Kentucky Geological Survey

1995-1996

ANNUAL REPORT

KENTUCKY GEOLOGICAL SURVEY
Donald C. Haney, State Geologist and Director
UNIVERSITY OF KENTUCKY, LEXINGTON

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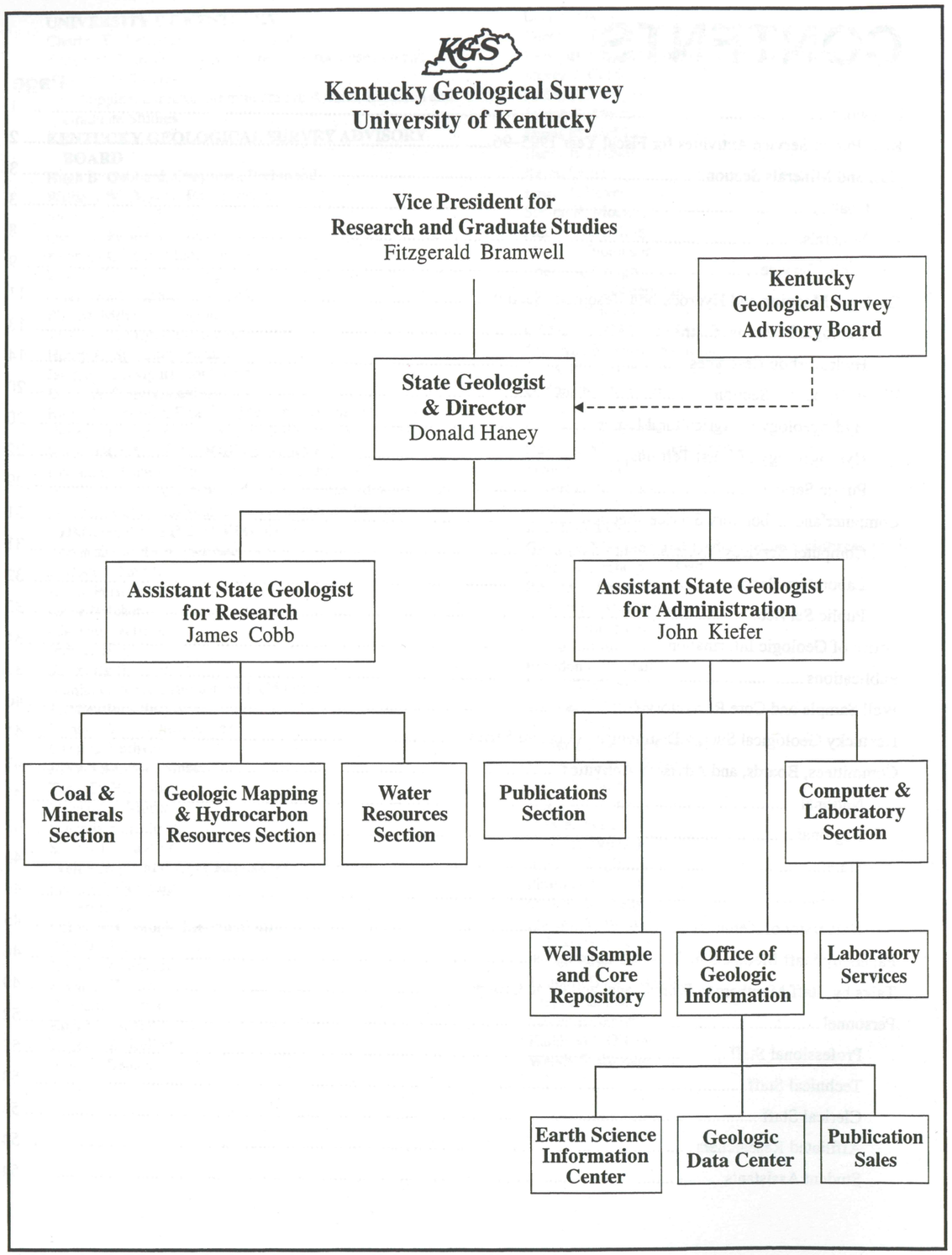


Mission Statement

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 databases 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 nontechnical reports and maps, as well as providing information through open-file reports and public databases.

FOREWORD

This annual report provides a summary of the activities of the Kentucky Geological Survey (KGS) during the past fiscal year (July 1, 1995–June 30, 1996). Virtually every sector of society requires information about the Earth: its resources, geologic hazards, and environments. The Survey has a long tradition of commitment to public service. KGS staff members provide technical support to numerous Federal and State agencies and serve on 104 committees, boards, and professional societies concerned with coal, water, oil and natural gas, industrial minerals, and geologic hazards. The Survey's public databases on energy, mineral, and water resources are continuously updated and are used by thousands of citizens, private industry, and government agencies each year. Geologists at the Survey gave 143 presentations to professional, government, public, and academic groups during the fiscal year and responded to over 12,000 inquiries.

As part of its commitment to public outreach, the KGS launched a World Wide Web site on November 30, 1995. Located at http://www.uky.edu/KGS/home.htm, the web site has information on rocks, minerals, and fossils of Kentucky, databases and publications available at the Survey, and a summary of research projects. The site is visited by an average of 65 people daily. More than 12,000 people visited the site from January through June 1996. This is a strong indication of the value to the public of the information now accessible on the KGS home page.

The task of characterizing Kentucky's geology and resources continues to evolve as the Survey responds to the public's constantly changing requirements for geologic and resource information. The Survey has a diverse research program that includes the study of coal resources, industrial and metallic minerals, oil and natural gas, and water resources and hydrology. New projects established in the past fiscal year were made possible by grants from Federal, State, and other agencies. The Survey's expertise in coal resource assessment and coal quality analysis is internationally respected. The Kentucky Coal Resources Information System established and maintained by Survey staff is one of the largest publicly available coal databases in the United States. The Survey's expertise in topographic mapping was recognized by the Federal government when the Geologic Mapping and Hydrocarbon Resources Section was given responsibility for a major program to digitize Kentucky's 7.5-minute geologic quadrangle maps for use in geographic information systems. This project is part of a cooperative program with the U.S. Geological Survey and is expected to be an ongoing effort in the rapidly expanding field of digital geologic maps and on-demand map production. The Water Resources Section continues to play a vital role in the State in numerous areas of research: karst hydrogeology, coalfield hydrology, nonpoint-source pollution, and water supply assessment. KGS scientists also participated in four research consortia: the Illinois Basin Consortium, the Central United States Earthquake Consortium, the Ohio River Basin Consortium for Research and Education, and the Appalachian Basin Coal Consortium. Further details of the Survey's projects and research results are found in this report.

KGS PUBLIC SERVICE ACTIVITIES FOR FISCAL YEAR 1995–96

Inquiries responded to	**12,873**
Coal and Minerals Section Professional Staff	1,011
Geologic Mapping and Hydrocarbon Resources Section Professional Staff	1,950
Water Resources Section Professional Staff	138
Kentucky Ground-Water Data Repository	1,169
Geologic Data Center visitors and phone inquiries	1,515
Field Office in Henderson, KY	1,383
Publication Sales Office	5,045
Earth Science Information Center	662
Oil and gas well record products sold	**28,122**
Well records copied	27,221
Electronic-data disks and well lists provided	198
Computer-generated overlays to topographic maps	703
Copies of electric logs and miscellaneous maps (number of feet)	**41,698**
Data entry or new records received for oil and gas well records (number of wells)	**3,418**
Well Sample and Core Repository	
Telephone Inquiries and Visitors	715
Samples analyzed by Laboratory Services Section	**1,461**
Fuels	478
Water	983
Kentucky Geological Survey publications completed	**10**
Publication and map sales	**27,797**
Publications sold	10,137
Topographic Maps	13,710
Geologic Quadrangle Maps	3,950
Talks to civic and professional groups	**143**
Papers by staff members in outside publications	**56**
Committees, boards, and societies served on	**104**
National	39
Regional	7
State	40
Local	7
University of Kentucky	11
Grants and contracts in effect	**25**

COAL AND MINERALS SECTION

Coal

Coal has long been Kentucky's leading mineral industry in terms of revenues generated and employment. The Kentucky Geological Survey has been conducting research to promote Kentucky's coal resources since the beginning of the Survey in 1838. In the 1980's, the Kentucky Geological Survey completed its most recent calculations of the original resource of surface and near-surface coals in the Commonwealth. These original resources were calculated to be 41 billion tons for the Western Kentucky Coal Field and 64 billion tons for the Eastern Kentucky Coal Field. A total of 7.5 billion tons of coal has been produced from Kentucky's coal fields. Subtracting mined coal and coal lost in mining (5.1 billion tons) from the original resources leaves 92.4 billion tons of remaining resources. Deep coals (below drainage) were not evaluated because of the lack of subsurface data.

Ongoing research at KGS is examining the availability of the remaining coal resources in Kentucky. The remaining resource is subdivided into several categories: coal available to mining using current mining technology; coal currently restricted from mining because of technological limitations; and coal not currently mined because of land-use restrictions. Land-use restrictions are minor compared to technological limitations (Figs. 1 and 2).

Given the current technology, it is predicted that mining of the remaining available surface and near-surface coals can continue for only a few more decades at present rates of production and current prices for coal. But Kentucky's vast amounts of remaining coal resources that are not currently mineable using standard technology could be mined if new technologies are developed. The biggest factor affecting development of new coal-mining technologies is economics; if the price of coal increases, then new technologies will be developed, and previously unmineable resources will become mineable.

Three technological limitations are, by far, the greatest for mining of the remaining resources: coal in small reserve blocks; coal too thin to deep mine; and coal "sterilized" by mining (i.e., coal within 40 feet vertically of an already deep-mined seam).

The most significant technological limitation is coal too thin to deep mine. Most of Kentucky's substantial remaining coal resources are thinner than 42 inches. Although a few deep mines are mining coal in this category, such coal deposits can be difficult to mine. Coals from 14 to 26 inches thick are not deep-mined without taking part of the roof in the process; generally, only metallurgical-grade coals, which bring a high price in the marketplace, are mined using this method (e.g., Blue Gem coal). New methods need to be developed to economically mine the huge resource of thin coal beds. Some companies that design mining equipment are planning for mining thin-seam coals.

Companies mining sterilized coal face several challenges. First, if an older mine has subsided, the roof, coal, and floor of the overlying coal will be broken up and no longer flat lying. In such cases, mining could be physically impossible and dangerous. Second, pillars of the newer overlying coal, which carry the weight of the entire overburden, might punch through the roof of the lower mine. This can also happen during mining below a pre-existing mine. Room-and-pillar mining below or above older room-and-pillar mines can be done, but requires vertically aligning (matching) pillars to distribute the stresses safely. Matching pillars requires having accurately surveyed maps of the older mine. In some cases, accurate maps do not exist and other methods will have to be developed to provide these maps. Surveying unvented old mines could be hazardous. Remote-sensing technologies might be developed that differentiate between coal pillars and mining voids through tens of feet of rock so that maps could be made without entering old mines. Robotic surveyors could also be used to enter old mines to make these maps.

During the past 20 years, most KGS coal-resource research has been based on 7.5-minute quadrangles. Coal-availability studies have concentrated on all coals

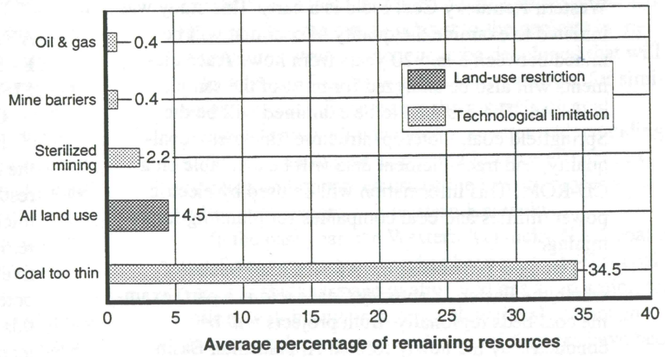


Figure 1. Representative eastern Kentucky mining restrictions based on eight quadrangles.

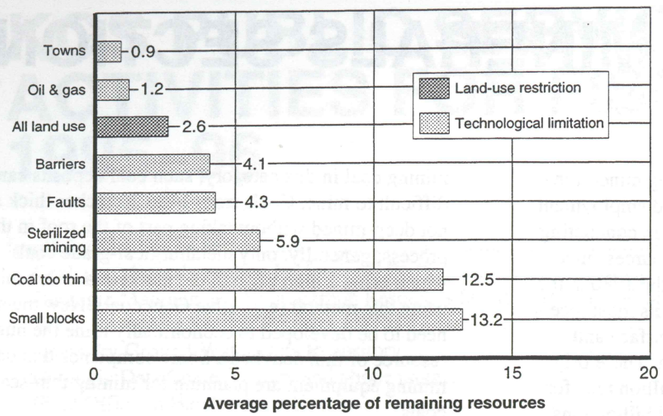


Figure 2. Representative western Kentucky mining restrictions based on seven quadrangles.

occurring in a few quadrangles selected to represent coal-producing regions. Information gathered from these few highly detailed quadrangle studies is now being used to help understand coal beds on a regional scale. Regional-scale coal maps will be useful for exploration and planning of future mines. Several new studies have begun that examine characteristics of coal beds at the scale of coal basins. These coal-basin studies gather information on outcrop area of coal beds, mined-out areas, thickness and structure of coal beds, zone relationships, resources, and quality. Among the products of these studies will be coal-bed atlases that illustrate all these features. The information used in these studies will be compiled in a geographic information system (GIS) and will be made available electronically and in paper publications.

The first of these regional studies is the Illinois Basin Consortium's Coal Quality Program. In this study, the Illinois, Indiana, Kentucky, and U.S. geological surveys are compiling maps for five of the most important coal beds in the Illinois Basin (of which the Western Kentucky Coal Field is a part). This study was initiated to examine the quality of coal that will be mined between 5 and 20 years from now. Trace elements will also be analyzed for most of the samples collected. The first bed to be examined will be the Springfield coal. Outcrop, structure, thickness, coal-quality, and trace-element data will be available on a CD-ROM. This information will be used by electric power utilities and coal companies for planning future mining.

Two new projects in the Appalachian Basin (of which the Eastern Kentucky Coal Field is a part) examine coal beds regionally. Both projects will be conducted by the newly formed Appalachian Basin Consortium, composed of the U.S. Geological Survey and the state geological surveys in the Appalachian region. The first of these projects is the National Coal Resource Assessment, sponsored by the U.S. Geological Survey. KGS has begun compiling information for maps of five important coal beds (Pond Creek, Fire Clay, and Upper Elkhorn Nos. 1, 2, and 3) in eastern Kentucky. Information such as bed outcrop, structure, thickness, zones, mined-out areas, and coal quality will be collected and mapped for each of these five coals. The U.S. Geological Survey will then combine these maps with other maps compiled by adjoining state surveys.

The second consortium project is the National Coal Quality Assessment Program, which will be partially funded by the Electric Power Research Institute and several utilities. KGS will be drilling and sampling coals in eastern Kentucky for quality and trace-element analysis. These new coal-quality data will be gathered from areas that will be mined within the next 5 to 20 years. The coal-quality data will be used to supplement data on the regional coal-bed maps produced by the USGS National Coal Resource Assessment Program.

The Kentucky Geological Survey also has projects on 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 databases 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 Survey also promotes technology transfer through workshops and publications.

Coal-Resource Assessment

AVAILABLE COAL RESOURCES IN THE EASTERN AND WESTERN KENTUCKY COAL FIELDS

Gerald A. Weisenfluh and Robert E. Andrews

In 1983, coal-resource estimates were completed for the Eastern and Western Kentucky Coal Fields. The results indicated that, for beds greater than 14 inches in thickness, 57 billion short tons and 38 billion short tons remained in eastern and western Kentucky, respectively. While these estimates of total resources suggest potential for mining to continue for hundreds of years, this potential may be greatly reduced if land-use and technological limitations 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 impact of mining restrictions. The research results will be valuable for planning the development of energy resources.

The KGS has prepared detailed coal-availability estimates in eastern Kentucky for nine of the 200 quadrangles in the region. These studies have shown that average mined-out tonnages represent only about 10 to 12 percent of the original resource estimates. However, the studies 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. In this coal field, large portions of the original estimates are represented by coal beds that are too thin to mine by modern underground-mining technology. Moreover, much of the available coal will be at greater depths than that being mined at the present time.

In western Kentucky, detailed estimates by quadrangle are still being prepared. Two quadrangles were completed this year and two more are planned for the coming year. In this region, a significant part of some coal beds has been rendered unmineable because overlying or underlying coal beds have been previously mined. Also, as in eastern Kentucky, some coals have been extensively mined out. As a result of differences in physiography and mineral ownership, larger mines are favored, and small mine blocks are a significant impediment to the economic development of coal. Finally, there are significant areas in western Kentucky where important coals will occur at depths greater than is economically mineable.

Results from the quadrangles studied, when completed, will be applied to new regional studies designed to determine the remaining and available coal resources for both coal fields.

DEEP-COAL AND ENERGY RESOURCES OF THE WESTERN KENTUCKY COAL FIELD

David A. Williams and Stephen F. Greb

Western Kentucky coal production is increasingly dependent on underground mining. Although information from operating mines can aid in understanding the local subsurface resources, subsurface data taken from mines not currently operating are also needed to accurately assess future coal and energy resources. By comparing subsurface data from recent mining operations with borehole data from other parts of the coal field, an improved understanding of coal-bed depth, thickness, and quality can be achieved. Because many of the currently mined coals in western Kentucky continue into surrounding states, comparisons with subsurface data from Indiana and Illinois can also assist in understanding the deep-coal and energy resources in western Kentucky.

The Kentucky Geological Survey has entered into a multi-year cooperative investigation with the Indiana Geological Survey, the Illinois State Geological Survey, the U.S. Geological Survey, the Electric Power Research Institute, and other industry organizations to identify and characterize deep-mineable resources in the Illinois Basin, which includes the Western Kentucky Coal Field. Data from all three states are being gathered to develop basinwide maps and databases delineating coal elevation, total coal thickness, clean-coal thickness, sulfur content, ash yield, and trace-element content of the major producing seams in the basin.

To date, more than 4,400 borehole descriptions have been computerized and correlated; this information will be used to plot thickness and elevation data for the Springfield (W. Ky. No. 9), Herrin (W. Ky. No. 11), and Baker (W. Ky. No. 13) coals in western Kentucky. The same coals are being investigated in Illinois and Indiana. Trends of thin, absent, and split coal are being identified. By mapping these coals on a regional scale, trends for specific characteristics that may be apparent in part of the basin may be projected into other parts of the basin where fewer data are available. In addition, the compilation of data into a common database will guide future exploration of deep coals by showing where existing data occur and where more data are needed.

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

Stephen F. Greb and David A. Williams

Most of the coal currently mined in western Kentucky is high in sulfur content, averaging well above the threshold of 1.2 pounds of SO_2 per million Btu required by the Federal Clean Air Act. Washing and other processes remove sulfur and ash from raw coal and improve western Kentucky coal quality, but even the cleaned coal is usually above compliance limits. Low-sulfur coals are mined in western Kentucky, but are not widespread. Because areas of low-sulfur coal are not widespread, they have not been widely investigated, and are poorly understood. To understand the controls on these better quality coals, the coals need to be sampled as they are mined. If the quality of the coal in a specific area can be related to the geology of the surrounding strata, a model can be developed that will help delineate future areas that have potential for similar quality coal. Even where the controls on coal quality are not well understood, a better understanding of the surrounding strata can aid in more efficient excavation and improved use of the low- to moderate-sulfur coal resources in western Kentucky.

In the past year, the Western Kentucky No. 4 coal of the Tradewater Formation has been studied. This coal varies in thickness and quality, and has a reputation for rolling (exhibiting undulating elevations). Although data are still being collected, several features have been noted. Many of the rolls or dips in seam elevation noted in surface mines are related to small faults. Some

of these faults cause small downdrops (grabens). The coal often thickens and decreases in quality on the downthrown side of the grabens. These local thickness and quality changes appear to be related to broader, regional changes in coal quality. Rolls and dips pose significant obstacles to mining at the surface and underground. An understanding of these features at the surface, where they can be easily observed, will aid in their identification in the subsurface, and lead to safer and more efficient use of the better quality coal in the future.

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

Stephen F. Greb

More than 70 percent of Kentucky's annual coal production is from the Eastern Kentucky Coal Field. Production comes from more than 60 coal beds. Although coals in eastern Kentucky are generally lower in sulfur content and ash yield than coals in western Kentucky, coal thickness, coal quality, and the ability to mine are highly variable. A better understanding of the variability of these important characteristics can be obtained from surface exposures of coal-bearing strata. Often, coal and roof traits uncovered at the surface can be used to characterize various aspects of coal mineability in the subsurface, where access to the coal is limited. Coal-bearing strata are continually being exposed by surface mining, deep mines, drilling, and road construction. Many of these manmade outcrops are only exposed for a short period before being reclaimed or overgrown. Therefore, it is important to gather data on the coal and surrounding strata from these sites. These data provide valuable information for future underground mining. New surface data on significant coal-bearing strata are collected and added to KGS databases. Collecting these data can help industry and resource planners better develop coal resources in the Eastern Kentucky Coal Field.

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, with a long mining history. Most of the mining has been concentrated in areas where the coal is most accessible, and the easily recovered resources are being depleted. Barring changes in coal markets, or new technology, 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 entered in KGS relational databases for public use. A computerized database of 5,950 subsurface records has been compiled, and is continually updated as new data are gathered. These records are used to correlate coal beds and determine bed thickness and elevations across the coal field. This task is complex, since many of the mined coals in eastern Kentucky occur in zones, and splitting of individual beds is common within a zone.

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 can be hazardous in deep mines, but is valuable as a fuel. Data are being accumulated to assess the potential for future coal-bed-methane production in eastern Kentucky. Very little data exist on gas content of Kentucky coals, but gas content can be calculated using a standard formula. Data from 704 records in the KGS Coal-Quality Database were used to calculate estimated gas contents for coals from both coal fields. Coal beds in both of Kentucky's coal fields were found to have coal-bed-methane potential.

COAL ATLASES FOR KENTUCKY

Gerald A. Weisenfluh, Ernest E. Thacker, Robert E. Andrews, and Stephen F. Greb

"Available Coal Resources in the Eastern and Western Kentucky Coal Fields" (see above) has identified the need to conduct resource analyses on a regional basis. This is because the quadrangle studies tend to be heavily influenced by local factors. While the quadrangle method has been successful in identifying important issues facing the future of the coal industry, better estimates of available coal will be obtained from regional studies. With this goal in mind, the Kentucky Geological Survey will be participating in the U.S. Geological Survey's National Coal Assessment Program, which will compile basinwide coal-resource and mining data for the most important coal beds. The selection of the coal beds to be studied was based on past production history, and production potential. They are the Pond Creek, Fire Clay, Upper Elkhorn Nos. 1, 2, and 3, and probably the Hazard No. 5A, and their equivalents. Coal availability factors will be incorporated into these regional resource studies so that the characteristics of coal to be mined in the future can be identified.

At this early stage in the project, outcrop data have been collected for the Pond Creek and Fire Clay coals in eastern Kentucky. Plans are being made to either scan or digitize maps showing these data so that outcrop information can be incorporated into a GIS and used for resource analyses. Other information, such as mined-out areas, bed thickness, bed structure, coal zones, and coal quality, will also be incorporated into these maps.

Coal-Mining Geology

MINEABILITY OF KENTUCKY COALS

Stephen F. Greb, Gerald A. Weisenfluh, and David A. Williams

In this project, mine sites are investigated to document coal thickness, coal quality, and trends in mine roofs and floors in both the Eastern and Western Kentucky Coal Fields. Data on geologic features such as faults, cutouts, splits, and roof falls must be collected as they are encountered so that their size, shape, and trends can be accurately documented. These data can then be used to help identify similar geologic problems in other mines. In some cases, trends of specific features can be projected in advance of mining so that potential geologic obstacles can be anticipated in future mines.

In eastern Kentucky, mines in the Fire Clay, Fire Clay rider, Taylor-Copland, and Hazard No. 8 coals were visited during the year. In the Fire Clay and Fire Clay rider coals, linear changes in thickness that appear to be related to underlying structures were encountered. These structures also locally influenced the position of paleochannels in the roof strata. The channels, in turn, created cutouts of the coal and in some cases, contained paleoslumps (ancient stream bank collapses), which caused extremely poor roof conditions. Because the trends of these features are structurally related, their occurrence could be projected into unmined areas to aid future mine planning. Investigations of contour surface highwalls above the Hazard No. 8 coal have shown a consistent trend in fractures that may also be related to regional structures. In addition, the coal appears to be overlain by quartz-rich sandstones (atypical for this stratigraphic interval of the Breathitt Group) that are much harder than sandstones above other coals in the same area.

In western Kentucky, mines in the Deanfield, Elm Lick, Mannington (W. Ky. No. 4), Springfield (W. Ky. No. 9), and Herrin (W. Ky. No. 11) coals were visited in the past year. Floor dips or rolls were noted in both the Mannington and Springfield coals. Some of these features are quite extensive—more than 2,000 feet in length. Characteristics of these features are being compiled to predict dips into unmined areas. Apparent fractures, called "slips" by miners, have also been recorded in the Springfield and Mannington coals. These linear roof fractures may be more than 500 feet in length. Trends of slip orientations are being compiled to predict fracture trends into unmined areas. The dominant north-south trend of these fractures is related to the regional stress field of the basin, and can be alleviated by aligning mine headings obliquely to the stress field. Secondary trends appear to be related to local structures and sandstone paleochannels in the roof, which vary considerably.

APPLICATION OF GEOGRAPHIC INFORMATION SYSTEMS TO COAL-FIELD GEOLOGY

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 various coal companies, the Kentucky Geological Survey has completed 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. This project used a geographic information system to evaluate various industrial uses, wetlands and wildlife management, reforestation, and forestry products.

A database listing the locations of existing surface-mined lands for the Hazard No. 9 and Taylor coal beds was compiled for Martin County. The Hazard No. 9 coal bed outcrop and locations of surface mines were plotted at a scale of 1:62,500. Other information plotted included land-use criteria such as population centers, surface-water runoff, power lines, sewer lines, and transportation networks. These data were compiled and manipulated in a GIS. Other features such as roads, streams, and oil and gas wells were also plotted. These data will be used by other agencies to determine the best use of these surface-mined lands.

Coal Quality and Petrography

COAL-QUALITY CHARACTERISTICS OF MAJOR MINEABLE COAL BEDS IN KENTUCKY

Cortland F. Eble

The Federal Clean Air Act Amendments of 1990 pose many challenges to the coal-producing and -utilization industries in Kentucky. The amendments have placed limitations on the amount of sulfur dioxide that can be emitted during coal combustion. Much of the coal in the Western Kentucky Coal Field, which has a moderate to high sulfur content, cannot be burned without specialized pollution-control devices. Nearly half of the coal-fired generating facilities in Kentucky are equipped with pollution-control devices, which allow utilities to burn high-sulfur coal in an environmentally safe manner.

In the year 2000, the Clean Air Act Amendments will require a further reduction in sulfur emissions from coal-fired power plants. At that time, both in-state and out-of-state utilities will be faced with some difficult decisions. Do utilities install more scrubbers and continue to burn moderate- to high-sulfur Kentucky coal? Or do they switch to low-sulfur coal exclusively? If utilities opt for the second strategy, will there be

enough low-sulfur reserves in Kentucky and adjacent Appalachian states to meet the increased demand, or will the utilities have to start importing low-sulfur coal from the western United States? These issues will have an impact on the coal-mining industry and the consumers of electricity generated from coal-fired power plants in Kentucky.

Another issue that may affect the electric utility industry, and ultimately the consumer, is environmentally sensitive elements in coal and their potential emissions regulation by the Environmental Protection Agency. Title III of the Clean Air Act Amendments of 1990 (which addressed acid rain deposition) cites 15 elements that naturally occur in coal as being potentially harmful if emitted to the atmosphere during coal combustion. To date, no recommendation has been made to monitor elemental emissions from coal-fired power plants. However, any future regulation is likely to have some impact on Kentucky coal as utilities implement reduction strategies.

The Kentucky Geological Survey has three active programs that address the issue of element occurrence and variability in Kentucky coal. The first project, which is in its second year and is a cooperative effort between the Kentucky Geological Survey, Kentucky Utilities (KU), and the U.S. Geological Survey, samples feed coal and combustion by-products from KU's largest coal-fired power plant (more than 2,000 megawatts) in Kentucky. Feed coal, fly ash, bottom ash, and limestone and gypsum (reacted) residue from flue-gas desulfurization are sampled, on a monthly basis, to document the fate and variability of Title III elements in coal during combustion in large industrial furnaces.

The second project samples, on a monthly basis, face-channel coal, run-of-mine coal, and preparation-plant waste products from a large underground mine in western Kentucky. The goal of this project is to gain a better understanding of the geologic controls on element occurrence and variability in one major, mineable Kentucky coal bed at the relatively small scale of a single mine.

The third project is a cooperative effort between the state geological surveys of Kentucky, Indiana, and Illinois, and the U.S. Geological Survey to identify and characterize economic coal reserves for future mining consideration. The results of this study will improve prediction of the amount and grade of coal that will be available for mining in the next 5 to 25 years.

The Kentucky Geological Survey continues to maintain and update a comprehensive, computerized coal-quality database that includes analytical data for more than 3,000 coal samples from both the Western and Eastern Kentucky Coal Fields. Many of these analyses include trace-element measurements. On an annual basis, the Survey's coal analytical laboratories, which have been in operation since 1989, analyze several hundred coal samples. 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 continuous updating and expansion of the already very large database so that it may better serve citizens and industry in the Commonwealth.

Minerals

Industrial and metallic minerals provide society with essential 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 to provide information on potential resources.

The demand for construction materials points out the need for a knowledge of resource distribution and quality. Growing requirements for construction aggregate in expanding urban areas are coupled with a combination of decreasing availability of aggregate from local, mostly surface, operations and an increasing resistance from citizens and government bodies to the opening of new extractive sites. KGS investigations have indicated that subsurface deposits of limestone and dolostone in the High Bridge Group (Ordovician) are potential sources of construction aggregate for the growing market in the northern Kentucky-Cincinnati region, but even the *proposed* opening of underground mines for aggregate production is encountering local resistance.

During this fiscal year, the section's mineralogist, Warren H. Anderson, was transferred to the Geologic Mapping and Hydrocarbon Resources Section of the KGS. The position Mr. Anderson held in the Coal and Minerals Section will not be filled. Accordingly, the status of several mineral projects has changed from active to inactive. Public inquiries concerning mineral identification and metallic mineral resources should be addressed to Dr. Garland R. Dever, Jr.

KGS is 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.

INDUSTRIAL LIMESTONE AND DOLOSTONE RESOURCES IN KENTUCKY

Garland R. Dever, Jr.

The availability of limestone and dolostone in Kentucky for industrial raw materials is being investigated by the Kentucky Geological Survey. Chemical quality of the stone is a critical factor in determining its suitability for industrial uses. The presence of high-calcium, high-carbonate, or low-silica stone in deposits thick enough to mine and currently being exploited for construction aggregate and agricultural limestone would permit producers to diversify their markets.

Geologic and economic aspects of the Fort Payne Formation in western Kentucky were studied by the Illinois State Geological Survey and KGS. Because of its relatively high silica content, higher than other carbonate rocks in western Kentucky, the stone from the Fort Payne can meet specifications for special uses, such as railroad ballast and skid-resistant aggregate.

During the course of a KGS project to determine the chemical quality of Mississippian limestones and dolostones in south-central and east-central Kentucky, variations in stratigraphic units were encountered across the region. Further investigation by KGS staff suggests that the variations in the distribution and thickness of carbonate units reflect the effects of coeval structural activity, mainly movement along faults. A completed report detailing conclusions of the study has been submitted for KGS publication.

NONFUEL-MINERAL STATISTICS

Garland R. Dever, Jr.

The Kentucky Geological Survey is completing a map (scale 1:500,000) of industrial and metallic mineral resources in the State. The map will show the principal distribution of selected deposits of limestone, dolostone, clay, shale, sand, gravel, and sandstone, and metallic and nonmetallic mineral deposits, as well as the location of active mineral-industry operations. Compilation of resource distribution was completed during the year. Final drafting of the map has started and will be finished in the 1996–97 fiscal year.

The Kentucky Geological Survey monitors the State's nonfuel-mineral industries and compiles information on industry activities and mineral-related government actions. This information is used to answer public-service inquiries and to prepare reviews. Summaries of 1995 industry activities and pertinent government actions in Kentucky were prepared for publication in *Mining Engineering* and in the U.S. Bureau of Mines' *Mineral Industry Surveys* and *Minerals Yearbook*.

The U.S. Bureau of Mines was abolished, but its minerals information functions were transferred to the U.S. Geological Survey in late January 1996. The *Mineral Industry Surveys*, *Mineral Commodity Summaries*, and *Minerals Yearbook* will continue to be published, and the Kentucky Geological Survey will continue to provide information for these reviews.

Public Service

EARTH SCIENCE EDUCATIONAL MATERIALS

Part of the mission of the Kentucky Geological Survey is to provide educational materials on earth science to the public. As the repository for coal, oil, natural gas, and water information, and the center for distribution of topographic and geologic maps, KGS has a wealth of material used in educational programs. 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 a few examples of the subjects addressed in KGS earth science education activities.

The number of requests for staff members to help in earth-science education across the Commonwealth has increased, and considering the popularity of earth-science topics, the demand for information will continue to grow. To accommodate 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 book that includes color photographs and descriptions of various rocks and minerals, describes 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 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.

During this fiscal year, KGS acquired a very large gypsum crystal from a local limestone company. This 1-ton crystal was carefully transported to the Mining and Mineral Resources Building at the University of Kentucky and set on a specially designed display stand in the foyer of the building. A press conference was held to unveil the specimen, and stories about and pictures of the specimen were carried in several newspapers. The specimen has great potential for educating children about mineral-forming processes.

PUBLIC ACCESS TO COAL INFORMATION AND COAL-DATA MANAGEMENT

Coal information is made available through formal publications, open-file reports, presentations to groups, and computerized databases. 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, resource, core-description, and coal-related engineering data. These data have been collected by

the Survey for the last two decades, and the databases 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 also added to the database. 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 database.

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. The Kentucky Geological Survey houses spore samples (maceration residues) of thousands of Kentucky coal samples, and maintains slides with the spores and pollen on them so they can be viewed under the microscope.

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, 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 recently discovered amphibian skeleton has been sent to Texas to be prepared and studied by a vertebrate paleontologist. After scientific study has been completed, the specimen will be returned to Kentucky, where it will be put on display. This skeleton is the first fossil amphibian skeleton found in Kentucky.

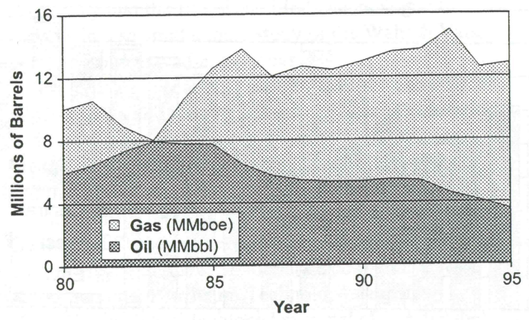
Elementary school students examine a mineral under a microscope.

GEOLOGIC MAPPING AND HYDROCARBON RESOURCES SECTION

The Petroleum and Stratigraphy Section was renamed the Geologic Mapping and Hydrocarbon Resources Section in 1996 to reflect a major change in the section's activities. The section has been charged with a major new program to digitize Kentucky's 7.5-minute geologic quadrangle maps for use in geographic information systems. The new activity is part of a cooperative program with the U.S. Geological Survey and is expected to be a long-term effort. The previous activities of the section in the areas of oil and natural gas will not change, and hydrocarbon-resource research and public service will remain important parts of the section's responsibilities.

In addition to its mapping responsibilities, the Geologic Mapping and Hydrocarbon Resources Section provides research and service relating to the exploration and development of natural gas and oil resources of the State. Regional geologic research is vital to understanding the stratigraphic and structural framework of the State. Such knowledge is critical in understanding the character and distribution of energy and mineral resources, as well as the geologic aspects of environmental issues.

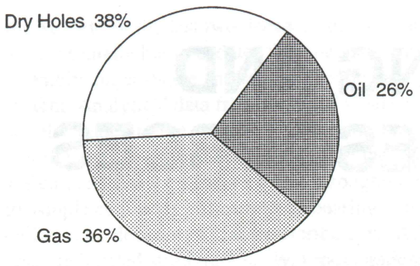
The value of geologic maps to society is considerable. The Earth is often considered static. The mountains and rivers that cross the landscape, and the bedrock that supports the surface, usually change little during the course of a lifetime. Geologic and hydrologic processes are, however, dynamic. Earthquakes, landslides, floods, and drought influence our lives. Human activities, in turn, can alter the geologic history of an area and affect the occurrence and impact of natural hazards. For example, changes in land use can induce changes in erosion, sedimentation, and groundwater supply. Information describing the physical world is critical for identifying solutions to land use and environmental issues. Geologic maps provide useful information for these purposes. GIS is a powerful tool for organizing and rapidly accessing information, which can be used for timely solutions and construction of models that can be applied to specific resource and environmental problems. Digital geologic information is an important building block in such systems. For these reasons, digital geologic mapping is being emphasized at the KGS.



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

Oil and natural gas continue to be important commodities for the Kentucky economy. In 1995 oil and natural gas production value was more than $180 million, bringing more that $8 million in severance taxes to the State. Nationally, the industry remains in a slump that extends back to 1986, although natural gas production has been rising the last several years. Natural gas production in Kentucky rose 2 percent in 1995 to 74.8 billion cubic feet (Bcf). Natural gas prices generally increased through the end of 1995 because colder weather during the year increased demand. Oil production continued its decline, falling 13 percent below last year's level to only 3.56 million barrels (MMbbl) in 1995. Most of the State's oil and natural gas production comes from stripper wells. In 1995, nearly 3 MMbbl of stripper oil were produced and 206 stripper wells were abandoned. In the same year, stripper-gas production accounted for 66.4 Bcf of natural gas, and 57 stripper gas wells were abandoned.

The activity summarized in this report is compiled on the basis of wells drilled, completed, and reported during the 1995 calendar year. Drilling activity in Kentucky increased 9 percent to 375 wells reported complete; overall success rate was 66 percent. During the year, 957 permits were issued, a drop of about 2 percent from a year ago. Only 12 exploratory wells were reported drilled, but this drilling resulted in the discovery of three new fields and pools, three deeper pools, and seven extensions of existing pools. Total footage drilled during the year was slightly down from the previous year to 737,000 feet, with an average well depth of 1,965 feet.



Well completions in Kentucky in 1995.

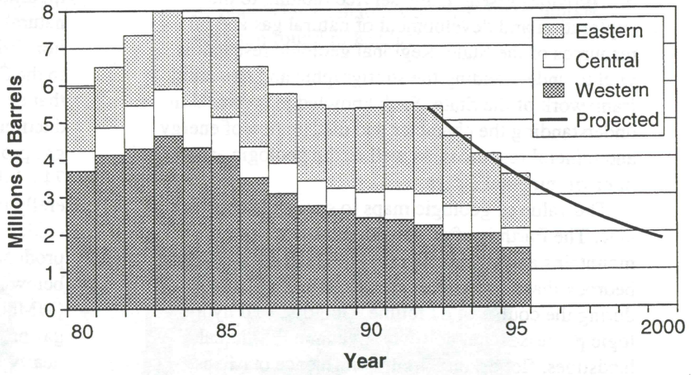
The Appalachian Basin of eastern Kentucky continued to produce the most oil and natural gas; Leslie County produced the most oil (543,000 barrels) and Pike County the most natural gas (26.3 Bcf). Edmonson County in west-central Kentucky accounted for the most permits: 228 permits issued in 1995. The Illinois Basin continues to have less activity and production than in the past.

The Devonian Clear Creek play in Edmonson County, west-central Kentucky, continues to be active. Oil production in the county increased nearly 80 percent to 129,000 barrels, propelling Edmonson County into the top 10 oil-producing counties in the State. The play continues north to the boundary of Mammoth Cave National Park, and is being extended into neighboring Hart County. 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.

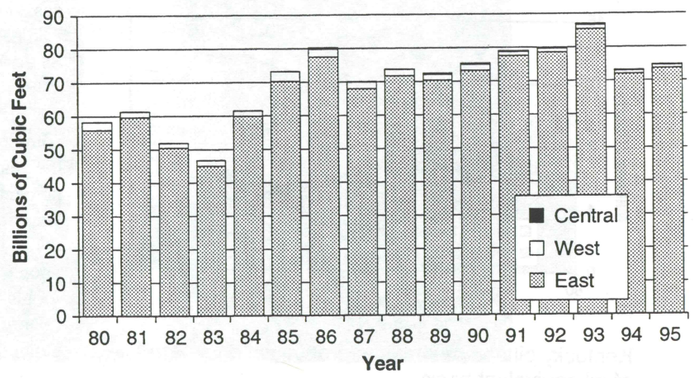
Another potentially important play is developing as the result of a natural gas discovery in 1994 in the Cambrian Rome Formation of southeastern Elliott County. The Carson No. 1 Kazee well is producing about 0.5 million cubic feet of natural gas per day at 6,258 to 6,270 feet. Deep well spacing units have been established, one other well has been drilled, and a second well has been permitted. Results from these other wells remain confidential. Logs from both of the deep Conoco tests in the Rough Creek Graben of western Kentucky in McLean and Grayson Counties are now available to the public. Both Kentucky tests, and 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 production during the past year, hydrocarbons still represent an important State and national resource. Hydrocarbons will be important bridging fuels well into the 21st 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 natural gas markets during the next decade will be electric power generation. Strong industrial demand is expected to increase annual U.S. natural gas consumption to 21 Tcf (trillion cubic feet) by the year 2000, outpacing the growth rate of all other energy sources. The U.S. Department of Energy (DOE) has recognized this potential and increased natural gas-related research funding by more than 2 percent for fiscal year 1996 (the only program to show an increase), despite massive cuts in other parts of the program. DOE has also developed the Domestic Natural Gas and Oil Initiative, which focuses heavily on increased domestic natural gas production.

The value of natural gas production in Kentucky continues to outstrip the value of oil production by a margin of more than 2 to 1. The State has large un-



Kentucky oil production, 1980–2000.



Kentucky natural gas production, 1980–95.

tapped natural gas resources that include a possible emerging coal-bed methane resource. 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, and could provide 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 natural gas from known domestic reservoirs is being recognized as an important source for the future domestic energy supply. Compiling oil and natural gas databases 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 deep basins in Kentucky are potentially important natural gas provinces. Companies are examining recently available reflection seismic data for the Rome Trough and the Rough Creek Graben and discussing natural gas exploration strategies. The Geologic Mapping and Hydrocarbon Resources 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. Surface and subsurface geologic information is key to several environmental issues, including earthquake risk, potential deep-well waste disposal, ground-water pollution, and NORM (Naturally Occurring Radioactive Material) associated with oil and natural gas production. The Geologic Mapping and Hydrocarbon Resources Section is currently participating in the University of Kentucky's Seismic Network to monitor earthquake activity in the State and, in particular, the western Kentucky part of the New Madrid Seismic Zone. Seismic hazards for municipalities and public works in western Kentucky are also being assessed. The section is also participating with the U.S. Geological Survey and the Illinois and Indiana geological surveys in a seismotectonic study of the Wabash Valley Seismic Zone and adjacent areas.

The Geologic Mapping and Hydrocarbon Resources Section plays an instrumental role in various consortia with other state geological surveys (i.e., the Illinois Basin Consortium, the Cincinnati Arch Consortium, and the Appalachian Oil and Natural Gas Research Consortium). The section is cooperating with the U.S. Geological Survey in several research projects. The section is also involved in interstate cooperative research with the Petroleum Technology Transfer Council, which has developed regional offices for the Illinois and Appalachian Basins.

Geologic Mapping

DIGITAL GEOLOGIC MAPPING IN KENTUCKY

Warren H. Anderson, Thomas N. Sparks, and Lance G. Morris

This new cooperative project with the U.S. Geological Survey is part of the National Geologic Map Database. It will make Kentucky the first state in the Nation to be mapped digitally, which is appropriate given that approximately 18 years ago Kentucky was the first major state in the Nation to have complete geologic map coverage at a scale of 1:24,000. The current project would not have been possible without the first project. When completed, the digital geologic quadrangle maps will be easily manipulated by computers and geographic information systems.

Large-scale maps are valuable for assessing Kentucky's natural-resource base; making site-specific assessments for coal-, mineral-, and petroleum-resource development; construction and urban development; engineering and planning studies; reclamation projects; water supply; and waste disposal. Large-scale paper maps are difficult to handle for regional geologic studies; digital geologic maps offer a greater variety of products. With digital geologic maps, researchers can segregate particular lithologic units, commodities, or geographic areas for study. In addition, quantitative attributes about these features, such as volumetrics and resource and reserve estimates, can be easily determined.

The initial phase of this project will concentrate on the Hazard District of the Kentucky River Basin. In the first year, 24 quadrangles from this district will be digitized. Plans call for another 137 quadrangles to be digitized over the following 2 years. The Kentucky River Basin area was chosen because it is rich in natural resources and is an economic base for the region. It is also the headwaters of the Kentucky River Basin, and the hydrogeology and environmental consequences of mining there can be easily examined.

The maps will be digitized from mylar stable-base composites. Using black-and-white scanning technology, raster image files will be generated and projected onto a computer screen. Selected raster files will then be semi-automatically vectorized. These vector files represent various geologic contacts and structure on the geologic maps. The files will then be referenced and entered into Arc/Info GIS software, where attributes will be assigned; adjacent quadrangle maps will be joined, and final map files will be plotted. Completed final maps will be produced at a scale of 1:100,000.

This initial phase of the project will be completed next year, and continuation of funding will be sought from the U.S. Geological Survey to complete the remainder of the quadrangles in the Kentucky River Basin before moving to other areas of the State.

Hydrocarbon Resources

GEOLOGY AND HYDROCARBON POTENTIAL OF THE CAMBRIAN GRABENS

James A. Drahovzal, David C. Harris, and Edward W. Woolery

The goal of this project is to gain a better understanding of the geologic evolution of the Cambrian Rough Creek Graben and Rome Trough as a means of evaluating their hydrocarbon (especially natural gas) potential. Several aspects of this study are being carried out concurrently, and have the overall goal of providing information on the pre-Knox interval of the two rift basins. This project includes several related studies that were formerly separate projects: "Stratigraphy and Sedimentology of Pre-Knox Sediments in the Rome and Rough Creek Grabens," "Seismic Processing and Interpretation of the Eastern Rough Creek Graben," "Regional Geology of the Kentucky-Ohio Trough," and "Regional Structural Cross Section, Illinois Basin, Western Kentucky." Regional reflection seismic data are being sought, particularly from major oil and gas companies.

Previous work on a deep well drilled by Conoco in the Rough Creek Graben in McLean County was presented at the Eastern Section of the American Association of Petroleum Geologists annual meeting in the fall of 1995. The results of this study, which will include a detailed well description, are being prepared for a KGS report that will be published in 1997. This initial work will be expanded into a joint project with the Illinois State Geological Survey to study all three deep wells drilled by Conoco in the Rough Creek Graben. This project is being conducted in cooperation with the Illinois Basin Consortium, and an annex agreement has been written outlining the project goals. Conoco has informally agreed to provide as much proprietary data as possible and is fully supportive of the project goals. Information to be contributed includes seismic data, thin sections of core and well cuttings, and digital log data. A summary report, to be prepared within the first year, will provide industry with basic data and interpretations from the three wells.

The results of a study on submarine basin-floor fans and fan deltas in the Rough Creek Graben, western Kentucky, was also presented at the Eastern Section of the American Association of Petroleum Geologists' annual meeting in the fall of 1995. These fan deposits constitute a potential natural gas reservoir facies in parts of both the Rough Creek Graben and the Rome Trough. A KGS report outlining areas of potential fan deposition is planned for next year.

As part of a cooperative seismotectonic research project with the U.S. Geological Survey, a basement map of the Wabash Valley is being compiled. Regional reflection seismic data, controlled by sparse deep-well data, have been used to interpret the top of the Knox Group, the base of the Knox Group, and the top of the Precambrian unconformity. A regional velocity model has been applied to the data to derive depth to the Precambrian unconformity. Contouring of the Precambrian surface is still being completed. The map will be completed in the fall of 1996, and will be published by KGS. The results of this study will be combined with maps of the Illinois and Indiana parts of the Wabash Valley area to produce a basement map for the entire area, to be published by the U.S. Geological Survey. The results of some of this work, outlining the evidence for three Precambrian-Cambrian rift sequences, were presented at the Seismological Society of America's annual meeting this spring in St. Louis.

Four manuscripts on the East Continent Rift Basin are being prepared, and will be published later in the year or in 1997; two of the manuscripts are in the review stage. One on the sedimentary petrology and one on the mafic rocks will be published by KGS. The third, on the structure based on potential field data, is being rewritten for outside publication. The fourth paper was presented at the Seismological Society of America's annual meeting in St. Louis and is planned to be developed into a paper for a special volume of *Seismological Research Notes* that will be issued next year or early in 1998.

A 1994 gas discovery in the Rome Trough in Elliott County resulted in several additional wells being drilled in the area in 1995 and 1996. Results of these new wells are still confidential, but a summary article was published in the *Oil and Gas Journal* in February 1996 to provide details of this deep gas play to industry. This paper may also attract industry funding for additional work in the Rome Trough. A preliminary top-of-basement structure map was also published by KGS for eastern Kentucky that will relate to future work on the pre-Knox interval in the Rome Trough and associated structures.

During the year, a U.S. Geological Survey Professional Paper was published on an interpretation of a northwest-oriented reflection seismic line extending from Caldwell County, Ky., through Hicks Dome in Illinois. This is the first in a series of interpretations for the Rough Creek Graben area, which is being studied by the Illinois Basin Consortium and the U.S. Geological Survey. Three other lines, all of which partially cross western Kentucky, are being interpreted by a group of scientists from the four geological surveys. A paper was given at the Eastern Section of the American Association of Petroleum Geologists' annual meeting in the fall of 1995 on the basin-floor fan deposits of the Rough Creek Graben and their possible natural gas resource implications. A preproposal to study the deep basin and the natural gas potential was presented to the U.S. Department of Energy in the winter of 1995. Discussions on the preproposal are under way with DOE and Conoco.

THE ATLAS OF MAJOR APPALACHIAN GAS PLAYS

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

This 3-year project was initiated October 1, 1991, with funding 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 database 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 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 on the Lockport-Big Six, Ordovician bioclastic carbonate, and pre-Knox plays have been prepared and submitted for Kentucky Geological Survey publication. The remaining reports written by KGS personnel will be submitted later for publication. The atlas is expected to be published in the summer of 1996.

GAS RESERVOIR CHARACTER OF DEVONIAN SHALES OF KENTUCKY

James A. Drahovzal and David C. Harris

This project is designed to provide a better understanding of the spatial distribution of high-yield natural gas zones within the State's Devonian gas shales and to stimulate the exploration and development of this important resource.

A proposal written in cooperation with faculty of the University of Kentucky Departments of Geological Sciences and Engineering was submitted to the National Science Foundation. The proposal requested the purchase of a trailer-mounted minivibrator to be used to acquire high-resolution p- and s-wave seismic reflection data. If funded, this instrument will be used to target potential Devonian shale reservoirs, particularly in western Kentucky. All other aspects of this study are currently inactive, pending outside funding and the necessary staff expertise.

STRATIGRAPHY AND RESERVOIR SEDIMENTOLOGY OF MISSISSIPPIAN CARBONATES IN KENTUCKY

David C. Harris and Thomas N. Sparks

The goal of this study is to interpret the stratigraphy, structure, depositional history, and geologic controls on hydrocarbon reservoir development and distribution in Mississippian limestones and dolomites in Kentucky. Phase I of the project, which covered the Appalachian Basin, was largely completed in early 1996 with the collection of stratigraphic data for a total of 7,713 wells; the data have been entered into a computer database. Products generated include structure maps and cross sections. The data and products have been transferred to the three participating companies. Upon collection of porosity data for some of the wells, Phase I will be complete. Maps and cross sections associated with the study are planned to be released for publication next year. Phase II, which would involve detailed study of three Big Lime fields, is currently inactive, but support for it is being sought.

TERTIARY OIL RECOVERY INFORMATION SYSTEM (TORIS) DATABASE ENHANCEMENT IN KENTUCKY

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

The U.S. Department of Energy developed the TORIS database for the purpose of characterizing the Nation's oil resources. Its goals were to (1) estimate potential domestic oil reserves, (2) project U.S. oil production potential, and (3) target research and development efforts on enhanced exploration, drilling, completion, and production technologies in order to exploit the existing domestic resource.

For Kentucky, TORIS currently contains data for only five oil reservoirs, all located in western Kentucky. The project identified 23 key fields 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. The total original resource in these fields is estimated to be 1.23 billion barrels of oil in place. Subtracting the known historical production of 223 million barrels, the remaining in-place resource is estimated to be in excess of 1 billion barrels.

The database and TORIS data summary sheets have been prepared and submitted to the U.S. Department of Energy. A project final report will be published by the Kentucky Geological Survey.

TERTIARY OIL RECOVERY INFORMATION SYSTEM (TORIS) DATABASE ENHANCEMENT IN WESTERN KENTUCKY

James A. Drahovzal, Brandon C. Nuttall, and Anna E. Watson

The TORIS project for western Kentucky is funded by the U.S. Department of Energy for the purpose of including a more representative portion of Kentucky's oil production in its national oil recovery database. The original TORIS database contains data for only five reservoirs in western Kentucky, which amount to only an estimated 4 percent of the original oil in place for the Kentucky part of the Illinois Basin. The five reservoirs are being re-investigated, and the original data will be revised. In addition, another five reservoirs have been chosen to be included in the study. Together, these 10 reservoirs will boost the reported original oil in place to an estimated 44 percent of the actual total for western Kentucky, much closer to the national average of 70 percent representation in the database.

A literature search has been conducted to obtain published data for the reservoirs. Consultants and major operators in each field have been requested to donate any available data (particularly production figures) to the project. Required data 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. During the next year, data collection and analysis will be completed, and the TORIS summary sheets will be submitted to the U.S. Department of Energy. Nonconfidential data and a bibliography will be placed on open file with the Kentucky Geological Survey.

GEOLOGIC MODELING OF FRACTURED CARBONATE RESERVOIRS IN CLINTON COUNTY, KENTUCKY

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

The goal of this project is to aid the oil industry in exploring for high-potential, but elusive, Lower and Middle Ordovician reservoirs. In particular, this project documents the results of a 2-year study that focuses on the geologic interpretation of a geophysical survey conducted by the Los Alamos National Laboratory.

The final report was completed and submitted to Los Alamos National Laboratory in December 1995. The report, entitled "Stress, Seismicity, and Structure of Shallow Reservoirs of Clinton County, Kentucky," concluded that some of the microseismicity associated with the producing horizon was the result of thrust faulting in response to the present-day stress field. The final report was placed on open file at the Kentucky Geological Survey.

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

James A. Drahovzal and Martin C. Noger

More than 60 percent of the hydrocarbons produced in Kentucky come from the Silurian–Devonian "Corniferous" (drillers' term) interval. Most of the oil and natural gas production is thought to be 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 Corniferous stratigraphy are critical in understanding its petroleum geology. In the past several years, additional well data have become available, and need to be integrated into an updated synthesis of the geology to develop successful hydrocarbon exploration models for the deeper areas.

Several studies dealing with Corniferous stratigraphy were completed as part of the Gas Atlas Project. These include studies of the Lower Devonian–Upper Silurian unconformity (Corniferous) and the Upper Silurian Lockport-Big Six plays. Reports on these plays will be published after July 1996 as part of the Appalachian Gas Atlas. Individual reports on both plays will be published by KGS later this year or next year. 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 local and regional interpretations. These studies will also provide information that should encourage secondary and tertiary oil recovery projects.

Further work on this project will require outside funding from industry or other interested groups.

TAR SANDS OF WESTERN KENTUCKY

James A. Drahovzal and Brandon C. Nuttall

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 are therefore of general significance to petroleum-geology research.

The tar sands have emerged as a significant element in a mass-balance study of hydrocarbons in the Illinois Basin carried out in cooperation with the Illinois Basin Consortium and the U.S. Geological Survey. A subsequent study conducted by KGS concluded that the tar sands demonstrate 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 were published as part of U.S. Geological Survey Bulletin 2137, "Feasibility Study of Material-Balance Assessment of Petroleum from the New Albany Shale in the Illinois Basin."

Additional cooperative work is under way with the U.S. Geological Survey to examine tar-sand samples and New Albany cuttings to determine a possible relationship.

The database on tar sands continues to be maintained, but further work with this resource will require additional staff and outside funding.

Regional Subsurface Geology and Geophysics

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 structure and isopach maps for the important geologic horizons and intervals within the Commonwealth. This information is critical not only for the energy and mineral industries of the Commonwealth, but also for environmental issues. Further, it will serve as a framework for future research by industry, government, and academia. An associated goal is to acquire additional geophysical data that may be available for the region. This project is 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.

Studies associated with the Wabash Valley project have resulted in a basement map being compiled for the Rough Creek Graben in western Kentucky. The map is based on existing deep-well and reflection seismic data, and will be published next year as part of a U.S. Geological Survey report. It will likely be expanded and published by KGS at a later date. These data, together with data from other projects, will be useful in the eventual production of a Statewide basement map. These maps are important to future oil and natural gas exploration in Kentucky.

A new gravity map has been published for the State. 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 sheet boundaries, the central and eastern sheets were never published. However, recent work has succeeded in matching contours and allowed the sheets to be combined. The gravity map was published as a single sheet at a scale of 1:500,000 in 1995.

Data collected as part of the regional Newman Limestone stratigraphic study are being interpreted. Structure maps of the top of the "Big Lime" (Newman Limestone) and the top of the Borden Group will be developed in 1996 and published in 1997 when the project's confidentiality agreement expires. Additional structure and isopach maps will be constructed in the future.

An important regional structure map for the Beech Creek Limestone Member of the Golconda Formation (Barlow Limestone) in the Illinois Basin will be made available as an open-file map in 1997.

New geophysical data-interpretation software was installed on the section's Sun workstation in early 1996. This software will allow processing and plotting of the expanding database of digital seismic data for use in regional mapping.

GEOLOGY ALONG KENTUCKY HIGHWAYS

Donald C. Haney and Martin C. Noger

The goal of this project is to illustrate the distribution of geologic units and note the prominent geologic features along important highways in Kentucky in a series of road logs. The publications will serve the public, and provide geologic information of value to academic researchers and resource and environmental geologists.

This project was given a lower priority in 1996 because of the large amount of drafting required for each road log. The Interstate Highway 64 guidebook will be published in 1996. The other guidebooks in progress will be published as time allows. These other guidebooks cover Interstate Highway 24/Western Kentucky Parkway/Bluegrass Parkway, AA Highway, Mountain Parkway, and Cumberland/Daniel Boone Parkways.

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 Networks," "Seismic Hazard Analysis in Kentucky," and "Representative Strong-Motion Stations in the New Madrid Seismic Zone."

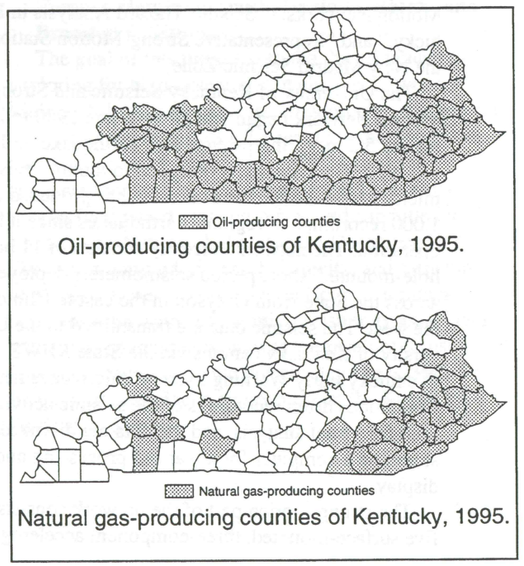
The University of Kentucky Seismic and Strong-Motion Network began operation in late 1980 following the 5.2 $m_{b,Lg}$ Sharpsburg, Ky., earthquake on July 27, 1980. The network is designed to monitor seismicity in and around the State, and has produced over 1,000 recordings of regional earthquakes since it began operation. The network currently 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 University of Kentucky 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 from the individual stations to the Seismic Lab at the University of Kentucky. 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 seismic station PAKY, all the stations in the network were in continuous operation during the 1995–96 fiscal year. Station VSAB was destroyed by lightning in July 1994. Operation of station PAKY was discontinued in September 1995, because the offices at the Paducah airport in which the telemetry equipment for the seismic station was housed were unexpectedly relocated across the airfield. The seismometer for station PAKY was installed in a 50-meter-deep borehole. Because there were no funds to drill a new hole, the station was abandoned.

During the 1995–96 fiscal year, a t-component strong-motion station was installed at the Kentucky Transportation Garage in Hickman, Ky. This station, funded by grants from the U.S. Geological Survey and the University of Kentucky Major Equipment Fund, is specifically designed to investigate the propagation of ground motions through the upper 22 meters of soil at the site. More specifically, recorded ground motions from earthquakes in the nearby New Madrid Seismic Zone will be compared with ground motions predicted from the seismic and geotechnical measurements made previously at the site. The strong-motion array is a state-of-the-art installation, and is expected to contribute significantly to efforts to improve the prediction of earthquake-induced ground motions throughout the Jackson Purchase Region.



Oil-producing counties of Kentucky, 1995.

Natural gas-producing counties of Kentucky, 1995.

Oil and Gas Data

OIL AND GAS MAPS

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

In an effort to update the oil and gas maps of the State, a series of 1:100,000-scale computer-generated quadrangle maps is being prepared that will be available to the public on a print-on-demand basis. The maps will provide a constantly updated reference for those interested in oil and gas and an economically efficient method of publication for KGS.

A computer-generated map for the Middlesboro 1:100,000-scale quadrangle has been completed and submitted for publication and editing. It is expected to be ready for public distribution by the end of 1996. Plotting of well locations not previously computerized has been completed, pool nomenclature problems are approximately 75 percent resolved, and a preliminary, computer-generated map has been produced for the Tompkinsville Quadrangle. The data-processing phase has been completed for the Williamson and Hazard Quadrangle maps; they will be processed in GIS when the previous two maps are completed. The Pikeville 1:100,000-scale map, which was previously published using conventional printing techniques, will also be prepared for computer drafting and publication.

In addition to the 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.

A 1:1,000,000-scale map showing the distribution of oil and gas well-location data, derived from the KGS Well Records Database, has been published as Kentucky Geological Survey Map and Chart Series 9. It is available as an on-demand, computer-generated plot and will be periodically updated with new location and completion information.

OIL AND GAS WELL-RECORD PRESERVATION

Brandon C. Nuttall, Bart Davidson, James A. Drahovzal, Luanne Davis, Eugenia E. Kelley, and Theola L. Evans

To protect the original paper files contained in the KGS Well Records Database from destruction by continual use, fire, and theft, and to make them more accessible to Survey staff, industry, government representatives, and the public, the individual well records are being optically scanned and stored as raster images 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 databases of its kind in the country. In 1991, records selected for scanning were ranked, based on stratigraphic significance, to better meet increasing research and public requests.

A procedure to generate bar codes for document identification and indexing has been implemented. Bar codes are assigned to each page of each document that is scanned. The bar-coded information will be used to 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 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 than 43,500 oil and gas records have been processed.

Except for miscellaneous older wells with minimal location or geologic data, preparation of records is complete and scanning is scheduled to begin in the summer of 1996.

WATER RESOURCES SECTION

For Kentucky to maximize its economic potential, large quantities of usable water are necessary. Kentucky must plan for increasing 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, 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 natural gas recovery, and agricultural practices. During this past year, the State has developed ground-water regulations to protect this vital resource. An understanding of the geology and hydrogeology of Kentucky is essential for appropriate regulations and the optimum development, utilization, and management of the State's water resources. The Water Resources Section provides information to municipalities, industry, Federal and State agencies, and private citizens concerning the occurrence, movement, quantity, and quality of surface water and ground water in the State.

New projects are designed to meet the present and future demands of Federal and State programs and the needs of Kentucky's 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 addition, KGS maintains the Kentucky Ground-Water Data Repository for all ground-water data collected by State agencies.

The availability of water is crucial for urban and rural economic development. The effect of land use on water quality and quantity is also an important factor in economic development. Therefore, basin-hydrology research is essential for future economic development in the Commonwealth. To facilitate this type of research, KGS has instituted a GIS for storage and use of Statewide data on land use, topography, geology, ground-water levels and water quality, and water-supply systems as the data become available. Several of the research programs deal with large basins, up to the size of the Kentucky River watershed, where the effects of land use and hydrogeology are being studied. In the past year, KGS established 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.

To achieve its mission during the past year, the Water Resources Section has conducted research in cooperation with the Kentucky Natural Resources and Environmental Protection Cabinet; various groups within the University of Kentucky, including the College of Agriculture, Kentucky 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 programs at KGS can be divided into the following five areas: hydrogeology of agricultural lands, hydrogeology of coal fields, hydrogeology of karst terrains, basin hydrogeology, and public service. The basin-hydrogeology category includes large-scale projects dealing with water supply, waste management, and the Kentucky Ground-Water Monitoring Network. The following summaries describe the results of projects conducted during the 1995–96 fiscal year. Water quality is one of the primary issues in most of the projects.

Hydrogeology of Agricultural Lands

GROUND-WATER QUALITY IN AN AGRICULTURAL AREA OF THE JACKSON PURCHASE REGION, IN HICKMAN COUNTY, KENTUCKY

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 is being studied. This site is characterized by 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 have been used to sample ground water and measure levels of both perched ground water and water in the deeper Eocene aquifer. Samples from domestic wells were analyzed for nitrate and other nitrogen compounds, common pesticides, oxidation reduction 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 milligrams per liter (mg/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 (OF-93-06), and further results are being summarized for a more extensive KGS publication. 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 Department of Agronomy, the Department of Biosystems and Agricultural Engineering, and the Kentucky Water Resources Research Institute of the University of Kentucky.

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

Philip G. Conrad, James S. Dinger, Jeffrey 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, 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. Tile drains in the field discharge into a 10-foot-deep drainage ditch. Nine monitoring wells are used to sample ground water from depths ranging from 5 to 28 feet.

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 were rarely detected below 8 feet in depth, and then only in trace amounts. 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. These wells will be removed in 1996.

Results have been shared with other researchers, and a report of interim findings has been placed on open file (OF-94-01). Also, a Master of Science thesis was written by Mr. Snell for the University of Kentucky Department of Geological Sciences. A more extensive KGS publication will be issued later. This project is funded through the Kentucky Senate Bill SB-271 Water-Quality Program.

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

Philip G. Conrad, James S. Dinger, Jeffrey 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. 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. Seven monitoring wells 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. The wells will be removed in 1996.

Results have been shared with other researchers, and a report of interim findings has been placed on open file (OF-94-01). Also, a Master of Science thesis has been written by Mr. Snell for the Department of Geological Sciences, University of Kentucky. A more detailed KGS publication will be issued later. This project is funded through the Kentucky Senate Bill SB-271 Water-Quality Program.

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

Dwayne M. Keagy, Shelley A. Minns, James S. Dinger, John H. Grove, and Joseph L. Taraba

The primary objective of this study is to evaluate the movement and fate of pesticides and nitrogen-related species in a farmed, upland bedrock setting that utilizes farming practices typical of western Kentucky. Gently rolling, upland areas in this region are the last major agricultural setting in Kentucky for which impacts of agricultural chemicals have not been assessed. The study site, located 5 miles southwest of Henderson, is a farm with corn, soybeans, wheat, and beef cattle. This farm was selected because of intensive agricultural activity, typical of the Western Kentucky Coal Field uplands, combined with intensive use of bedrock-derived ground water for domestic supplies.

Existing data from the KGS and other sources have been used to obtain preliminary stratigraphic control and construct depth-to-bedrock and depth-to-water maps for the farm site. Publications have been collected and studied to better understand the soils, stratigraphy, and hydrogeology of the region. Special attention in the literature has been given to the occurrence of loess deposits. Preliminary samples were collected from domestic wells and streams on the farm to determine the extent of nitrate and pesticide contamination in the ground water prior to monitoring-well installation. Daily rainfall at the farm site has been recorded since September 1995 following the installation of a continuously recording rain gage. A detailed soil survey using a hand-driven soil probe was conducted to identify the presence or absence of dense subsurface soil layers so that the number and locations of monitoring wells could be predicted.

A monitoring-well network (five nests) was installed to provide information on the occurrence of nitrogen-related species and pesticides in the unconfined aquifer, and to delineate the ground-water flow system. A domestic well was also installed to gather information on the occurrence of nitrate in the landowner's existing well. Before domestic and monitoring wells were installed, soil cores from ground surface through to bedrock were recovered at each nest location, the domestic well location, and the landowner's feed lot, to determine the existence of buried soils, depth to bedrock, and soil nitrogen and organic carbon content. One bedrock core to 110 feet was recovered to determine stratigraphy under the site, which will make possible better placement of bedrock monitoring wells. A 10-foot packer injection and sampling test was conducted on both the bedrock core hole and domestic well borehole to determine hydraulic conductivities and the vertical presence of nitrate contamination in the aquifer. Nineteen vertically independent monitoring wells, installed to sample both soil and bedrock ground water, were positioned as five well nests in both surface and buried soils. Well nests were installed to compare the occurrence of nitrogen-related species and pesticides in the ground water below a corn field to the ground water below a pasture and alfalfa field. Regular sampling of the monitoring wells, domestic wells, streams, and seeps for agriculture-related contaminants at the farm site has begun.

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 transport and fate of agricultural chemicals in similar agricultural and hydrogeologic settings. This project is funded through the Kentucky Senate Bill SB-271 Water-Quality Program.

Hydrogeology of Karst Terrains

ASSESSMENT OF GROUND-WATER QUALITY AND QUANTITY AT THE UNIVERSITY OF KENTUCKY WOODFORD COUNTY RESEARCH FARM

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

In the spring of 1995, ground-water monitoring at the farm was suspended for an indefinite period because funds were curtailed. Streamflow sampling continued at four weir sites until January 1996. A KGS open-file report (OF-93-04) was released, which discusses the hydrogeologic findings of this study. A Report of Investigations has also been prepared that discusses the impact of changing topographic data resolution on nonpoint-source (NPS) pollution modeling. This study revealed that three times as many sinkholes can be identified on a 2-foot contour map than on a 10-foot contour map. This increase in the number of sinkholes results in a two-fold increase in the amount of subsurface drainage that could be delineated with the use of a map. This increase in subsurface drainage is the most important factor affecting model results, producing significant differences in predicted runoff volumes, peak runoff rates, sediment yields, and nutrient yields when comparing 2-foot contour data with 10-foot contour data. Without extensive field reconnaissance in karst terrains, a 10-foot contour map is insufficient to delineate topographic data for an NPS pollution model.

This project was funded through the Kentucky Senate Bill SB-271 Water Quality Program and the U.S. Department of Agriculture.

CHARACTERIZATION AND QUANTIFICATION OF NONPOINT-SOURCE POLLUTANT LOADS IN THE PLEASANT GROVE SPRING BASIN, LOGAN COUNTY, KENTUCKY: A CONDUIT-FLOW-DOMINATED KARST AQUIFER UNDERLYING AN INTENSIVE-USE AGRICULTURAL REGION

James C. Currens

This study is now in its fourth year of Federal and State funding. The installation of Best Management Practices (BMP's) by farm owners in the watershed is now well under way. Field efforts during the year were largely limited to maintaining equipment and continuing water-quality monitoring during BMP implementation. Nevertheless, several quantitative ground-water dye traces were conducted. The focus of effort on the project has shifted to data management, estimation of contaminant mass flux, and recalculation of basin and crop areas using GIS technology. The project report on the first 3 years of study is nearly ready for publication. In addition, work has begun on a report on determining the minimum sampling frequency required for monitoring karst springs.

The Pleasant Grove Spring Basin in southern Logan County was selected for study because it is largely free of nonagricultural pollution sources. Approximately 92 percent of the watershed is in agricultural production. Water samples are collected at Pleasant Grove Spring and other sites in the basin, on both a regular schedule and by automatic sampling machines during storm events. The samples are analyzed for pesticides (by ELISA, or enzyme linked immunosorbent assay, or immunoassay), nitrate, and suspended solids. More extensive analyses are conducted quarterly. Results to date indicate atrazine herbicide is the contaminant of the greatest environmental and human health concern in the basin. Triazines (including atrazine) exceed drinking water MCL's during spring flooding. Bacteria counts are also a concern, particularly for domestic-supply users of ground water. Nitrate is the most widespread, persistent contaminant in the basin, but concentrations do not exceed MCL's for drinking water. Suspended sediment loads are also an environmental concern.

The ultimate goal of the Pleasant Grove Spring ground-water basin study is to demonstrate the effectiveness of the U.S. Department of Agriculture's (USDA) Water Quality Incentive Program for protecting ground-water quality. Federal funding was granted in April 1995 to the USDA Natural Resources Conservation Service to implement a variety of changes to agricultural practices in the basin, but full-scale implementation did not get under way until the fall of 1995. If improvement in the ground-water quality cannot be demonstrated on a basin-wide scale, in a real-world setting, then the effectiveness of the implemented practices and the program's success in obtaining the producers' cooperation will need to be re-evaluated.

ATLAS OF KARST GROUND-WATER BASINS IN KENTUCKY

James C. Currens and Joseph A. Ray

A major change was made is this cooperative project with the Kentucky Natural Resources and Environmental Protection Cabinet–Division of Water during 1995–96. The researchers explored several possibilities for presenting the data and decided that a series of karst ground-water basin maps will have priority over data in a tabular format. The first map in this Statewide series is being drafted and is near completion. Each map will cover a 30 x 60 minute area at a scale of 1:100,000. The catchment area will be shown for each basin for which there are 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 separately at a large scale as examples of basin types or where more detail is available and of special value. The project goal is to assemble the maps into an atlas. 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. This project is conducted as time permits, without special funding.

GROUND-WATER STUDY OF THE TOYOTA PLANT SITE, GEORGETOWN, KENTUCKY

Gary K. Felton and Lyle V.A. Sendlein

An 18-month study of the Toyota Motor Manufacturing (TMM) plant site and the surrounding area was completed in cooperation with the Kentucky Water Resources Research Institute of the University of Kentucky during the fiscal year. The objective of this project was to characterize the ground water that is potentially affected by the TMM plant site. Parameters measured included occurrence, flow direction, and, if possible, velocity. Because the area is karstified, surface water and ground water are intimately connected; hence, surface water was frequently an important component of this work.

Data from TMM construction plans and monitoring work done subsequent to construction were requested from Toyota. Aerial color photographs were acquired from various government agencies. Maps were constructed from the various data sources and data layers were combined to provide a complete picture of the plant site's geology and ground-water hydrology. Fracture-trace analysis and field reconnaissance was performed. Fifty-one sinkholes were found on site, 182 in the entire study area. Several springs, both on site and off site, were discovered. Dye-trace analysis was performed to determine connectivity and to help build a conceptual model of the subsurface flow system. Existing chemical analysis was complemented with chemical analysis done by the Kentucky Geological Survey and the College of Agriculture of the University of Kentucky.

Dye-trace data, monitoring-well level data, and basic fluid mechanics were used to determine that the ground-water flow beneath the basements of the buildings was essentially isolated from the surrounding ground-water systems because the sump systems in the basements maintained a continuous flow toward the TMM buildings. This "zone of isolation" extended no more than 7 to 14 feet away from the edge of the buildings. As such, these buildings would not be sources of contamination to the surrounding ground-water systems. Some buildings did not have these basement-sump systems and hence were not isolated from the surrounding ground-water systems.

Most ground water in the zone near the surface of the TMM site is derived from infiltration on site, flows relatively rapidly and relatively short distances, and exits the ground in small hillside seeps and springs that are typically at the upper surface of the Millersburg Formation, which is approximately 25 feet below the

TMM plant site. A small component of this water may migrate slowly to a deeper system.

Flow beneath the Millersburg layer occurs in two ways. Off the TMM site, in the deeper Tanglewood or Grier units, two major conduit systems are connected to the surface by the Dry Run swallett and the Lanes Run swallett. The Dry Run swallett is connected to the conduit system, which discharges at Railroad Spring, and the Lanes Run swallett is connected to a conduit system that terminates at Marshall Spring. If surface water is discharged from the TMM plant and is not contained by the sump system beneath the plant, it will either end up in Railroad Spring or Marshall Spring, and under high-flow conditions a portion will flow to Elkhorn Creek.

A deep ground-water zone in the eastern section of the TMM site (confirmed by monitoring wells) does not have much subsurface water movement or surface connectivity. Water in this zone is saline, high in sulfates, and relatively immobile.

Four dye traces were used to estimate the range of travel times in the two types of karst systems. The range of velocities found in the upland, epikarstic system was between 192 feet per day (ft./day) and 6,000 ft./day, with expected velocity closer to 6,000 ft./day. Velocities in the deeper conduit system were between 1,584 ft./day and 4,320 ft./day, with expected velocity closer to 4,320 ft./day.

The project results were published as Kentucky Water Resources Research Institute Report 194.

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 Counties 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 level rather than agricultural activity.

Nitrate varies temporally, and had a maximum concentration of 5.06 ppm nitrate-nitrogen, which is half of the Environmental Protection Agency's 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. The nutrient yield was estimated at 11.0 pounds of nitrate-nitrogen per acre per year and 1.7 pounds of phosphate per acre per year.

Ground water contained no pesticides in March, but pesticides showed up later in the spring after they were applied, though not in hazardous concentrations. This suggests that the annual high winter flows 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 triazines should be coordinated with weather conditions to prevent runoff 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.

Nitrate, phosphate, triazine, suspended solids, and fecal bacteria data were used to evaluate the impact of the sampling period on resulting characterizations of water quality. Monthly sampling was sufficient to determine mean annual nitrate values. Frequency of sampling had no significant effect on the mean values of phosphate, triazines, and suspended solids.

A final project report was submitted to the sponsor, and a KGS publication is in review. This project spawned an investigation into the impact of turf grass management on water quality. The project is ongoing in the same watershed (see "Maximum Daily and Annual Nutrient and Pesticide Loads from Turfgrass Management Areas").

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.

MAXIMUM DAILY AND ANNUAL NUTRIENT AND PESTICIDE LOADS FROM TURFGRASS MANAGEMENT AREAS

Gary K. Felton, Andrew J. Powell, and Dwayne L. Edwards

Two subwatersheds with distinct land uses were identified, delineated, and equipped for flow measurements and water sampling. Water will be sampled from a stream at three locations during the chemical application season. The stream originates as a spring, and farther down the basin it sinks into the karst conduit system. The first sampling location is upstream from suburban development and a golf course. The second location is where a suburban development surrounds the stream. The third location is where flow exits a golf course. All water samples will be tested for nitrate and phosphate.

The 609-acre residential subwatershed (37 percent residential, 63 percent pasture and forest) was delineated. Storm event samplers have been installed above and below the residential area, and weekly samples are being collected. Every sample is analyzed for nutrients and the spring samples are analyzed for 2,4-D.

The 190-acre golf course subwatershed (65 percent golf course, 35 percent pasture and forest) was monitored from April through November of 1994. Samples were tested for nitrate and pesticides specific to golf courses. Approximately 6.3 kilograms per hectare (kg/ha) of nitrate-nitrogen (NO_3-N) left the golf course, compared to 12.3 kg/ha for the overall watershed. In early spring, 2,4-D was detected at levels between 1.5 and 2.5 mg/L, chlorpyrifos was detected at levels between 0.005 and 0.015 mg/L, metalaxyl was detected once at 0.9 mg/L, and chlorothalonil was never detected. Diazinon, which was not applied to the golf course, was detected at up to 1.4 mg/L, and probably originated from home lawn care activities.

The third sampling site is a spring-fed stream that drains approximately 175 acres of the golf course. The stream is fed by small springs and seeps along much of its course. In addition, part of the stream is dammed to create a pond. The administrator for the golf course provided data on when, how much, and over what area each chemical was applied. Therefore, water samples were analyzed only for chemicals that were applied.

Every sample was analyzed for nutrients. Eleven samples were analyzed for 2,4-D. Two levels, 2.4 mg/L and 1.8 mg/L, were above the detection limit of 0.9 mg/L; the MCL is 10 mg/L. Each sample that showed a presence of 2,4-D was followed by a sample below the detection limit.

Chlorpyrifos was found above the detection limit (0.006 mg/L) three times: 0.015 mg/L, 0.014 mg/L, and 0.008 mg/L. These were found only in April.

An advisory committee will be convened that is composed of golf course superintendents, lawn care company managers, environmentally concerned and aware participants from outside the University of Kentucky, turfgrass specialists, and water flow specialists. This group will (1) document concerns from every point of view, (2) find points of agreement, (3) evaluate existing BMP's from other states, (4) review a BMP manual as it is developed. Once this group has reached some conclusions, it will prepare various publications to inform the public. Workshops will be conducted to explain the program and the BMP concept, reinforce the philosophy, and provide technical advice.

HYDROLOGY OF LARGE SPOIL AREAS

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

The coal-mining process can often transform rugged, upland pre-mining topography into usable, gently rolling topography that is less prone to flooding than the rugged terrain that existed before the mining occurred. These changes can be beneficial for future economic development and diversification. Cyprus Mountain Coals, a subsidiary of Cyprus-Amax, Inc., owns 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 land will be created from coal mining by the year 2010 at the Star Fire site through mountaintop removal techniques. This will provide a site for new land uses and future economic development. KGS is conducting an applied research program to determine the water resources at the site, which will be vital for the site's successful development. Data provided by KGS will aid in the planning for alternative land uses after mining has been completed. This project represents one of the largest mine-spoil studies in the United States. The importance of this study was acknowledged by Robert Uram, the Director of the Federal Office of Surface Mining, and Bruce Babbitt, the U.S. Secretary of the Interior, when they visited the site in 1995.

Water-table elevation data from monitoring wells, springs, and ponds indicate that three 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, but are separated by the buried bedrock topography below the spoil.

Surface-water flow has been measured using hand-held flow meters. 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.

A full-scale study to determine the amount of settlement occurring in the spoil is being conducted. Four traverses across the spoil area have been surveyed and 80 settlement monuments installed along these lines. A total of 14,000 linear feet of traverses will be surveyed twice a year to measure transient movement. These data, in conjunction with data collected previously from damage around the monitoring wells, will allow us to evaluate the impact of variables such as age of spoil, thickness, and pre-mining topography on the degree and rate of settlement.

Water samples are collected for chemical analysis on a semi-annual basis from the monitoring wells and major springs that crop out at the spoil's periphery. Wells located in the hollow-fill areas are found to be more responsive to precipitation events and contain fewer dissolved constituents compared to wells located in the main spoil body. Water sample analyses from all areas of the site reveal that the major dissolved constituents are calcium, magnesium, and sulfate. The most recent data collected reveal that little, if any, change in the chemical character is occurring in ground water in the spoil through time.

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. Data loggers will be installed at the points of major discharge to obtain more continuous quantitative data to provide water data for experimental agricultural and aquaculture projects.

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 is being prepared for publication.

This project is funded by Cyprus Southern Realty through Cyprus-Amax, 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 monitor ground water to provide background conditions for water-quality investigations as well as valuable information regarding the interaction between recharge and discharge in forested basins.

Water levels in four wells are continuously monitored in the Clemons 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, to monitor the changes, if any, in the hydrologic regime as mining progresses.

Water-quality samples have been collected on a biannual basis. Digital data loggers have been installed to record continuous water-level response to precipitation and the discharge of streams that drain the basins containing the wells. These data are used to test the validity of interpretations and conceptual models derived from data collected at other sites. Geochemical data from these wells show excellent agreement with a hydrochemical facies model being proposed for the Eastern Kentucky Coal Field.

Additional geochemical studies are continuing concerning ground-water seeps emanating from coal seams that crop out in the forest. These seeps are being studied to determine the origin and mineralogical composition of chemical precipitates that have formed in areas where the seeps discharge. 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 (OF-95-01), "Interim Report on Ground-Water Monitoring in Robinson Forest," is available to the public. The report contains hydrologic 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

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 by movable hydraulic jacks during extraction of the coal. 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.

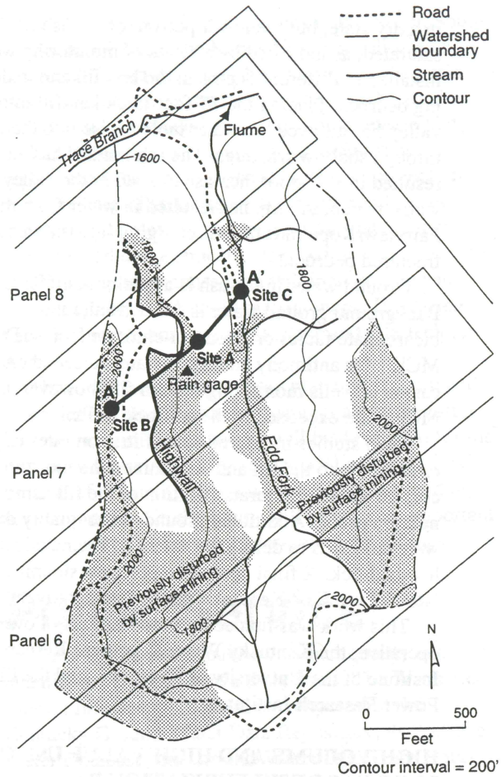
Information from the core holes was used to design 24 ground-water monitoring wells that were installed during the summer of 1992. Initial water-level data from these wells and the results of water-quality sampling indicate the presence of complex ground-water flow and hydrogeochemical systems that represent 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 fractures were collected daily for approximately 1 month while undermining took place in the summer of 1994. Water-level changes were observed in three piezometers as mining approached the 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 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.

A second drilling program was conducted in the summer of 1995 to measure the behavior of the ground-water system after mining. Two core holes were drilled, one each at the ridge-top and valley-bottom nests, to determine the extent of fracturing, and pressure-injection tests were conducted in 10-foot intervals to examine changes in hydraulic conductivity. Two monitoring wells were installed in the valley-bottom nest to replace the wells destroyed by mining so that changes in ground-water level and water quality could be measured. To date, water levels have not recovered sufficiently to allow water-quality samples to be obtained.

This study is a cooperative effort with the U.S. Office of Surface Mining Reclamation and Enforcement, the Kentucky Department of Surface Mining Reclamation and Enforcement, the Kentucky Water Resources Research Institute of the University of Kentucky, 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 in review. Post-mining data collection will continue through September 1996.

This project is funded by the Kentucky Department of Surface Mining Reclamation and Enforcement, through funds provided by the U.S. Office of Surface Mining and matched by the Kentucky Geological Survey.



Monitoring-point locations in the Edd Fork watershed.

EVALUATION OF COAL-ASH DISPOSAL IN SURFACE COAL MINES

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

For the past 6 years, the Institute for Mining and Minerals Research, the Kentucky Water Resources Research Institute, the Department of Geological Sciences, and the Kentucky Geological Survey at the University of Kentucky 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 were completed in 1994, and KGS publications describing each site are in preparation.

Research at the upland bedrock site was completed during 1995, and a KGS publication is in preparation. 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 was 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 allowed the water table to rise into the ash through shallow fractures. The ash landfill has also resulted in a 25-foot increase in head in the valley walls, which, in turn, has resulted in water from the Fairview/Kope interface discharging into the shallow fractured bedrock.

Ground water in the ash is a calcium-sulfate facies. Background ground water is either a calcium-bicarbonate facies or a sodium-chloride facies. The 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.

Field studies measured the infiltration rates of precipitation into the fill and determined the moisture content in the unsaturated portion of the fill using a neutron probe. Additional ground-water quality data were collected to define the extent of leachate in shallow bedrock. A final contract report was submitted in late 1995 to East Kentucky Power Cooperative.

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

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

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

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 cementing 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 of the University of Kentucky.

The initial site selected had to be abandoned for safety reasons. Currently, a suitable site is being sought by the Center for Applied Energy Research, University of Kentucky. Once the site is selected, KGS will oversee the drilling of core holes and monitoring wells to assess the environmental implications of ash disposal.

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

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

David R. Wunsch, Philip G. Conrad, Dwayne M. Keagy, and James S. Dinger

Research is being conducted to define natural background flow and chemical characteristics of ground water in the Eastern Kentucky Coal Field. The objectives 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. Information from this study will be valuable to individuals making decisions regarding the use of ground-water resources and the implementation of Kentucky's ground-water protection regulations. Industries that operate in eastern Kentucky, including mining, oil and natural gas, and landfill operations, need this information for both permitting and compliance.

Several sites have been evaluated to determine the physical hydrogeology of coal seams and the interbedded rocks. 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. Interpretative reports generated from these data will 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 are valuable to regulatory agencies and the companies they regulate for permit requirements. The data also help define aquifers and increase knowledge of ground water in the Eastern Kentucky Coal Field.

Several sites representative of the geology of the coal field have been intensively monitored to collect hydrogeologic and hydrochemical data. These data will be used to correlate ground-water occurrence and natural water quality, and define the hydrochemical facies that exist in aquifers in eastern Kentucky. Hydrochemical facies are defined as distinct ground-water zones that are categorized based on cation and anion concentrations within defined limits. KGS ground-water studies suggest that distinct hydrochemical facies are related to specific zones of ground-water flow, such as valley bottoms or the surrounding uplands. A hydrochemical facies model has been developed that identifies these hydrochemical faces in the subsurface and relates them to the ground-water flow system. In addition, the occurrence of minor elements that can affect human health, such as fluoride and barium, can be predicted based on hydrogeologic parameters and the occurrence and location of specific hydrochemical facies. Data collected from various geographic sites around the coal field demonstrate that the model is valid on a regional basis. A presentation describing this model was made at a national geologic conference.

Basin Hydrology

GEOGRAPHIC INFORMATION SYSTEM FOR WATER-RESOURCES STUDIES

Daniel I. Carey

Broad-based support for water-resources planning requires the dissemination of information on issues, alternative solutions to problems, 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 database to be used for water-resources planning and management.

Arc/Info software is used to create and maintain spatial data at a Statewide and basin level on water supplies, water usage, soils, ground water, water quality, demographics, transportation, infrastructure, oil and natural gas activities, topography, and political subdivisions. These data and the GIS are used to support water-, coal-, and petroleum-resource studies. The development of the spatial database using existing sources will continue.

KENTUCKY RIVER BASIN WATER-SUPPLY ASSESSMENT

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

The Kentucky Water Resources Research Institute of the University of Kentucky assembled a team of researchers to examine water-supply issues in the Kentucky River Basin. The work is being performed under contract to the Kentucky River Authority. The study consists of five basic tasks: (1) assessment of previous water-supply reports, (2) analysis of water supplies in the upper forks of the basin, (3) evaluation of water supply, (4) development of a drought response plan, (5) development of a long-range water-supply plan. This 18-month study will be completed by October 31, 1996.

Previous studies were evaluated with regard to conservation, management, and growth assumptions, and to reflect the impact of proposed construction projects. Public and private water supplies in the headwater region of the basin were characterized in a summary report, "Evaluation of Water Supplies in the Headwaters of the Kentucky River Basin." The initial report included analysis of water supplies in the North, South, and Middle Fork of the Kentucky River sub-basins. Analysis of headwater supplies throughout the basin (those not relying on the main stem of the Kentucky River) will be included in a report to be released later.

The water-supply evaluation will identify water-supply needs based on alternative growth projections. With the help of an advisory committee and public meetings, a consensus will be built for water-supply planning and management in the basin.

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 recommend strategies for meeting water-supply goals in the future. 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 analysis of future water-supply conditions.

Public Service

Questions from the public on water quality and quantity are answered on a daily basis. The Water Resources Information System is composed of the Kentucky Ground-Water Data Repository, the Surface-Water Database, the Ground-Water Dye-Trace Database, and two newly instituted programs, the Geographic Information System Database and the Kentucky Ground-Water Monitoring Network. During the past year, responses were provided for about 1,140 requests for surface-water and ground-water information using these databases. Assistance was also provided for approximately 100 requests for technical data interpretation and some field visits.

THE KENTUCKY GROUND-WATER DATA REPOSITORY

See the description under "Office of Geologic Information."

KENTUCKY GROUND-WATER MONITORING NETWORK

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

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 more effective sharing of public information.

Information will be summarized in reports that will be used by the public, agencies, businesses, municipalities, and other users of ground water in Kentucky. Computerized raw data will be available through the Ground-Water Data Repository. Funding for the monitoring network will be sought in the coming year.

SURFACE-WATER DATABASE

A surface-water database 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 databases, users can obtain geologic, topographic, and surface- and ground-water data from a centralized location. Providing easily accessible data in a centralized location will encourage greater efficiency and use of data by consultants, agencies, local governments, and citizens.

Currently, the surface-water database includes flow and water-quality data. Low-flow and flood statistics will be incorporated on a priority basis. The database greatly enhances the Survey's ability to respond to public requests; it integrates with the Survey's geographic information system database (see "Geographic Information System for Water-Resources Studies") to facilitate planning and research for water resources.

SECTION 319(H) PROGRAM MANAGEMENT

Section 319(h) of the Federal Clean Water Act concerns 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 of the University of Kentucky, 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 short- and long-term goals for the control of nonpoint-source pollution in the State. 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 the U.S. Environmental Protection Agency as it awards funds to the State to address nonpoint-source pollution in the future.

COMPUTER AND LABORATORY SERVICES SECTION

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

All staff members now have personal computers (PC's) on their desks. These PC's are connected via Pathworks, Digital Equipment Corporation's (DEC) Local Area Network (LAN). The LAN is served from a DEC Alpha 2100, which is also a database server.

In addition to the PC's, KGS has a number of workstations for specific tasks. These include an Alpha 3000 model 500, used for geographic information system applications, 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 database and report-writing facilities (Oracle Rdb, VAX Datatrieve, Sapiens, and SmartStar), word processors and desktop publishers (Microsoft Word and Adobe PageMaker), geologic modeling packages (Minex and Surface III), computer-aided drafting and presentation graphics packages (AutoCAD, FreeLance Plus, Harvard Graphics, Corel Draw), and geographic information systems (Arc/Info, running on a Digital Alpha workstation; GRASS, operating on a Sun Sparc10; and ArcView, running on both PC's and workstations).

During the year, KGS acquired a large-format, gray-scale scanner and software to assist with the geologic map digitizing project. It scans mylar or paper copies of the geologic maps into an image. Using CadCore software or ARCscan, the images are processed to obtain the vectors of the geologic contacts.

OPERATING SYSTEM MAINTENANCE AND UPGRADE

The key to having a successful computer system with current technology is a versatile network backbone. 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 routed to the University of Kentucky Network (UKnet), which, in turn, is linked to most of the national networks.

PC's (clients) provide local computing power to the researchers, while a server provides both applications and data from a central repository. Although more complicated to maintain and manage, this "client-server" computing environment gives researchers flexibility and access to off-the-shelf software. In 1992, KGS began to fully integrate its growing number of personal computers into the LAN. DEC's Pathworks LAN is being used because it uses Digital's OpenVMS server, where the Survey's large geologic and hydrogeologic databases are stored.

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 databases, KGS personnel are able to provide a higher level of service to the public by using relatively easy-to-use PC software. The LAN has also enabled researchers to take advantage of the Internet (the so-called Information Superhighway). This gives the researchers access to additional resources such as Federal databases and data from other State agencies, and allows them to exchange ideas with colleagues almost anywhere in the world.

DATABASE CONVERSION, UPDATE, AND MAINTENANCE

Since the early 1980's the Kentucky Geological Survey has used computer technology to coordinate the compilation and maintenance of geologic and hydrologic data for the Commonwealth of Kentucky. These data comprise a large, detailed, and comprehensive collection of public-domain petroleum, coal, water, and limestone data. The various data sets in this database are accessed thousands of times per year, and results are provided in hard copy and magnetic media to the public, consultants, industry, government, and researchers.

KGS maintains these data sets using state-of-the-art, multi-table, relational-data-base technology. This system provides users with the tools necessary to efficiently compile, manage, retrieve, and manipulate KGS's dynamic public-domain data sets. Currently, KGS's database contains the following:

- more than 30,000 coal-thickness measurements
- more than 2,500 coal-quality analyses

- coal resources information (by bed) for eastern Kentucky
- historic coal production totals for Kentucky
- more than 30,000 water well and spring locations
- more than 15,000 ground-water analyses
- more than 1 million surface-water measurements

To search for and display these data, users have a variety of software products available to them on their desktops. Developers and programmers can use SQL (Structured Query Language) and ISQL (Interactive Structured Query Language) to conduct command line or programmatic searches. Researchers, administrators, and the public can view the database using query-by-form applications in SmartStar and Datatrieve. In addition, new Windows-based GUI's (Graphical User Interfaces) such as Microsoft Access can be used to connect to the database through Pathworks. The Windows-based tools provide users with the ability to build ad-hoc queries and reports or link other applications (e.g., spreadsheets, word processors) to the database.

In the future, the large oil and gas data sets will be added to the database, and existing user interfaces will be enhanced.

Ongoing data acquisition is accomplished through KGS research projects and donations from private industry and government agencies.

Future improvements will include:

- Linking the database to geographic information systems such as Arc/Info and GRASS to provide the capability of dynamically evaluating the Survey's spatial data
- Providing direct public access to part of the database using KGS's World Wide Web site and Web search engines

Laboratory Services

The KGS laboratory facilities are used to 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 uses a Laboratory Information Management System (LIMS) to track sample status from log-in to final reporting. This LIMS technology is based on current EPA recommendations for ensuring data integrity in an automated laboratory operation. The laboratory staff also provide electronic data transfer using various types of media and database formats.

The laboratory facilities at KGS include the following analytical equipment and 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 flame ionization, electron capture, photoionization, electrolytic conductivity, and nitrogen-phosphorus detectors
  - immunoassay for selected pesticides
  - total organic carbon
- for mineralogy:
  - X-ray diffraction spectrometry (XRD)
  - X-ray fluorescence spectrometry (XRF)
- 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)

During the past fiscal year, the fuels division of the laboratory 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 700 water samples were received in the water division of the laboratory 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 division of the laboratory also participates in both the USGS Standard Reference Sample Program and the EPA Water Supply Laboratory Performance monitoring programs.

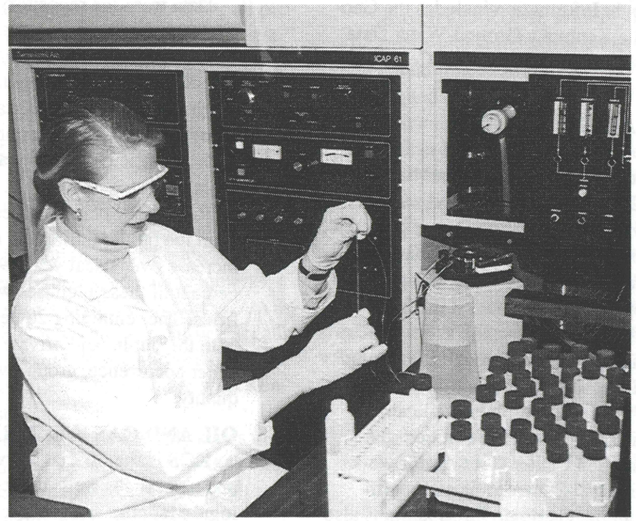
Public Service

The Computer and Laboratory Services Section assists KGS staff, as well as other University departments, Federal and State organizations, industry, and the public.

The cooperative study with Dr. Gregory Burg of the UK Department of Entomology using graphic furnace atomic spectroscopy to detect rubidium in ticks continued this year. The data produced from this study will determine the feasibility of using rubidium chloride as an elemental marker in ticks.

Water was analyzed for the Department of Environmental Protection, Kentucky Natural Resources and Environmental Protection Cabinet. The laboratory cooperated with the Department of Geological Sciences, University of Kentucky, in a project to analyze rocks by X-ray spectrometry.

The laboratory staff participated in a collaborative study of two rock reference materials for major and minor elements in cooperation with the National Geophysical Research Institute in Hyderabad, India. Dr. Rivai Bakti from the University of Sriwijaja, Indonesia, worked in the KGS coal quality laboratory for 3 months analyzing Indonesian peat samples. The laboratory participated in the First International Proficiency Testing Trial of Analytical Geochemistry Laboratories, organized by the International Working Group of the Association Nationale de la Recherche Technique, Paris.



Laboratory technician prepares samples for inductively coupled argon plasma analysis.

OFFICE OF GEOLOGIC INFORMATION

Public service is one of the most important functions of the Kentucky Geological Survey. KGS personnel respond to more than 11,000 requests for geologic information per year, averaging approximately 42 requests per business day. Clearly, the Kentucky Geological Survey fulfills a vital role as a public-service organization. Established on January 1, 1996, the Office of Geologic Information allows the Survey to consolidate efforts to make geologic data available to the public in a timely and effective manner. The Office of Geologic Information includes the Geologic Data Center, the Kentucky Ground-Water Data Repository, the Earth Science Information Center, and the Publication Sales Office.

GEOLOGIC DATA CENTER

The Geologic Data Center was created in 1994 to archive geologic data in both electronic and hard-copy formats. The Data Center has access to every major database in the Survey, enabling Data Center personnel to answer many public inquiries. Requests that require more detailed assistance or further explanation are forwarded to the appropriate professional staff member.

The KGS serves the Commonwealth as the official repository for ground-water data (through the Kentucky Ground-Water Data Repository) and for oil and gas well records. All of this information is available through the Geologic Data Center. In addition, the Earth Science Information Center Coordinator works through the Geologic Data Center to provide earth-science data to the public. Geologic information is also provided in response to questions from the public at the Survey's field office in Henderson, Ky.

THE KENTUCKY GROUND-WATER DATA REPOSITORY

The Kentucky Ground-Water Data Repository was created in 1990 by the Kentucky Geological Survey under mandate from the Kentucky General Assembly (KRS 151:035). The purpose of the repository is to archive ground-water data collected by State agencies, other organizations, and independent researchers and make it available to the public. Prior to the establishment of the repository, ground-water data were located at many different agencies throughout the State. The goal of the repository is to provide ground-water data for Kentucky at a centralized location in a manner that meets the needs of the public.

Data in the repository have been provided by over 15 different agencies. The largest contributor of data on a regular basis is the Kentucky Division of Water, Ground Water Branch. The Branch processes drillers' logs from the Certified Water Well Drillers Program, initiated in 1985. Data may be provided 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, publications, and other related information. Efforts are continuing to compile ground-water data from State agencies and other sources in the industrial, academic, public-health, and research sectors. This task will continue as new data are generated.

Data from the repository are being used to generate geographic information system maps using Arc/Info software. 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 such as pesticide contents and water-quality characteristics may also be mapped.

Repository personnel responded to 1,169 inquiries from the public during the fiscal year, a 47 percent increase over fiscal year 1994–95. Approximately 80 percent of these inquiries were from environmental firms. The remaining 20 percent were inquiries from both the public and private sectors concerning ground-water occurrence, ground-water supply, and water quality.

OIL AND GAS WELL RECORDS

KGS is the official repository for records of all oil and natural gas wells drilled in the State, and the Geologic Mapping and Hydrocarbon Resources 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 1,147 new wells were processed and recorded by the Survey last year. The Kentucky Geological Survey staff also reviews and enters into the computerized database as many of the older well records as time permits; 3,037 records were added to the database in 1995. Nearly 30,000 new wells were added under the accelerated scanning program. The computerization of the Well Record Library and new software are expected to greatly enhance the speed and efficiency of data retrieval. By the end of 1996, data for approximately 170,000 wells should be available.

During fiscal 1995–96, 1,290 visitors were assisted and 1,235 phone requests were processed concerning oil and gas information at the Lexington and Henderson facilities. A total of 27,221 copies of well records were supplied. More than 27,500 feet of logs representing more than 1,700 wells were copied for the public.

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-six well lists, 703 computer-generated overlays to topographic maps, 176 copies of "Distribution of Oil and Gas Wells" (KGS Map and Chart Series 9), and 72 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 since completed.

PUBLICATION SALES AND DATA DISTRIBUTION

Now a part of the newly established Office of Geologic Information, the Publication Sales Office makes available published information about Kentucky's mineral and water resources 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. Publications from other sources, as well as open-file reports dealing with Kentucky geology, are also available.

Kentucky and Rhode Island are the only states in the country that have complete 7.5-minute, 1:24,000-scale topographic and geologic map coverage. The Publication Sales Office maintains stock of all 779 topographic maps and most of the 707 geologic quadrangle maps pertaining to Kentucky that are still in print. All available 1:250,000- and 1:100,000-scale topographic maps of Kentucky, and complete coverage of hydrologic atlases published by the U.S. Geological Survey, are also kept in stock. Numerous other geologic, geophysical, structure, hydrologic, and mineral-resource maps are also 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 about Kentucky geology are available for purchase at the Publication Sales Office. KGS also 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 number of requests for maps and reports. During the past fiscal year, the office responded to 5,045 requests for information. In addition, the office distributed 13,710 topographic maps, 3,950 geologic quadrangle maps, 4,812 publications, and 5,325 miscellaneous geologic reports, for a total of 27,797 items (an average of 107 items per business day).

EARTH SCIENCE INFORMATION CENTER

The Kentucky Geological Survey's Earth Science Information Center (KGS-ESIC) provides information regarding the availability of current and historic maps, 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.

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 database of geographic names (GNIS) for Kentucky, which contains more than 30,000 place names used on Kentucky topographic maps, is available. The ESIC Coordinator can also refer individuals to other agencies and organizations with earth science information.

Close coordination between KGS-ESIC, the Geologic Data Center, and the Publication Sales Office makes it possible for customers to obtain desired materials or information with 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.

During 1995–96 fiscal year, 662 requests for information were answered by KGS-ESIC. Of these requests, 25 percent were for map-related information, 22 percent were for geodetic control data, 11 percent were for aerial photography and radar or space imagery, 10 percent concerned digital map products, and 32 percent were for information about available publications.

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

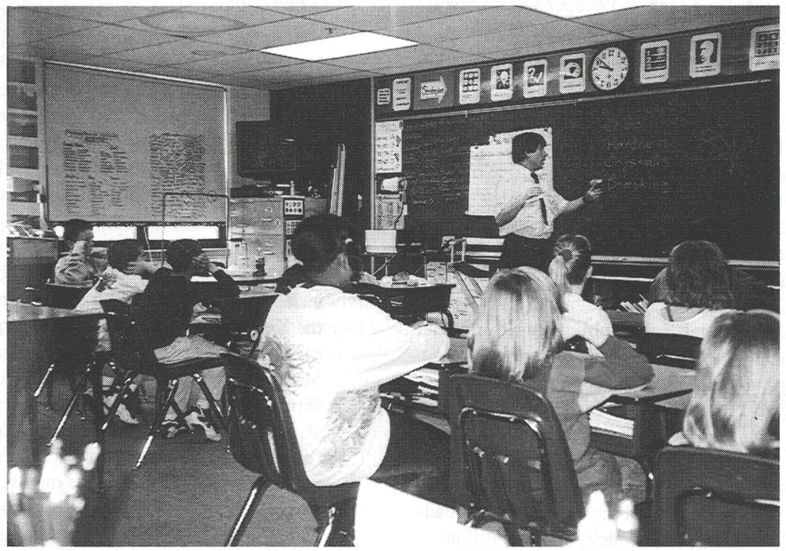
TOPOGRAPHIC MAPPING REVISION

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 one of the first states to be entirely mapped topographically at a scale of 1:24,000 almost 40 years ago. This program, administered at KGS by the Earth Science Information Center,

is designed to maintain revised and up-to-date maps for all areas of the Commonwealth.

The following 15 revised 7.5-minute-quadrangle topographic maps were received from the U.S. Geological Survey during the 1995–96 fiscal year: Campbellsville, Concord (Ky.-Ohio), Friendship (Ky.-Ohio), Garrison (Ky.-Ohio), Glen Dean, Hooven (Ohio-Ind.-Ky.), Jeffersonville (Ind.-Ky.), Kelly, Maretburg, Maysville East (Ohio-Ky.), Melber, Murray, New Albany (Ind.-Ky.), Smiths Grove, and Vanceburg (Ky.-Ohio).

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



Brandon C. Nuttall gives a lesson in geology to elementary school students.

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.

Donald W. Hutcheson retired as Head of the Publications Section in February 1996, after 26 years of service. Dr. Carol L. Ruthven succeeded him in June 1996.

Publications of the Kentucky Geological Survey are made available to the public at a nominal cost and are widely distributed. Maps and reports are available for purchase from the Publication Sales Office, 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 to make the data available for public use prior to publication. Open-file reports are available for inspection at the Publication Sales Office during regular office hours. Copies of materials that can be reproduced are available for purchase.

The following publications were issued by the Kentucky Geological Survey during the 1995–96 fiscal year.

Information Circulars

IC 53. High-Carbonate, Low-Silica, High-Calcium Stone in the High Bridge Group (Upper Ordovician), Mason County, North-Central Kentucky, by Warren H. Anderson and Lance S. Barron, 33 p.

The High Bridge Group (Middle Ordovician) of northeastern Kentucky is a major source of limestone and dolomite for construction, agricultural, and industrial stone. These industries require carbonate rocks of high chemical purity. Chemical analyses of foot-by-foot samples from a Mason County core show that three zones of high-calcium and several thick zones of high-carbonate and low-silica stone are present in the High Bridge at a mineable depth. Mason County is located in northeastern Kentucky, on the Ohio River, and offers river access to transportation to the metropolitan Covington-Cincinnati market and the northern portion of the Eastern Kentucky Coal Field for mine-related markets.

IC 54. Cambrian Hydrocarbon Potential Indicated in Kentucky's Rome Trough, by David C. Harris and James A. Drahovzal, 11 p.

A recent gas discovery in the Rome Trough has resulted in a new phase of deep exploration in eastern Kentucky. This activity is located in Elliott County, near the northern boundary fault of the Cambrian Rome Trough Graben. The Carson Associates No. 1 Kazee well was drilled in 1994, and blew out with a reported uncontrolled flow of 11 million cubic feet of gas per day. Although completed at a much lower rate, this well renewed interest in the deep gas potential of the Rome Trough, which has seen sporadic drilling activity since the 1940's. Gas production in the Rome Trough is from marine sandstones and fractured shales assigned to the Cambrian Rome Formation or Conasauga Group. These units are significantly thicker in the fault-bounded extensional graben that trends west-southwest to northeast in eastern Kentucky and continues through West Virginia and Pennsylvania into New York. Recent mapping of the Precambrian basement surface has refined the structure of eastern Kentucky and the Rome Trough. Reservoir facies include fine to very fine grained, micaceous, and glauconitic sandstones and fractured shales. Coarser sandstones may occur near border faults, in fan-delta deposits. Traps are primarily structural, and faulting was contemporaneous with deposition. Stratigraphic traps may also exist in the trough, but have not been proven by drilling to date. Stratigraphic traps may include sandstones deposited in turbidite fans in deeper parts of the graben. Potential hydrocarbon source rocks have not been identified. Limited geochemical analyses of well and outcrop samples from the Rome and Conasauga intervals show poor hydrocarbon source potential. Composition of gas produced from the Rome Trough varies significantly in eastern Kentucky. Several occurrences of gas high in nitrogen and helium content were found in the western part of the trough, and may be related to proximity to the Grenville Front. Gas of commercial quality is typical in the eastern part of the trough, where several wells are producing gas with Btu values over 1,000. Significant hydrocarbon potential remains in the Rome Trough, but this play is characterized by complex faulting that influenced the deposition and distribution of potential reservoir

rocks. Interpretation of high-quality seismic data will be a key factor to future success in this play.

Map and Chart Series

MCS 7. Bouguer Gravity Map of Kentucky, by G. Randy Keller and Donald C. Adams, scale 1:500,000.

MCS 8. Preliminary Map of the Structure of the Precambrian Surface in Eastern Kentucky, by James A. Drahovzal and Martin C. Noger, scale 1:500,000, plus 9 p. of text.

MCS 9. Distribution of Oil and Gas Wells in Kentucky, Based on the Kentucky Geological Survey Computer Database, by Daniel I. Carey and Brandon C. Nuttall, scale 1:1,000,000.

MCS 10. Mapped Karst Ground-Water Basins in the Lexington 30 x 60 Minute Quadrangle, by James C. Currens and Joseph A. Ray, scale 1:100,000.

Report of Investigations

RI 9. Effects of Longwall Mining on Hydrogeology, Leslie County, Kentucky—Part 1: Pre-Mining Conditions, by Shelley A. Minns, James A. Kipp, Daniel I. Carey, James S. Dinger, and Lyle V.A. Sendlein, 37 p.

An investigation of the hydrologic effects of longwall coal mining is in progress in the Eastern Kentucky Coal Field. The study area is located in a first-order watershed in southern Leslie County over Shamrock Coal Company's Beech Fork Mine (Edd Fork Basin on the Helton 7.5-minute quadrangle). Longwall panels approximately 700 feet wide are separated by three-entry gateways 200 feet wide. The mine is operating in the Fire Clay coal (Hazard No. 4); overburden thickness ranges from 300 to 1,000 feet. Mining in the watershed began in late summer 1993. Undermining of the instrumented panel (panel 7) is anticipated for summer 1994. This report documents pre-mining hydrogeologic conditions.

Three sites over panel 7 (ridge-top, valley-side, and valley-bottom settings) were selected for intensive monitoring. An NX core hole was drilled at each site to provide stratigraphic control for well installation, to evaluate fractures, to conduct pressure-injection tests, and to provide a borehole for installation of time domain reflectometry cables. A rain gage and flume were installed in the basin in summer 1992. Twenty-four monitoring wells, completed in July 1992, provide water-level and water-quality data on individual stratigraphic zones represented by the three well locations.

Interpretation of pre-mining conditions was used to develop a conceptual model of ground-water flow in the study basin. Three ground-water zones were identified on the basis of hydraulic properties. The shallow-fracture zone, a highly conductive region parallel to the ground surface, extends to a depth of 60 to 70 feet. The elevation-head zone includes the ridge interior, mostly above drainage, where total head consists of elevation head only. The pressure-head zone, largely below drainage, is the region where total head is the sum of elevation head and pressure head. Two fresh-water geochemical facies are also present. Shallow ground water is a calcium-magnesium-bicarbonate-sulfate type, whereas ground water in the deeper regional system is sodium-bicarbonate type.

Anticipated effects from longwall mining include a decrease in water levels in the pressure-head zone. Temporary decreases are expected in the shallow-fracture zone as newly created void spaces subsequently fill. The elevation-head zone should not be greatly affected because it is predicted to be in the aquiclude zone.

Reprints

R 42. Rhythmic Sedimentation in a Mixed Tide and Wave Deposit, Hazel Patch Sandstone (Pennsylvanian), Eastern Kentucky Coal Field, by Stephen F. Greb and Allen W. Archer, p. 96–106.

The Hazel Patch sandstone is an informal unit of the lower Middle Pennsylvanian Breathitt Formation, which is locally dominated by facies containing alternating sand and shale layers, or rhythmic bedding. Three types of rhythmites are defined. Cyclic rhythmites show a sinusoidal vertical stacking trend of thickening and thinning laminae, amalgamated rhythmites show partially or possibly cyclic trends that have been reworked or erosively truncated by overlying form sets, and noncyclic rhythmites show only random thickness distribution and no evidence of original cyclicity.

Lower in the sandstone, noncyclic rhythmites are associated with swaly to quasi-planar bedding, even bedding, and ripples with rounded crests, and are inferred to have formed in response to storm waves and combined flows. Higher in the sandstone, noncyclic, amalgamated, and cyclic rhythmites are present in association with herringbone stratification and pinstripe laminae, and are inferred to have formed under the influence of tidal currents. Cyclic tidal rhythmites are present near the base of a shallow channel deposit. These rhythmites contain sandstone-shale couplets (indicative of presumed diurnal tides), 11 to 12 laminae cycles (neap-spring tidal sedimentation), and 25 to 27 laminae cycles (lunar monthly sedimentation). Upward and laterally within the channel, truncation of neap-cycle laminae by spring-cycle ripples, and a loss of continuous clay drapes in amalgamated rhythmites led to preservation of only monthly or greater depositional cycles.

Vertical facies trends in the sandstone are interpreted to represent upward shallowing from a wave-influenced outer estuarine or shallow shelf environment to an intertidal sand flat to an exposed low-lying coast upon which peats accumulated. The fact that cyclic rhythmites were preserved only in a shallow channel, stratigraphically near the middle of the unit, may indicate that accommodation space and a medial estuarine position with little wave reworking and bioturbation controlled the preservation of the various orders of cycles.

Special Publications

SP 22. Exploring the Geology of the Cincinnati/Northern Kentucky Region, by Paul Edwin Potter, 115 p.

The eight counties of the Cincinnati/northern Kentucky region, locally called the *Tri-State,* in adjacent parts of Ohio, Kentucky, and Indiana, have a rich, diverse geology that has strongly influenced its inhabitants from initial settlement to the present time. The region has also produced an amazing number of talented amateur and professional geologists. Much of the geology is easily observed in hundreds of outcrops at the surface, but an even larger part is buried and can only be studied using wells and seismic images.

Ten major events occurring at a subcontinental or continental or even global scale have shaped the geology of the Cincinnati/northern Kentucky region over the last billion years. Among these events were two continental collisions separated by about 700 million years, several major floodings by the world ocean, the formation of the Cincinnati Arch, and the repeated global coolings of the last million years. A few of the practical consequences of these events include the present landscape and its diverse soils, availability of ground water, plus future supply of construction materials, urban development of hillsides, and storage and disposal of urban and industrial wastes.

A glossary of technical terms, a list of sources for more information, suggestions for field work, and an extended, annotated bibliography provide additional useful material for further study of this fascinating urban area.

Miscellaneous

KGS Annual Report, 1994–1995, 68 p.

Five-Year Plan, 1995–2000: A Strategic Plan for Research and Graduate Studies, 73 p.

WELL SAMPLE AND CORE REPOSITORY

The KGS Well Sample and Core Repository provides easy access and permanent storage of material from several sources in one place for immediate or future use. Samples and cores submitted to the repository are processed, catalogued, stored, and made available for researchers from industry, government, academic institutions, and the public to inspect. More than 17,000 sets of well cuttings and 1,500 cores representing over 22 million vertical feet of drilling is currently on file at the facility. A computerized index lists all cores and samples processed after 1980 that are available for public use.

The Repository was closed for most of the 1995–96 year for moving from the American Building on March 21, 1995, into a warehouse. The inventory was completely moved by May 2, but the repository was not reopened for public use until November. The move was a massive undertaking: over 3,000 pallets containing rock samples, equipment, furniture, and supplies were transported during the move.

More than 22,000 feet of well samples were processed and added to the collection at the repository during the fiscal year. More than 3,200 boxes of core were repaired, and 4,120 feet of cores and samples were reboxed. Several companies and government agencies were asked to donate rock samples for research; they responded with 182 cores and well cuttings representing more than 490,000 feet of vertical drilling. Repository personnel traveled to collection stations Statewide to retrieve an additional 147 sets of well cuttings.

More than 70,000 core boxes were labeled, and flood-damaged well sample sets were tagged with unique numbers to differentiate them from undamaged sets. An additional 1,500 unwashed sample sets awaiting processing were transferred into 3,200 storage boxes, and information on them was added to the database.

During the year, more than 627 individual inquiries for information were answered by phone. Eighty-eight visitors to the facility were assisted, and 14 people were provided with information about the facility, materials at the repository, or various aspects of geology. Stratigraphic contacts in rock cores and cuttings were identified for nine researchers. In addition, 40 samples from well cuttings and core from eight wells were sampled for research. Over 250 sample descriptions were provided to the public. Twenty-six tours of the facility were given to interested groups and individuals.

To prevent future water damage to well sample sets, plastic envelopes with inserts were developed and purchased. A prototype for a new waterproof storage box was designed; unfortunately, the waterproof boxes proved too costly to manufacture at this time. Instead, a newly designed cardboard sample box was developed and purchased.

The Repository is located at 554 South Forbes Road and is open from 8:00 a.m. to 12 noon and 1:00 p.m. to 4:30 p.m. For additional information, call 606-255-2439.

DEVELOPMENT OF FACILITIES AT THE WELL SAMPLE AND CORE REPOSITORY

Patrick J. Gooding

The Kentucky Geological Survey Well Sample and Core Repository is the official repository for well cuttings and core samples from wells drilled in Kentucky. These materials are valuable for exploration and development of oil, gas, coal, tar sands, oil shale, limestone, and other industrial and metallic minerals in Kentucky.

The benefits from well samples and cores are timeless, because as new geologic and engineering concepts evolve, and new analytical techniques are developed, there is a constant need to go back and re-examine and re-evaluate the samples. The goal of the repository is to provide a representative set of well cuttings and core samples for every square mile in the State, and make these samples available to industry, government, academic institutions, and the public.

Because of the University's decision to demolish the American Building, home of the repository since 1986, and build a parking structure on the site, the KGS Well Sample and Core Repository was moved in 1995 to a temporary location on South Forbes Road until a permanent facility can be built.

The new facility will be a metal-sided structure located on University property near the Center for Applied Energy Research Laboratory on Iron Works Pike. Initially it will provide 48,000 square feet of space, including approximately 24,000 square feet for core and sample storage and shipping and receiving areas. A large, well-lighted area will be provided for visitors to study the materials. In addition, space will be provided for sample processing and preparation and study of materials.

The new Well Sample and Core Repository will be a state-of-the-art facility, and will provide valuable service to the citizens of the Commonwealth and help in the continued development of Kentucky's mineral resources. The new facility will also provide greater storage, more efficient methods of retrieval, and enhanced examination and lab facilities.

KENTUCKY GEOLOGICAL SURVEY DISTINGUISHED LECTURE SERIES

The Distinguished Lecture Series was initiated 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."

The 1996 Distinguished Lecture was in honor of John E. Barton, and was presented by J. Freeman Gilbert, professor of geophysics at the Institute of Geophysics and Planetary Physics and Scripps Institution of Oceanography at the University of California-San Diego. His talk was entitled "Geology, Government, and the Public-Professional Interfaces." Dr. Gilbert has been pursuing research in computational geophysics, geophysical inverse problems, structure of the earth, and earthquake sources. He is also chairman of the Board on Earth Sciences and Resources of the National Research Council, and chairs external advisory committees for the Institute of Geophysics and Planetary Physics at Los Alamos National Laboratories and the Institute of Tectonics at the University of California-Santa Cruz. He is a member of advisory committees for the Division of Geological and Planetary Sciences at California Institute of Technology and the Department of Earth, Atmospheric, and Planetary Sciences at Massachusetts Institute of Technology, as well as a member of the National Research Council's Committee on the Future of the Global Positioning System. Dr. Freeman has been honored as an Overseas Fellow at Churchill College at the University of Cambridge in England and as a Foreign Honorary Fellow by the European Union of Geosciences. He has been a guest lecturer at the Academy of Sciences in the former Soviet Union, and continued his lecture tour in Moscow, Tashkent, Tiblisi, and Leningrad. He delivered a plenary lecture to the European Geophysical Society in Copenhagen, Denmark, in 1990, and was awarded a gold medal by the Royal Astronomical Society (London) in 1981, the Balzan Prize by the Fondazione Internazionale Premio E. Balzan (Milan, Italy) in 1990, and Doctor Honoris Causa by Utrecht University (the Netherlands) in 1994. Closer to home, he is a Fellow of the American Geophysical Union, a member of the National Academy of Sciences, a member of Sigma Xi, a Fellow of the American Academy of Arts and Sciences, and a Fellow of the Geological Society of America, which awarded him the Arthur L. Day Medal in 1985.

John E. Barton, Kentucky's seventh State Geologist, was appointed Commissioner of Geology and Forestry in 1918 when the Kentucky General Assembly, in an effort to streamline the government, abolished the State Board of Forestry and the Kentucky Geological Survey and created the Department of Geology and Forestry (also known as the Fifth Survey). The former State Geologist, Joseph B. Hoeing, was offered the position of Deputy Commissioner, but declined. Kentucky was experiencing an oil boom during Barton's tenure, which resulted in greater demands being placed upon Barton. Recognizing that his training was in forestry and not geology, Barton hired Willard R. Jillson as an assistant geologist late in 1918; the following year Jillson was appointed State Geologist and Deputy Commissioner.

Soon the Department of Geology was publishing geological publications at a steady rate, largely related to oil and gas exploration. "The Geology of Kentucky," one of the most outstanding reports ever issued by the Kentucky Geological Survey, was published during this period; the comprehensive overview of the historic, physical, stratigraphic, structural, and economic geology of Kentucky, written by Professor A.M. Miller of the University of Kentucky, served as the basic reference on geology and mineral resources of Kentucky for many years. The inability of two unrelated scientific organizations to function efficiently under one head soon became apparent, and the Legislature abolished the Fifth Survey in 1920 and reorganized the Kentucky Geological Survey into a separate department and created a forestry bureau under the Department of Agriculture.

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

No lecture in 1990

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.

John E. Barton—1996
J. Freeman Gilbert

State Geologist Donald C. Haney congratulates 1996 Distinguished Lecturer J. Freeman Gilbert.

COMMITTEES, BOARDS, AND ADVISORY ACTIVITIES

National

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, Ky.
Donald C. Haney: Division of Environmental Geology
David C. Harris: Treasurer, Eastern Section, 1995; Secretary, Eastern Section, 1996; Eastern Section Membership Committee

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

American Society of Agricultural Engineers
Gary K. Felton: Committee for Student Organizations; Technical Committee for Reclamation of Disturbed Lands; Technical Committee for Porous Media Flow

American Society for Testing and Materials
Henry E. Francis: Subcommittee on Coal and Coke; Subcommittee on Water; Subcommittee on Quality and Statistics; Subcommittee on Laboratory Accreditation; Subcommittee on Lime

Association of American State Geologists
Donald C. Haney: Awards Committee; Water Policy Committee

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

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

Geological Society of America
Cortland F. Eble: Secretary-Treasurer of the Coal Geology Division; Liaison for the Coal Geology Division with the Society of Organic Petrographers
Donald C. Haney: Geology and Public Policy Committee; Past-Chairman, Southeastern Section
John D. Kiefer: Southeastern Section Committee on Geology and Public Policy; National Membership Committee

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

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/National Research Council
Donald C. Haney: Board on Earth Sciences and Resources; Executive Committee, Board on Earth Sciences and Resources; Committee on Earth Resources

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

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

Regional

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

Central Appalachian Alliance
James C. Cobb: Steering Committee

Illinois Basin Consortium
James C. Cobb: KGS Coordinator
James A. Drahovzal: KGS Research Coordinator; Seismic Task Force

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

Clement Mineral Museum
Warren H. Anderson: Advisor

Geographic Information Advisory Council
Daniel I. Carey

Geological Society of Kentucky
James C. Cobb: Eastern Vice President, 1996
Richard A. Smath: Secretary, 1995
Thomas N. Sparks: Newsletter Editor
Kevin J. Wente: Eastern Vice President, 1995; President, 1996
David A. Williams: Western Vice President, 1995

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

Hazard Mitigation Enterprise Zone Commission
Ronald L. Street

Interagency Technical Advisory Committee, Kentucky Groundwater Monitoring Network
Philip G. Conrad: Co-chairman, Network Design Subcommittee; Co-chairman, Data Format Subcommittee
David R. Wunsch

Kentucky Agriculture Water Quality Authority
Donald C. Haney

Kentucky Board of Registration for Professional Geologists
Donald C. Haney

Kentucky Cabinet for Economic Development
Warren H. Anderson: Committee on Post-Mined Land Use and GIS Inventory
James C. Cobb: Committee on Post-Mining Land Use

Kentucky Engineering Earthquake Response Team
Daniel I. Carey

Kentucky Geographic Information Systems Advisory Council
Donald C. Haney: Executive Committee

Kentucky Groundwater Management Data Committee
Bart Davidson, Richard E. Sergeant

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

Kentucky Long-Term Policy Research Center
James C. Cobb: Technical Contributor

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 Interagency Coordination Committee
James S. Dinger

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

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

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

Natural Resources Conservation Service Modeling Development Committee
Daniel I. Carey: Chairman, Data Collection/Sharing Subcommittee
Gary Felton: Chairman, Model Calibration Subcommittee
Alex W. Fogle: Chairman, Available Models Subcommittee

NORM Task Force
James A. Drahovzal

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 Expansion Area Master Plan Committee
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; Steering Committee

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

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

University of Kentucky

Center for Applied Energy Research Advisory Board
Donald C. Haney

College of Agriculture
James S. Dinger: Nonpoint-Source Assessment Advisory Committee

Department of Agricultural Engineering
Daniel I. Carey: Adjunct 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

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

Kentucky Project of the Central Appalachian Alliance
James S. Dinger
David R. Wunsch

Kentucky Senate Bill (SB-271) Program
James S. Dinger: Advisory Committee; Coordinating Committee

Research Advisory Committee
James C. Cobb

Research and Graduate Studies Unit Safety Committee
Henry E. Francis

Staff Study Task Force Committee
James C. Cobb

United Way Campaign
John D. Kiefer: RGS Coordinator

PAPERS BY STAFF MEMBERS IN OUTSIDE PUBLICATIONS

Archer, A.W., Feldman, H.R., **Greb, S.F.,** Kuecher, G.J., Kvale, E.P., and Naylor, R.D., 1995, Laminated shales in Carboniferous coal measures—Limnic or paralic? [abs.]: Geological Society of America Abstracts with Programs, v. 27, p. A-31.

Archer, A.W., and **Greb, S.F.**, 1995, An Amazon-scale drainage system in the Early Pennsylvanian of central North America: Journal of Geology, v. 103, p. 611–627.

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DiMichele, W.A., Hook, R.W., Chaney, D.S., Miller, T.R., and **Eble, C.F.**, 1995, A drowned lycopsid forest above the Mahoning coal (Conemaugh Group, Upper Pennsylvanian) in Jefferson County, Ohio [abs.]: Geological Society of America Abstracts with Program, v. 27, no. 2, p. 49.

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Dinger, J.S., Minns, S.A., and Sendlein, L.V.A., 1995, Hydrogeologic implications of backfilling FGD material in highwall-miner adits: Proceedings, U.S. Department of Energy Contractors Symposium, 6 p.

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Felton, G.K., and Taraba, J.L., 1995, The impact of karst water quality sampling frequency on parameter estimates: American Society of Agricultural Engineers Paper 95-2426.

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Greb, S.F., and Chesnut, D.R., Jr., 1995, Tectonic, climatic, and eustatic controls on Morrowan sedimentation in the Central Appalachian Basin [abs.]: Geological Society of America Abstracts with Programs, v. 27, p. A-32.

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Pierce, B.S., **Eble, C.F.**, and Hower, J.C., 1995, Palynology and petrography of the Stockton coal [abs.]: Geological Society of America Abstracts with Program, v. 27, no. 2, p. 80.

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Shearer, S.A., Barnhisel, R.A., Watkins, G.A., **Fogle, A.W.,** Higgins, S.F., Ellis, M.A., and Catlett, R.V., 1996, Site-specific management of herbicides on crop lands: Project Progress Report, University of Kentucky College of Agriculture, 15 p.

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Warner, R.C., Hootkany, A.N., Blanton, C.D., Taraba, J.L., Byers, M.E., and **Felton, G.K.,** 1995, Subsurface leaching potential of animal waste holding ponds: Laboratory and preliminary field investigations [abs.]: Proceedings, 1995 Kentucky Nonpoint Source Conference, Kentucky Division of Water, Nonpoint Source Program, and Kentucky Water Resources Research Institute, 1 p.

Woolery, E.W, Wang, Zhenming, **Street, R.L.,** and Harris, J.B., 1996, A P- and SH-wave seismic reflection investigation of the Kentucky Bend Fault Scarp in the New Madrid Seismic Zone: Seismological Research Letters, v. 67, no. 2, p. 67–74.

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Wunsch, D.R., 1996, Ground-water monitoring strategy: Eastern Kentucky Coal Field, *in* Framework for the Kentucky Ground-Water Monitoring Network: A report of the Interagency Technical Advisory Committee: Kentucky Water Resources Research Institute, p. 11–13.

Wunsch, D.R., 1996, Ground-water monitoring strategy: Western Kentucky Coal Field, *in* Framework for the Kentucky Ground-Water Monitoring Network: A report of the Interagency Technical Advisory Committee: Kentucky Water Resources Research Institute, p. 13–15.

TALKS BY STAFF MEMBERS TO PROFESSIONAL AND CIVIC GROUPS

Anderson, W.H., 1995, Rocks and minerals of Kentucky: Bluegrass Gem and Mineral Show, Lexington, Ky., September 17, 1995; Fall Festival, Falls of the Ohio State Park, Clarksburg, Ind., September 23, 1995.

Anderson, W.H., 1996, Rocks and minerals of Kentucky: Clays Mill Elementary School, Lexington, Ky., February 16, 1996.

Carey, D.I., 1995, GIS activities at the Kentucky Geological Survey: ARC/INFO Midwest Users Conference, Champaign, Ill., September 27–29, 1995.

Carey, D.I., 1995, Use of GIS in water supply studies: Eleventh Annual Scientific Symposium, Ohio River Basin Consortium for Research and Education, Fort Mitchell, Ky., October 2, 1995.

Carey, D.I., 1996, Evaluation of water supplies in the Upper Forks of the Kentucky River Basin: Kentucky River Water Supply Advisory Committee, Lexington, Ky., April 18, 1996.

Carey, D.I., and Morris, L.G., 1995, Evaluation of water supplies in the Kentucky River headwaters, progress report: Kentucky River Water Supply Study Advisory Committee, Lexington, Ky., November 14, 1995.

Carey, D.I., and Morris, L.G., 1995, Evaluation of water supply systems in the Kentucky River headwaters: Public meeting, Kentucky River Water Supply Study, Hazard Community College, Hazard, Ky., July 5, 1995.

Carey, D.I., and Morris, L.G., 1996, Development of a GIS for the Kentucky River Basin: Kentucky Water Resources Annual Symposium, Lexington, Ky., February 13, 1996.

Chesnut, D.R., Jr., 1995, Carboniferous fossils of Kentucky: Fall Fossil Festival, Falls of the Ohio State Park, September 23, 1995.

Chesnut, D.R., Jr., 1995, Geological adventures in the Altay Mountains of southern Siberia: Blue Grass Gem and Mineral Club, October 15, 1995.

Chesnut, D.R., Jr., and Ettensohn, F.H., 1996, Geological adventures in the Altay Mountains of southern Siberia (or Mutt and Jeff go slumming through Siberia): University of Kentucky Department of Geological Sciences Seminar Series, Lexington, Ky., February 1, 1996.

Conrad, P.G., 1995, Development of a Statewide network for monitoring ground-water quality and quantity: Water Resources Research Institute First Wednesday Luncheon Seminar, Lexington, Ky., October 4, 1995.

Conrad, P.G., 1996, Recommended framework for a Statewide ground-water monitoring network by an interagency technical advisory committee: Kentucky Water Resources Annual Symposium, Lexington, Ky., February 13, 1996.

Currens, J.C., 1995, Mass flux of agricultural nonpoint-source pollutant loads in a conduit-flow-dominated karst aquifer, Logan County, Kentucky: Section 319, Nonpoint Source Conference, Frankfort, Ky., September 19–20, 1995.

Currens, J.C., 1996, Mass flux of agricultural nonpoint-source pollutant loads in a conduit-flow-dominated karst aquifer, Logan County, Kentucky: Kentucky Water Resources Research Institute, First Wednesday Luncheon Seminar, Lexington, Ky., March 6, 1996.

Davidson, Bart, 1995, The availability of data from the Kentucky Geological Survey's Geologic Data Center: Kentucky Society for Professional Engineers in Mining Seminar, Lexington, Ky., August 11, 1995.

Davidson, Bart, 1995, Energy and fossils of Kentucky: Lexington Children's Museum, Lexington, Ky., October 7, 1995.

Davidson, Bart, 1995, The Kentucky Ground-Water Data Repository: Ohio River Basin Consortium for Research and Education Eleventh Annual Scientific Symposium, Fort Mitchell, Ky., October 1, 1995.

Davidson, Bart, 1996, Careers in geology: Lincoln County Middle School, Stanford, Ky., March 27, 1996; Kingston Elementary School, Kingston, Ky., June 7, 1996.

Davidson, Bart, 1996, Dinosaurs: Mayfield Elementary School, Richmond, Ky., April 3, 1996.

Davidson, Bart, 1996, Fossils of Kentucky: Lexington Children's Museum, Lexington, Ky., February 3, 1996.

Davidson, Bart, 1996, Geology: Clays Mill Elementary School Symposium, Kentucky Geological Survey, Lexington, Ky., May 27, 1996.

Davidson, Bart, 1996, The geology of Kentucky: Rotary Club, Somerset, Ky., April 1, 1996.

Davidson, Bart, 1996, Rocks and minerals of Kentucky: Cassidy Elementary School, Lexington, Ky., February 21, 1996; Middleton Elementary School, Middleton, Ky., March 1, 1996.

Davidson, Bart, and Fogle, A. W., 1995, The application of GIS in mapping selected ground-water parameters using data from the Kentucky Ground-Water Data Repository: Ohio River Basin Consortium for Research and Education Eleventh Annual Scientific Symposium, Fort Mitchell, Ky., October 2, 1995.

Davidson, Bart, Fogle, A.W., and Wente, K.J., 1996, The application of GIS in mapping selected ground-water parameters using data from the Kentucky Ground-Water Data Repository [poster]: Kentucky Water Resources Annual Symposium, Lexington, Ky., February 13, 1996.

Dever, G.R., Jr., 1996, Faults in eastern Kentucky: Natural History Weekend, Natural Bridge State Park, Slade, Ky., March 15, 1996.

Dever, G.R., Jr., 1996, Geology of the Natural Bridge area: Natural History Weekend, Natural Bridge State Park, Slade, Ky., March 16, 1996.

Dever, G.R., Jr., 1996, Industrial minerals: University of Kentucky Department of Geological Sciences, Lexington, Ky., May 22, 1996.

Dinger, J.S., and Felton, G.K., 1995, Effects of agricultural best management practices on ground-water quality in the Mammoth Cave National Park region, Kentucky—Phase I: Site selection, equipment installation, and pre-BMP monitoring: Kentucky Nonpoint Source Pollution Conference, Frankfort, Ky., September 19, 1995.

Dinger, J.S., Minns, S.A., and Sendlein, L.V.A., 1995, Hydrogeologic implications of backfilling FGD material in highwall-miner adits: U. S. Department of Energy Contractors Symposium, Carbondale, Ill., September 27, 1995.

Drahovzal, J.A., 1995, Exploration strategies and possible submarine fan complexes in the Rough Creek Graben, western Kentucky: American Association of Petroleum Geologists Eastern Section Annual Meeting, Schenectady, N.Y., October 17, 1995.

Drahovzal, J.A., 1996, Cambrian and Precambrian rifting in central and western Kentucky: Evidence from reflection seismic data: Geological Society of Kentucky Geoscience Symposium, Lexington, Ky., May 30, 1996.

Drahovzal, J.A., 1996, Precambrian and Cambrian rifting in the southeastern Midcontinent: Seismological Society of America Annual Meeting, St. Louis, Mo., April 3, 1996.

Drahovzal, J.A., 1996, Some new aspects of the deep structure and basement geology in Kentucky: West Virginia University Department of Geology Colloquium, Morgantown, W.Va., April 18, 1996.

Eble, C.F., 1995, The Clean Air Act Amendments of 1990: Impacts on Kentucky coal: Geological Society of America, Annual Meeting, New Orleans, La., November 7, 1995.

Eble, C.F., 1995, The Harbour seam at Table Head, Sydney Basin: A Westphalian D mire margin and its succession to clastic wetland forest: Geological Society of America, Annual Meeting, New Orleans, La., November 7, 1995.

Eble, C.F., 1995, Trace elements in Kentucky coal: Kentucky Geological Survey Trace-Element Seminar, Lexington, Ky., March 1, 1995.

Eble, C.F., 1996, Coal as a fossil: Paleontological Society of Kentucky meeting, Lexington, Ky., February 1, 1996.

Eble, C.F., 1996, Coal-quality parameters and Title III trace elements in eastern Kentucky coals: Spatial and temporal trends: International Ash Utilization Symposium, April 1, 1996.

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