground mining of coals must continue.

Because the surrounding states of Illinois and Indiana have similar coals, the Kentucky Geological Survey has entered into a tri-state agreement with the Illinois and Indiana geological surveys to research the potential for deep mining or coal-bed-methane development of major subsurface coals in the Illinois Basin. Coal-bed-methane generation has been documented in some Illinois Basin coals and may be an important future resource in western Kentucky.

Currently, there are limited data in the public domain on the occurrence and distribution of the 13 major trace elements in coals that are considered potentially hazardous air pollutants. The state geological surveys of the Illinois Basin have joined with industry and the U.S. Geological Survey in a cooperative research program to identify and characterize deep-mineable resources in the basin.

In the past year, approximately 14,000 feet of subsurface core was described in the field, and the descriptions are being entered into coal-thickness and stratigraphic data bases. Nearly 500 downhole geophysical logs were also examined and used to construct cross sections of the coal-bearing strata in western Kentucky. These sections show the thickness and elevation of the major coal seams at depth, and are being correlated into the surrounding states so that regional trends in coal quality and thickness may be re-examined. These correlations will allow the three states to create regional structure and isopach maps of the major coal beds, which will help drilling programs find potential deep-coal resources in the future. A data base on trace-element information is also being created. Data will be obtained by drilling and coring selected coals in order to characterize the trace elements, coal quality, and roof rock in areas where they are not presently being mined but have the potential for development.

GEOLOGIC ANALYSIS OF THE COAL-BEARING ROCKS OF WESTERN KENTUCKY FOR THE DEVELOPMENT OF COAL RESOURCES

Stephen F. Greb and David A. Williams

In 1994, approximately 38 million tons of coal were produced from the Western Kentucky Coal Field. Almost all of that coal was high in sulfur, averaging well above the threshold of 1.2 pounds of SO_2 per million Btu required by the Clean Air Act. Washing and other beneficiation processes remove sulfur and ash from raw coal and improve western Kentucky coal quality, but the coal is still beyond compliance limits.

Low-sulfur coals occur in western Kentucky, but are not widespread. They are difficult to locate and explore. The reason for local occurrences of better quality coals may be related to the depositional or burial history of the coal. If geologic reasons can be determined for the quality, thickness, or trace-element distributions of western Kentucky coals, models based on these characteristics can be used to aid in future exploration of coals with favorable characteristics. Data from surface and near-surface exposures of coal and surrounding strata are critical for the development of these models. Such data also can be used to illustrate typical roof strata and coal-bed-thickness variations that might be expected in the subsurface.

In the past year, the Elm Lick coal of the Tradewater Formation in western Kentucky was studied. This coal is locally low in sulfur and is correlated with the Brazil coals of central Indiana, which are also locally low in sulfur. The correlation of these coals indicates a stratigraphic target zone for potential low-sulfur coal reserves in the broad area between present mines. Low-sulfur occurrences within the trend are being investigated. In some areas, low sulfur may have resulted from the manner in which the original peat swamps were buried. Many western Kentucky coals are overlain by rocks we think were deposited in marine waters. Marine waters are high in sulfates, and consequently introduced sulfur into the peat, which became coal. Low sulfur values in the Elm Lick coal zone may have been caused by burial in more fluvially influenced or estuarine environments. However, very rapid lateral changes in the sulfur content of the Elm Lick coal that do not correspond to changes in roof geology may indicate secondary controls on quality, such as migration of fluids through the coal after burial. Detailed case studies of these coals are important for developing exploration models for local high-quality coals for the future.

GEOLOGIC ANALYSIS OF THE COAL-BEARING ROCKS OF THE EASTERN KENTUCKY COAL FIELD FOR THE DEVELOPMENT OF COAL RESOURCES

Stephen F. Greb

The coal-bearing rocks of the Eastern Kentucky Coal Field contain about 10 high-quality coal beds and a total of 50 significant coal beds. The important characteristics of coal quality and mineability differ greatly among these coals. New data on the important characteristics of coal beds are continually being created by surface mining, deep mining, drilling, and road construction. Often, characteristics of coal and roof strata uncovered at the surface can be used to characterize various aspects of coal mineability in the subsurface, where exposures of the coal are limited. Collecting these data can help industry and resource planners develop coal resources in the Eastern Kentucky Coal Field. KGS provides a variety of information about coal to the public and industry.

In the past year, data were collected from several new roads

and surface mines in eastern Kentucky. Coal-thickness and -quality data from these sites were added to KGS public-access data bases. Descriptions of roof geology and coal-bed splits and cutouts were also made, and will be used in the future to construct isopach and structure maps. An example of the kind of sites studied is the extension of Kentucky Highway 3 toward Inez, Ky., which exposed coals and roof strata in an area where exposures are limited. The road cuts through an old mine, where collapsing adits below shaly roof strata provide a unique view into the effect of lateral variation in rock type and layering on roof support.

COAL-BED-METHANE AND DEEP-COAL RESOURCES OF THE EASTERN KENTUCKY COAL FIELD

Stephen F. Greb

The Eastern Kentucky Coal Field is one of the world's most productive coal-mining regions. The total amount of coal mined and lost from this coal field during the past 200 years of mining is nearly 7.5 billion tons. Most of the mining has been concentrated in areas where the coal is most accessible, and the easily recovered resources are being depleted. Therefore, deeper coal deposits will become increasingly important in the future. Predicting coal-bed thickness, coal-bed quality, and roof-rock trends into unmined areas in the subsurface requires that correlations be made between exploratory cores and known mines and exposures.

Data on deep-coal resources come from core descriptions and geophysical logs provided by private and government agencies. Thickness and elevation data from these sources are placed in KGS relational data bases for public use. A computer data base of more than 5,000 subsurface records is presently being compiled.

The same data used to identify potentially mineable subsurface coals can also be used to identify potential areas of coal-bed methane. Methane is a gas that is potentially hazardous in deep mines, but valuable as a fuel. During the past year wells were drilled to produce coal-bed methane in Kentucky, and data are being accumulated to assess the potential for future coal-bed-methane production in eastern Kentucky.

Coal-Mining Geology

MINEABILITY OF KENTUCKY COALS

Stephen F. Greb and John K. Hiett

Coal-mining geology is the application of geology to mining problems. It is used to analyze and predict coal thickness, coal quality, and mine-roof trends. Coal and roof data across large regions are examined to determine large-scale trends in thickness and quality, and locally to discover secondary and tertiary trends in the coal and roof. Identification of potential geologic obstacles such as faults, cutouts, and splits is critical to coal-mineability investigations. Data about these obstacles from mines in Kentucky must be collected as they are encountered so that case studies of the features can be made. These case studies help identify geologic problems in other mines, and allow plans to be formulated before the coal is mined.

In the past year, a study of the Fire Clay coal used more than 2,000 mine maps, 3,000 thickness measurements, 300 field descriptions, 200 core descriptions and geophysical logs, and proximate analyses from 97 localities to provide a detailed illustration of its regional variability in thickness, quality, and roof rock. The study also provided numerous case studies of geologic problems encountered during mining of the coal. Thickness variations in the Fire Clay coal resulted from the varying extent of as many as three separate benches of coal, two broad belts of cutouts on the northern and southern margin of the study area, a narrow belt of cutouts within the main belt of thick coal, and local drops in elevation of the Fire Clay rider to the top of the Fire Clay coal. Mining problems included roof cutouts and paleoslump conditions along the central channel trend, coal-rider roof problems in belts parallel to the cutout trends, and local splits and concretions toward the north and south margins of the coal.

Kentucky Geological Survey geologists are also conducting research to identify factors that affect the mineability of two coal beds near the Pine Mountain thrust fault in southeastern Kentucky. One of the mines is in the Copland seam. This bed has not been mined elsewhere by underground methods. The other coal bed, the Fire Clay rider, has been previously mined in the study area, and the results of this investigation will be used to assist in the planning and development of a new mine on an adjacent tract.

POST-MINING LAND USE AND ECONOMIC DEVELOPMENT

Warren H. Anderson

In coordination with the Kentucky Cabinet for Economic Development, the U.S. Office of Surface Mining, the Kentucky Natural Resources and Environmental Protection Cabinet, the Kentucky Department of Mines and Minerals, and coal companies, the Kentucky Geological Survey has initiated a new project to examine the potential uses of reclaimed surface-mined lands. Industrial development on reclaimed lands is important to provide a stable economic base for Kentucky's coal-producing counties. Various industrial uses, wetlands and wildlife management, reforestation, and forestry products can be evaluated by using a geographic information system (GIS).

This pilot project will identify and compile a data base of existing surface-mined lands in Martin County and compare this information with other land-use criteria such as population centers, surface-water runoff, power lines, sewer lines, transportation networks, and coal-bed outcrop. These data will facilitate estimation of coal resources, evaluation of surface-mine disturbance, and prediction of post-mining land use.

Preliminary evaluation of GIS systems, review of surface-mine maps and data, organization of project priorities, and compilation of digital information have been initiated. This pilot project will continue for 1 year and could develop into a Statewide program.

Coal Quality and Petrography

COAL-QUALITY CHARACTERISTICS OF MAJOR MINEABLE COAL BEDS IN KENTUCKY

Cortland F. Eble

Title IV of the Clean Air Act Amendments of 1990, which will control acid deposition, will affect 261 electric utility units at 109 power plants in 21 states. In Kentucky, 17 units belonging to six utility companies will be affected. Phase I, which will begin in 1995, will require coal-burning electric utilities to greatly reduce SO_2 emissions. To meet these new compliance standards, utilities in Kentucky and across the United States are switching to burning low-sulfur coal or are installing sulfur-reduction devices (e.g., stack scrubbers, fluidized bed combusters) to help control sulfur emissions.

Although acid deposition control has received a great deal of attention over the past several years, Title III of the Clean Air Act Amendments, "Hazardous Air Pollutants," is also an important, but probably less well known, regulation that will significantly affect the coal and electric utility industries. Of the 189 substances (mainly chemical compounds) cited in Title III that will require monitoring with the implementation of Phase I in 1995, 13 are elements that commonly occur in trace concentrations (generally parts per million) in coal. These 13 elements are antimony, arsenic, beryllium, cadmium, chlorine, cobalt, chromium, lead, mercury, manganese, nickel, phosphorus, and selenium. Coal-burning electric utilities will be required to monitor levels of these elements in the coal feed stock they burn, and coal suppliers probably will be required to test for and report the levels of the elements in the coal they sell to power plants. Because all 13 elements occur in trace concentrations, testing for them requires very specialized and sophisticated testing equipment, which translates into greatly increased costs.

When coal is mined, the raw product consists of coal and rock; rock is contributed from small partings in coal that cannot be avoided during the mining process. To concentrate the coal and get rid of the rock, including pyrite (which is a primary contributor of sulfur in coal), coal is washed or cleaned in large facilities called preparation plants. Most of the trace elements considered under Title III are partially removed by standard coal-cleaning practices. Some elements are reduced by more than 50 percent after cleaning. The fact that virtually all Illinois Basin coal is routinely cleaned prior to shipment and use becomes paramount when trace-element concentrations in coals from different regions are compared. For example, coal from the western United States has gained recent publicity primarily because of its low sulfur content. The trace-element concentrations of these coals are also reported to be very low, which makes them doubly attractive. This attractiveness is somewhat superficial, however, because western United States coals are routinely shipped raw (with no coal cleaning), and much more coal from this region has to be burned in order to achieve the same heating level as is being achieved by burning Illinois Basin coal. Given these factors, trace-element concentrations in coal are roughly equal between the western United States and the Illinois Basin; some elements, notably mercury, are actually higher in western United States coal, according to currently available data.

One project designed to answer these problems is a cooperative program between KGS, Kentucky Utilities, and the U.S. Geological Survey to study the fate of trace elements in coal in a coal-fired power plant. Since July 1994 we have been sampling feed coal, fly ash, and bottom ash from a coal-burning generating station. This station has four 500-mega-

watt pulverized air-injection furnaces, each with a peak burn rate of 200 tons per hour. We are sampling unit 1, which burns high-sulfur western Kentucky and southern Indiana coal, and unit 3, which burns low-sulfur eastern Kentucky and southern West Virginia coal. We are also planning to visit some of the mines that supply coal to collect face-channel and bench samples. The samples from western Kentucky and southern Illinois can probably also be used as part of the Illinois Basin coal-quality study. KGS collects and prepares samples, and runs the following analyses: proximate, ultimate, calorific value, total sulfur, ash fusion, and X-ray fluorescence. The U.S. Geological Survey is testing for trace-element concentrations using atomic absorption and neutron activation. The project is designed for 3 years.

Proposed research by the Indiana, Illinois, and Kentucky Geological Surveys will identify previously unexplored areas of the Illinois Basin where a high probability exists for the development of mineable coal. Because probably less than 5 percent of the Illinois Basin has been explored and developed, a program of this type is critical to the coal industry in the basin, since economic conditions have forced all but a few companies to abandon exploration efforts.

Although some utilities that presently are using Illinois Basin coal are switching to alternative fuel sources in order to comply with the sulfur-reduction mandate, many others are opting to continue burning Illinois Basin coal using sulfur-reduction devices (e.g., stack scrubbers), citing a locally abundant and reliable fuel source. This trend will likely continue into the next century, which emphasizes the continuing need to find and quantify new high-quality coal resources.

We also have a cooperative study with MAPCO coal company to study trace-element variability in their DOTIKI and RITIKI Mines in western Kentucky. In-mine coal, cleaned coal, and preparation-plant refuse will be sampled and tested by KGS. This project will contribute to the Illinois Basin coal-quality study.

The Kentucky Geological Survey continues to maintain and update a comprehensive, computerized coal-quality data base that includes trace-element measurements for over 700 samples of Kentucky coal. Each year the Survey's coal analytical laboratories, which have been in operation since 1989, analyze several hundred coal samples. Presently, the lab routinely performs proximate (moisture, volatile matter, fixed carbon, and ash yield), ultimate (elemental carbon, nitrogen, hydrogen, and oxygen), total sulfur content, calorific value, ash fusion, and X-ray fluorescence analyses, and plans are being developed to expand the analytical capabilities to include testing for trace elements. This will allow us to continually update and expand our already very large data base so that it may better serve citizens and industry in the Commonwealth.

Industrial and Metallic Minerals

Industrial and metallic minerals provide essential materials for society by furnishing raw materials for agricultural, ceramic, chemical, construction, energy, metallurgical, and manufacturing industries. The Kentucky Geological Survey investigates the chemical composition, physical properties, geographic distribution, and geologic setting of industrial and metallic minerals in the State in order to provide information on potential resources for industry.

The information from KGS also can be used to evaluate resources for new markets and to determine new sources of raw materials. With advances in technology and industrial processes and products, new markets and needs for industrial and metallic minerals are developing, each with its own compositional and physical specifications. As an example of a changing market, the principal use for limestone and dolostone in the State traditionally has been in construction and agriculture, but Federal legislation to control sulfur dioxide emissions from coal-burning plants has resulted in new markets for carbonate rocks as sorbents in flue-gas desulfurization and fluidized-bed combustion systems.

In north-central Kentucky, recent expansion of the Cincinnati/Northern Kentucky International Airport and the associated increase in commercial and residential construction has highlighted the region's demand for aggregate. A combination of a growing market for construction materials and decreasing availability of aggregate from local surface operations has emphasized the need for alternate sources of aggregate. Subsurface deposits of limestone and dolostone in the High Bridge Group (Ordovician), which KGS investigations have indicated are potential sources of crushed stone, are targets for exploratory drilling by companies seeking to locate sites in the region that are suitable for producing aggregate.

KGS is currently conducting research projects designed to provide information needed by the future users and producers of industrial and metallic minerals. These projects and some of their results are described in the following sections.

CHEMICAL CHARACTERIZATION OF CARBONATE ROCKS IN THE HIGH BRIDGE GROUP

Warren H. Anderson

Chemical characterization of limestone products suitable for industrial use as chemical stone and sulfur sorbents has been conducted at several sites in central Kentucky, including the most recent one in Mason County. This detailed chemical characterization facilitates future mining of the High Bridge Group by providing information such as ledge descriptions, chemical analysis, and thickness values.

The Clean Air Act Amendments of 1990 have created a large demand for limestone and dolostone resources to be used as chemical stone and sulfur sorbents in electric generating stations along the Ohio River Valley. Chemical analysis of the high-calcium and high-carbonate zones described in this project will benefit suppliers and users of limestone products.

All descriptive and analytical work for the Mason County project has been completed; the manuscript was completed in early 1995, and will be published shortly. Preliminary results of the chemical data indicate that in Mason County a thick, high-calcium zone exists near the top of the Tyrone Limestone, and several high-carbonate zones exist at mineable depths in the Camp Nelson Limestone. In northeastern Kentucky, the thick high-calcium zone is present only in this portion of the High Bridge Group.

INDUSTRIAL AND METALLIC MINERAL RESOURCES AND MINERAL INDUSTRIES MAP OF KENTUCKY

Garland R. Dever, Jr., and Warren H. Anderson

The distribution of industrial and metallic mineral resources in Kentucky is being compiled for a new, 1:500,000-scale, mineral-resources map of the State. It will show the distribution of limestone (construction-grade and industrial-grade), dolostone, sand, gravel, clay, shale, and metallic and nonmetallic mineral deposits, as well as the location of active mining and mineral operations.

Mapping of sand and gravel deposits, including silica sand, glacial outwash, and alluvial sand and gravel, has been completed. The distribution of ceramic, common, refractory, absorbent, and structural clay and shale has been compiled. Locations of mineral deposits, such as fluorite, barite, and sphalerite, in the mineral districts of western, central, and south-central Kentucky have been plotted. Other pertinent mineral occurrences also were noted for inclusion on the map. Mapping of the distribution of construction-grade

and industrial-grade limestones is more than 50 percent completed.

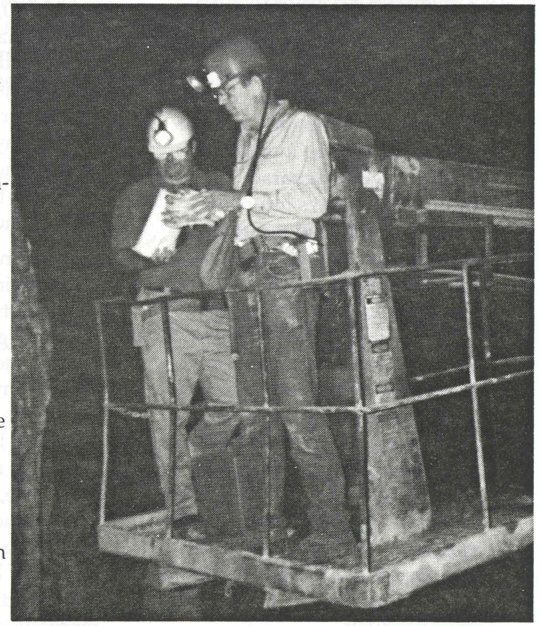
LIMESTONE AND DOLOSTONE RESOURCES FOR COAL-RELATED INDUSTRIES

Garland R. Dever, Jr.

The Kentucky Geological Survey is determining the availability of limestone and dolostone in the State for industrial uses, including flue-gas desulfurization systems used by coal-burning plants, and rock dusting by coal producers. The chemical quality of the stone is a critical factor.

Sampling procedures used for characterizing the chemical composition of limestone and dolostone deposits in the State were evaluated statistically by the University of Kentucky Biostatistics Consulting Unit. Data from sites in Fayette and Madison Counties, which had been sampled by KGS, were used for the analysis.

For the statistical evaluation, we assumed that an important objective of sampling was to determine the mean composition of a ledge of limestone or dolostone. The study showed a relationship between the sampling interval and the reliability of the mean carbonate (or contaminant) value for a ledge. Moderately high reliability (80 to 85 percent) can be obtained by taking three to four samples per ledge. If high reliability (90 percent) of the mean value is desired, samples should be taken at 1-foot intervals. Very high reliability (95 percent or more) would require sampling at ½-foot intervals.



Garland Dever samples the Camp Nelson Limestone in the Boonesborogh Quarry.

Title III of the Clean Air Act Amendments of 1990 established an initial list of hazardous air pollutants, or air toxics, that are subject to regulation by the U.S. Environmental Protection Agency. The list includes elements commonly found in trace amounts in coal and carbonate rocks.

At the present time, it is not clear if the quantity of trace elements contributed by carbonate rocks during use in industrial processes, such as flue-gas scrubbing, will exceed air- and water-quality standards. The National Geochemical Data Base (NGDB) of the U.S. Geological Survey contains trace-element data for carbonate rocks, and USGS has provided KGS with NGDB analyses for samples from Ohio Valley states. The sample population from the Ohio Valley is relatively small, but the data give an indication of elemental concentrations, which can serve as a guide for evaluating carbonate rocks of the region for industrial uses. Analyses of 749 Ohio Valley samples show the following range of concentrations (in parts per million) for 11 of the elements listed under Title III (antimony, cadmium, and selenium showed no value exceeding the lower analytical threshold):

Antimony	< 68
Arsenic	0.41–250
Beryllium	< 1–10
Cadmium	< 2
Chromium	< 1–300
Cobalt	0.84–30
Lead	< 1–200
Manganese	10–7,000
Mercury	0.01–0.1
Nickel	< 1.5–100
Selenium	< 200

SAND AND GRAVEL RESOURCES OF THE OHIO RIVER VALLEY

Warren H. Anderson

The results of this project, which summarizes the Pleistocene sand and gravel resources in northern Kentucky, were published in 1994 as Report of Investigations 8, "Sand and Gravel Resources of the Ohio River Valley." These deposits are finite resources, and are situated near several major metropolitan areas. Knowledge of the geology of these deposits will enable effective land-use planning and economic development.

Project results indicate three major glacial deposit terraces of pre-Illinoian, Illinoian, and Wisconsinan age. The larger sand and gravel resources were deposited downstream from several major glacial meltwater streams near North Bend Bottom and Petersburg in Boone County. Carbonate rocks are the dominant lithology in the older pre-Illinoian deposits; glaciers excavated the dominant bedrock lithology in the Midcontinental United States, which consists of carbonate rocks. The younger Wisconsinan terraces are the most desirable resource for mining, because of the reworking and concentration of quartz gravels. The high-gravel, low-silt/clay, and abundant limestone/dolostone content make these deposits attractive for mining. The high carbonate content, extensive reworking, and weathering of the older pre-Illinoian deposits make them the least desirable for construction aggregate.

NONFUEL MINERAL STATISTICS

Garland R. Dever, Jr.

As part of the U.S. Bureau of Mines' state-activities function, the Bureau and the Kentucky Geological Survey collected and compiled information about Kentucky's mineral industry for many years. The information was disseminated through Bureau of Mines publications such as the "Minerals Yearbook," "Annual Report," and "Mineral Industry Surveys."

The state-activities function of the Bureau of Mines was discontinued on October 1, 1994, following an extensive reorganization and program review in the agency. Multipage chapters on state mineral industries will no longer be prepared for the minerals yearbooks and annual reports. The Bureau has announced that it plans to publish, with input from state geological surveys, an annual two-page summary of state mineral industry activities in its "Mineral Industry Surveys" (MIS) format. In addition to releasing an individual MIS for each state, all state MIS's will also be published together in a new version of the minerals yearbook.

KGS will continue to monitor and compile information on Kentucky's mineral industry. The information will be used to answer public-service inquiries and to prepare reviews of industry activities.

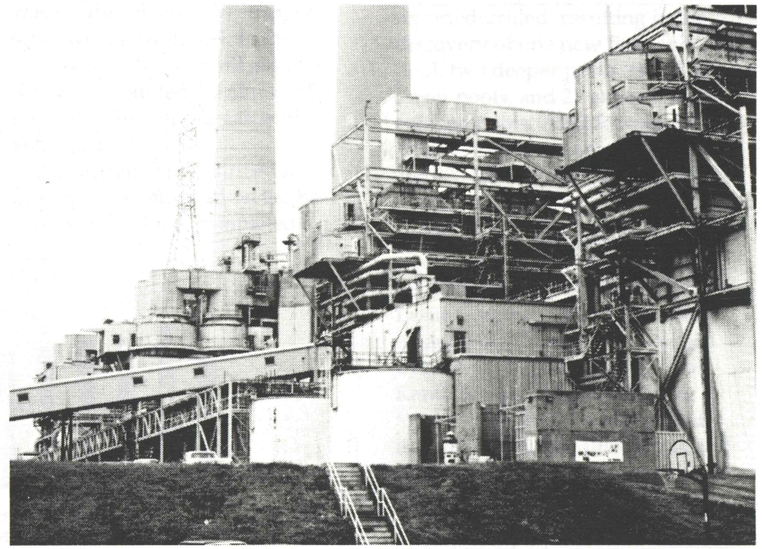
INDUSTRIAL MINERAL RESOURCES OF THE JACKSON PURCHASE REGION

Warren H. Anderson

Silica sand, ceramic clay, ball clay, and heavy minerals in Cretaceous and Tertiary sediments in the Jackson Purchase Region in western Kentucky have been examined. Ball clays are mined extensively in the Purchase area, and future studies will examine some of these clays. The initial phase of this project will examine the silica sand potential of the McNairy Formation.

Silica sand is a high-purity sand used in glassmaking for various products such as plate glass, auto glass, dinnerware, and fiber optics. Silica sand has been mined in the McNairy Formation in western Kentucky, and several potential silica sand deposits still exist in the McNairy.

The McNairy sand is a fluvial-deltaic micaceous sandstone that locally contains a high percentage of a pure silica sand. It has been mined in Calloway County. The high percentage of muscovite in the McNairy could also mean an additional by-product for mining operations. In some areas the McNairy is a limonitic/hematitic sandstone containing small amounts of titanium minerals such as rutile and ilmenite. Also, heavy metals make up 2 to 3 percent of the sandstone, locally. Initial field work has been conducted to sample various McNairy locations, and some laboratory and analytical work has been initiated.



Four scrubbers control SO_2 emissions from Louisville Gas and Electric Company's Mill Creek generating station in Jefferson County. The wet-scrubbing units use Ste. Genevieve Limestone from west-central Kentucky.

GEOCHEMICAL DATA BASE FOR KENTUCKY

Warren H. Anderson

Accelerated urban and industrial growth in Kentucky creates a need for a background geochemical data base of naturally occurring chemical elements. A geochemical data base would provide chemical information to evaluate geochemical anomalies for environmental studies, petroleum or mineral exploration, agronomy/soil science, hydrogeology, and biochemistry/human health science. The Kentucky Geological Survey receives hundreds of inquiries for geochemical data annually from various agencies.

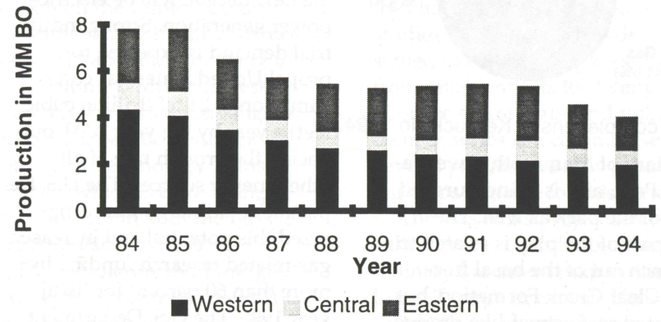
Several reconnaissance geochemical investigations have been conducted in Kentucky, and these resulting data will be incorporated into a computer data base, which will be made available for public use through the Kentucky Geological Survey's Geologic Data Center.

This project is in the initial stage of project design. Compilation of geochemical data and reviews of scanning technology for use in this project have begun. If funding can be obtained, this project can be completed in 3 years.

Petroleum and Stratigraphy

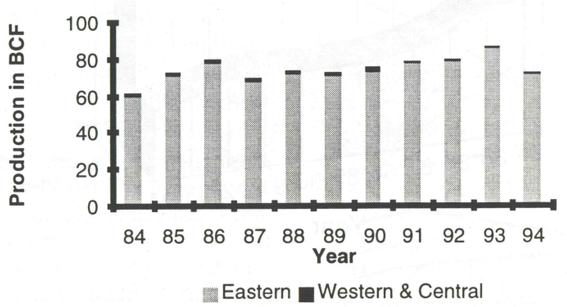
The research responsibility of the Petroleum and Stratigraphy Section is twofold: to conduct oil and gas research, and carry out research on the regional geology of the Commonwealth. Regional geologic research is vital to understanding the stratigraphic and structural framework of the State. Such knowledge is critical for understanding the character and distribution of energy and mineral resources, as well as the geologic aspects of environmental issues.

Oil and natural gas are important commodities for the Kentucky economy. In 1993 oil and gas production value was more than $251 million, bringing more that $12 million in severance tax to the State. Nationally, the industry remains in a slump that extends back to 1986; however, natural gas production has been rising the last several years. Although this year's natural gas production apparently dropped 16 percent to 73.08 billion cubic feet (bcf), this drop is actually the result of a change in reporting procedures. There is no reason to believe that natural gas production has not continued to rise, as it did earlier in this decade, although the true rise this year may have been modified somewhat by the decline in price caused by a warmer than usual winter. Oil production continued its slow decline, falling 10 percent below last year's level to 4,125,014 barrels in 1994. Most of the State's oil and gas production comes from stripper wells. In 1994, nearly 3.4 million barrels (bbl) of stripper oil was produced, and 289 stripper wells were abandoned. In the same year, stripper-well gas production accounted for almost 65 bcf of gas; 76 stripper gas wells were abandoned.



Kentucky oil production, 1984–94.

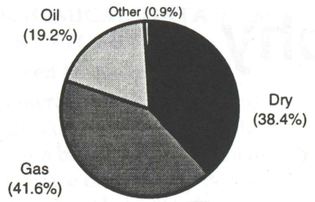
The activity summarized in this report is compiled on the basis of wells drilled, completed, and reported during the 1994 calendar year. Drilling activity in Kentucky decreased by nearly a third during the year, with only 344 wells reported complete and an overall success rate of 60 percent. During the year only 972 permits were issued, a drop of about 22 percent from a year ago. Fifty-nine exploratory wells were reported drilled, resulting in the discovery of one new field and pool, two deeper pools, two shallower pools, and 21 extensions of existing pools. Total footage drilled during the year was 766,000 feet, with an average well depth of 2,281 feet.



Kentucky gas production, 1984–94.

The Appalachian Basin of eastern Kentucky continued to produce the most oil and natural gas; Leslie County produced the most oil and Pike County the most gas. Clinton County in south-central Kentucky continued to account for the most permits: 156 permits issued in 1994. The Illinois Basin continues to have less activity and production than in the past.

The new play in southwestern Edmonson County, west-central Kentucky, continued to attract attention and increased permitting. The play continues north to the



Well completions in Kentucky in 1994.

boundary of Mammoth Cave National Park, and is being pursued north of the park as well. The main part of the play is related to the pinch out of the basal fractured Clear Creek Formation, but suspected reef or reef-like production is also occurring in the underlying Silurian units.

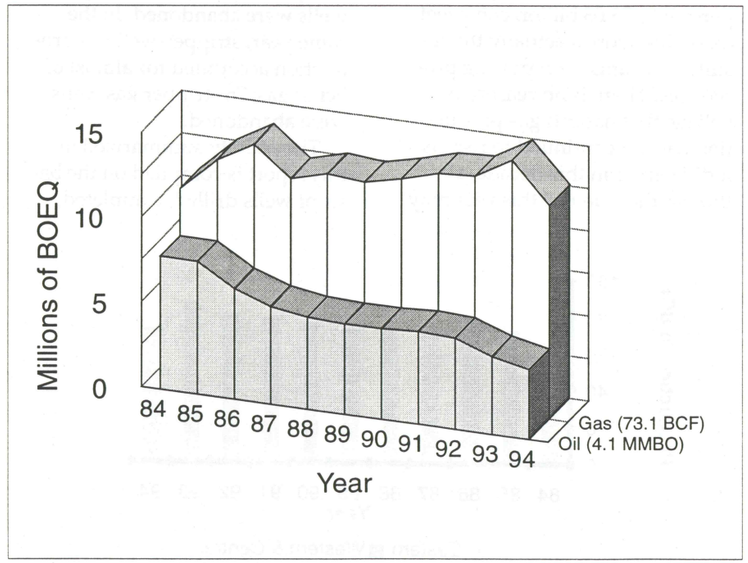
Another potentially important play is developing as the result of a gas discovery during the year from the Rome Formation of southeastern Elliott County. The Carson No. 1 Kazee well is producing about 0.5 million cubic feet of gas per day at 6,258 to 6,270 feet. Several other wells will likely be drilled in the area this summer.

Logs from both of the deep tests in the Rough Creek Graben of western Kentucky in McLean and Grayson Counties are now available to the public. Both tests, including a third in Gallatin County, Ill., were dry holes, although the one in McLean County had both oil and gas shows in the pre-Knox target horizons.

Despite the falling oil and natural gas production during the past year, hydrocarbons still represent an important State and national resource. They will be important bridging fuels well into the twenty-first century until renewable energy resources can be developed. Nationally, natural gas will play a significant role in the future domestic energy mix, because of its environmental acceptability, low cost, domestic availability, and importance to the emerging alternative fuels industry. One of the most significant future gas markets during the next decade will be electric-power generation. Strong industrial demand is expected to propel United States gas consumption to 21 tcf (trillion cubic feet) a year by the year 2000, outpacing the growth rate of all other energy sources. The U.S. Department of Energy has recognized this potential and increased gas-related research funding by more than 60 percent for fiscal year 1995. The U.S. Department of Energy (USDOE) has also developed the Domestic Natural Gas and Oil Initiative, which focuses heavily on increased domestic natural gas production. However, possible budget cuts for USDOE could result in recision of 1995 funding levels, as well as affect future funding.

Despite the decline in gas production during the year, the value of gas production in Kentucky continues to outstrip the value of oil production Statewide by a margin of more than 2.3 to 1. The State has large untapped natural-gas resources; with the proper incentives and support, careful planning and commitment, and pipeline availability, this sector of Kentucky's economy could show significant growth during the next decade, providing the Commonwealth with a strong energy base, a vital industry, well-paying jobs, and increased oil and gas revenues, together with sustainable development.

Recovery of oil and gas from known domestic reservoirs is being recognized as an important source for the future domestic energy supply. Compiling oil and gas data bases and atlases is a vital first step in evaluating these resources. Such data will be useful to reservoir-characterization studies, which are critical for the future development of exploration and production strategies. The Petroleum and Stratigraphy Section



Kentucky oil and gas production on a barrels-of-oil equivalent basis.

is finishing research projects that provided information for a gas atlas and the Tertiary Oil Resources Information System (TORIS) for the Appalachian Basin in eastern Kentucky, and is seeking to add similar research for the Illinois Basin of western Kentucky.

The deep basins in Kentucky are potential important gas provinces. Companies are examining recently available reflection seismic data for the Rome Trough and the Rough Creek Graben and discussing exploration strategies for natural gas. The Petroleum and Stratigraphy Section is involved in several studies of available seismic data for the Rough Creek Graben and is discussing possible future cooperative research projects in both basins with industry and academia.

Environmental concerns are increasingly important in Kentucky as well as the nation. Subsurface geologic information is key to several of these issues, including earthquake risk, potential deep-well waste disposal, groundwater pollution, and NORM (Naturally Occurring Radioactive Material) associated with oil and gas production. The Petroleum and Stratigraphy Section is currently participating in the University of Kentucky Seismic Network to monitor earthquake activity in the State and, in particular, the New Madrid Seismic Zone of western Kentucky. Seismic hazards for municipalities and public works in western Kentucky are also being assessed.

The Petroleum and Stratigraphy Section continues to play an instrumental role in various consortia with other state geological surveys. We are continuing our association with the Illinois Basin Consortium, the Cincinnati Arch Consortium, and the Appalachian Oil and Natural Gas Research Consortium. In addition, we are cooperating with the U.S. Geological Survey in several research projects, and are completing work with the Clinton County government and the Los Alamos National Laboratory to study the high-volume Ordovician reservoirs. We are also discussing interstate cooperation with the Petroleum Technology Transfer Council, which is developing regional offices in both the Illinois and Appalachian Basins.

The Petroleum and Stratigraphy Section performs research and service in six general areas: basin analysis, regional geology, hydrocarbon resources, geophysics, oil and gas data, and drill cuttings and core samples.

Basin Analysis

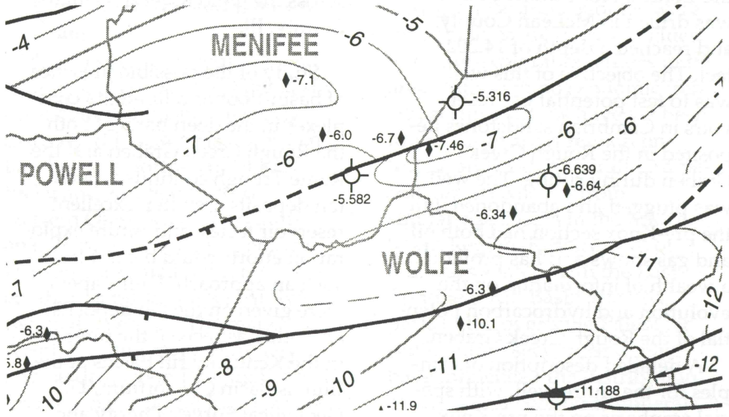
REGIONAL SUBSURFACE MAPS IN KENTUCKY

David C. Harris, James A. Drahovzal, and Martin C. Noger

The goal of this research is to produce a series of regional facies, isopach, and structure maps for important geologic horizons and intervals of the Commonwealth. This information is critical not only for the energy and mineral industries of the Commonwealth, but also for addressing environmental issues. In addition, these maps will serve as the basis for future basin-analysis studies. This project was designed to expand maps resulting from other projects to cover parts of or the entire State, and publish them in series at a common scale. Several projects are now producing maps suitable for this series.

The Gas Atlas project has resulted in the compilation of a preliminary basement map for the Rome Trough in eastern Kentucky. The map is based on existing deep-well, limited seismic, and some potential field data. The map is currently in press, and is considered preliminary because of additional recent data for the area purchased in cooperation with the U.S. Geological Survey. These data, together with data from the Rough Creek Graben and the Reelfoot Rift, will be useful in the eventual production of a Statewide basement map. Such a map is important to future oil and gas exploration in Kentucky.

A number of structure-contour and isopach maps from the top of the Newman Limestone to the top of the Devonian New Al-



Portion of the new basement map for eastern Kentucky.

bany/Chattanooga Shale are currently being generated as part of the Newman Limestone project. These maps will be prepared for publication next year.

In addition, an important regional structural map for the Beech Creek Limestone Member of the Golconda Formation (Barlow Limestone) in the Illinois Basin has been submitted for publication. This map will be reviewed and should be published next year.

STRATIGRAPHY AND SEDIMENTOLOGY OF PRE-KNOX STRATA IN THE ROME TROUGH AND ROUGH CREEK GRABEN

David C. Harris, David A. Williams, Warren H. Anderson, and James A. Drahovzal

Several aspects of this study are being carried out concurrently, but all have the overall goal of providing information on the pre-Knox interval of the two rift basins of Kentucky.

The study is taking advantage of a deep exploratory well that was drilled by Conoco, Inc., in the Rough Creek Graben of western Kentucky in late 1992. This well, the Conoco No. 1 Mark Turner, was drilled in McLean County, and reached a depth of 14,202 feet. The objective of this well was to test potential gas reservoirs in Cambrian sandstones deposited in the Rough Creek Graben during rifting. The well was plugged and abandoned, but the pre-Knox section had both oil and gas shows and has provided a wealth of information on the evolution and hydrocarbon potential of the Rough Creek Graben.

A detailed description of samples for the entire well, with special emphasis on the pre-Knox section, has been completed. Samples were collected for source-rock analysis, which is being performed by the USGS. Correlations with other pre-Knox wells in the Rough Creek Graben indicate that a previously undrilled synrift lithic sandstone interval was encountered in the bottom of the well. Although nonporous in the Turner well, this zone may have reservoir potential in other parts of the basin. A thick zone of dolomitized oolitic grainstones in the upper pre-Knox section is stained with bitumen, indicating that hydrocarbons were present in the deep basin. Other sections were reported to have had gas shows during drilling.

No additional research on the Turner well was possible during the year, but results of previous research were presented at two meetings during 1994–95. Research will continue in the second half of 1995 with description of samples from Conoco's second deep well in the Rough Creek Graben, the No. 1 Shain well in Grayson County, and publication of the Conoco Turner results. The Illinois Basin Consortium is planning a study that would analyze and correlate all three wells drilled in the graben by Conoco, including one completed just across the Ohio River in Gallatin County, Ill.

Study of the possible presence of basin-floor and fan-delta complexes in the deep parts of both the Rough Creek Graben and the Rome Trough continued. Such fan deposits are often excellent reservoir facies, and future exploration efforts could benefit from such an approach. Four papers were given on the fan deposits and other aspects of the pre-Knox in the Kentucky rift basins at the Illinois Basin Consortium/U.S. Geological Survey Energy and Mineral Resources Workshop in September 1994.

A preliminary top-of-basement structure map for eastern Kentucky that will tie to future work on the pre-Knox interval in the Rome Trough and associated structures was also published.

REGIONAL SUBSURFACE STRATIGRAPHY AND PETROLOGY OF THE NEWMAN LIMESTONE, APPALACHIAN BASIN, EASTERN KENTUCKY

David C. Harris and Thomas N. Sparks

The goal of this project is to provide the regional stratigraphic and petrologic data necessary for oil and gas companies to evaluate the hydrocarbon potential of the Newman Limestone (Big Lime) in eastern Kentucky. Increasing production from this interval in recent years is indicative of the potential of the zone, but realization of this potential will require a consistent and accurate regional data set for interpretation. The project began in early 1994 and is being partially funded by three private companies.

The project objectives include collecting stratigraphic-tops data for approximately 8,000 selected wells, and Big Lime porosity data for approximately 1,100 wells. These data will be entered into a computer data base, which will be used by the project participants for regional mapping and prospect identification.

Data collection is currently in progress, and will be completed in mid-1995. The Big Lime interval has been divided into four subzones, and these subzones are being correlated regionally. Fourteen regional cross sections compiled from digitized well logs have been completed. After a 1-year confidentiality period, all data will be made available to the public.

DEEP STRUCTURAL FRAMEWORK OF THE WABASH VALLEY FAULT SYSTEM AND ITS RELATION TO THE NEW MADRID SEISMIC ZONE

James A. Drahovzal

The relationship of the Wabash Valley Fault System and its seismicity to the New Madrid Seismic Zone farther south is currently not well understood. An understanding of the structural geology and tectonic history of the deeper part of the Illinois Basin in western Kentucky is critical for studies of earthquake mechanisms and hazards in western Kentucky.

This project was completed during the year, and a final report was submitted to the sponsor, the U.S. Geological Survey's Earthquake Hazards Reduction Program. The project was in cooperation with the Illinois Basin Consortium, and included contributions from the Illinois State Geological Survey and the Indiana Geological Survey. Its goal was to assess the reflection seismic data available for the area and acquire as much of those data as possible. During the year, consortium members met with various oil- and gas-industry and seismic-acquisition representatives to review available seismic surveys of the Illinois Basin. As a result, reflection seismic data representing more than 1,200 miles were obtained from eight companies. More than 900 line miles of these data are from western Kentucky. Data acquired during the year for western Kentucky include seismic lines in Grayson County contributed by Conoco and Texas Gas Transmission Company. Acquisition activities continue with several other companies, even though the project is concluded.

Interpretation of the seismic data sets provided by the U.S. Geological Survey was completed through individual work and several workshop sessions with Illinois Basin Consortium and U.S. Geological Survey geologists. The results of these interpretations were presented in two papers at the Illinois Basin Consortium/U.S. Geological Survey Workshop in Evansville, Ind., in September 1994. The manuscript, "Structure of the Reelfoot-Rough Creek Rift System, Fluorspar Area Fault Complex, and Hicks Dome, Southern Illinois and Western Kentucky—New Constraints from Regional Seismic Reflection Data," was completed as a joint effort of the Illinois Basin Consortium and the U.S. Geological Survey. The report deals with the interpretation of Seismic Service, Inc., seismic line DIB-2, and is in press at the U.S. Geological Survey as part of the Professional Paper series. Similar reports are planned for the other three lines acquired by the U.S. Geological Survey for the Illinois Basin Consortium.

REGIONAL GEOLOGY OF THE KENTUCKY-OHIO TROUGH

David C. Harris and James A. Drahovzal

This research geologically and geophysically delineates the East Continent Rift Basin, a recently discovered Precambrian sedimentary basin in north-central Kentucky and adjacent parts of western Ohio and eastern Indiana. During the year technology transfer continued, with the presentation of poster papers at two regional meetings. The manuscript, "Sedimentary Petrology and Hydrocarbon Potential of the Precambrian Middle Run Formation in Kentucky and Adjacent Parts of Ohio and Indiana," contains all petrologic data and interpretations on the Middle Run Formation resulting from the project. The manuscript, "Petrology and Geochemistry of Some Precambrian Mafic Rocks, Kentucky and Indiana," discusses the origin and tectonic significance of basalts associated with the Middle Run Formation. Both papers have been technically reviewed and are ready for final editing.

Some further research on the basin has been undertaken with two faculty members and a student at Western Michigan University. The research focuses on the geophysical constraints related to the timing of the development of the East Continent Rift Basin as it relates to the Fort Wayne Rift and the Grenville Province. The study is resulting in a new understanding of the tectonic evolution of the basin. A manuscript is currently being written, which will be submitted to a national journal later this year.

Results of this project continue to force a major re-interpretation of the deep-basement geology of central Kentucky. The complex sedimentary rift basin now known to exist, where previously only granites and rhyolites were thought to occur, provides clues to future exploration efforts in the area. Although no economic mineral accumulations have yet been found, large areas remain untested, and both minerals and petroleum are known from similar-age basins in the Midcontinent Region. Reactivation of faults associated with the East Continent Rift Basin affected parts of the overlying Paleozoic sedimentary section, and may have influenced the distribution of oil, gas, or economic minerals in younger rocks. Research related to this project will continue

as new data and funding are obtained.

STRATIGRAPHY AND RESERVOIR SEDIMENTOLOGY OF MISSISSIPPIAN CARBONATES IN KENTUCKY (ILLINOIS BASIN)

David C. Harris and Terence Hamilton-Smith

Mississippian carbonates in the Illinois Basin of western Kentucky (Fort Payne, Warsaw, St. Louis, and Ste. Genevieve Formations) are some of the most significant hydrocarbon-producing intervals in the Commonwealth. The goal of this project is to better define the regional subsurface stratigraphy, and interpret the geologic controls on hydrocarbon reservoir development and distribution. The results of this work will benefit the oil and gas industry in the Illinois Basin, both in discovering new reserves, and in increasing oil recovery from known Mississippian pools.

There was only minor activity on this project during the year because research emphasis was shifted to Mississippian carbonate reservoirs of the Appalachian Basin (see Newman Limestone project above).

Regional Geology

GEOLOGY ALONG KENTUCKY HIGHWAYS

Donald C. Haney and Martin C. Noger

The construction of highways in Kentucky has resulted in roadcuts that display important geologic features. Many prominent geologic features are also exposed only short distances from the highways. Numerous inquiries about these features are received by the Kentucky Geological Survey. Reports about the geology along Kentucky's major interstate highways, designed for professionals and the public at large, will fill a definite need.

A report on the Cumberland and Daniel Boone Parkways was completed during the year and turned in to the Publications Section for drafting and editing. Another report on the Alexandria-Ashland (AA) Highway is nearing completion. Two reports, one on Interstate Highway 64 and one on Interstate Highway 24 and the Western Kentucky Parkway, are currently being drafted and edited by the Publications Section.

SUBSURFACE STRATIGRAPHY AND RESERVOIR GEOLOGY OF THE SILURIAN–DEVONIAN CORNIFEROUS OF KENTUCKY

Joseph F. Meglen and Martin C. Noger

More than 60 percent of the hydrocarbons produced in Kentucky has come from the Silurian–Devonian Corniferous interval. Most of the oil and gas production is apparently associated with trapping along an erosional unconformity on the flanks of the Cincinnati Arch. The Corniferous holds the potential of being an important hydrocarbon-producing interval in the deeper parts of the Appalachian and Illinois Basins. The details of the Corniferous stratigraphy are critical in understanding its petroleum geology. In the past several years, additional well data have become available. These new data need to be integrated into an updated synthesis of the geology in order to develop successful hydrocarbon exploration models for the deeper areas.

During the year, several studies related to the Gas Atlas Project were completed and submitted for publication. These include studies on the Lower Devonian–Upper Silurian unconformity (Corniferous) and the Upper Silurian Lockport-Big Six plays. Reports on these plays will be published later this year or early next year as part of the Appalachian Gas Atlas. Current plans call for KGS publication of these manuscripts as well.

These studies will aid the petroleum industry in formulating development and exploration strategies for the potentially productive rocks of the Silurian–Devonian carbonate interval in Kentucky by providing maps and interpretations on local and regional bases. These studies will also provide information that should encourage secondary and tertiary oil-recovery projects.

REGIONAL STRUCTURAL CROSS SECTIONS, ILLINOIS BASIN, WESTERN KENTUCKY

Martin C. Noger and James A. Drahovzal

This project to compile structural cross sections continues in cooperation with the Illinois Basin Consortium. The Illinois Basin, which covers parts of western Kentucky, southwestern Indiana, and Illinois, is a sedimentary, interior cratonic sag basin that has produced some 4 billion barrels of oil from its shallow parts. The potential exists for large accumulations of hydrocarbons in deeper pre-Upper Mississippian strata. Construction of a network of structural cross sections from available data will provide an understanding of the regional structural geology, stratigraphy, and evolution of the basin, and illustrate known and potential hydrocarbon sources, traps, reservoirs, and seals. The cross sections, in addition, will provide a geologic framework for future geologic and mineral-resource and environmental studies.

No work was completed on this project during the year because of Mr. Noger's retirement and shifts in research emphasis. Preliminary blackline copies of the printed cross sections are available from each of the IBC member surveys.

Hydrocarbon Resources

GAS POTENTIAL OF THE NEW ALBANY SHALE, ILLINOIS BASIN, WESTERN KENTUCKY

Terence Hamilton-Smith, Brandon C. Nuttall, and James A. Drahovzal

The goal of this project, carried out by the Illinois Basin Consortium, is to stimulate future production of natural gas from the New Albany Shale in the Illinois Basin of western Kentucky, southwestern Indiana, and southern Illinois. The project has been funded by the individual geological surveys and the Gas Research Institute (GRI).

A regional New Albany Shale well data base, with over 2,000 entries from western Kentucky alone, has been compiled, and stratigraphic cross sections have been completed across the basin. Final maps have been completed for the Illinois Basin, which show major structural features, New Albany Shale gas production, structure, thickness, core locations, and reflectance of shale vitrinite. Project results have been presented at talks and poster sessions in Lexington and Owensboro, Ky.; Evansville and Bloomington, Ind.; and Champaign, Ill. The final report was published by the Indiana Geological Survey in mid-1994 as Illinois Basin Studies 2, on behalf of the Gas Research Institute and the Illinois Basin Consortium. It is available from Publications Sales at the Kentucky Geological Survey and at the other Illinois Basin Consortium member surveys.

GAS RESERVOIR CHARACTER OF DEVONIAN SHALES OF KENTUCKY

Terence Hamilton-Smith

Devonian shales, containing the largest natural gas reserves in Kentucky, are concentrated mainly in the giant Big Sandy Field of eastern Kentucky and western West Virginia. Significant shale gas exploration potential also exists elsewhere in Kentucky, particularly in the New Albany Shale of the western part of the State. Shale gas is contained in a unique fractured reservoir, which has resisted attempts at evaluation and commercial development with traditional methods.

A paper, "Temperature and Pressure Controls on the Fractured Devonian Shale Play of the Appalachian Basin," was published by the Ohio Geological Society in late 1994. A reservoir study of New Albany Shale gas production in the Shrewsbury Consolidated Field in Grayson, Butler, and Edmonson Counties is continuing; recent preliminary results were presented at a professional meeting in Evansville, Ind. Completion of this field study is anticipated in 1995, and KGS will publish the results. In conjunction with the Illinois Basin Consortium and the U.S. Geological Survey, a mass-balance study of oil generation from the Devonian shale of the Illinois Basin was completed and will be published shortly as a USGS Bulletin.

RESERVOIRS OF THE CINCINNATI ARCH, CENTRAL KENTUCKY

Terence Hamilton-Smith, David C. Harris, and Brandon C. Nuttall

This project has been merged with Application of GIS Techniques for Geologic Modeling of Fractured Carbonate Reservoirs in Clinton County, Kentucky. Upper Ordovician oil reservoirs in south-central Kentucky continue to attract national attention because of continuing high-volume production in southern Clinton County. Deepening of an abandoned well in 1990 resulted in record-setting initial production for the region of 3,500 barrels of oil per day from fractured limestones of the High Bridge Group. Additional high-volume wells drilled in the vicinity of the discovery well established the existence of a large and productive reservoir, with uncertain character and distribution. A second new field discovery in the High Bridge Group in northern Clinton County has been extended by the drilling of several successful development wells.

This project was initiated to help reduce exploration risk by improving the ability to predict the distribution of major tectonic fracture systems responsible for high-volume production. In late 1993, KGS was awarded a contract by Los Alamos National Laboratory to provide geological support for a microseismic research project in Clinton County, which has the potential to image the reservoir fracture system. The objectives of this project changed somewhat during the year because of personnel changes, but it is still focused on the development of a geologic model for fractured carbonate reservoirs in the Clinton County area. The geographic information system and remote-sensing aspects of the study are being de-emphasized.

Preliminary results of this project were published by the Society of Petroleum Engineers in late

1994. Surface field mapping of joint orientation and subsurface structural mapping will be combined with the microseismic results in a paper to be submitted for publication by the American Association of Petroleum Geologists in late 1995.

TAR SANDS OF WESTERN KENTUCKY

Terence Hamilton-Smith

Tar sands of western Kentucky comprise a major hydrocarbon resource of over 3 billion barrels of heavy oil and tar in place in the shallow subsurface. This resource has been developed episodically for over 100 years, depending on price and market considerations. With the declining availability and rising price of conventional oil, the tar sands will probably be commercially valuable again in the future. In addition to their commercial potential, the western Kentucky tar sands provide a record of oil migration in the Illinois Basin, and so are of general significance to petroleum geology research.

In cooperation with the Illinois Basin Consortium and the U.S. Geological Survey, KGS has compiled a report showing that tar sands have emerged as a significant element in a mass-balance study of hydrocarbons in the Illinois Basin; the report will soon be published as a USGS Bulletin. A subsequent study conducted by KGS concludes that tar sands show that oil migration in the Illinois Basin included a major component of flow from the deep basin center eastward toward the Cincinnati Arch. Results of this study will be submitted for publication in 1995.

NORM (NATURALLY OCCURRING RADIOACTIVE MATERIALS) EVALUATION IN THE OIL FIELDS OF KENTUCKY

Terence Hamilton-Smith, Brandon C. Nuttall, and James A. Drahovzal

This project was initiated as a result of reported radioactivity associated with oil production in the Martha oil field in eastern Kentucky. Such associated radioactivity is referred to as NORM (Naturally Occurring Radioactive Materials) contamination. An interdisciplinary technical group was formed that includes representatives of the Kentucky Geological Survey, the Kentucky Department for Environmental Protection, the Kentucky Division of Oil and Gas, and the Kentucky Oil and Gas Association, with leadership provided by the Radiation Branch of the Kentucky Department for Health Services. This committee met often in 1993 to evaluate the potential NORM hazard in the oil and gas fields of Kentucky.

Available data suggest that NORM contamination resulting from the petroleum industry in Kentucky is associated specifically with radium-bearing scale deposited in pipes, facilities, and pits resulting from brine production associated with oil, including both primary water production and waterflood stimulation. Gas and oil production without associated water is not expected to result in a NORM hazard. Results of NORM investigations to date have been presented at meetings in Kentucky sponsored by the University of Kentucky Department of Geological Sciences, the Kentucky Oil and Gas Association, and the Kentucky Geological Survey. Future work will depend on the initiative of the Kentucky Department for Health Services.

CARBONIFEROUS OIL FIELDS OF KENTUCKY (ILLINOIS BASIN)

Terence Hamilton-Smith and David C. Harris

The Carboniferous beds of western Kentucky contain the largest oil reserves of the State. Daviess and Union Counties were two of the 10 leading counties in the Illinois Basin in 1992 in terms of new wells drilled, accounting for 15 of the 86 new oil-well completions drilled in western Kentucky.

Research in this project will focus on reservoir evaluation using geophysical logs, supplemented by available core, test, and production information. The results of this research will benefit industry and government by providing an objective basis for the accurate assessment of reserves, as well as improving procedures for the more cost-effective development of the resource.

A reservoir evaluation of the Antioch Field of Hopkins County is in progress, using proprietary data provided by both Ashland Exploration and Har-Ken Oil Company. TERRASTATION[1] log analysis and mapping software installed on a Sun workstation at KGS are being used for the analysis. This field study will result in a subsequent publication by KGS.

Agreement has also been reached with Har-Ken Oil Company to conduct a reservoir evaluation of the New Cypress Northeast Field in Muhlenberg County. Work to date consists of preparation of a data base and collection of cores. This field study will also result in a publication by KGS.

Because of other priorities, no progress was made on this project during the year.

1 Any use of trade, product, or firm names in this publication is for descriptive purposes only and does not imply endorsement by the Kentucky Geological Survey or the University of Kentucky.

Geophysics

SEISMIC PROCESSING AND INTERPRETATION OF THE EASTERN ROUGH CREEK GRABEN

Edward W. Woolery, James A. Drahovzal, and Ronald L. Street

This new project is sponsored by a gift to the Kentucky Geological Survey from American Energy Products, Inc. Its goal is to examine the geologic structure of the Rough Creek Graben as it relates to the East Continent Rift Basin. An understanding of the relationship between these geologic features will provide valuable insight into future hydrocarbon exploration strategies in the graben and into the geologic evolution of this part of the State.

Available seismic data for the area will be compiled, and velocity-depth analyses will be carried out, where possible. The results of this research are expected to provide (1) a definition of basement in the eastern Rough Creek Graben and the graben's overall configuration, (2) identification of any potential reservoir rock in the Proterozoic units that lie below the Cambrian graben, (3) an understanding of the relationships between the older Precambrian units and the younger Cambrian units, and (4) the extent of the basal Cambrian fan systems that have been identified in the western part of the graben and determine their hydrocarbon reservoir potential.

Several important data sets have been acquired from three companies that have been active in the area. Additional data sets are being sought. The seismic data on hand are being reformatted for velocity analysis on a microcomputer, and synthetic seismograms are being prepared from well data in the area. Some preliminary interpretations of several seismic horizons have been made and extended across the area. A paper describing the results of the study is planned for presentation later in the year or in 1996.

OPERATION OF THE UNIVERSITY OF KENTUCKY SEISMIC AND STRONG-MOTION NETWORK

Ronald L. Street

This project includes projects formerly referred to as Operation of the Kentucky Seismic and Strong-Motion Network, Seismic Hazard Analysis in Kentucky, and Representative Strong-Motion Stations in the New Madrid Seismic Zone.

Operation of the University of Kentucky Seismic and Strong-Motion Network began in late 1980 following the 5.2 $m_{b,Lg}$ July 27, 1980, Sharpsburg, Ky., earthquake. The network is designed to monitor seismicity in and around the State, and has produced over 1,000 recordings of regional earthquakes since it began operation. The network presently consists of 11 borehole-mounted, short-period seismometers deployed across the State from Grayson in the east to Clinton in the west. The seismic data are transmitted to the UK campus via the State KEWS (Kentucky Early Warning System) microwave network. Continuous drum recordings of the seismic activity are used for visual analysis, and the data are digitized and stored on a computer for advanced processing and display.

The strong-motion part of the network consists of five surface-mounted three-component accelerographs, and two vertical (surface and borehole instruments) accelerometer arrays located in western Kentucky and northwestern Tennessee, in the vicinity of the New Madrid Seismic Zone. The data are transmitted by telephone modem links between the individual stations and the Seismic Lab at UK. The strong-motion network is designed to investigate the effects of thick sequences of unconsolidated sediments associated with the lower Ohio River Valley, the central Mississippi River Valley, and the Mississippi Embayment on earthquake ground motions, and provide engineers with high-quality data that can be used in the design and construction of safer structures.

With the exception of station VSAB, all the seismic and strong-motion stations in the network were in continuous operation during the 1994–95 fiscal year. VSAB was destroyed by lightning in July 1994. The station has been partially replaced with a three-component, free-field accelerometer and accelerograph.

Seismicity in the Commonwealth and surrounding states during the past year has been sparse. Only five earthquake epicenters have been located in the Commonwealth since July 1, 1994: one in Ballard County, two in Fulton County, one in Meade County, and one in Muhlenberg County. Several earthquakes in neighboring states were recorded by the network during the past year, the most unusual being a magnitude 3.8 earthquake in southern Ohio, near the community of Belfast. Most of the other

earthquakes in neighboring states were in northeastern Arkansas, southeastern Missouri, and southern Illinois. None of these events were of sufficient magnitude to be felt in Kentucky.

During the coming fiscal year the Kentucky Seismic Network will be expanded and upgraded. Two seismic stations are to be added to the network, one in Hickman County and one near the Carlisle/Ballard county line. The additional stations will permit us to more precisely locate the seismicity in the four-county area of Hickman, Carlisle, Ballard, and McCracken; the long-term objective is to determine the relationship between the low-level seismicity in the four-county area and the much higher level of seismicity in the New Madrid, Mo., area.

In addition to the two seismic stations to be installed during the coming fiscal year, one strong-motion station will be replaced, a new one is to be established, and an existing one is to be upgraded. The free-field strong-motion station at Hickman, Ky., is to be replaced with a free-field and downhole accelerometer. A new strong-motion station consisting of a three-component free-field and a three-component downhole accelerometer, and a state-of-the-art accelerograph, is to be established near Bardwell, Ky. The existing three-component, free-field strong-motion station at Ridgely, Tenn., will be upgraded to include a three-component downhole accelerometer; this work is being done in cooperation with Lamont-Doherty Earth Observatory.

Funding for the expansion and upgrading of the network is coming from the Kentucky Department of Housing, the U.S. Geological Survey, and the Kentucky Division of Disaster and Emergency Services. Microwave links to the new seismic stations will be provided by the Kentucky Division of Telecommunications.

INVESTIGATIONS OF SHALLOW STRUCTURAL DEFORMATION IN THE CENTRAL NEW MADRID SEISMIC ZONE

James B. Harris

The style and extent of deformation in shallow, unconsolidated sediments of Quaternary age, and the relationship between near-surface structure and deeper faults, is unknown throughout much of the New Madrid Seismic Zone. The objective of this continuing research is to use seismic reflection methods to image shallow structure in an attempt to document the nature and timing of near-surface deformation. High-resolution seismic reflection profiles have been collected across the Lake County Uplift, a topographic bulge (encompassing part of far western Kentucky) that is believed to be associated with contemporary seismicity in the central New Madrid Seismic Zone.

Preliminary results of high-resolution shear-wave seismic reflection data indicate that shallow faults extend into Quaternary (possibly Holocene) sediments. Deformational styles include normal and reverse faults, a possible flower structure (near-surface expression of a strike-slip fault), and folding. In addition to the reconnaissance survey across the Lake County Uplift, the research has generated several complementary projects, including reflection profiling of the Reelfoot Scarp and investigations of near-surface shear-wave splitting in the Central New Madrid Seismic Zone.

GRAVITY MAP OF KENTUCKY

James B. Harris

In 1978, the western sheet of the Bouguer gravity map of Kentucky was published by the Kentucky Geological Survey at a scale of 1:250,000. Because of difficulties in matching contours across map boundaries, the central and eastern sheets were never published. However, recent work has succeeded in matching contours, which allows the sheets to be combined. The gravity map will be published on one sheet at a scale of 1:500,000 in 1995.

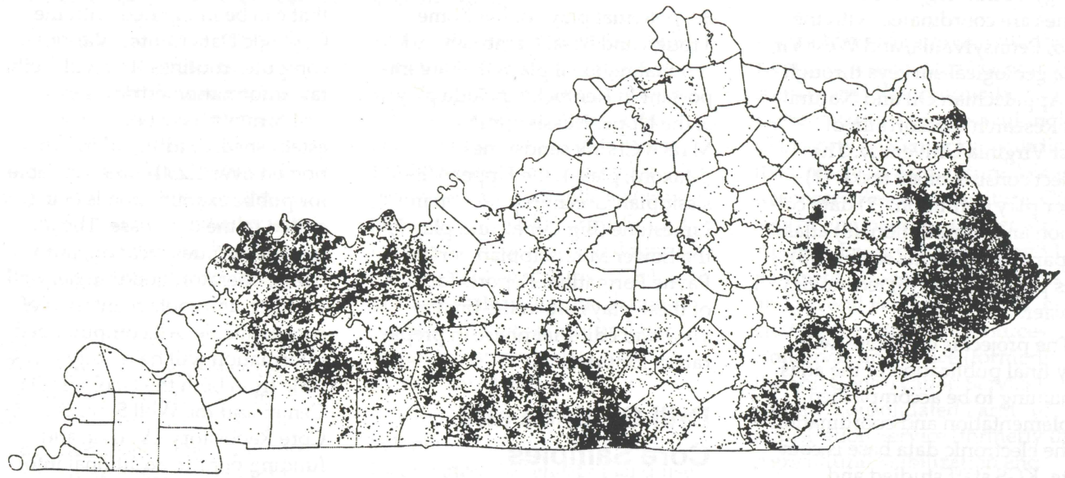
Oil and Gas Data

OIL AND GAS MAPS OF KENTUCKY

David A. Williams, Brandon C. Nuttall, Anna E. Watson, Daniel I. Carey, and Lance G. Morris

The effort to update the Oil and Gas Map of Kentucky has been absorbed by the Atlas of Major Gas Plays of the Appalachian Basin project. The data-processing phase has been completed for the Williamson, Hazard, and Middlesboro 1:100,000-scale quadrangles. This phase includes resolving location and pool nomenclature problems, defining pool boundaries, and mapping production according to geologic system. Work has begun on using a GIS approach for the Middlesboro 1:100,000-scale map. The Williamson and Hazard Quadrangles will be computer-drafted. Plotting of well locations not previously computerized has been completed for about 70 percent of the Tompkinsville Quadrangle 1:100,000-scale map.

In addition to a series of published 1:100,000-scale maps, other planned products include a 1:500,000-scale oil and gas map of Kentucky to supplement the State geologic map, and an atlas of stratigraphic and spatial distribution of oil and gas production.



Reduced, black-and-white version of new, electronically generated oil and gas map of Kentucky, which will be available soon from KGS.

A 1:1,000,000-scale map showing the distribution of oil and gas well-location data, derived from the well records data base, is being compiled utilizing GIS software available at the Survey. This map is being edited and will be released to the public. The final decision on publication format has not been made, but release of this information is expected before the end of 1995.

TERTIARY OIL RECOVERY INFORMATION SYSTEM (TORIS)

James A. Drahovzal, Brandon C. Nuttall, Matthew Humphreys, Anna E. Watson, and Thomas N. Sparks

The U.S. Department of Energy (DOE) developed the TORIS data base for the purpose of characterizing the nation's oil resources. Its goals were to (1) estimate potential domestic oil reserves, (2) project United States oil production potential, and (3) target research and development efforts on enhanced exploration, drilling, completion, and production technologies for exploiting the existing domestic resource. For Kentucky, TORIS contains data for only five oil reservoirs, all located in western Kentucky.

Preliminary estimates of original oil in place were compiled, and 23 key fields were identified that account for approximately 80 percent of the original oil in place in the eastern Kentucky portion of the Appalachian Basin. These fields represent oil production from 39 different stratigraphic intervals ranging in age from Pennsylvanian to Cambrian. Data are being compiled on these fields for inclusion in the TORIS data base. Data required by the project include field size in acres, number of producing wells, porosity, permeability, pay thickness, oil and water saturation, original oil in place, current production, and reserves.

The initial data estimates have been coded onto data sheets. A spreadsheet data base has been implemented for data storage and output. A literature search is being conducted to obtain additional published data. Operators and individuals that could assist with supplying field-specific data not otherwise available have been identified and contacted. In the next year, data collection and analysis will be completed, and the required TORIS summary sheets will be submitted to the U.S. Department of Energy.

ATLAS OF MAJOR APPALACHIAN GAS PLAYS

James A. Drahovzal, Brandon C. Nuttall, Matthew Humphreys, Anna E. Watson, and Theola L. Evans

This 3-year project was initiated October 1, 1991, with fund-

ing from the DOE Morgantown Energy Technology Center. Activities are coordinated with the Ohio, Pennsylvania, and West Virginia geological surveys through the Appalachian Oil and Natural Gas Research Consortium of West Virginia University. The project consists of six tasks: (1) major play definition, (2) data collection and compilation, (3) atlas preparation, (4) atlas review, (5) atlas printing, and (6) technology transfer.

The project is complete, with only final publication of the atlas remaining to be accomplished. Implementation and coordination of the electronic data base is complete. KGS staff studied and authored reports on play 14, the Middle Devonian–Lower Mississippian fractured shales; play 21, the Lower Devonian–Upper Silurian unconformity (Corniferous); play 23, the Upper Silurian Lockport-Big Six; play 28, the Upper Ordovician bioclastic carbonate (Trenton); play 30, the Middle Ordovician St. Peter sandstone and Wells Creek Formation; and play 32, potential plays of the Rome Trough and basal Cambrian. Additional regional plays that are important in Kentucky include play 3, the Upper Mississippian Mauch Chunk sandstones (Maxon); play 4, the Upper Mississippian Greenbriar-Newman Limestone (Big Lime); and play 7, the Lower Mississippian Fort Payne Formation. Reports for all of these plays are in the final review and editorial phase in preparation for printing.

Drill Cuttings and Core Samples

COMPUTERIZATION OF CORE REPOSITORY DATA

Patrick J. Gooding

Kentucky Geological Survey staff at the Well Sample and Core Repository have been working with personnel from the Computer and Laboratory Services Section over the past year to develop a more user-friendly, interactive core and sample data base that can be integrated with the Geologic Data Center. Various computer routines that will facilitate information retrieval in several formats have been established. Additional information on over 1,250 cores available for public examination is being added to the data base. The information includes location, farm name, operator, quadrangle, well number, and footage interval of core available. All computerized information will be readily accessible from both the Geologic Data Center and the Well Sample and Core Repository. As time and funding permit, additional information such as formation at total depth, formation tops, and sample descriptions will be added to the data base. A catalog of cores available for public inspection at the Well Sample and Core Repository will be published.

Water Resources

In order for Kentucky to maximize its economic potential, large quantities of usable water are necessary. Kentucky must plan for the wise use of its water resources, including both ground-water and surface-water supplies, for the expansion of industry and urban areas, and to further develop its mineral and agricultural resources.

Over the past 20 years, no fewer than 10 Federal acts have been enacted to protect water. State regulatory agencies developed programs dealing with mining and mine reclamation, solid and liquid waste disposal, sewage disposal, water supply, oil and gas recovery, and agricultural practices. During this past year, the State has concentrated on developing ground-water regulations to protect this vital resource. An understanding of the geology and hydrogeology of Kentucky is essential for development of these regulations and the optimum development, utilization, and management of the State's water resources. The Water Resources Section provides information to municipalities, industry, State and Federal agencies, and private citizens concerning the occurrence, movement, quantity, and quality of surface and ground water in the State.

Data necessary to maximize our water resources come not only from previously published studies, but new projects designed to meet the present and future demands of State and Federal programs and the needs of Kentucky citizens. The Water Resources Section has directed much of its efforts over the past year to designing such projects and implementing them by drilling monitoring wells, sampling springs, and monitoring surface waters. In response to the 1990 State Legislature's mandate that KGS establish a repository for all ground-water data collected by State agencies (KRS 151:035), and the appropriation of initial funds by the 1992 Legislature, KGS has developed the computer framework for the repository and has begun transferring data from other State agencies.

Urban and rural economic development is tied to the availability of water. The effect of land use on water quality and quantity is also an important factor in economic development because of regulatory policies. Therefore, basin-hydrology research is essential for future economic development in the Commonwealth. This type of research requires comprehensive data bases for both ground water and surface water. Data for surface water are collected in a cooperative program with the Kentucky Division of Water and the U.S. Geological Survey; data for ground water are collected from KGS research programs and from other State agencies, industry, and private citizens. In the past year, KGS has begun the establishment of the Kentucky Ground-Water Monitoring Network in cooperation with other State and Federal agencies; the network will facilitate the collection, computerized storage, and analysis of ground-water data. This activity should consolidate and accelerate efforts to define and characterize aquifer systems in Kentucky.

In order to achieve its mission during the past year, the Water Resources Section has conducted research in cooperation with the Kentucky Cabinet for Natural Resources and Environmental Protection; various groups within the University of Kentucky including the College of Agriculture, Water Resources Research Institute, College of Engineering, Center for Applied Energy Research, and Department of Geological Sciences; and several Federal agencies including the Natural Resources Conservation Service (formerly the Soil Conservation Service) and the Consolidated Farm Administration Service (formerly the Agricultural Stabilization and Conservation Service).

Water Resources research programs at KGS can be divided into four areas: hydrogeology of agricultural lands, hydrogeology of coal fields, hydrogeology of karst terrains, and basin hydrogeology. The following summaries describe the results of research projects conducted during the 1994–95 fiscal year. Water quality is one of the primary issues in most of the projects.

Hydrogeology of Agricultural Lands

IMPACT OF NONPOINT-SOURCE POLLUTION ON AQUIFERS AND SURFACE WATER IN HICKMAN COUNTY, JACKSON PURCHASE REGION

Philip G. Conrad, James S. Dinger, Lyle V.A. Sendlein, and Carl Petersen

Ground-water quality of a 2.5-mile-long drainage basin in Hickman County was studied. This site has extensive cultivation, row crops, and use of fertilizers and pesticides. Its geology (loess, continental deposits, and semi-consolidated sandstone) is

representative of most of the Jackson Purchase Region, and residents depend on ground-water supplies.

Seventeen monitoring wells at the site are used to sample ground water and measure levels of both perched ground water and water of the Eocene aquifer. Samples from domestic wells were taken monthly until March 1995 and analyzed for nitrate and other nitrogen compounds, common pesticides, redox potential, and total organic carbon. Water-level data and measurements of hydraulic conductivity are being used to model ground-water recharge and flow in this setting. One of the major causes of high nitrate concentrations in some of the wells of the region may be poor well construction, and research into this possibility will be pursued as funding is available.

Concentrations of triazine pesticides during 3 years of sampling were below the maximum contaminant level (MCL) of 3.0 µg/L for atrazine set by the U.S. Environmental Protection Agency. Nitrate-nitrogen concentrations are regularly over the MCL of 10 mg/L in some of the private wells tested; this has been a recent focus of research at the site.

A report on interim findings has been placed on open file, and further results are being summarized for a KGS publication. No further sampling in 1995 is anticipated. This project is funded through the Kentucky Senate Bill SB-271 Water-Quality Program and is a cooperative effort between the Kentucky Geological Survey, the UK Department of Agronomy, the Kentucky Water Resources Research Institute, and the UK Department of Agricultural Engineering.

IMPACT OF NONPOINT-SOURCE POLLUTION ON AQUIFERS AND SURFACE WATER IN HOPKINS COUNTY, WESTERN KENTUCKY COAL FIELD

Philip G. Conrad, James S. Dinger, Jeffery D. Snell, and Lyle V.A. Sendlein

Variations in ground-water quality are being studied in a tilled farm field in Hopkins County that has been planted in corn for most of the last 40 years. This farm, along with the Daviess County study site (see below), represents the flat bottom lands of the Western Kentucky Coal Field. Unconsolidated silt and clay-rich silt lie above sandstone, shale, and coal bedrock at a depth of 26 feet.

Monthly sampling of spring in Hickman County.

Tile drains in the field discharge into a 10-foot-deep drainage ditch. Nine monitoring-well screens range in depth from 5 to 28 feet. One set of samples was collected during the past year, and was analyzed for nitrogen compounds that had not been tested for during the bulk of sampling in previous years.

Nitrate-nitrogen concentrations were above the 10 mg/L MCL in the shallowest ground water, but ground water from bedrock was consistently far below the MCL. Atrazine and simazine herbicides applied were rarely detected below 8 feet in depth, and then only in trace concentrations. Concentrations in ground water less than 8 feet deep were lower in 1993 than in 1992 because of dryer conditions in the weeks during and after herbicide application. Dry conditions led to greater degradation of the herbicides before there was much recharge of ground water from rainfall. Additional sampling is not anticipated at this time.

Results have been shared with other researchers, and a report of interim findings has been placed on open file. Also, a Master of Science thesis was written by Mr. Snell. A KGS publication will be issued later. This project is funded through the Kentucky Senate Bill SB-271 Water-Quality Program and is a cooperative effort between the Kentucky Geological Survey, the UK Department of Agronomy, the Kentucky Water Resources Research Institute , and the UK Department of Agricultural Engineering.

IMPACT OF NONPOINT-SOURCE POLLUTION ON AQUIFERS AND SURFACE WATER IN DAVIESS COUNTY, WESTERN KENTUCKY COAL FIELD

Philip G. Conrad, James S. Dinger, Jeffery D. Snell, and Lyle V.A. Sendlein

Variations in ground-water quality are being studied at a farm field and a nearby wooded lot in Daviess County. This farm site is one of two under study in flat bottom lands of the Western Kentucky Coal Field (see above). The site consists of unconsolidated clay- and silt-rich lacustrine deposits above shale, sandstone, and coal bedrock that lie 23 to 40 feet below the ground surface. The farm is tile drained, and the closest drainage ditches are about 6 feet deep. The farm field and wooded lot occasionally flood during wet years.

Nine monitoring wells in the farm field range from 2 to 70 feet in depth. Eight monitoring points in the woods are installed to similar depths for comparison with results at the farm field. One set of samples was collected during the past year, and was analyzed for nitrogen compounds that had not been tested for during the bulk of sampling in previous years.

Nitrate-nitrogen concentrations remained below 1.5 mg/L in ground water at the crop and wooded sites. Metolachlor and 2,4-D herbicides applied at the site in 1992 moved downward most readily through upper sediments via deep mud cracks and deeper root macropores from old tree roots. Vertical movement of the herbicides was greatly diminished below the deep root zone. Additional sampling is not anticipated at this time.

Results have been shared with other researchers, and a report of interim findings has been placed on open file. Also, a Master of Science thesis has been written by Mr. Snell. A KGS publication will be issued later. This project is funded through the Kentucky Senate Bill SB-271 Water-Quality Program and is a cooperative effort between the Kentucky Geological Survey, the UK Department of Agronomy, the Kentucky Water Resources Research Institute, and the UK Department of Agricultural Engineering.

ASSESSMENT OF NITRATE AND PESTICIDE IMPACTS ON UPLAND BEDROCK AQUIFERS IN THE WESTERN KENTUCKY COAL FIELD

Dwayne M. Keagy, Shelley A. Minns, and James S. Dinger

The primary objective of this new study is to evaluate the movement and fate of pesticides and nitrate in a farmed, upland bedrock setting that utilizes farming practices typical of the Western Kentucky Coal Field. Gently rolling, upland areas in the Western Kentucky Coal Field are the last major agricultural setting in Kentucky for which impacts of agricultural chemicals have not been assessed. The study site, yet to be selected, will be located in Henderson, Union, or Webster Counties, all of which are major producers of corn, soybeans, wheat, and tobacco. This three-county region has been targeted for study because of widespread agricultural activity combined with intensive use of bedrock-derived ground water for domestic supplies.

A preliminary hydrogeologic evaluation compiled from existing data will commence as soon as a suitable site is selected; it will be used to design a site-specific monitoring program. A nested monitoring-well network will be installed to provide information on nitrate and pesticide occurrence in shallow bedrock, and to delineate the ground-water flow system. Results of this study will be used to provide a working conceptual model for ground-water flow in the Western Kentucky Coal Field and relate it to the potential mechanisms and fate of agricultural chemicals in similar agricultural settings.

This project is funded through the Kentucky Senate Bill SB-271 Water-Quality Program and is a cooperative effort between the Kentucky Geological Survey, the UK Department of Agronomy, and the UK Department of Agricultural Engineering.

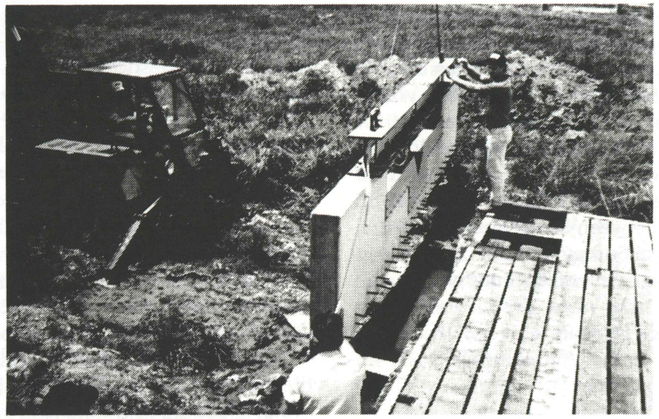
Hydrogeology of Karst Terrains

IMPACT OF NONPOINT-SOURCE POLLUTION ON AQUIFERS AND SURFACE WATER, WOODFORD COUNTY, INNER BLUE GRASS

Dwayne M. Keagy, Alex W. Fogle, James S. Dinger, and Lyle V.A. Sendlein

The site of this project is at the University of Kentucky's Woodford County Research Farm. Since the farm is owned by UK, farm practices can be coordinated to facilitate research goals and at the same time develop effective agricultural practices.

Conduits exist at various elevations throughout the near-surface strata in association with the regional water table and insoluble units that form aquitards. These aquitards locally impede the downward migration of ground water to the regional water table and also control the elevations of localized perched water and certain springs. Part of the catchment area of the larger springs is



Installing a flume to measure streamflow at Woodford County Farm.

off the farm, as indicated by dye tracing and differences in water quality. Dye tracing and map interpretation indicate that fractures and structural dip also influence ground-water flow.

During the past year dye tracing on the farm continued. Weirs were installed and instrumented to measure surface flow on the farm. Two additional monitoring wells were installed. One was installed at a pre-existing well nest to monitor ground water from the regional water table, and the other was placed in a perched-water condition in the soil.

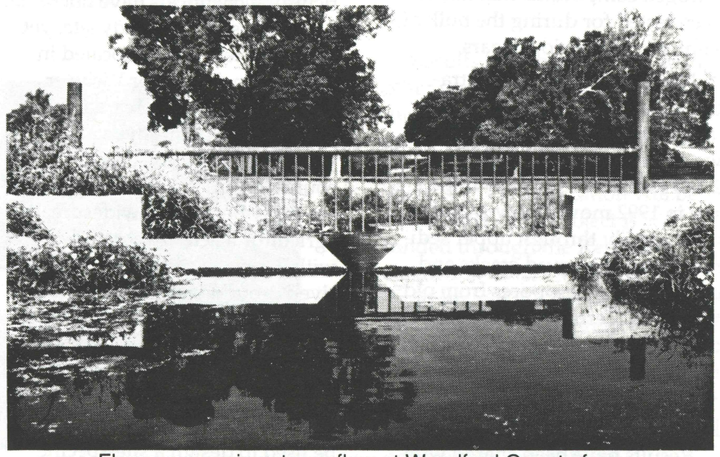
Maps of the farm and surrounding area (3,500 acres) at a 2-foot contour interval were prepared from aerial photography and plotted at a scale of 1 inch equals 200 feet on 17 map sheets. Digitized aerial photographs were also plotted at a scale of 1 inch equals 200 feet on 17 sheets to delineate cultural and hydrologic features of the site. All map sheets and photographs were digitized and were used as the base for a GIS analysis. An analysis of drainage patterns revealed that 30 percent of the drainage within the farm boundary is subsurface via sinkholes, whereas previously published U.S. Geological Survey 10-foot contour maps indicated that only about 1.6 percent of the drainage is subsurface. This finding is significant in terms of the fate and transport of agricultural chemicals and animal wastes.

A detailed map of the farm soils was also completed in the past year. Twenty-six soil units have been identified on the farm. The soils map has also been digitized and registered with the GIS data base for future analyses of nutrient and pesticide movement.

Monitoring of agriculture-related contaminants (pesticides, nutrients, and bacteria) at well nests, weirs, and springs continued throughout the 1994–95 year. The occurrence of nitrate, including numerous nitrogen-related species, was also investigated. Analysis and interpretation of water-quality and -quantity data continue.

Detectable concentrations of pesticides were found at all sites draining areas associated with their application. Triazines, metolachlor, and carbofuran were the most commonly detected pesticides. In general, the highest pesticide concentrations were found in the shallowest monitoring points, although conduit quick-flow transmission of pesticide-laden surface water resulted in short-lived, high pesticide concentrations deeper within the bedrock. Where high concentrations of triazines were detected soon after application in the spring, levels generally remained above the detection limit for the following year.

Nitrate was detected in nearly all samples, and only minor temporal changes in concentrations were observed. Wells and springs associated with fields where nitrogen fertilizer had been applied



Flume measuring streamflow at Woodford County farm.

produced the highest nitrate concentrations. In general, nitrate concentrations at well nests decreased with depth, although at well nests where nitrogen fertilizer had been applied, concentrations were highest at the soil-bedrock interface.

Bacterial counts in springs and streams often exceeded drinking-water standards; peak counts occurred in June and July. The predominant source of bacterial contamination of water at the farm was determined to be domestic animal waste.

In the spring of 1995, ground-water monitoring at the farm was suspended for an indefinite period due to curtailment of funds. A KGS open-file report that discusses interim findings of this study will be released. This project is funded through the Kentucky Senate Bill SB-271 Water-Quality Program and the U.S. Department of Agriculture. It is a cooperative effort between the Kentucky Geological Survey, the UK Department of Agronomy, the Kentucky Water Resources Research Institute, and the UK Department of Agricultural Engineering.

CHARACTERIZATION AND QUANTIFICATION OF NON-POINT-SOURCE POLLUTANT LOADS IN A CONDUIT-FLOW-DOMINATED KARST AQUIFER UNDERLYING AN INTENSIVE-USE AGRICULTURAL REGION, LOGAN COUNTY

James C. Currens

The goal of this research is to measure the degree to which a program to install best management practices (BMP's) on farms overlying a karst aquifer will improve ground-water quality. The Pleasant Grove Spring Basin, in southern Logan County, Ky., was selected for study because it is largely free of non-agricultural pollution sources. The area of the drainage basin was determined by ground-water dye tracing and is approximately 10,291 acres. Approximately 92 percent of the watershed is in agricultural production. Ground-water flow in the basin is divided into a diffuse (slow-flow) regime and a conduit (fast-flow) regime. The diffuse and conduit flow regimes have a major influence on the timing of contaminant peaks and valleys in storm-event chemographs.

Nitrate is the most widespread, persistent contaminant in the basin, but concentrations do not exceed MCL's for drinking water. Atrazine has been consistently detected in low concentrations, and other pesticides occasionally occur. Triazines (atrazine) exceeded drinking-water MCL's during spring flooding. Flow-weighted average concentrations for 1992–93 were 4.91 µg/L for atrazine-equivalent triazines and 5.0 mg/L for nitrate-nitrogen. Averages for 1993–94 were 0.97 µg/L and 5.7 mg/L, respectively. Bacteria counts occasionally exceeded standards for drinking-water supplies. Bacteriological speciation failed to identify the source of high bacteria counts at Pleasant Grove Spring, but showed the high counts are not of indigenous origin. Federal funding was granted in April 1995 to the U.S. Department of Agriculture's Natural Resources Conservation Service to implement a variety of changes to agricultural practices in the basin, and the expected resulting improvement in water quality will be monitored. If improvement in the ground-water quality cannot be demonstrated on a basinwide scale, in a real-world setting, then the effectiveness of the implemented practices and the program's success in obtaining the producers' cooperation may need to be re-evaluated.

This study recently completed its third year of Federal- and State-funded activity. Field activity during the year was largely limited to maintaining equipment and continuing the monitoring. From July l, 1994, through April 1, 1995, 47 base-flow, 24 storm-event, and 9 quality-control samples were collected. Base-flow and storm-event samples are analyzed primarily for pesticides by ELISA (enzyme-linked immunosorbent assay, or immunoassay) and for nitrate. One quantitative ground-water dye trace was conducted, and several discharge measurements were made. Considerable effort was expended on data management and report writing. Crop maps for 1992, 1993, and 1994 were completed. Mass fluxes for 1992–93 and 1993–94 for nitrate-nitrogen, atrazine-equivalent, metolachlor-equivalent, and carbofuran were estimated.

An open-file report describing the first phase of the research was released in 1994. A comprehensive KGS report on the first 3 years of work has been written and is now being reviewed for publication. This project is funded by a grant from the program to administer section 319(h) of the Federal Clean Water Act, sponsored by the Kentucky Division of Water, Nonpoint Source Section.

AGRI-CHEMICALS AT THE OUTLET OF A SHALLOW CARBONATE AQUIFER IN JESSAMINE AND WOODFORD COUNTIES, KENTUCKY

Gary K. Felton

A 4,700-acre ground-water catchment area is located in Woodford and Jessamine Coun-

ties in the Inner Blue Grass Region of Kentucky, and discharges at Garretts Spring in Woodford County. Approximately 40 water wells, over 400 sinkholes, two karst windows, and one sinking stream exist within its confines. Approximately 53 percent of the land is used for beef and horse farms, and a golf course; 16 percent for row crops; 12 percent for orchards; 13 percent is forest; and 6 percent is residential.

Water samples from Garretts Spring were collected and analyzed twice a week for calcium, magnesium, chlorine, sodium, phosphate, sulfate, nitrate, total solids, suspended solids, conductivity, fecal coliform bacteria, fecal streptococci bacteria, atrazine, and alachlor.

Values for phosphate ranged from 0.3 to 0.5 parts per million (ppm), with a mean of 0.6 ppm. Because soil tests have shown there is seldom a need to add phosphate to the soil in the study area, and in the Blue Grass Region of Kentucky in general, natural soils are likely responsible for the elevated phosphate mean rather than agriculture activity.

Nitrate varies temporally, and had a maximum concentration of 5.06 ppm, which is half of the EPA MCL of 10 ppm. Low concentrations occur in August and September after prolonged dry periods with associated low flow levels, and may simply reflect the reduced transport of nitrogen through the soil profile. As rainfall replenishes soil moisture and becomes excessive, which is typical in fall and winter, the nitrate concentration rapidly increases to approximately 3.0 ppm during late winter.

Ground water contained no pesticides in March, but pesticides showed up later in the spring of the year after they were applied, though not in hazardous concentrations. This suggests that the annual winter floods completely purge this system of pesticides, and then pesticides reappear in the system after they are applied to fields the following spring.

Mean fecal coliform (FC) and fecal streptococci (FS) counts indicate that significant bacteriological activity is present at Garretts Spring, and chlorination would be required to use the spring as a drinking-water supply. Occasional FC/FS values greater than 1.0 indicate that human waste is in the water. The high counts of fecal bacteria occurred between June 1 and August 25. The FC/FS ratio was only greater than 1.0 during lower flow conditions.

These data suggest that several management practices could improve water quality in the basin. Peak concentration of nitrate in late February indicates that winter cover crops might be an appropriate conservation measure. Triazine use is limited in this watershed and is not a health concern. However, when triazines are used, they are detected in the spring and, therefore, the application of triazine should be coordinated with weather conditions to prevent runoff of triazines from the fields into the karst aquifer. Bacteria are predominantly from animal sources, which indicates that animal access to the streams, springs, and sinkholes should be controlled. Bacteria could be coming from both wild and domestic animals. Finally, occasional high FC/FS ratios indicate that man, most likely through poor septic systems, is having an impact on the water quality.

This research was sponsored by the U.S. Department of Agriculture and funds from the Kentucky Senate SB-271 program through the UK College of Agriculture.

Hydrogeology of Coal Fields

STAR FIRE PROJECT: HYDROGEOLOGY OF A LARGE MINE-SPOIL AREA

David R. Wunsch, James S. Dinger, Daniel I. Carey, and C. Douglas R. Graham

The economy of eastern Kentucky is highly dependent on the coal-mining industry. Economic growth and diversity in the coal field are severely limited, in part by the steep topography and the lack of abundant water resources. However, the coal-mining process often transforms the rugged pre-mining terrain to usable, flat land that is less prone to flooding. Cyprus Mountain Coals, a subsidiary of Amax-Cyprus, Inc., owns the 17,000 acres of land at its Star Fire surface mine, located in Knott, Perry, and Breathitt Counties. An estimated 10,000 acres of usable flat land will be created by the year 2010 at the Star Fire site through mountaintop-removal techniques, thus providing a site for new land uses and future economic development. KGS has conducted an applied research program to determine the water resources at the site, which will be vital for the site's successful development. The company has an interest in the post-mine development of the property, and data provided by KGS will aid in the planning for alternative land uses after mining has been completed.

Water-table elevation data from monitoring wells, springs, and ponds indicate that two saturated zones exist within the spoil: one in the interior section of the spoil, and two additional zones at lower elevations in the two adjoining hollow fills. Most likely, these saturated zones are in hydrologic connection in the southeastern section of the spoil body, but are separated by the pre-mining topography in the northwestern area of the spoil.

Surface-water flow has been measured using weirs and handheld flow meters. A V-notch weir equipped with digital data-recording capabilities was installed to monitor continuous surface-water outflow from the mine site. Mass-balance calculations show that the majority of mine discharge is derived from ground water released from the spoil. Data interpreted from the 14 monitoring wells at the site indicate a zone of saturation at the base of the spoil that averages 22.8 feet in thickness and stores an estimated 1.49 billion gallons. Slug tests were performed in individual wells to determine the hydraulic characteristics of the saturated portion of the spoil. Hydraulic conductivity (K) values ranging from 2.0×10^{-5} to more than 9.0×10^{-4} centimeters per second (cm/s) were calculated for the spoil surrounding the wells.

Measurements around the surface seals of the monitoring wells reveal that settlement is occurring throughout the spoil area. Some areas are subsiding at a maximum rate of 0.2 foot per year. A complicated array of surveying monuments is being installed to accurately monitor vertical and horizontal spoil settlement.

Water samples are collected for chemical analysis on a semiannual basis from the monitoring wells and major springs that crop out at the spoil's periphery. Wells located in the hollow-fill areas were found to be more responsive to precipitation events and contain fewer dissolved constituents compared to wells located in the main spoil body. The analysis of water samples from all areas of the site reveal that the major dissolved constituents are calcium, magnesium, and sulfate.

Geochemical modeling revealed that the ground water in the interior of the spoil is near equilibrium or saturated with respect to gypsum. Ground water in the hollow-fill areas is undersaturated with respect to gypsum, probably because of dilution. Plans for the future include the installation of a new gaging station at the outflow of a newly constructed sediment pond and the installation of a continuous water-quality monitoring system at the mine outflow to monitor seasonal water-quality variations throughout the year.

The interpretation of hydrological, hydrogeological, and geochemical data has led to the construction of a conceptual model of ground-water flow at the site. A detailed report, "Hydrogeology, Hydrogeochemistry, and Spoil Settlement at a Large Mine-Spoil Area: Star Fire Tract, Eastern Kentucky," is presently being prepared for publication. In addition, a presentation describing KGS research at the site was given at an international meeting on water issues.

This project is funded by Cyprus Southern Realty through Amax-Cyprus, Inc.

HYDROLOGIC INVESTIGATIONS IN ROBINSON FOREST

David R. Wunsch and James S. Dinger

The University of Kentucky's Robinson Forest contains some of the largest undisturbed tracts of land in eastern Kentucky. This setting provides a unique opportunity to conduct ground-water monitoring that can provide background conditions for water-quality investigations as well as valuable information regarding the interaction between recharge and discharge in forested basins.

Ten monitoring wells have been installed in two land parcels of the forest. Six wells were placed in the Laurel Fork tract, which is presently being mined. Water-level data and samples for chemical analysis were collected immediately after installation. These wells have since been destroyed by mining. Four additional wells are located in the Clemmons Fork area of the main block of the forest. Two of these wells have been placed near the forest boundary, where active coal mining is occurring, in order to monitor the changes, if any, in the hydrologic regime as mining progresses.

Water-level data and water-quality samples have been collected on a biannual basis. Digital data loggers have been installed to record water-level response to precipitation and the discharge of streams that drain the basins containing the wells. These data will also be used to validate the interpretations and conceptual models derived from data collected at other sites.

In addition, water samples from seeps emanating from coal seams that crop out in the forest are being studied to determine the origin and mineralogical composition of chemical precipitates that have been associated with the seeps. Chemical data from these seeps show that the water is highly mineralized due to mining. Mineral saturation indices calculated by geochemical models are consistent with the minerals found forming at the seep discharge points. A KGS open-file report, "Interim Report on Ground-Water Monitoring in Robinson Forest," is available to the public; the report contains hy-

drologic and geochemical data collected at the forest. This information will provide insight into the complexities of ground water and its relationship to secondary mineralization in the Eastern Kentucky Coal Field.

The project is funded through the office of the Vice-President for Research and Graduate Studies, University of Kentucky.

EFFECTS OF DEEP COAL MINES ON HYDROGEOLOGY

James A. Kipp, Shelley A. Minns, James S. Dinger, Daniel I. Carey, and Lyle V.A. Sendlein

Subsidence-related deformation and associated hydrologic changes are being evaluated at an active longwall coal mine in eastern Kentucky on Edd Fork near Helton in Leslie County. In longwall mining, a working face several hundred feet wide is advanced between parallel headings, producing a series of large, rectangular, mined-out panels. The face is temporarily supported during extraction of the coal by movable hydraulic jacks. As these supports advance with the face, the unsupported roof fractures into blocks that collapse into the mined-out area. The remaining overburden then subsides onto this rubble.

For this project, three cores were drilled at ridge-top, valley-side, and valley-bottom positions to provide stratigraphic information for the study site. Pressure-injection testing was also conducted in each core hole in 10-foot intervals using inflatable packers to isolate test sections. The resulting data provided documentation of the pre-mining hydraulic characteristics of the rocks over the area to be mined.

Information from the core holes was used to design 24 ground-water monitoring wells that were installed during the summer of 1992. Initial water-level data from these wells and the results of water-quality sampling indicate the presence of complex ground-water flow and hydrogeochemical systems that represent pre-mining conditions. A flume and rain gage measure the discharge of Edd Fork and collect precipitation data in the study basin so that changes in hydrology can be fully evaluated.

Data on piezometric water levels and surface fracture development were collected daily for approximately 1 month during the undermining event that occurred in the summer of 1994. Water-level changes were observed in three piezometers as mining approached the instrumented sites from two panels away (approximately 1,450 feet); over half of the 24 piezometers exhibited water-level changes during mining in the adjacent panel. Two-thirds of the piezometers were affected during the actual undermining of the instrumented panel, and 13 piezometers structurally failed. Coaxial cables grouted into each core hole were monitored using time domain reflectometry to evaluate rock deformation in response to mining subsidence.

This study is a cooperative effort with the U.S. Office of Surface Mining, the Kentucky Department of Surface Mining Reclamation and Enforcement, the UK Department of Geological Sciences, the UK Water Resources Research Institute, and the coal industry. A KGS publication on the pre-mining hydrogeology is in final preparation, and data from that report are available to the public as a KGS open-file report. A project report to the funding agency on physical and hydrologic changes during the mining period is scheduled for completion in September 1995. Post-mining data collection will continue during fiscal year 1995-96.

This project is being funded through the Kentucky Department of Surface Mining Reclamation and Enforcement, with matching funds provided by the U.S. Office of Surface Mining.

EFFECT OF COAL ASH DISPOSAL ON THE HYDROLOGIC ENVIRONMENT

Shelley A. Minns, Lyle V.A. Sendlein, James S. Dinger, and James C. Currens

For the past 5 years the UK Institute for Mining and Minerals Research, the Kentucky Water Resources Research Institute, the UK Department of Geological Sciences, and the Kentucky Geological Survey have been conducting research on the effects of coal-ash disposal in different hydrologic environments. The environments are a karst system, a river alluvium setting, and an ash fill in a bedrock valley. All disposal sites are operated by the East Kentucky Power Cooperative. Projects in the karst and alluvial settings are complete, and KGS publications describing each site are in preparation.

Research at the upland bedrock site is scheduled for completion during fiscal year 1995–96. The site is in northern Kentucky in bedrock composed of the Kope, Fairview, and Grant Lake Formations. All these units have relatively low hydraulic conductivity, except in the upper few tens of feet, where fracturing caused by natural rock weathering has occurred prior to ash being placed in the landfill. Coal ash is deposited in a dry state, but the lower portion of the ash fill is saturated, as indicated by a series of monitoring wells installed to different depths in the landfill and underlying bedrock. Placing the 75-foot-thick landfill into the valley has apparently allowed the water table to rise into the ash through shallow fractures. Ground water in the ash is a calcium sulfate facies. Background ground water is either a calcium bicarbonate facies or a sodium chloride facies. MCL's for antimony and arsenic are exceeded on occasion in wells monitoring the ash fill; however, no MCL's are exceeded in the bedrock wells. A Master's thesis on this phase of the project was completed under the direction of Dr. Sendlein.

Field studies are under way to measure the infiltration rates of precipitation into the fill and also to determine the moisture content in the fill using a neutron probe. A tipping-bucket rain gage equipped with a digital recorder collects rainfall data. Additional ground-water quality data are being collected to define the extent of leachate in shallow bedrock. A final project report is scheduled for completion in September 1995.

This work was funded by East Kentucky Power Cooperative, the Kentucky Water Resources Research Institute, and the Electric Power Research Institute.

HIGH-VOLUME/HIGH-VALUE USE OF FLUE-GAS DESULFURIZATION BY-PRODUCTS IN UNDERGROUND MINES

Shelley A. Minns, Lyle V.A. Sendlein, and James S. Dinger

The objective of this project is to determine the technical, environmental, and economic feasibility of placing flue-gas desulfurization (FGD) by-products into mine entries created by a highwall miner system. The highwall miner is a remotely operated, continuous mining system designed to recover coal up to 1,200 feet underground from horizontal entries along a highwall face. Solidified backfill derived from FGD material will be used as structural support for mined entries so that intervening pillars may be mined.

The cementitious and chemical properties of the FGD material are being characterized in the laboratory. Site investigations and environmental monitoring are the responsibility of the Kentucky Geological Survey and the Kentucky Water Resources Research Institute.

The study site is located in Greenup County, Ky., on property owned by Addington Resources, Inc. Mine-adit locations have been surveyed, and a plat of the site has been completed. Three core holes were drilled near entryways to provide stratigraphic information. Pressure-injection tests were conducted in each hole on 5-foot intervals to document hydrologic properties of the strata. The coal bed targeted for backfilling is two to three orders of magnitude more conductive than non-fractured sandstone and shale. A monitoring-well network will be installed during the summer of 1995 in order to collect approximately 1 year's worth of baseline hydrologic data prior to backfilling.

This project is funded by the U.S. Department of Energy and Addington Resources, Inc., and managed by the UK Center for Applied Energy Research in cooperation with the Kentucky Geological Survey, Kentucky Water Resources Research Institute, UK Department of Civil Engineering, Kentucky Transportation Center, and UK Department of Mining Engineering.

GROUND-WATER GEOCHEMISTRY AND ITS RELATIONSHIP TO GROUND-WATER FLOW IN THE EASTERN KENTUCKY COAL FIELD

David R. Wunsch, James A. Kipp, Philip G. Conrad, Dwayne M. Keagy, Shelly A. Minns, and James S. Dinger

The Water Resources Section is conducting research to define natural background flow and chemical characteristics of ground water in the Eastern Kentucky Coal Field. Such information is imperative for the fair and effective implementation of Kentucky's ground-water protection regulations. Industries that operate in eastern Kentucky, including mining, oil and gas, and landfill operations, are in need of this information for both permitting and compliance.

KGS ground-water studies suggest that distinct geochemical facies are related to specific zones of ground-water flow. Several representative sites have been monitored to conduct hydrogeologic and hydrogeochemical studies, which will be used to interpret and define the interaction between ground-water occurrence and natural water quality. The objectives of this study are to (1) correlate the hydraulic characteristics of coal-bearing rocks with site geology, (2) characterize the occurrence, movement, and quality of ground water, (3) document the occurrence of trace elements and their relationship to specific ground-water types, and (4) gain a better understanding of the hydrogeologic characteristics of the area for effective ground-water monitoring.

Water-level and constant-head pressure-injection measurements and water samples have been taken at sites in Perry, Breathitt, Knott, and Leslie Counties. These tests document the importance of coal seams and shallow fractures to the movement of ground water

in the region. Reports generated from these data describe the hydraulic characteristics of Pennsylvanian rocks and provide insights into the complex movement, occurrence, and chemistry of ground water in eastern Kentucky. Data generated from these studies will be valuable to regulatory agencies and the industries they regulate for permit requirements, as well as definition and protection of aquifers, and will add to the knowledge of ground water in the Eastern Kentucky Coal Field.

Basin Hydrology

GROUND WATER IN THE KENTUCKY RIVER BASIN

Daniel I. Carey, James C. Currens, James S. Dinger, James A. Kipp, David R. Wunsch, and Philip G. Conrad

Members of the Water Resources Section at the Kentucky Geological Survey have completed a number of studies on ground water in the Kentucky River Basin within recent years. These studies have covered such diverse topics as the effects of oil production on water quality, the occurrence of high barium concentrations in ground water of eastern Kentucky, ground-water geochemistry in eastern Kentucky, a reconnaissance of ground-water supply resources, production of fresh water from the Knox Group, and the quality of domestic well water.

A summary of KGS research, and data from local, State, and Federal sources, was developed into KGS Information Circular 52, "Ground Water in the Kentucky River Basin." The report provides a comprehensive look at what we know about ground water in the basin, as well as up-to-date information on ground-water use and the potential for developing additional ground-water supplies. It also gives an overview of ground-water quality, which includes an examination of human activities that may threaten ground-water resources, and a discussion of contaminants that occur naturally in the basin. The report is a compilation of many types of data and contains an extensive bibliography of ground-water references. Its Plate 1 is a generalized hydrogeologic map of the Kentucky River Basin, printed in color at a scale of 1:500,000; Plate 2 shows the locations of large-yield wells and springs in the basin.

WATER RESOURCES PLANNING AND MANAGEMENT IN THE KENTUCKY RIVER BASIN

Daniel I. Carey

Broad-based support for water-resources planning requires the dissemination of information on issues, alternatives, and the consequences of policy decisions. In general, this information must be gathered from a variety of sources and clearly summarized. As part of its research activities, the Kentucky Geological Survey has begun assembling a spatial data base for water-resources planning and management.

Spatial data at a Statewide and basin level on soils, ground water, water quality, demographics, oil and gas activities, topography, and political subdivisions were entered into the Arc/Info geographic information system at the Survey. These data and the GIS were used to support water-, coal-, and petroleum-resource studies. The development of the spatial data base using existing sources will continue.

KENTUCKY RIVER BASIN WATER-SUPPLY ASSESSMENT

Daniel I. Carey, James S. Dinger, and Lance G. Morris

The University of Kentucky Water Resources Research Institute assembled a team of researchers from the University to examine water-supply issues in the Kentucky River Basin. The work is being performed under contract to the Kentucky River Authority. The study will be performed through five basic tasks:

1. Assessment of previous water-supply reports
2. Analysis of water supplies in the upper forks
3. Evaluation of water supply
4. Development of a drought response plan
5. Development of a long-range water-supply plan.

Previous studies will be evaluated with regard to conservation, management, and growth assumptions, and to reflect the impact of proposed construction projects.

Ground-water and surface-water supplies in the headwater region of the basin will be evaluated for efficiency, reliability, and quality. Recommendations for system improvements will be made and ranked.

The water-supply evaluation will provide alternative water-supply needs based on a range of possible scenarios, including alternative growth projections, conservation, and system additions. With the help of the advisory committee and public meetings, water-supply planning goals will be identified, which will represent, if not a consensus, a majority of interests.

The drought response plan will include a decision support system for drought management.

The system will incorporate both expert systems and GIS technology.

The long-range water-supply plan will be developed based on the earlier tasks. The plan will recommend strategies for meeting water-supply goals over time. A computer simulation model will be developed for the Kentucky River Authority. The model, which will be capable of reflecting changing water supply and demand conditions in the basin, will become an important tool for the Authority to use to analyze water-supply conditions in the future.

The duration of the study is 18 months, and it will be completed by October 31, 1996. Through the use of an advisory committee and public meetings, we hope a consensus can be built for water-supply planning and management in the basin.

HYDROLOGY OF MINED WATERSHEDS

Daniel I. Carey

Surface-water monitoring stations have been installed in four watersheds in different areas of eastern Kentucky as part of our basin hydrogeology studies. The station on Edd Fork in Leslie County, a watershed of less than 200 acres, provides data to support hydrogeologic studies on the impact of underground mining. The station on Long Fork in Knott County provides data to support evaluations of water resources and post-mining development. Two monitoring stations have been installed on adjacent small watersheds in the University of Kentucky's Robinson Forest in cooperation with the UK Department of Forestry. These stations collect flow and water-quality data to support an evaluation of the impacts of mining on surface water and ground water in the area.

COMPUTER AND LABORATORY SERVICES

The Computer and Laboratory Services Section operates state-of-the art laboratory equipment and acquires or develops computer software and hardware. These tools enable researchers to analyze geologic and hydrogeologic data and collect, store, and manipulate data for reports, maps, charts, and other products for use by industry, government, and the private sector.

Computer Services

The key to a successful computer system with current technology is a versatile network. With its building-wide computer network, KGS is able to interconnect various mini-, desktop, and personal computers. This versatility allows many types of operating systems to access data from a variety of sources. The network in the building has also been connected to the University of Kentucky Network (UKnet), which, in turn, is linked to most of the national networks.

In addition to personal computers (PC's), KGS has a number of workstations for specific tasks. These include an Alpha 3000 model 500, used for geographic information system applications; a VAXstation 4000 model 60, for desktop publishing; and a VAXstation 4000vlc, used with X-ray diffraction instrumentation. Three Sun workstations are also used for specific research projects requiring software only available on those platforms.

Peripheral equipment includes large-format inkjet and pen plotters, digitizers, high- and medium-speed printers, and long-document scanners. Software includes data-base and report-writing facilities (DEC Rdb, VAX Datatrieve, and Smartstar), wordprocessing and desktop publishing (MASS-11 and Interleaf Desktop Publishing System), geologic modeling (MINEX and Surface III), computer-aided drafting and presentation graphics (AutoCAD, FreeLance Plus, Harvard Graphics, Corel Draw), and geographic information systems, which include Arc/Info running on a Digital Alpha workstation, and GRASS, which operates on a Sun Sparc10.

Personal Computer Local Area Network

"Client-server" is the current buzzword in computing technology. Clients, which at KGS are PC's, provide local computing power to the user, while the server provides both applications and data from a central repository. Although more complicated to maintain and manage, this computing environment gives users greater flexibility and access to off-the-shelf software. In 1992, KGS began to fully integrate its growing number of personal computers into the Local Area Network (LAN). DEC's PathWorks LAN is being used because it utilizes Digital's OpenVMS server, where our large geologic and hydrogeologic data bases are stored.

Most KGS researchers now have PC's on their desks. During the past year KGS hired a full-time employee to manage and support the LAN. In addition, KGS upgraded to a Digital Alpha 2100 server. This machine is designed for an LAN environment rather than an interactive character-cell environment, which characterized the old technology. Also, because of the growing amount of data collected by researchers, KGS expanded its disk storage capacity to over 20 gigabytes.

Overall, the LAN has been a successful tool for KGS researchers. Many users are discovering different methods for analyzing data and preparing reports and presentations. With the integration of the KGS data base, KGS personnel are able to provide a higher level of services to the public by using relatively easy-to-use PC software. The LAN has also enabled researchers to take advantage of the Internet, allowing them access to additional resources such as Federal data bases and data from other State agencies, and allowing them to exchange ideas with colleagues from all over the world.

A Comprehensive Geologic/Hydrologic Data Base

In the early 1980's the Kentucky Geological Survey began using computer technology to develop, compile, and maintain a collection of geologic and hydrologic data relating to the Commonwealth of Kentucky. These data comprise the most detailed and comprehensive collection of non-proprietary petroleum, coal, water, and limestone data publicly available. These data sets are searched thousands of times per year, and results are provided in hard copy and magnetic media to the general public, consultants, industry, government, and researchers.

Currently, KGS maintains these data using multi-file relational-data-base technology. This state-of-the-art data storage and retrieval system allows KGS to efficiently manage, search, and manipulate these ever-expanding and diverse public-domain data sets. To facilitate use of these data, a variety of querying software products are available:

- For direct command line or programmatic searches, SQL and ISQL can be used.
- To create a character-based menu and query-by-form interface, Smartstar can be used.
- To link old applications to the current relational data base, Datatrieve can be used.
- To build ad hoc queries and reports or link other applications (i.e., spreadsheets, wordprocessors) to the data base, Microsoft Access, a Windows-based interface, can be used.

Recently installed hardware and data base software upgrades have dramatically increased the usefulness of our data base in a number of ways:

- Increased processor speed, faster disk drives, additional system memory, and a more efficient query optimizer have significantly decreased data search time.
- Scanned images, photographs, and video recordings can now be stored in the data base. When fully implemented, this ability will allow users to do such things as examine computerized core descriptions while viewing photographs of the core, and review information about an oil well while viewing the scanned images of electric logs of the well.

During the next year, additional data sets will be added to the data base, and existing user interfaces will be enhanced and updated. New data acquisition is accomplished through KGS research projects and ongoing donations from private industry and government agencies. Additional planned improvements are:

- Linking the data base to geographic information systems such as Arc/Info and GRASS, which will provide the capability to dynamically evaluate the Survey's spatial data.
- Provide direct public access to the data base via the Kentucky "Information Highway" and the World Wide Web.
- Evaluate "public access" data stations in the Geologic Data Center.
- Provide users with a query-by-form user interface to the data base, which will allow users to move through the various database components by selecting options from a series of menus.

Laboratory Services

The KGS laboratory facilities analyze the chemical and physical characteristics of water, rock, coal, oil and gas, and other natural resources. The laboratories make use of state-of-the-art automated equipment to provide researchers with the necessary data to complete their geologic and hydrogeologic reports. KGS will be replacing its current, in-house-developed Laboratory Information System (LIMS) with a LIMS based on PC-LAN in order to meet the information-processing requirements of the laboratory such as sample log-in, data storage, quality assurance, auditing, and reporting of results.

The laboratory facilities at KGS include the following analytical equipment/capabilities:

- for metals:
  - inductively coupled argon plasma (ICAP)
  - flame atomic absorption (FAA) and graphite furnace atomic absorption (GFAA)
- for organics and pesticides:
  - gas chromatographs with mass selective, flame ionization, electron capture, photoionization, electrolytic conductivity, and nitrogen-phosphorus detectors
  - immunoassay for pesticides
  - total organic carbon
- for mineralogy:
  - X-ray diffraction spectrometry (XRD)
- for coal quality:
  - proximate analysis (Leco MAC 400 Determinator)
  - ultimate analysis (Leco CHN 600)
  - total sulfur (Leco SC-444)
  - calorimeter (Leco AC 300)
  - ash fusibility (Leco AF 600)

The Year in Review

The Fuels Division of the Laboratory Services Section analyzed over 300 coal and mineral samples for coal quality and mineralogy. The laboratory participates in two round-robin testing programs for coal samples: the Interlab Network, operated by Standard Laboratories, Inc., and Service Program for the Evaluation of Codes and Standards, operated by the Canadian Centre for Mineral and Energy Technology.

During the year, over 900 water samples were received in the Water Division for the analysis of metals, organic pesticides, and other water-quality parameters such as acidity, hardness, inorganic anions, and dissolved and suspended solids. An average of 33 different parameters were analyzed for each sample. The Water Laboratory also participates in both the USGS Standard Reference Sample Program and the EPA Water Supply Laboratory Performance monitoring programs.

PUBLICATIONS

One of the major functions of the Kentucky Geological Survey is making the results of research projects and field investigations readily available to the public. Publication of this information serves to disseminate geologic data generated by Survey staff, members of cooperating agencies, and other earth scientists doing research pertaining to Kentucky's geology and mineral resources. The Survey also publishes the proceedings of technical sessions and symposia, and guidebooks for geologic field conferences.

Publications of the Kentucky Geological Survey are made available to the public at a nominal cost and receive widespread distribution. Maps and reports are available for purchase from the Publication Sales Office, which is located in the Mining and Mineral Resources Building at the corner of Rose Street and Clifton Avenue on the University of Kentucky campus.

In addition to published reports, KGS also maintains an extensive collection of open-file reports, maps, manuscripts, theses, and other material, including coal-thickness data, logs of core holes, sample descriptions, seismic network data, and gravity base station networks. Copies of most U.S. Geological Survey open-file reports dealing with Kentucky geology are also maintained. Some of the material will eventually be published, but has been placed on open file in order to make the data available for public use prior to publication. Open-file reports are available for inspection at Survey offices in the Mining and Mineral Resources Building on the University of Kentucky campus during regular office hours. Copies of materials that can be reproduced are available for purchase.

Computer-plotted overlay maps showing the locations of oil and gas wells are available by 7.5-minute quadrangle. These maps are plotted on semitransparent material so that they may be used in conjunction with topographic or geologic maps available at the same scale. Locations are shown for all wells in the Survey's computer data base at the time the overlay map is plotted. Computer-generated well lists are available to accompany the maps.

The following publications were issued by the Kentucky Geological Survey during the 1994–95 fiscal year.

Guidebook

Geology of the Devonian Strata of the Falls of the Ohio Area, Kentucky-Indiana: Stratigraphy, Sedimentology, Paleontology, Structure, and Diagenesis, by R. Todd Hendricks and others, 65 p.

This guidebook for the Annual Field Conference of the Geological Society of Kentucky, held September 10–11, 1993, consists of the field trip roadlog and also discussions of the geology of the area.

Information Circulars

IC 47. *Available Coal Resources of the Salyersville South 7.5-Minute Quadrangle, Magoffin County, Kentucky*, by Robert E. Andrews, Gerald A. Weisenfluh, John K. Hiett, and Richard E. Sergeant, 44 p.

Nine coal beds in the Salyersville South Quadrangle are potentially mineable. This study, which employed GIS methods to calculate tonnages of coal, found that 80.6 million short tons of the remaining coal in the quadrangle are available for mining. Approximately 23.4 million tons of the estimated 183.4 million tons of original coal resources have been mined or lost to mining, and 79.4 million tons are unavailable, mainly because the beds are too thin for underground mining.

IC 48. *Trace Elements in Coal: The Next Challenge*, by Cortland F. Eble and James C. Cobb, 4 p.

Elements such as lead and mercury that occur in coal in very small amounts are commonly referred to as trace elements. Although coal contains only tiny amounts of these elements, the large volumes of coal burned each year have the potential to release large amounts of these elements into the environment. The 11 trace elements commonly occurring in coal, which have been listed as hazardous air pollutants, are antimony, arsenic, beryllium, cadmium, cobalt, chromium, mercury, manganese, nickel, lead, and selenium. The concentration of trace elements in Kentucky coal is a growing concern, and certainly warrants further study.

IC 49. *Limestone and Lime for SO_2 and Pollutant Control in the Ohio Valley*, by James C. Cobb and Garland R. Dever, Jr., 5 p.

This is the general introduction for the conference, Limestone and Lime for SO_2 Control in the Ohio Valley, held November 29–30 and December 1, 1992, in Lexington, Ky. The conference emphasized the importance of limestone reagents as sources for controlling SO_2 emissions from coal-fired power plants, and brought together experts from utility companies to describe important factors in limestone performance in scrubbers and from the stone industry to discuss important factors in limestone and lime production.

IC 50. *Oil and Gas Drilling Activity Summary for Kentucky, 1993*, by Brandon C. Nuttall, 133 p.

Production statistics for wells reported as having been completed during the calendar year 1993 are presented in this publication. Drilling activity in Kentucky in 1993 increased 8 percent over 1992 levels to 1,375 reported well completions and a success rate of 58 percent. Leslie County continued to be the top oil-producing county in Kentucky with 817,557 barrels, or 18 percent of the total State production. Pike County was the most prolific gas-producing county in the State with more than 31.5 billion cubic feet of gas.

IC 51. *Chemical and Statistical Analysis of a Sampled Interval in the Camp Nelson Limestone (Upper Ordovician), Madison County, Central Kentucky*, by Garland R. Dever, Jr., and others, 19 p.

A 67-foot section of Camp Nelson Limestone, which is being mined at Boonesborough, was sampled for major-element analysis. This interval consists of two zones (23 and 30 feet thick) of low-silica stone (4 percent or less total SiO_2) separated by a 14-foot section of slightly argillaceous limestone with an average silica content of 5.19 percent. The 23-foot-thick zone has an average total carbonate content of 96.03 percent, and the 30-foot-thick zone averages 93.17 percent total carbonate. A statistical study showed a relationship between the sampling interval and the reliability of the mean carbonate value. For a given ledge, moderately high reliability (0.80 to 0.85) can be obtained by taking three or four samples. If high reliability (0.90) is required, samples should be taken at 1-foot intervals. Very high reliability would require sampling at 0.5-foot intervals.

IC 52. *Ground Water in the Kentucky River Basin*, by Daniel I. Carey and others, 67 p., 2 plates.

Approximately 135,000 people living in the Kentucky River Basin depend upon privately owned ground-water sources for their domestic water supplies—approximately 19 percent of the total population and 36 percent of the rural population. The most productive wells are drilled into fractured bedrock and alluvium along the Kentucky River floodplain. Only a few wells yield enough water to supply a large demand; however, if aquifers are protected from pollution by proper well construction, ground water will continue to provide a reliable water supply in many areas of the basin. Discharge of ground water from springs and seeps also augments the volume of water in the Kentucky River during periods of low flow. Limited discharge data available for springs and large wells in the basin strongly suggest that ground water could potentially be used to supplement current water supplies during drought.

Report of Investigations

RI 8. *Sand and Gravel Resources Along the Ohio River Valley in Boone, Gallatin, and Carroll Counties, Kentucky*, by Eugene J. Amaral with contributions by Warren H. Anderson, 59 p.

Samples of glacial outwash sand and gravel were analyzed in order to characterize their particle size, composition, morphology, and degree of surface alteration, and to determine the geologic significance of lateral and stratigraphic variations in these properties. Pre-Illinoian and Illinoian Pleistocene outwash, located on uplands bordering the Ohio River Valley, are unfavorable as a source of aggregate because of the abundance of deeply weathered, unsound particles and the large amounts of deleterious sandstone and chert. Younger Wisconsinan outwash deposits within the Ohio River Valley, in contrast, provide favorable sources of aggregate, containing the largest concentrations of sound, coarse and fine sediments with the least amount of deleterious materials.

Special Publications

SP 20. *Rocks and Minerals of Kentucky*, by Warren H. Anderson, 82 p.

This information guide and reference for more than 100 different rocks and minerals that occur in Kentucky also has a discussion of basic Kentucky geology. It is accompanied by 16 pages of full-color photographs of mineral specimens and contains numerous selected references for further reading.

SP 21. *Impact of Hazardous Air Pollutants on Mineral Producers and Coal-Burning Plants in the Ohio Valley (Title III, Clean Air Act Amendments of 1990)*, 28 p.

This publication consists of abstracts of papers presented at a conference held in Lexington, Ky., March 19–21, 1995. The conference was sponsored jointly by the state geological surveys of Illinois, Indiana, Kentucky, Ohio, Pennsylvania, and West Virginia and the coal associations of the region. Technical sessions addressed the potential impact of Title III, trace elements in coal, air-toxics-control technology, and ash disposal and by-product recovery.

Thesis Series

TS 7. *Site Amplification of Seismic Ground Motions in the Paducah, Kentucky, Area*, by James B. Harris, 52 p.

Amplification of earthquake ground motions by near-surface geological conditions has been recognized as a major cause of damage in areas underlain by thick, unconsolidated sediments. Several communities in the lower Ohio River Valley and elsewhere in the Jackson Purchase Region of Kentucky are at risk to earthquake damage because of their foundation on thick, unconsolidated sediments and proximity to the New Madrid and Southern Illinois Seismic Zones. Due to its size and location, Paducah is one of the most vulnerable cities in the region. Site conditions at 37 locations in Paducah and the surrounding area were modeled to determine response to hypothetical earthquakes in the Mew Madrid and Southern Illinois Seismic Zones. Results of site-response analysis indicate that the magnitude of amplifications ranges from less than 5 to more than 20 times, depending upon the thickness of unconsolidated material in the area.

Miscellaneous

IBS 2. *Gas Potential of the New Albany Shale (Devonian and Mississippian) in the Illinois Basin*, by Nancy R. Hasenmueller and others, 83 p. plus maps.

This project was conducted by the Illinois Basin Consortium, consisting of the Illinois, Indiana, and Kentucky geological surveys, in order to review the existing data and evaluate the gas-producing potential of the New Albany Shale in the three-state region. Although commercial gas has been produced from the New Albany in this area in the past, results of this study indicate that full development of this potentially large resource has not yet occurred.

KGS Annual Report, 1993-1994, 59 p.

Status of the Topographic Mapping Revision Program in Kentucky (March 1, 1995), 1 sheet.

KGS List of Publications (September 1994), 58 p.

Cooperative Topographic Mapping

The Kentucky Geological Survey has participated in an ongoing cooperative program with the U.S. Geological Survey for topographic map revision in the State since Kentucky became the first major state to be entirely mapped topographically at a scale of 1:24,000 almost 40 years ago. This program is designed to maintain revised and up-to-date maps for all areas of the Commonwealth.

The following 27 revised 7.5-minute-quadrangle topographic maps were received from the U.S. Geological Survey during the 1994–95 fiscal year: Aberdeen (Ind.-Ky.-Ohio), Auburn, Austin, Brooks, Carrollton (Ky.-Ind.), Crestwood, Cumberland City, Florence (Ind.-Ky.- Ohio), Jeffersontown, Kosmosdale (Ky.-Ind.), Laconia (Ind.-Ky.), Lebanon East, Lebanon West, Louisville East, Louisville West, Madison East (Ind.-Ky.), Mauckport (Ind.-Ky.), Mount Washington, Patriot, Pleasant Green Hill, Rising Sun (Ind.-Ky.), Scottsville, Smithfield, Spurlington, Vevay North (Ind.-Ky.), Vevay South (Ind.-Ky.), and Wolf Creek Dam.

Topographic map revision by the U.S. Geological Survey is moving toward the production of digital maps and digitized map data. This is in response to the increasing need for these type of data in computer-run geographic information systems; however, paper maps will continue to be printed for use by the general public. Complete revision of the Elizabethtown Quadrangle in 1991 marked the first topographic map in Kentucky to be reproduced from digital data. Currently, 15 maps in Kentucky are undergoing digital revision as part of the cooperative topographic map revision program.

A map showing the status of the topographic mapping revision program is available from the Kentucky Geological Survey free upon request.

PUBLIC SERVICES

Water Resources Section

The Water Resources Section provides daily consultation to the public on both water quality and quantity through its geologists and the Water Resources Information System. At present, the Water Resources Information System is composed of the Kentucky Ground-Water Data Repository, the Surface-Water Data Base, the Ground-Water Dye-Trace Data Base, and two newly instituted programs, the geographic information system Data Base and the Kentucky Ground-Water Monitoring Network. During the past year the Section answered approximately 1,000 requests for surface- and ground-water information using these data bases, which are discussed below.

THE KENTUCKY GROUND-WATER DATA REPOSITORY

The Kentucky Ground-Water Data Repository has been in service since 1990, when it was created by the Kentucky Geological Survey under mandate from the Kentucky General Assembly (KRS 151:035). The purpose of the Repository is to archive and disseminate ground-water data collected by State agencies, other organizations, and independent researchers. Eight State agencies and two Federal agencies involved in the collection of some form of ground-water information have been contacted to determine the type and quantity of ground-water data they have. Prior to the initiation of the Repository, ground-water data were housed at many different locations throughout the State. The goal of the Repository is to provide Kentucky ground-water data at a centralized location in a manner that meets the needs of the public.

Data for the Repository have been generated by over 15 different sources. The largest contributor of data on a regular basis is the Kentucky Division of Water, Ground Water Branch, which processes drillers' logs from the Certified Water Well Drillers Program, initiated in 1985. Data are disseminated to the public on various media, including hard-copy printouts, magnetic tapes of several different types, and diskettes.

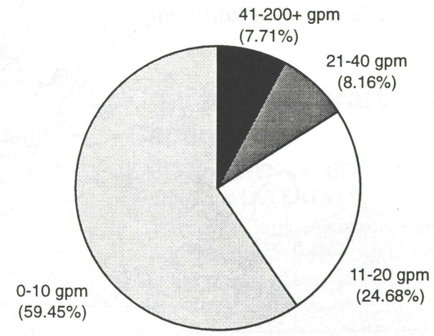
Also included in the Repository are hard-copy maps, field notes, ground-water publications, and other related information. Efforts are under way to compile ground-water data from State agencies and other sources in the industrial, academic, public health, and research sectors. This task will be ongoing as new ground-water data are generated.

Data from the Repository are currently being used to generate geographic information system coverages, using the Arc/Info system. Statewide, regional, and selected county maps have been completed that show depth to bedrock, depth to ground-water surface, well yield, and surface topography. Other important ground-water parameters may also be mapped.

Repository personnel responded to 844 inquiries from the public during the fiscal year, a 55 percent increase over fiscal year 1993–94. Approximately 80 percent of these inquiries were from environmental engineering and remediation companies performing site assessments. The remaining 20 percent were general inquiries from both the public and private sectors concerning ground-water occurrence, ground-water supply, and water quality.

KENTUCKY GROUND-WATER MONITORING NETWORK

This network will characterize the ground-water resources of the State. Approximately 900,000 Kentuckians currently use ground-water supplies. An ad hoc advisory committee, with representation from State and Federal agencies, industry, and professionals who deal with water-resources issues, is assisting KGS in developing plans for the network. In addition, all water-quality data in the Kentucky Ground-Water Data Repository are being summarized to evaluate their usability. Summaries are organized by physiographic region, and the most useful parts of this review will be published in a summary report.



Yields of wells listed in the Kentucky Ground-Water Data Repository (only 4,505 wells listed at present).

The review and summary of this information clearly show that existing data are inadequate to define aquifers, zones of differing water quality, and flow systems that affect water quality and supply. The network will coordinate the efforts of the many agencies that collect ground-water quality data. Increased awareness and coordination can prevent duplication of effort and allow better sharing of public information.

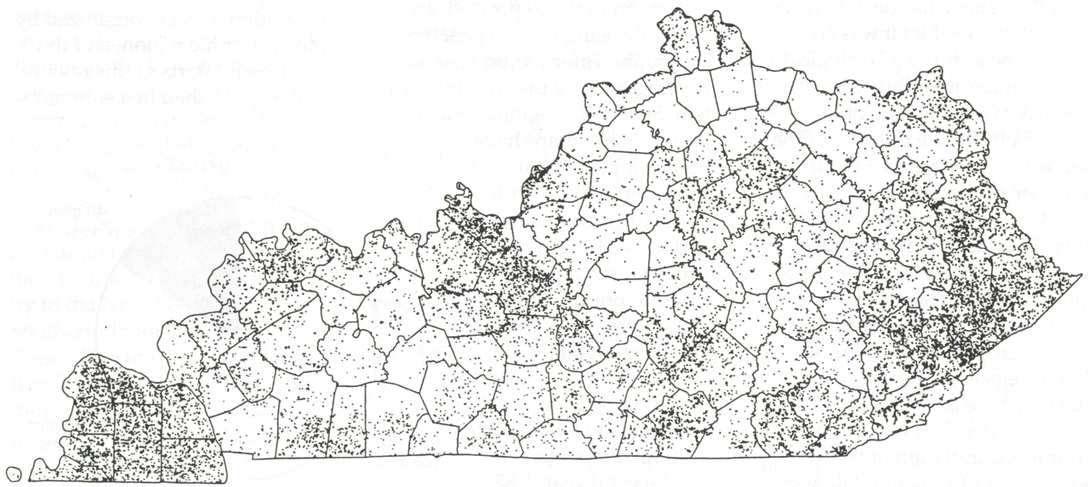
Data collected through the network will be very useful for defining aquifers, flow systems, and zones of water quality. Information will be summarized in reports that will be used by the public, agencies, businesses, municipalities, and other users of ground water in Kentucky. In addition, computerized raw data will be available through the Ground-Water Data Repository. Funding for the monitoring network will be sought in the coming year.

GROUND-WATER DYE-TRACE DATA BASE AND KARST GROUND-WATER BASIN ATLAS

This cooperative program has proceeded as time permits, without special funding, for the past 3 years. Progress was made during the year as new ground-water dye-trace data were gathered, and the existing files were edited. Also, several possibilities for presenting the data have been explored, and we have decided that a series of karst ground-water basin maps will be more useful than data in a tabular format. Base maps have been obtained, and areas of responsibility tentatively assigned. Work on the first map in the series is under way. The goal is to assemble the maps into an atlas. Each map will cover a 30 by 60 minute area at a scale of 1:100,000. The catchment area will be shown for each basin with sufficient data to delineate the basin boundary. Less well-defined basins will be represented by lines connecting ground-water dye-trace input points with recovery points. In addition, some basins will be presented at a large scale in order to serve as examples of basin types or to show more detail when it is available and of special value. These maps will provide the first Statewide delineation of karst basins in Kentucky. The value of such maps and data for water supply, ground-water protection, and general economic development is significant.

SURFACE-WATER DATA BASE

A surface-water data base for Kentucky continues to be expanded for use in research and to provide data for public inquiries. With the addition of this information to the KGS data bases, users can obtain geologic, topographic, and surface- and ground-water data from a centralized location. Providing easily accessible data



The 22,000 well locations in the Kentucky Ground-Water Data Repository.

in a centralized location will encourage greater efficiency and utilization of data by consultants, agencies, local governments, and citizens groups.

Currently, the surface-water data base includes flow and water-quality data. Low-flow and flood statistics will be incorporated on a priority basis. The availability of the data base greatly enhances our ability to respond to public requests, and integrates with the Survey's geographic information system (see below) to facilitate planning and research for water resources.

GEOGRAPHIC INFORMATION SYSTEM DATA BASE

Whether studying ground water or surface water, or water quantity or quality, one must consider many factors, such as geology, soils, topography, land use, water use, demographics, and political subdivisions. Broad-based support for water-resources planning requires the dissemination of information on issues, alternatives, and the consequences of policy decisions. In general, this information must be gathered from a variety of sources and summarized in a manner that clearly displays the information. As part of its research and public service activities, the Kentucky Geological Survey is assembling a spatial data base for water-resources planning and management.

Spatial distribution of the above factors at a Statewide and basin scale is being entered into the Arc/Info geographic information system at the Survey on a project-by-project basis. These data are available to outside agencies and the public, and are being used to support water-, coal-, and petroleum-resource studies. KGS is continuing the expansion of the spatial data base to include such data as the demographics of water supply and use, sewage and waste disposal, mapping of public and private water-supply service areas, and other data related to water-resource management.

During the past year, GIS has been employed to map ground-water parameters on a Statewide scale. GIS coverages have been completed for depth to water, ground-water surface elevation, and depth to bedrock for the entire State. Coverages for some counties have been completed for nitrate-nitrogen, and we are now able to map other water-quality parameters, including pesticides, major cations and anions, and trace elements.

A menu-driven interface has been designed to allow the user to define the number of counties to be mapped, the contour interval, the parameter to be contoured, and the map scale. Work is continuing on the development of the interface in order to broaden its application to a wider variety of data and map types.

The majority of the data used to generate these GIS coverages was provided by water-well drillers at the time each well was completed. The wells from which these data were taken were completed between 1985 and 1993. Total depths of the wells range from 10 feet to 800 feet. Over 200,000 unregistered private water wells are estimated to exist in Kentucky; therefore, only about 10 percent of all the wells are represented in our data base.

These GIS coverages are currently being developed into publications that should prove useful to the general public, water-well drillers, environmental geologists and engineers, land-use planners, and other research organizations.

SECTION 319(H) PROGRAM MANAGEMENT

Section 319(h) of the Federal Clean Water Act deals with the curtailment of nonpoint-source pollution from city, urban, and rural land uses. The Kentucky Geological Survey, through a contract with the Kentucky Water Resources Research Institute, is assisting the Kentucky Division of Water in managing this program. A program coordination team consisting of University and State agency personnel has been established to look at both short- and long-term goals with respect to the control of nonpoint-source pollution in the State. In addition, two coordinators have been hired to assist the Division in developing grant work plans and proposals, and to review and track contractual agreements with individuals researching nonpoint-source pollution. An advisory group consisting of citizens, industry, researchers, and State agencies was formed, and a meeting was held to identify the major concerns about nonpoint-source pollution and potential program elements. This information will be used to develop a new comprehensive plan that will be reviewed by U.S. EPA as it awards funds to the State to address nonpoint-source pollution in the future.

Coal and Minerals Section

EARTH SCIENCE EDUCATIONAL MATERIALS

Part of the mission of the Kentucky Geological Survey is to educate the public about earth science. As the repository for coal, oil, natural gas, and water information, and the outlet for topographic and geologic maps, KGS has a wealth of material that is converted into educational pro-

KGS staff presented educational talks to numerous school groups throughout the year.

grams. KGS answers thousands of inquiries on earth science annually. KGS staff members teach seminars and give talks on all aspects of earth science, from map reading to dinosaurs to waste management. Rocks and minerals, fossils at the Falls of the Ohio, roadside geology along many State highways, the geologic story of various State parks, and the geologic history of Kentucky are just some of the subjects KGS has covered in the past.

Over the past several years, demand for staff members to help in earth-science education across the Commonwealth has increased, and considering the popularity of earth-science topics from dinosaurs to potential earthquakes, the demand for information will continue to increase. To accomodate this demand, KGS has set up a committee to evaluate plans to broaden its educational programs. Possible programs include teacher seminars, traveling exhibits, and a centralized earth-science education repository where educators from around the State could find information they could use in their classrooms.

"Rocks and Minerals of Kentucky," a popular new book that includes color photographs and descriptions of various rocks and minerals of Kentucky, was published by KGS in 1994. It details most of the minerals that occur in the State, from the common calcite crystals to the rare millerite and Kentucky agate. This reference book will be of interest to rock collectors and scientists. An accompanying set of slides of the minerals in this book will also be made available for educational purposes.

A sample set of three rocks and minerals is still made available upon request, at no charge, to schools, scouts, and hobby collectors. KGS also provides assistance in identification of rocks, minerals, fossils, meteorites, and manmade alloys.

PUBLIC ACCESS TO COAL INFORMATION AND COAL-DATA MANAGEMENT

The most important mission of the Kentucky Geological Survey is to provide information to the public on mineral resources. Coal information is made available through formal publications, open-file reports, presentations to groups, and computerized data bases. The Kentucky Coal Resources Information System (KCRIS) was established to provide coal-related data to the public. KCRIS contains computerized and open-file coal-quality, thickness, resources, core-description, and coal-related engineering data. These data have been collected by the Survey for the last two decades, and the data bases are continually being updated with new information.

Public requests are answered from the data in the system. Analytical data from the KGS Coal Laboratory are added to the data base as well. KGS personnel work continuously to code and enter data into the computer system, and KGS geologists travel throughout the State to sample coal beds, measure coal-bearing outcrops, collect core descriptions, and describe core. All coal data are located stratigraphically, topographically, and geographically before they are entered into the data base.

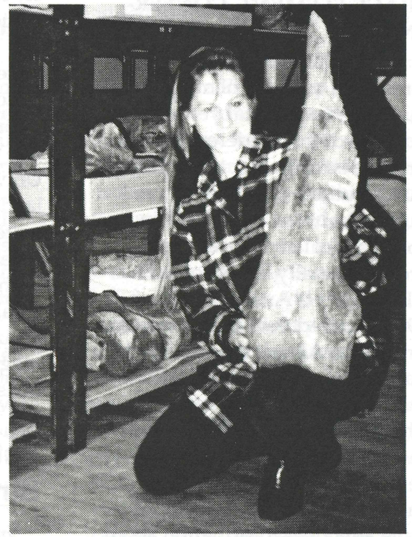
PALEONTOLOGIC ANALYSIS OF KENTUCKY FOSSILS

Kentucky, because of its extensive outcrops of sedimentary rocks, is one of the most famous sources in the United States for fossils. KGS receives numerous requests every week from the public concerning fossils and fossil identification. Occasionally a scientifically important fossil is discovered in Kentucky, which requires a more thorough, scientific, paleontologic analysis. KGS must ensure that important fossils discovered in Kentucky receive proper scientific treatment. For example, an ancient animal trackway discovered in McCreary County was brought to the attention of a KGS paleontologist, who recognized the trackway as the earliest known reptile fossil in North America. A scientific paper fully describing the fossil was published. A press release brought public attention to the fossil.

In some cases, KGS sends fossils to specialists elsewhere for analysis. For example, a fossil insect wing (the only insect fossil ever found in Kentucky) was sent to a specialist in Germany, who determined that it was the oldest representative of a family of insects ever discovered.

KGS is also responsible for oversight of fossils found on State property. Many thousands of Ice Age mammal fossils, including the wooly mammoth, were recovered at Big Bone Lick State Park in northern Kentucky by scientists from the University of Nebraska in the 1960's. This fiscal year KGS has constructed a data base of fossils collected by Nebraska scientists from data supplied by the University of Nebraska. Fossils recovered from previous digs (including Nebraska's) at Big Bone Lick include the giant goose, turkey, a possible wolf, a possible black bear, modern bison, ancient bison, two types of musk ox, American moose, wapiti elk, common Virginia deer, extinct stag moose, caribou, flat-headed peccary, extinct North American horses, a possible tapir, American mastodon, wooly mammoth, and two types of giant ground sloth. The most common fossil found at Big Bone Lick has been bison. The herbivores were attracted to Big Bone Lick because of salt springs. The big mammals tramping through the water-laden, clayey deposits created a deep, sticky mire, which trapped all sorts of salt-starved mammals who came to lick the salt. Bones are generally not articulated because subsequent trampling long after death caused the bones to be spread apart.

The fossils from Big Bone Lick are not only of scientific interest, but are important in historical terms: Big Bone Lick was one of the first paleontologic sites discovered in North America. Collections were made at Big Bone Lick in 1739 by Major Charles LeMoyne de Longueuil, the Commander of French troops in Canada, and the specimens his troops collected reside in the Musee National d'Histoire Naturelle in Paris, France. President Thomas Jefferson sent Captain William Clark, of Lewis and Clark fame, to collect bones there in 1807. Clark's collection was divided and sent to the American Philosophical Society in Philadelphia, the Musee d'Histoire Naturelle de France, and President Jefferson's personal collection; some of the specimens still reside at Monticello. Very few of the bones collected at Big Bone Lick remain in Kentucky. However, efforts are being made to return some of the bones collected by the University of Nebraska. Two scientists from



University of Kentucky geologists examined fossil bones stored at the University of Nebraska that were collected from Big Bone Lick, Ky. *Left:* Dr. Donald Chesnut with a mastodon tooth. *Right:* Dr. Anne Webster with a mastodon or mammoth thigh bone.

the University of Kentucky (one from KGS) visited the Nebraska State Museum this fiscal year to examine the Big Bone Lick collection and to determine which specimens should be returned to Kentucky. A new museum at Big Bone Lick would be a perfect place to show off these important fossils to Kentuckians and would be a boost to tourism in that area.

KGS receives coal samples on a regular basis. Some of these are from coal beds that require further stratigraphic identification. The study of fossil spores and pollen (palynology), chemically released from coals, can assist in stratigraphic identification of coal and can provide clues about the origin of coal. Palynological analysis can be conducted at KGS when it is deemed scientifically important. During this fiscal year a number of palynological analyses were performed on coals from both of Kentucky's coal fields. Results of these studies are published in the scientific literature.

TRACE-ELEMENT CONFERENCE

KGS organized a regional conference on trace elements in coal during the past fiscal year. The purpose of this conference was to provide information to the coal industry, utilities, and the general public about trace elements in coal, particularly those considered potentially hazardous. The Clean Air Act Amendments of 1990 required the Environmental Protection Agency to investigate hazardous air pollutants (HAP's), including 13 that occur in coal. The EPA will announce its findings and intentions regarding regulation of HAP's trace elements in 1996. This conference gave attendees information about the chemistry and behavior of trace elements in coal, their occurrence and distribution, sources of information, and preliminary views of the regulatory agencies. Ninety-five participants attended this conference.

Computer and Laboratory Services

The primary function of the Computer and Laboratory Services Section is to aid the KGS staff with its computer and analytical chemistry needs. In addition, CALS personnel often assist and cooperate with other University departments, State and Federal organizations, industry, and the general public.

During the past year, we cooperated with Dr. Gregory Burg of the UK College of Agriculture in a study on using graphite furnace atomic absorption spectroscopy to detect rubidium in ticks. The data produced from this study will determine the feasibility of using rubidium chloride as an elemental marker in ticks. We also worked with the American Society for Testing and Materials, the National Institute of Standards and Technology, three United States laboratories, and two international laboratories to certify fluorine in coal. Another cooperative venture was with the Open University in Milton Keynes, England, to study two rock reference materials. In addition, we participated in a collaborative study with the Association of Official Analytical Chemists to determine atrazine content in water using magnetic particle-based immunoassay.

Petroleum and Stratigraphy Section

In addition to its research responsibility, the Petroleum and Stratigraphy Section provides services relating to the exploration for and development of oil and gas resources.

OIL AND GAS WELL RECORDS

KGS is the the official repository for records of all oil and gas wells drilled in the State, and the Petroleum and Stratigraphy Section is responsible for these records on file in the Geologic Data Center in Lexington. A variety of records, such as drillers' logs, wireline logs, well-location survey plats, plugging affidavits, and completion reports, are on file for an estimated 225,000 wells. In addition, well-data files for western Kentucky are available at the Henderson office.

Records for 1,668 new wells were processed and recorded by the Survey last year. The Kentucky Geological Survey staff also reviews and enters into the computerized data base as many of the older well records as time permits; 6,829 records were added to the data base in 1994, including 406 added under the accelerated scanning program. The computerization of the Well Record Library and the expanded utility of supporting data sets are expected to greatly enhance the speed and efficiency of data retrieval. By the end of 1995, data for approximately 135,000 wells should be available.

Last year, 1,730 visitors were assisted and 1,326 phone requests for information were processed at the Lexington and Henderson facilities. A total of 20,150 copies of well records were supplied. More than 27,000 feet, representing logs for more than 1,773 wells, were copied for the public in 1994.

Custom printouts based on user specifications can be made on request. Well-location base maps are available as overlays for the U.S. Geological Survey 1:24,000-scale 7.5-minute topographic quadrangle maps. Data are also available in machine-readable form on floppy disks. One hundred twenty-four well lists, 644 computer-generated overlays to topographic maps, and 108 floppy diskettes were made during the fiscal year.

For those areas not completed, the following well locations are available for plotting: all wells reported complete since January 1, 1981; all locations for which a permit has been issued since January 1, 1984; all pre-Trenton wells; all Devonian and deeper wells of western Kentucky and the majority of eastern Kentucky; and all Class II (injection and disposal) wells reported active in 1979 and completed since.

OIL AND GAS WELL-RECORD PRESERVATION

Since the oil and gas well-record files of the Kentucky Geological Survey are used extensively by the public and staff members, the paper files are deteriorating rapidly, and it has become evident that the files must be made available by some alternate method. In order to protect the original paper files from destruction by continual use, fire, and theft, and to make them simultaneously more accessible to Survey staff, industry, government representatives, and the general public, the individual well records are being optically scanned, and raster images are being stored on magnetic tape. These images include available petrophysical logs.

To date, records for 32,541 wells have been scanned, resulting in one of the largest data bases of its kind in the country. In 1991, records selected for scanning were arranged by priority, based on stratigraphic significance, in order to better meet increasing research and public demands.

A procedure to generate bar codes for document identification and indexing was implemented. Bar codes will be assigned to each page of each document that is to be scanned. The bar-coded information will be used to appropriately index each image and automatically generate unique file specifications for image storage. Strategies for accelerating the scanning operation have also been implemented. The emphasis is on processing and indexing oil and gas well-record data that are not currently available on computer, in order to prepare the documents for scanning. The procedures will eventually include ground-water and water-well information, coal records, and industrial-mineral data. Since implementing this new procedure in the last quarter of 1994, more that 8,000 oil and gas records have been processed.

DEVELOPMENT OF FACILITIES AT THE KGS WELL SAMPLE AND CORE REPOSITORY

The Kentucky Geological Survey was designated by the State legislature in 1960 as the official repository for oil and gas drilling records and well samples (KRS:353). In addition to collecting rock cores and well cuttings to comply with this mandate, the Survey has also made a concerted effort to collect valuable cores and samples from other exploratory efforts, including those from coal and industrial minerals. By maintaining a repository for cores and samples, KGS provides an extremely valuable service to the Commonwealth. Persons engaged in the exploration for and development of Kentucky's mineral resources must have detailed knowledge about the rock strata in which the deposits occur, as well as information about associated deposits. For rock strata that lie beneath the earth's surface, this knowledge can be gained only from drill cores and well cuttings. Cores and well samples also provide essential information for a better understanding of our ground-water resources and related environmental problems.

The cost of obtaining well samples and cores is extremely high, and it is grossly inefficient and expensive to drill new holes each time new information is needed. Therefore, a repository that archives the results of previous exploration and makes this valuable information available to the public is the only reasonable solution. The Repository now contains cuttings and cores from more than 20 million feet of exploratory drilling from over 22,400 locations. These samples represent an estimated initial expenditure of approximately $535 million. New material representing hundreds of thousands of feet of drilling are added to the Repository annually.

The staff at the KGS Well Sample and Core Repository continues to move toward better and more efficient ways to provide services. Unfortunately, our moves are not always in the direction we have anticipated nor as productive as we have hoped. Our recent "moving experience" is a good example. Although the University of Kentucky had extensively renovated the American Building, our former facility, problems such as leaking walls, collapsing roof, and extremely uneven floors continued. The possibility of floods, such as the one that occurred in June 1992 and caused more than $400,000 in damage to boxed cores, well cuttings, and KGS publications stored in the building, also re-

mained. The June 1992 flood made the facility unavailable to the public for an extended period and caused extensive delays in washing, packaging, and indexing samples. Given the problems of the American Building, the University decided in late 1994 to demolish the American Building and build a parking structure on the site. The KGS Well Sample and Core Repository was moved during April and May of 1995 to 554 South Forbes Road, Warehouse 23, directly across from the Lexington Quarry. This, our second move in 10 years, has resulted in another temporary setback in our ability to serve the public. However, the new facility, a renovated tobacco warehouse, should provide a much better facility than the old American Building. We hope to open the facility to the public by July 1, 1995. If you have special needs or wish to contribute cores or samples to the Repository, please contact Patrick Gooding at 606-255-2439.

At the same time, plans are underway for a new Repository to be built on University property in the near future. KGS will be working with the University, the KGS Advisory Board, and members of the Kentucky General Assembly to obtain authorization and funding for the new facility. Although this will necessitate another move, the facility should provide adequate storage and research and sample-examination space for the public; more important, it will provide the continuity of public service we have been seeking.

KGS apologizes for any inconvenience to its clients. We assure you, it has not been much fun for us either, but the end results will be positive.

Publications Section

PUBLICATION SALES AND DATA DISTRIBUTION

The Publication Sales Office of the Kentucky Geological Survey makes published information about Kentucky's mineral and water resources available to thousands of customers each year. Maps and reports published by the Kentucky Geological Survey and U.S. Geological Survey account for most of the materials sold, but publications from other sources, as well as open-file reports dealing with Kentucky geology, are also available.

The Publication Sales Office is located on the first floor of the Mining and Mineral Resources Building at the corner of Rose Street and Clifton Avenue on the University of Kentucky campus. Convenient parking for customers is located in the University of Kentucky Faculty Club parking lot behind the Mining and Mineral Resources Building.

The office stocks 7.5-minute-quadrangle topographic and geologic maps for the entire State. These maps are at a scale of 1:24,000 (1 inch on the map represents 2,000 feet on the ground) and depict in great detail Kentucky's topography and geology. All available 1:250,000- and 1:100,000-scale topographic maps of Kentucky, as well as complete coverage of Hydrologic Atlases published by the U.S. Geological Survey, are also kept in stock. In addition, numerous other geologic, geophysical, structure, hydrologic, and mineral-resource maps are available from the KGS sales office. Open-file maps showing landslides and related features are available for approximately 250 quadrangles in eastern and south-central Kentucky; copies of these maps are available at a nominal cost.

All KGS reports that are still in print and USGS reports that deal with Kentucky geology are available for purchase at the Publication Sales Office. In addition, KGS maintains an extensive collection of open-file materials, including reports and maps, which can be reproduced for customers at a nominal charge.

The Publication Sales Office handles a large volume of requests for maps and reports. During the past fiscal year, this office distributed approximately 22,500 maps and 3,500 reports, as well as 20,150 copies of well records and other miscellaneous items. Most mail orders are shipped out the day after they are received.

A List of Publications, which shows available maps and reports and gives complete ordering instructions, is available free upon request.

EARTH SCIENCE INFORMATION CENTER

The Kentucky Geological Survey–Earth Science Information Center (KGS-ESIC) answers inquiries regarding the availability of current and historic map information, aerial photography, satellite imagery, geodetic control, and digital cartographic data. The office also answers questions about the availability of all types of earth-science information in Kentucky. The KGS-ESIC office is located in Room 104A on the first floor of the Mining and Mineral Resources Building adjacent to the KGS Publication Sales Office.

Resources available to the KGS-ESIC office for answering requests include a file of more than 5,700 microfiche indexes to aerial photography (available also on CD-ROM), satellite data (with an up-to-date, micro-image index), and historic maps (a microfilm file containing 37,400 historical topographic maps of the United States). Access to the USGS electronic data base of geographic names (GNIS) for Kentucky, which contains more than 30,000 place names used on Kentucky topographic maps, is available. Also, information is available about how to contact various USGS agencies for geophysical data, seismic data, gravity-anomaly information, magnetic data, and navigational information from the U.S. Army Corps of Engineers and Tennessee Valley Authority.

Close coordination between KGS-ESIC and the KGS Publication Sales Office makes it possible for many persons to obtain desired materials or information as the result of a single inquiry or visit to the Kentucky Geological Survey. However, in some cases it may be necessary to refer persons to another State or Federal agency, or private firm, as the source for a particular product.

More than 600 individual inquiries for information were answered by KGS-ESIC during the 1994–95 fiscal year. Of these requests, 36 percent were for map-related information, 15 percent were for geodetic control data, 14 percent were for aerial photography or space imagery, 4 percent concerned digital map products, and 31 percent were for information about available publications. Ordering assistance to obtain the desired materials was provided for many of the requests.

During the year, the KGS-ESIC representative participated in numerous activities to help make earth-science information available to the public. These activities included making presentations about topographic maps to students and professional groups, and working with the State Mapping Advisory Committee.

KENTUCKY GEOLOGICAL SURVEY DISTINGUISHED LECTURE SERIES

The Distinguished Lecture Series was begun in 1988 to commemorate former State Geologists of Kentucky. The first lectures were held in conjunction with the Kentucky Geological Survey's sesquicentennial celebration and honored William W. Mather, Kentucky's first State Geologist. Sesquicentennial Distinguished Lecturers were William L. Fisher, "Oil and Gas Research: Opportunities and Challenges"; Harold J. Gluskoter, "Coal Geology: Who Is Mining the Store?"; Philip Cohen, "Ground-Water Situation in the United States"; Allen F. Agnew, "Industrial Minerals and Rocks—Who Needs Them?"; and Charles J. Mankin, "The Role of Geology in Shaping Public Policy."

The second Distinguished Lecture, in honor of David Dale Owen, was presented in 1989 by Hermann W. Pfefferkorn, whose topic was "The Orinoco Delta in Tropical South America as a Model for Coal-Bearing Strata in the United States." Aureal T. Cross presented the Nathaniel S. Shaler Distinguished Lecture in 1991; the title of his presentation was "Aspects of Plants in Coal and the Coalification Process." In 1992, Paul Edwin Potter was chosen as the John R. Procter Distinguished Lecturer in honor of Kentucky's fourth State Geologist. The title of Dr. Potter's lecture was "Contributions to Sedimentology—Geology from the North American Heartland." The 1993 KGS Distinguished Lecture honored Dr. Wallace W. Hagan, who retired as State Geologist and Director of the Kentucky Geological Survey in 1978. The presentation was made by Philip E. LaMoreaux, who spoke on "The Importance of Environmental Geology." The Charles Joseph Norwood Distinguished Lecture was presented in 1994 by Robert D. Hatcher, Jr., who spoke on "The Impasse Over Disposal of Hazardous and Radioactive Waste, and Environmental Degradation—Political Juggernaut or Opportunity for Geological Scientists?"

In 1995 the Joseph B. Hoeing Distinguished Lecture was presented by John M. Sharp, Jr., whose topic was "Modeling Flow in Fractured Rocks and the Effects of Fracture Skins." Dr. Sharp has been Professor of Geology since 1985 at the University of Texas at Austin, where he currently holds the Chevron Centennial Professorship in Geology. From 1989 to 1993 he was the Gulf Foundation Centennial Professor of Geology, and from 1986 to 1989 he was the C.E. Yager Professor of Geology. Last year he was a visiting scientist at the Centre for Groundwater Studies at Adelaide, Australia. His main areas of interest are hydrogeology and environmental geology. Dr. Sharp is a Fellow of the Geological Society of America and is a past Councilor of GSA, a member of the GSA Executive Committee, and an associate editor of the GSA Bulletin. In 1979 he received the O.E. Meinzer Award from GSA for outstanding contributions to hydrogeology. He is the current editor of *Environmental and Engineering Geosciences* and was formerly an associate editor of the *Journal of Applied Hydrology*. He is chairman of the American Institute of Hydrology Board of Registration. In addition, he is a member of at least a dozen geological societies.

State Geologist Donald C. Haney congratulates 1995 Distinguished Lecturer John M. Sharp, Jr.

The 1995 Distinguished Lecture was in honor of Joseph B. Hoeing, who was appointed Kentucky's sixth State Geologist in 1912. He previously had served as a geologist and cartographer at KGS under Nathaniel S. Shaler and John R. Procter, and had also been U.S. Deputy Mineral Surveyor of Colorado from 1878 to 1880. As State Geologist, Hoeing moved the Kentucky Geological Survey from the School of Mines at the University of Kentucky to the State capitol. His Survey had a well-balanced program of economic and scientific investigations, and published numerous reports, including a large number of mineral-resource reports that remained unpublished from the Norwood Survey. Hoeing is probably best known for his many excellent county, regional, and State maps. He served as State Geologist until 1918, when the Kentucky General Assembly combined the State Board of Forestry with the Kentucky Geological Survey under the directorship of John E. Barton, State Forester. At that time, Hoeing resigned, rather than serve in the subordinate position of Deputy Commissioner and State Geologist in the newly formed Department of Geology and Forestry.

Distinguished Lectures

William W. Mather—1988
William L. Fisher
Harold J. Gluskoter
Philip Cohen
Allen F. Agnew
Charles J. Mankin

David Dale Owen—1989
Hermann W. Pfefferkorn

Nathaniel S. Shaler—1991
Aureal T. Cross

John R. Procter—1992
Paul Edwin Potter

Wallace W. Hagan—1993
Philip E. LaMoreaux

Charles Joseph Norwood—1994
Robert D. Hatcher, Jr.

Joseph B. Hoeing—1995
John M. Sharp, Jr.

COMMITTEES, BOARDS, AND ADVISORY ACTIVITIES

International

Global Sedimentary Basins Stress Project
Terence Hamilton-Smith

***International Journal of Surface Mining* Review Committee**
James A. Kipp

National

Alumni Advisory Board for the Department of Geology, University of Iowa
James A. Drahovzal

American Association of Petroleum Geologists
James C. Cobb: Eastern Section Councilor for Energy Minerals Division
James A. Drahovzal: Delegate of the Geological Society of Kentucky to the House of Delegates; Chairman, Eastern Section Membership Committee; Research Committee; Chairman, Eastern Section 1997 meeting in Lexington, Kentucky
David C. Harris: Treasurer, Eastern Section; Eastern Section Membership Committee

American Geological Institute
James C. Cobb: Chair, *Geotimes* Editorial Committee
Donald C. Haney: Past-President; AGI Foundation

American Society for Testing and Materials
Cortland F. Eble: Task group leader for updating microscopic standards for coal
Henry E. Francis: Subcommittee D-5 on Coal and Coke; Subcommittee D-19 on Water; Subcommittee E-11 on Quality and Statistics; Subcommittee E-36 on Laboratory Accreditation

American Society of Agricultural Engineers
Gary K. Felton: P-207, Committee for Student Organizations; SW-264, Technical Committee for Reclamation of Disturbed Lands; SW-211, Technical Committee for Porous Media Flow

Appalachian Oil and Natural Gas Research Consortium
James A. Drahovzal: KGS Research Coordinator

Association of American State Geologists
Donald C. Haney: Chairman, Cooperative Planning Committee

Association of Earth Science Editors
Donald W. Hutcheson: Nominations Committee

Central United States Earthquake Consortium
John D. Kiefer: State Geologists Committee

Editorial Board of the Journal *Ground Water*
James A. Kipp: Auxiliary Member

Energy Advisory Board
Donald C. Haney: Secretary, Fuel Cycle Peer Review Panel

Geological Society of America
Cortland F. Eble: Secretary-Treasurer of the Coal Geology Division
Stephen F. Greb: Coal Geology Division, Member at Large
Donald C. Haney: Chairman, Geology and Public Policy Committee; Chairman, Southeastern Section
John D. Kiefer: Southeastern Section Committee on Geology and Public Policy; National Membership Committee

Interstate Oil and Gas Compact Commission
James A. Drahovzal: Enhanced Recovery Committee
Donald C. Haney: Research Committee
John D. Kiefer: Environmental Affairs Committee

National Academy of Science
Donald C. Haney: Executive Committee; Board on Earth Science and Resources; Committee on Mineral Resources

National Research Council Panel on the Review of the Oil Recovery Demonstration Program of the Department of Energy
James A. Drahovzal

Potential Gas Committee
Terence Hamilton-Smith

U.S. Department of Energy
James C. Cobb: Committee on Coal Resources
James A. Drahovzal: Natural Gas Strategic Plan, Supply Technical Panel

U.S. Geological Survey
James C. Cobb: Volunteer Associate Scientist

U.S. Secretary of the Interior's National Geologic Mapping Advisory Committee
Donald C. Haney

Virginia Water Resources Research Center
James A. Kipp: Proposal Reviewer

Regional

Illinois Basin Consortium
James A. Drahovzal: 1994 Chairman; KGS Research Coordinator; Seismic Task Force Advisor

Impact of Hazardous Air Pollutants on Mineral Producers and Coal-Burning Plants in the Ohio Valley, Program Committee for 1995 Conference
Garland R. Dever, Jr.

Ohio River Basin Consortium for Research Education
John D. Kiefer: Board of Directors, representative for the University of Kentucky

Tri-State Correlation Committee
Cortland F. Eble, Stephen F. Greb, David A. Williams

State

Geographic Information Advisory Council
Daniel I. Carey

Geological Society of Kentucky
O. Barton Davidson: Treasurer, 1994
Shelley A. Minns: Eastern Vice President, 1994
Richard A. Smath: Secretary, 1994–95
Thomas N. Sparks: Newsletter Editor, 1995
Kevin J. Wente: Eastern Vice President, 1995
David A. Williams: Western Vice President, 1995

Governor's Council on Nonpoint Source Pollution
Donald C. Haney

Governor's Earthquake Hazards and Safety Technical Advisory Panel
John D. Kiefer: Chairman, Technical Subcommittee
Ronald L. Street

Governor's Groundwater Advisory Council
James C. Currens: Data Management Committee
James S. Dinger: Chairman, Data Management Committee; Groundwater Monitoring Committee
Donald C. Haney
James A. Kipp: Groundwater Monitoring Committee
Richard E. Sergeant: Data Management Committee

Hazard Mitigation Enterprise Zone Commission
Ronald L. Street

Kentucky Board of Registration for Professional Geologists
Donald C. Haney

Kentucky Cabinet for Economic Development
James C. Cobb: Committee on Post-Mining Land Use

Kentucky Department of Mines and Minerals, Division of Oil and Gas, Oil and Gas Issues Work Group
James A. Kipp

Kentucky Engineering Earthquake Response Team
Daniel I. Carey

Kentucky Groundwater Management Data Committee
O. Barton Davidson, Richard E. Sergeant

Kentucky Information Resource Management Commission
Steven J. Cordiviola: Special Committee on Imaging
Donald C. Haney

Kentucky Long-Term Policy Research Center
James C. Cobb

Kentucky Museum of Natural History
Donald R. Chesnut, Jr.: President, Board of Directors

Kentucky Oil and Gas Association
John D. Kiefer: Technical Support Committee to the Hazardous Waste Disposal Task Force

Kentucky On-Site Sewage Disposal Advisory Committee
David R. Wunsch

Kentucky Paleontological Society
Donald R. Chesnut, Jr.: Scientific Advisor

Kentucky River Authority
Daniel I. Carey: Policies and Procedures Subcommittee; Water Quality Subcommittee
Donald C. Haney

Kentucky Stratigraphic Nomenclature Committee
Donald R. Chesnut, Jr., Garland R. Dever, Jr., Stephen F. Greb

Kentucky Water Availability Advisory Council
James S. Dinger

Kentucky Water Resources Research Institute, Federal Facilities Oversight Unit
James C. Cobb, James S. Dinger, James A. Kipp, David R. Wunsch

Kentucky Water-Well Drillers' Certification Board
James S. Dinger

Ky-A-Syst (Home and Farmstead Environmental Assessment)
James A. Kipp: State Advisory Committee

Mammoth Cave Karst Area Water-Quality Oversight Committee
James C. Currens

NORM Task Force
James A. Drahovzal, Terence Hamilton-Smith

Local

Advisory Board of the Lexington-Fayette Urban County Council Storm Water Management Committee
James C. Currens, John D. Kiefer

Lexington-Fayette Urban County Government Greenspace Commission
John D. Kiefer

Lexington-Fayette Urban County Government McConnell Springs Restoration Committee
John D. Kiefer: Chairman, Environmental Subcommittee

Lexington-Fayette Urban County Government Storm-Water Committee
John D. Kiefer

Lexington Living Arts and Science Center, Science Advisory Board
Stephen F. Greb

National Speleological Society, Blue Grass Grotto
James C. Currens: Director

University

Building Naming Committee
Donald C. Haney

College of Agriculture
James S. Dinger: Nonpoint-Source Assessment Advisory Committee
Gary K. Felton: Committee on Education in Environmental Engineering; Search Committee for Faculty Member in Surface-Water Hydrology

Department of Agricultural Engineering
Daniel I. Carey: Adjunct Assistant Professor
Gary K. Felton: Assistant Professor

Department of Geological Sciences
James C. Cobb, James S. Dinger, James A. Drahovzal: Adjunct Associate Professors
James A. Drahovzal: Adjunct Associate Professor, Graduate Faculty
David R. Wunsch: Instructor

Environmental Systems Program
James C. Cobb: Program Coordinator and Instructor
Donald C. Haney
John D. Kiefer: Course Instructor

Groundwater Center Committee
Donald C. Haney

Kentucky Center for Energy Research Advisory Board
Donald C. Haney

SB-271 Program
James S. Dinger: Advisory Committee; Coordinating Committee
Gary K. Felton: Coordinating Committee

United Way Cabinet
James C. Cobb: KGS Coordinator
John D. Kiefer: RGS Coordinator

PAPERS BY STAFF MEMBERS IN OUTSIDE PUBLICATIONS

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QUANTITATIVE MEASURES OF KGS ACTIVITY FOR 1994–95

Public requests answered	8,314
Coal and minerals	901
Water	1,100
Petroleum	6,313
Well Record Library inquiries	3,056
Phone	1,326
Visitors	1,730
Well records copied	20,150
Electronic-data disks and lists	108
Well-location overlays	644
Well logs copied (feet)	27,002
Wells processed	1,668
Wells computerized	6,829
Ground-Water Data Repository	844
Publication Sales	26,000
Maps sold	22,500
Publications sold	3,500
Earth Science Information Center requests	622
Map requests	224
Geodetic control	92
Aerial-photo information	66
Digital map information	22
Publication information	193
Satellite imagery	18
Radar imagery	7
Editorial, manuscripts processed	137
KGS publications	36
Journal/symposium articles	40
Abstracts/other papers	61
Committees, boards, societies	99
International	2
National	44
Regional	5
State	30
Local	6
UK	12
Contract and grant reports	15
Talks to civic and professional groups	93
Papers to symposiums and journals	65
Visits to schools, mineral shows, and science fairs	28
Academic	
Graduate committees	18
Ph.D.	6
M.S.	12
Classes and short courses taught	14
Project proposals submitted	30
Grants and contracts in force	25
State and Federal grants: 11 active, totalling $789,210/year	
Grants with other units of UK: 10 active, totalling $498,313/year	
Grants with industry: 3 active, totalling $173,104/year	
New awards: 5 total	
Conferences, symposia, and field trips sponsored	8
Well Sample and Core Repository visitors	137
Inquiries	973
Cores sampled	20
Core data provided	582
Topographic map revisions	20

Mission Statement

The Kentucky Geological Survey at the University of Kentucky is a State-mandated organization whose mission is the collection, preservation, and dissemination of information about mineral and water resources and the geology of the Commonwealth. KGS has conducted research on the geology and mineral resources of Kentucky for more than 150 years, and has developed extensive public data bases for oil and gas, coal, water, and industrial minerals that are used by thousands of citizens each year. The Survey's efforts have resulted in topographic and geologic map coverage for Kentucky that has not been matched by any other state in the Nation.

One of the major goals of the Kentucky Geological Survey is to make the results of basic and applied research easily accessible to the public. This is accomplished through the publication of both technical and non-technical reports and maps, as well as providing information through open-file reports and public data bases.