1997–98

Annual Report

Kentucky Geological Survey
University of Kentucky
Lexington, Kentucky

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John D. Kiefer, Assistant State Geologist for Administration
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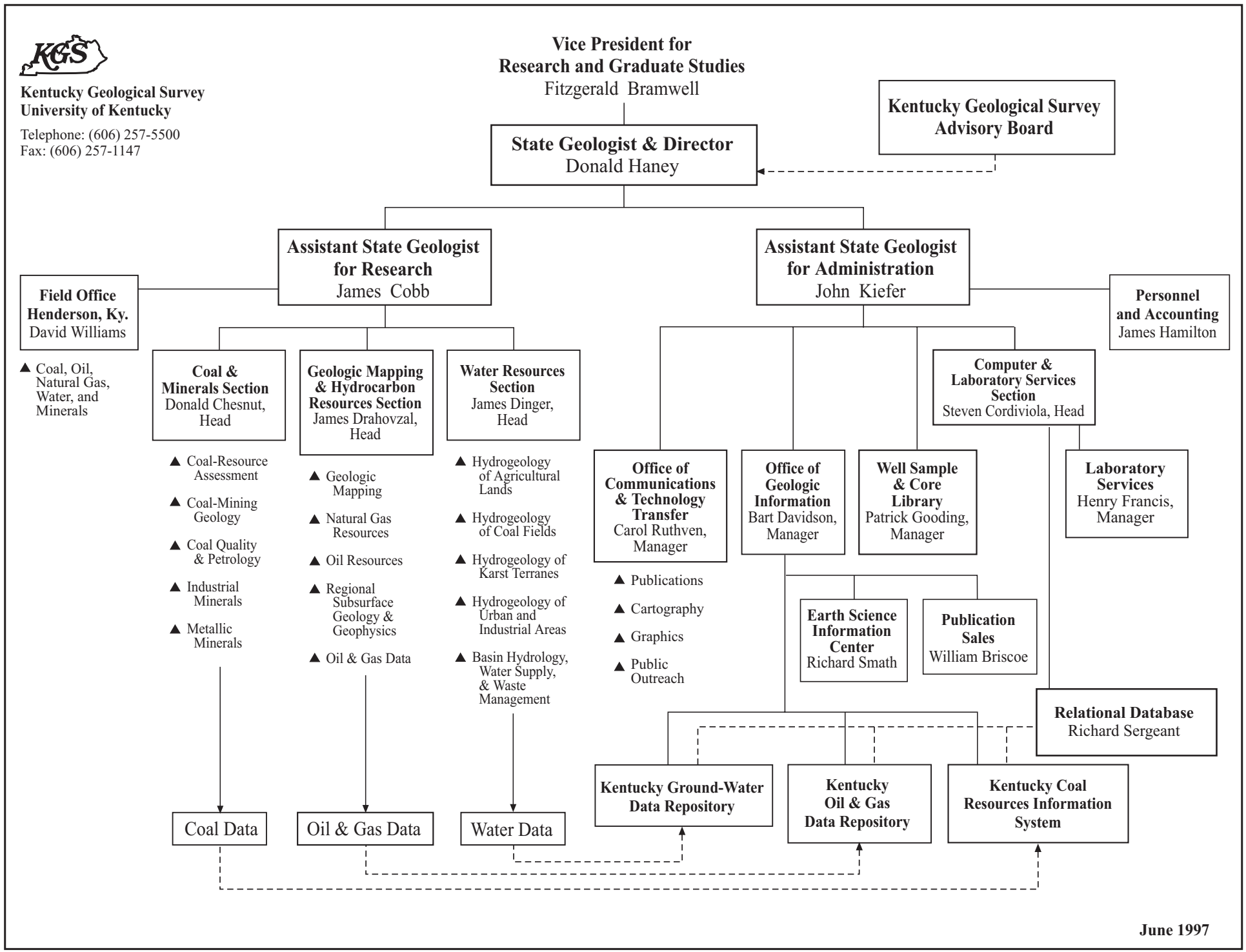
On the cover: A portion of the flood-prone map of the Jackson quadrangle.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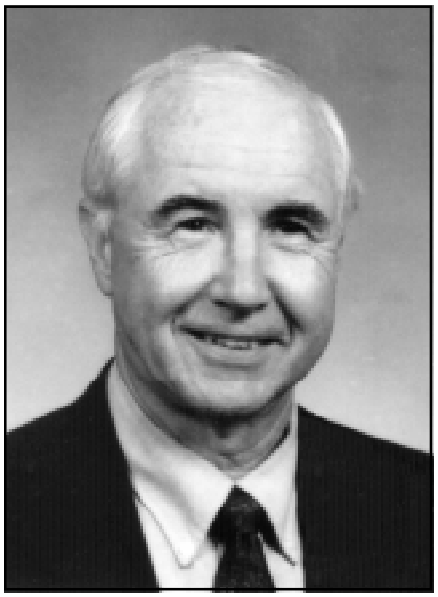
System
June 1997

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 natural 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.

DIRECTOR'S REPORT



The Achievements of the Eleventh Survey: An Overview of the Past 20 years

This year marks the twentieth year of the Eleventh Survey of the Kentucky Geological Survey (KGS). There have been 10 previous geological surveys in Kentucky since the first formal survey, designated the First Survey, was established in 1854. It is an appropriate time to highlight the accomplishments of the past 20 years and reflect on the future.

Although our mission of investigating the mineral and water resources of Kentucky has remained unchanged, society's needs have changed substantially. During the past 20 years, society has faced energy crises, water-supply shortages, concerns about mining, resource depletion, acid precipitation, global warming, nonpoint-source pollution, uncontrolled development, and natural hazards. Concern about these issues has increased and is not likely to diminish in the future. Our research has focused on addressing these issues and responding to the specific needs of the people of Kentucky.

Several research achievements of the Eleventh Survey stand out: national leadership in coal-resource assessment and digital geologic mapping, and research on ground-water resources for environmental protection and economic development. KGS has served the state of Kentucky through the management of three data repositories of geologic information for use by researchers and the public. The Survey has also been successful in building new and expanded physical facilities to better serve the public and to conduct research.

Coal-Resource Assessment

The energy crises of 1973–74 and 1979–80 created a heightened appreciation of our economy's dependence on inexpensive sources of oil, natural gas, and coal, and the national security risks and adverse impact on the U.S. balance of payments caused by a growing reliance on imported oil. Accurate resource assessment became a priority for government and private-sector decision makers. As a leading coal-producing state, we emphasized investigation of the availability, quality, and economics of coal recovery in the Eastern and Western Kentucky Coal Fields.

The Survey completed a comprehensive assessment of the resources of the Western Kentucky Coal Field in 1978 and the resources of the Eastern Kentucky Coal Field in 1983. The reports were published according to coal reserve district, and the coal resources were analyzed on the basis of 7.5-minute quadrangles. The detailed data collected in these investigations provided the backbone of the Kentucky Coal Resources Information System (KCRIS), which is one of the largest publicly available coal databases in the United States.

The Survey's pioneering work in the assessment of the amount of coal available for mining has enabled KGS to become a national leader in this field. Prior to the coal-availability studies by KGS, the prevailing assumption was that an unlimited amount of coal was available for the indefinite future. Decision makers neglected to distinguish between estimated "resources" and recoverable "reserves." Not all coal in the ground is available for mining with existing technology and current coal prices. Reliable estimates of the actual amount of coal available for mining were needed to avoid the risk of long-range planning premised on a false sense of resource availability, which could lead to unwise capital investments and policy decisions.

To address these concerns, the Survey developed a model for determining the availability of coal resources. The model took into account the impact of land-use restrictions, technology restrictions, and economic constraints that can limit the recovery of coal. KGS researchers provided conclusive evidence that current production levels in Kentucky cannot be sustained in the future without new advances in technology for

mining thin seams of coal and mining deep reserves of coal, or significantly higher market prices for coal.

The coal-availability research program has received almost $2 million in federal funding during the past decade. The KGS model for determining coal-resource availability has gained widespread respect among scientists in the academic community, government, and industry. The U.S. Geological Survey, other states, and foreign countries are now using the model.

Digital Geologic Mapping

The Kentucky Geological Survey has become a national leader in modern digital geologic mapping. This would not have been possible without the mapping achievements of the tenth State Geologist, Dr. Wallace Hagan. He was responsible for a $21 million cooperative geologic mapping project with the U.S. Geological Survey that made Kentucky the first major state to have complete geologic map coverage at a scale of 1:24,000. The project, which began in 1960 and was completed in 1978, resulted in the publication of 707 multicolored, 7.5-minute geologic quadrangle maps. Unprecedented in terms of time and money, it was the largest geologic mapping project ever undertaken in the United States.

The geologic maps provided the foundation for the next two decades of research and mapping in the Eleventh Survey and served as the basis for many derivative products that have contributed to economic development and environmental protection in Kentucky. In 1981, the Survey published a geologic map of Kentucky (1:250,000 scale), and in 1988 it published a wall map of the geology of Kentucky (1:500,000 scale). In 1998, KGS will publish a new map at a scale of 1:500,000 of the mineral and fuel resources of Kentucky. Derivative maps have been used for coal-resource assessment, oil and gas exploration, mineral-resource development, water-quality protection, identification of areas prone to landslides, siting landfills, and assessing earthquake risks.

To launch the digital mapping project, we seized a valuable opportunity created by the Congressional approval of the National Geologic Mapping Act of 1992. The legislation, designed to strengthen geologic mapping efforts nationwide, included a far-sighted provision for possible future funding for digitizing existing maps to establish a national geologic mapping database. The Survey made a commitment to take full advantage of matching funds from the federal government for an ambitious project to digitize all of the geologic quadrangle maps for Kentucky by the year 2007. Upon completion, this will be the most comprehensive, detailed bedrock database in the world for an area the size of Kentucky.

Ground-Water Resources

Investigations of ground-water resources have been a major focus of research at KGS and have been steadily expanded during the past 20 years. Our research relating to environmental protection includes studies of ground-water quality in agricultural areas, the impact of nonpoint-source pollution on aquifers and surface water, the impact of nitrate and pesticide pollution on bedrock aquifers in coal fields, the impact of disposal of coal ash in surface coal mines, and the geochemistry of ground water and its relationship to the flow of ground water in coal fields.

The Survey has performed a leading role in the Kentucky Interagency Ground-Water Monitoring Network in cooperation with several state agencies. In the spring of 1998, the Survey received a legislative mandate to establish a long-term ground-water monitoring network for the purpose of characterizing the quality, quantity, and distribution of Kentucky's ground-water resources.

One-quarter of Kentucky's land surface is underlain by karst terrane that is vulnerable to pollution and sinkhole collapse. Pollutants seep into ground water through sinkholes and spread rapidly to farm and municipal water supplies. The Survey is publishing maps showing karst flow systems. These maps are being used for wellhead-protection programs and by the agricultural community to improve water quality. Models of transport of pollutants in karst systems are also being created. Much of this research has been conducted in cooperation with the UK College of Agriculture, the Kentucky Water Resources Research Institute, and the Kentucky Cabinet for Natural Resources and Environmental Protection.

Research relating to economic development and water supply includes investigations of the hydrogeology of large spoil areas on land used for coal mining, the identification of wells in eastern Kentucky with high yields of water that can meet the needs of rural residents, and the potential use of ground water from abandoned underground coal mines for municipal water supplies. Modern technology used in these investigations includes GIS, and Landsat and SLAR (side-looking airborne radar) imagery data.

The Survey has received national attention from the success of the Star Fire research project in eastern Kentucky. This 10-year project, with funding of $1 million received since 1988, has been a collaboration between a national coal company and the University of Kentucky. Research at the Star Fire tract has created one of the

nation's best examples of resource extraction in conjunction with planned post-mining land use. KGS geologists are studying the settlement of soil on land after mining is completed, the construction of aquifers, and water quality and supply. They are also studying water quality at two large surface-water impoundments downstream of the mine that will ultimately be used for wildlife management and recreation. The research has important implications for future use of land after coal has been mined, and for water quality and supply, which are essential for economic development in eastern Kentucky.

Geologic Information and Public Service

In 1983, the Survey purchased a VAX 11/750 mainframe computer manufactured by Digital Equipment Corporation and entered the computer age. The first major challenge was to enter oil and gas well records into a database and make the data available to KGS researchers and the public. Before long, plots of oil and gas well-location maps were printed on demand for the public. Today, records such as drillers' logs, wireline logs, well-location survey plats, plugging affidavits, stratigraphic tops, and completion reports are on file and publicly available at the Kentucky Geological Survey. The Kentucky Oil and Gas Data Repository has more than 175,000 well records, of which more than 150,000 have been indexed in a computer database. A project is currently under way to scan all of these well records in digital format for archival purposes.

Under a legislative mandate from the state, KGS established the ground-water data repository in 1990 to archive at a central location the ground-water data collected by more than 15 agencies, other organizations, and independent researchers. These data, in turn, are made accessible to the public and enable geologists at KGS to respond to approximately 100 questions a month from the public regarding ground-water resources in Kentucky. The repository is used extensively by industry personnel, environmental geologists, engineers, officials from regulatory and other government agencies, land-use planners, soil scientists, architects, drillers, researchers, and students.

Data in the Kentucky Coal Resources Information System have been collected by KGS geologists over the last 20 years. Two major data sets make up KCRIS. The first contains coal-thickness measurements and descriptions of coal at natural outcrops, roadcuts, and mine exposures. The second set contains data for coal-quality analysis of samples from mines, natural outcrops, and cores. KGS staff also maintains a borehole database of records of continuous core and rotary holes drilled for coal exploration and development. These data are coded and entered into a computer system and are available for use by the public, government agencies, and the coal industry.

Data from these three repositories are now being linked in a relational database that is a detailed and comprehensive publicly available collection of nonproprietary petroleum, coal, water, and limestone data for Kentucky. KGS personnel access the database to respond to thousands of public inquiries each year and compile information for ongoing research. Future plans include creation of a virtual geoscience resource center to provide the public with direct access to most of the KGS databases via workstations at the University of Kentucky and remote access via the Internet. This would give individuals electronic access to enable them to independently search and retrieve geologic maps and data.

Improved Infrastructure

In 1978, Survey staff members were scattered in offices in several buildings on the University of Kentucky campus, there were no laboratory facilities, and the Publication Sales office and well record library had limited space and were not easily accessible to the public. The Survey secured a new three-story, 120,000-square-foot building for its main research and administrative offices. Working closely with the mineral and energy industries of Kentucky and the leadership of the Kentucky General Assembly, and with assistance from the KGS Advisory Board, the Survey succeeded in securing funding for a new building, which included a modern environmental research laboratory. The Mining and Mineral Resources Building was dedicated on April 8, 1988, and provided the Survey with its own laboratory facilities, enlarged its computing capabilities, and increased space for its Publication Sales office and well record library.

Additional space, however, was soon required for the Survey's Well Sample and Core Library, which is the fifth largest collection of publicly accessible data of this type in the country. Over a 20-year period, this collection had been stored in three different buildings and had been damaged by major floods, ice and snow storms, and transportation from one location to another. With the support of the Vice President of Research and Graduate Studies, a permanent 48,000-square-foot building to provide storage, laboratories, and facilities for public use was completed in 1998 on university property conveniently located close to the Kentucky Department

of Mines and Minerals and the Division of Oil and Gas.

For the past decade, the Survey has operated an environmental research laboratory for analysis of water, coal, and rocks and minerals. These analytical services support research by KGS scientists and researchers at the University of Kentucky, various state agencies, and some private sector companies. In 1997, the Survey established an internship in environmental chemistry to provide undergraduate students with hands-on experience in a research laboratory.

Future Directions

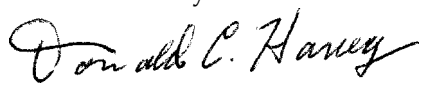
Coal mining will remain important to the economy of Kentucky well into the future, if investments are made in new mining technology and an improved understanding of the geology of the remaining resource. In particular, Kentucky has a great potential for producing high-value specialty coals. Research is needed in geology, chemical engineering, and marketing to promote the development of specialty coal products. The Survey's expertise in assessment of coal available for future mining, analysis of coal quality, and coal-mining geology will continue to be important for research at the University of Kentucky, within the state, and throughout the nation.

Digital geologic maps will be valuable for many facets of economic development. The utility of digital geologic maps, when used with GIS, is virtually unlimited. The maps will be useful for evaluation and development of coal, mineral, and petroleum resources. They will be used by land-use planners; geographers; geologists; engineers; developers; miners; ecologists; federal, state, and local government agencies; and many other individuals and organizations. Our digital geologic mapping project will remain a top priority.

Urban and rural economic development and quality of life for citizens require large quantities of clean water. The water-resources research program at KGS will continue to focus on water-quality and water-supply issues. The long-term ground-water monitoring network will be particularly important in the future for improving our understanding of the quality, quantity, and distribution of ground-water resources in Kentucky.

The Survey's research strengths in coal, oil and gas, and water resources, and our expertise in data management and geologic mapping, provide the backbone of our public service. Researchers at the Survey respond to more than 12,000 requests for information or technical exchange from the public each year. Our staff serves on more than 100 committees, boards, and professional societies at the international, national, regional, state, and local level. Since 1978, we have published more than 190 publications. We will continue to use our expertise as geologists to address problems in society. In summary, we are well prepared to meet the challenges of the next 20 years.

Donald C. Haney



State Geologist and Director

PUBLIC SERVICE ACTIVITIES

Requests for Information or Technical Exchanges
- Coal and minerals—1,140
- Oil and gas—4,390
- Water—2,025
- Earth Science Information Center—529

Publication Sales Office
- Visitors or requests for information—3,401

Oil and gas permit applications processed—990

Oil and gas completions, terminations, drilling affidavits, and changes processed—1,579

Well Sample and Core Library
- Visitors or requests for information—616*

Oil and gas well record products sold
- Well records copied—21,670
- Electronic-data disks and well lists —135
- Computer-generated overlays to topographic maps—458

Copies of electric logs and miscellaneous maps (number of feet)—20,676

Data entry or new records received for oil and gas well records (number of wells)—3,496

Samples analyzed by Laboratory Services—1,650

Kentucky Geological Survey publications completed—16

Publication and map sales
- Publications—5,861
- Topographic maps—10,075
- Geologic quadrangle maps—2,605

Talks to civic and professional groups—164

Papers by staff members in outside publications—63

Committees, boards, and societies
- International—4
- National—17
- Regional—15
- State—37
- Local—15
- University of Kentucky—20

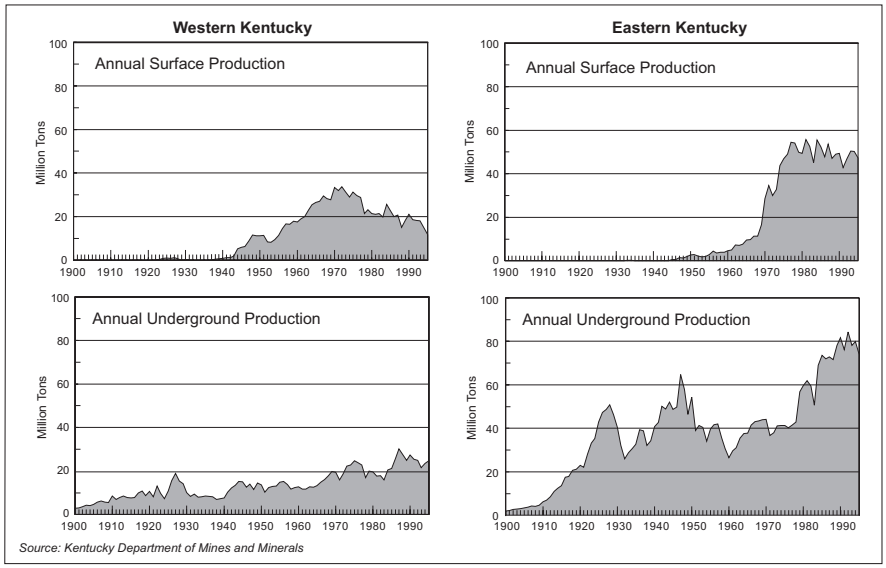
Grants and contracts in effect—30

*The Well Sample and Core Library was closed for much of the fiscal year because of construction of the new facility.

COAL AND MINERALS

Coal and industrial rocks and minerals are important to Kentucky's economic growth and development. In 1996, the latest year for which statistics are available, the coal industry employed more than 19,000 miners, and tax revenues generated from all economic activity related to the industry provided more than $494 million to the General Fund in Kentucky[1]. Today, more than 50 percent of the nation's electricity is generated in coal-fired power plants, and 95 percent of the electricity generated in Kentucky comes from coal.

Many factors affect Kentucky coal production, but the size and quality of the reserves is one of the most important. In order to better understand the reserves, KGS has undertaken a project partly funded by the U.S. Geological Survey to construct detailed coal maps of the most important seams in the state. The first coal beds being studied are the Springfield of western Kentucky and the Pond Creek/Lower Elkhorn, Fire Clay/Hazard No. 4, and Upper Elkhorn Nos. 1, 2, and 3 of eastern Kentucky. In this project, maps are digitized, and thousands of data points are compiled in a computerized geographic information system (GIS). Data included in these maps are outcrop, elevation, thickness, and quality of coals; mined-out areas; and information about mineable benches.



Annual production from 1990 to 1995 by coal field and mine type.

The preliminary results reveal where remaining resources are likely to be found and what they are like. Large blocks of thick, near-surface, high-quality coal will be very hard to find in the next few years. Future coal exploration should focus on remaining blocks that are much smaller in extent, either highly variable in thickness or uniformly thin (less than 48 inches), or are deeper than previously mined coals. Regional studies are important to the coal industry and the public, so KGS has begun holding public seminars to communicate the research results. The first seminar, on the Pond Creek/Lower Elkhorn coal, was held in Prestonsburg in eastern Kentucky in the fall of 1997. Seminars on other coal beds will be presented in 1998 once the studies are completed.

Industrial and metallic rocks and minerals furnish society with raw materials for agricultural, ceramic, chemical, construction, energy, metallurgical, and manufacturing industries. The value of industrial minerals to the economy is often underestimated, but extremely important for the future growth and development of the state. The principal industrial rocks in Kentucky (limestone, dolostone, sand, gravel, clay, shale, and sandstone) are used chiefly in the construction industry, agriculture, and mining and for sulfur reduction in electrical power plants. Kentucky's rock and

[1]Kentucky coal facts [5th ed.], 1997: Kentucky Coal Marketing and Export Council and Kentucky Coal Association, 49 p.

Information generated by the coal 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.

mineral industry, including the manufacture of cement and lime, had a value of $453 million in 1996[1]. Crushed stone (limestone and dolostone) is the leading industrial rock produced in the state. It had a value of $243 million in 1996, and $285 million in 1997[2]. Kentucky ranked sixth in the United States in the production of crushed stone in 1997[2]; it ranked fourth in the production of limestone, and the second largest limestone quarry in the United States is the Reed Quarry in Livingston County, Ky.[3] In recent years, fluorspar, barite, and the metallic minerals sphalerite and galena (ores of zinc and lead) have been mined in the state, although none are being mined at the present time. Small quantities of cadmium, germanium, and silver have been recovered as by-products from these metallic ores.

Staff in the Coal and Minerals Section do research on coal-resource assessment, coal-mining geology, coal quality, and industrial rocks and minerals. KCRIS contains coalbed descriptions, coal-thickness measurements, coal-quality analyses, and borehole descriptions. Most of this information is in electronic form and is continually updated. A similar database on rocks and minerals is being developed. In addition to the databases, the Coal and Minerals research staff promotes technology transfer through workshops, seminars, and publications.

Coal-Resource Assessment

Available Coal Resources in the Eastern and Western Kentucky Coal Fields

Gerald Weisenfluh and William Andrews

In 1983, coal-resource estimates completed for Kentucky's two coal fields indicated that, for beds greater than 14 inches thick, 57 billion short tons and 38 billion short tons remained in eastern and western Kentucky, respectively. Although these estimates suggest long-term potential for mining, 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 administered by the U.S. Geological Survey to quantify the impact of these mining restrictions. The results will be valuable for planning the development of energy resources. Under this program, KGS has prepared coal-availability estimates for nine 7.5-minute quadrangles in eastern Kentucky. These estimates have shown that average mined-out tonnages represent only about 10 to 12 percent of the original resource estimates. Key coal beds such as the Fire Clay and Pond Creek have been extensively mined, however. In the Eastern Kentucky Coal Field, large portions of the original

The dark band in the center of this roadcut on U.S. 119 in eastern Kentucky is the Kendrick marine zone, a marker bed that appears throughout the Appalachian Basin. The coal immediately below the Kendrick, the Amburgy, is an important resource in the Eastern Kentucky Coal Field. Photo by Cortland Eble.

[1]U.S. Geological Survey, Kentucky annual estimate: U.S. Geological Survey Mineral Industry Surveys, 7 p.
[2]U.S. Geological Survey, 1998, Crushed stone and sand and gravel in the fourth quarter of 1997: U.S. Geological Survey Mineral Industry Surveys, 9 p.
[3]U.S. Geological Survey, 1998, Crushed stone, annual review—1996: U.S. Geological Survey Mineral Industry Surveys, 31 p.

estimates are represented by coal beds too thin to mine by modern underground-mining technology. Moreover, much of the available coal is too deep to be economically mined at the present time.

For western Kentucky, nine quadrangle studies have been completed. In this region, a significant amount of some coal beds has been rendered unmineable because overlying or underlying coal beds have been previously mined. Also, some coals have been extensively mined, particularly by surface methods. As a result of the region's physiography and mineral ownership, larger mines are favored, and small mine blocks are an impediment to the economic development of coal. Some coals occur in western Kentucky at depths greater than is economically feasible to mine.

Deep Coal and Energy Resources of the Western Kentucky Coal Field

David Williams, Stephen Greb, and William Andrews

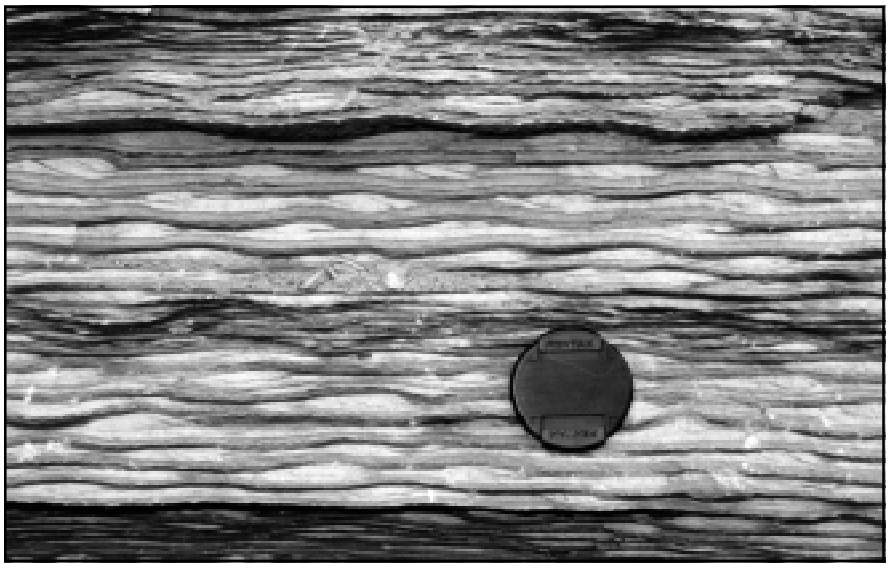
Western Kentucky coal production is increasingly dependent on underground mining. Information from operating mines, as well as from mines not currently operating, can aid in our understanding of local subsurface resources and lead to an accurate assessment of future coal and energy resources. Subsurface data from recent mining operations are being compared with borehole data from other parts of the coal field so that coalbed depth, thickness, and quality can be better understood. In the past year, 7,829 feet of exploration cores was logged for research on deep coal resources, and numerous borehole records were encoded. To date, 5,193 borehole descriptions have been coded and computerized; of this number, 3,045 are publicly available.

Geologic Analysis of the Coal-Bearing Rocks of the Western Kentucky Coal Field for the Development of Coal Resources

Stephen Greb and David Williams

Most of the coal currently mined in western Kentucky is high in sulfur content, averaging well above the threshold of 1.2 lb of sulfur dioxide per million Btu required by the federal Clean Air Act. Washing and other processes remove sulfur and ash from raw coal and improve quality, but even the cleaned coal is usually above compliance limits. Low- to moderate-sulfur coals such as the Western Kentucky No. 4 are mined, but are not widespread. To understand the controls on these better quality coals, the coals need to be sampled as they are mined. If the quality of a coal in a specific area can be related to the geology of the surrounding strata, models might be developed that will help delineate future areas with the potential for similar quality coal.

Limited sampling of the Western Kentucky No. 4 coal on the southwestern edge of the coal field has shown that coal thickness was locally influenced by contemporaneous faulting; in many places, coal thickens on the downdropped side of narrow splinter faults and thins on small fault blocks south of the main fault system. Many of the faults had not been previously encountered and were unknown prior to mining. Increased sulfur contents near some of the faults, possibly because of fluid movement toward the faults, may indicate a relationship between faults and coal quality.



Rhythmically bedded strata that were deposited under tidal influences in an estuarine environment, called a tidalite, commonly occurs above coal beds in Kentucky. Photo by Cortland Eble.

Geologic Analysis of the Coal-Bearing Rocks of the Eastern Kentucky Coal Field for the Development of Coal Resources

Stephen Greb and Cortland Eble

More than 70 percent of Kentucky's annual coal production is from the Eastern Kentucky Coal Field. Although generally lower in sulfur content and ash yield than coal from western Kentucky, coal from eastern Kentucky is highly variable in thickness and quality.

In the past year, analysis of coal-bench architecture continued. Many eastern Kentucky coals are composed of distinct benches or units of coal separated from each other by thin but widespread partings. Often these benches have different quality and thickness characteristics. These differences

can be overlooked when the whole coal is analyzed. By analyzing coal characteristics at the bench scale, the effect of the characteristics of a single bench on the whole-coal quality or thickness variability can be examined. Because a mined seam at any location is a product of its benches, regional bench-scale analysis provides a useful tool for understanding and predicting lateral variation in coal characteristics. Often, thick, multiple-bench coals have poorer quality than laterally equivalent, thinner coals because of the presence of a local low-quality bench.

Coalbed Methane and Deep Coal Resources of the Eastern Kentucky Coal Field

Stephen Greb and William Andrews

The Eastern Kentucky Coal Field is one of the world's most productive coal-mining regions, and has a long mining history. Past 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 coalbed thickness, coalbed quality, and roof-rock trends in unmined areas in the subsurface will require correlations between exploratory cores and known mines and exposures. To make these correlations in the future, borehole records available from coal companies operating in Kentucky are continually collected. These records are coded, computerized, and used for a wide variety of applications. Currently, 4,679 borehole records from eastern Kentucky are publicly available.

Current understanding of deep coal resources in the Eastern Kentucky Coal Field suggests that in addition to the potential of subsurface mineable resources, there is also potential for the production of coalbed methane.

Coal Atlas for Kentucky

Gerald Weisenfluh, Ernest Thacker, and Stephen Greb

The project, Available Coal Resources in the Eastern and Western Kentucky Coal Fields (see above), has identified a number of factors that significantly affect the potential for mining Kentucky's coal. This work has led to an effort to quantify these factors over larger regions and devise means of transferring this information to the largest possible audience. With this goal in mind, the Kentucky Geological Survey is participating in the U.S. Geological Survey's National Coal Assessment Program, which is compiling basinwide coal-resource and mining data for the most important coal beds in the country. A similar program that covers the Western Kentucky Coal Field is being conducted by the Illinois Basin Consortium (composed of the Kentucky, Indiana, and Illinois geological surveys), the U.S. Geological Survey, and the Electric Power Research Institute. The results will eventually become part of the national coal assessment.

Based primarily on projected production, the Pond Creek, Fire Clay, Upper Elkhorn Nos. 1, 2, and 3, Hazard No. 5A, and equivalent coal beds were selected for study. Data on outcrop, mined-out areas, thickness, structure, and quality have been compiled for the Pond Creek and Fire Clay coals. Data for a third bed are currently in preparation. These data will be transferred to the U.S. Geological Survey for compilation into the final product.

The beds chosen for study in western Kentucky are the Springfield, Herrin, and Baker. This information will be included in the Eastern Interior Basin portion of the national coal assessment.

Data from Kentucky, Indiana, and Illinois have been 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 Illinois Basin.

Coal-Mining Geology

Mineability of Kentucky Coals

Stephen Greb, Gerald Weisenfluh, and David Williams

Mine sites are being investigated to document coal thickness, coal quality, and trends in mine roofs and floors in both the Eastern and Western Kentucky Coal Fields. Data must be collected on geologic features such as faults, cutouts, splits, and roof falls as they are encountered so that their size, shape, and trends can be used to help identify similar geologic problems in other mines. Data on features that affect the mineability of Kentucky coals are collected from individual mines with known problems, and from other coal projects. At a mine operator's request, KGS geologists will visit the mine to help identify or rectify problems arising from geologic obstacles.

In the past year, data were collected on (1) dips or floor rolls in the Pond Creek coal, in which the coal thickened into narrow, linear depressions in the mine's floor; (2) riders causing roof problems where they came close to the mined Baker, Hazard No. 8, and Pond Creek coals; and (3) some unusual flow rolls, paleoslumps, and other deformed beds above the Hazard No. 8 coal.

Reports on these features will be available in the future.

Application of Geographic Information Systems to Coal-Field Geology

Stephen Greb and Carlos Galcerán

Geographic information systems store geographically referenced data in a computer and are designed to manipulate, analyze, and display those data. With GIS, multiple coverages (data sets for features on a map) can be combined and analyzed for a wide variety of applications.

In the past year, KGS finished a cooperative project with the Tennessee Valley Authority to develop a GIS database containing information on active and inactive coal preparation plants, loading facilities, and transportation networks in Kentucky. The project used data from the U.S. Geological Survey, the Governor's Office of Coal Marketing and Export, the Kentucky Transportation Cabinet, and other agencies. GIS coverages of the coal transportation infrastructure in Kentucky (road, rail, and river) and load-out facilities have been prepared and will be available to the public in the near future.

Coal Quality and Petrology

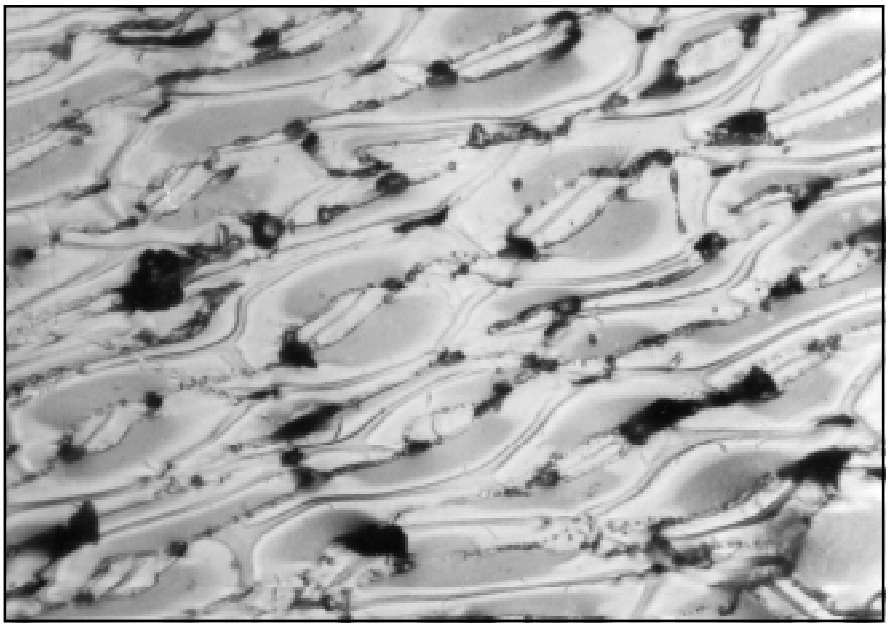
Coal-Quality Characteristics of Major Mineable Coal Beds in Kentucky

Cortland Eble

The effects of federal regulations that limit the amount of sulfur dioxide that can be emitted during coal combustion have been felt throughout the Commonwealth. Almost half of Kentucky's coal-fired generating plants are now equipped with pollution control devices, which is well above the national average of 22 percent. In part, this has allowed much of the coal in western Kentucky, which has a moderate to high sulfur content, to remain a viable economic supply for utilities. The potential regulation of 15 trace elements that occur naturally in coal may also have some impact on Kentucky coal production.

This past year has brought two new challenges to Kentucky coal. The first is a proposal for an additional reduction of nitrous oxide emissions from coal-fired power plants in the Ohio Valley. Although the future of this proposal is not clear, any additional nitrous oxide regulations will almost certainly have an impact on Kentucky coal. The second challenge is much more far-reaching than the first. It is a proposal to reduce greenhouse gases produced by the combustion of fossil fuels. If implemented, the use of coal for electricity generation might be severely curtailed, which would not only be detrimental to Kentucky's coal industry, but to the nation's coal industry as a whole.

To help meet these challenges, the Kentucky Geological Survey collects and analyzes hundreds of coal samples each year. The accumulated data, which are publicly accessible, help identify which coal beds contain the most desirable properties (for example, low ash, low sulfur, high calorific value). This information can then be used to help direct future exploration and mining.



Coal is composed of macerals, which are analogous to minerals in a rock. This is a photomicrograph of the maceral semifusinite, which is wood or bark tissue oxidized by fire or microbial decay. Magnification 640X. Photo by Cortland Eble.

Public Access to Coal Information and Coal-Data Management

Data in the Kentucky Coal Resources Information System have been collected by the Survey for the last two decades. The databases benefit the public, government agencies, and the coal industry, and are continually updated with new information. Analytical data from the KGS coal laboratory are also added to the database.

Two major data sets make up KCRIS. The first contains coal-thickness measurements and descriptions of coal at natural outcrops, roadcuts, and mine exposures. Coalbed correlations were determined by KGS and the U.S. Geological Survey. This data set is currently limited to the Eastern Kentucky Coal Field. The

second set contains data for coal-quality analysis and has the results of analyses of coal samples from mines, natural outcrops, and cores. All sampling and analytical work was performed under quality-control conditions by KGS, the UK Center for Applied Energy Research, and the U.S. Geological Survey. Coal-quality data are available for both coal fields.

A borehole database contains records of continuous core and rotary holes drilled for coal exploration and development. Records were obtained from industry and government sources in both coal fields. The results of coal-resource estimates for 7.5-minute quadrangles, coal-availability estimates for selected 7.5-minute quadrangles, and stratigraphic correlations between coal districts are also available.

Geologists at KGS work continuously to code and enter data into the computer system and travel throughout the state to sample coal beds, measure coal-bearing outcrops, collect core descriptions, and describe core. All data are identified stratigraphically, topographically, and geographically before they are entered into the database. Data from KCRIS are available through the Office of Geologic Information or the staff of the Coal and Minerals Section.

Minerals

Industrial Limestone and Dolostone Resources in Kentucky

Garland Dever

The availability of limestone and dolostone resources in Kentucky for industrial uses is being investigated by the Kentucky Geological Survey. For use as industrial raw materials, chemical quality commonly is the determining specification.

Limestone and dolostone deposits across the state have been sampled to determine their chemical composition. KGS is preparing regional and county resource reports that will present chemical and lithologic data for the sampled sites, and will outline the geographic and stratigraphic distribution of potential sources of industrial-grade stone. Limestone samples from southeast-central Kentucky are currently being processed and analyzed.

Nonfuel-Mineral Statistics

Garland Dever

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 of state activities and mineral-resource reports.

Summaries of 1997 Kentucky activities were prepared for publication in *Mining Engineering* and the U.S. Geological Survey's *Mineral Industry Surveys* and *Minerals Yearbook.*

Mineral and Fuel Resources Map of Kentucky

Warren Anderson and Garland Dever

The Kentucky Geological Survey is completing a new map at a scale of 1:500,000 that shows mineral and fuel resources in the state. It delineates the distribution of industrial and metallic mineral resources, coal fields, tar sands, gas storage fields, and producing areas for oil, gas, and coal. The map will be published in 1998.

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GEOLOGIC MAPPING AND HYDROCARBON RESOURCES

The value of geologic maps to society is considerable. The earth is often considered static, because 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 droughts influence our lives. Human activities, too, 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 ground-water supply. Extraction of water, oil and natural gas, coal, and other minerals can result in subsidence and the subsequent loss of property value. Information describing the physical world is critical for identifying solutions to land use and environmental issues. Geologic maps provide useful information for these purposes.

As part of a cooperative program with the U.S. Geological Survey, KGS has been charged with a major project to digitize Kentucky's 7.5-minute geologic quadrangle maps for use in geographic information systems. GIS is a powerful tool for organizing and rapidly accessing information on digital maps and can be used for timely solutions and construction of models. These models can be applied to specific resource and environmental problems. Digital geologic information is an important building block in GIS. For these reasons, digital geologic mapping is being emphasized at KGS.

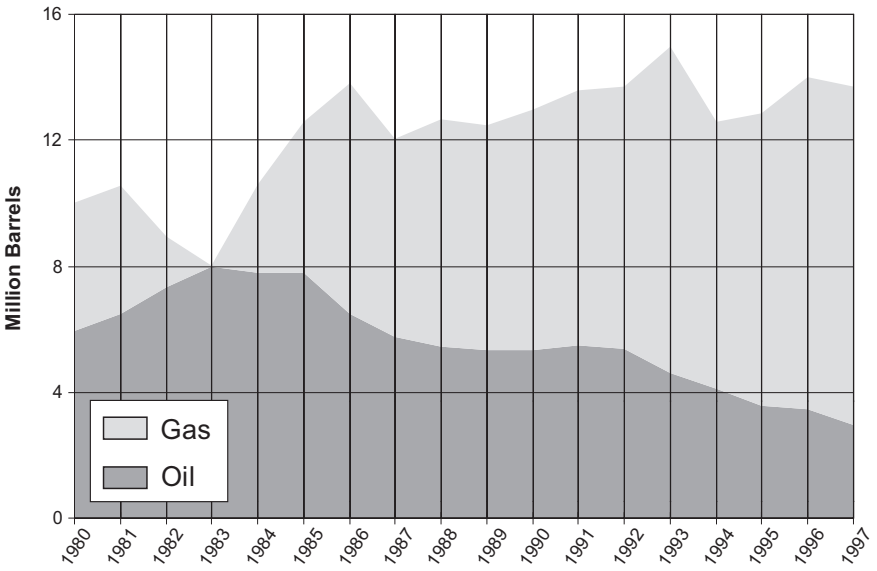
In addition to these surface mapping projects, regional geologic framework studies are conducted. Much of this work takes advantage of the approximately 175,000 oil and gas well records archived in the Office of Geologic Information and geophysical data in KGS files. Regional geologic research is vital in developing a sound stratigraphic and structural framework for 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. These activities directly support the exploration and development of natural gas and oil resources in the state.

KGS supports the operation of the Kentucky Seismic and Strong-Motion Network, which monitors earthquake activity in the state. In addition, KGS staff and other researchers at the University of Kentucky use high-resolution seismic-reflection data in environmental, engineering, and hydrocarbon-resource studies.

Oil and natural gas continue to be important commodities for the Kentucky economy. In 1997, the value of oil and natural gas production was more than $267 million, bringing $12 million in severance tax revenue to the state[1]. Nationally, the industry remains in

The Kentucky Geological Survey is a national leader in digital geologic mapping.

[1]Revenue and production calculations from data supplied by the Kentucky Revenue Cabinet.



Kentucky production of oil and natural gas (on an oil-equivalent basis).

a slump that extends back to 1986, although natural gas production has been rising the last several years. Natural gas production held essentially steady in 1997, falling only 2 percent to 79.5 billion cubic feet (Bcf). Oil production continued its decline, falling 15 percent below last year's level to 2.94 million barrels in 1997.

The Appalachian Basin of eastern Kentucky produced 98 percent of the state's natural gas and 35 percent of the oil. Leslie County, the third most prolific oil-producing county, produced 380.4 thousand barrels of oil and Pike County produced the most natural gas (30 Bcf). In the Illinois Basin, Union County continued as the top oil-producing county in Kentucky, although production fell 12 percent from the previous year to 425,435 barrels.

The value of natural gas production in Kentucky continues to outstrip the value of oil production by a margin of more than two to one. The state has large untapped natural gas resources that include coalbed methane. Despite falling oil production, hydrocarbons still represent an important state and national resource. Hydrocarbons will be important bridging fuels well into the 21st century, until renewable energy resources become more cost-effective to produce and consume.

Geologic Mapping

Digital Geologic Mapping in Kentucky

Warren Anderson, Thomas Sparks, and Lance Morris

KGS staff members are producing 7.5-minute digital geologic quadrangle maps at a scale of 1:24,000 for Kentucky. The maps and accompanying data sets are the result of a cooperative effort between the Kentucky Geological Survey and the U.S. Geological Survey as part of the National Geologic Mapping Program.

The new digital data sets have many uses and can be manipulated in a geographic information system. The most important use of digital geologic information is planning for economic development in Kentucky. Many economic development initiatives require geologic information for environmental impact studies, assessment of the availability of natural resources for site development, and geologic, engineering, or reclamation studies and highway construction planning.

This project will make Kentucky the first state to have its geology digitized at a scale of 1:24,000. In the first 2 years of the project, 54 of the 7.5-minute quadrangles in the Hazard and Irvine 30 x 60 minute quadrangles were completed. Information from other digital products, such as digital orthoquarter quadrangles, digital elevation models, digital raster graphic images, and satellite imagery, can be overlaid, registered, and plotted with the geology.

In the third year of this project, thirty 7.5-minute quadrangle maps from the Harrodsburg 30 x 60 minute quadrangle will be digitized. The Kentucky River Basin has been the focus of recent digital mapping, but in future years mapping will be concentrated in other parts of the state as priorities dictate. The goal is to have complete digital coverage for the state by the year 2007.

Scanning and Preservation of Geologic Quadrangle Maps

Steven Cordiviola and Daniel Carey

KGS, in cooperation with the University of Kentucky libraries, purchased a color scanning system that can scan images up to 66 inches wide. The system's initial use will be to preserve the more than 700 geologic quadrangle maps (GQ's) that cover the state of Kentucky. Eventually, the libraries will use the system to scan all of their large manuscripts.

The planning and inventory phase was completed this year. All

Kentucky will become the first state in the nation to have its geology digitized at a scale of 1:24,000.

but eight of the GQ's are available as flat maps; scanning unfolded maps provides a better image for scanning. The physical characteristics of each map, such as size, number of colors on the map, physical condition, and special features, were entered in a relational database. These data will eventually be linked to the main KGS database for use by researchers and the public.

The scanning phase began at the end of the fiscal year and will continue throughout the remainder of 1998. Scanning, storing, and preserving each image is time-consuming. The average file size is 700 megabytes, so KGS is investigating compression techniques to reduce file sizes without losing detail. Reducing the file size would allow more people to use the image. The scanned images will be preserved on 4-millimeter magnetic tape, CD-ROM, and possibly the new imaging DVD technology.

In early 1999, the scanned images will be reduced to the map image alone, without the ancillary information (such as stratigraphic columns, scales, and other text). The image will then be georeferenced so that it can be used with GIS applications.

State Mapping Advisory Committee

Donald Haney, Warren Anderson, James Drahovzal, and Richard Smath

Topographic maps are used by and are critical to planners, engineers, natural resource companies, farmers, and the public for planning and recreational use. These maps are the fundamental tools for depicting landscape, topography, road network, drainage, and cultural features. The State Mapping Advisory Committee is responsible for recommending to the National Mapping Division of the U.S. Geological Survey which Kentucky topographic maps should be revised.

The U.S. Geological Survey appears to have changed some of its earlier decisions about topographic map revision, in response to concerns expressed by the Kentucky Geological Survey and the Association of American State Geologists about map quality, content, cost, and availability. The USGS is currently seeking cost-effective methods to maintain high-quality topographic maps.

Natural Gas Resources

Geology and Hydrocarbon Potential of the Cambrian Grabens

James Drahovzal and David Harris

This multipart project studies the geologic evolution of the Cambrian Rough Creek Graben and Rome Trough to evaluate their hydrocarbon potential, especially for natural gas.

Conoco Deep Test Study. This project has been largely inactive during the last year because of other priorities. Conoco, Inc., has transmitted data to KGS for use in the project, including seismic data, thin sections of core and well cuttings, and digital log data. A preliminary report on the Conoco No. 1 Turner well is being prepared, and further work in cooperation with the Illinois State Geological Survey will 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. An annex agreement outlining the project goals has been approved. A summary report, to be prepared after the first year, will provide industry with basic data and interpretations for the three wells.

Rome Trough Study. A 1994 gas discovery in the Rome Trough in Elliott County has renewed exploration interest in the Cambrian pre-Knox interval in eastern Kentucky. At least seven development wells have been drilled in the Homer Field in Elliott County, and several new wildcat wells have been drilled elsewhere in the Rome Trough. Wells reported to date have produced an initial flow of 11 to 21 million cubic feet of gas per day. To assist industry in the development of this important play, a research consortium was designed to provide the geologic data and interpretations needed to increase success. In early 1998 two organizational meetings were held with industry representatives to obtain feedback on the proposed consortium. A final revised proposal for the Rome Trough Consortium was submitted to industry in late March 1998. The study area includes all of eastern Kentucky, southern Ohio, and northern West Virginia. Colleagues from the Ohio and West Virginia geological surveys will collaborate on parts of the project. The consortium will be funded in equal shares by the participating companies. If funded, the 2-year project is scheduled to begin in July 1998. All results will be held confidential for 2 years.

Submarine Basin-Floor Fan and Fan-Delta Study. Seismic-reflection data from the central and western parts of the Rough Creek Graben were interpreted and found to show fan complexes in the Cambrian and Proterozoic intervals. The fan complexes may be important hydrocarbon reservoirs. Two presentations were made during the year on these results and their implications for potential natural gas resources, at the Oklahoma City Geophysical Society meeting and at the national meeting of the American Association of Petroleum Geologists.

Wabash Valley Basement Map. As part of a cooperative seismotectonic research project with the U.S. Geological Survey, a map of the top of the Precambrian in the Wabash Valley area has been published by the U.S. Geological Survey. The map shows igneous

rocks and neotectonic and geophysical features, and is helpful for earthquake studies in the southern Illinois Basin. The map indicates that historic and recent seismic activity is relatively light in much of western Kentucky north of the New Madrid Seismic Zone. A map of the area showing only the Precambrian structure is being planned as an Illinois Basin Consortium publication.

East Continent Rift Basin Study. Recent reflection-seismic data indicate that the Middle Proterozoic of the East Continent Rift Basin apparently extends to western Kentucky. An overlying Late Proterozoic sequence is also present in western Kentucky, but is probably eroded in the central part of the state. These two Precambrian rift sequences have implications for hydrocarbon- and mineral-resource exploration, as well as for understanding earthquake-source mechanisms. The results of the study were published as a special volume of *Seismological Research Letters* in July 1997. Two manuscripts on the East Continent Rift Basin are in review, and will be submitted to KGS for publication. One is about the sedimentary petrology and the other about the mafic rocks.

Rough Creek Graben Study. Seismic-reflection data for seismic profiles in the central and eastern part of the Rough Creek Graben and adjacent areas were interpreted during the year. Results of some of this work were published in a special volume of *Seismological Research Letters* in July 1997. As part of the Wabash Valley seismotectonic study, sponsored by the U.S. Geological Survey and the Illinois Basin Consortium, a map showing the configuration of the top of the Precambrian for the graben and the surrounding area was published by the USGS. Much of this work is critical to understanding the development of deep hydrocarbon plays in and adjacent to the graben, as well as assessing earthquake-source mechanisms in far western Kentucky. Currently, there is little evidence for historic or recent seismic activity in the western part of the Rough Creek Graben. This area may represent a seismic gap between the more active New Madrid and Wabash Valley Seismic Zones.

Gas Reservoir Character of Devonian Shales of Kentucky

David Harris and James Drahovzal

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

Gas production from the New Albany Shale in western Kentucky dates back to the late 1800's, but little historic drilling to Devonian and deeper horizons had been done in western Kentucky. A developing gas play in the Devonian New Albany Shale of western Kentucky was extended from southern Indiana into the Commonwealth in 1996. A company involved in this play has built a pipeline and is using its recently completed wells to supply an industrial chemical facility.

In order to provide digital geophysical log data to industry for evaluation of the New Albany, a log database has been established at KGS. This database allows digital data to be extracted by well and depth. The data will be provided to the public on diskettes. Additional log data are continually being added to this database. Future studies on fractured reservoirs in the Devonian shale are being considered that will take advantage of the minivibrator and 48-channel seismograph acquired by KGS and the UK Departments of Geological Sciences and Civil Engineering.

Gas Storage Fields of Kentucky

David Harris

This project was initiated in late 1996. It will establish a database for active and inactive natural gas storage fields, and delineate areas that have potential for establishing new gas storage reservoirs. In addition, a new gas pipeline map will be constructed using GIS software. This map will also show the locations of existing gas storage reservoirs. Developing a GIS-based gas storage and pipeline database will be useful for the natural gas producing and transportation industries, and also for government agencies that manage disaster and emergency response activities. Emergency preparedness is of particular concern in western Kentucky, where several large interstate pipelines cross fault systems that have been active in the past.

The first step in the project was to construct a GIS-based pipeline map for the Commonwealth. In 1997 KGS was awarded funding to participate in the National Pipeline Mapping System State Agencies Pilot Test. This project, sponsored by the U.S. Department of Transportation, converted test pipeline location data submitted by operators into GIS format. Three data sets were completed in February 1998, and a final report was submitted to the Department of Transportation. KGS will apply for continued funding to participate in the national program. In addition,

Regional subsurface geologic maps being prepared by the Kentucky Geological Survey will have information that is crucial for guiding energy and mineral exploration and development, and addressing environmental issues.

KGS will be soliciting donations of pipeline location data from operators in the Commonwealth to expand the GIS database.

Oil Resources

Tertiary Oil Recovery Information System (TORIS) Database Enhancement in Western Kentucky

Brandon Nuttall, James Drahovzal, Anna Watson, and Thomas Sparks

TORIS is a national database containing reservoir and geologic data originally developed by the National Petroleum Council in 1984 for reassessment of the nation's enhanced oil recovery potential. It is used by the U.S. Department of Energy (DOE) to characterize the nation's oil resources and develop national energy strategies. In the original study, not all basins were adequately represented. No data were included for reservoirs in the Appalachian Basin region of eastern Kentucky; data from only five reservoirs (an estimated 4 percent of the total original oil in place) were included for the Illinois Basin region of western Kentucky.

In 1995, a DOE-funded, 12-month project began with a goal of accounting for approximately 80 percent of the eastern Kentucky original oil in place. In 1996, a project to account for at least 44 percent of western Kentucky's original oil in place was begun. In both studies literature searches were conducted, consultants and major operators were contacted for data, all available data were analyzed, and summary sheets for each reservoir were compiled and submitted to DOE.

Forty-six reservoirs in 33 fields representing the oil-producing regions of eastern, central, and western Kentucky were selected for the study. The original oil in place is estimated to have been more than 1.7 billion barrels; the remaining oil in place is estimated to be more than 1.3 billion barrels. The Lower Mississippian Weir sandstone of eastern Kentucky accounts for approximately 41 percent of the total remaining oil in place.

Stratigraphy and Reservoir Sedimentology of Mississippian Carbonates in Kentucky

David Harris and Thomas 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 completed in early 1996 and resulted in the collection of stratigraphic data for more than 7,700 wells. These data have been entered into a computer database. Digital stratigraphic data resulting from this project were made available to the public on diskette as KGS open-file report OF-97-03 in 1997. Final drafting of the regional cross sections that were constructed during the project was largely completed in late 1997, and these sections will be published in 1998. Interpretation of the data collected during the project is now in progress. Structure and isopach mapping of Mississippian units is being conducted under the Regional Subsurface Maps in Kentucky project. The first map (top of the Big Lime structure) will be published in 1998.

Tar Sands of Western Kentucky

Brandon Nuttall and James Drahovzal

Tar sands of western Kentucky comprise a major hydrocarbon resource of more than 3 billion barrels of heavy oil and tar in place in the shallow subsurface. This resource has been developed episodically for more than 100 years, depending on price and market considerations. With the declining availability and rising price of conventional oil, the tar sands will probably be commercial 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 significance to petroleum geology research. A database on tar sands continues to be maintained, but further research is not anticipated in the near term.

Regional Subsurface Geology and Geophysics

Regional Subsurface Maps in Kentucky

David Harris and James Drahovzal

The goal of this research is to produce a series of regional structure and isopach maps for the important geologic horizons and intervals in Kentucky. This information is critical not only for energy and mineral industries, but also for environmental issues. Furthermore, 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 a series at a common scale.

Studies associated with a project to prepare a seismotectonic map atlas for the Wabash Valley Seismic Zone resulted in a map of the top of the Precambrian for the western part of the Rough Creek Graben and the northern part of the Reelfoot Rift in western Kentucky. The map was published by the U.S. Geological Survey in late 1997. The map also will be published by the Illinois Basin

Consortium at a later date. These data, together with data from other projects, will be useful in the eventual production of a statewide basement map.

Data collected as part of the regional Newman Limestone stratigraphic study are being interpreted. A structure map of the top of the Newman Limestone (Slade Formation) was submitted for technical review in 1997. Revisions have been made, and it will be published in 1998. This map covers most of eastern Kentucky. The next unit to be mapped will be the top of the Mississippian Borden Group (base of the Big Lime). Then, a Big Lime isopach map will be generated.

An important regional structure map of the Beech Creek Limestone Member of the Golconda Formation (Barlow limestone) in the Illinois Basin, compiled by Avery Smith, a consultant from western Kentucky, is available as an open-file map (OF-97-05).

Seismotectonic Map Atlas for the Wabash Valley Seismic Zone

John Kiefer, James Drahovzal, and Steven Cordiviola

This project in cooperation with the other state surveys of the Illinois Basin Consortium and the U.S. Geological Survey was completed in early 1998 with the publication of USGS's Geologic Investigations Series I-2583-A–F. The series is an up-to-date atlas of the Wabash Valley Seismic Zone, which encompasses parts of western Kentucky, southeastern Illinois, and southwestern Indiana. The atlas contains geologic and seismologic information useful for the development of earthquake-mitigation programs and disaster-planning exercises. Map I-2583-A illustrates the seismicity of the Wabash Valley Seismic Zone. I-2583-B illustrates the zone's earthquake intensities. I-2583-C shows the locations of selected wells on geophysical survey and modeling lines. I-2583-D illustrates faults, igneous rocks, and geophysical and neotectonic features. I-2583-E shows geologic materials, and I-2583-F shows infrastructure for emergency-response planning.

A similar study for the Cincinnati area is under way in cooperation with the Central United States Earthquake Consortium.

Acquisition of State-of-the-Art Instrumentation to Do High-Resolution Shear-Wave Investigations in the New Madrid Seismic Zone

Ron Street, James Drahovzal, Issam Herick, and Kevin Sutterer

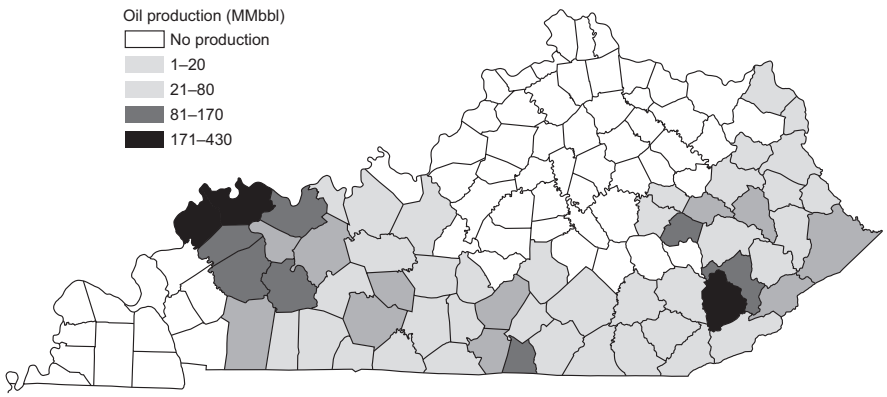
With funding from this project, equipment was acquired to support research and teaching to (1) detect and characterize deformed unconsolidated sediment associated with neotectonic activity in the vicinity of the New Madrid Seismic Zone, (2) determine the thickness of unconsolidated sediments, needed to understand their dynamic response to seismic loading, and (3) target potential fractured Devonian shale reservoirs, particularly in western Kentucky. This equipment includes a 24-bit, IFP, 48-channel seismograph with an extended memory and built-in correlator, and a trailer-mounted Vibroseis unit with a hold-down weight of 7,500 lb (3,401 kg), capable of generating P-waves and inline and cross-line S-waves. The Vibroseis unit can generate a usable signal within the frequency range of 10 to 550 Hz, with linear, nonlinear, or segmented sweeps.

The Kentucky Seismic and Strong-Motion Networks

Ron Street

The 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 monitors seismicity in Kentucky and areas bordering the state. It consists of 10 borehole-mounted, short-period vertical seismometers deployed from Grayson in the east to Clinton in the west. The seismic data are continuously transmitted to the University of Kentucky campus via the Kentucky Early Warning System microwave network. Data are simultaneously displayed as drum recordings of the seismic activity for visual analysis and stored on a computer for advanced processing and display. Since placed in operation, the network has recorded data for approximately 1,100 earthquakes.

Data from stations along the Mississippi River are used to investigate the effects of thick sequences of unconsolidated sediments on the propagation of seismic waves from earthquakes in the New Madrid Seismic Zone. The network provides engineers with high-quality data that can be used to design and construct safer structures.



Oil-producing counties in Kentucky, 1997.

The strong-motion network consists of seven surface-mounted, three-component accelerographs and two vertical arrays consisting of surface and borehole accelerometers. Data from the accelerographs are recorded digitally on site and transmitted by telephone modem links from the individual stations to the seismic laboratory at the University of Kentucky.

Eighty-eight strong-motion records have been collected to date. The largest earthquakes for which strong-motion records have been acquired are the 4.5 $m_{b,Lg}$ southeastern Missouri earthquakes of September 26, 1990, and May 4, 1991. The largest peak acceleration observed is one of 0.33 g in the Kentucky Bend region on December 2, 1997.

Illinois Basin Consortium Cross Section C-1 in Central and Western Kentucky

Martin Noger and James Drahovzal

A cross section from central to western Kentucky extends from the California No. 1 Spears well in Lincoln County to the Shell No. 1 Davis well in Crittenden County. It crosses from the western flank of the Cincinnati Arch into the Rough Creek Graben, taking advantage of the new deep Conoco wells (see Geology and Hydrocarbon Potential of the Cambrian Grabens, above). The upper part of the section to the top of the Knox has been completed using available geologic mapping and well data. The lower part of the section will be supplemented with seismic-reflection data. The cross section will be useful to those interested in the stratigraphy and structure of the Rough Creek Graben and its relationship to the Cincinnati Arch, and to those drilling for natural gas and oil in the area. This is part of a grid of cross sections being produced by the Illinois Basin Consortium that will be completed during the 1998–99 fiscal year.

Oil and Gas Data

Oil and Gas Maps

Brandon Nuttall, Anna Watson, and Lance Morris

In an effort to update the oil and gas maps of the state, a series of 1:100,000-scale computer-generated 30 x 60 minute quadrangle maps is being prepared that will be available to the public on a print-on-demand basis. The maps will provide a periodically updated reference for oil and gas drilling activity and results.

A computer-generated map for the Tompkinsville 30 x 60 minute quadrangle has been released as KGS Map and Chart Series 13. Additional maps are being compiled from digital line graph base maps available from the U.S. Geological Survey combined with oil and gas well location data from the Kentucky Oil and Gas Data Repository. A template for these maps, using the ArcView software package, based on the Tompkinsville 30 x 60 minute quadrangle map, has been developed. The Evansville and Hazard maps, based on the template, have been released as Map and Chart Series 14 and 15, respectively. The Beaver Dam, Bowling Green, Corbin, and Williamson quadrangle maps will be completed shortly.

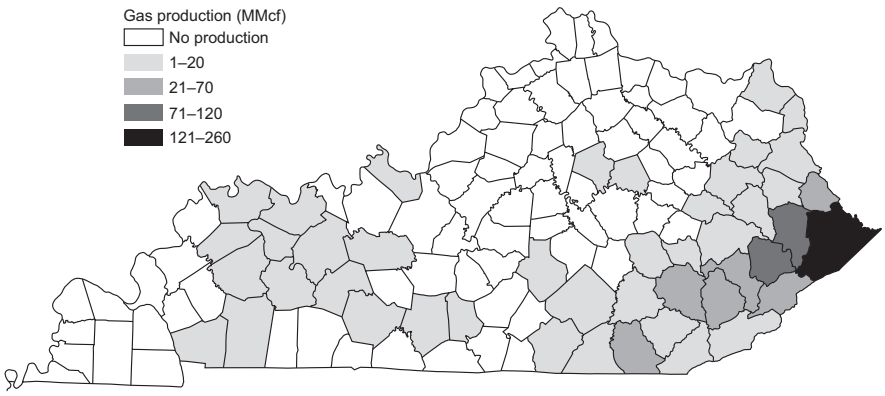
Summary maps at a scale of 1:1,000,000 are also being compiled and will include a map of Cambrian and deeper tests of Kentucky. The statewide oil and gas well location map published on demand as Map and Chart Series 9 has been updated and reformatted.

Oil and Gas Records

Anna Watson and Brandon Nuttall

The Kentucky Geological Survey 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 in the Office of Geologic Information. Records such as drillers' logs, wireline logs, well-location survey plats, plugging affidavits, stratigraphic tops, and completion reports are on file for an estimated 175,000 wells. The Henderson field office also maintains copies of all files for wells in western Kentucky. These materials are maintained, updated, and made available to the public. In addition, they are used by the KGS staff in basic and applied research projects. KGS is also responsible for advising the Kentucky Division of Oil and Gas on the accuracy of plats, spacing requirements, and special requirement areas for all oil and gas permit applications for the state.

During the fiscal year, records for 1,579 wells were processed for completions, changes, terminations, and plugging, and 990 permit applications were reviewed. All available stratigraphic tops data from western Kentucky



Gas-producing counties in Kentucky, 1997.

logs are being entered in a database.

Statewide Stratigraphic Tops Study

Anna Watson

The goal of this project is to produce a consistent and accurate stratigraphic tops database for all areas of the state for which suitable geophysical log data exist. Cross sections and subsurface maps of selected stratigraphic intervals will also be prepared for publication. At least one well with the deepest and most complete log suite will be selected for each 5-minute Carter coordinate quadrangle. Stratigraphic tops will be correlated with tops data from neighboring wells and will be identified as completely as possible from surface to total depth. Additional log coverage will be used where necessary in structurally complex areas. All new data will be added to the existing tops database. Cross sections and subsurface maps of the state and various regions will be produced and will be available, along with the enhanced tops database, as on-demand products for the public and for use in KGS research.

Development of a Virtual Regional Resource Center Using the Resources of the Internet and the World Wide Web

Brandon Nuttall

A national model by the Petroleum Technology Transfer Council calls for the establishment of regional and satellite resource centers where operators and producers in a basin can access information on a variety of existing and emerging technologies to support efficient and economic exploration and development of the domestic petroleum resource. These technology transfer centers will act as libraries, providing information for drilling and completion, reservoir characterization, environmental regulatory compliance, and exploration issues.

A project is being considered for funding by the Illinois State Geological Survey, the lead organization for the Midwest Region of the Petroleum Technology Transfer Council. The project's goal is to develop a World Wide Web site as a virtual regional resource center. This site will serve as an electronic gateway to the petroleum-related resources and services available at the Kentucky Geological Survey and the Midwest Region of the Petroleum Technology Transfer Council. Searchable lists of publications, basic fact sheets, and information on current KGS research will be made available and will include oil and gas well location maps, oil and gas well location and completion data, production data, reservoir-specific information, sample data files, and links to other petroleum resource and technology sites.

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WATER RESOURCES

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, at least 10 federal acts have been enacted to protect water. With guidance from these acts, state regulatory agencies have 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. The state has developed ground-water regulations to protect this vital resource. An understanding of the varied hydrogeologic conditions in Kentucky is essential for appropriate regulations and the optimum development, utilization, and management of the state's water resources.

KGS has directed much of its efforts over the past year toward designing new projects to meet the present and future demands of federal and state programs and the needs of Kentucky's citizens. These projects are implemented by drilling monitoring wells, sampling springs, and monitoring surface water. In addition, KGS maintains the Kentucky Ground-Water Data Repository, which contains 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. Therefore, basin hydrology research is essential for future economic development. To facilitate this type of research, KGS has instituted a geographic information system for storage and use of statewide data on land use, topography, geology, ground-water levels and quality, and water-supply systems. Several 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.

A long-term ground-water monitoring network is being established in cooperation with an interagency technical advisory board composed of 13 state agencies and is chaired by the director of the Kentucky Water Resources Research Institute. House Bill 172 formalizes the ad hoc Kentucky Interagency Ground-Water Monitoring Network, which has been in existence for the past 2 years.

The Kentucky Geological Survey has been given a mandate to establish a long-term ground-water monitoring network to characterize the quality, quantity, and distribution of Kentucky's ground-water resources.

Hydrogeology of Agricultural Lands

Assessment of Nitrate and Pesticide Impacts on Bedrock Aquifers in the Western Kentucky Coal Field

Glynn Beck, Philip Conrad, James Dinger, John Grove, and Joseph Taraba

This study is evaluating the movement and fate of pesticides and nitrate in a farmed, upland bedrock setting in Henderson County, in the Western Kentucky Coal Field. The site represents the gently rolling upland areas common in this region, and includes corn, soybeans, wheat, and beef cattle.

Monitoring wells, domestic wells, and streams are being sampled to identify any trends in nitrate and pesticides in ground water. Daily rainfall has been recorded at the site since September 1995.

Five well nests with three to four monitoring wells each were installed in 1996. A domestic well was also installed to gather information on the occurrence of nitrate. Soil cores down to bedrock were used to identify buried soils, measure depth to bedrock, and analyze soil nitrogen and organic carbon content with depth.

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 information on potential transport and fate of agricultural chemicals in similar agricultural and hydrogeologic settings. Agricultural specialists

The Survey is leading an interagency effort to map and explain where high and low concentrations of nitrate, iron, and other contaminants generally occur in ground water.

will use this information to help determine best management practices for this setting.

Funding for this project is provided by Kentucky Senate Bill SB-271. It is a cooperative effort between KGS, the Department of Biosystems and Agricultural Engineering, and the Department of Agronomy at the University of Kentucky.

Protection of Well-Water Supplies from Nitrate Contamination

James Dinger, Glynn Beck, Philip Conrad, John Grove, and Joseph Taraba

Approximately 6 percent of private wells in the Jackson Purchase Region yield water that exceeds the U.S. Environmental Protection Agency's maximum contaminant level for nitrate. The spatial pattern of nitrate contamination in the region has defied explanation. This project will determine if some private water wells in the Jackson Purchase Region are being contaminated by quick, downward movement of nitrate from the land surface along the well bore to the well pump, and will focus on potential poor well seals that allow leakage. Because shallow ground water usually contains greater concentrations of nitrate than occur at greater depth, pumping may cause high-nitrate water to flow downward through the well bore when the seal is poor. Leakage will be detected using bromide water tracing, water-chemistry variations, and six monitoring wells installed near a subset of the wells to be studied. If poor well seals are responsible for some of the elevated nitrate in water supplies, then this knowledge will be incorporated in outreach education programs for citizens of the region. Local officials and well owners are being contacted to identify suitable wells for the study. Preparations are being made for initial well sampling and tracing water movement.

Funding for this project is provided by Kentucky Senate Bill SB-271. It is a cooperative effort between KGS, the Department of Biosystems and Agricultural Engineering, and the Department of Agronomy at the University of Kentucky.

See the subsection "Hydrogeology of Karst Terranes" for a description of the study on nonpoint-source pollution in the Pleasant Grove Spring Basin.

Hydrogeology of Coal Fields

Hydrology of Large Spoil Areas

David Wunsch, Douglas Graham, Daniel Carey, and James Dinger

Surface coal mines often transform rugged, upland topography into usable, gently rolling land that is less prone to flooding than the land it replaced. These changes can be beneficial for economic development and diversification. KGS is conducting research to evaluate water resources and spoil settlement at the Star Fire Mine, which will be vital for the site's successful postmining development. Data collected by KGS will also be applicable to other areas of Appalachia.

Data collection from ponds and springs at the site was continued to determine their suitability for hosting stocked fish. The ponds are part of Cyprus Amax Company's Wildlife Refuge Area, and the company is interested in their use for fishing. The water is derived from ground water stored in the spoil. Computerized data loggers continuously collect data from surface-water impoundments and springs at the site, so that water-quality predictions can be made for future impoundments.

The amount and distribution of spoil settlement is also being studied. Four traverses across the spoil area have been surveyed, and 70 settlement monuments are currently being monitored along these lines. The monuments were surveyed in November 1997 and April 1998 to measure vertical and lateral movement. Aerial photographs have been used to map the progression of mining to determine when spoil was placed in

Nitrate and pesticides sprayed on crops by farmers can sometimes contaminate ground water. Photo by James Currens.

different parts of the site. A GIS database for the site will allow expedient and accurate calculations of spoil thickness and settlement. These data, in conjunction with data collected previously around monitoring wells, will allow evaluation of the effects of spoil thickness, age, and premining topography on the degree and rate of settlement. Areas underlain by recent spoil have settlement rates approaching 1.0 feet per year.

This project is funded by Cyprus Southern Realty Corporation through Cyprus Amax Company, and from the University of Kentucky's E.O. Robinson Trust.

Ground-Water Geochemistry and Its Relationship to Ground-Water Flow in the Eastern Kentucky Coal Field

David Wunsch, Philip Conrad, and James Dinger

Research is being conducted to define 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 on the use of ground-water resources and the implementation of Kentucky's ground-water protection regulations. These data also aid in the development of statewide ground-water monitoring strategies. Industries that operate in eastern Kentucky, including mining, oil and natural gas, and landfill operations, need this information for both permitting and compliance activities.

Several sites representative of the geology of the coal field have been intensively monitored to collect hydrogeologic and hydrochemical data. During the past year, water samples were collected for chlorine-36, carbon-14, and tritium analyses, which can aid in determining the age of ground water. These data will be used to correlate ground-water occurrence and water-rock interactions, and define the hydrochemical facies in aquifers in eastern Kentucky. Hydrochemical facies are distinct ground-water zones categorized by relative cation and anion concentrations. 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. 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.

Hydrologic Investigations in Robinson Forest

David Wunsch, Douglas Graham, and James 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, which will provide background conditions for water-quality investigations, as well as valuable information regarding the hydrology of forested basins.

Water levels in four wells are monitored in the Clemons Fork area of the main block of the forest. 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 will be used to study ground-water and surface-water interactions at the sites. Geochemical data from these wells show excellent agreement with a hydrochemical facies model being proposed for the Eastern Kentucky Coal Field.

Other monitoring wells were installed to monitor the occurrence of the shallow saltwater interface in relation to the surface topography. A 700-feet-deep well on a ridge top was installed to determine the depth of the saltwater interface below upland areas. A 150-feet-deep well was also installed in an adjacent valley to identify the interface in the valley bottom. As anticipated, salt water was discovered to be closer to the surface in the valley bottom. This finding is also consistent with a hydrochemical facies model developed for the coal field. These data will provide the basis for drilling strategies that will minimize the intrusion of salt water in wells used for water supplies.

KGS staff members have allowed college students studying ground-water hydrology access to these wells in the forest, and have also shared their expertise.

The project is funded through the E.O. Robinson Trust at the University of Kentucky.

High-Volume and High-Value Use of Flue-Gas Desulfurization By-Products in Underground Mines

Stephen Fisher, James Dinger, and Lyle Sendlein

Placing flue-gas desulfurization (FGD) by-products into underground mine openings has been proposed to stabilize auger holes and allow mining of coal that is currently inaccessible. However, leachate from FGD ash has the potential to release heavy metals and other solutes to the environment, where they can mix and react with in situ ground water, alter natural conditions, and adversely affect local ground-

KGS researchers are investigating fractures and faults that may produce high volumes of underground water for wells in eastern Kentucky.

water quality. This study uses geochemical modeling to evaluate the effects of FGD leachate on ground-water compositions in the Eastern Kentucky Coal Field. The methodology, results, and conclusions will be applicable to other areas of the Appalachian coal field.

The modeling will simulate a grouted auger-mine site in an upper valley location with many auger mines. These upper valley sites represent the major recharge zones for the ground-water systems, which are important sources of drinking water from domestic wells, and are the sources of recharge to first- and second-order streams in the Eastern Kentucky Coal Field. Ash leachate compositions for eastern Kentucky coal have been determined experimentally by the Center for Applied Energy Research at the University of Kentucky. The compositional range of shallow ground waters is based on data reported from wells in the Eastern Kentucky Coal Field. The geochemical modeling software PHREEQC is being used to determine the composition of leachate and ground-water mixtures.

This study 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.

Hydrogeologic Evaluation of High-Yield Well Potential in the Eastern Kentucky Coal Field

David Wunsch, Robert Andrews, and James Dinger

The Kentucky Geological Survey is using geologic and remote-sensing techniques to identify preferential locations for high-yield ground-water supplies in eastern Kentucky. Water-well yields from the rocks that underlie eastern Kentucky are low compared to yields from other parts of the country. Wells in eastern Kentucky that produce significant amounts of water (greater than 30 gallons per minute) usually occur where secondary permeability features such as fractures or faults are present in the rock.

Methods used to locate these features have been used elsewhere with some success. The state-of-the-art technologies used by KGS should make it easier to define specific areas where high-yield water wells may be located that can be used for community and industrial supplies.

Landsat and SLAR (side-looking airborne radar) imagery data are used for parts of the Eastern Kentucky Coal Field. Lineament coverages have been compiled for approximately 40 percent of the coal field. The resulting digital data images have been georeferenced using GIS technology, and field checking of specific locations is under way using a global positioning system. Field checking of lineaments drawn from this research indicates good correlation with outcrops that exhibited higher fracture densities than surrounding areas.

Two study sites were chosen for exploration drilling. Three wells were drilled at each site. One site near Jackson showed promising results; two of the three wells there produced yields that were greater than 90 percent of the yields reported for all wells in the KGS database for Breathitt County. A third site for exploration drilling is being selected.

The project is funded through the E.O. Robinson Trust at the University of Kentucky.

Fractures exposed at a roadcut along Kentucky 80, which were identified by lineament analysis. Photo by David Wunsch.

Characterization of Hydraulic Conductivity in the Eastern Kentucky Coal Field

David Wunsch and James Dinger

The hydrologic characteristics of rocks that compose the Eastern Kentucky Coal Field vary dramatically in both the horizontal and vertical dimensions. For example, a coal seam with a hydraulic conductivity of 10^{-4} centimeters per

second (cm/s) may be directly overlain by a shale with a hydraulic conductivity of 10^{-7} cm/s, a 1,000-fold difference. This disparity makes adequately predicting ground-water occurrence and movement difficult, which has implications for dewatering mines, landslides caused by leaking coal barriers, contaminant transport, and for water-supply wells. In addition, the increased hydraulic conductivity of fractured rock and coal seams has apparently captured and diverted freshwater recharge. This process minimizes the flushing of old, mineralized water from aquifers, which may be part of the cause for the shallow saltwater interface common in eastern Kentucky.

The Kentucky Geological Survey has been collecting hydraulic conductivity data from all lithologic types found in the coal field. The majority of the data have been collected in conjunction with other studies. A database containing hydraulic conductivity data from approximately 350 water-injection packer tests has been assembled. Statistical analysis of the data indicates that fractured rock and coal seams are on average 10 to 100 times more conductive than shale, sandstone, or other interbedded lithotypes common to the area. The hydraulic conductivity of all rock types decreases with depth.

The quantification of these data is important to engineers and scientists who deal with water-quality and supply issues in the Eastern Kentucky Coal Field. A report summarizing the hydraulic conductivity data is planned for the coming year.

Water Supplies from Underground Coal Mines in Letcher and Knott Counties

Dennis Cumbie and James Dinger

Steep terrain and highly dissected topography in the Eastern Kentucky Coal Field limit the amount of surface water available for municipal supplies. Naturally occurring ground-water systems are sporadic, difficult to locate, and limited by water-quality problems. The potential of abandoned underground coal mines to serve as alternative sources for municipal water supplies is being studied. The goals are to (1) identify and characterize abandoned underground mines that may provide adequate water supplies, (2) evaluate water quantity and quality in those mines, (3) identify and address issues of water quality, safety, and property ownership, which may inhibit the use of water from underground mines, and (4) develop a model for evaluating the quantity of water in underground mines.

Abandoned underground coal mines may be a major source of community water supplies.

This study is being funded by the Kentucky River Authority, and focuses on underground mines near population centers in Knott and Letcher Counties, in the headwaters region of the North Fork of the Kentucky River. Sixteen abandoned deep mines have been identified as potential water sources, which have estimated storage volumes ranging from 114 to 550 million gallons per mine. High-volume pumping tests on selected mines indicate natural recharge rates ranging from 150,000 to 450,000 gallons per day. Long-term monitoring of water levels in deep mines will show seasonal variations in water storage, and therefore water-supply capability.

Detailed analysis of water quality during pumping tests has shown little variability of quality for a particular mine. Quality does vary substantially from mine to mine, however. This indicates that water-quality analyses should be performed for each mine, and those results should be compared with current water-treatment technologies before a mine is developed as a water-supply source.

Hydrogeology of Karst Terranes

Monitoring the Impacts of the Animal Research Center on Surface- and Ground-Water Quality

Alex Fogle, Joseph Taraba, and Ira Joe Ross

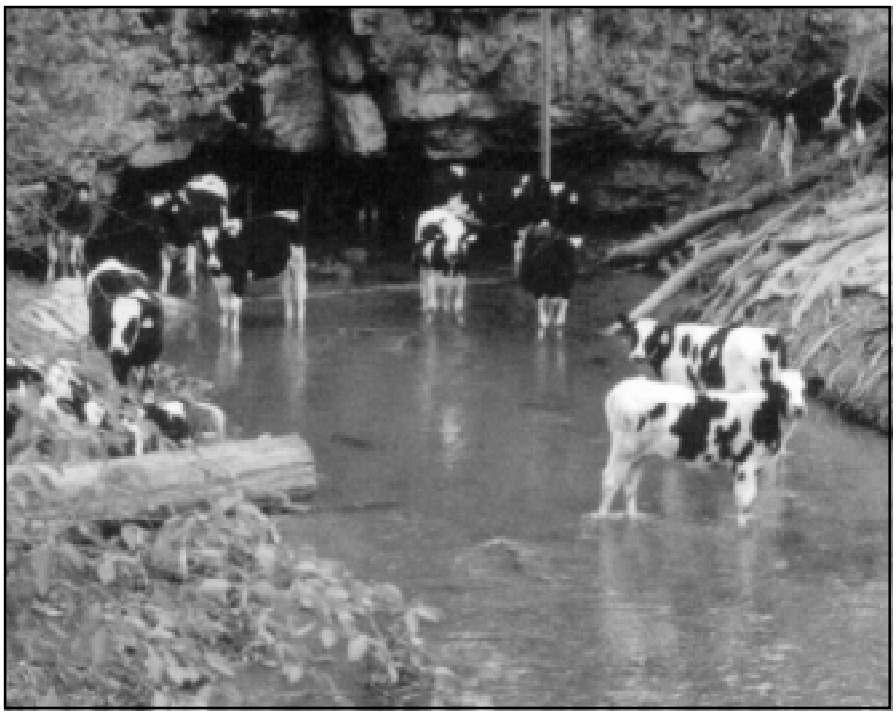
The University of Kentucky is constructing the Animal Research Center on karst terrain in Woodford County. As with all farms in Kentucky, it must meet the requirements of the Agricultural Water Quality Authority, that each farm develop a water-quality protection plan. A minimal, ongoing monitoring program was instituted in October 1996 to determine the impact of the center's construction and opera-

This test well was used to evaluate the potential of high-yield wells in eastern Kentucky. Photo by Robert Andrews.

tions on water quality. The program provides baseline and support data for several ongoing and future research projects dealing with the impacts of animal activity, feed production, and animal-waste utilization in a karst hydrogeologic system. Monitoring points include nine stream sites, seven springs, and three well nests with four to five wells, each constructed to different depths. A relational database includes water-quality, stage and flow, and weather data. Data collected by previous projects at the center are being incorporated into the database. A GIS database has been constructed and used to assist in land-use and hydrologic planning and has been dynamically linked with the water-quality database.

Since October 1996, nearly 500 water samples have been collected, resulting in more than 7,000 constituent analyses. Weather and stage and flow data from six stream sites have been collected and archived dating back to November 1994. Nitrate-nitrogen, pH, electrical conductivity, temperature, dissolved oxygen, and turbidity have been continuously monitored at the center's principal pour point since July 1997. The movement and storage of water within the soil profile will be monitored when construction is complete, and will be crucial in determining antecedent moisture conditions for modeling purposes.

The project is funded through the Kentucky Senate Bill SB-271 Water Quality Program and the U.S. Department of Agriculture. It is a cooperative effort between the Kentucky Geological Survey and the Department of Biosystems and Agricultural Engineering of the University of Kentucky.



Waste from cattle can be a source of water pollution in karst terranes. Photo by James Currens.

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 Currens

The study of the Pleasant Grove Spring karst ground-water basin is now in its final year. Monitoring detects changes in water quality that may be attributed to the fully implemented best management practices program. The focus of the project has shifted from field work to data management, estimation of contaminant mass flux, and recalculation of basin and crop areas using GIS technology. Further refinement of data analysis methodologies is continuing in anticipation of the completion of the program.

The goal of the 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's Natural Resources Conservation Service to implement a variety of changes to agricultural practices in the basin. If improved ground-water quality cannot be demonstrated on a basinwide scale, in a real-world setting, then the effectiveness of the implemented practices and the program's success in obtaining the producers' cooperation will need to be reevaluated. The project report on the first 3 years of study is in preparation.

Inventory of Karst Springs in Fayette County

James Currens, Ken Pidgeon, and Qianhong Wu

A database of information on springs in Fayette County has been compiled, and a draft version of a small-scale map showing locations of karst springs has been completed. This work is largely the

Maps of karst ground-water basins in Kentucky will be valuable for policy makers interested in water-supply issues, ground-water protection, and economic development.

result of efforts by Ken Pidgeon, of the Kentucky Natural Resources and Environmental Protection Cabinet–Division of Water. He recorded location, elevation, flow volume, and a general description for each site. The inventory will include existing data in the Kentucky Ground-Water Data Repository. The data and map are being formalized into publishable form. This work is done on an as-time-permits basis and is funded by KGS.

Bibliography of Karst Geology in Kentucky

James Currens and Qianhong Wu

A comprehensive bibliography of karst-related literature for Kentucky through 1977 was published by KGS in 1978. The new bibliography covers the last 20 years, and more than 800 new references have been tabulated through 1997. Thus far, extensive searches of online and hard-copy bibliographies have been conducted and a computer database of the relevant karst literature has been established. Before a report can be completed the database requires review, to ensure that the majority of important references have been cited. Having this literature easily accessible will make evaluations of water resources and pollution problems of the karst regions of Kentucky much faster and more comprehensive. This work is done on an as-time-permits basis and is funded by KGS.

Atlas of Karst Ground-Water Basins in Kentucky

James Currens and Joseph Ray

A series of ground-water basin maps showing swallow holes, springs, hypothetical flow routes, and estimated ground-water basin boundaries of karst springs is being developed. Each map will cover a 30 x 60 minute area at a scale of 1:100,000. The ground-water basin boundary will be shown for each basin for which there are sufficient data to delineate the boundary. Less well-defined basins will be represented by lines connecting ground-water dye-trace input points and recovery points. In addition, some basins will be mapped at a large scale if they will serve as examples of basin types or if 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.

In addition to the Lexington 30 x 60 minute quadrangle, for which work was completed in 1996, four other quadrangles are nearing completion: Campbellsville, Harrodsburg, Beaver Dam, and Somerset. Revision of the Lexington map and the possible addition of other quadrangles is also planned. This project is funded by KGS and the Kentucky Natural Resources and Environmental Protection Cabinet.

Hydrogeology of Urban and Industrial Areas

Maximum Daily and Annual Nutrient and Pesticide Loads from Turfgrass Management Areas

Michael Williams, James Dinger, Andrew Powell, and Dwayne Edwards

To evaluate the quality of effluent exiting from a turf management area, two subwatersheds with distinctive land uses were selected for sampling. The smaller watershed has an intermittent stream, a golf course, and homes surrounding the golf course. This watershed drains into a larger watershed containing Sinking Creek, a perennial stream, and supports both residential and agricultural land uses.

A survey in the larger watershed determined the extent to which lawn-care products are used. Of the 52 homeowners surveyed, approximately 33 percent used lawn-care services, 17 percent applied lawn-care products themselves, and the remainder used no lawn care other than mowing. The most common products other than fertilizer were herbicides used to control broadleaf weeds and crabgrass. None of the application rates exceeded those recommended by the manufacturers.

Pesticide concentrations in Sinking Creek rarely exceeded minimum detection limits during the sampling period. Following spring pesticide application, 2,4-D was detected only twice, at less than 4 micrograms per liter (µg/L), below the U.S. Environmental Protection Agency's (EPA) maximum contaminant level (MCL) of 70 µg/L.

The intermittent stream exiting the golf course subwatershed was monitored from April through November 1994. The pesticides 2,4-D and diazinon were detected at levels up to 2.5 µg/L and

1.4 µg/L, respectively. No MCL has been established for diazinon, but a lifetime health advisory level (HAL) of 0.6 µg/L has been promulgated by the EPA. The diazinon is most likely from the residential neighborhood surrounding the golf course, because it is not approved for use on golf courses. Diazinon was found consistently in samples taken from August 30 to October 5, 1994, although at much lower levels than the peak and HAL reported above.

Drafts of a manual outlining best management practices have been developed with the assistance of an advisory committee. This project is funded by section 319 funds from the U.S. Environmental Protection Agency, through the Kentucky Division of Water. It is in cooperation with the University of Kentucky Department of Biosystems and Agricultural Engineering and the Department of Agronomy.

Hydrogeologic Investigations at the Paducah Gaseous Diffusion Plant, McCracken County, Kentucky

Stephen Fisher and James Dinger

The Paducah Gaseous Diffusion Plant in McCracken County is a uranium-processing facility where the concentration of uranium-235 is enriched to produce material that can be used as nuclear reactor fuel. In 1988, the U.S. Department of Energy discovered that ground water north of the plant was contaminated with trichloroethylene, which is commonly used as a solvent, and technetium-99, a radioactive isotope produced in nuclear reactors. In addition, plant facilities include waste-disposal trenches and burial grounds that contain radioactive waste and volatile and semivolatile organic compounds. These trenches and burial grounds may be leaking radioactive and organic contaminants.

Kentucky Geological Survey researchers are assisting the Federal Facilities Oversight Unit of the Kentucky Water Resources Research Institute at the University of Kentucky in assessing environmental investigations and remediation activities at the plant. Major activities during the past year included preparing reviews and comments on reports and plans for site investigations, investigating the chemical species of aqueous uranium in local ground water, investigating release rates of uranium from waste, and developing a numerical model that can be used to predict the transport and fate of uranium leached from waste-disposal facilities.

The Paducah investigations are funded by the U.S. Department of Energy through the Kentucky Water Resources Research Institute.

Basin Hydrology, Water Supply, and Waste Management

Hydrogeologic Conditions Around Deep Aeration Lagoons at the Bardstown Waste-Water Treatment Plant

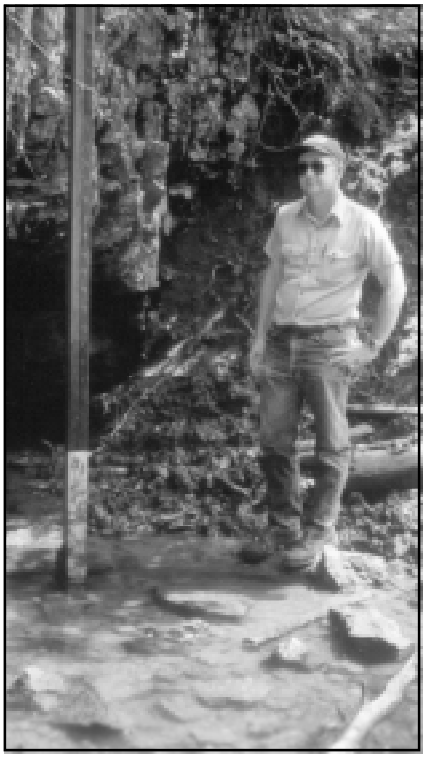
David Wunsch, Gregory Secrist, and Lyle Sendlein

Deep-cell aerated lagoons are an efficient primary treatment process for sewage and waste water. When used for waste-water treatment, their impact on ground-water quality and movement must be considered. This is especially pertinent now that lagoon technology is being considered for managing wastes from large-scale livestock operations.

KGS, in cooperation with the Kentucky Water Resources Research Institute at the University of Kentucky, collected hydraulic and geochemical data from eight monitoring wells and four surface-water monitoring sites on the plant property. Results indicate a large hydraulic gradient between the lagoons at the plant and the surrounding stream, Town Creek. However, initial water-level measurements in wells surrounding the lagoons suggest no major leakage. No flowing artesian conditions or unusually high water levels were observed in any of the wells.

Shallow wells responded quickly to recharge events, whereas bedrock wells were relatively unresponsive. The hydraulic conductivities of the unconsolidated material monitored by the shallow wells are several orders of magnitude greater than for the underlying bedrock. Surface-water flow measurements and hydraulic data from the monitoring wells indicate that Town Creek is a losing stream adjacent to the lagoons.

Major-ion chemistry and interpretation of the chloride, bromide, and fluoride data suggest that Town Creek, not the lagoons, influences the water chemistry in



Stream flow is measured with a staff gage like the one in this photograph. Photo by James Cobb.

the shallow wells. Recharge from the creek occurs mainly during high flow.

The results from a one-time sampling for bacteria indicate that the total coliform in the monitoring wells ranged from 10 to 1,920 colonies per 100 milliliters. Analysis for *E. coli* bacteria showed that only one well contained measurable counts (10 colonies per 100 milliliters). Their presence may be the result of contamination during sampling.

The lagoons do not appear to be adversely affecting the shallow ground-water system. They provide efficient primary water treatment without significantly contaminating the ground water. Moreover, the design and engineering used for the Bardstown plant could be a model for cost-effective, efficient primary water-treatment systems capable of long-term operation without affecting the local ground-water system.

The study was funded by the Kentucky Natural Resources and Environmental Protection Cabinet–Division of Water.

Hydrogeologic Investigations at the Maxey Flats Disposal Site, Fleming County, Kentucky

Stephen Fisher and James Dinger

The Maxey Flats disposal site is located on an isolated plateau in Fleming County, in northeastern Kentucky. Radioactive waste was buried in shallow trenches at Maxey Flats from 1963 to 1972, and burial ceased when it was discovered that tritium and other radioisotopes were leaking from the disposal trenches.

Kentucky Geological Survey researchers are assisting the Federal Facilities Oversight Unit of the Kentucky Water Resources Research Institute at the University of Kentucky in evaluating the hydrogeology of the Maxey Flats plateau to evaluate the performance of existing monitoring wells and recommend future sampling strategies, select locations for new monitoring wells both around the restricted area and at the property boundary, review results of computer models designed to evaluate effects of various trench cap designs, and design investigations to locate fractures that could transport contaminants beyond the restricted area. Because most ground-water flow at Maxey Flats is controlled by fractures, defining potential contaminant transport paths requires more detailed investigations than have been conducted previously.

This project is funded by the Kentucky Cabinet for Health Services through the Kentucky Water Resources Research Institute of the University of Kentucky.

Geographic Information System for Water-Resources Planning and Management

Daniel Carey

Water-resources planning requires the distribution of information on issues, solutions to problems, and the consequences of policy decisions. This information must be gathered from a variety of sources and must be clearly summarized. As part of its research activities, the Kentucky Geological Survey is assembling a spatial database for water-resources planning and management.

ARC/INFO and ArcView GIS are used to organize 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 also used to support water, coal, and petroleum resource studies.

Kentucky Interagency Ground-Water Monitoring Network

Philip Conrad

House Bill 172, signed into law in March 1998, creates a long-term ground-water monitoring network in Kentucky. This law became effective July 15, 1998. The Kentucky Geological Survey is mandated to implement the program in coordination with the Interagency Technical Advisory Committee on Groundwater, which is composed of 13 state agencies. The network will characterize the quality, quantity, and distribution of Kentucky's ground-water resources. This information will be used to "develop community and private water supplies; address resource allocation concerns; set boundaries on wellhead protection areas; recognize groundwater degradation if it occurs; and evaluate and improve the quality and quantity of data collected through all programs" (HB 172).

Several agencies have been instrumental in developing an informal ground-water monitoring network in Kentucky. Starting in 1995, an ad hoc technical advisory committee for this network identified the most important monitoring and characterization goals common to several state agencies. The network was named the Kentucky Interagency Ground-Water Monitoring Network. Agencies that have contributed samples for this network include the Kentucky Division of Water, Kentucky Geological Survey, and Kentucky Division of Pesticides. The Division of Water was awarded federal funding through the Kentucky Nonpoint Source Program for additional sampling in south-central Kentucky (1997–98) and in the Kentucky River Basin (1998–99). Draft publications on nitrate and fluoride in ground water have been written by personnel from the Kentucky Geological Survey and the Kentucky Division of Water. Financial support for student assistance on publications and data management was provided by the Kentucky Water Resources Research Institute at the University of Kentucky. The Kentucky Geological Survey will

publish these and other network reports.

Program 319 Advisory Management

James Dinger, John Kiefer, Daniel Carey, Philip Conrad, and Lyle Sendlein

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 Natural Resources and Environmental Protection Cabinet–Division of Water in managing this program. A 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, and to hold an annual conference for those doing research with section 319 funds.

Surface-Water Database

Daniel Carey

The surface-water database for Kentucky continues to be expanded for use in research and to provide data to respond to public inquiries. With the addition of surface-water data to the KGS relational database, citizens 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.

The surface-water database contains 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 and can be used with the Survey's GIS database (see above) to facilitate planning and research for water resources.

Water-Quality Survey for Kentucky Army National Guard Training Sites

Carlos Galcerán and James Dinger

The Kentucky Department of Military Affairs has contracted with the Kentucky Geological Survey to assess the quality of surface-water resources at the Wendell Ford, Artemus, and Clay City training sites operated by the Kentucky Army National Guard.

The goals of this project are to assess the impact of current activities on surface water at the sites and exiting from the sites, and to develop a long-term plan to monitor surface-water quality. Water-quality measurements and analysis of the data collected will provide a baseline and the framework to allow the National Guard to determine how well it is protecting the land and water resources at these sites. This assessment will indicate what precautions must be instituted to minimize deterioration of the water resources, and provide the scientific basis to help guide future use of these sites. It will provide the data critical to developing an efficient, long-term, water-quality monitoring plan.

Particular emphasis is being placed on heavily used areas. Physical, chemical, and biological parameters are being monitored and analyzed for each land use, under wet and dry climatic conditions, in order to develop a protocol for long-term monitoring. The monitoring plan will be used to meet state requirements and to assess the long-term impact of various land uses on the surface-water resources of the sites.

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COMPUTER AND LABORATORY SERVICES

The Computer and Laboratory Services Section operates state-of-the-art laboratory equipment and acquires up-to-date computer software and hardware to provide KGS researchers tools to analyze geologic and hydrogeologic data and collect, store, and manipulate data for reports, maps, charts, and other products for the public. The KGS laboratory facilities are used to analyze the chemical and physical characteristics of water, rock, coal, oil and natural gas, and other natural resources. KGS uses a laboratory information management system (LIMS) to track sample status from log-in to final reporting. The LIMS is based on current EPA recommendations for ensuring data integrity in an automated laboratory operation. The laboratory staff also provides electronic data transfer using various types of media and database formats.

During the fiscal year, water samples were analyzed for the Kentucky Natural Resources and Environmental Protection Cabinet–Division of Water. The data from these samples are used by the Kentucky Interagency Ground-Water Monitoring Network. The laboratory cooperated with the UK Department of Geological Sciences in a project to analyze rocks and minerals by X-ray spectrometry and X-ray diffractometry. The laboratory also participated in the Third International Proficiency Testing Trial of Analytical Geochemistry Laboratories, organized by the International Working Group of the Association Nationale de la Recherche Technique, Paris. Laboratory analyses were also performed in support of KGS research projects. A summary of analyses performed by the laboratory is found on page 7.

Christopher Cotterill, a chemistry major at the University of Kentucky, was selected for the internship in environmental chemistry. Under the supervision of the KGS laboratory manager, Henry Francis, and Professor Leonidas Bachas, Cotterill studied metal concentrations in water samples from Kentucky. This investigation is relevant for detecting hazardous levels of heavy metals in samples of drinking water. The internship program is a partnership established in 1997 between KGS, the office of the Vice President for Research and Graduate Studies, and the Kentucky Water Resources Research Institute.

KGS maintains a state-of-the-art relational database for geologic and hydrologic information that is the most detailed and comprehensive publicly available collection of nonproprietary petroleum, coal, water, and limestone data for Kentucky. Currently, the system is accessed using a variety of interface products such as SQL (structured query language), Datatrieve, and Microsoft Access. KGS personnel access the database to respond to thousands of public inquiries each year and compile data for ongoing research. Future plans are to provide direct public access (with limits) to the database via workstations in the Office of Geologic Information and remote access through the Internet.

The Kentucky Geological Survey purchased a software site license for Blue Marble geographic products. The license is applicable to the entire university community. Blue Marble provides geographic coordinate system conversion utilities and utilities for use with global positioning systems, and allows users to register and rectify scanned images of maps, and aerial and satellite photos to their proper spatial location.

Lab personnel use this equipment to determine total sulfur and total carbon contents in coal. Photo by Collie Rulo.

Office of Geologic Information

Public service is one of the most important functions of the Kentucky Geological Survey. By consolidating geologic data in a single office, KGS staff members are able to make information available to the public in a timely and effective manner. The Office of Geologic Information includes the Kentucky Ground-Water Data Repository, Kentucky Oil and Gas Data Repository, Kentucky Coal Resources Information System, Earth Science Information Center, and Publication Sales office.

Geologic data in electronic and hard-copy formats are archived in the Office of Geologic Information. The office has access to all the major databases of the Survey, enabling staff members to respond to many inquiries from the public. Requests that require more detailed assistance or further explanation are forwarded to the appropriate research staff at the Survey.

A detailed summary of products made available to the public by the Office of Geologic Information is found on page 7.

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 and distribute ground-water data collected by state agencies, other organizations, and independent researchers and make them publicly available at a centralized location in a manner that meets the needs of the public.

Data in the repository have been provided by more than 15 different agencies. The largest contributor of data on a regular basis is the Kentucky Division of Water, Groundwater Branch. The branch processes drillers' logs from the Certified Water Well Drillers Program, initiated in 1985.

Data are provided to the public on various media, including hard-copy printouts, diskettes, and CD-ROM's. Data may also be transferred electronically via e-mail or ftp.

Also included in the repository are hard-copy maps, field notes, publications, and other related information. Efforts to compile ground-water data from state agencies and other sources in the industrial, academic, public-health, and research sectors are continuing as new data are generated.

Repository personnel responded to more than 1,600 inquiries from the public during the fiscal year. Most of these inquiries were from environmental consulting firms. The remaining inquiries were from the public and private sectors and concerned ground-water occurrence, supply, and quality.

Kentucky Oil and Gas Data Repository

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 Office of Geologic Information. Records such as drillers' logs, wireline logs, well-location survey plats, plugging affidavits, and completion reports are on file for approximately 175,000 wells. In addition, files for western Kentucky wells are available at the Henderson field office.

Custom printouts based on user specifications are 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.

Kentucky Geological Survey staff review and enter into the

KGS personnel respond to more than 12,000 requests for geologic information each year, averaging approximately 48 requests per business day.

KGS sold or distributed more than 18,500 maps and publications—an average of 74 items per business day.

computerized database as many of the older well records as time permits. The project to archive well records continues. Since the actual scanning of well records began in November of 1996, more than 44,500 documents have been scanned. As of June 30, 1998, data for 152,000 wells are available through the database.

Electronic Data

Most KGS data can be provided to the public in electronic format. Tabular reports of oil and gas, water, and coal data are available on diskette, CD-ROM, and via e-mail or ftp, making it easy to enter the information into personal databases or spreadsheets. Digital topographic maps are available on CD-ROM for the entire state. These digital raster images, georeferenced to the UTM projection, were created by the U.S. Geological Survey at scales of 1:24,000, 1:100,000, and 1:250,000. Digital elevation models containing topographic information at a scale of 1:24,000 are also available on CD-ROM. Other geographic information system maps are available either on diskette, CD-ROM, or via ftp.

Earth Science Information Center

The Earth Science Information Center (ESIC) provides information regarding the availability of current and historic maps, aerial photography, satellite imagery, geodetic control, and digital cartographic data. Close coordination between the ESIC coordinator and other KGS staff 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.

Resources available to the 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, microimage 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 for Kentucky, which contains more than 30,000 place names used on Kentucky topographic maps, is available.

During the year, the 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.

Publication Sales Office

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.

Open-file maps showing landslide susceptibility 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.

Kentucky has 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 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.

The Office of Geologic Information contains data used by thousands of customers each year. Photo by Collie Rulo.

Office of Communications and Technology Transfer

Products of KGS research include geologic reports and maps; data compilations; oil, gas, and water well records; oil, gas, coal, and mineral core archives; and educational materials. Many research reports, maps, and data compilations are now available in electronic format.

KGS technology transfer efforts are designed to encourage the widespread use of research products developed at the Survey. The Internet is providing the public with easier access to data and a method for rapid distribution and retrieval of data and products, and search engines enable rapid identification of required data. The Internet facilitates delivery of low-cost, high-quality products. KGS is working toward establishing one-stop shopping for geologic data in Kentucky using the Internet and the KGS World Wide Web site. The Survey is also making geologic data and products available to the public through electronic mail, diskettes and CD-ROM's, an anonymous ftp site, and technology transfer workshops.

During the fiscal year, technical support was provided to facilitate a smooth interface between graphics software and GIS software for digital geologic mapping. A 1:500,000-scale base map of Kentucky, derived from the U.S. Geological Survey stable-base Mylar map of the same scale, was made available to KGS staff using AutoCAD; the map can be imported into GIS software. Cartographic work continued on a new mineral and fuel resources map of Kentucky at a scale of 1:500,000. The scope of the map was expanded to include the distribution of oil-, gas-, and coal-producing areas, tar sand deposits, gas storage fields, and coal field boundaries. A bibliographic database of all the U.S. Geological Survey geologic quadrangle maps that cover Kentucky was prepared and made available to KGS staff. Cartographic assistance was provided to the UK Department of Geography for its publication, *Atlas of Kentucky* (Ulack, Richard, editor-in-chief, 1998*:* Lexington, The University Press of Kentucky, 316 p.). Publicity and communications for the annual meeting of the Eastern Section of the American Association of Petroleum Geologists was organized by the Office of Communications and Technology Transfer.

Numerous slides, papers, reports, abstracts, and poster sessions were edited and prepared for outside publication or for presentation at professional and other meetings by KGS staff. Communication materials for the Survey were prepared and 16 publications were completed. The following publications were issued by the Kentucky Geological Survey during the 1997–98 fiscal year.

Making the results of research projects and field investigations easily accessible to the public at a nominal cost is an essential part of the mission of KGS.

Information Circulars

IC 58. Cambrian Pre-Knox Group Play in the Appalachian Basin, by David C. Harris and Mark T. Baranoski, 26 p.

Gas production from pre-Knox Group reservoirs in the Appalachian Basin has been reported from small fields in northeast-

ern Ohio, northeastern Kentucky, northwestern West Virginia, and southwestern Ontario, Canada. Production from these reservoirs has been limited, and in many cases marginally economic, but the large number of gas shows reported from deep wells in the Appalachian Basin is indicative of significant future exploration potential. Cambrian clastic and carbonate units represent the deepest drilling targets in the basin, and much of the prospective interval remains untested.

The stratigraphic interval in this play includes all sedimentary units below the Cambrian–Ordovician Knox Group (and the equivalent Gatesburg Formation in Pennsylvania and New York). In Ohio this interval comprises, in ascending order, the Upper Cambrian Mt. Simon Sandstone, Rome Formation, Conasauga Formation (and the partially equivalent Eau Claire Formation), and the Kerbel Formation. This sequence extends into northern Kentucky, and abruptly thickens across several normal faults into the Rome Trough. This Cambrian basin extends from central Kentucky through northwestern West Virginia, into western Pennsylvania. The Rome Trough contains an older and dramatically thickened pre-Knox section, with as much as 12,000 feet of pre-Knox sediments in some areas. The basal Mt. Simon Sandstone of Ohio and northern Kentucky is not present in the Rome Trough, because of a facies relationship with Rome Formation siltstones and shales. Within the trough, an older sandstone, informally named the Basal sandstone, is present immediately above Precambrian crystalline basement rocks.

IC 59. Kentucky's Coal Industry: Historical Trends and Future Opportunities, by Gerald A. Weisenfluh, James C. Cobb, John C. Ferm, and Carol L. Ruthven, 9 p.

Coal has been produced in Kentucky since the late 18th century. In the early years, all mining was by underground methods, but surface mining became the dominant method during and after World War II. In recent years, surface-mine production in both fields has decreased in favor of underground mining.

In the last half of this century, the traditional steam coal market has virtually disappeared, leaving electric power generation and coking coal for the steel industry as the principal markets. More than half of all coal produced in the state has been produced in the last 25 years. Whether this level of production can be profitably sustained is questionable.

More than 50 percent of the coal in eastern Kentucky is less than 28 inches thick, while more than 69 percent of the coal in western Kentucky is greater than 42 inches thick. Although eastern Kentucky's resources are thinner, they have a lower sulfur content and higher calorific value than western Kentucky's.

Traditional resource estimates have overestimated the amount of coal that can actually be mined because they have not taken into account factors such as competing land uses and geologic and engineering constraints. The Kentucky Geological Survey is participating in a national program to determine coal availability.

A number of regulatory and taxation issues will have an impact on the coal industry in Kentucky, but how much of an impact is uncertain. These issues include the Clean Air Act Amendments, liability for unreclaimed surface mines, regulatory flexibility to permit changes in postmine land use, and changes in the state's workers' compensation law.

Advances in thin-seam and remote-mining technology will be crucial, particularly in eastern Kentucky, where most of the coal occurs in thin seams. Improvements in coal-preparation technology could make Kentucky's higher sulfur coals more attractive. There may be potential for extraction of methane gas from coal beds, as an energy by-product.

Detailed knowledge of the physical and chemical character of Kentucky's coal beds will be vital in their development. Acquisition of this knowledge could be facilitated by cooperation among private industry, public agencies, and research institutes.

Map and Chart Series

MCS 14. Oil and Gas Map of the Evansville 30 x 60 Minute Quadrangle, compiled by Brandon C. Nuttall, scale 1:100,000.

MCS 15. Oil and Gas Map of the Hazard 30 x 60 Minute Quadrangle, compiled by Brandon C. Nuttall, scale 1:100,000.

Data compiled from the Kentucky Oil and Gas Data Repository show the locations of oil and gas pools and fields, organized by producing zone. These maps will provide the public, government agencies, and the petroleum industry with a vital tool for planning, exploration, and development of oil and gas resources in Kentucky.

Reports of Investigations

RI 11. Hydrogeology and Ground-Water Monitoring of Coal-Ash Disposal Sites in a Karst Terrane, Burnside, South-Central Kentucky, by Shelley Minns Hutcheson, Lyle V.A. Sendlein, James S. Dinger, James C. Currens, and Arsin M. Sahba, 21 p.

The effects of two coal-ash disposal facilities on ground-water quality at the John Sherman Cooper Power Plant, located in a karst region of south-central Kentucky, were evaluated using dye traces in springs. Springs were used for monitoring rather than wells, because in a karst terrane wells are unlikely to intercept individual conduits.

A closed-out ash pond located over a conduit-flow system discharges to three springs in the upper Salem and Warsaw Formations along Lake Cumberland. Water discharging from these downgradient springs is similar to springs unaffected by ash-disposal facilities and is a calcium-bicarbonate type. No constituent concentrations found in this flow system exceeded maximum contaminant levels (MCL's) or secondary maximum contaminant levels (SMCL's) defined by the U.S. Environmental Protection Agency.

An active ash pond is situated over another conduit-flow system that discharges to springs in the lower St. Louis Limestone. Water discharging from these downgradient springs is intermediate between the calcium-bicarbonate type of the unaffected springs and the calcium-sulfate type of the active ash pond. No constituent concentrations found in this flow system exceeded MCL's or SMCL's.

A third flow system associated with a coal stockpile adjacent to the plant is delineated by springs in the St. Louis Limestone and the Salem and Warsaw Formations that discharge calcium-sulfate type water. Chromium and cadmium concentrations exceeded MCL's in at least one sample from this flow system. Iron, manganese, sulfate, and total dissolved solid concentrations exceeded SMCL's in at least one sample.

The closed-out ash pond appears to have no adverse impact on the water quality, nor does the active ash pond. In general, the coal stockpile has a more adverse impact on ground-water quality in the study area than the ash-disposal facilities.

RI 12. Fresh-Water Aquifer in the Knox Group (Cambrian–Ordovician) of Central Kentucky, by James A. Kipp, 15 p.

Fresh water can be found in Cambrian and Ordovician carbonate rocks of the Knox Group in central Kentucky. The top of the aquifer is as much as 300 feet above mean sea level (m.s.l.) on the crest of the Cincinnati Arch, but descends off the flanks of the arch. Water is normally found in the upper 100 to 250 feet of the Knox, primarily in secondary porosity apparently associated with the unconformity at the top of the unit. Knox wells commonly exceed 750 feet in total depth, but because the aquifer is artesian, water rises to an elevation of about 500 feet above m.s.l. in most wells in central Kentucky. Some wells near the crest of the Cincinnati Arch produce water with relatively low concentrations of dissolved solids (500 to 3,000 milligrams per liter [mg/L]). Concentrations of dissolved solids commonly exceed 10,000 mg/L away from the crest of the arch. The Knox aquifer provides modest quantities of water (normally on the order of 10 to 20 gallons per minute) with less than 1,000 mg/L of dissolved solids to several wells in the Inner Blue Grass Region. As a result, it is a potential source of water for rural domestic supplies in central Kentucky.

RI 13. Impact of Topographic Data Resolution on Hydrologic and Nonpoint-Source Pollution Modeling in a Karst Terrane, by Alex W. Fogle, 22 p.

To prevent or reduce the contamination of ground water from agricultural sources, best management practices (BMP's) such as land-use changes, modifications to control surface runoff, various tillage methods, variations in rates and kinds of chemical applications, and handling procedures for chemicals are being employed and analyzed for effectiveness. The effectiveness of a BMP is often estimated before implementation by evaluating the BMP through the use of computer simulation models. The interactions between surface water and ground water that are unique to karst terranes are not incorporated into the frequently used predictive models. The purpose of this study was to document the impact of topographic data resolution on model input and performance in a karst setting.

An analysis of the impacts of topographic data resolution on data collection and output for the AGNPS computer model revealed that the sinkhole drainage area for two karst catchments located in the Blue Grass Region of central Kentucky is approximately doubled when using a 2-foot contour interval instead of a 10-foot interval. This doubling of the subsurface drainage was caused by a threefold increase in the number of sinks identified on

the 2-foot contour interval map. The increase in the subsurface drainage was the most significant factor affecting model results, and resulted in significant differences between predicted runoff volumes, peak runoff rates, sediment yields, and nutrient yields for 2-foot contour interval data compared with 10-foot contour interval data.

Reprint

R 44. Proterozoic Sequences and Their Implications for Precambrian and Cambrian Geologic Evolution of Western Kentucky: Evidence from Seismic-Reflection Data, by James A. Drahovzal, p. 553–566.

Analyses of two seismic-reflection lines in western Kentucky indicate the presence of two Proterozoic, unconformity-bounded sequences. One is autochthonous and of probable Late Proterozoic age; the other is allochthonous and of probable Middle Proterozoic age. Reflector patterns and apparent relationships to similar sequences elsewhere in the region suggest that the two sequences are of continental-rift origin. The two Proterozoic sequences lie beneath and adjacent to rocks of the Cambrian rift sequence in the Rough Creek Graben. The oldest sequence, the pre-Grenville sequence, was apparently folded and thrust faulted by the Grenville compressional event, implying that it is older than ~0.975 Ga (Middle Proterozoic). Two seismic-reflection pattern types are present in the western Kentucky data that may relate to the Middle Run (lithic arenite) and volcanic sequences defined farther east near the Grenville Front. The presence of imbricate, thrust-belt geometries in the pre-Grenville sequence extends the known westward limit of Grenville compressional structures into western Kentucky. The younger, post-Grenville sequence is less deformed and was apparently formed after the Grenville compressional event; several lines of evidence indicate that it is Late Proterozoic (0.7 to 0.6 Ga) in age. This probable siliciclastic and volcanic-rift sequence is represented by only thin remnants in western Kentucky and has no equivalent near the Grenville Front in southwestern Ohio and central Kentucky. Rocks of the better documented Cambrian rifting event belong to the thick, pre-Knox sequence in the Rough Creek Graben of western Kentucky and lie unconformably above these earlier sequences. A previously undocumented, northward-thickening interval within the lower part of the Cambrian pre-Knox sequence is recognized north of the Rough Creek Graben.

Open-File Reports

OF 89-02. Crustal Structure Beneath the Cincinnati Arch in South-Central Kentucky Using Magnetic, Gravity, and Seismic Reflection Data, by Beth P. Ullom, 156 p.

OF-95-02. Stress, Seismicity, and Structure of Shallow Oil Reservoirs in Clinton County, Kentucky, by Terence Hamilton-Smith, 99 p.

OF-97-02. Geologic Features Relevant to Ground-Water Flow in the Vicinity of the Paducah Gaseous Diffusion Plant, by James A. Drahovzal and R. Todd Hendricks, 17 p.

OF-97-03. Subsurface Stratigraphy of the Mississippian in Eastern Kentucky, by David C. Harris and Thomas N. Sparks, 3½-inch diskette.

OF-97-04. Mass Flux of Agricultural Nonpoint-Source Pollutants in a Conduit-Flow-Dominated Karst Aquifer, Logan County, Kentucky, by James C. Currens, 201 p.

OF-97-05. Geologic Structure on the Base of the Beech Creek (Barlow) Limestone or Equivalent, by Avery E. Smith, scale 1:250,000.

Miscellaneous

KGS Annual Report, 1996–1997, 67 p.

KGS List of Publications, November 1997, 73 p.

Well Sample and Core Library

Samples of rock cuttings from selected oil and gas test wells drilled in Kentucky are required by the Oil and Gas Conservation Act of 1960 (KRS chapter 353) to be archived by the Kentucky Geological Survey. The Well Sample and Core Library contains more than 20,000 sets of well cuttings from 120 counties, 2,500 cores from 95 counties, and 95 sets of auger samples from 11 counties. The cost of replacement for the contents of the library is conservatively estimated at $585 million.

Rock samples are requested from drillers of selected oil and gas wells; cores are also donated, primarily by private companies. Certain cores are sometimes kept confidential for 1 year at the request of the company that drilled them. The Survey's goal is to obtain a representative set of well samples for each Carter coordinate section (about 1 square mile) of the state. The library also provides storage for samples obtained from research projects. Facilities are provided for researchers, students, government employees, industry personnel, and the public to study the library's materials.

The library was expected to be open for public use by December 1997. However, the contractor made errors in construction, and had to replace the concrete floor of the mezzanine to comply with the building design specifications. The resulting delay in completion of the building also damaged more than 22,000 boxes of core that had to be stored outdoors. Additional damage resulted from a record-level snowfall in March 1998. The facility was opened to the public in late spring.

The new facility, totaling 48,000 square feet, is located on university property at 2500 Research Park Drive, off of Iron Works Road, near the Kentucky Horse Park. This facility will allow for future expansion. All cores and well samples are organized to allow easy identification by farm name, county, operator, location, and permit number. The cores and cuttings are available for public inspection from 8:00 a.m. to 4:30 p.m., Monday through Friday.

PUBLIC SERVICE

Educational Outreach

During fiscal year 1997–98, KGS staff gave 71 presentations on geology to local elementary and middle school students. In addition, Stephen Greb was involved in the Fayette County Science Partners Program throughout January and February 1998. In this program in the Fayette County school system, science professionals and teachers collaborate to plan new curriculum for grades 3 through 7. Also, KGS geologists were active in the Fayette County science fair, serving as judges and on the planning committee for the fair.

Stephen Greb provided illustrations for trail displays at McConnell Springs Park in Lexington. He also led a field trip for alumni of the UK Department of Geological Sciences.

Stephen Greb, Collie Rulo, and David Harris designed a pamphlet on the outreach program of the American Association of Petroleum Geologists–Eastern Section.

Donald Chesnut and Stephen Greb are the administrators for two new listservs on the Internet, sponsored by KGS and the Kentucky Society of Professional Geologists. Chesnut's listserv is for individuals interested in the geology of Kentucky or in the profession of geology. Greb's is for K–12 earth science teachers. Both listservs are accessible via electronic mail.

KGS geologists also worked with Kentucky Educational Television on potential programs on the Middlesboro astrobleme (a meteor-impact structure) and rocks and minerals in Kentucky. Brandon Nuttall was a guest on a call-in show on Lexington radio station WVLK discussing the NASA Pathfinder mission to Mars.

Earth Science Education Network

In recent years, earth science education has been mandated for different grade levels than previously. This has required teachers with little or no experience in earth science to teach unfamiliar topics. To assist teachers and attract the interest of students in Kentucky, geologically significant locales from across the state were used to explain earth science concepts. To broaden the scope of the network, links to the best sites on the Internet were selected by geologists at KGS, based on the accuracy of the information, appropriateness for kindergarten through grade 12 audiences, quality of graphics, and availability of free classroom activities and handouts. This information was assembled at a single location, and annotations for each link were provided to enable teachers to find needed information without having to search myriad sites. The network includes hundreds of color photos and images, fact sheets, lesson plans and classroom exercises, e-mail addresses and phone numbers of individuals involved in earth science outreach, and a listserv to connect teachers and resource persons to exchange ideas and information. As the site has become more popular, input and materials from educators have been received and incorporated to enhance the site as a learning environment.

To meet the increasing need for earth science information, KGS built a virtual learning environment in the fall of 1996. National science education standards were used to design materials for the Earth Science Education Network, located at <http://www.uky.edu/KGS/education/education.html>.

World Wide Web Site

The KGS World Wide Web site at <http://www.uky.edu/KGS/home.htm> continues to be popular, averaging 68,600 "hits" per month during the fiscal year. In January 1998, the site received the Study Web Academic Excellence Award. The site has extensive information on coal, oil and gas, water resources, rocks and minerals, fossils, and the geology of Kentucky. A virtual regional resource center has an online inventory of oil and gas data organized by region and county, drilling statistics, general information about oil and gas data, and responses to frequently asked questions. A geospatial data library has electronic maps (county and state boundaries, area devel-

opment districts, census block tracts, major river basins, geologic features, hydrology and watersheds, state roads and highways, and a base map of the United States). The site also has the Earth Science Education Network, with extensive resources for kindergarten through grade 1 teachers.

Teaching

Stephen Greb presented teachers' workshops on KGS's Earth Science Education Network at the Falls of the Ohio State Park in Clarksville, Ind., and at the joint meeting of the Eastern Section of the American Association of Petroleum Geologists and The Society for Organic Petrology. He also taught a workshop on geology on the World Wide Web to Fayette County teachers.

David Wunsch and James Currens taught the applied hydrogeology section of the UK Department of Geological Sciences summer field camp. Patrick Gooding gave the students a tour of the KGS Well Sample and Core Library.

James Cobb, John Kiefer, and David Wunsch taught courses at the University of Kentucky. In addition, Daniel Carey has been certified by ESRI, Inc., as a qualified instructor for its ArcView geographic information system software. Carey taught seven workshops on ArcView for KGS and UK staff during the past fiscal year.

Technology Transfer

Gerald Weisenfluh and Ernest Thacker gave a workshop on core logging to Kentucky River Coal Corporation personnel in Hazard, Ky. The workshop provided techniques on describing cores.

Brandon Nuttall taught a short course on the basics of petroleum geology for the UK Department of Agronomy–Natural Resources Conservation Service summer camp course, in Robinson Forest.

The Survey gave a seminar in Prestonsburg in eastern Kentucky to discuss the Pond Creek (Lower Elkhorn) coal, which is one of the most important coal beds in the state. This was the first in a series of coal assessment seminars to transfer to industry the results of KGS coal research projects. Two other seminars on core description were presented to the Kentucky Natural Resources and Environmental Protection Cabinet. The seminars provided techniques on standardizing terminology.

Brandon Nuttall and James Drahovzal developed and organized a workshop, "Advanced Well-Logging Techniques in the Appalachian Basin." It was sponsored by the Appalachian Region of the Petroleum Technology Transfer Council, the Kentucky Society of Professional Geologists, and the Kentucky Geological Survey, and was taught by Brad Posner of Schlumberger Well Services. The workshop helped geologists and engineers in the oil and gas industry understand some of the new well-logging technologies being introduced in the Appalachian Basin.

John Kiefer chaired a session of a workshop on landslide mitigation sponsored by the Natural Resources Conservation Service, in Robinson Forest, eastern Kentucky.

Foreign Researchers

Cortland Eble collaborated with scientists from the Czech Geological Survey in Prague and the Silesian Museum in Opava.

Ute Gebhardt and Tanja Merkel of the University of Hamburg, Germany, visited the Survey as part of their research on Carboniferous stratigraphy. They are comparing nonmarine carbonate deposition in the Saale Basin of Germany and the Appalachian Basin.

Conferences

John Kiefer chaired a symposium on landslides at the Southeastern Section of the Geological Society of America annual meeting in Charleston, W.Va., in March 1998, and presented a paper on landslides in Kentucky.

Czech scientists Zybnek Simuniek (left) and Eva Purkynova (center) examine fossil specimens with Mitch Blake of the West Virginia Geological and Economic Survey during their visit to the United States. Photo by Cortland Eble.

Representatives from the Kentucky Geological Survey presented an exhibit in Washington, D.C., for members of Congress. The exhibit, sponsored by the Association of American State Geologists, explained the importance of and benefit to the public of the National Geologic Mapping Program. The centerpiece of the exhibit was the KGS digital geologic mapping program.

As president of the Kentucky Society of Professional Geologists, Donald Chesnut organized and convened the society's annual symposium. Several KGS scientists made presentations at the symposium.

KGS staffed booths at a Career Day, sponsored by the University of Kentucky and the Agricultural Extension Service, at Robinson Forest in Quicksand, Ky.; the Kentucky Science Teachers' Association fall conference, in Lexington, Ky.; an earthquake-awareness event (sponsored by the Lexington Living Arts and Science Center and funded by Kentucky-American Water Company) in Lexington, Ky.; UK's Career Day for the College of Arts and Science; and UK's Staff Appreciation Day (sponsored by the UK Women's Forum).

Daniel Carey was the general chairman of a statewide conference on GIS technology. The conference, Kentucky's GIS Data—A Shared Responsibility, was sponsored by the Kentucky Geographic Information Advisory Council and the Office of Geographic Information Systems. Approximately 300 representatives from the private sector, state and local government agencies, and universities and colleges attended the conference held in Somerset, Ky.

Field Trips

Stephen Greb, Garland Dever, and Warren Anderson coordinated the 1997 Kentucky Society of Professional Geologists field trip on the economic geology of the Inner Blue Grass Region. John Kiefer, Brandon Nuttall, and David Harris also contributed to the field trip guidebook.

Bart Davidson coordinated geological presentations and field trips for the Lexington-Fayette Urban County Government Summer Shades program at three local middle schools during the summer of 1997. Ten KGS geologists presented talks about various aspects of geology or assisted students with the identification of rocks and fossils at a local outcrop.

Hosting Professional Meetings

The Kentucky Geological Survey supported the 1997 joint meeting of the Eastern Section of the American Association of Petroleum Geologists and The Society for Organic Petrology in Lexington, September 27–30, 1997. This meeting was a tremendous success and had a record level of attendance (more than 460 participants). James Drahovzal served as general cochair, and numerous KGS staff members served on the planning committee, gave technical presentations, and led field trips and workshops.

KGS Publications

Kentucky Geological Survey, 1997, Annual report, 1996–1997: 67 p.

Kentucky Geological Survey, 1997, List of publications, November 1997: 73 p.

Contributions to Kentucky Society of Professional Geologists Guidebook

Greb, S.F., Dever, G.R., Jr., and Anderson, W.H., eds., 1997, Economic geology of the Inner Blue Grass Region: Kentucky Society of Professional Geologists, 47 p.

Anderson, W.H., Van, Sam, and Greb, S.F., Minerals of the Blue Grass—The Central Kentucky Mineral District, p. 11–16.

Anderson, W.H., Van, Sam, and Greb, S.F., Storm deposits (tempestites) in the Grier Limestone Member of the Lexington Limestone, central Kentucky, p. 11–16.

Dever, G.R., Jr., Stone industry in central Kentucky, p. 4–6.

Dever, G.R., Jr., and Greb, S.F., Geology of the High Bridge Group in central Kentucky, p. 29–31.

Ettensohn, Frank, Greb, S.F., and Rast, Nicholas, Fossil ball-and-pillow structures and tempestites—Evidence for earthquakes, p. 25–28.

Greb, S.F., Ordovician fossil key, p. 42.

Greb, S.F., and Dever, G.R., Jr., The Curdsville and Tyrone Limestones—Evidence for tides, storms, and volcanic ash falls, p. 21–24.

Greb, S.F., and Dever, G.R., Jr., The Lexington Fault System, p. 28.

Greb, S.F., Dever, G.R., Jr., and Anderson, W.H., Economic geology of the Inner Blue Grass Region, p. 1–13.

Greb, S.F., Dever, G.R., Jr., and Anderson, W.H., Limestone mining and uses, p. 7–10.

Harris, D.C., The East Continent Rift Basin—A new Precambrian province in central Kentucky, p. 39–41.

Kiefer, J.D., Hydrogeology of McConnell Springs, Lexington, Kentucky, p. 32–34.

Nuttall, B.C., Oil and gas in the Blue Grass, p. 36–38.

Abstracts

Davidson, Bart, Digital data at the Kentucky Geological Survey's Office of Geologic Information: Program, Kentucky's GIS Data—A Shared Responsibility, Kentucky Geographic Information Advisory Council and Office of Geographic Information Systems, p. 13.

Greb, S.F., and Ruthven, C.L., 1998, Earth Science Education Network: Geological Society of America, Abstracts with Programs, v. 30, no. 4, p. 15.

Kiefer, J.D., 1998, Hickman, Kentucky—A moving, but costly, experience: Geological Society of America, Abstracts with Programs, v. 30, no. 4, p. 21.

Presentations

Anderson, W.H., Kentucky Geological Survey mineral collection: Bluegrass Gem and Minerals Club, Lexington, Ky., August 17, 1997.

Anderson, W.H., Mineral deposits of Kentucky: Bluegrass Gem and Minerals Club, Lexington, Ky., November 16, 1997.

Cobb, J.C., Looking for Hutton's Grave: Kentucky Society of Professional Geologists annual banquet, Lexington, Ky., September 27, 1997.

Cobb, J.C., Presidential address at the opening session and award ceremony for the joint meeting of the Eastern Section of the American Association of Petroleum Geologists and The Society for Organic Petrology, Lexington, Ky., September 28, 1997.

Davidson, Bart, Digital data at the Kentucky Geological Survey's Office of Geologic Information: Kentucky's GIS Data—A Shared Responsibility, Kentucky Geographic Information Advisory Council and Office of Geographic Information Systems, Somerset, Ky., May 18, 1998.

Davidson, Bart, The geology of Kentucky: The Rotary Club of Lexington (Sunrise), Lexington, Ky., October 7, 1997; Kiwanis Club, Mount Vernon, Ky., February 26, 1998.

Davidson, Bart, Rocks, minerals, and geology: Bourbon County Middle School, Paris, Ky., July 10, 1997; Winburn Elementary School, Lexington, Ky., July 22–23, 1997; Milk and Honey Summer School Program, Lexington, Ky., August 11, 1997; Webelos scout troop, Richmond, Ky., September 30, 1997; Tates Creek Elementary School, Lexington, Ky., October 17, December 11, 1997; Julius Marks Elementary School, Lexington, Ky., November 19, 1997; Paducah Middle School, Paducah, Ky., January 12, 1998; Daniel Boone Elementary School, Richmond, Ky., March 6, 1998.

Greb, S.F., Earth Science Teachers' (K–12) Workshop: Joint meeting of the Eastern Section of the American Association of Petroleum Geologists and The Society for Organic Petrology, Lexington, Ky., September 29, 1997.

Greb, S.F., Geology of Kentucky: Rough River State Park, Ky., May 20, 1998.

Greb, S.F., How scientists know what ancient animals looked like: Lexington Children's Museum, Lexington, Ky., April 15, 1998.

Greb, S.F., and Chesnut, D.R., Jr., Earth science education—Linking Kentucky to the world: Joint meeting of the Eastern Section of the American Association of Petroleum Geologists and The Society for Organic Petrology, Lexington, Ky., September 29, 1997.

Greb, S.F., Chesnut, D.R., Jr., and Ruthven, C.L., Earth Science Education Network [computer demonstration], Kentucky Geological Survey 38th annual seminar, Lexington, Ky., May 14, 1998.

Greb, S.F., and Ruthven, C.L., Earth Science Education Network: Geological Society of America–Southeastern Section annual meeting, Charleston, W.Va., March 30–31, 1998.

Haney, D.C., Employment opportunities for recent and future graduates in geology: Geological Society of America–Southeastern Section annual meeting, Charleston, W.Va., March 29, 1998.

Kiefer, J.D., Geologic hazards and their impact on Kentucky: Governor's Conference on Natural Hazards, Lexington, Ky., June 15, 1998.

Kiefer, J.D., Hickman, Kentucky—A moving, but costly, experience: Geological Society of America–Southeastern Section annual meeting, Charleston, W.Va., March 30–31, 1998; 3d annual Kentucky Geosciences

Symposium, Kentucky Society of Professional Geologists, Lexington, Ky., May 15, 1998.

Kiefer, J.D., Landslide hazards in Kentucky: Kentucky Hazard Mitigation Team workshop, sponsored by the Federal Emergency Management Agency, Frankfort, Ky., May 15, 1998.

Kiefer, J.D., Recognizing landslide-prone areas: Natural Resources Conservation Service Landslide Mitigation Workshop, Robinson Forest, Ky., April 14–15, 1998.

Ruthven, C.L., Technology transfer initiatives at the Kentucky Geological Survey: Kentucky Geological Survey 38th annual seminar, Lexington, Ky., May 14, 1998.

Smath, R.A., The fluorescent minerals of the Franklin and Sterling Hill, New Jersey, mines: Bluegrass Gem and Minerals Club, Lexington, Ky., July 23, 1997.

Smath, R.A., Public service offerings at the Kentucky Geological Survey: State ESIC Conference, Reston, Va., September 17, 1997; Rolla, Mo., November 11, 1997.

Smath, R.A., Rocks and minerals: Bourbon County Middle School, Paris, Ky., July 10, 1997; Jessie Clark Middle School, Lexington, Ky., July 21, 1997; Milk and Honey Summer School Program, Lexington, Ky., August 11, 1997; Paducah Middle School, Paducah, Ky., January 12, 1998; cub scout troop, Lexington, Ky., January 21, 1998.

Watson, A.E., Impact structures in Kentucky: Kentucky Paleontological Society, Lexington, Ky., April 17, 1998.

Watson, A.E., Impact structures of Kentucky: Bluegrass Astronomy Club, Raven Run Wildlife Sanctuary, Ky., June 19, 1998.

Wente, K.J., Career trends in geology: Appalachian Explorers program, University of Kentucky, Lexington, Ky., June 16, 1998.

Wente, K.J., Fossils of Kentucky: 4-H Summer Shades field trip, Lexington, Ky., July 23, 1997.

Wente, K.J., Rocks and minerals—An introduction to earth science: Bourbon County Middle School, Paris, Ky., July 10, 1997; 4-H Summer Shades Program, Lexington, Ky., July 21, 1997; Deep Springs Elementary School, Lexington, Ky., September 19, 1997; Julius Marks Elementary School, Lexington, Ky., November 19, 1997.

Wente, K.J., What's a geologist? A lesson in earth science: Tates Creek Elementary School, Lexington, Ky., October 17, 1997; Breckinridge Elementary School, Lexington, Ky., December 12, 1997.

Williams, D.A., Soaper, R.C., and Beck, E.G., Environmental atlas of Henderson [poster display]: Kentucky Geological Survey 38th annual seminar, Lexington, Ky., May 14, 1998.

Williams, D.A., Soaper, R.C., and Beck, E.G., Henderson environmental atlas: Kentucky Geological Survey 38th annual seminar, Lexington, Ky., May 14, 1998.

AWARDS AND APPOINTMENTS

David Wunsch has been named the American Geological Institute Congressional Science Fellow for 1998–99. The American Geological Institute is a nonprofit federation of 31 geoscience and professional associations that represents more than 100,000 geologists and scientists. The Congressional Science Fellows assist members of Congress with national science and technology policy issues. Wunsch is the first person from Kentucky to be chosen as a Congressional Science Fellow. He will be on professional leave from the university for a year beginning in September 1998 to complete his fellowship.

Kevin Wente, Bart Davidson, Thomas Sparks, and James Cobb received distinguished service awards at the annual banquet of the Kentucky Society of Professional Geologists.

Dennis Cumbie was one of 10 students in 1997 to receive an award for outstanding student paper in the hydrology section of the American Geophysical Union 1996 fall meeting in San Francisco, Calif.

Stephen Fisher received the award for best paper in the Environmental Geoscience Division at the Eastern Section meeting of the American Association of Petroleum Geologists.

Donald Chesnut was elected president of the Kentucky Society of Professional Geologists.

David Harris was elected president of the Eastern Section of the American Association of Petroleum Geologists.

Patrick Gooding received the 1997 University of Kentucky Research and Graduate Studies Outstanding Staff Award. Gooding, a geologist at the Survey for 20 years, has been dedicated and diligent in managing the Well Sample and Core Library.

Carol Ruthven was elected to a 2-year term on the Board of Directors of the Kentucky Women's Leadership Network.

Donald Haney became an honorary West Virginian at the Southeastern Section meeting of the Geological Society of America in Charleston, W.Va. This honor was bestowed in recognition of Haney's contributions in facilitating geologic mapping projects and collaborative research on matters of geologic interest in both states and Haney's contributions to the state, regional, and national geoscience communities during the past three decades.

Donald Haney also was designated a Roy J. Shlemon Mentor in Applied Geology at the Southeastern Section meeting of the Geological Society of America. Haney served as a mentor in a program developed and sponsored by the GSA Institute for Environmental Education. This program presents workshops for upper-level undergraduate and graduate students to guide them in the transition from geology student to professional geologist.

Donald Haney was appointed to the Mineral Resources Committee of the National Association of State Universities and Land-Grant Colleges.

James Drahovzal was appointed to the Graduate Studies Committee in the UK Department of Geological Sciences. He was also appointed by the president of the American Association of Petroleum Geologists to AAPG's Ad Hoc Committee on Constitutionality and Bylaw Amendment Process.

Lance Morris was a cofounder of the GIS Bluegrass Users Group. The group will provide a forum for the exchange of knowledge, techniques, and data among GIS users; maintain communication between individuals and industry, state, county, and local governments, and educational institutions; and publish bulletins and newsletters.

The Kentucky Geological Survey received the StudyWeb Academic Excellence Award for its Web site on fossils (<http://www.uky.edu/KGS/coal/webfossl/fosslbig.htm>). StudyWeb, one of the Internet's premier sites for educational resources for teachers and students, named the KGS site one of the best educational resources on the Web.

Henry Francis received a certificate of service from the American Society for Testing and Materials, Committee D-5 on Coal and Coke, in appreciation of his 10 years of active participation.

Kentucky Geological Survey Distinguished Service Award

Lyle Sendlein, director of the Kentucky Water Resources Research Institute at the University of Kentucky, was the recipient of the 1998 Kentucky Geological Survey Distinguished Service Award. The award, presented by State Geologist Donald Haney at the Survey's 38th annual seminar, was granted to Sendlein for his contributions to the advancement of the earth sciences for the benefit of society.

State Geologist Donald Haney (right) presents the Kentucky Geological Survey Distinguished Service Award to Lyle Sendlein. Photo by James Cobb.

NEW STAFF MEMBERS

Dennis Cumbie, Hydrogeologist II, is working on a project funded by the Kentucky River Authority to study water supplies from underground coal mines in Letcher and Knott Counties. Cumbie received his bachelor of science degree in communications from Arkansas State University. He received a master's degree from the University of Tennessee–Knoxville. His research focused on the transport of colloidal particles in low-hydraulic-conductivity fractured media. Prior to joining KGS, he worked as a research associate at the Institute for Rare Isotope Measurements at the University of Tennessee.

Philip Fields, Geological Technician, is working in the Henderson field office, assisting with groundwater sampling and data entry. Originally from Russelville, Ark., he received a bachelor's degree in Geological Engineering from the New Mexico Institute of Mining and Technology in Socorro, N. Mex. He was previously employed by various mining companies exploring for precious metals in the western United States.

Lee Helms, Research Analyst, has 19 years of environmental laboratory experience. Helms is originally from southern California, and received his bachelor of science degree in chemistry from San Diego State University.

Danielle Kelly-Buchanan was hired as a Geological Technician. Originally from Shreveport, La., she has a bachelor's degree in natural resources from the University of Kentucky. She previously worked for the Kentucky Department of Forestry.

Kammy McCleery-Malloy, Office Assistant, is originally from Wilbraham, Mass., and received a bachelor's degree in music performance from Chatham College in Pittsburgh, Penn. She did graduate work at the State University of New York at New Paltz for secondary teaching certification in social studies, and also served with the American Red Cross in Vietnam as a field morale worker.

Jennifer Miller, Senior Laboratory Technician, has a bachelor's degree in geology from the University of Kentucky, and analyzes water samples for various parameters. Previously, she had worked on the digital geologic mapping project at KGS.

Shane Schmidt, Geologist I, is working on the coal-availability project. Schmidt, has a bachelor's degree in geology from the University of Indianapolis, and defended his master's thesis in geological sciences at UK in June. He previously worked as a logger for J.B.C. Downhole Vision, Inc.; as a teaching assistant in the UK Department of Geological Sciences; as a hydrologic assistant for the U.S. Geological Survey; and as a field technician for EnviroSciences, Inc.

COMMITTEES, BOARDS, AND ADVISORY ACTIVITIES

International

- American Association of Petroleum Geologists
- Association of Earth Science Editors
- Geological Society of America
- The Society for Organic Petrology

National

- American Geological Institute
- American Society for Testing and Materials
- American Society of Agricultural Engineers
- Association of American State Geologists
- Geological Society of America National Committee on Geology and Public Policy
- Geology Alumni Advisory Board for the Department of Geology, University of Iowa
- Implementation Committee for the National Geologic Mapping Program
- Interstate Oil and Gas Compact Commission
- Mineral Resources Committee of the National Association of State Universities and Land-Grant Colleges
- National Academy of Science/ National Research Council
- National Association of State Universities and Land-Grant Colleges
- National Water Resources Policy Committee
- Natural Resources Conservation Service
- U.S. Department of Energy
- U.S. Department of the Interior
- U.S. Environmental Protection Agency
- U.S. Geological Survey
- U.S. Secretary of the Interior's National Geologic Mapping Advisory Committee

Regional

- Advisory Committee for the Rapp Granary–Owen Foundation, New Harmony, Ind.
- Appalachian Basin Coal Consortium
- Appalachian Oil and Natural Gas Research Consortium
- Appalachian Region of the Petroleum Technology Transfer Council
- Central United States Earthquake Consortium
- Cincinnati Arch Consortium
- Cyprus Amax Co. Wildlife Management Area Education Committee
- Eastern Section, American Association of Petroleum Geologists
- Southeastern Section of the Geological Society of America
- Illinois Basin Consortium
- Midcontinent Lithospheric, Earthquake, and Resource Studies
- Midwest Region of the Petroleum Technology Transfer Council
- Ohio River Basin Consortium for Research and Education
- Technical Guidance Committee for the Pittsburgh Office of the Federal Office of Surface Mining
- Tri-State Correlation Committee

State

- Clement Mineral Museum
- Governor's Earthquake Hazards and Safety Technical Advisory Panel
- Hazard Mitigation Enterprise Zone Commission
- Kentucky Agricultural Water Quality Authority
- Kentucky Board of Registration for Professional Geologists
- Kentucky Cabinet for Economic Development, Post Land Mining Use Committee

- Kentucky Department for Environmental Protection
- Kentucky Division of Conservation
- Kentucky Division of Disaster and Emergency Services
- Kentucky Division of Water
- Kentucky Engineering Earthquake Response Team
- Kentucky Geographic Information Advisory Council
- Kentucky Ground-Water Management Data Committee
- Kentucky Human Resources Cabinet
- Kentucky Information Resource Management Commission
- Kentucky Interagency Ground-Water Monitoring Network Advisory Committee
- Kentucky Interagency Watershed Work Group
- Kentucky Long-Term Policy Research Center
- Kentucky Museum of Natural History
- Kentucky Oil and Gas Association
- Kentucky On-Site Sewage Disposal Advisory Committee
- Kentucky Paleontological Society
- Kentucky River Basin Team
- Kentucky River Authority
- Kentucky Section of the American Institute of Professional Geologists
- Kentucky Society of Professional Geologists
- Kentucky Stratigraphic Nomenclature Committee
- Kentucky Water Availability Advisory Council
- Kentucky Water Interagency Coordination Committee
- Kentucky Watershed Monitoring and Assessment Committee
- Kentucky Watershed Prioritization Committee
- Kentucky Watershed Steering Committee
- Kentucky Water-Well Drillers' Certification Board
- Kentucky Women's Leadership Network, Board of Directors
- Legislative Research Commission
- Mammoth Cave Karst Area Water-Quality Oversight Committee
- S.A.V.E. Coalition of Kentucky

Local

- City of Georgetown
- City of Lawrenceburg
- City of Louisville
- City of Versailles
- Evansville Disaster Resistant Community
- Fayette County Environmental Commission
- GIS Bluegrass Users Group
- Lexington Living Arts and Science Center
- Lexington-Fayette Urban County Council Storm Water Management Committee
- Lexington-Fayette Urban County Government Expansion Area Master Plan Committee
- Lexington-Fayette Urban County Government McConnell Springs Restoration Committee
- Lexington-Fayette Urban County Government Storm Water Advisory Committee
- Lexington-Fayette Urban County Government Greenspace Commission
- Lexington-Fayette Urban County Government Water Supply Planning Committee
- National Speleological Society, Blue Grass Grotto

University of Kentucky

- Arboretum Committee
- Center for Applied Energy Research Advisory Board
- College of Agriculture
- Cost Accounting System Appeals Committee
- Department of Biosystems and Agricultural Engineering
- Department of Forestry
- Department of Geological Sciences
- Environmental Initiative Committee
- Environmental Systems Program
- Kentucky Project of the Central Appalachian Alliance
- Kentucky Senate Bill (SB-271) Program
- Kentucky Transportation Center
- Kentucky Water Resources Research Institute, Research and Policy Committee
- Lexington Campus Research Committee
- Natural and Engineering Sciences Promotion and Tenure Committee
- Research Advisory Committee
- Research and Graduate Studies Unit Safety Committee
- Research and Graduate Studies Web Steering Committee
- Staff Study Task Force
- Wellness Advocates

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Kentucky Division of Disaster and Emergency Services
Kentucky Division of Waste Management
Kentucky Division of Water
Kentucky Natural Resources and Environmental Protection Cabinet
Kentucky River Authority
Kentucky Senate Bill SB-271
Illinois Basin Consortium
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Tennessee Valley Authority
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