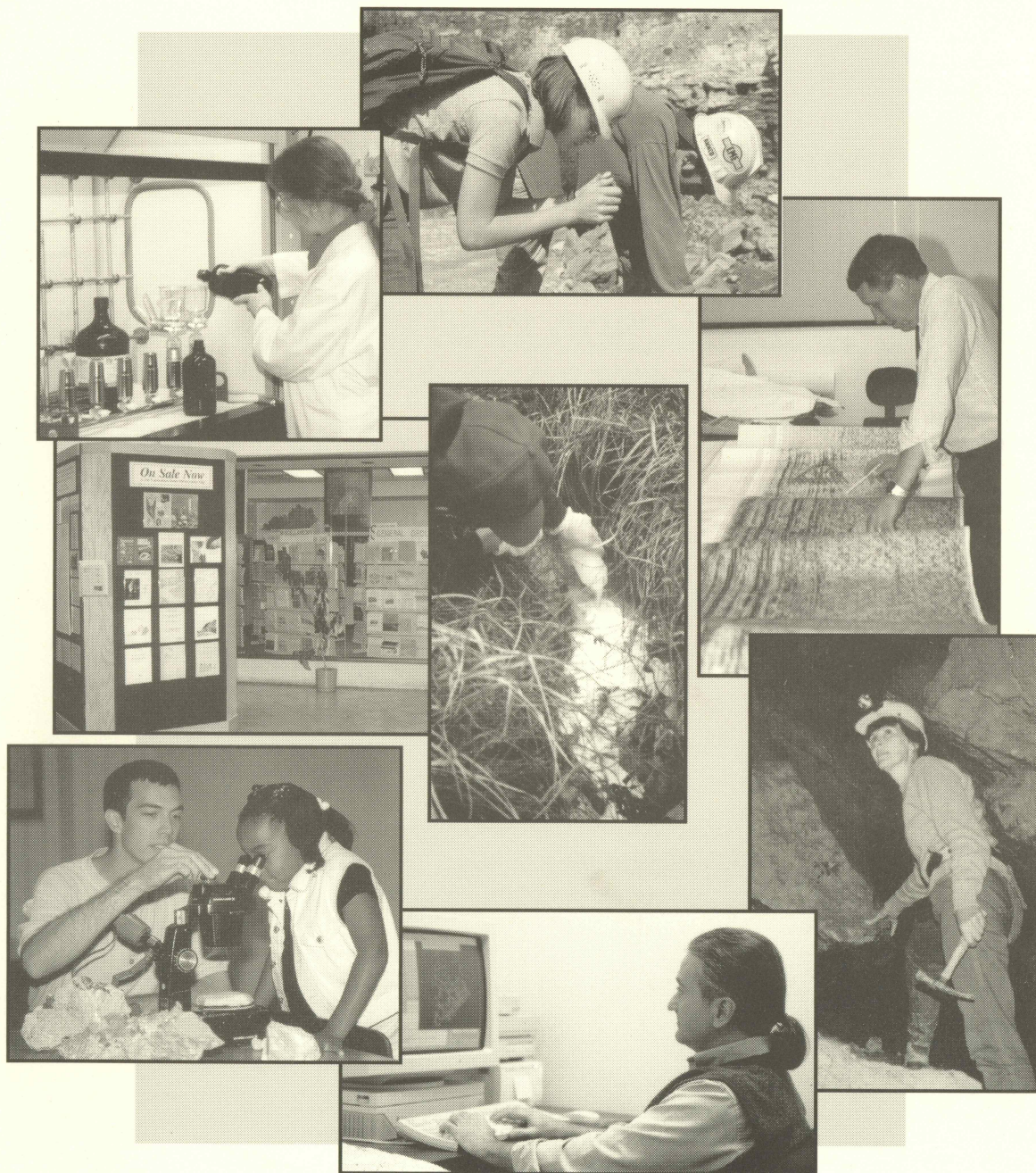


Kentucky Geological Survey
Donald C. Haney, State Geologist and Director
University of Kentucky



Kentucky Geological Survey
Annual Report
1996-1997



1996-1997

ANNUAL REPORT

KENTUCKY GEOLOGICAL SURVEY

UNIVERSITY OF KENTUCKY

LEXINGTON, KENTUCKY

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CONTENTS

	Page
Organization Chart	iv
Mission Statement	1
Public Service Activities for Fiscal Year 1996-97	2
Executive Summary	3
New Grants Received in Fiscal Year 1996-97	5
Coal and Minerals Section	6
Coal	7
Minerals	12
Geologic Mapping and Hydrocarbon Resources Section	13
Geologic Mapping	14
Hydrocarbon Resources	15
Water Resources Section	21
Computer and Laboratory Services Section	31
Computer Services	31
Laboratory Services	32
Office of Geologic Information	34
Office of Communications and Technology Transfer	37
Well Sample and Core Library	40
Public Service	41
Distinguished Lecture Series	46
Memorial: Wallace Woodrow Hagan	47
37th Annual Seminar	48
International Visitors	49
Awards	50
Awards Received by KGS Staff Members	50
KGS Distinguished Service Award	51
New Staff Members	52
Papers by Staff Members in Outside Publications	54
Talks by Staff Members to Professional and Civic Groups	57
Committees, Boards, and Advisory Activities	62
National	62
Regional	62
State	62
Local	63
University of Kentucky	63
Research Funding Sources	64
Personnel	65
Professional Staff	65
Technical Staff	66
Clerical Staff	67
Affiliated Researchers	67
Student Assistants	67



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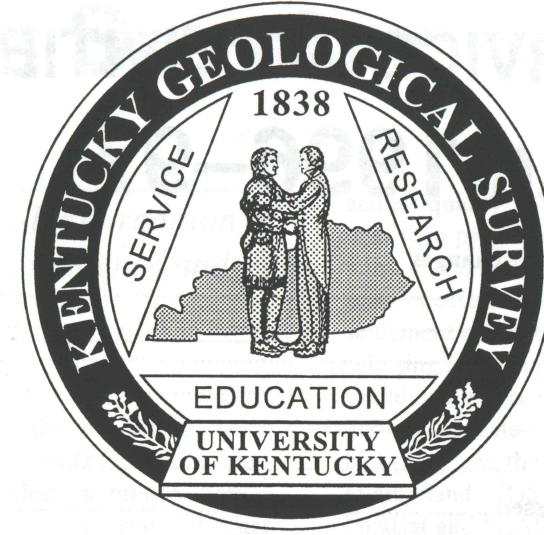
Relational Database
Richard Sergeant

Kentucky Ground-Water
Data Repository

Kentucky Oil & Gas
Data Repository

Kentucky Coal
Resources Information
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.

PUBLIC SERVICE ACTIVITIES FOR FISCAL YEAR 1996–97

Requests for Information or Technical Exchanges

Coal and minerals	1,132
Oil and gas	4,433
Water	1,338
Earth Science Information Center	679

Publication Sales Office

Visitors or requests for information	4,387
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Oil and gas permit applications processed	991
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Oil and gas completions, terminations, drilling affidavits, and changes processed	1,870
---	-------

Well Sample and Core Library

Visitors or requests for information*	571
---	-----

Oil and gas well record products sold

Well records copied	16,128
Electronic-data disks and well lists provided	40
Computer-generated overlays to topographic maps	450

Copies of electric logs and miscellaneous maps (number of feet)	19,757
---	--------

Data entry or new records received for oil and gas well records (number of wells)	2,732
---	-------

Samples analyzed by Laboratory Services Section	2,000
---	-------

Kentucky Geological Survey publications completed	22
---	----

Publication and map sales

Publications	5,857
Topographic maps	13,045
Geologic quadrangle maps	3,275

Talks to civic and professional groups	117
--	-----

Papers by staff members in outside publications	48
---	----

Committees, boards, and societies

National	18
Regional	12
State	38
Local	10
University of Kentucky	11

Grants and contracts in effect	24
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*Data are incomplete because the Well Sample and Core Library was closed to the public during the relocation of materials from the old facility to the new building.

EXECUTIVE SUMMARY

The Survey has a century-long tradition of commitment to research excellence and public service.

When it was established in the mid-1800's, the Kentucky Geological Survey (KGS) was given responsibility for the collection, preservation, and dissemination of information about mineral and water resources, fossil fuels, mapping, and the geology of the State. In 1992, KGS became a full member of the University of Kentucky (UK) by legislation approved by the General Assembly. The Survey has a century-long tradition of commitment to research excellence and public service.

This report summarizes the activities of KGS during the past fiscal year (July 1, 1996–June 30, 1997). The Survey employed 68 full-time staff members (75 percent of which are professional staff) and 15 student assistants. KGS staff provided technical support to 89 committees, boards, or advisory groups at the national, regional, State, and local level and at the University of Kentucky. Survey staff responded to more than 12,500 requests for information or technical exchange. Survey staff also gave 117 talks to civic and professional groups and had 48 papers published in external publications.

The KGS World Wide Web site continues to be very popular: there were an average of 7,171 "hits" per month. This was three times higher than the monthly average reported in fiscal year 1995–96 and clearly indicates the value to the public of the information accessible at this site. In the fall of 1996, the Kentucky Earth Science Education Network was created to bring together the numerous individuals involved in earth science education across the State. At this site, <<http://www.uky.edu/KGS/education/education.html>>, teachers and students from kindergarten through grade 12 can discover interesting Kentucky earth science facts, links to more than 20 earth science topics, classroom activities, and other resources.

During this past fiscal year, 24 grants and contracts were in effect that provided funding for a diverse research program. Coal mining will remain one of the State's most valuable industries, and coal-resource assessment and coal-quality studies will be imperative for future economic growth. Assessment of coal available for mining and evaluation of coal quality relative to end-use applications

and air-quality and water-quality regulations remain important programs for KGS. The availability of flat, post-mining land and water are key to future economic development in eastern Kentucky. The risk of landslides and land settlement are factors that should be considered when selecting industrial sites and designing infrastructure (buildings, roads, water and gas pipelines). KGS staff are performing state-of-the-art research on coal-field hydrology and the implications for settlement on post-mining land. KGS staff are also using technologies such as Landsat and SLAR (side-looking airborne radar) imagery, geographic information system (GIS) software, and remote sensing to identify high-yield water wells in eastern Kentucky for community and industrial supplies.

Approximately one-quarter of the land surface in Kentucky is underlain by well developed karst terrane. Therefore, the land is prone to collapse (sinkholes) and has many ground-water basins. This has implications for the transportation of pollutants and the protection of ground-water quality. The Survey has conducted numerous hydrogeologic investigations of nonpoint-source pollution and water quality. Through these investigations, KGS is providing a substantial contribution to environmental science research in Kentucky.

The Survey is considered a center of excellence for digital geologic mapping in the United States. KGS is converting highly detailed geologic information from paper maps to digital form that can be used for a wide variety of GIS applications. The demand for traditional hard-copy geologic maps is great: the Survey sold more than 3,000 geologic quadrangle maps to the public during fiscal year 1996–97. The utility of these maps will increase greatly as they are digitized.

Within the UK community, KGS participated in research programs with the departments of Geological Sciences, Forestry, Civil Engineering, and Agronomy; the Kentucky Water Resources Research Institute; and the Center for Applied Energy Research. As adjunct faculty, KGS scientists taught courses, advised students, and served on graduate thesis committees. Two KGS staff members coordinated a section of the environmental systems program and one KGS staff member taught a course in low-temperature geochemistry. The Survey also created a student internship in environmental science.

Outside of the UK community, KGS participated in research programs funded by Federal and State agencies, resource and utility companies, and numerous research consortia including the Appalachian Basin Consortium,

Illinois Basin Consortium, the Cincinnati Arch Consortium, the Appalachian Oil and Natural Gas Research Consortium, the Central United States Earthquake Consortium, the Electric Power Research Institute, and the Midcontinent Lithospheric, Earthquake and Resource Studies group.

In summary, the Survey has maintained a diverse research program in coal and minerals, geologic mapping and hydrocarbon resources, and water resources. More

than \$1 million in additional grants was secured during fiscal year 1996–97. The Survey has achieved national recognition for its coal-resource assessment research and creation of digital geologic maps. It is also becoming a major center at the University of Kentucky for the application of GIS technology in geoscience research. Six research projects using GIS technology were featured at the Survey's annual seminar. The details of these and other projects are found in this report.

New Grants Received in Fiscal Year 1996–97

KGS received \$1,112,563 in new grant funding during fiscal year 1996–97.

Coal and Minerals

- \$41,400 grant from the U.S. Geological Survey (USGS) as part of a multistate cooperative research program to assess the coal resources of major coal beds
- \$150,000 grant from the USGS for continuation of an 8-year research program to determine the factors that affect the availability of coal for mining in Kentucky
- \$160,000 grant from the USGS to allow KGS scientists to collaborate with experts who have conducted research on the availability of coal for mining in the past at the U.S. Bureau of Mines
- \$123,949 grant for the National Coal Resources Data System project of the USGS
- \$5,000 gift from the Smithsonian Institution in recognition of the research contributions of Cortland Eble
- \$8,000 grant from the USGS to evaluate and upgrade USGS Mineral Resource Data System records for Kentucky deposits

Geologic Mapping and Hydrocarbon Resources

- \$105,445 grant from the USGS for the digital geologic mapping of 7.5-minute quadrangles in the Kentucky River Basin
- \$110,000 grant from the National Science Foundation, received by KGS, the Department of Geological Sciences, and the Department of Civil Engineering, to acquire state-of-the-art field equipment to do seismic investigations in the New Madrid Seismic Zone
- \$13,800 grant from the Federal Facilities Oversight Unit of the Kentucky Water Resources Research Institute at the University of Kentucky to study geologic features relevant to ground-water flow in the vicinity of the Paducah Gaseous Diffusion Plant in Kentucky

- \$16,334 grant from the Petroleum Technology Transfer Council to develop a virtual regional resource center

Water Resources

- \$167,680 grant from the E.O. Robinson Trust to study water and mining related issues in eastern Kentucky
- \$25,550 grant from the Kentucky Natural Resources and Environmental Protection Cabinet to study the effects of sewage lagoons on the shallow ground-water system near Bardstown, Ky.
- \$58,200 grant from the E.O. Robinson Trust to continue research on the characterization of ground water and spoil settlement at a large surface mine in eastern Kentucky
- \$69,100 grant from the E.O. Robinson Trust to continue research using remote-sensing and GIS techniques to identify geologically significant locations with the potential for producing high-yield water wells for public or industrial supplies in the Eastern Kentucky Coal Field
- \$50,000 grant from the U.S. Environmental Protection Agency via the Kentucky Natural Resources and Environmental Protection Cabinet–Division of Water, received by KGS and the Kentucky Division of Water, to digitize and publish maps depicting known ground-water dye trace results

Other

- \$6,605 from Space Imaging EOSat of Thornton, Colo., received by KGS and the Department of Geological Sciences, as part of the CARTERRA Research Program, to investigate remote-sensing applications for preliminary archaeological site identification in Monte Verde, Chile
- \$1,500 grant (\$1,000 from UK Research and Graduate Studies and \$500 from the Kentucky Water Resources Research Institute of the University of Kentucky) to establish a Research and Graduate Studies internship in environmental chemistry

COAL AND MINERALS SECTION

Coal has been produced in Kentucky's two coal fields since the beginning of the 19th century and has been the State's most important mineral resource since that time. In 1994, the latest year for which statistics are available, the coal industry employed more than 24,000 miners, and tax revenues generated from all economic activity related to the industry provided more than 11 percent of General Fund receipts in Kentucky. 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. Clearly, demand for coal is strong and will remain so well into the future.

Many factors affect Kentucky coal production: the size and quality of the reserves, market demand and competition, transportation, mining and processing technology, and government regulation. Understanding the complex relationships among these factors will help identify future opportunities for continued development of coal resources and realization of the associated economic benefits for coal-producing counties and the State.

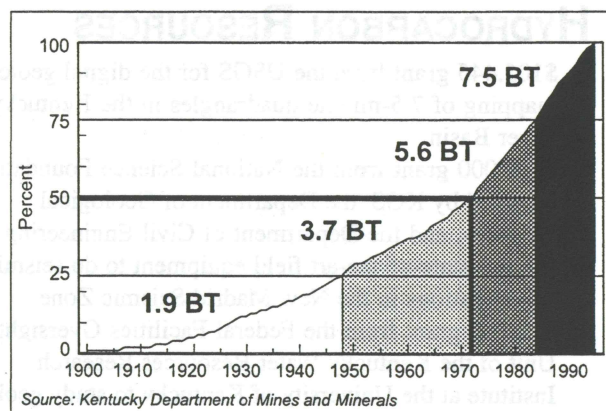
Changes in coal utilization within the last half of this century have had a significant impact on the production and marketing of coal from Kentucky. First, traditional fuel markets and coal for steam locomotives virtually disappeared, leaving electric power generation and coking coal for the steel industry as the principal markets. Eastern Kentucky underground mine production was especially influenced by large-scale replacement of steam by diesel locomotives from 1950 to 1960. This was followed by a shift from northern fuel markets to southern utility markets. In addition, the market for coking coal was greatly diminished by downsizing in the steel industry in the 1970's. Existing and anticipated clean air legislation also affected the marketing of both high- and low-sulfur coal. Initially, demand for high-sulfur coal diminished, but as electric power-generating facilities with scrubbing technology became available, this demand returned. More recently, Kentucky coal has been faced with strong competition from inexpensive low-sulfur coal from the Powder River Basin in Wyoming and Montana. This coal is now capturing some traditional utility markets for Kentucky coal located in the Midwest and eastern United States.

As a result of major technological advances in mining techniques, more coal is being mined in Kentucky than ever before, and this is being accomplished with fewer mines and fewer employees. Over half of all coal produced in the State has been extracted only within the last 25

years, and the question arises whether this level of production can be profitably sustained in the future. The answer will depend on a thorough understanding of the current reserves; mining, transportation, and processing technologies; the nature of future markets; and the impact of regulations. The socioeconomic impact of these changes in Kentucky coal mining will also require careful assessment because of the economic impact that mining jobs have for the State.

Staff in the Coal and Minerals Section are involved with research projects on coal-resource assessment, coal-mining geology, coal quality and petrology, and minerals. Coal-related information generated by these projects is made available through the Kentucky Coal Resources Information System (KCRIS), which is one of the largest publicly available coal databases in the United States. KCRIS contains coalbed descriptions, coal-thickness measurements, coal-quality analyses, and borehole descriptions. Most of this information is in electronic form and is continually updated. The research staff promotes technology transfer through workshops and publications as well.

The Coal and Minerals Section also investigates industrial and metallic minerals in Kentucky to determine their chemical composition, physical properties, geographic distribution, and geologic setting. Industrial and metallic minerals furnish society with raw materials for agricultural, ceramic, chemical, construction, energy, metallurgical, and manufacturing industries.



Annual cumulative percentage of Kentucky coal production.

Survey staff members are conducting research projects designed to provide information needed by the future users and producers of industrial and metallic minerals.

The principal industrial minerals in Kentucky are limestone, dolostone, sand, gravel, clay, shale, sandstone, fluorspar, and barite. In recent years, the metallic minerals sphalerite and galena (ores of zinc and lead) have been mined in the State, but none are being mined at the present time. Small quantities of cadmium, germanium, and silver have been recovered as by-products from metallic ores.

COAL

Coal-Resource Assessment

AVAILABLE COAL RESOURCES IN THE EASTERN AND WESTERN KENTUCKY COAL FIELDS

Gerald A. Weisenfluh and William M. Andrews

In 1983, coal-resource estimates completed for Kentucky's two coal fields indicated that, for beds greater than 14 in. 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 (USGS) to quantify the impact of these mining restrictions. The results will be valuable for planning the development of energy resources. Under this program, the 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. However, key coal beds such as the Fire Clay and Pond Creek have been extensively mined. In the Eastern Kentucky Coal Field, large portions of the original 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 mined at the present time.

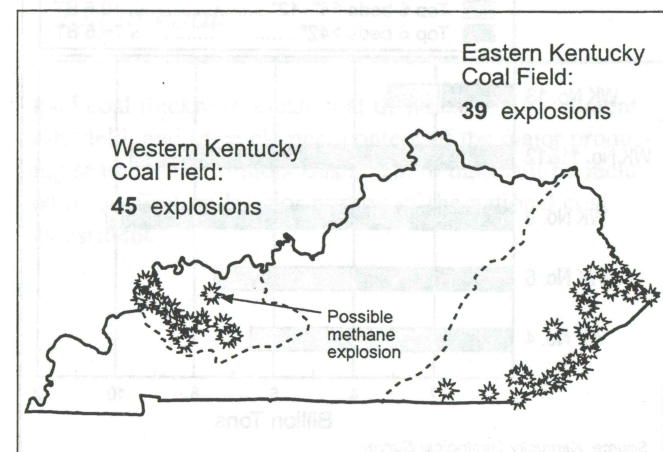
For western Kentucky, nine quadrangle studies have been completed. In this region, a significant amount of some coal beds has been rendered unmineable because overlying or underlying coal beds have been previously mined. Also, some coals have been extensively mined, particularly by surface methods. As 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 A. Williams, Stephen F. Greb, and William M. 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 understanding 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, 500 ft of coal-exploration cores were logged for research on deep coal resources, and numerous borehole records were encoded. To date, 5,052 borehole descriptions have been coded and computerized; of this number, 3,043 are available to the public.

In addition, a database of historical deep mine explosions, caused by excess methane, was compiled. By far the most explosions (28) have been recorded in the Springfield (Western Kentucky No. 9) coal. The large number of explosions may partly be a function of the amount of mining in the Springfield coal (27.9 million short tons annual production), and the Springfield coal being one of the first coals to be widely mined below drainage in Kentucky. Most of the explosions have occurred in Hopkins (16), Union (8), and Webster (6) Counties, which are in the deepest part of the Western Kentucky Coal Field. Many deep mines in the Springfield coal have had repeated explosions at depth. Several areas in which multiple explosions have been recorded are adjacent to fault zones. This information may prove important in future mine planning and also in future development of coalbed methane as an energy resource in western Kentucky.



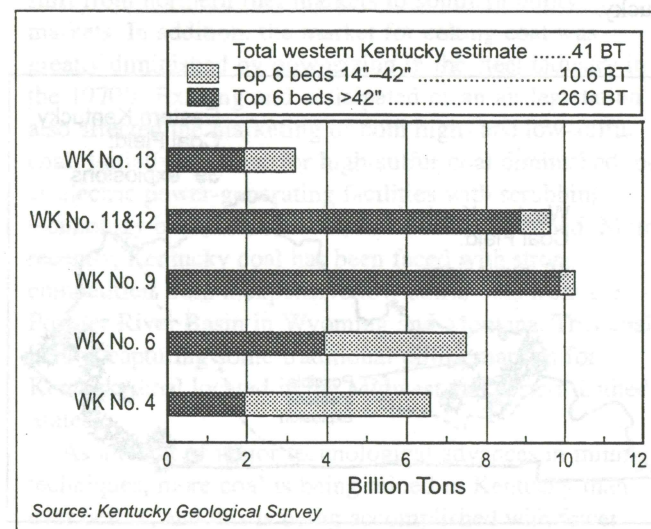
Methane explosions in the Eastern and Western Kentucky Coal Fields, 1887-1994.

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

Stephen F. Greb and David A. Williams

Most of the coal currently mined in western Kentucky is high in sulfur content, averaging well above the threshold of 1.2 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 western Kentucky coal 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, we need to sample them 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.

The Western Kentucky No. 4 coal is mined in the southwestern part of the Western Kentucky Coal Field. It varies in thickness, quality, and the elevation at which it occurs. In some surface exposures these elevation changes appear to be the result of displacement by small faults. Small rolls and cutouts in deep mines follow straight, parallel trends that may be related to faults observed in surface exposures, although crosscutting makes correlation difficult. Limited information also indicates that coal quality may decrease toward some of the larger faults. More information is needed on the relation between faulting and the thickness and quality of the No. 4 coal. A better understanding of faults at the surface, where they



Distribution for the top six coal beds by thickness in western Kentucky.

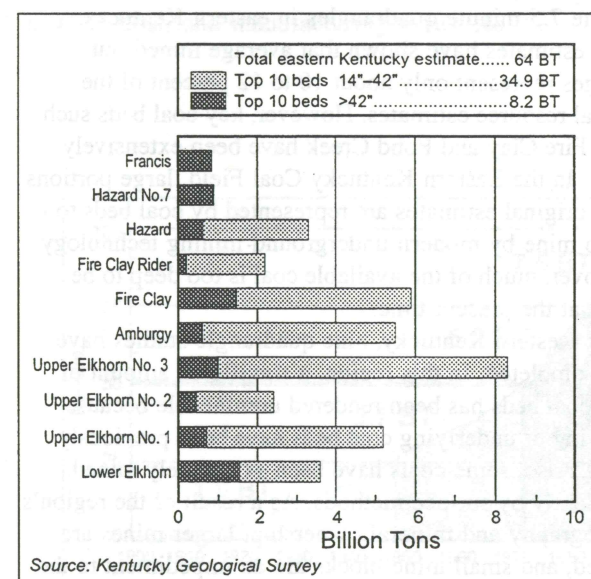
can be easily observed, will aid in their identification in the subsurface, and lead to safer and more efficient use of the better quality coal.

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

Stephen F. Greb and Cortland F. 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. A better understanding of the variability of these important characteristics can be obtained from surface exposures of coal-bearing strata. Often, coal and roof traits uncovered at the surface can be used to characterize various aspects of coal mineability in the subsurface, where access to the coal is limited. Because many man-made outcrops are only exposed for a short period before being reclaimed or overgrown, gathering data on the coal and surrounding strata from these sites while they are exposed is important. Collecting these data can help industry and resource planners better develop coal resources in the Eastern Kentucky Coal Field.

In the past year, surface and in-mine exposures of the Fire Clay (Hazard No. 4), Pond Creek, and Stockton coals, three of the most heavily mined coals in the central Appalachian Basin, were investigated. Each seam is



Distribution for the top 10 coal beds by thickness in eastern Kentucky.

composed of multiple benches of coal separated by high-ash zones or rock partings. Individual coal benches often have distinctly different quality and thickness patterns; lower and rider benches generally have poorer quality and more variable thickness than middle coal benches. 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. The results of this study may explain why thick, multiple-bench coals often have poorer quality than laterally equivalent, thinner coals.

The Eastern Kentucky Coal Field is one of the world's most productive coal-mining regions, and has a long mining history.

COALBED METHANE AND DEEP COAL RESOURCES OF THE EASTERN KENTUCKY COAL FIELD

Stephen F. Greb and William M. 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. More than 4,500 eastern Kentucky borehole records, which have been coded and computerized and are available to the public, are available for this purpose.

The deep coal resources of the Eastern Kentucky Coal Field have great potential for the production of coalbed methane. Thirty-nine methane explosions were recorded in eastern Kentucky from 1887 through 1994, many in coals that occur at or just below drainage. This will become more significant as future mining operations target below-drainage coals. Although coalbed-methane concentrations can be hazardous in deep mines, they may prove valuable as a future fuel resource. In many basins, coals are excellent reservoirs for methane gas. Six eastern Kentucky counties have an estimated coalbed-methane potential of more than 250 cubic ft of gas per ton of coal. Two of these counties, Pike and Harlan, occur in a region of higher rank coals, which is more favorable for methane generation. These preliminary estimates should encourage future research on the gas content of below-drainage eastern Kentucky coals.

COAL ATLASES FOR KENTUCKY

Gerald A. Weisenfluh, Ernest E. Thacker, and Stephen F. 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 includes 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. Digital outcrop, mined-out area, thickness, and quality data have been compiled for the first two of these beds. 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. Data from Kentucky, Indiana, and Illinois have been gathered to develop basinwide maps and databases delineating coal elevation,

Six eastern Kentucky counties have an estimated coalbed-methane potential of more than 250 cubic ft of gas per ton of coal.

total coal thickness, clean-coal thickness, sulfur content, ash yield, and trace-element content of the major producing seams in the Illinois Basin. These data will be included in the Eastern Interior portion of the national coal assessment.

Coal-Mining Geology

MINEABILITY OF KENTUCKY COALS

Stephen F. Greb, Gerald A. Weisenfluh, and David A. 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 on geologic features such as faults, cutouts, splits, and roof falls must be collected as they are encountered so that their size, shape, and trends can be used to help identify similar geologic problems in other mines.

Paleoslumps, which represent ancient movement and rotation of semiconsolidated sediment, as happens when a bank collapses on the side of a stream, were found in three mines. Paleoslumps are often obvious in surface exposures, in which a section through the slump is exposed, but identifying them in underground mines, where slumps are viewed from beneath, is difficult. Because bedding in paleoslumps is deformed or inclined, these features cause instability in mine roofs, haul roads, surface highwalls, and other excavations. In addition, coals beneath paleoslumps often exhibit folding, faults, truncation, clastic dikes, and locally increased thickness, which can hinder or stop mining. Documentation and analysis of paleoslumps in different mining conditions is critical for defining characteristics that will aid recognition of these features in mines. One feature that has been noted along several paleoslumps is the sudden appearance of over-thickened coal. Although thick coals are obviously a target of exploration, anomalously thick coals may actually indicate adjacent paleoslumps accompanied by hazardous roof conditions and loss of seam thickness.

APPLICATION OF GEOGRAPHIC INFORMATION SYSTEMS TO COAL-FIELD GEOLOGY

Stephen F. Greb and Carlos M. Galcerán

Geographic information systems (GIS) store geographically referenced data in a computer and are designed to manipulate, analyze, and display those data. With GIS, multiple coverages (layers of data about the features on the map) can be combined and analyzed together. GIS has numerous applications in coal geology. For example, the KGS compiled a GIS database for surface-mined lands in Martin County, which contains information on the Hazard No. 9 coal bed outcrop, surface mine locations, population centers, areas of surface-water runoff, power line locations, sewer line locations, transportation routes, streams, and oil and gas well locations. These coverages can be combined

and analyzed in any combination using GIS software to evaluate the best use of these surface-mined lands under a wide variety of conditions.

In the past year, the KGS entered into a cooperative agreement with the Tennessee Valley Authority (TVA) to develop a GIS database containing information on active and inactive coal preparation plants, loading facilities, and transportation networks in Kentucky. This information will be used to determine the proximity of refuse coal ponds to TVA fossil-fuel plants. The project will be of use to a wide range of agencies and applications. As part of the project, data from the U.S. Geological Survey, the Kentucky Coal Marketing and Export Council, the Governor's Office of Coal Marketing and Export, the Kentucky Energy Cabinet, the Kentucky Transportation Cabinet, TVA, and other agencies have been gathered and entered into the databases. GIS coverages of coal preparation plant locations, transportation routes (road, rail, and river), and load-out facilities are being prepared.

Coal Quality and Petrology

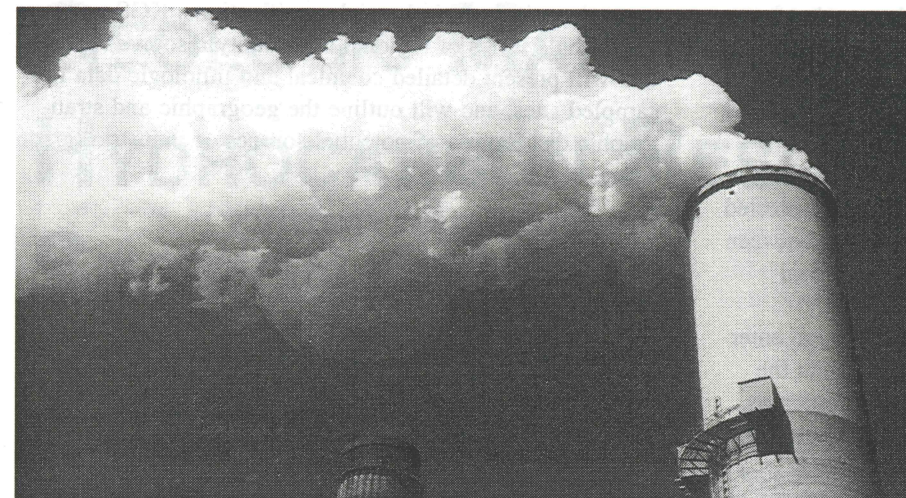
COAL-QUALITY CHARACTERISTICS OF MAJOR MINEABLE COAL BEDS IN KENTUCKY

Cortland F. Eble

The effects of Federal regulations that limit the amount of sulfur dioxide that can be emitted during coal combustion have already been felt throughout the Commonwealth. Much of the coal in western Kentucky, which has a moderate to high sulfur content, cannot be burned without pollution-control devices. In the year 2000, new Federal regulations will require a further reduction in sulfur emissions from power plants. Utilities burning western Kentucky coal must decide whether to install more scrubbers or switch to burning low-sulfur coal. Potential regulation of 15 trace elements that occur naturally in coal



A geographic information system is used to analyze a Kentucky coal bed. Photo by Stephen Greb.



Samples from coal-fired power plants are used to assess the occurrence and variability of trace elements in feed coal and combustion by-products. Photo by Cortland Eble.

will have some impact on Kentucky coal as utilities implement reduction strategies. 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 (e.g., low ash, low sulfur, high calorific value). This information can then be used to help direct future exploration and mining.

Specific efforts to help us better understand and promote the use of Kentucky coal include a cooperative study between the Kentucky Geological Survey, electric utilities, and the U.S. Geological Survey. This study, which is in its third year, is designed to assess trace element occurrence and variability in samples of feed coal and combustion by-products at a large coal-fired power plant in Kentucky. Samples are collected monthly to document the fate and variability of trace elements in coal during combustion in large industrial furnaces. Another project samples face-channel coal, run-of-mine coal, and preparation-plant waste products from a large underground mine in western Kentucky to gain a better understanding of the geologic controls on element occurrence and variability in one major, mineable Kentucky coal bed.

THE KENTUCKY COAL RESOURCES INFORMATION SYSTEM

Staff members of the Coal and Minerals Section have collected data in hard-copy and electronic formats for the benefit of the public, government agencies, and the coal industry. Data in the Kentucky Coal Resources Information System (KCRIS) have been collected by the Survey for

the last two decades, and the databases are continually being updated with new information. Analytical data from the KGS coal laboratory are also added to the database.

There are two major data sets in KCRIS. The first contains coal thickness measurements and descriptions of coal at natural outcrops, roadcuts, and mine exposures. Coalbed correlations were determined by the KGS and U.S. Geological Survey. This data set is currently limited to the Eastern Kentucky Coal Field. The second data set contains data for coal-quality analysis and has the results of analysis of coal samples from mines, natural outcrops, and cores. All of the sampling and analytical work was performed under quality-control conditions by the KGS, the Center for Applied Energy Research at the

University of Kentucky, and the U.S. Geological Survey. Coal-quality data are available for the Eastern and Western Kentucky Coal Fields.

The study of fossil spores and pollen chemically released from coals (palynology) can assist in stratigraphic identification of coal and provide clues about the origin of coal. Palynologic analysis can be conducted at KGS when it is deemed scientifically important. During this fiscal year, a number of palynologic analyses were performed on coals from both of Kentucky's coal fields. Results of these studies are published in the scientific literature. The Kentucky Geological Survey houses spore samples (maceration residues) of thousands of Kentucky coal samples, and maintains slides of spores and pollen for viewing under a microscope.



Information is checked before it is entered into the Kentucky Coal Resources Information System. Photo by Stephen Greb.

The Survey has a borehole database with records of continuous core and rotary holes drilled for coal exploration and development. Records were obtained from industry and government sources in both the Eastern and Western Kentucky Coal Fields. Information is also available on the results of coal resource estimates for 7.5-minute quadrangles, coal-availability estimates for selected 7.5-minute quadrangles, stratigraphic correlations between coal districts, and paleontologic localities in both coal fields.

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 coal data are identified stratigraphically, topographically, and geographically before they are entered into the database. Data from KCRIS and the other data sets referred to here are available through the Office of Geologic Information.

MINERALS

INDUSTRIAL LIMESTONE AND DOLOSTONE RESOURCES IN KENTUCKY

Garland R. Dever, Jr.

Limestone and dolostone furnish raw materials for construction, agriculture, and various industries. Physical properties determine a stone's suitability for construction. Specifications for agricultural and industrial uses are mainly based on chemical composition.

The Kentucky Geological Survey is investigating the chemical quality of carbonate rocks in Kentucky to determine the availability of stone for industrial uses. Analyses of samples indicate that the limestone and dolostone are highly varied in chemical quality, but that

some deposits meet industrial specifications. KGS is preparing a series of regional and county resource reports that will present detailed chemical and lithologic data for sampled sites, and will outline the geographic and stratigraphic distribution of potential sources of industrial-grade stone.

NONFUEL-MINERAL STATISTICS

Garland R. Dever, Jr.

The Kentucky Geological Survey collects and compiles information on the State's nonfuel-mineral industries. Information on industry activities and mineral-related government actions is used to prepare reports concerning mineral resources and operations, reviews of State activities, and answers to public-service inquiries. Reviews are published annually in Mining Engineering and in the U.S. Geological Survey's Mineral Industry Surveys.

KGS received a grant from the U.S. Geological Survey to evaluate and upgrade USGS Mineral Resource Data System records for Kentucky deposits. For this project, KGS is evaluating the quality of current Kentucky records, entering new records into the system for selected mineral deposits, and classifying mineral deposits and occurrences.

MINERAL RESOURCES AND MINERAL INDUSTRIES MAP OF KENTUCKY

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

The Survey is completing a new map (1:500,000 scale) of industrial and metallic minerals and mineral industries in the State. The scope of the map was expanded to include all of Kentucky's mineral resources. The distribution of oil-, gas-, and coal-producing areas, tar sand deposits, gas storage fields, and coal field boundaries were added to the map. Digitizing of mineral resources and mineral industries has been completed.

GEOLOGIC MAPPING AND HYDROCARBON RESOURCES SECTION

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 drought 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 land 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.

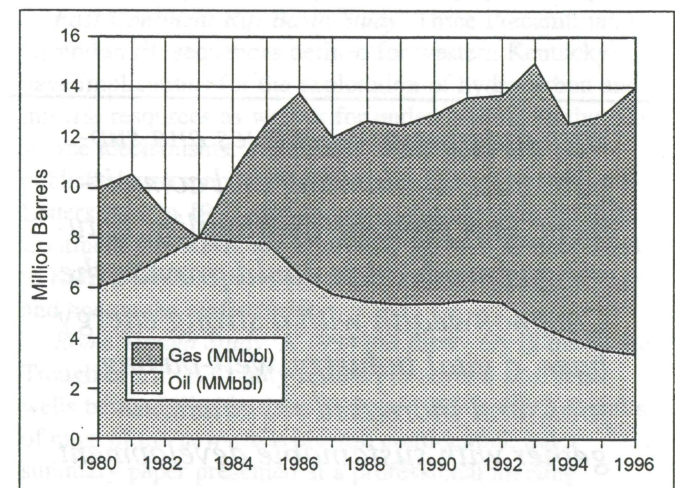
As part of a cooperative program with the U.S. Geological Survey, the KGS has been charged with a major project to digitize Kentucky's 7.5-minute geologic quadrangle maps for use in geographic information systems. GIS is a powerful tool for organizing and rapidly accessing such information and can be 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 such systems. For these reasons, digital geologic mapping is being emphasized at the KGS.

In addition to these surface mapping projects, regional geologic framework studies are conducted by the staff of the Geologic Mapping and Hydrocarbon Resources Section. Much of the latter work takes advantage of the data from the approximately 180,000 oil and gas wells that are archived in the Office of Geologic Information and geophysical data present 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.

Geophysical research is also undertaken by the section. The 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 are part of geophysical research activities associated with the use of 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 1996, oil and natural gas production value was more than \$273 million, bringing more than \$12 million in severance tax revenue to the State. Nationally, the industry remains in a slump that extends back to 1986, although natural gas production has been rising the last several years. Natural gas production in Kentucky rose nearly 9 percent in 1996 to 81.4 billion cubic feet (Bcf). Oil production continued its decline, falling 3.3 percent below last year's level to 3.45 million barrels in 1996.



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

The Appalachian Basin of eastern Kentucky produced 99 percent of the State's natural gas and 38 percent of the State's oil. Leslie County, the second most prolific oil-producing county, produced 466.4 million barrels of oil and Pike County produced the most natural gas (30.9 Bcf). Pike County also accounted for the most permits: 106 issued in 1996. In the Illinois Basin, Union County became the top oil-producing county in Kentucky with an increase of nearly 28 percent from the previous year to 483,486 barrels.

Despite the falling oil production during the past year, hydrocarbons still represent an important State and national resource. Hydrocarbons will be important bridging fuels well into the 21st century, until renewable energy resources can be developed. Nationally, natural gas will play a significant role in the future domestic energy mix, because of its environmental acceptability, low cost, domestic availability, and importance to the alternative fuels industry. One of the most significant future natural gas markets during the next decade will be electric power generation. Strong industrial demand is expected to increase annual U.S. natural gas consumption to 21 trillion cubic feet by the year 2000, outpacing the growth rate of all other energy sources.

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 a possible emerging coalbed-methane resource. With the proper incentives and support, careful planning and commitment, and pipeline availability, this sector of Kentucky's economy could show significant growth during the next decade, and could provide the Commonwealth with a strong energy base, a vital industry, well-paying jobs, and increased revenues, together with sustainable development.

With the proper incentives and support, careful planning and commitment, and pipeline availability, natural gas production could provide the Commonwealth with a strong energy base, a vital industry, well-paying jobs, and increased revenues, together with sustainable development.

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

GEOLOGIC MAPPING

DIGITAL GEOLOGIC MAPPING IN KENTUCKY

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

This project is a cooperative effort between the Kentucky Geological Survey and the U.S. Geological Survey's National Geologic Mapping Program. Its purpose is to produce digital geologic maps based on existing hard-copy, 1:24,000-scale, 7.5-minute geologic quadrangle maps of Kentucky. A joint U.S. Geological Survey-Kentucky Geological Survey project ending in 1978 resulted in Kentucky being the first major state in the Nation to be geologically mapped at this scale.

The current project will make Kentucky the first state to digitize its geology at this scale. In the first year of the project, 24 quadrangles in the Hazard District of the Kentucky River Basin were completed. The final product delivered to the U.S. Geological Survey is a digital map of the 24-quadrangle area at a scale of 1:100,000. Also included is a georeferenced database that contains details of map-element attributes.

These new digital geologic products will have many uses. Particular lithologic units, commodities, or geographic areas can be segregated for study. In addition, quantitative attributes about these features can be easily determined, such as volumetrics, resource, and reserve estimates. Such analyses are of significant value in site-specific assessments for coal, mineral, and petroleum resources; construction and urban development; engineering, planning, and reclamation; and water-supply and waste-disposal studies.

In the second year of this project, thirty-one 7.5-minute maps from the Irvine and Harrodsburg 1 x 2 degree quadrangles will be digitized. Plans call for another 106 quadrangles to be digitized in future years to complete the Kentucky River Basin before the project moves to other areas of the State.

STATE MAPPING ADVISORY COMMITTEE

Donald C. Haney, Warren H. Anderson, James A. Drahovzal, and Richard A. Smath

Topographic maps are the fundamental tools for depicting landscape, topography, road network, drainage, and cultural features. These maps are used by and are critical to planners, engineers, natural resource compa-

nies, farmers, and the public for planning and recreational use. 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.

Because of recent changes in revision procedures, the quality and content of newly revised topographic maps are not the same as for earlier versions. The Kentucky Geological Survey and the Association of American State Geologists have expressed concern about map quality, content, cost, and availability. The U.S. Geological Survey has acknowledged the seriousness of the issues and is seeking cost-effective answers to solve these problems, in order to maintain a high-quality product.

GEOLOGY ALONG KENTUCKY HIGHWAYS

Donald C. Haney, Martin C. Noger, and James C. Cobb

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

This project receives a low priority because of the large amount of drafting required for each road log. The design of the road logs is being reassessed. Future road logs will cover Interstate Highway 64, Interstate Highway 24/Western Kentucky Parkway/Bluegrass Parkway, Alexandria-Ashland (AA) Highway, Mountain Parkway, and Cumberland/Daniel Boone Parkways.

HYDROCARBON RESOURCES

Natural Gas Resources

THE ATLAS OF MAJOR APPALACHIAN GAS PLAYS

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

This project was initiated in 1991, with funding from the U.S. Department of Energy Morgantown Energy Technology Center. Activities were coordinated with the Ohio, Pennsylvania, and West Virginia geological surveys through the Appalachian Oil and Natural Gas Research Consortium of West Virginia University. The project consisted of six tasks: (1) major play definition, (2) data collection and compilation, (3) atlas preparation, (4) atlas review, (5) atlas printing, and (6) technology transfer.

The project was completed during the year with the publication of the atlas and associated databases. KGS staff wrote reports on play 14, the Middle Devonian-Lower Mississippian fractured shales; play 21, the Lower Devo-

nian-Upper Silurian unconformity ("Corniferous"); play 23, the Upper Silurian Lockport-Big Six; play 28, the Ordovician bioclastic carbonate (Trenton) play; play 30, the Middle Ordovician St. Peter Sandstone and Wells Creek Formation; and play 32, potential plays of the Rome Trough and basal Cambrian. Additional regional plays important in Kentucky are play 3, the Upper Mississippian Mauch Chunk sandstones (Maxon); play 4, the Upper Mississippian Greenbrier-Newman Limestone (Big Lime); and play 7, the Lower Mississippian Fort Payne Formation.

Reports on two of the plays were published during the year as stand-alone KGS publications: one on the Ordovician bioclastic carbonate play (Information Circular 55) and one on the St. Peter Sandstone play (Information Circular 57). A report on the pre-Knox play has been prepared and submitted for publication by the Kentucky Geological Survey. The remaining reports written by KGS personnel will be submitted later.

GEOLOGY AND HYDROCARBON POTENTIAL OF THE CAMBRIAN GRABENS

James A. Drahovzal and David C. 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.

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 for the Wabash Valley area has been completed. Regional seismic-reflection data, controlled by sparse deep-well data, have been used to interpret the top of the Knox Group, the base of the Knox Group, and the top of the Precambrian unconformity. A regional velocity model has been applied to the data to derive depth to the Precambrian unconformity. The map is planned for publication by KGS next year.

East Continent Rift Basin Study. Three Precambrian-Cambrian rift sequences defined for western Kentucky have implications for the exploration of hydrocarbon and mineral resources as well as for understanding earthquake source mechanisms. The results of the study will be published as a special volume of Seismological Research Letters later in 1997. Two other manuscripts on the East Continent Rift Basin are in review, and will be submitted to KGS for publication: one on the sedimentary petrology and one on the mafic rocks.

Rome Trough Study. A 1994 gas discovery in the Rome Trough in Elliott County resulted in several additional wells being drilled in the area from 1995 to 1997. Results of most of the new wells are still confidential, but a summary paper presented at a professional meeting

provided known details of this deep gas play. Industry funding to continue research on the Rome Trough in eastern Kentucky is being sought.

Rough Creek Graben Study. Seismic-reflection data for four seismic profiles in the western part of the Rough Creek Graben and adjacent areas were interpreted during the year. The work was conducted as part of a joint project by the Illinois Basin Consortium and the U.S. Geological Survey. The results of this study will be published in a special volume of Seismological Research Letters later in 1997. The work is critical for understanding the development of deep hydrocarbon plays in and adjacent to the graben.

GAS RESERVOIR CHARACTER OF DEVONIAN SHALES OF KENTUCKY

David C. Harris and James A. 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.

A developing gas play in the Devonian New Albany Shale of western Kentucky was extended from southern Indiana into the Commonwealth in 1996. Gas production from the New Albany Shale in western Kentucky dates back to the late 1800's, but little drilling to Devonian and deeper horizons has been done in western Kentucky. 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 planned that will take advantage of the minivibrator and 48-channel seismograph recently acquired by KGS and the UK Departments of Geological Sciences and Civil Engineering.

GAS STORAGE FIELDS OF KENTUCKY

David C. Harris

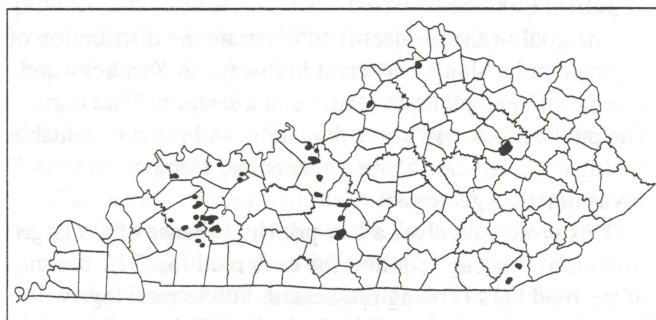
This project, initiated in late 1996, has three major goals: (1) establish a database for active and inactive natural gas storage fields in the State, (2) delineate areas that have potential for establishing new gas storage reservoirs, and (3) construct a new gas-pipeline map for the State using GIS software; this map will also include known gas storage reservoirs.

Developing a GIS-based gas storage and pipeline database has utility for both the natural gas-producing and -transportation industries, and 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.

Gas storage systems have become more important in recent years since the gas transmission industry was deregulated as a result of Federal Energy Regulatory Commission order 636. This regulation requires gas pipeline companies to separate services such as sales, transportation, and storage of natural gas. Pipeline companies are now primarily transporters of gas, and storage facilities are commonly required to meet peak demand periods.

Data are being collected from pipeline operators to construct the gas-pipeline map. Pipeline data available in GIS format may be used as a basis for more detailed mapping.



Locations of gas storage fields in Kentucky.

Oil Resources

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

Brandon C. Nuttall, James A. Drahovzal, Anna E. Watson, and Thomas N. 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 target of identifying and incorporating into the database approximately 80 percent of the eastern Kentucky original oil in place. In 1996, a project to incorporate at least 44 percent of western Kentucky's original oil in place was

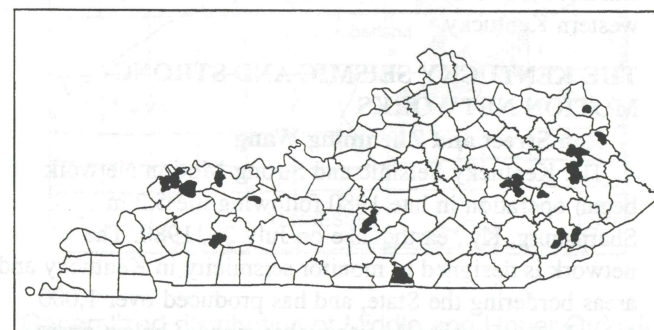
begun. In both studies literature searches were conducted, consultants and major operators contacted for necessary data, all available data analyzed, and summary sheets for each reservoir compiled and submitted to the DOE, completing the contracts.

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. A final report and bibliography from the combined projects has been approved for KGS publication.

STRATIGRAPHY AND RESERVOIR SEDIMENTOLOGY OF MISSISSIPPIAN CARBONATES IN KENTUCKY

David C. Harris and Thomas N. Sparks

This study will 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 collection of stratigraphic data for 7,713 wells. These data have been entered into a computer database. All data from Phase I were released to the public on May 20, 1997. Regional cross sections that were constructed during the project will be published by KGS. Data collected during the project are now being interpreted. Structure and isopach maps of Mississippian units are being compiled as part of the Regional Subsurface Maps in Kentucky project (see below). The first map to be published will be of the structure on the top of the "Big Lime." A second phase of the project, a detailed study of three "Big Lime" fields, is currently inactive, but support for it is being sought.



Kentucky oil fields currently represented in the TORIS database.

TAR SANDS OF WESTERN KENTUCKY

Brandon C. Nuttall and James A. Drahovzal

Tar sands of western Kentucky comprise a major hydrocarbon resource of over 3 billion barrels of heavy oil and tar in place in the shallow subsurface. This resource has been developed episodically for over 100 years, depending on price and market considerations. With the declining availability and rising price of conventional oil, the tar sands will probably be 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 general significance to petroleum-geology research.

The tar sands have emerged as a significant element in a mass-balance study of hydrocarbons in the Illinois Basin, carried out in cooperation with the Illinois Basin Consortium and the U.S. Geological Survey. A subsequent study conducted by KGS concluded that the tar sands demonstrate that oil migration in the Illinois Basin included a major component of flow from the center of the deep basin eastward toward the Cincinnati Arch. Results of this study were published as part of U.S. Geological Survey Bulletin 2137, "Feasibility Study of Material-Balance Assessment of Petroleum from the New Albany Shale in the Illinois Basin."

Additional cooperative work is under way with the U.S. Geological Survey to determine if the New Albany Shale is a source for the tar sands.

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 C. Harris and James A. Drahovzal

The goal of this research is to produce a series of regional structure and isopach maps for the important geologic horizons and intervals of the Commonwealth. This information is critical not only for the energy and mineral industries of the Commonwealth, but also for 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 (see below) resulted in a preliminary 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 is based on existing deep-well and seismic-reflection data, and has been submitted to the U.S. Geological Survey as part of a report to be published later in the year. The map may be published by KGS at a later date. These data, together with data from other projects, will be useful in the eventual production of a statewide basement map.

Data collected as part of a regional stratigraphic study of Mississippian carbonate rocks (see above) are now being interpreted. A computer-generated structure map of the top of the "Big Lime" interval in the subsurface was completed. This map covers most of eastern Kentucky, and has been submitted for publication in KGS's Map and Chart Series. A structural map of the top of the Mississippian Borden Group (base of the "Big Lime") will be compiled next, followed by an isopach map of the "Big Lime."

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, will soon be made available as an open-file map.

SEISMOTECTONIC MAP ATLAS FOR THE WABASH VALLEY SEISMIC ZONE

John D. Kiefer, James A. Drahovzal, and Steven J. Cordiviola

This project in cooperation with the other state surveys of the Illinois Basin Consortium and the U.S. Geological Survey will provide an up-to-date atlas of the Wabash Valley Seismic Zone, which encompasses parts of western Kentucky, southeastern Illinois, and southwestern Indiana. The atlas will contain geologic and seismological information useful for the development of state earthquake mitigation programs and disaster exercises. The atlas will consist of a Quaternary geologic map, a regional liquefaction features map, an earthquake-induced landslide map, a surface structure map, a Precambrian basement map, and a base map showing lifelines, critical facilities, and other features important for emergency-response efforts. These maps have been completed and submitted to the U.S. Geological Survey for editing. Publication is expected later in 1997 or in 1998. A similar study for the Cincinnati area is being initiated by the KGS in cooperation with the Central United States Earthquake Consortium.

GEOLOGIC FEATURES RELEVANT TO GROUND-WATER FLOW IN THE VICINITY OF THE PADUCAH GASEOUS DIFFUSION PLANT: COMPILATION OF GEOLOGICAL AND GEOPHYSICAL DATA

James A. Drahovzal and R. Todd Hendricks

A 4-month project funded by the Federal Facilities Oversight Unit of the Kentucky Water Resources Research Institute at the University of Kentucky investigated

whether geologic features were controlling the flow of ground water and associated pollutants in the vicinity of the Paducah Gaseous Diffusion Plant near Paducah, Ky. The study concluded that northeast-trending, high-angle faulting in unconsolidated sediments in the area, expressed on remote-sensing data and interpreted from high-resolution seismic-reflection data, likely controls two northeast-oriented contaminant plumes north of the plant site. These and other features, including alluvial channels and liquefaction structures, may also represent contamination pathways. In addition, faulting and the liquefaction could present serious foundation problems in the event of earthquakes.

A proposal for further research has been presented to the Federal Facilities Oversight Unit. Additional seismic-reflection work is being carried out to characterize the nature of the faulting in the area and its influence on contaminant transport.

ACQUISITION OF STATE-OF-THE-ART INSTRUMENTATION TO DO HIGH-RESOLUTION SHEAR-WAVE INVESTIGATIONS IN THE NEW MADRID SEISMIC ZONE

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

An equipment proposal written in cooperation with faculty of the University of Kentucky Departments of Geological Sciences and Civil Engineering was submitted to the National Science Foundation and funded in 1996. The proposal requested the purchase of a trailer-mounted minivibrator to be used to acquire high-resolution p- and s-wave seismic-reflection data and a 48-channel, 24-bit seismograph. Both items have been received and are currently being tested.

This equipment will be used in several ways for research and teaching purposes 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.

THE KENTUCKY SEISMIC AND STRONG-MOTION NETWORKS

Ron Street and Zhenming Wang

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 is designed to monitor seismicity in Kentucky and areas bordering the State, and has produced over 1,000 recordings of regional earthquakes since it began operation. The network consists of 10 borehole-mounted, short-

period seismometers deployed from Grayson in the east to Clinton in the west. The seismic data are transmitted to the University of Kentucky campus via the Kentucky Early Warning System microwave network. Continuous drum recordings of the seismic activity are used for visual analysis, and the data are digitized and stored on a computer for advanced processing and display.

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

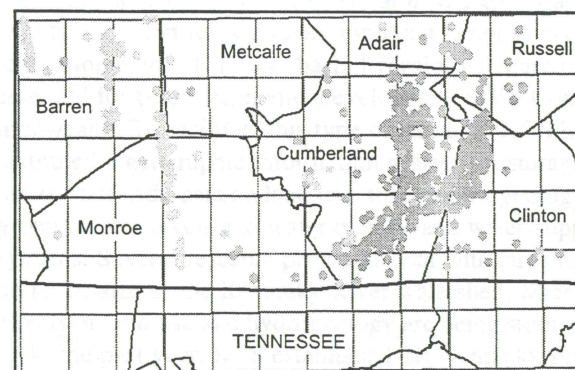
No major earthquakes that originated in Kentucky were recorded during the year, but many were recorded that originated outside the State.

Oil and Gas Data

OIL AND GAS MAPS

Brandon C. Nuttall, Anna E. Watson, and Lance G. Morris

In an effort to update the oil and gas maps of the State, a series of 1:100,000-scale computer-generated 30 x 60 minute quadrangle maps is being prepared that will be



Generalized distribution of Middle and Upper Ordovician producing oil wells in the Tompkinsville 30 x 60 minute quadrangle.

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 Middlesboro 30 x 60 minute quadrangle has recently been released as Map and Chart Series 11. 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 KGS well records database. A template for these maps, using the ArcView® software package from ESRI, based on a 30 x 60 minute quadrangle map for Tompkinsville, has been approved. The Tompkinsville map has been released as Map and Chart Series 13. The Evansville, Hazard, and Williamson 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 is being updated as well.

OIL AND GAS RECORDS

Anna E. Watson and Brandon C. Nuttall

The 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 on file in the Office of Geologic Information. A variety of records, such as drillers' logs, wireline logs, well-location survey plats, plugging affidavits, stratigraphic tops, and completion reports, are on file for an estimated 180,000 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 staff in basic and applied research projects. KGS is also responsible for advising the Division of Oil and Gas on the accuracy of the plat, spacing requirements, and special requirement areas for all oil and gas permit applications for the State.

During 1996, records for 1,936 wells were processed for completions, changes, terminations, and plugging and 802 permit applications were reviewed. All available stratigraphic tops data from western Kentucky logs are being entered in a database. An effort is under way to increase the number and quality of stratigraphic tops data being entered in the tops database for eastern and central Kentucky.

DEVELOPMENT OF A VIRTUAL REGIONAL RESOURCE CENTER USING THE RESOURCES OF THE INTERNET AND THE WORLD WIDE WEB

Brandon C. 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 that may be consulted by individuals seeking assistance for drilling and completion, reservoir characterization, environmental regulatory compliance, and exploration issues. A fundamental problem has been lack of access to data. Many operators feel they are isolated from technological innovations that could help them solve their problems.

This project has one main objective: to develop a framework for a World Wide Web site and a series of informational pages for use as a virtual regional resource center. These pages 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 Survey research in Kentucky 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, links to other petroleum resource and technology related sites, and other information.

This proposed 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.



WATER RESOURCES SECTION

For Kentucky to maximize its economic potential, large quantities of usable water are necessary.

Kentucky must plan for increasing use of its water resources, including both ground-water and surface-water supplies, for the expansion of industry and urban areas and to further develop its mineral and agricultural resources.

Over the past 20 years, 10 Federal acts have been enacted to protect water. State regulatory agencies developed programs dealing with mining and mine reclamation, solid and liquid waste disposal, sewage disposal, water supply, oil and natural gas recovery, and agricultural practices. The State has developed ground-water regulations to protect this vital resource. An understanding of the geology and hydrogeology of Kentucky is essential for appropriate regulations and the optimum development, utilization, and management of the State's water resources. The Water Resources Section provides information to municipalities, industry, Federal and State agencies, and private citizens concerning the occurrence, movement, quantity, and quality of surface water and ground water in the State.

New projects are designed to meet the present and future demands of Federal and State programs and the needs of Kentucky's citizens. The Water Resources Section has directed much of its efforts over the past year to designing such projects and implementing them by drilling monitoring wells, sampling springs, and monitoring surface waters. In addition, KGS maintains the Kentucky Ground-Water Data Repository for all ground-water data collected by State agencies.

The availability of water is crucial for urban and rural economic development. The effect of land use on water quality and quantity is also an important factor in economic development. Therefore, basin hydrology research is essential for future economic development in the Commonwealth. To facilitate this type of research, KGS has instituted a geographic information system for storage and use of statewide data on land use, topography, geology, ground-water levels and water 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.

In the past year, KGS established the Kentucky Inter-agency Ground-Water Monitoring Network in cooperation with other State and Federal agencies; the network will facilitate the collection, computerized storage, and analysis

of ground-water data. This activity should consolidate and accelerate efforts to define and characterize aquifer systems in Kentucky.

A highlight for the year for the Water Resources Section was hosting the 41st Midwest Ground Water Conference. The 3-day conference was attended by approximately 150 hydrologists and included a field trip to Mammoth Cave National Park and 2 days of technical papers and posters.

Hydrogeology of Agricultural Lands

All of the projects below pertaining to the hydrogeology of agricultural lands are funded through the Kentucky Senate Bill SB-271 Water-Quality Program and are cooperative efforts between the Kentucky Geological Survey and the Department of Agronomy, the Department of Biosystems and Agricultural Engineering, and the Kentucky Water Resources Research Institute at the University of Kentucky.

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

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

Ground-water quality in a 2.5-mi-long watershed in Hickman County is being evaluated. The site is characterized by extensive agricultural activity. Its geology (loess, continental deposits, and semiconsolidated sands) is representative of most of the Jackson Purchase Region in western Kentucky, and most residents of the area depend on ground water for domestic water supplies.

Seventeen monitoring wells at a farm site were used to sample ground water and measure levels of both perched ground water and water in the deeper Eocene aquifer. Samples from domestic wells were analyzed for nitrate and other nitrogen compounds, common pesticides, oxidation-reduction potential, and total organic carbon content. One of the major causes of high nitrate concentrations in some wells of the region may be poor well construction, and research into this possibility will be pursued as funding is available.

Concentrations of triazine pesticides during 3 years of sampling were below the maximum contaminant level (MCL) of 3.0 milligrams per liter (mg/L) set by the U.S.

Environmental Protection Agency. Nitrate-nitrogen concentrations regularly exceeded the MCL of 10 mg/L in some of the private wells tested.

A report on interim findings has been placed on open file (KGS open-file report OF-93-06), and two draft reports are in review. A University of Kentucky M.S. thesis on this site was successfully defended in the fall of 1996 by Carl Petersen of the Department of Geological Sciences.

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

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

Data on variations in ground-water quality are being summarized for a tilled farm field in Hopkins County that has been planted in corn for most of the last 40 years. Tile drains in the field discharge into a 10-ft-deep drainage ditch. This farm, along with the Daviess County study site (see below), is representative of the flat bottom lands of the Western Kentucky Coal Field.

Nitrate-nitrogen concentrations were above the 10 mg/L MCL in the shallowest ground water, but ground water from bedrock was consistently far below the MCL. Atrazine and simazine herbicides were rarely detected below 8 ft in depth, and then only in trace concentrations. Concentrations in ground water less than 8 ft deep were

lower in 1993 than in 1992 because of dryer conditions in the weeks during and after herbicide application. Dry conditions led to greater degradation of the herbicides before there was much recharge of the ground-water system from rainfall.

Results have been shared with other researchers, and a report of interim findings has been placed on open file (KGS open-file report OF-94-01). Two additional publications are in review.

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

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

Data on variations in ground-water quality are being summarized for a farm field and a nearby wooded lot in Daviess County. The farm is tile drained, and the closest drainage ditches are about 6 ft deep. The farm field and wooded lot occasionally flood during wet years. Monitoring wells were installed and monitored for nitrate-related compounds and herbicides.

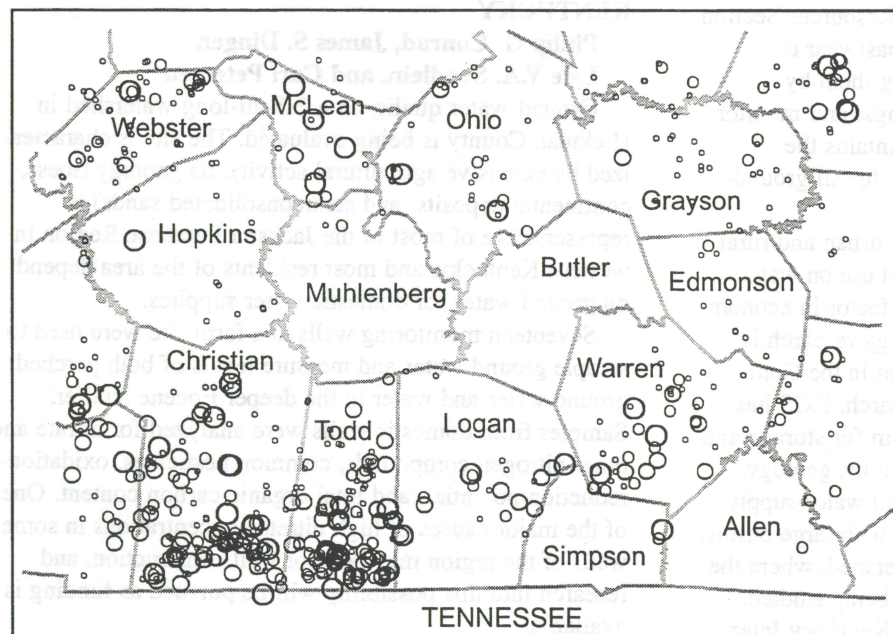
Nitrate-nitrogen concentrations were below 1.5 mg/L in ground water at the crop and wooded sites. Metolachlor and 2,4-D herbicides applied at the site in 1992 moved downward readily through upper sediments via deep mud cracks and deeper root macropores from old tree roots. Vertical movement of the herbicides was greatly diminished below the deep root zone.

Results have been shared with other researchers, and a report of interim findings has been placed on open file (KGS open-file report OF-94-01). Two draft publications on the site are currently in review.

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

E. Glynn Beck, Philip G. Conrad, James S. Dinger, John H. Grove, and Joseph L. 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.



Nitrate concentrations in ground water and springs in western Kentucky. The larger the circle, the greater the concentration. The largest circles indicate concentrations greater than the maximum contaminant level for nitrate recommended by the U.S. Environmental Protection Agency.

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

Hydrogeology of Coal Fields

HYDROLOGY OF LARGE SPOIL AREAS

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

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

Detailed studies of the ponds and springs at the site determined their suitability for hosting stocked fish. The ponds at the site are part of the Cyprus Amax Company's Wildlife Refuge Area, and the company is interested in using one of them for recreational fishing. The water that fills the ponds is derived from ground water stored in the spoil. Our data indicate that the pond used for trout stocking is stratified by temperature and has a low dissolved oxygen content of 2.0 mg/L during the summer months, but oxygen content increases to about 10.0 mg/L during winter.

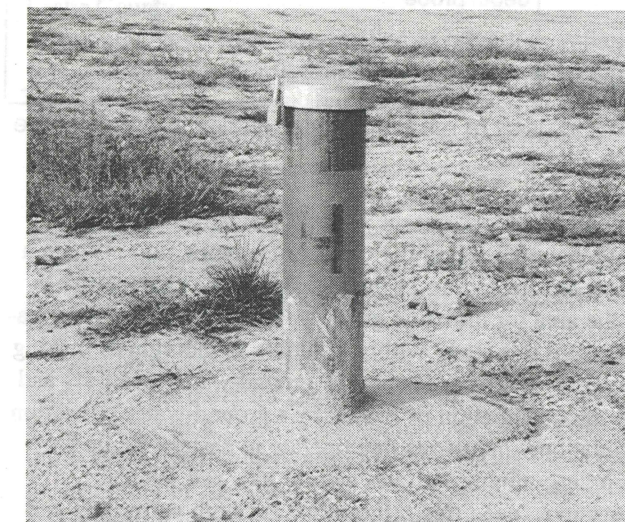
The amount of spoil settlement occurring is also being determined. Four traverses across the spoil area have been surveyed, and 80 settlement monuments installed along these lines. The monuments were surveyed in October 1996 and March 1997 to measure vertical and lateral movement. These data, in conjunction with data collected previously around monitoring wells, will allow us to evaluate the effects of spoil thickness, age, and premining topography on the degree and rate of settlement.

This project is funded by Cyprus Southern Realty Corp. through Cyprus Amax Company.

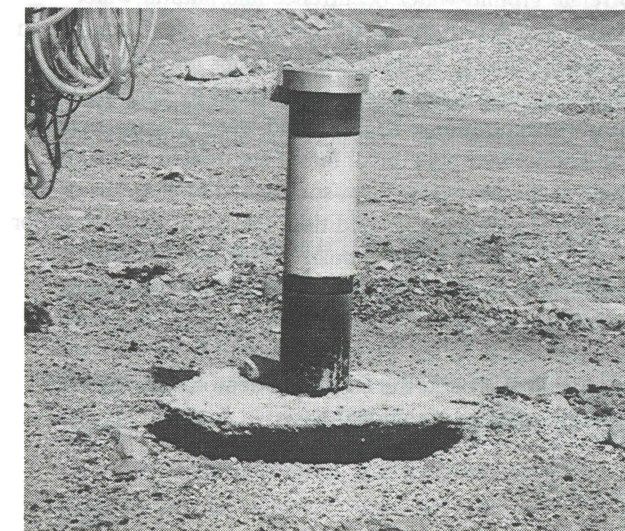
GROUND-WATER GEOCHEMISTRY AND ITS RELATIONSHIP TO GROUND-WATER FLOW IN THE EASTERN KENTUCKY COAL FIELD

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

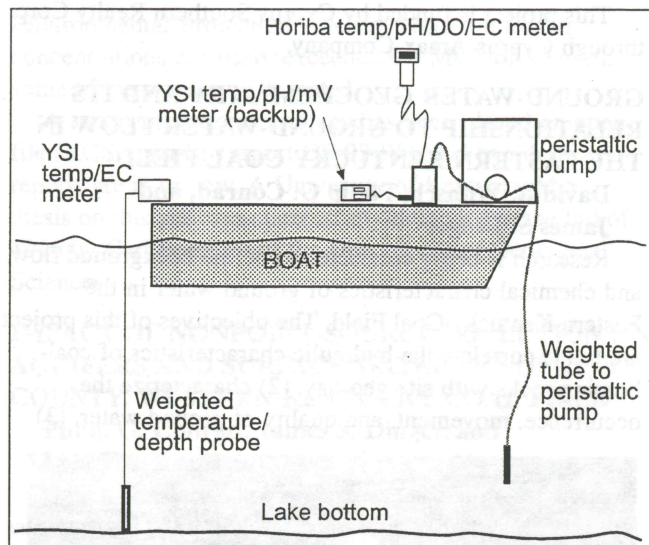
Research is being conducted to define background flow and chemical characteristics of ground water in the Eastern Kentucky Coal Field. The objectives of this project are to (1) correlate the hydraulic characteristics of coal-bearing rocks with site geology, (2) characterize the occurrence, movement, and quality of ground water, (3)



In July 1990, the cement surface seal of a monitoring well at the Star Fire tract was flush with the spoil surface.



By July 1992, the spoil had settled considerably, leaving the cement seal "floating" in the air.



Method used to measure water quality in ponds at the Star Fire tract.

document the occurrence of trace elements and their relationship to specific ground-water types, and (4) gain a better understanding of the hydrogeologic characteristics of the area for effective ground-water monitoring. Information from this study will be valuable to individuals making decisions regarding the use of ground-water resources and the implementation of Kentucky's ground-water protection regulations. Industries that operate in eastern Kentucky, including mining, oil and natural gas, and landfill operations, need this information for both permitting and compliance.

Several sites representative of the geology of the coal field have been intensively monitored to collect hydrogeologic and hydrochemical data. These data will be used to correlate ground-water occurrence and natural water quality, and define the hydrochemical facies in aquifers in eastern Kentucky. Hydrochemical facies are defined as distinct ground-water zones categorized by 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.

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

R. Stephen Fisher, James S. Dinger, and Lyle V.A. Sendlein

Placing flue-gas desulfurization (FGD) by-products into underground mine openings has been proposed as a way to stabilize auger holes and thus 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-water quality. This study will use 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 be directed toward simulating a grouted auger-mine site in an upper valley location with many auger mines. These upper valley sites are important because they 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 will be determined experimentally by the Center for Applied Energy Research at the University of Kentucky. The compositional range of shallow ground waters will be based on data reported from wells in the Eastern Kentucky Coal Field. The geochemical modeling code PHREEQ will be 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.

HYDROLOGIC INVESTIGATIONS IN ROBINSON FOREST

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

The University of Kentucky's Robinson Forest contains some of the largest undisturbed tracts of land in eastern Kentucky. This setting provides a unique opportunity to monitor ground water, 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 continuously 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 are used to test the validity of interpretations and conceptual models derived from data collected at other sites. Geochemical data from these wells show excellent agreement with a hydrochemical facies model being proposed for the Eastern Kentucky Coal Field.

Three additional monitoring wells were installed in the main block of the forest during the summer of 1996. These wells were installed to determine the occurrence of the shallow salt-water interface in relation to the surface topography. A 700-ft-deep well on a ridge top was installed to determine the depth of the salt-water interface below upland areas. A 150-ft-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 for minimizing the intrusion of salt water in wells used for domestic supplies.

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

HYDROGEOLOGIC EVALUATION OF HIGH-YIELD WELL POTENTIAL IN THE EASTERN KENTUCKY COAL FIELD

David R. Wunsch, Robert E. Andrews, and James S. Dinger

The Kentucky Geological Survey was awarded funds for the 1996-97 fiscal year from the E.O. Robinson Trust to begin the study of the use of geologic and remote-sensing techniques to identify preferential locations for high-yield ground-water supplies in eastern Kentucky. Water well yields derived from the rocks that underlie eastern Kentucky are low compared to other parts of the country. Wells in eastern Kentucky that produce significant amounts of water (i.e., greater than 30 gallons per minute) usually occur where secondary permeability features such as fractures or faults are present in the rock.

General methods used to locate these features have been used elsewhere in the United States and other parts of the world with some success. The state-of-the-art technologies we are using should enhance our ability to locate specific areas of eastern Kentucky where high-yield water wells may be located that can be used for community and industrial supplies.

We have acquired Landsat and SLAR (side-looking airborne radar) imagery data for computer manipulation for the entire Eastern Kentucky Coal Field. The digital data images created from this imagery have been georefer-

enced using GIS technology, and field checking of specific locations is currently under way using a global positioning system.

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

EFFECTS OF DEEP COAL MINES ON HYDROGEOLOGY

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

Subsidence-related deformation and associated hydrologic changes are being evaluated at an active longwall coal mine in eastern Kentucky on Edd Fork near Helton in Leslie County.

Initially, three cores were drilled at ridge-top, valley-side, and valley-bottom positions to provide stratigraphic information for the study site. Pressure-injection testing was also conducted in each core hole at 10-ft intervals.

Information from the core holes was used to design 24 ground-water monitoring wells that were installed during the summer of 1992. A flume and rain gage measured the discharge of Edd Fork and collected precipitation data in the study basin so that changes in hydrology could be fully evaluated.

Data on piezometric water levels and surface fractures were collected daily for approximately 1 month while undermining took place in the summer of 1994. Two-thirds of the piezometers were affected during the actual undermining of the panel, and 13 piezometers failed structurally. Coaxial cables grouted into each core hole were monitored using time-domain reflectometry to evaluate rock deformation in response to mining subsidence.

A second drilling program in the summer of 1995 measured the behavior of the ground-water system after mining. Two core holes, one each at the ridge-top and valley-bottom nests, determined the extent of fracturing, and pressure-injection tests at 10-ft intervals examined changes in hydraulic conductivity. Two monitoring wells

The state-of-the-art technologies we are using should enhance our ability to locate specific areas of eastern Kentucky where high-yield water wells may be located that can be used for community and industrial supplies.

were installed in the valley-bottom nest to replace the wells destroyed by mining so that changes in ground-water level and water quality could be measured.

This study, which terminated in October 1996, was a cooperative effort with Diamond Shamrock Coal Co. and the Kentucky Water Resources Research Institute of the University of Kentucky. Publications on research about the hydrology before mining and during mining are in final preparation. A project report on the effects after mining is being written.

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

CHARACTERIZATION OF HYDRAULIC CONDUCTIVITY IN THE EASTERN KENTUCKY COAL FIELDS

David R. Wunsch and James S. Dinger

The hydrologic characteristics of rocks that comprise 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 tremendous disparity makes adequately predicting water occurrence and movement difficult, which has implications for dewatering mines, contaminant transport, and for water supply wells.

The Kentucky Geological Survey has been actively collecting hydraulic conductivity data from all lithologic types found in the coal field. The majority of the data are collected in conjunction with other studies. A database containing hydraulic conductivity data from approximately 350 individual water-injection packer tests has been assembled. Statistical analysis of data indicates that fractured rock and coal seams are on average approximately 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 routinely deal with water quality and supply issues in the Eastern Kentucky Coal Field. A report summarizing the hydraulic conductivity data is planned for development during the coming year.

Hydrogeology of Karst Terranes

MONITORING THE IMPACTS OF THE ANIMAL RESEARCH CENTER ON SURFACE- AND GROUND-WATER QUALITY

Alex W. Fogle, Joseph L. Taraba, and Ira Joe Ross

The University of Kentucky is designing an Animal Research Center, to be located on karst terrane in Woodford County. As with all farms in Kentucky, it must meet the requirements of the Agricultural Water Quality Authority established by Senate Bill 241, which requires that each farm develop a water quality protection plan. Intelligent hydrologic planning is based upon detailed knowledge of the hydrologic system under consideration, as well as of the influences upon that system. A minimal, ongoing water-quality monitoring program was designed in early 1996 and instituted in October 1996 to determine the impact of the center's construction and operations on water quality. The monitoring program will provide baseline and support data for several ongoing and future research projects dealing with the impacts of animal activity in a karst hydrogeologic system. Potential monitoring points include 13 weirs and three well nests with four to five wells each constructed to different depths. An electronic, relational database has been developed for the water-quality data that will be collected. Data collected by previous projects at the center have been gathered and are being incorporated into the database. A GIS database has also been started to assist in land-use and hydrologic planning. Several maps have been produced for these 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.

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

James C. Currens

This study is now in its fifth year of Federal and State funding. The implementation of best management practices by farm owners in the watershed is complete. Field efforts during the year were largely limited to maintaining equipment and continuing water-quality monitoring. Ground-water dye traces continue to be conducted. 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.

gy. The project report on the first 3 years of study is in preparation. In addition, a draft report on determining the minimum sampling frequency required for monitoring karst springs has been prepared.

The ultimate 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 Natural Resources Conservation Service to implement a variety of changes to agricultural practices in the basin, but full-scale implementation did not get under way until the fall of 1995. If improvement in the ground-water quality cannot be demonstrated on a 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 re-evaluated.

INVENTORY OF KARST SPRINGS IN FAYETTE COUNTY

James C. Currens and Ken Pidgeon

A small-scale map of Fayette County showing karst springs will be accompanied by a computer listing of spring names, Carter coordinate locations, and characteristics such as estimated discharge. This work is largely the result of efforts by Mr. Pidgeon, of the Kentucky Natural Resources and Environmental Protection Cabinet–Division of Water, but will include data in the Kentucky Ground-Water Data Repository. The data that have been collected will be an important contribution toward the karst atlas project (see below), specifically for the Lexington and Harrodsburg Quadrangles.

This work is done on an as-time-permits basis and is funded by KGS.

ATLAS OF KARST GROUND-WATER BASINS IN KENTUCKY

James C. Currens and Joseph A. 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. One map, of the Lexington 30 x 60 minute quadrangle, has been published. One map is in preparation for publication, and drafts of three other maps are now complete. Two additional maps are being compiled. Each map will cover a 30 x 60 minute area at a scale of 1:100,000. The catchment area will be shown for each basin for which there are sufficient data to delineate the basin boundary. Less well-defined basins will be represented by lines connecting ground-water dye-trace input points 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. The value of such maps and data for water supply, ground-water protection, and general economic development is significant.

This project is funded by KGS and the Kentucky Natural Resources and Environmental Protection Cabinet.

PROGRAM 319 ADVISORY MANAGEMENT

James S. Dinger, John D. Kiefer, Daniel I. Carey, Philip G. Conrad, and Lyle V.A. 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. Two grant administrators assist the Division of Water in developing grant work plans and reviewing and tracking contractual agreements with individuals researching nonpoint-source pollution.

Hydrogeology of Urban and Industrial Areas

HYDROGEOLOGIC CONDITIONS AROUND DEEP AERATION LAGOONS AT THE BARDSTOWN WASTE-WATER TREATMENT PLANT

David R. Wunsch and Lyle V.A. Sendlein

Deep-cell aerated lagoons have been recognized as an efficient primary treatment process for sewage and waste water. These lagoons have proven to be effective in lowering the suspended solids content while minimizing the accumulation of sludge that normally settles at the bottom of lagoons. After decades of use, large primary treatment lagoons fell out of favor because of their large area requirements and limited denitrification capabilities. Aerated lagoons, in conjunction with improved secondary treatment technology, are again being considered in the design for new waste-water treatment plants. An important consideration when using lagoons for waste-water treatment is their impact on the quality and movement of water in the subsurface.

The Survey, in cooperation with the Kentucky Water Resources Research Institute at the University of Kentucky, installed eight monitoring wells around the lagoons at the Bardstown, Ky., sewage plant. The plant is approximately 1 mile from the center of town, near the confluence of Town Creek and Beech Fork. Preliminary data from water

samples collected from the site indicate that the lagoons do not appear to be affecting the shallow ground-water system. Wells installed in bedrock contain brackish water, which probably represents connate water trapped in the sediments. Water samples are also being collected from upstream and downstream locations along Beech Fork. These data, along with stream discharge data, will help determine if the lagoons are leaking significantly.

This study is funded by the Kentucky Natural Resources and Environmental Protection Cabinet—Division of Water.

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

James S. Dinger, Robert M. Williams, Andrew J. Powell, Dwayne L. Edwards, and Daniel I. Carey

Two areas of the Sinking Creek watershed in Jessamine County with distinctly different land uses were selected for water sampling. One area contains a golf course and surrounding residential development, and discharges midway in the second area—Sinking Creek. The latter area contains both residential and agricultural land uses. It originates as a spring in the agricultural portion of the watershed, and sinks into a karst formation after passing through the Tashamingo subdivision.

The stream exiting the golf course subwatershed was monitored from April through November 1994. The pesticides 2,4-D and chlorpyrifos were detected at levels up to 2.5 parts per billion (ppb) and 0.015 ppb, respectively. Diazinon was found at levels up to 1.4 ppb. The diazinon source is most likely from lawn care activities in the residential neighborhood surrounding the golf course, because diazinon 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 reported above.

The Survey sampled Sinking Creek in the upper reach and in the Tashamingo subdivision from April 1996 through February 1997. During the sampling period, weekly grab samples and three storm sample sequences (spring, summer, and fall) were taken and tested for 2,4-D, diazinon, and chlorpyrifos. Only several samples from May and June 1996 contained trace amounts; no pesticides were found above detection limits in late summer and early fall, in spite of intensive lawn care activities taking place during this period.

Because of the insignificant amounts of turfgrass chemicals in the Sinking Creek watershed, we are proposing to move this study of controls on the fate and transport of the commonly used chemicals in Kentucky to the Coldstream research farm at the University of Kentucky, where plot studies and rainfall simulators will be used.

This project is funded by funds from the U.S. Environmental Protection Agency, administered through the Kentucky Natural Resources and Environmental Protection Cabinet—Division of Water. It is being carried out in cooperation with the University of Kentucky Department of Biosystems and Agricultural Engineering and the Department of Agronomy.

HYDROGEOLOGICAL INVESTIGATIONS AT THE PADUCAH GASEOUS DIFFUSION PLANT, MCCrackEN COUNTY, KENTUCKY

R. Stephen Fisher and James S. Dinger

The Paducah Gaseous Diffusion Plant in McCracken County is a uranium processing facility where the concentration of U-235 is enriched by gaseous diffusion 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. Investigations to determine the nature and source of soil and ground-water contamination, as well as the mobility, transport, and fate of trichloroethylene and technetium-99, are in progress.

Kentucky Geological Survey researchers are assisting the Kentucky Water Resources Research Institute's Federal Facilities Oversight Unit at the University of Kentucky in assessing environmental investigations and remediation activities at the plant. Major activities during the past year included a review of information sources to determine background concentrations of inorganic contaminants in soils, surface water, and ground water, and an evaluation of radioactive contaminant sources from specific waste area groupings and surface waste-management units.

This work is being performed in conjunction with studies of stratigraphy and faulting being conducted by the Geologic Mapping and Hydrocarbon Resources Section of the Kentucky Geological Survey and the University of Kentucky Department of Geological Sciences.

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

HYDROGEOLOGICAL INVESTIGATIONS AT THE MAXEY FLATS DISPOSAL SITE, FLEMING COUNTY, KENTUCKY

R. Stephen Fisher and James S. Dinger

The Maxey Flats disposal site is located on an isolated plateau in Fleming County, northeastern Kentucky. Radioactive waste material was buried in shallow trenches at Maxey Flats from 1963 to 1972, 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 select locations for monitoring wells and to evaluate well performance at the disposal site. The purpose of the monitoring wells is to determine whether ground water has or will carry contaminants beyond the property boundary. 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.

Basin Hydrology, Water Supply, and Waste Management

GEOGRAPHIC INFORMATION SYSTEM FOR WATER-RESOURCES PLANNING AND MANAGEMENT

Daniel I. Carey

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

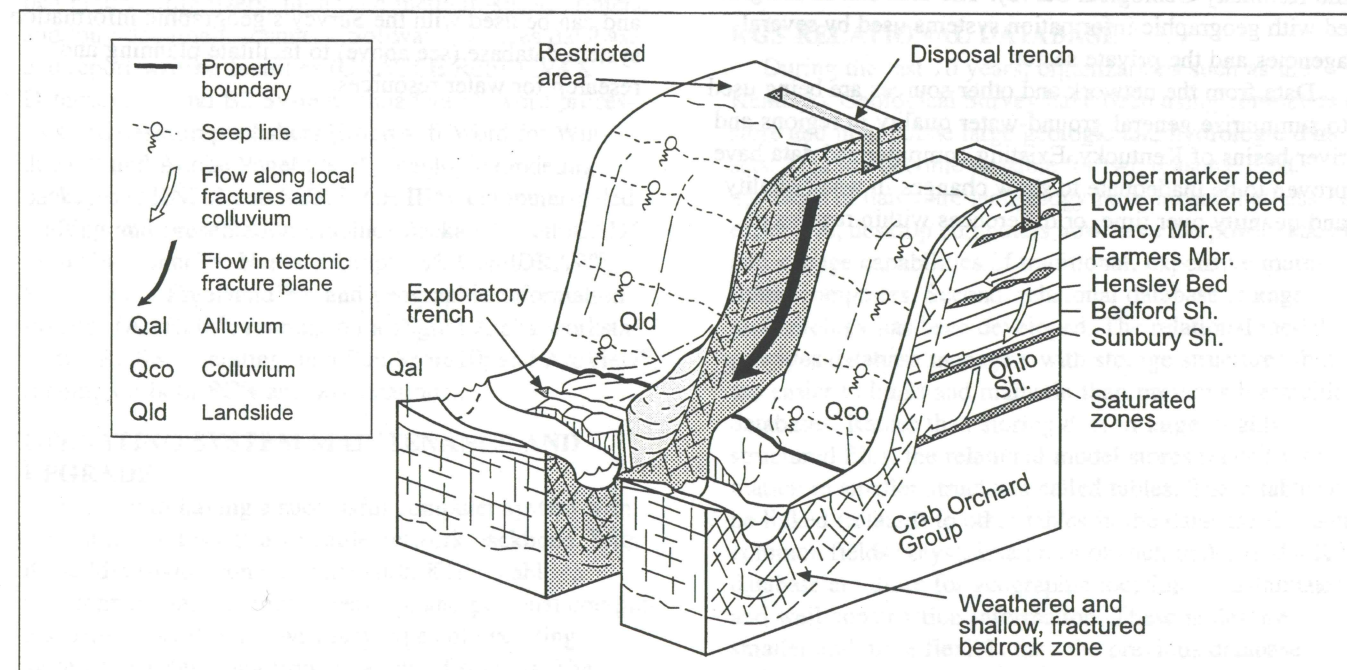
Arc/Info® software is used to create and maintain spatial data at a statewide and basin level on water supplies, water usage, soils, ground water, water quality, demographics, transportation, infrastructure, oil and natural gas activities, topography, and political subdivisions. These data and the GIS are used to support water, coal, and petroleum resource studies.

KENTUCKY RIVER BASIN WATER-SUPPLY ASSESSMENT

Daniel I. Carey, Alex W. Fogle, and Lance G. Morris

The Kentucky Water Resources Research Institute of the University of Kentucky (KWRRI) has assembled a team of researchers to examine water supply issues for the Kentucky River Basin. The work was performed under contract to the Kentucky River Authority. The study consisted of five basic tasks: (1) assessment of previous water supply reports, (2) analysis of water supplies from the main stem of the Kentucky River, (3) evaluation of water supply, (4) development of a drought response plan, and (5) development of a long-range water supply plan. This 20-month study was completed in December 1996.

Previous studies were evaluated with regard to conservation, management, and growth assumptions, and to determine the impact of proposed construction projects. Public and private water supplies in the headwater regions of the basin were characterized in two KWRRI reports: "Task 2, Part 1—Evaluation of Water Supplies in the Upper Forks of the Kentucky River" (KWRRI/RR-0396) and "Task 2, Part 2—Evaluation of Water Supplies in the Red River, Dix River, and Main Stem Watersheds of the Kentucky River" (KWRRI/RR-0496). Analysis of headwa-



Hydrogeologic model of ground-water flow at the Maxey Flats disposal site.

ter supplies throughout the basin (those not relying on the main stem of the Kentucky River) were included in the reports. The water supply evaluations also identified water supply needs based on alternative growth projections.

The long-range water supply plan recommended strategies for meeting water supply goals. A computer simulation model was developed for use by the Kentucky River Authority. The model, capable of reflecting changing water supply and demand conditions in the basin, will become an important tool for analysis of future water supply conditions.

KENTUCKY INTERAGENCY GROUND-WATER MONITORING NETWORK

Philip G. Conrad

The Kentucky Interagency Ground-Water Monitoring Network and its Technical Advisory Committee coordinates many of the nonregulatory ground-water monitoring efforts in the State. The network's goals include effective categorization of data, making the data available to the public via the Kentucky Ground-Water Data Repository, and characterizing the ground-water resources of Kentucky. Interagency meetings have been held to set strategies and review network effectiveness. The network addresses monitoring and characterization goals common to several agencies. An ad hoc technical advisory committee with representation from Federal and State agencies that deal with water resources issues is assisting KGS in developing the network. Data are collected by several agencies, including the Kentucky Natural Resources and Environmental Protection Cabinet's Division of Water and the Kentucky Geological Survey. The data can be integrated with geographic information systems used by several agencies and the private sector.

Data from the network and other sources are being used to summarize general ground-water quality in regions and river basins of Kentucky. Existing computerized data have proven to be inadequate to show changes in water quality and quantity over time, or differences within regions of

Kentucky. Increased coordination among agencies is helping to target future data collection to overcome shortcomings in existing data, and set strategies for ongoing monitoring. The advisory committee also helps prevent duplication of effort and facilitates transfer of information to the Ground-Water Data Repository. Categorizing ground-water sources according to aquifers, flow systems, and speed of travel is beginning, and will help characterize ground-water resources. The data can be used to evaluate the effectiveness of stewardship programs such as agricultural best management practices over time, which will result in a realistic representation of water quality in Kentucky and a delineation of seasonal and long-term changes in typical ground-water resources.

Funding for the monitoring network will be sought in the coming year.

SURFACE-WATER DATABASE

Daniel I. 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.

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

COMPUTER AND LABORATORY SERVICES SECTION

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

COMPUTER SERVICES

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

In addition to the PC's, KGS has a number of workstations for specific tasks. These include an Alpha 3000 model 500, used for GIS applications, and a VAXstation 4000vlc, used with X-ray diffraction instrumentation. Three Sun workstations are also used for specific research projects requiring software only available on those platforms.

Peripheral equipment includes large-format inkjet and pen plotters, digitizers, high- and medium-speed printers, and long-document scanners. Software includes database and report-writing facilities (ORACLE Rdb™, VAX Datatrieve™, and B2 Systems Smartstar®), word processors and desktop publishers (Microsoft Word for Windows™ and Adobe PageMaker®), geologic modeling packages (MINEX and SURFACE III®), computer-aided drafting and presentation graphics packages (AutoCAD®, Lotus Freelance™, Harvard Graphics®, CorelDRAW®, Macromedia FreeHand™), and geographic information systems (Arc/Info®, running on a Digital Alpha workstation; GRASS, operating on a Sun Sparc10; and ArcView®, running on both PC's and workstations).

OPERATING SYSTEM MAINTENANCE AND UPGRADE

The key to having a successful computer system with current technology is a versatile network backbone. With its building-wide computer network, KGS is able to interconnect various mini-, desktop, and personal computers. This versatility allows many types of operating systems to access data from a variety of sources. The

network in the building has also been routed to the University of Kentucky Network (UKnet), which, in turn, is linked to most of the national networks.

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

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

KGS RELATIONAL DATABASE

During the last 10 years, organizations such as the Kentucky Geological Survey have been using computers to store and manipulate large geologic and hydrologic data sets. This has become possible for two reasons. First, advances in hardware technology have meant that less expensive, desktop computers now have the power, speed, and storage capabilities of traditional, expensive main-frame computers. Second, relational database storage methodology has been developed. The relational model provides database managers with storage structures that are easier to build and maintain than previous hierarchical databases. Rather than storing data in large, highly structured files, the relational model stores related information in smaller structures called tables. These tables can be linked (related) to other tables in the database through common fields (keys). Examples of such tables in the KGS database are those for geographic location, coal-thickness, and well-construction information. These tables are smaller and more flexible than the previous database technology.

KGS currently maintains a state-of-the-art relational database for geologic and hydrologic information on a computer system with more than 50 gigabytes of storage capacity. This constitutes the most detailed and comprehensive collection of nonproprietary petroleum, coal, water, and limestone data for the Commonwealth that is publicly available. 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.

At the present time, the KGS relational database contains:

- Data from 73,782 unique locations in Kentucky (including all 120 counties in Kentucky and 750 of the 779 topographic quadrangle maps that cover Kentucky)
- 3,951 coal sample descriptions
- 33,749 coal thickness measurements
- 4,418 proximate coal analyses
- 2,888 ultimate coal analyses
- 31,971 water well construction records
- 317,610 water analysis results
- 2,000,000 surface water measurements

In the near future, data from more than 225,000 oil and gas wells will be added to the database, as well as more than 200,000 water analyses associated with locations already in the database.

The KGS relational database constitutes the most detailed and comprehensive collection of nonproprietary petroleum, coal, water, and limestone data for the Commonwealth that is publicly available.

LABORATORY SERVICES

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. The

laboratories make use of state-of-the-art automated equipment to provide researchers with the necessary data to complete their geologic and hydrogeologic reports.

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

The laboratory facilities include the following analytical equipment and capabilities:

For metals:

- inductively coupled argon plasma (ICAP)
- flame atomic absorption (FAA) and graphite furnace atomic absorption (GFAA)

For inorganics:

- ion chromatograph
- UV-visible spectrophotometer

For volatile organic compounds, pesticides, and other organic analytes:

- gas chromatographs with flame ionization, electron capture, photoionization, electrolytic conductivity, and nitrogen-phosphorus detectors
- immunoassay for selected pesticides
- total organic carbon

For mineralogy:

- X-ray diffraction spectrometry (XRD)
- X-ray fluorescence spectrometry (XRF)

For coal quality:

- proximate analysis
- ultimate analysis
- total sulfur
- calorimeter
- ash fusibility

During the past fiscal year, the fuels division of the laboratory analyzed more than 200 coal and mineral samples for coal quality and mineralogy. The laboratory participates in two round-robin testing programs for coal samples: the Interlab Network, operated by Standard Laboratories, Inc., and Service Program for the Evaluation of Codes and Standards, operated by the Canadian Centre for Mineral and Energy Technology.

During the year, more than 1,600 water samples were received in the water division of the laboratory for the analysis of metals, organic pesticides, and other water-quality parameters such as acidity, hardness, inorganic anions, and dissolved and suspended solids. The water division of the laboratory also participates in both the USGS Standard Reference Sample Program and the EPA Water Supply Laboratory Performance monitoring programs.

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

- Water samples were analyzed for the Kentucky Natural Resources and Environmental Protection Cabinet—Division of Water. The data from these samples will be 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 participated in the Second International Proficiency Testing Trial of Analytical Geochemistry Laboratories, organized by the International Working Group of the Association Nationale de la Recherche Technique, Paris.

The Survey has established an internship in environmental chemistry to give undergraduate students hands-on experience in a research laboratory and provide them with course credit for work experience under the direction of their academic advisor and the KGS laboratory manager.

- A cooperative effort with Alan Fryar of the UK Department of Geological Sciences studied adsorption and leaching interaction between basalt rocks and trace levels of the chemical trichloroethene in water.
- The Survey has established an internship in environmental chemistry to give undergraduate students hands-on experience in a research laboratory and provide them with course credit for work experience under the direction of their academic advisors and the KGS laboratory manager. The program is a partnership between KGS, the office of the Vice President for Research and Graduate Studies, and the Kentucky Water Resources Research Institute. It is administered by the UK Office for Experiential Education. The Survey is coordinating the internship with academic departments at the university. The first student chosen for the internship was Gilman Peterson, a chemistry major. The purpose of the internship was to investigate the chronic leaching of coal-refuse waste using ICP-AES as the analytical probe.

OFFICE OF GEOLOGIC INFORMATION

Providing geologic information to the public is one of the most important functions of the Kentucky Geological Survey. KGS personnel respond to more than 12,500 requests for geologic information per year, averaging approximately 50 requests per business day. Clearly, the Kentucky Geological Survey fulfills a vital role as a public-service organization. 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.

The KGS serves the Commonwealth as the official repository for ground-water data (the Kentucky Ground-Water Data Repository) and for oil and gas well records (the Kentucky Oil and Gas Data Repository). 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.

THE KENTUCKY GROUND-WATER DATA REPOSITORY

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

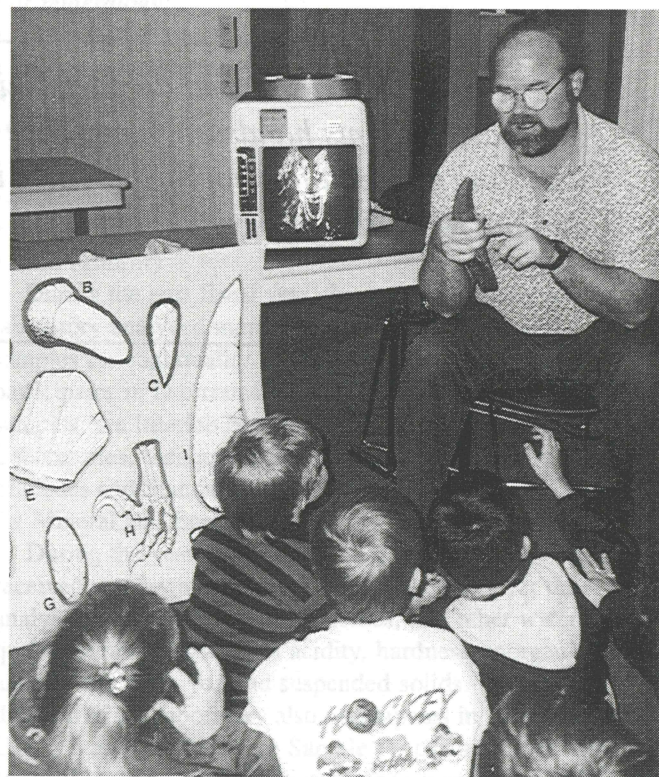
Data in the repository have been provided by more than 15 different agencies. The largest contributor of data on a regular basis is the Kentucky Natural Resources and Environmental Protection Cabinet-Division of Water, Ground Water Branch. The Ground Water Branch processes drillers' logs from the Certified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

Data may be provided to the public on various media, including hard-copy printouts, magnetic tapes of several different types, diskettes, and CD-ROM.

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

Data from the repository are being used to generate GIS maps using Arc/Info® software. Statewide, regional, and selected county maps have been completed that show depth to bedrock, depth to ground-water surface, well yield, and surface topography. Other important ground-water parameters such as pesticide contents and water-quality characteristics can also be mapped.

Repository personnel responded to 1,220 inquiries from the public during the fiscal year. Most of these inquiries were from environmental firms. The remaining inquiries



Office of Geologic Information personnel often visit elementary schools to educate children about geology. Photo by Tammi Johnson.

were from both the public and private sectors concerning ground-water occurrence, ground-water supply, and water 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. A variety of records, such as drillers' logs, wireline logs, well-location survey plats, plugging affidavits, and completion reports, are on file for approximately 180,000 wells. In addition, well-data files for western Kentucky are available at the Henderson field office.

A total of 802 new permits were issued in 1996. Kentucky Geological Survey staff review and enter into the computerized database as many of the older well records as time permits. During 1996, new records for 1,930 wells were updated, added, or processed in the database and information for 802 new wells was added for permits issued. The scanning program was accelerated, and as a result, information for 16,669 wells was added to the database. Since the actual scanning of well records began in November 1996, more than 10,000 documents have been scanned. As of April 1997, data for 150,568 wells are available through the database.

During fiscal year 1996-97, 1,231 visitors were assisted and 1,136 phone requests were processed at the Lexington and Henderson offices; these requests concerned oil and gas information. A total of 16,128 copies of well records were supplied. More than 19,700 feet of logs were copied for the public during the fiscal year.

Custom printouts based on user specifications can be made on request. Well-location base maps are available as overlays for the U.S. Geological Survey 1:24,000-scale, 7.5-minute topographic quadrangle maps. Data are also available in machine-readable form on diskettes. Eighty-seven well lists, 450 computer-generated overlays for topographic maps, 67 copies of KGS Map and Chart Series 9 ("Distribution of Oil and Gas Wells"), and 40 diskettes were made during the fiscal year.

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 landslides and related features are available for approximately 250 quadrangles in eastern and south-central Kentucky; copies of these maps are available at a nominal cost.

All KGS reports that are still in print and U.S. Geological Survey reports about Kentucky geology are available for purchase at the Publication Sales Office. KGS also maintains an extensive collection of open-file materials, including reports and maps, which can be reproduced for customers at a nominal charge.

During the past fiscal year, the Publication Sales Office responded to 4,387 requests for information. In addition, the office distributed 13,045 topographic maps, 3,275 geologic quadrangle maps, and 5,857 publications, for a total of 22,177 items (an average of 89 items per business day).

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The Publication Sales Office handles a large number of requests for maps. Kentucky and Rhode Island are the only states in the country that have complete 7.5-minute, 1:24,000-scale topographic and geologic map coverage. The Publication Sales Office has 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 kept in stock. Numerous other geologic, geophysical, structural, hydrologic, and mineral-resource maps are also available from the Publication Sales Office.

TOPOGRAPHIC MAPPING REVISION

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

Eight revised 7.5-minute quadrangle topographic maps were received from the U.S. Geological Survey during the 1996-97 fiscal year: Bowling Green South, Cairo, Calvert City, Grand Rivers, Hickory, Mayfield, Maysville East (Ky.-Ohio), and Rome (Ind.-Ky.).

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

EARTH SCIENCE INFORMATION CENTER

The Kentucky Geological Survey's Earth Science Information Center (KGS-ESIC) provides information regarding the availability of current and historic maps, aerial photography, satellite imagery, geodetic control, and digital cartographic data. The office also answers questions about the availability of all types of earth science information in Kentucky.

Resources available to the KGS-ESIC office for answering requests include a file of more than 5,700 microfiche indexes to aerial photography (available also on CD-ROM), satellite data (with an up-to-date, micro-image index), and historic maps (a microfilm file containing 37,400 historical topographic maps of the United States). The U.S. Geological Survey's electronic database of geographic names (GNIS) for Kentucky, which contains more than 30,000 place names used on Kentucky topographic maps, is accessible.

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

During the 1996-97 fiscal year, 679 requests for information were answered by the KGS-ESIC coordinator. Of these requests, approximately 25 percent were for map-related information, 20 percent were for geodetic control data, 10 percent were for aerial photography and radar or space imagery, 10 percent concerned digital map products, and 35 percent were for information about available publications.

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

TRIBUTE TO JEAN KELLEY

Eugenia (Jean) Kelley retired from the Office of Geologic Information on September 13, 1996, after 16 years of dedicated service to the University of Kentucky; 15 of those years were spent working for the Survey. She was an essential member of a team that developed the oil and gas well record library at the Kentucky Geological Survey and she helped bring its electronic data resources to the level of service today enjoyed by customers of KGS and visitors to the Survey. During her tenure at the Survey, she earned her GED and advanced from a clerical, data-entry position to a position in which she developed geotechnical skills. She helped formulate some of the first document-handling and archiving techniques for the document preservation project. She processed incoming oil and gas well permit applications and well completion reports. Her curiosity about how to accomplish a task led to the implementation or improvement of many of the programs currently in use. Her cheerful willingness to assist the public was appreciated by many.

OFFICE OF COMMUNICATIONS AND TECHNOLOGY TRANSFER

One of the major functions of the Kentucky Geological Survey is making the results of research projects and field investigations readily available for the public. In August 1996, the Publications Section was renamed the Office of Communications and Technology Transfer. As KGS staff are increasingly using new technologies such as GIS software, CD-ROM's, and on-demand printing, the methods used for communicating the research results of KGS projects are changing rapidly. Research reports are available in electronic format, in addition to traditional hard-copy technical reports and open-file reports. The unit was renamed to reflect the diverse range of products generated by the KGS. The new name also reflects an intention to integrate the services provided by the editing, drafting, and cartographic staff into a long-term communication strategy for the Survey. The manager is responsible for public communication and outreach, and providing assistance to the state geologist and both assistant state geologists in matters pertaining to communication and technology transfer.

The Office of Communications and Technology Transfer assists KGS staff by providing editing, cartographic, and drafting support for publication of manuscripts; products for on-demand printing; publication of maps and charts; preparation of slides, overhead transparencies, posters for professional meetings; and GIS and digital map products. During this fiscal year, we provided assistance to the Paducah Gaseous Diffusion Plant project in preparing a 1:100,000-scale base map and overlay information. This was a major effort that involved compilation of digital line graph files and other data in AutoCAD™ for development of a digital base map. We provided assistance and technical advice to the digital geologic mapping project and in drafting and laying out in AutoCAD™ the blueprints for the construction of the new Well Sample and Core Library.

Cartographic work began for the preparation of a statewide 1:100,000-scale base map. A 1:500,000-scale base map of Kentucky, based on the U.S. Geological Survey stable-base 1:500,000-scale map, was made available to KGS staff using GIS software. Drafting and cartographic support continued for a GIS project to create an environmental atlas for the Henderson Quadrangle in conjunction with staff from the Henderson field office. Cartographic work continued for preparation of a new 1:500,000-scale

map of industrial and metallic minerals and mineral industries in the State. 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.

Numerous slides, papers, reports, and abstracts were edited for outside publication and for presentation at various professional and other meetings. The following publications were issued by the Kentucky Geological Survey during the 1996-97 fiscal year.

INFORMATION CIRCULARS

IC 55. *The Middle and Upper Ordovician Bioclastic Carbonate ("Trenton") Play in the Appalachian Basin*, by Brandon C. Nuttall, 21 p.

The bioclastic carbonate play in the Appalachian Basin (referred to by drillers as the "Trenton") includes both gas and oil produced from Middle and Upper Ordovician stratigraphic and combination traps in linear reservoirs often mistaken for reefs. The Granville Consolidated Pool in Clinton County, Ky., is typical of fields in this play where production is associated with multiple stacked sequences of offshore bars. An estimated 50 to 100 million cubic feet (MMcf) of gas per year is known to be produced from this field, not accounting for production from an unknown number of domestic supply wells. Using Monte Carlo simulation, the undiscovered recoverable resource for this play was estimated to be 127 billion cubic feet (Bcf) of natural gas. While production from this play is currently reported from nine fields in south-central and eastern Kentucky and five fields in New York, potential reservoir rocks are present throughout most of the Appalachian Basin from New York to Tennessee. These reservoirs will probably not be an important primary target for future drilling except in southern and eastern Kentucky. As exploration and development continues for Lower Ordovician and Upper Cambrian reservoirs, these bioclastic carbonate bars will merit further evaluation.

IC 56. *Oil and Gas Drilling Activity Summary of Kentucky, 1994*, compiled by Brandon C. Nuttall, 116 p.

This report includes information on wells reported

during the calendar year 1994 (January 1 through December 31) as having been completed. Any stratigraphic tests that may have been permitted or drilled during the year are not included in this report unless the completion data were released to the Survey by the operator.

Additional information on each well is on file at the Office of Geologic Information. Well data are also available posted on overlays to topographic maps and in electronic form on diskette.

IC 57. The Middle Ordovician St. Peter Sandstone Gas Play in the Appalachian Basin, by Matthew Humphreys and Anna E. Watson, 19 p.

The Middle Ordovician St. Peter Sandstone gas play in eastern Kentucky includes several small fields associated with the Kentucky River and Irvine-Paint Creek Fault Zones. Although the prospective area for the play follows the Rome Trough into southwestern West Virginia and possibly even into southern Ohio, the only developed fields are in eastern Kentucky. Of these, the Furnace Field (Irving-Furnace Consolidated), Estill County, Ky., discovered in 1947, and the Trapp Field, Clark County, Ky., discovered in 1962, are the largest and have a cumulative production estimated to be 2.2 Bcf from 30 wells.

The most promising areas for future exploration in the St. Peter Sandstone should be where major faults coincide with thick sandstone deposition along the northern boundary of the Rome Trough.

MAP AND CHART SERIES

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

Ground-water flow paths and basin boundaries were interpreted from dye traces conducted by numerous researchers over the past 50 years, published data, and the compilers' personal knowledge. The resulting map will be useful for regional and initial investigations, and can be used to quickly identify the ground-water basins and springs to which a site may drain. It can be used to evaluate springs' potential as water supplies. In addition, the map is a geographic index to literature on ground water from karst terranes for the area.

MCS 11. Oil and Gas Map of the Middlesboro 30 x 60 Minute Quadrangle, by Anna E. Watson, Lance G. Morris, Brandon C. Nuttall, and Daniel I. Carey, 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. The map 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 eastern Kentucky.

MCS 12. A Deep-To-Shallow Transition in the Fort Payne Formation (Lower Mississippian), Kentucky Highway 61, Cumberland County, Kentucky, by David L. Meyer, Paul E. Potter, Jennifer L. Thies, William I. Ausich, and Stephen A. Leslie, 1 sheet.

The best exposed and most accessible section of the Upper Devonian Chattanooga Shale and Mississippian Fort Payne and Warsaw Formations in Kentucky shows the transition from deep-water, anoxic black shales and Waulsortian mud mounds to well-washed slope carbonates that pass upward into the large-scale, shallow-water carbonate crossbeds of the Warsaw Formation—all in only 2 miles of high roadcuts along Kentucky Highway 61, located 6 miles south of Burkesville in Cumberland County. Here in the beautiful Cumberland Saddle region the roadcut's thin carbonate turbidites and small channels can be studied to determine the primary dip and bedding of slope carbonates, classic Lower Mississippian fossils can be collected, and the details of the large marine Warsaw crossbeds can be considered. This is an outstanding section in which to study the diverse and fascinating problems of Lower Mississippian carbonates and their famous underlying anoxic black shales in a carefully documented structural cross section, which also provides an introduction to the paleoecology of these deposits.

MCS 13. Oil and Gas Map of the Tompkinsville 30 x 60 Minute Quadrangle, comp. 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. The map 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 eastern Kentucky.

REPORT OF INVESTIGATIONS

RI 10. Hydrogeology, Hydrogeochemistry, and Spoil Settlement at a Large Mine-Spoil Area in Eastern Kentucky: Star Fire Tract, by David R. Wunsch, James S. Dinger, Page B. Taylor, Daniel I. Carey, and C. Douglas R. Graham, 49 p.

An applied research program at the Star Fire surface mine in eastern Kentucky, owned and operated by Cyprus Amax Company, defined spoil characteristics to develop and monitor water resources, which will help identify a reliable water supply for future property

development. Water stored in the mine spoil may provide a usable ground-water supply, and the spoil could also be engineered to provide base flow to surface-water reservoirs.

OPEN-FILE REPORTS

OF-48-01. The Seventy Six Oil Pool: Clinton County, Kentucky, by E.B. Wood, 1948, 8 p.

OF-62-04. Waterflood Study: Ken-Brad Oil Company and Neil Oil Company Properties, Part of Big Sinking Pool, Powell County, Kentucky, by Y.M. Sahraie and M.F. Krieg, 19 p.

OF-63-03. Engineering Study of the Hobbs Area, Big Sinking Pool, Lee County, Kentucky, by M.F. Kreig, 1963, 8 p.

OF-74-04. Engineering Study of the Stray Weir Sand, the First Weir Sand, and the Second Weir Sand Reservoirs in the Northwest Portion of the Martha Field, Lawrence County, Kentucky, by R.O. Haas, 1974, 39 p.

OF-74-05. Engineering Study of the Stray Weir Sand, the First Weir Sand, and the Second Weir Sand Reservoirs in the Southeast Portion of the Martha Field, Lawrence County, Kentucky, by R.O. Haas, 1974, 28 p.

OF-93-04. Interim Report on the Occurrence of Pesticides, Nitrate, and Bacteria on Ground-Water Quality in a Karst Terrane—The Inner Blue Grass Region, Woodford County, Kentucky, by D.M. Keagy, J.S. Dinger, A.W. Fogle, and L.V.A. Sendlein, 1993, 31 p.

OF-93-05. Interim Report on the Occurrence of Pesticides and Nutrients in the Epikarst of the Inner Blue Grass Region, Bourbon County, Kentucky, by D.M. Keagy, J.S. Dinger, S.K. Hampson, and L.V.A. Sendlein, 1993, 22 p.

OF-93-06. Impact of Agricultural Practices at a Site in the Jackson Purchase Region, Hickman County, Kentucky: Interim Findings, by P.G. Conrad, J.S. Dinger, L.V.A. Sendlein, and J.B. Armstrong, 1993, 19 p.

OF-94-01. Impact of Agricultural Practices at Two Sites in Pleistocene Lacustrine Deposits, Daviess and Hopkins Counties, Kentucky: Interim Findings, by P.G. Conrad, J.S. Dinger, L.V.A. Sendlein, and Jeffrey Snell, 1994, 28 p.

OF-94-14. New Albany Shale Methane Adsorption Isotherms—Kentucky, Illinois, Indiana, by R.M. Cluff, 1994, 37 p.

OF-95-03. Hydrogeology and Ground-Water Monitoring of Coal-Ash Disposal Sites in a Karst Terrane, Burnside, South-Central Kentucky—Data Report, by S.A. Minns, L.V.A. Sendlein, J.S. Dinger, J.C. Currens, and A.M. Sahba, 1995, 42 p.

OF-97-01. Review of Illinois State Geological Survey study on Quaternary Faulting in Southern Illinois and Reconnaissance of Neotectonic Structures of Southern Illinois and Western Kentucky, by J.D. Kiefer, J.A. Drahovzal, J.C. Cobb, and D.A. Williams, 1997, 7 p.

OF-97-02. Geologic Features Relevant to Ground-Water Flow in the Vicinity of the Paducah Gaseous Diffusion Plant, by J.A. Drahovzal and R.T. Hendricks, 1997, 33 p., 5 pl.

MISCELLANEOUS

KGS Annual Report, 1995-1996

WELL SAMPLE AND CORE LIBRARY

One of a geologist's most important tasks is developing new fossil fuel and mineral resources. Exploration for and development of oil, natural gas, and minerals is a vital component of economic development in Kentucky. Although many new tools for subsurface exploration are available, the examination of actual rock and core samples continues to be a critical part of geologic analysis for oil and gas exploration and development.

The Kentucky Geological Survey is designated by State statute (KRS chapter 353) as the official repository for oil and gas well records in Kentucky. The Oil and Gas Conservation Act of 1960 requires that the samples of rock cuttings from selected oil and gas test wells drilled in Kentucky be saved and archived by KGS. In addition, the Survey makes every effort to locate and archive other valuable cores drilled throughout the State. The Kentucky Geological Survey's Well Sample and Core Library currently 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. At today's cost, the value of replacing these cores and samples is conservatively estimated at \$585 million.

Cores are generally donated by private companies or obtained from research projects, and rock samples are requested for selected wells drilled for oil and gas. Occasionally, a company will request that certain cores remain confidential. The cores may be kept confidential for 1 year. The ultimate goal is to obtain a representative set of well samples for each Carter coordinate section of the State (approximately 1 square mile) for samples and cores obtained from exploratory drilling in Kentucky. Storage is also provided for samples from specific research projects of the Kentucky Geological Survey. The Survey provides facilities for researchers, students, government employees, industry personnel, and the public to study the material.

A central repository benefits all researchers in perpetuity, and retains valuable samples that may otherwise be discarded after a project is completed. A successful

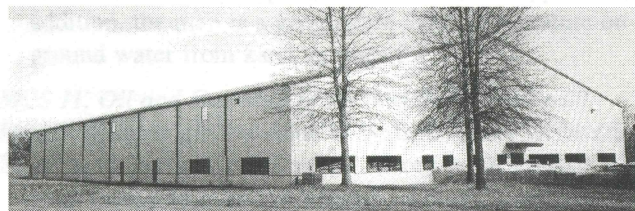
exploratory program that uses KGS cores or samples can contribute millions of dollars to the State's economy. A central repository has the advantage of storing materials from numerous sources in one location. At the Well Sample and Core Library, geologists can examine the cores and samples acquired by their own companies, in addition to those from other companies working in Kentucky.

Well samples are delivered by operators to nine collection stations located throughout the State, where they are collected by library personnel. The samples are identified, tagged, and placed into temporary storage. After footage intervals and total depths are verified, a list of all samples received is prepared. The list records the names of the companies donating samples. The samples are then retrieved, washed and dried, and placed into envelopes for archiving. A permanent call number is assigned and the sample set is shelved.

The Well Sample and Core Library began moving to a permanent facility in April 1997. The new facility was constructed on Research Park Drive off of Iron Works Pike on University of Kentucky property across from the Kentucky Horse Park. The building is located near the Center for Applied Energy Research and offices of the Kentucky Department of Mines and Minerals and the Division of Oil and Gas. The new facility is designed to allow expansion for future space requirements. The Survey also plans to establish a computer link between the Well Sample and Core Library and the Office of Geologic Information on the University of Kentucky campus.

The new building has a total of 48,000 sq ft of space. The main warehouse has 24,000 sq ft, the mezzanine level has 12,000 sq ft of general storage space, and 12,000 sq ft of space is available for public viewing of cores and samples, a sample processing laboratory, and administrative offices. The new warehouse provides easy accessibility and permanent storage for the entire collection of cores and cuttings.

There are several methods of locating samples and cores at the repository. Information Circular 3 (ser. 11), "Catalog of Well Samples, Cores, and Auger Samples on File at the Kentucky Geological Survey," lists all cores and samples on file at the library up to 1980. A database has been developed that will allow samples and cores received from 1980 to the present to be located by farm name, county, operator, Carter coordinate location, call number, permit number, and box number. All samples and cores, except for those currently being held confidential, are available for public inspection at the library from 8:00 a.m. to 4:30 p.m., Monday through Friday.



KGS's new Well Sample and Core Library, located on Research Park Drive. Photo by Patrick Gooding.

PUBLIC SERVICE

The collection, preservation, and dissemination of information about mineral and water resources and the geology of the Commonwealth is central to the mission of the Kentucky Geological Survey. The Survey has conducted research on the geology and mineral resources of Kentucky for more than 150 years, and has developed extensive public databases for oil and gas, coal, water, and industrial minerals that are used by thousands of citizens each year. One of the major goals of the Survey is to make the results of basic and applied research easily accessible to the public. This is accomplished through the publication of technical and nontechnical reports and maps, and providing information through open-file reports and public databases.

Public dissemination of data and research results is also accomplished by making information available on the KGS World Wide Web site at <<http://www.uky.edu/KGS/home.htm>>, numerous public speaking engagements to professional and civic groups, and participation in science education meetings and conferences. The KGS Web site includes descriptions of current research projects, information about the mineral and water resources of the Commonwealth, an overview of the geology of Kentucky, summaries of the fossils, rocks, and minerals found in Kentucky, and a new Kentucky Earth Science Education Network. On average, each day there were 236 "hits" on the KGS World Wide Web site during the 1996-97 fiscal year. (A "hit" refers to each time one of the pages of the Web site is viewed.) There were a total of 86,060 "hits"

during the fiscal year. In the last fiscal year, there were an average of 2,001 hits per month. During this fiscal year, the monthly average more than tripled, increasing to 7,171. This is a strong indication of the value to the public of the information now accessible on the KGS Web site.

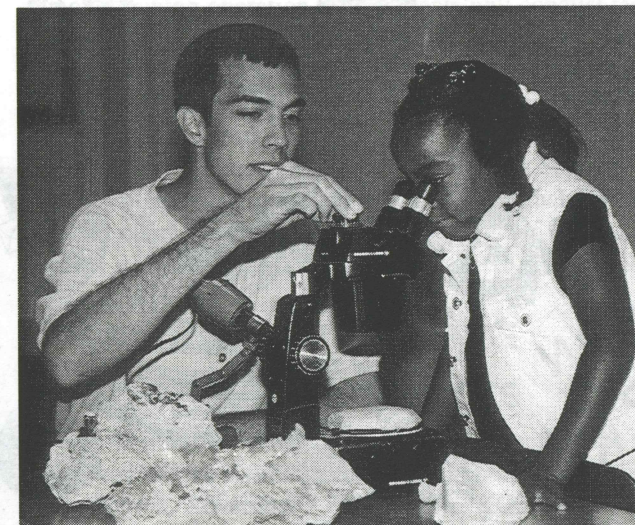
PUBLIC DATABASES

Management of data resources is the foundation of all research and public service work of the Survey. Information available in publicly accessible databases at the Survey is a critical component in the prudent development of oil, natural gas, coal, and minerals; protection of water quality; water supply studies; risk assessment of geologic hazards; environmental protection; and economic development. Efficient and effective organization, management, and dissemination of data are essential in assisting researchers, students, industry, consultants, planners, and policy-makers. The primary goal of KGS in data resources management is to continue to develop the Survey as a leading center for readily accessible, publicly available earth science data in Kentucky.

The Survey currently has 10 databases online, several of which are considered to be the most comprehensive of their type in the Nation. The major databases for coal, oil and gas, and water are discussed in the research sections and the section for the Office of Geologic Information elsewhere in this report.

GUIDING FUTURE DIRECTIONS FOR THE NATIONAL TOPOGRAPHIC MAPPING PROGRAM

Donald Haney, State Geologist and Director, is chairman of a committee of the Association of American State Geologists that is working with the National Mapping Division of the U.S. Geological Survey to determine future directions for the national topographic mapping program. He is also serving on the National Cooperative Geologic Mapping Advisory Committee. The 16-member committee was established under the National Geologic Mapping Act of 1992. Haney was an original author of the bill and assisted in its passage into legislation. This committee is overseeing implementation of Federal and State geologic mapping activities.



A future scientist learns how to use the microscope. Photo by Tammi Johnson.

GUIDING FUTURE COAL POLICY DIRECTIONS IN KENTUCKY

On November 12, 1996, James Cobb presented a paper titled "Coal and Kentucky's Future" at the Exploring the Frontier of the Future conference in Louisville, Ky., sponsored by the Kentucky Long-Term Policy Research Center. The conference was attended by approximately 300 participants from the public and private sector and academic community from across the State. This paper was published in December 1996 in the biennial report of the Kentucky Long-Term Policy Research Center. Gerald Weisenfluh and Carol Ruthven of the Kentucky Geological Survey and John Ferm of the Department of Geological Sciences at the University of Kentucky were coauthors of the paper.

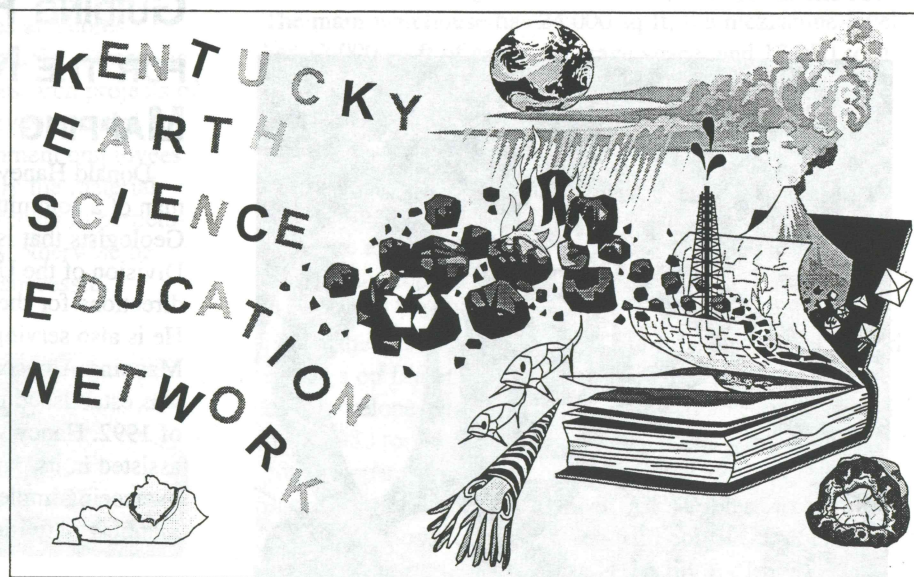
EARTH SCIENCE EDUCATION OUTREACH

The Kentucky Geological Survey has a wealth of material that can be used to assist earth science teachers and students. To respond to the increasing demand for earth science education material, the Education Committee and other KGS staff members established the Kentucky Earth Science Education Network in the fall of 1996 at <<http://www.uky.edu/KGS/education/education.html>>. At this site, teachers and students from kindergarten through grade 12 can discover interesting Kentucky earth science facts, links to more than 20 earth science topics (e.g., dinosaurs, fossils, volcanoes, meteorites, rocks and minerals, astronomy, earthquakes), classroom activities, sources of information, popular publications, and a calendar of events.

The goal of the network is to bring together the numerous individuals involved in providing earth science resources to teachers across the State. One of the steps in designing the network was determining what type of information teachers needed. Most teachers requested information that would help them address assessments set by the Kentucky Education Reform Act, which are based largely on national science standards. To address this need, "The Key to Earth Science Education Standards" contains links to World Wide Web sites arranged by science standards and earth science

topics. Key words can also be chosen alphabetically through "Earth Science Links." Sites used for each topic or standard were chosen by members of the Education Committee based on the accuracy of information, appropriateness for kindergarten through grade 12 (K-12) audiences, quality of images and graphics, and availability of free classroom activities and handouts. The network is designed to be dynamic and will be updated continually.

Other features of the network that provide information useful for students include "Geology of Kentucky," an illustrated introduction to the geology, geography, and earth history of the State; "Fossils of Kentucky," a well-illustrated guide to the fossils of the State organized by fossil type and age, which includes comments about finding fossils in Kentucky and explanations of geologic time; "Rocks and Minerals of Kentucky," a guide to rocks and minerals of the State that contains information about identifying rocks and minerals typically found in Kentucky; "Did You Know?," an illustrated guide to interesting facts (with fact sheets) about Kentucky geology; and "Classroom Activities," a collection of lesson plans, demonstrations, and activities for K-12 classrooms. "Sources of Information about Kentucky" lists individuals around the State who have experience in providing earth science information to K-12 teachers and are willing to participate in classroom visits, field trips, and science fairs. "Kentucky Earth Science Calendar" provides dates and locations of earth science meetings and trips around the Commonwealth. "Kentucky Kids Dig Earth Science" is a photo gallery of Kentucky schoolchildren participating in earth science activities to help promote student involvement in the earth sciences.



The logo for the Kentucky Earth Science Education Network at KGS's World Wide Web site. Art by Stephen Greb.

Stephen Greb, chairman of the Education Committee, gave three talks and computer demonstrations of the Kentucky Earth Science Education Network during the fiscal year. He presented a workshop at the Kentucky Science Teachers Association fall conference in Lexington, November 7-9, 1996; the 18th annual Kentucky Education Technology Conference in Louisville, March 7-8, 1997; and the second annual Kentucky Geosciences Symposium in Lexington, May 23, 1997. More presentations at professional meetings are planned.

GEOLOGICAL EDUCATION INITIATIVES IN KENTUCKY

Stephen Greb was appointed in the fall of 1996 as the representative for Kentucky on the Education Committee of the Southeastern Section of the Geological Society of America (GSA). He will report to the committee on geological education initiatives in Kentucky and serve as a conduit for information from the GSA to Kentucky. The GSA provides \$1,000 a year for education projects for kindergarten through grade 12 for the southeast region. Emphasis is placed on hands-on projects for students and workshops for teachers.

Douglas Graham of the Water Resources Section is collaborating with the University of Kentucky Forestry Department and an educational consultant from Cincinnati, Ohio, to develop a curriculum for middle school students (grades 6 through 8) to take various measurements to independently assess the impact of coal mining on water quality. Kits to test levels of acidity, sulfate, and iron in water are being used. The project is being conducted at the Star Fire tract, a large coal mine-spoil area in eastern Kentucky. The site is part of a mountaintop-removal mining operation. The students will conduct tests on water coming out of the mouth of an old underground mine and then downstream from the mine. They will also test at a natural seep from a coal seam and then downstream from the seam.

James Dinger, head of the Water Resources Section, made two presentations on Kentucky Educational Television for children in kindergarten through grade 12 to discuss issues related to floods, on March 23 and 24, 1997.

PARTICIPATION IN SCIENCE EDUCATION CONFERENCES

The Kentucky Geological Survey had a booth at the fall conference of the Kentucky Science Teachers Association in Lexington, November 7-9, 1996. The KGS booth was coordinated with three other booths organized by the Kentucky Coal Association, the Society for Mining, Metallurgy, and Exploration (SME), and the UK Depart-

ment of Mining Engineering. The four groups collaborated to provide thousands of individual samples of numerous rocks, minerals, and fossils found in Kentucky. The samples were distributed to teachers for use in their classrooms. Stephen Greb also presented a workshop for teachers, which provided sample sets of rocks and minerals from Kentucky, information on the earth history of Kentucky, current information on dinosaurs, and exercises for teachers to incorporate in their lesson plans.

The Kentucky Geological Survey had an exhibit at the 18th annual Kentucky Education Technology Conference in Louisville, March 7-8, 1997. Stephen Greb and Paul Howell of the UK Department of Geological Sciences presented a workshop that demonstrated to teachers how to use the resources of the Internet to teach earth science. The Kentucky Earth Science Education Network was established on the KGS World Wide Web site at <<http://www.uky.edu/KGS/education/education.html>> for this workshop. The "WebDogs" site on the UK Department of Geological Sciences Web site, at <<http://www.uky.edu/ArtsSciences/Geology/webdogs/welcome.html>>, was also used in the workshop.

TECHNICAL ADVICE FOR AN ENVIRONMENTAL EDUCATION PARK AT MCCONNELL SPRINGS, LEXINGTON, KENTUCKY

James Currens and John Kiefer worked with the Friends of McConnell Springs Committee to produce a video on McConnell Springs, the birthplace of Lexington. John Kiefer served on the Steering Committee for McConnell Springs, a civic organization coordinated through the Lexington-Fayette Urban County Government. The committee is developing an environmental education park at the springs. James Currens demonstrated ground-water dye-tracing techniques at the springs for part of the video. The film, produced and directed locally by Arthur Rouse and Brad Riddel, was shown in public schools in Lexington in September 1996. The McConnell Springs Park and Visitors Center officially opened in October 1996.

INFORMATION ON GEOLOGIC HAZARDS

John Kiefer was elected the 1996 chairman of the Central United States Earthquake Consortium. The consortium awards research grants to states to study ways to reduce risks to society from earthquakes. Kiefer is also chairman of a new council established to evaluate earthquake predictions in the Midwest. A few years ago,

Midwestern states were adversely affected by a highly publicized inaccurate prediction of a major earthquake in the New Madrid Seismic Zone. The council will respond to such predictions with scientific, rather than anecdotal, evidence. Kiefer is also participating with a group of officials selected by the U.S. Geological Survey to establish the research needs in the next decade for earthquake studies in the central United States.

Kiefer presented a paper entitled "Geotechnical Issues in an Urban Karst Environment" at the Geology and Public Policy Symposium of the Southeastern Section of the Geological Society of America annual meeting at Auburn University, Auburn, Ala., on March 27, 1997. He was asked to serve as chairman of the Geology and Public Policy Committee of the Southeastern Section of GSA and he is an ex officio member of the GSA National Committee on Geology and Public Policy.

Kiefer also gave a talk entitled "The Impact of Earthquakes on Underground Gas Storage Facilities" to the Midwest Gas Storage Association, Mutual Aid Group, in Louisville, Ky., on April 9, 1997.

INFORMATION ON GEOLOGY AND URBAN PLANNING

John Kiefer is a member of the Lexington-Fayette Urban County Government Greenspace Commission and has been working with urban county council members and the urban county government to develop an acceptable plan for expansion of the urban services area and the possible rezoning of more than 5,000 acres of land in Fayette County in central Kentucky.

FIELD TRIPS TO EXAMINE THE GEOLOGY OF THE KENTUCKY BLUE GRASS

The National Association of State Boards of Geologists met in Lexington, October 17-19, 1996. On October 19, John Kiefer and Jim Rebmann of the Lexington-Fayette Urban County Government, led a field trip on engineering geology to explain sinkholes and other problems associated with ground water and dissolution of limestone in karst terrane in the Lexington area.

Anna Watson, of the Geologic Mapping and Hydrocarbon Resources Section, and Richard Smath, the Earth Science Information Center coordinator, led a "Geology Walk" to interpret the geology of Raven Run Park for a group of young children on June 7, 1997, for a National Trails Day program. The "Geology Walk" was organized by the Parks and Recreation Department of the Lexington-Fayette Urban County Government.

On April 12, James Currens and John Kiefer led the UK Department of Geological Sciences Alumni Weekend field trip, "Springs of the Bluegrass." Stops included Sinking Creek, Garretts Spring, and McConnell Springs. The field trip, which focused on the hydrogeology of the area and the impacts of development, also served as a class trip for the department's hydrogeology course (GLY 585). The trip was videotaped by UKTV, edited, and broadcast via satellite to students enrolled in GLY 585 during the summer session.

HOSTING PROFESSIONAL MEETINGS

James Dinger, head of the Water Resources Section, was the coordinator for the 41st Annual Midwest Groundwater Conference, held in Lexington from September 29-October 1, 1996. The conference was hosted by the Kentucky Geological Survey and cosponsored by the Kentucky-U.S. Environmental Protection Agency EPSCoR program, the Kentucky Water Resources Research Institute, the Division of Water of the Kentucky Natural Resources and Environmental Protection Cabinet, and the Water Resources Division for Kentucky of the U.S. Geological Survey.

Water Resources Section members organized the technical sessions of the 1996 Kentucky Nonpoint-Source Pollution Conference held in Lexington, September 17-18, 1996, sponsored by the Nonpoint-Source Pollution Control Program, Kentucky Natural Resources and Environmental Protection Cabinet-Division of Water, and the Kentucky Water Resources Research Institute.

TEACHING SHORT COURSES AND WORKSHOPS

James Cobb and Gerald Weisenfluh initiated an in-mine geologic mapping program and have begun to work with several Kentucky coal companies as part of this program. On April 3, 1997, the Kentucky Geological Survey and the UK Department of Mining Engineering hosted a 2-hour presentation on the use of geologic mapping in underground coal mines. This presentation was part of an effort by the university to increase the involvement of geologists in the recognition and documentation of geologic conditions in Kentucky's mines. The benefit of this program to the coal industry is twofold. Results from the studies may be used to anticipate safety concerns in existing mines and to better plan for future development. The program will also provide training to prospective and current industry personnel. The KGS plans to expand this program in the future.

Brandon Nuttall of the Geologic Mapping and Hydrocarbon Resources Section presented a lecture on basic geology, focusing on petroleum geology, to a class of natural resources students at a summer camp at Robinson Forest sponsored by the UK Department of Agronomy, on May 23, 1997. Topics discussed included the importance of natural resources, environmental impact of oil and gas extraction, and existing Kentucky regulations. He also presented a talk on the history of the petroleum industry in Kentucky at the University of Cincinnati Department of Geology's Petroleum Seminar, on May 30, 1997.

PROMOTING CAREERS IN GEOLOGY

Anna Watson of the Geologic Mapping and Hydrocarbon Resources Section organized and staffed a display on careers in geology at a Career Day for the Wilderness Road Council Girl Scouts at Eastern Kentucky University in Richmond, Ky., on March 22, 1997. Approximately 1,500 people attended.

PALEONTOLOGY OF KENTUCKY FOSSILS

Kentucky, because of its extensive outcrops of sedimentary rocks, is one of the most famous sources in the United States for fossils. KGS receives numerous requests every

week from the public concerning fossils and fossil identification. Occasionally, a scientifically important fossil is discovered in Kentucky, which requires more thorough analysis. KGS must ensure that important fossils discovered in Kentucky receive proper scientific treatment. In some cases, KGS sends fossils to specialists elsewhere for analysis. After scientific study has been completed, the specimen will be returned to Kentucky, where it will be put on display. KGS staff members also discuss fossils in their visits to schools to discuss earth science topics, and groups of schoolchildren who visit the Survey are shown the collection of fossils on display in the Mining and Mineral Resources Building at the University of Kentucky, where the Survey is housed.

A new addition to the KGS Map and Chart Series, "A Deep-to-Shallow Transition in the Fort Payne Formation (Lower Mississippian), Kentucky Highway 61, Cumberland County, Kentucky," by D.L. Meyer, P.E. Potter, J.L. Thies, W.I. Ausich, and S.A. Leslie, 1997, may be of interest to individuals studying fossils in Kentucky. The subject is a section of the Upper Devonian Chattanooga Shale and Mississippian Fort Payne and Warsaw Formations along 2 miles of high roadcuts along Kentucky Highway 61, located 6 miles south of Burkesville in Cumberland County. The roadcut's thin carbonate turbidites and small channels can be studied, and classic Lower Mississippian fossils can be collected.



Girl scouts learn about careers in geology at the Wilderness Road Council's Career Day. Photo by Gaye Brisson.

DISTINGUISHED LECTURE SERIES

The Distinguished Lecture Series was initiated in 1988 to commemorate former State Geologists of Kentucky. The first lectures were held in conjunction with the Kentucky Geological Survey's sesquicentennial celebration and honored William W. Mather, Kentucky's first State Geologist. This year's lecture honored Willard R. Jillson, the eighth State Geologist. Marcus Milling, Executive Director of the American Geological Institute (AGI), was selected to deliver the Distinguished Lecture for 1997 on February 20, 1997. His lecture was titled "Changing Trends in the Geosciences."

Marcus Milling has over 20 years experience in the oil and gas industry, having worked for Exxon Production Research Co., ARCO's Geological Research Group in Plano, Tex., and the Bureau of Economic Geology at The University of Texas at Austin. In 1992 he took leave from the university to accept the position of Executive Director of AGI. The institute is an umbrella organization serving 29 geoscience societies with over 70,000 members.

Shortly after coming to AGI, Milling oversaw the creation of the institute's Government Affairs Program to provide the geoscience community with a focused voice in Washington, D.C., and keep geoscientists informed on public policy issues affecting them. The program came of

age following the 1994 mid-term elections, when the new congressional majority sought to abolish the U.S. Geological Survey, U.S. Bureau of Mines, and other scientific agencies. AGI coordinated efforts to convince legislators of the importance of the work done by these agencies and, by extension, the value of the geosciences.

DISTINGUISHED LECTURES

William W. Mather—1988

William L. Fisher
Harold J. Gluskoter
Philip Cohen
Allen F. Agnew
Charles J. Mankin

David Dale Owen—1989

Hermann W. Pfefferkorn

No lecture in 1990

Nathaniel S. Shaler—1991

Aureal T. Cross

John R. Procter—1992

Paul Edwin Potter

Wallace W. Hagan—1993

Philip E. LaMoreaux

Charles Joseph Norwood—1994

Robert D. Hatcher, Jr.

Joseph B. Hoeing—1995

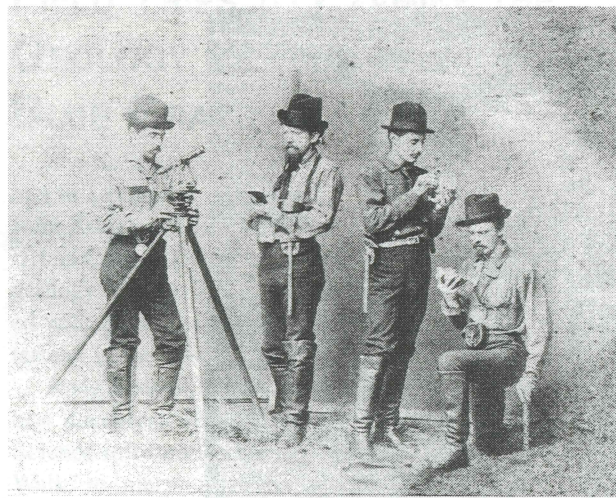
John M. Sharp, Jr.

John E. Barton—1996

Freeman Gilbert

Willard R. Jillson—1997

Marcus Milling



From left: W.B. Page, P.N. Moore, C.J. Norwood, and J.R. Procter, KGS employees, 1875, Lexington, Ky. Norwood and Procter went on to become State Geologists for Kentucky. Photo from KGS archives.

MEMORIAL WALLACE WOODROW HAGAN

The geological community mourns the loss of one of its longest and most active members. Wallace W. Hagan, Director of the Kentucky Geological Survey from 1958 to 1978, died July 18, 1997, in Lexington at the age of 84. He maintained an active role in geology in Kentucky until his death. His warm humor, cheerful disposition, and great knowledge of geology were trademarks that will be missed by all who knew him.

Born in Griggsville, Ill., he received his bachelor's, master's, and doctoral degrees in geology from the University of Illinois. Before coming to Kentucky, he was park geologist at Mesa Verde National Park in Colorado and worked for companies in Detroit, Indiana, and Illinois. Prior to his appointment as State Geologist of Kentucky, he was a well-known petroleum geologist from Owensboro, Ky., and he had been active in developing oil reserves in western Kentucky in the 1950's.

He is best known for his success in securing funding for and overseeing a \$21 million statewide geologic mapping project in cooperation with the U.S. Geological Survey. The 18-year 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 and made Kentucky the first major state to be completely mapped geologically at a scale of 1:24,000. The maps are used by engineers; developers; miners; ecologists; Federal, State, and local government agencies; and many other individuals and organizations. In recognition of this achievement, Dr. Hagan received the John Wesley Powell Award from the U.S. Department of the Interior and the U.S. Geological Survey in 1972.

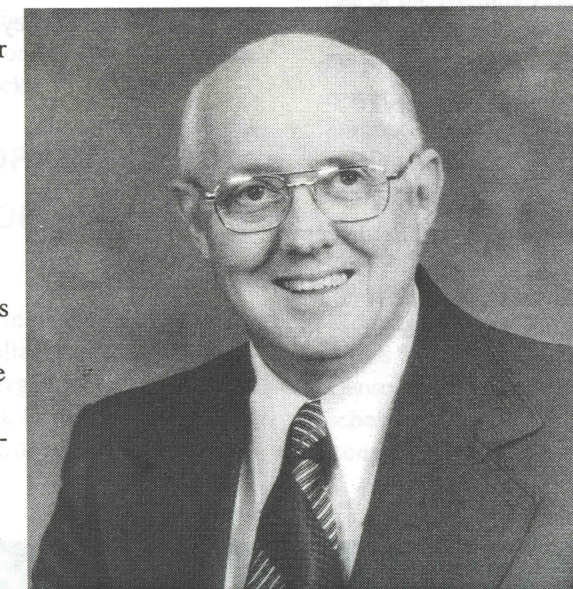
Dr. Hagan always emphasized to Survey staff members the importance of applying geology to the needs of the Commonwealth. He strived to get the maximum mileage out of the Survey's often-limited resources. In both good and difficult times, his humor always won out. His wealth of oil field stories was limitless.

Throughout his career, he received numerous awards. He was chosen Distinguished Scientist of the Year in 1977 by the Kentucky Academy of Science. He was granted the American Association of Petroleum Geologists Public Service Award in 1982. He received the Kentucky Geological Survey Distinguished State Geologist Award in 1993.

In the spring of 1997, he was granted the Kentucky Geological Survey Advisory Board Distinguished Service Award. He had been president of the Association of American State Geologists and served in various leadership roles for the American Institute of Professional Geologists, which awarded him its Lifetime Achievement Award.

Dr. Hagan was an Honorary Life Member of the Geological Society of Kentucky and an active member for more than 30 years. He was also instrumental in passing legislation in Kentucky in 1993 for the registration of professional geologists.

A scholarship for geology students at the University of Kentucky has been established in Dr. Hagan's name. Contributions may be made through the UK Department of Geological Sciences at 101 Slone Research Building, University of Kentucky, Lexington, KY 40506-0053, phone (606) 257-3758.



We gratefully acknowledge the assistance of Elizabeth Wade Hall, of the Lexington Herald-Leader, in preparing this memorial. Ms. Hall is Dr. Hagan's granddaughter.

37TH ANNUAL SEMINAR

Shortly after becoming the eleventh State Geologist, Donald Haney reinstituted the Survey's practice of holding annual seminars on its research. Over the years these seminars have kept colleagues at the university, State and Federal agencies, and industry, as well as the public, informed about KGS research findings and public service initiatives. The 37th annual seminar was held on May 22, 1997.

To highlight the importance of geographic information systems (GIS) technology at the Survey, a symposium featuring presentations on projects using GIS occupied the morning session:

- Cobb, J.C., "GIS at KGS"
- Weisenfluh, G.A., "Using GIS in Coal Resource Estimates"
- Carey, D.A., "Using GIS for Water Supply Studies of the Kentucky River"
- Anderson, W.H., "Using GIS for Digital Geologic Mapping"
- Harris, D.C., "Using GIS for Subsurface Analysis"
- Nuttall, B.C., "Using GIS for Oil and Gas Mapping"
- Wunsch, D.R., "Using GIS for a New Lineament Map for Kentucky"

The afternoon session highlighted research and public service activities at the Survey:

- Kiefer, J.D., "New Well Sample and Core Library"
- Kiefer, J.D., "Public Service and Outreach"
- Currens, J.C., "Karst Atlas for Kentucky"
- Conrad, P.G., "Ground-Water Monitoring Network"
- Wunsch, D.R., "Mine-Spoil Hydrogeology and Settlement"
- Eble, C.F., "The Western Kentucky No. 4 Coal"
- Greb, S.F., "Unusual Impediments to Mining the Amburgy"
- Drahovzal, J.A., "Geologic Mapping and Hydrocarbon Resources Research"



The audience listens attentively to a speaker during the Kentucky Geological Survey's 37th annual seminar. Photo by Collie Rulo.

INTERNATIONAL VISITORS

RESEARCH COLLABORATION WITH THE CZECH GEOLOGICAL SURVEY

Cortland Eble hosted a visit by two scientists from the Czech Republic, Eva Purkynova and Jana Drabkova, November 18-22, 1996. Their visit to the University of Kentucky was in relation to a research project funded by the National Science Foundation. This research team is comparing and contrasting the types of ancient vegetation that developed in the intermontane Carboniferous basins of the Czech Republic with age-equivalent floras that inhabited the coastal plain settings of the central and southern Appalachians. The visiting scholars were given a tour of the research and laboratory facilities of the Kentucky Geological Survey and taken on a 2-day field trip to visit coal outcrops in eastern Kentucky.

RESEARCH COLLABORATION WITH ENGINEERS FROM BORDEAUX, FRANCE

Gerald Weisenfluh and John Ferm of the UK Department of Geological Sciences are collaborating with engineers from the Laboratoire Énergétique et Phénomènes de Transfert (L.E.P.T.), École Nationale Supérieure D'Arts et Métiers in Bordeaux, France.

Yannick Anguy, an engineer with L.E.P.T., is using data from the Kentucky Coal Resources Information System to construct three-dimensional computer models to characterize the geometry of coal beds in Kentucky.

VISITOR FROM THE NANJING INSTITUTE OF GEOLOGY AND PALEONTOLOGY OF BEIJING, CHINA

As part of a 2-month visit to the United States, Gejun Lee of the Nanjing Institute of Geology and Paleontology in Beijing, China, visited the Kentucky Geological Survey for several days in December 1996. The Nanjing Institute is world renowned for research in paleontology. The purpose of Lee's visit to the United States was to meet leading scholars in the field of paleobotany. Many experts in China have retired in recent years, so there are only about five or six young scholars conducting research in paleobotany there today. Lee met with Donald Chesnut, Chief Paleontologist at the Kentucky Geological Survey, and other researchers at the Survey. He also visited with James Conkin of the Department of Geography and Geosciences at the University of Louisville, as well as scholars in Florida, Illinois, and the Smithsonian Institution in Washington, D.C.



Pictured with Cortland Eble (center) are Eva Purkynova (left) and Jana Drabkova (right). Photo by Collie Rulo.

AWARDS

AWARDS RECEIVED BY KGS STAFF MEMBERS

Fourteen awards were received by KGS staff members during the past year. These awards and other distinctions have been granted by national, regional, and State organizations, as well as universities in Kentucky and other states.

- John Kiefer was elected the 1996 chairman of the Central United States Earthquake Consortium. The consortium awards research grants to states for the reduction of risks to society from earthquakes. Kiefer is also chairman of a new council established to evaluate earthquake predictions in the Midwest. In addition, he has been asked by the U.S. Geological Survey to participate in a group of officials who will establish research needs in the next decade for earthquake studies in the central United States.
- James Cobb was chosen the 1996 recipient of the Donald C. Haney Outstanding Alumnus Award presented by the Department of Geology at Eastern Kentucky University. The award was created in recognition of Haney's 18 years of service as chairman of the department. Cobb received his M.S. degree from Eastern Kentucky University in 1974, and in recent years has served as an adjunct faculty member in the Department of Geological Sciences at the University of Kentucky.
- James Cobb delivered the John Webster Foster Geohydrology Lecture at Illinois State University on March 19, 1997. The title of his lecture was "The Kufra and Sarir Agricultural Projects in the Libyan Arab Republic." This was the inaugural lecture in honor of a former faculty member.
- The Kentucky Geological Survey received a gift of \$5,000 from the Smithsonian Institution in recognition of the research contributions of Cortland Eble. This is the first time since 1986 that the University of Kentucky has received money from the Smithsonian Institution. Eble specializes in the study of pollen and spores and is one of only four Paleozoic palynologists practicing in the public sector in the United States. He examines coal and rock samples to identify vegetation patterns that might establish whether changes in climate were an important factor controlling the deposition of sediments beneath the earth's surface 285 to 320 million years ago. This research has important implications for coal resource assessment.

- Cortland Eble was named a Distinguished Lecturer by the Coal Division of the Geological Society of America. He will be presenting lectures at universities and colleges across the United States on topics related to his areas of expertise, which are coal petrography, carboniferous palynology, and analysis of trace elements in coal and the potential environmental impacts of coal combustion.

Fourteen awards were received by KGS staff members during the past year. These awards and other distinctions have been granted by national, regional, and State organizations, as well as universities in Kentucky and other states.

- Stephen Greb was appointed this fall as the representative for Kentucky on the Education Committee of the Southeastern Section of the Geological Society of America (GSA). He will report to the committee on geological education initiatives in Kentucky and serve as a conduit for information from the GSA to Kentucky. The GSA provides \$1,000 a year for education projects for kindergarten through grade 12 for the southeast region.
- Stephen Greb received the best poster award in the Energy Minerals Division at the annual meeting of the Eastern Section of the American Association of Petroleum Geologists, held in Charleston, W.Va., October 14, 1996. The title of his poster was "Mining Conditions and Deposition in the Amburgy (Westphalian B) Coal, Breathitt Group, Central Appalachian Basin." It was the third time he received the award; he also won in 1988 and 1989.
- Stephen Greb, Cortland Eble, and James Hower of the Center for Applied Energy Research at the University of Kentucky received the best paper award in the Energy Minerals Division at the annual meeting of the Eastern Section of the American Association of Petroleum Geologists, held in Charleston, W.Va., October 14,

1996. The title of their paper was "Coal-Bench Architecture as a Means of Understanding Regional Changes in Coal Thickness and Quality."

- James Drahovzal received the A.I. Levorsen Award for the best paper presented at the annual meeting of the Eastern Section of the American Association of Petroleum Geologists, held in Charleston, W.Va., October 14, 1996. The title of his talk was "Cambrian and Precambrian Rifting in Central and Western Kentucky: Evidence from Reflection-Seismic Data."
- David Harris was elected vice president of the Eastern Section of the American Association of Petroleum Geologists.
- James Dinger was appointed by Governor Paul Patton to the Kentucky Agricultural Water Quality Authority. The authority is responsible for developing and implementing plans to protect water quality with regard to agricultural and silvicultural activities in the Commonwealth.

- James Currans was recognized for his research and public service contributions to the community and State as part of the University of Kentucky's Unsung Heroes program.
- Carol Ruthven was selected in a statewide competition for the class of 1997 of the Kentucky Women's Leadership Network. The program includes leadership training, discussion of major policy issues, and meetings with business, cultural, educational, and political leaders across the State.

KGS DISTINGUISHED SERVICE AWARD

John Tate, Property Supervisor of Cyprus Southern Realty Corporation, was given the 1997 KGS Distinguished Service Award in recognition of his consistent support of the coal-field hydrology research program in eastern Kentucky during the past decade.



State Geologist Donald Haney presents the KGS Distinguished Service Award to 1997 recipient John Tate, of Cyprus Southern Realty Corporation, a Cyprus Amax Company, at the Survey's annual seminar. Photo by Collie Rulo.

NEW STAFF MEMBERS

COAL AND MINERALS SECTION

William M. ("Drew") Andrews, Jr., was born in Frankfort, Ky. As an undergraduate at the University of Kentucky, he participated in coal research at the Center for Applied Energy Research. He received his bachelor's degree in geological sciences from the University of Kentucky in 1993, and spent 18 months at Duke University studying structural geology and tectonics. He completed his master's degree in geological sciences at the University of Kentucky in 1997. In the Coal and Minerals Section, he assists with coal availability projects and coal data management for western Kentucky.

Carlos M. Galcerán, Jr., was born in Havana, Cuba. In the Coal and Minerals Section, he is developing a GIS database of active and inactive coal preparation plants, loading facilities, and transportation networks to determine the proximity of refuse coal ponds to Tennessee Valley Authority fossil-fuel plants. Prior to joining the Survey, he was employed as an environmental geologist and geophysicist and worked for Gecoh Exploration in Lexington, Ky.; Environmental Site Assessments in Coral Gables, Fla.; Texasgulf in Midland, Tex.; and Mobil Exploration & Producing U.S., in Denver, Colo. He

worked as a research assistant from 1985-87 at the Kentucky Geological Survey when he was in the master's degree program in geological sciences at the University of Kentucky. He received his master's degree in 1988 and graduated with a bachelor's degree in mathematics and physics from the University of Miami in 1982.

Julia A. Hyatt is originally from Knoxville, Tenn. She received a bachelor's degree in geology with highest honors from the University of North Carolina (UNC) at Chapel Hill in May 1996. She completed a hydrogeology internship at Oak Ridge National Laboratory as part of the Science and Engineering Research Semester Program in 1995 and was a teaching assistant at UNC. In the Coal and Minerals Section, she is compiling a database for Kentucky coal production data. She will begin a Ph.D. program at the Massachusetts Institute of Technology in the fall of 1997, concentrating on structural geology and metamorphic petrology.

Jeffrey A. Esterle was born in Louisville, Ky., and received his bachelor's degree in geological sciences from the University of Kentucky in 1996. He was granted a National Association of Geologic Teachers internship and worked as a hydrologic technician for the Water Resources Division of the U.S. Geological Survey in San Antonio,

Tex., in 1996. In the Coal and Minerals Section, he assists in the national coal assessment study by preparing coal thickness data, doing coal bed correlation, and assembling data in a coal quality database and a core hole database.

GEOLOGIC MAPPING AND HYDROCARBON RESOURCES SECTION

Virginia Marie Sullivan was born in Winchester, Va. She is completing a master's degree in geological sciences at the University of Kentucky. She received a bachelor's

degree in geology from Juniata College in Huntingdon, Pa., in 1995. Virginia is working as a GIS technician in the Geologic Mapping and Hydrocarbon Resources Section of the Survey. Her responsibilities include autovectorization of 1:24,000-scale geologic quadrangle maps in Kentucky for digital compilation into 1:100,000-scale maps. Prior to joining the Survey, she worked as a teaching assistant in the Department of Geological Sciences at the University of Kentucky and as a scientific intern for the Pennsylvania Bureau of Forestry.

WATER RESOURCES SECTION

E. Glynn Beck was born in Wilmington, N.C. He received his bachelor's degree in geology at East Carolina University in 1994 and will complete his master's degree at that school in October 1997. Glynn is the principal investigator for a project studying pesticides and nitrates in Henderson, Ky. He also serves as an extension agent in western Kentucky for the Water Resources Section of the Survey.

R. Stephen Fisher is a hydrogeologist with the Water Resources Section. He received his Ph.D. in geology from The University of Texas at Austin. He has 14 years of professional experience in geochemical, environmental, and hydrologic research. His primary research interests are low-temperature aqueous geochemistry, environmental geochemistry, nonpoint-source pollution, and water-rock interactions.

PERSONNEL AND FINANCE SECTION

Anjanette Gifford of Mount Olivet, Ky., works as the receptionist and as a staff assistant at the Survey. She received an associate in arts degree from Maysville Community College in 1992 and a bachelor of arts degree in history at the University of Kentucky in 1996. Prior to joining the Survey, she worked as an instructor for the Robertson County Board of Education.



New KGS staff members. Seated: Julia Hyatt. Standing, first row, from left: Stephen Fisher, Marie Sullivan, Anjanette Gifford, Carlos Galcerán. Standing, back row, from left: Jeff Esterle, Glynn Beck. Not pictured: Drew Andrews. Photo by Collie Rulo.

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TALKS BY STAFF MEMBERS TO PROFESSIONAL AND CIVIC GROUPS

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COMMITTEES, BOARDS, AND ADVISORY ACTIVITIES

NATIONAL

- American Association of Petroleum Geologists
- American Geological Institute
- American Society for Testing and Materials
- American Society of Agricultural Engineers
- Association of American State Geologists
- Geological Society of America
- 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
- National Academy of Science/National Research Council
- National Water Quality Assessment Program Liaison Committee
- National Water Resources Policy Committee
- 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
- Central Appalachian Alliance
- Central United States Earthquake Consortium
- Cincinnati Arch Consortium

- Cyprus Amax Co. Wildlife Management Area Education Committee
- Geological Society of America, Southeastern Section
- Illinois Basin Consortium
- Midcontinent Lithospheric, Earthquake, and Resource Studies
- 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
- Governor's Geographic Information Advisory Council
- Ground-Water Technical Advisory Group of the Kentucky Department for Surface Mining Reclamation and Enforcement
- Hazard Mitigation Enterprise Zone Commission
- Kentucky Agricultural Water Quality Authority
- Kentucky Board of Registration for Professional Geologists
- Kentucky Cabinet for Economic Development
- Kentucky Certified Water-Well Drillers' Regulatory Program Advisory Board
- Kentucky Department for Environmental Protection, Water Well Certification Board
- Kentucky Division of Disaster and Emergency Services
- Kentucky Division of Water, Nonpoint-Source Management Committee
- Kentucky Engineering Earthquake Response Team
- Kentucky Geographic Information Systems Advisory Council

- Kentucky Ground-Water Management Data Committee
- Kentucky Ground-Water Monitoring Network Advisory Committee
- Kentucky Information Resource Management Commission, Special Committee on Imaging
- Kentucky Interagency Watershed Work Group
- Kentucky Long-Term Policy Research Center
- Kentucky Museum of Natural History
- Kentucky Natural Resources Conservation Service's Model Development Team
- Kentucky Oil and Gas Association
- Kentucky On-Site Sewage Disposal Advisory Committee of the Human Resources Cabinet
- Kentucky Outlook 2000: Technical Advisory Committee
- Kentucky Paleontological Society
- Kentucky River Authority
- Kentucky Society of Professional Geologists
- Kentucky Stratigraphic Nomenclature Committee
- Kentucky Water Availability Advisory Council
- Kentucky Water Interagency Coordination Committee
- Kentucky Water Resources Research Institute, Federal Facilities Oversight Unit
- Kentucky Water-Well Drillers' Certification Board
- Kentucky Women's Leadership Network
- Legislative Research Commission
- Mammoth Cave Karst Area Water-Quality Oversight Committee
- Natural Resources Conservation Service, Kentucky Landslide Mitigation Committee
- Naturally Occurring Radioactive Materials Task Force
- S.A.V.E. Coalition of Kentucky (Earthquake Disaster Response Team)

LOCAL

- City of Georgetown
- City of Louisville, Brownsfield Advisory Board
- Fayette County Environmental Commission
- Lexington Living Arts and Science Center, Science Advisory Board
- Lexington-Fayette Urban County Council Storm Water Management Committee, Advisory Board
- 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 Task Force
- Lexington-Fayette Urban County Greenspace Commission
- National Speleological Society, Blue Grass Grotto

UNIVERSITY OF KENTUCKY

- Center for Applied Energy Research Advisory Board
- College of Agriculture, Nonpoint-Source Assessment Advisory Committee
- Department of Geological Sciences
- Environmental Systems Program
- Kentucky Project of the Central Appalachian Alliance
- Kentucky Senate Bill (SB-271) Program
- Research Advisory Committee
- Research and Graduate Studies Planning Committee
- Research and Graduate Studies Unit Safety Committee
- Research and Graduate Studies Web Steering Committee
- Staff Study Task Force

RESEARCH FUNDING SOURCES

Funding for active research projects at the Kentucky Geological Survey is received from a wide array of private and public sources. The following is a list of external agencies funding research investigations at the Survey:

Addington Resources, Inc.
 Cyprus Southern Realty Corporation
 Electric Power Research Institute
 Kentucky Cabinet for Health Services
 Kentucky Department of Surface Mining Reclamation and Enforcement
 Kentucky Division of Communications
 Kentucky Division of Disaster and Emergency Services
 Kentucky Division of Military Affairs
 Kentucky Division of Waste Management
 Kentucky Division of Water
 Kentucky Natural Resources and Environmental Protection Cabinet
 Kentucky Senate Bill SB-271
 Kentucky Utilities
 Kentucky Water Resources Research Institute
 Illinois Basin Consortium
 National Science Foundation
 Petroleum Technology Transfer Council
 Tennessee Valley Authority
 U.S. Department of Agriculture
 U.S. Department of Energy
 U.S. Environmental Protection Agency
 U.S. Geological Survey
 U.S. Office of Surface Mining, Technical Guidance Committee for the Pittsburgh Office
 UK College of Agriculture
 UK Office of the Vice President for Research and Graduate Studies
 UK E.O. Robinson Trust

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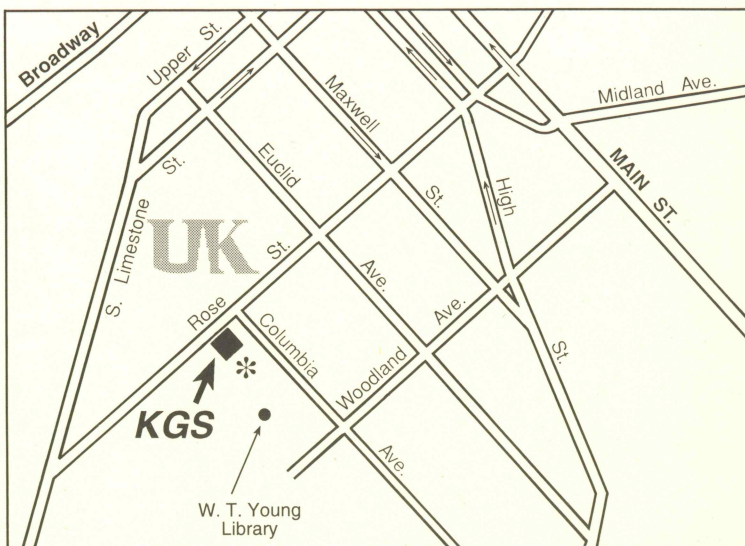
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Location of Kentucky Geological Survey offices in the Mining and Mineral Resources Building on the University of Kentucky campus. Asterisk (*) denotes visitor parking area.

