

Kentucky Geological Survey

ANNUAL REPORT

FOR FISCAL YEAR

1992-1993

KGS



KENTUCKY GEOLOGICAL SURVEY

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

1992-1993 ANNUAL REPORT

**KENTUCKY GEOLOGICAL SURVEY
UNIVERSITY OF KENTUCKY
LEXINGTON, KENTUCKY**

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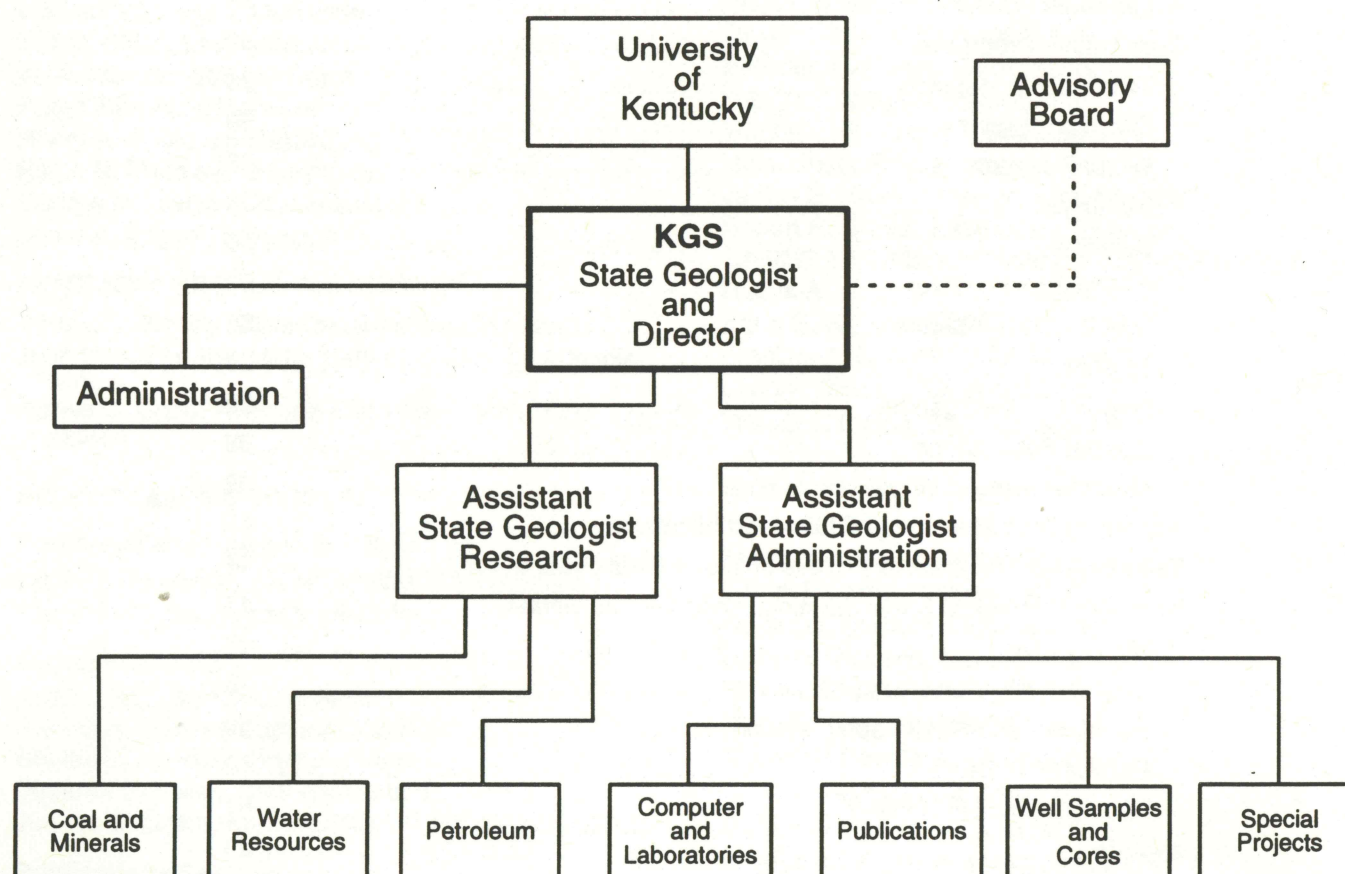
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ORGANIZATION OF THE KENTUCKY GEOLOGICAL SURVEY



FOREWORD

The Kentucky Geological Survey has conducted research on the mineral and water resources of Kentucky for the past 155 years. These efforts have resulted in topographic and geologic map coverage for Kentucky that has not been matched by any other state in the United States, and public data bases on energy, mineral, and water resources that are used by thousands of citizens, private industry, and government agencies each year. Virtually every sector of modern society requires information about the earth: its resources, hazards, and environments. Society's needs for geologic and resource information change and therefore the job of characterizing Kentucky's geology and resources also changes. The Kentucky Geological Survey has continued to build its public data bases and perform basic research to satisfy the changing needs of the Commonwealth.

KGS provides technical advice to a large number of State and Federal agencies. In addition, the Survey places great emphasis on public-service activities. Members of the Survey staff are actively involved in special committees and public-service groups dealing with coal, water, oil and gas, industrial minerals, and geologic hazards. In particular, Dr. Donald C. Haney, State Geologist and Director of the Kentucky Geological Survey, is currently serving as president of the American Geological Institute, a federation of the 20 major geological and related professional associations that serve the earth sciences. He was inaugurated as president October 26, 1992, at the annual meeting of the Geological Society of America in Cincinnati, Ohio. During his tenure as president, Dr. Haney plans to emphasize national geologic mapping, earth-science education in public schools, and AGI's advocacy role for the earth-science community. In addition, Dr. Haney has been appointed to the Board on Earth Sciences and Resources of the National Research Council, which is the principal operating agency of the National Academy of Sciences. The Board on Earth Sciences and Resources coordinates the National Research Council's advice to the Federal government on earth-science issues, ranging from basic research, through application, to assistance in policy formulation. The Board is responsible for conducting studies and preparing reports on fundamental issues in the earth sciences and on the directions that disciplines of the earth sciences should be taking, as well as issues relating to the energy and mineral resources of the Nation. Dr. Haney will serve as a member of the board until the end of 1995.

The objective of this annual report is to provide a brief summary of the activities of the Kentucky Geological Survey during the past fiscal year (July 1, 1992–June 30, 1993).

RESEARCH ACTIVITIES

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

Coal

Historically, coal has been Kentucky's most economically important mineral resource. Because of its large bituminous resource from both the Western and Eastern Kentucky Coal Fields, Kentucky continues to be one of the most important coal producers in the United States. Although some of Kentucky's coal is used for steel making, chemical stock, and household heating, most of it is used by coal-burning electrical utilities in the eastern United States.

However, many aspects of coal production and coal utilization are changing across the Nation. Near-surface coal resources in Kentucky and adjacent states are being depleted at the same time that some western states are increasing their production of coal. Wyoming and other western states have an abundant supply of easily mined surface and near-surface coal, and they are shipping more coal east, where it competes directly with Kentucky coal.

In addition, the Clean Air Act Amendment of 1990 has a significant effect on the utilization of some of Kentucky's higher sulfur coals. Blending high- and low-sulfur coals and using scrubbers to reduce SO₂ emissions will be required if most of Kentucky's coal reserves are to be used in the future.

Both blending and scrubbing rely upon information on coal quality and trace-element content of coal. The identification of Kentucky's future mineable resources and characterization of these resources in terms of coal quality is a vital role performed by the Kentucky Geological Survey.

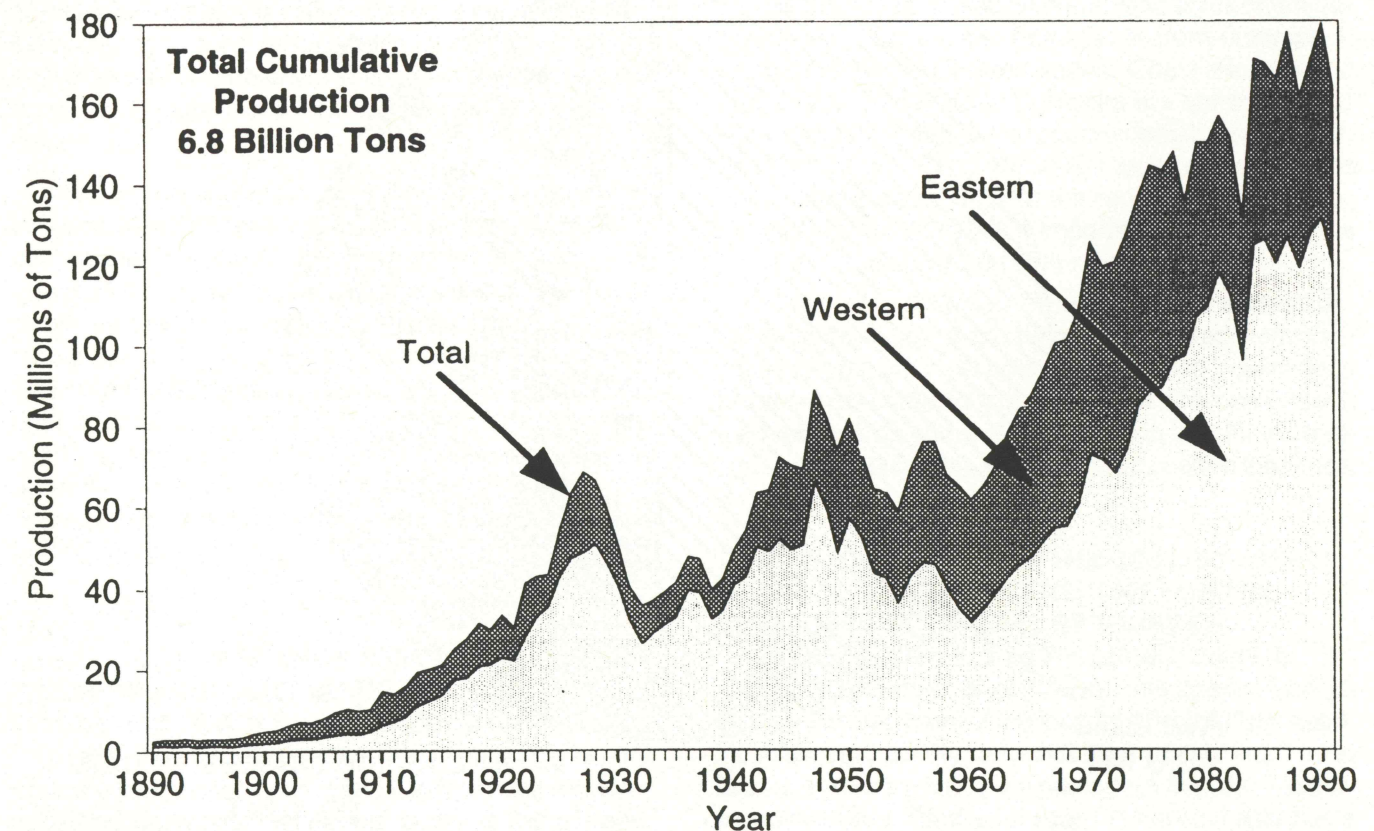
One of the major research issues confronting coal utilization today is the trace-element content of coal. Coal contains a large variety of constituents, such as carbon and sulfur, which are well known, but also a class of substances called trace elements, which occur in very small amounts. The Clean Air Act Amendments of 1990 require the emissions of trace elements from coal burning at power plants to be regulated in the future. The trace elements named in the law are antimony, arsenic, beryllium, cadmium, chromium, cobalt, lead, manganese, mercury, nickel, and selenium. These trace elements occur in coal in amounts measured in parts per million. The abundance and distribution of these elements in coal is not well known, and therefore predicting their occurrence is not currently possible with any reasonable degree of accuracy. More research in this area is needed, and the Kentucky Geological Survey along with the West Virginia Geologic and Economic Survey and the U.S. Geological Survey is developing research programs to address this issue. These programs require sampling important coal beds, analyzing samples for trace elements, and making the data available for public use. A proposal for a national coal-quality assessment for trace elements has been developed. Funding is being sought through Federal agencies.

In order to meet the demands for coal-related information, the Coal Section is conducting research designed to answer several questions: how much coal remains

in Kentucky; how much of this coal is available for mining; and which coals meet the strict sulfur and trace-element specifications of the Clean Air Act? The Kentucky Geological Survey has undertaken projects to (1) quantify and characterize the surface and near-surface coal resources in Kentucky that are available for mining, (2) identify deep-coal resources that are largely unexplored, but important to future production, (3) build a data base on coal quality and trace-element content needed by coal-burning utilities, and (4) provide solutions to geology-related coal-mining problems to better utilize available coal resources. These projects are described in more detail in the following pages.

Coal-related information obtained by the Kentucky Geological Survey is made available through the Kentucky Coal Resources Information System (KCRIS), which is one of the largest coal data bases in the United States. KCRIS contains descriptions of coal beds, coal-thickness measurements, coal-quality analyses, and bore-hole descriptions. Most of this information is in electronic form and is updated on a continual basis. Information is also made available to the public through publications.

Total Coal Production in Kentucky 1890 to 1991



Coal-Resource Assessment

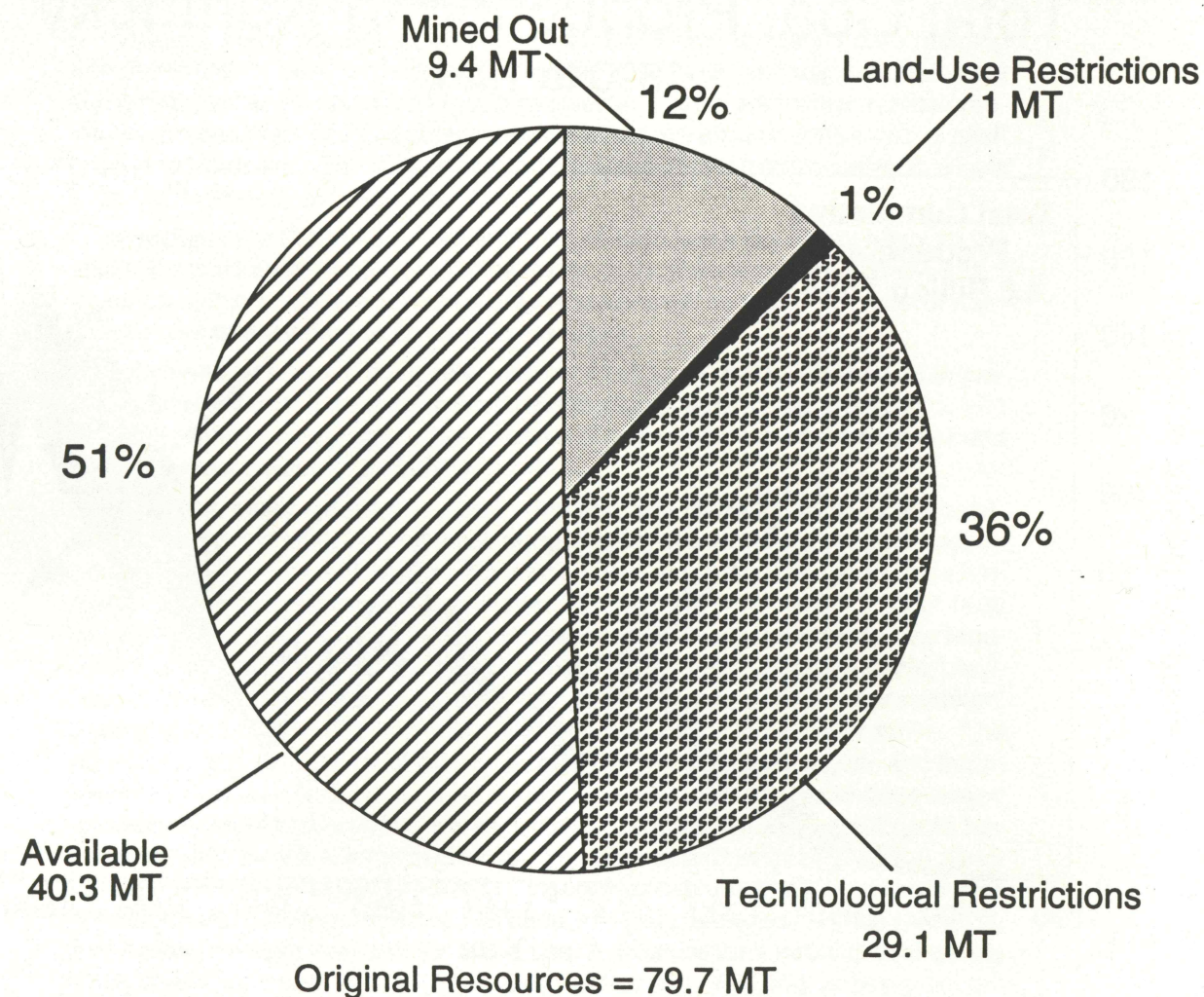
AVAILABLE COAL RESOURCES IN EASTERN AND WESTERN KENTUCKY

WEISENFLUH, Gerald A., ANDREWS, Robert E., HIETT, John K., and GREB, Stephen F.

In 1983, detailed coal-resource estimates were completed for the Eastern and Western Kentucky Coal Fields. The results of this work indicated that for beds greater than 14 inches in thickness 57 billion short tons and 38 billion short tons remained in eastern and western Kentucky, respectively. While these estimates of the total resources suggest future mining is possible for hundreds of years, this potential may be greatly reduced if land-use and technological restrictions to mining are considered. Coal Availability for Economic Development is an ongoing Nationwide research program in-

tended to quantify the kinds and magnitudes of such restrictions to mining in order to plan the development of energy resources.

The use of computers employing geographic-information-system (GIS) technology now makes it practical to modify the estimates of original resources, taking into account such diverse factors as mined-out areas, mine buffers, oil and gas wells, protected lands, cemeteries, roads, streams, and population centers. These revisions are being prepared for selected 7.5-minute quadrangles (58 square miles), and the results extrapolated to the remainder of the region. Assessments for eight quadrangles in eastern Kentucky have been completed. The ninth and final eastern Kentucky quadrangle in this program will be completed this year and work will commence on quadrangles in the Western Kentucky Coal Field.



Summary of results for the Coal Availability Study for the Booneville Quadrangle. MT = millions of tons.

The results of the eight studies show that slightly more than half of the original resources is available for mining. The most important factor reducing availability is coal too thin to be mined by underground methods, a technological restriction. Coal mined out or lost in mining accounts for only 6 percent of the original resources. Land-use restrictions account for another 6 percent; this factor was heavily affected by large amounts of public lands such as forests and parks in one quadrangle. Therefore, past production and mining restrictions indicate that, in general, 46 percent of the original resources are not available for mining. While this amount still suggests a large available resource, studies by the U.S. Bureau of Mines, which take additional factors into account, such as mining costs, types of mining, production rates, transportation, and other economic and engineering factors, show that only a small fraction of this available resource (about 8 to 20 percent) is economically recoverable under foreseeable market conditions.

While the eight quadrangles vary substantially in the magnitude of various restrictions, these results highlight a chief concern for eastern Kentucky coal: thin coal. Because thin coal is a restriction only for underground mining, a follow-up study is being initiated to assess the mining potential for all quadrangles in the region. The findings of this mining-potential study will enhance our ability to extrapolate the availability results into the coal field.

The coal availability program gives a much more realistic picture of Kentucky's coal-mining future, except that coal quality is not sufficiently taken into account. The quality of the remaining coal is not precisely known, but rough estimates suggest that less than 50 percent meets the guidelines for sulfur content specified by the 1990 Clean Air Amendments. Other chemical constituents, such as certain trace metals, are more poorly understood and could reduce availability further. A program designed to compile and analyze information on coal-quality characteristics is described in one of the following sections.

DEEP COAL AND ENERGY RESOURCES OF THE WESTERN KENTUCKY COAL FIELD

WILLIAMS, David A., and GREB, Stephen F.

The Western Kentucky Coal Field has a long history of coal mining. For most of that history, mining has concentrated on readily accessible coals at the surface. However, surface reserves are being depleted, and each year the focus on deeper, subsurface coal mining increases. To better understand subsurface coal reserves, coal-bearing strata at the surface must be corre-

lated into the subsurface by using data from coal and petroleum test cores and downhole geophysical logs.

In order to correlate coal beds in the subsurface, key beds are identified that have distinctive geophysical log signatures. Many intervals of coal-bearing strata are easy to identify in this manner. The Springfield (W. Ky. No. 9) coal can be traced in the subsurface throughout the Illinois Basin in western Kentucky, southern Illinois, and southern Indiana. However, other coals such as the Mannington (W. Ky. No. 4) are more difficult to correlate and require new research to understand their distribution in the subsurface.

In the past year more than 200 key beds or tops were identified on subsurface records and more than 15,000 feet of core from the Western Kentucky Coal Field was described. Also, an index of gamma ray/density geophysical logs is being constructed that identifies key stratigraphic intervals in the subsurface. Recent efforts have been directed toward solving correlation problems between the Davis (W. Ky. No. 6) and Dekoven (W. Ky. No. 7) coal beds. These coal beds split and pinch out locally. In many areas it is difficult to identify these coals in the subsurface. Meetings with geologists from Indiana and Illinois have focused on correlating coals of the Caseyville and Tradewater Formations from outcrops to the subsurface in all three states. Coals mined in the Tradewater Formation in Kentucky are not continuous with Tradewater-equivalent coals in Indiana and Illinois. The Tradewater Formation in Kentucky contains some of the lowest sulfur coals in the region; understanding the coals in this formation is important for assessing the potential for deep mining in the future.

To determine the extent of coals across the basin, detailed cross sections are being constructed from geophysical logs, coal test holes, and outcrop descriptions to trace beds in the subsurface. Cross sections through Kentucky will be connected to those in Illinois and Indiana to characterize the extent of deep coals in the Illinois Basin.

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

GREB, Stephen F., and WILLIAMS, David A.

The development of coal resources depends on an accurate assessment of the local and regional mineability, thickness, quality, and extent of coal beds. These factors are controlled by the geology of the coal and surrounding strata. Each coal seam in the coal field has a range of characteristics that were controlled by the manner in which the coal and surrounding strata were originally deposited and altered during burial. Understanding the manner in which the coal and surrounding strata

were deposited enables predictions to be made of areas with favorable mineability, coal thickness, and coal quality.

Measurements of coals and coal-bearing strata are needed to make accurate geologic interpretations. This year the Kentucky Geological Survey collected 54 coal samples, made detailed descriptions of 38 coal-bearing cores, and collected more than 166 coal-thickness measurements in the Western Kentucky Coal Field. In addition, numerous outcrops of coal-bearing strata were measured and sampled for geologic data.

A major focus of this project in the last year was a cooperative agreement with the state surveys of Illinois and Indiana to study the coal-bearing rocks of the Tradewater and Caseyville Formations in all three states. These two formations occur beneath the principal coal-producing Carbondale Formation. They contain some coal beds, such as the Amos and Foster coals, that are low in sulfur content. Understanding the occurrence and distribution of low-sulfur coals in a region typified by high-sulfur coals is important to the future development of the region. As part of the Tradewater Working Group, the Kentucky Geological Survey has analyzed nearly 100 coal samples, and has begun to study several coal-bearing exposures to determine how the coals and interburden were deposited.

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

CHESNUT, Donald R., Jr., and GREB, Stephen F.

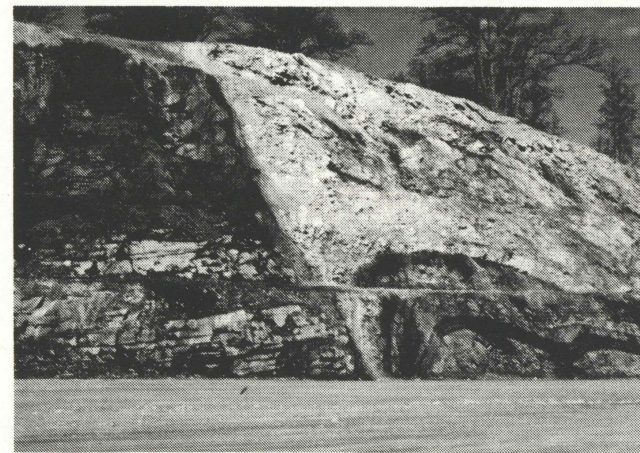
In 1983, the Kentucky Geological Survey completed a 7-year study that determined the Eastern Kentucky Coal Field contained 64 billion tons of original coal resources greater than 14 inches thick. However, according to the coal-availability program described in a previous section, much of the original resource has been mined out, is too thin to mine underground, or is not mineable because of environmental, land-use, or technological restrictions. A new project with the U.S. Department of Energy will improve the estimates of coal reserves in the Demonstrated Reserve Base (DRB) by utilizing recent findings from the coal-availability program. When completed, this project will categorize resources by mining type (surface or underground) and quality (SO_2/Btu). This project will report the demonstrated reserve base by county, major coal bed, mining method, and categories of Btu and sulfur content. In addition, the project will assess the accessible and recoverable reserves for the coal field using the same categories used in the DRB.

Geologic analysis is also used to investigate why coals are absent in some areas of the coal field. For instance, large sandstone deposits occur at the expense of coal along the western edge of the coal field. A study of these sandstones will help predict where mineable coals occur in the subsurface. During the last fiscal year a member of the Coal Section completed his KGS-supported dissertation, "Sedimentology of a Pennsylvanian Sandstone (Lower Breathitt Formation) from Bedding-Plane Exposures, Laurel River Dam Spillway, Whitley County, Kentucky." This project involved detailed mapping of a Pennsylvanian sandstone exposed along the margin of the Eastern Kentucky Coal Field. Results showed that rather than being deposited in a single environment of deposition, the sandstone was first deposited in a marine- to brackish-water bay or estuary under tidal-current and wave action, then reworked along a shoreline, and then deposited in rivers that emptied into the estuary. Each of these environments of deposition produced distinctive types of bedding, grain size, and sorting that can be used to identify areas of better stone quality for local sand production, and to delineate complex trends in sandstone geometry.

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

CHESNUT, Donald R., Jr.

The frontier for future coal production in the Eastern Kentucky Coal Field is the relatively unknown deep-coal resources that occur well below valley bottoms. Little is known about deep-coal resources because very few coal-test boreholes have penetrated to the base of the coal-bearing rocks; most drilling programs are designed to explore coals that are accessible from outcrop above the level of the valley bottoms. New information is being



Fault displaces sandstones and shales of the Breathitt Formation at a roadcut along Kentucky Highway 25E at Artemas, Kentucky.

collected from the few deep coal tests that have been drilled, as well as the more abundant oil and gas test holes that penetrate coal-bearing rocks. This information is being entered into an electronic data base, where it will be available for geologic analysis. An analysis of the subsurface geology of coal-bearing formations has been completed and will be published as "Stratigraphic Analysis of the Coal-Bearing Rocks of the Eastern Kentucky Coal Field." A manuscript describing the general occurrence of deep subsurface coal-bearing rocks in eastern Kentucky has been submitted for review. Coal-thickness and coal-quality data developed in this project will also be added to the appropriate KGS data bases.

Coal-Mining Geology

MINEABILITY OF KENTUCKY COALS

GREB, Stephen F., and HIETT, John K.

The mineability of individual coal seams in eastern Kentucky is a factor of coal thickness, extent, quality, roof conditions, and accessibility. Coal beds that are extensively mined tend to be uniform in thickness, have good quality characteristics, and good roof conditions. However, even seams that are extensively mined may have local changes in thickness, quality, or roof conditions that can make the coal uneconomical to produce at current market conditions. To better understand the geologic reasons for changes in coal-bed thickness, quality, and roof conditions, the Fire Clay (Hazard No. 4) coal was chosen for this pilot study. The coal is being mapped in a 15-quadrangle area of Breathitt, Knott, Perry, Leslie, and Letcher Counties where it has had a long history of mining, and where it is known to range in thickness from 0 to more than 70 inches.

To date the surface outcrops of the coal seam, 846 underground mines, and 298 surface mines have been digitized. Thickness and elevation data from more than 3,000 mine maps, existing Kentucky Geological Survey data, and data obtained from industry sources are being entered into a data base for generation of isopach and structure maps of the Fire Clay coal seams. Preliminary cross sections and isopach maps show that the Fire Clay coal thins and becomes unmineable for several reasons. A channel system can be mapped through at least three quadrangles. A general northward thinning of the coal seam occurs through the splitting of the lower bench from the Fire Clay coal, and in some areas by thinning of the upper bench beneath a sandstone. In other areas, the upper bench of this coal splits into several smaller seams. Field investigations of mines along each of these trends are being undertaken to better understand the rates at which the thickness and quality of

the seam changes in each of the different areas, and the geologic reasons for the changes. In this way, better predictive models for coal resources can be developed.

The Kentucky Geological Survey visits mines that ask for assistance or have encountered unusual geological conditions as part of the Mineability Project. Visits to mines in eastern Kentucky revealed additional examples of seam "cut-outs," and roof problems related to these features. A visit to a mine in the Amburgy Seam in Pike County revealed a mining obstruction related to concentrations of limestone called coal balls in the roof. Coal balls are rare in eastern Kentucky mines, and this occurrence was studied in detail in the hope that a better understanding of these features will aid in future prediction of their occurrence prior to mining. The coal balls are also of great scientific importance because fossil plant material from the surrounding coal is so well preserved in these coal balls that the original cellular structures of the coal-forming plants can be seen. Samples from the Amburgy coal balls are presently being studied at the University of Kentucky, the University of Illinois, and the Smithsonian Institution in Washington, D.C.

Coal Quality and Petrology

COAL-QUALITY CHARACTERISTICS OF MAJOR MINEABLE COAL BEDS IN KENTUCKY

EBLE, Cortland F.

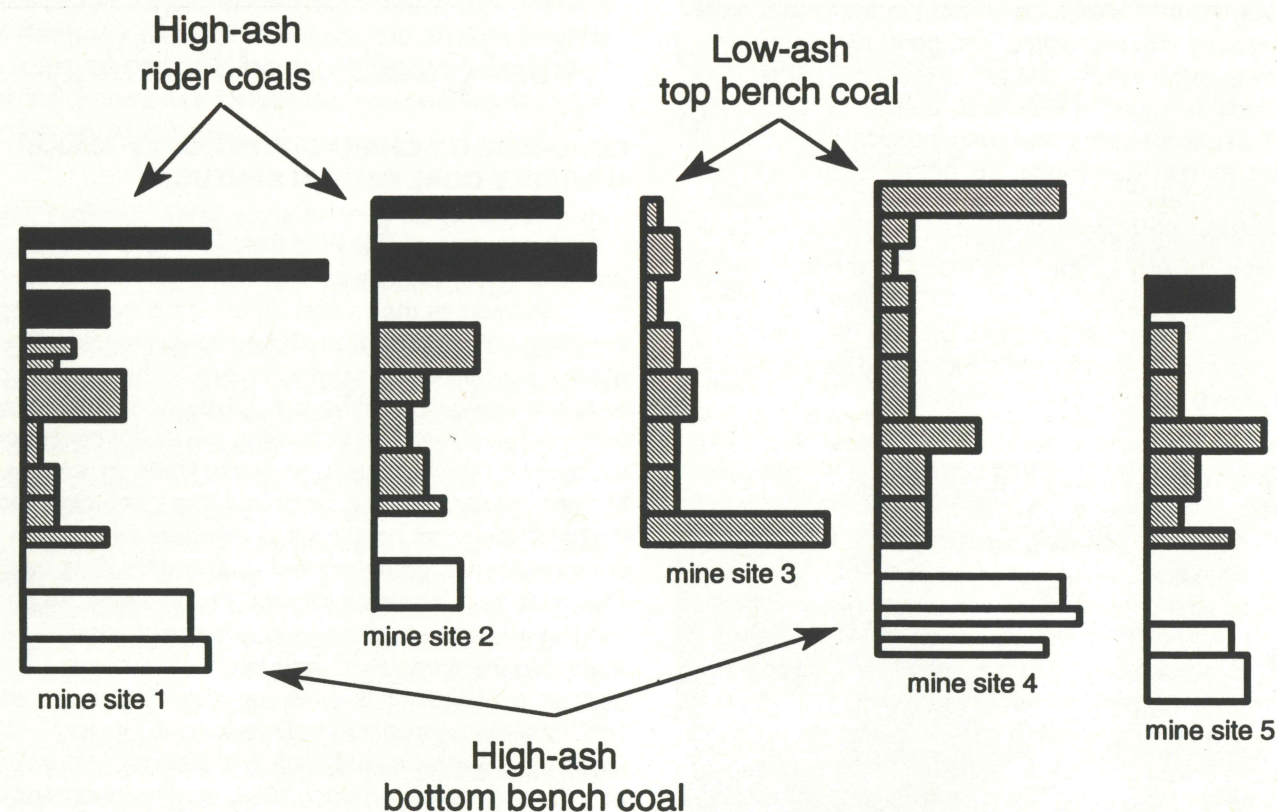
With passage of Title IV of the Clean Air Act Amendments of 1990, virtually all coal-burning utilities in Kentucky and across the United States have had to adopt some type of sulfur dioxide (SO_2) control program. Most utilities have already installed or are in the process of installing flue-gas scrubbers, fluidized-bed combustion units, or have switched to burning low-sulfur coal in order to meet the stricter SO_2 emission limits. In response to these newly imposed restraints, the Kentucky Geological Survey has continued to maintain and update a comprehensive, computerized coal-quality data base. This data base contains information on Kentucky coal ranging from standard analyses such as proximate, ultimate, Btu (heating value), and total sulfur, to more specialized analytical data such as major-element oxide and trace-element concentrations in coal. The Kentucky Geological Survey's coal analytical laboratories, which have been in operation since 1989, analyze hundreds of coal samples each year. The lab routinely performs proximate (moisture, volatile matter, fixed carbon, and ash), ultimate (elemental carbon, hydrogen, nitrogen, and oxygen), total sulfur, Btu, ash fusion, and X-ray fluorescence (major-element oxides) analyses, as well as palynology and coal petrography when required. The

vast coal-quality data base is continuously updated with new analyses. All of the data are available to the public.

Although many of the coal-quality data are derived from full-bed-thickness channel samples, many recently incorporated collections have been sampled in small-scale, vertically continuous increments in order to gain a better understanding of variability of coal-quality parameters such as ash and sulfur in Kentucky's major mineable coal resources. An example of this effort is the Fire Clay coal bed pilot study, which is being conducted in an area of eight 7.5-minute quadrangles in the Eastern Kentucky Coal Field (described in the Coal Mineability section above). Increment sampling from 28 locations in this area has shown that the bottom coal bench, coal below the distinctive and laterally traceable flint-clay parting, is thin, laterally discontinuous, and of poor quality. In contrast, the top coal bench is thick, laterally continuous, and of very good quality. Thin rider coals, where present, usually are of poor quality. Using the increment sampling method, we have identified the top bench of the Fire Clay coal as being the thickest and best quality

coal to mine in the study area. In all but a few samples the top bench of the Fire Clay is a compliance coal resource on a raw-coal basis, whereas the bottom bench is typically thin and rarely within compliance. It is anticipated that this information will be of assistance in future mining in the Fire Clay coal bed.

The information gained from the Fire Clay coal pilot study has already been applied to a similar study in the Illinois (Eastern Interior) Basin. Coal beds of the Trade-water Group in the Illinois Basin are being studied to identify potential low-sulfur coal reserves in western Kentucky and adjacent areas. Preliminary results have indicated that high-sulfur coal zones within these beds are commonly restricted to the top 6 inches to 1 foot of the beds, and that the underlying coal will usually be much lower in sulfur. In these cases it may be possible to separate the high-sulfur top part from the lower sulfur bottom part using bench-loading surface-mining techniques. More work is currently being done on the Trade-water interval to better understand coal-quality trends within these economically important beds.



Ash-yield distribution in the Fire Clay coal bed from selected mine-collection sites in the Fire Clay pilot project study area. Results indicate that the bottom bench and, where present, rider coals generally are high in ash yield. Therefore, a high percentage of the bottom bench and rider coal will often be rejected during coal preparation. In contrast, the top bench is low overall in ash yield, although the top and bottom portions of this bench are occasionally high in ash (e.g., mine sites 3 and 4). The middle portions of the top bench represent the best-quality coal in the Fire Clay coal bed in the pilot project study area.

Industrial and Metallic Minerals

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

CHEMICAL CHARACTERIZATION OF CARBONATE ROCKS IN THE HIGH BRIDGE GROUP

ANDERSON, Warren H.

This project is a continuation of a regional study to determine chemical characteristics of the limestone and dolomite in the central Kentucky area. With the passage of the Clean Air Act Amendments of 1990, limestone and dolomite resources are in demand for use as chemical stone and sulfur sorbents in utility stations along the Ohio River. A core from Mason County has been described and partially analyzed; all samples have been prepared for analysis and 150 samples remain to be analyzed. The X-ray fluorescence analytical equipment is in operation and laboratory staff are in the process of compiling standards and running preliminary analysis for comparative purposes. A manuscript is being compiled that will be published as an Information Circular.

INDUSTRIAL AND METALLIC MINERAL RESOURCES AND MINERAL INDUSTRIES MAP OF KENTUCKY

DEVER, Garland R., Jr., and ANDERSON, Warren H.

The distribution of industrial and metallic minerals is being compiled for a new resource map (scale 1:500,000) of Kentucky. The map will show (1) limestone, dolomite, clay, shale, sand, gravel, and sandstone resources, (2) metallic and nonmetallic mineral deposits, and (3) active quarries, mines, pits, dredges, and plants.

Delineation of resource distribution will be based mainly on the Statewide geologic mapping (scale 1:24,000) that was accomplished during the U.S. Geological Survey-Kentucky Geological Survey cooperative mapping program (1960-78). A new State geologic map (scale 1:500,000), based on the Statewide mapping and printed in 1992, is furnishing a framework for the resource compilation.

LIMESTONE AND DOLOMITE RESOURCES FOR COAL-RELATED INDUSTRIES

DEVER, Garland R., Jr.

Limestones in Meade, Breckinridge, and Hardin Counties of west-central Kentucky are being investigated to determine their chemical quality and the availability of high-calcium limestone for industrial uses. The geographic and stratigraphic distribution of chemically pure limestones in the three counties will be documented by chemical analyses and geologic descriptions for deposits sampled in quarries, mines, and roadcuts. Limestone deposits in part border the Ohio River, affording stone producers access to river transportation, as well as to rail and highway networks.

The Kentucky Geological Survey and the Kentucky Crushed Stone Association hosted a 2-day regional conference, "Limestone and Lime for SO₂ and Pollutant Control in the Ohio Valley" on November 30, 1992. Speakers and panels addressed the availability of limestone and lime for SO₂ control, current and anticipated sorbent requirements by coal-fired utilities, stone specifications, utility experience with carbonate sorbents, waste management, and related subjects. The conference was cosponsored by the Ohio Valley Mineral Consortium, composed of the state geological surveys and aggregate/stone associations of Illinois, Indiana, Kentucky, Ohio, Pennsylvania, and West Virginia, and the National Stone Association. Approximately 300 people attended the conference. A second conference on similar subjects is being planned for the spring of 1994.

SAND AND GRAVEL RESOURCES OF THE OHIO RIVER VALLEY

ANDERSON, Warren H.

Pleistocene sand and gravel resources along the Ohio River are used for construction materials in urban and industrial settings. These deposits are situated near several major metropolitan areas; knowledge of the geology of these deposits will enable effective land-use planning and economic development. The project examines the distribution and variation in thickness, texture, and composition of these deposits to determine



Curved and striated surface of thrust fault in lower member of Newman Limestone, Whitesburg Quarry, Letcher County.

particle size, soundness, composition, abrasion, percent deleterious materials, as well as sedimentology and petrology.

Results indicate that of the three major glacial deposit terraces (pre-Illinoian, Illinoian, and Wisconsin), the Wisconsin terraces are the most desirable resource for mining. The high-gravel, low silt/clay, and abundant limestone/dolomite content make these deposits attractive for mining.

All field, laboratory, and computer work has been completed. A manuscript is being prepared for publication.

NONFUEL MINERAL STATISTICS

DEVER, Garland R., Jr.

The value of the State's nonfuel mineral production in 1992 reached a record high of about \$412 million, based on estimated data compiled by the U.S. Bureau of

Mines. Compared to 1991, crushed stone production gained 25 percent; it accounted for 60 percent of the 1992 nonfuel mineral value. Output of cement and construction sand and gravel also increased. Slight declines in the production of lime, common clay and shale, and ball clay were reported. With the sharp increase in value, Kentucky ranked twenty-fifth nationally in 1992 nonfuel mineral production, rising from twentieth-ninth in 1991.

The Kentucky Geological Survey and U.S. Bureau of Mines collect and compile information on Kentucky's nonfuel mineral industry and mineral-related government actions. Data are shared by the two agencies under terms of a Memorandum of Understanding and are published in the Bureau of Mines' "Minerals Yearbook," "Mineral Industry Surveys," and commodity reports. KGS also uses the information to prepare reviews of industry activities, to answer public-service inquiries, and to compile a mineral-producer directory.

Petroleum and Stratigraphy

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

Oil and natural gas are important commodities for the Kentucky economy, ranking third and fifth, respectively, in value of natural resources produced in the State. In 1991 oil- and gas-wellhead value of production was about \$248 million, bringing an estimated \$19 million in associated taxes to the State. Nationally, the industry remains in a slump that extends back to 1986. Although activity is down in Kentucky, oil and gas production has remained surprisingly steady since 1986, with gas production actually rising over the last 2 years to equal 1986 levels.

Drilling activity in Kentucky in 1992 was relatively steady with 1,270 well completions and a success rate of 66 percent. Compared to 1991, oil production declined slightly to 5,381,711 barrels, while gas production increased to 79.7 billion cubic feet. A total of 220 exploratory wells were drilled, resulting in the discovery of 15 new fields and pools, 8 deeper pools, 2 shallower pools, and 77 extensions of existing pools. Total footage drilled during the year was 2,417,787 feet, with an average well depth of 1,903 feet. Most of the production came from stripper wells that in 1991 produced more than 4.5 million barrels. During the same year, 281 stripper wells were abandoned.

There were 540 wells reported complete in the Appalachian Basin of eastern Kentucky. Of these wells, 418 penetrated the Mississippian-Devonian Ohio Shale or deeper units, with a 97 percent success rate. A total of 215 wells were successfully completed as gas wells within the shale, with an average initial open flow of 324 Mcfd (thousand cubic feet per day).

Leslie County continued to be the top oil-producing county in Kentucky with 1,077,775 barrels produced, or 20 percent of the total State production. Twenty-nine wells were reported complete, with a success rate of 51 percent. The primary drilling target was the Mississippian Newman Limestone ("Big Lime" of the drillers), with an average initial potential of 98 b/d (barrels per day).

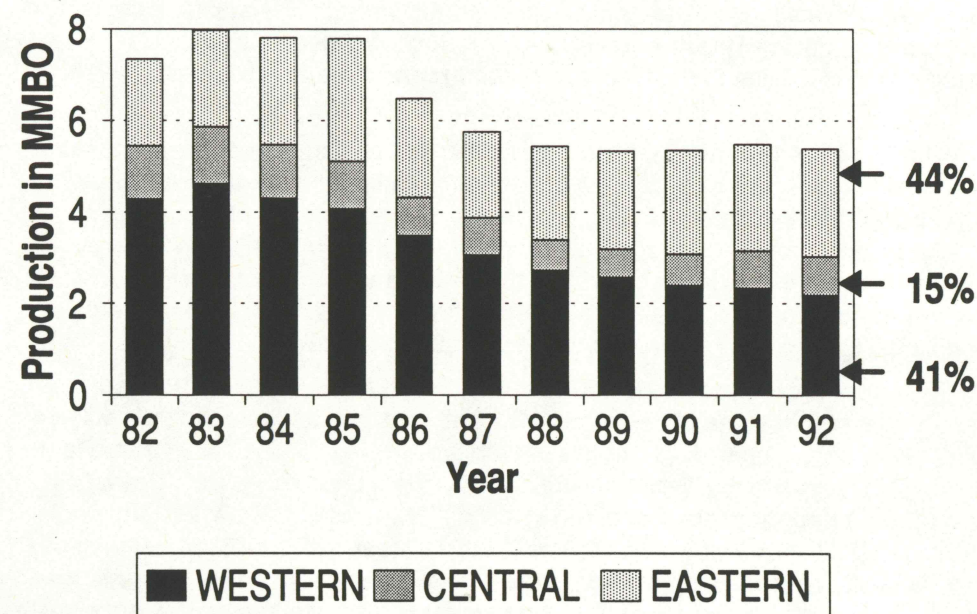
Clinton County has experienced the most rapid growth in oil production over the last several years, increasing nearly eight-fold from 55,000 barrels in 1989 to more than 407,000 barrels in 1992. The majority of these wells were completed in fractured carbonates of the Ordovician High Bridge and Knox Groups. Recently a new field discovery in the High Bridge Group was made in northern Clinton County with a reported initial production rate of 2,950 b/d. Clinton County was also the most active county in Kentucky in 1992, with 207 wells reported complete.

Pike County was the most active county in eastern Kentucky with 129 wells reported complete. It was also the most prolific gas-producing county in the State. The overall success rate was 98 percent with only two dry holes reported. Gas production in Pike County, primarily from the Mississippian-Devonian Ohio Shale, totaled more than 27.6 bcf (billion cubic feet).

While oil production in western Kentucky continued its decline, drilling increased 17 percent to 218 wells reported complete. Muhlenberg was the most active county in western Kentucky, with 52 wells reported. In the Midland Field, 20 wells were completed as gas storage wells in the Mississippian Bethel Sandstone. The remaining

Oil Production in Kentucky

1982 to 1992 by Region



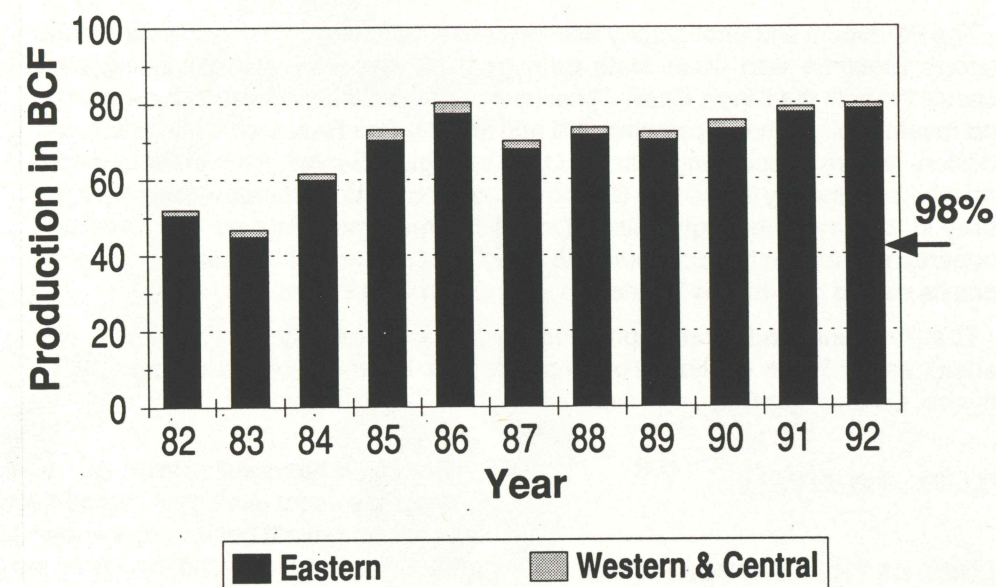
successful wells were completed in other Chesterian sandstones and the O'Hara and McClosky zones of the Mississippian Ste. Genevieve Limestone.

Daviess, Henderson, and Union Counties remained active, with most wells being completed in the Pennsylvanian Tradewater Formation and the Mississippian Tar Springs, Aux Vases, and Ste. Genevieve Formations. Despite the downsizing that has occurred nationally as well as locally, there are several bright spots in Kentucky's future. Positive signs include the active exploration in the Rough Creek Graben for deep gas, the high level of interest in the Rome Trough as a potential future gas province, continued high rates of drilling and oil production in Clinton and Cumberland Counties, the continued success and moderately high oil production from the Mississippian Newman Limestone in eastern Kentucky, and the promise of extensive gas exploration in many areas of the State in the near future.

Hydrocarbons figure to be important bridging fuels well into the twenty-first century until renewable energy resources can be developed. Nationally, natural gas will play a significant role in the future domestic energy mix, because of its environmental acceptability, low cost, domestic availability, and importance to the emerging alternative fuels industry. One of the most significant future gas markets during the next decade will be electric-power generation. Strong industrial demand will propel United States gas consumption to 21 tcf (trillion cubic feet) a year by the year 2000, outpacing the growth rate of all other energy sources. The startling 50 to 60 percent increase in natural-gas prices from last year is a good indication of the importance of natural gas. Kentucky has large untapped natural-gas resources; with the proper incentives and support, careful planning and commitment, and pipeline availability, this sector of Kentucky's economy could show significant growth during the decade, providing the Commonwealth with a strong energy base, a vital industry, well-paying jobs, and increased oil and gas revenues, together with sustainable development.

Gas Production in Kentucky

1982 to 1992



Recovery of oil and gas from known domestic reservoirs is being recognized as an important source for the future domestic energy supply. Compiling oil and gas data bases and atlases is a vital first step in evaluating these resources. Such data will be useful to reservoir-characterization studies critical in the future development of exploration and production strategies. The Section is currently involved in a gas atlas and Tertiary Oil Resources Information System (TORIS) studies for the Appalachian Basin in eastern Kentucky.

Deep basins in Kentucky are potential important gas provinces. Companies are examining recently available reflection seismic data for the Rome Trough and discussing exploration strategies for natural gas production. The published research by the Cincinnati Arch Consortium has stimulated interest in the newly discovered East Continent Rift Basin.

Section 29 tax credits for the production of nonconventional fuel sources ended on December 31, 1992. Well permitting related to these resources increased near the end of the year. Fewer Devonian Ohio Shale gas tests will probably be drilled during 1993 as a result, but the drilling of other types of gas prospects are expected.

Horizontal drilling is becoming a more commonly applied technology. Only one horizontal hole was completed in Kentucky this year, but several are planned. To be successful, this technology requires detailed subsurface geologic information. KGS will continue to provide this information and increase the research and services needed to support this and other emerging technologies.

Environmental concerns are increasingly important in Kentucky as well as the Nation. Subsurface geologic information is key to several of these issues, including earthquake risk, potential deep-well waste disposal, and ground-water pollution. We are currently participating in the University of Kentucky seismic network to monitor earthquake activity in the State and, in particular, the New Madrid Earthquake Zone of western Kentucky. Seismic hazards for municipalities and public works in western

Kentucky are being assessed. Surface faulting as it relates to seismicity in the central New Madrid Seismic Zone is also being investigated. Research to investigate the contemporary state of stress in the lithosphere is being proposed, as is a study to map shallow faults and their relationship to deeper basement faults in the New Madrid area.

The Petroleum and Stratigraphy Section continues to play an instrumental role in various consortia with other state geological surveys. We are continuing our association with the Illinois Basin Consortium and the Cincinnati Arch Consortium, and recently joined the Appalachian Oil and Natural Gas Research Consortium. In addition, we are cooperating with the U.S. Geological Survey in several research projects, and recently joined with Clinton County and the Los Alamos National Laboratory in a study of the high-volume Ordovician reservoirs. And we are currently cooperating in a five-state consortium to seek U.S. Department of Energy funding to compile oil and gas atlases for the Illinois and Michigan Basins.

The Petroleum and Stratigraphy Section performs research and service in six general areas: Basin Analysis, Regional Geology, Hydrocarbon Resources, Geophysics, Oil and Gas Data, and Drill Cuttings and Core Samples.

Basin Analysis

REGIONAL GEOLOGY OF THE KENTUCKY-OHIO TROUGH

HARRIS, David C., DRAHOVZAL, James A., and WALKER, Dan

The goal of this research has been to geologically and geophysically delineate the East Continent Rift Basin, a recently discovered Precambrian sedimentary basin located in north-central Kentucky and adjacent parts of western Ohio and eastern Indiana. This project was completed in late 1991 by the Cincinnati Arch Consortium, a research team composed of the Kentucky, Ohio, and Indiana Geological Surveys. The project was funded in part by six oil companies, and confidentiality requirements prevented official release of results to the public before late 1992. During the year a summary report was published, several presentations were made at national meetings, and news releases were sent to several scientific magazines.

Results of the project were presented at a symposium on Precambrian rift basins in eastern North America held at the Geological Society of America annual meeting in Cincinnati last fall. A summary publication discusses the major conclusions of the project. This publication, "The East Continent Rift Basin: A New Discovery" (KGS Special Publication 18), provides a concise description of the basin, its geographic limits, proposed origin, and potential for hydrocarbon and other mineral resources. In addition to the summary publication, the complete two-volume final report to project participants was put on open-file, and is available to the public for the cost of duplication.

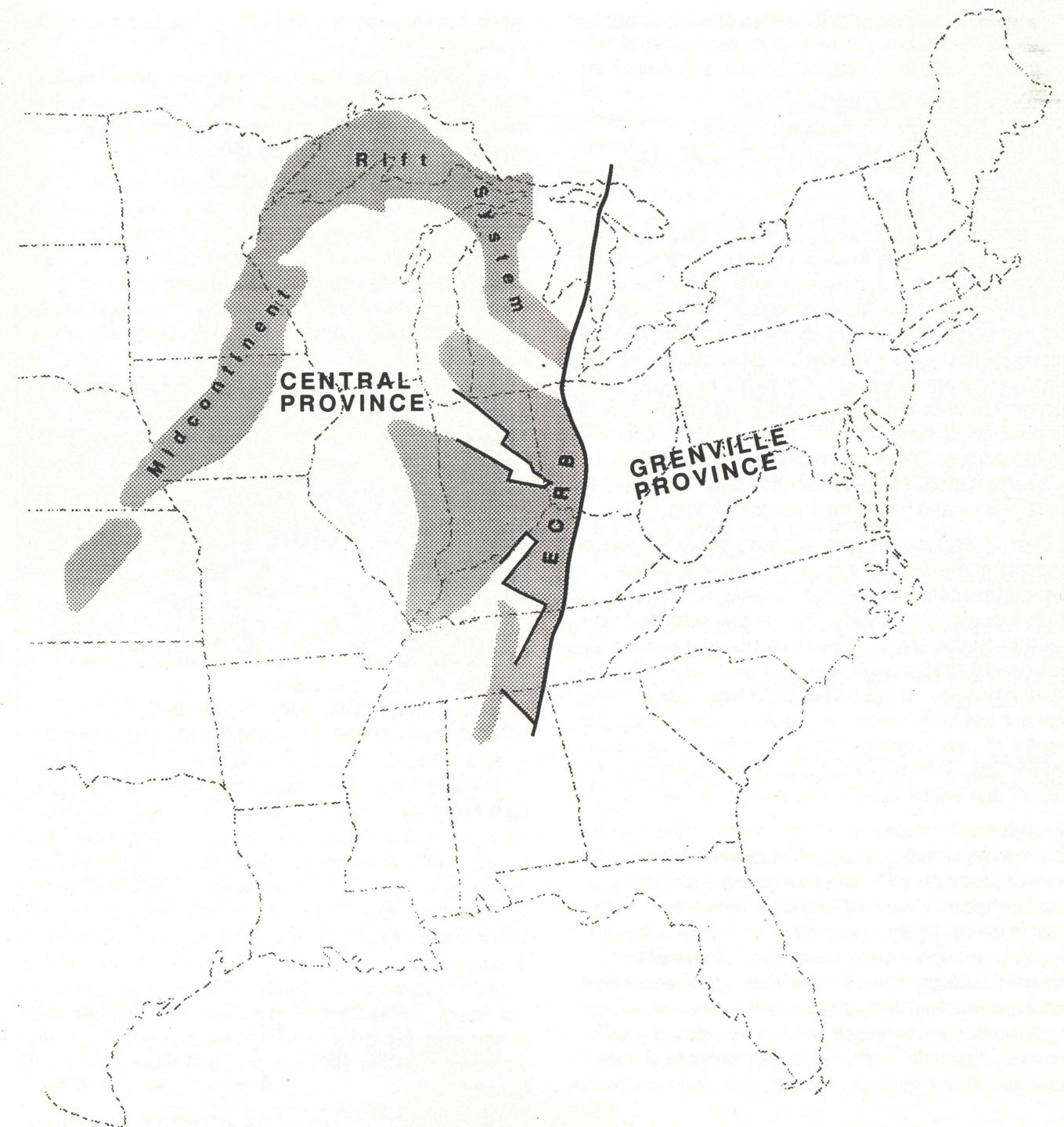
This project has resulted in a major reinterpretation of the deep basement geology in central Kentucky. A complex sedimentary rift basin is now known to exist where previously only granites and rhyolites were thought to be present. No economic mineral accumulations have yet been found, but a large area remains untested, and both minerals and petroleum are known from similar-age basins to the northwest in the Midcontinent. Reactivation of faults associated with the East Continent Rift Basin affected parts of the overlying Paleozoic sedimentary section, and may have influenced the distribution of oil, gas, or economic minerals in younger rocks.

A joint project proposal with the COCORP group at Cornell University and the Ohio and Indiana geological surveys has been submitted to industry. Research related to this project will continue as new data and funding are obtained.

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

HARRIS, David C., and HAMILTON-SMITH, Terence

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



The East Continent Rift Basin (ECRB) is a newly discovered basin in eastern North America.

This year work shifted to similar-age carbonate reservoirs in the Appalachian Basin of eastern Kentucky, in order to respond to increasing industry interest in the Big Lime interval (*see* Appalachian Basin Big Lime Project, *below*). Detailed descriptions were made of two continuous cores from boreholes in Simpson and Logan Counties. Lithofacies identified in these cores were correlated

to geophysical logs from nearby wells so that depositional facies could be recognized in uncored wells. A search for additional cores for the project resulted in Shell Western Exploration & Production donating all its cores and cuttings from Kentucky to the Survey. Some of this material will provide important data for the project. Eight cores remain to be described, after which regional

cross sections and stratigraphic interpretations will be made.

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

HARRIS, David C.

In response to increasing oil industry interest, a proposal for an externally funded, 2-year proprietary study of Mississippian gas and oil reservoirs was written. The goal of this project is to provide the regional stratigraphic and petrologic data necessary for oil and gas companies to evaluate the hydrocarbon potential of the "Big Lime" carbonate in eastern Kentucky. Increasing production from this interval in recent years is indicative of the potential of the zone, but realization of this potential will require a consistent and accurate regional data set for interpretation. The proposal has been submitted to numerous oil and gas companies for funding.

Over 29,000 records are available at KGS for wells penetrating the Big Lime in eastern Kentucky, but few stratigraphic data have been collected or compiled from these records. Stratigraphic tops will be collected from 9,500 to 10,000 Big Lime penetrations in eastern Kentucky, and a stratigraphic data base will be created. This effort will focus on the 9,400 wells for which geophysical logs are available, because these records provide the degree of accuracy needed to identify subtle trends. Drillers' logs will be utilized only in areas with sparse control, and will be carefully evaluated before use.

Regional structure and isopach maps, and cross sections will be prepared as part of the study. These regional-scale products will indicate areas worthy of more detailed in-house analysis. Controls on porosity development in these largely stratigraphic reservoirs will be determined through a petrologic study of available core and well cuttings. Depositional and diagenetic trends found to control porosity will be used to construct regional reservoir fairway maps, which will indicate areas prone to depositional or diagenetic porosity development.

REGIONAL SUBSURFACE MAPS IN KENTUCKY

HARRIS, David C., DRAHOVZAL, James A., and NOGER, Martin C.

The goal of this research is to produce a series of regional facies, isopach, and structure 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 addressing environmental issues. In addition, these

maps will serve as the basis for future basin analysis studies.

This project was designed to expand maps resulting from other projects to cover the entire State, and publish them in series at a common scale. Several projects are now producing maps suitable for this series.

A pre-Middle Devonian subcrop map for the Commonwealth is being compiled as part of the Subsurface Stratigraphy and Reservoir Geology of the Silurian-Devonian Corniferous of Kentucky Project. This map will document the distribution of formations below the pre-Chattanooga/Ohio/New Albany Shale unconformity. Many of these formations are important oil producers in Kentucky.

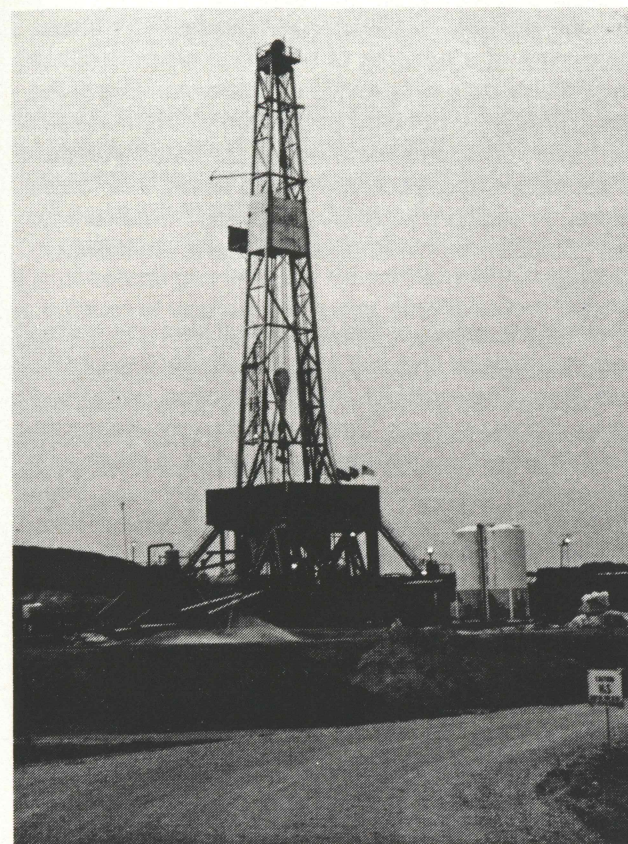
A map of the top of the Precambrian crystalline basement is being prepared. Recent studies in central Kentucky have resulted in a far different picture of this surface than previously thought. Initial work in western Kentucky, especially in the vicinity of the Rough Creek Graben, has resulted in a preliminary top of basement map based on newly available reflection seismic data and deep drilling. This map has implications for future oil and gas exploration in Kentucky.

STRATIGRAPHY AND SEDIMENTOLOGY OF PRE-KNOX SEDIMENTS IN THE ROME AND ROUGH CREEK GRABENS

NOGER, Martin C., HARRIS, David C., WILLIAMS, David A., ANDERSON, Warren H., and DRAHOVZAL, James A.

The emphasis of this project has changed during the past fiscal year from the Rome Trough of eastern Kentucky to the Rough Creek Graben of western Kentucky. In late 1992, an important deep exploratory well was drilled by Conoco, Inc., in the Rough Creek Graben of western Kentucky. This well, the Conoco No. 1 Mark Turner, was drilled in McLean County, and reached a depth of 14,202 feet. The objective was natural gas potentially trapped within Cambrian synrift sandstones of the Rough Creek Graben. The well was plugged and abandoned, but Conoco has permitted a second deep well to be drilled to 19,000 feet during 1993 in Grayson County.

Results from the Conoco Turner well are confidential for 1 year, but with Conoco's permission, KGS has begun analyzing data collected in the well. The goal of this new project is to provide a summary of all well data to the public when the data are officially released. A detailed description of the well cuttings is now in progress. Source-rock analyses will be performed by the U.S. Geological Survey, and sample intervals have been selected. Well-log tapes have been loaded into the TerraStation log analysis software package. Lithologic de-



The Conoco No. 1 Mark Turner well drilled synrift sediment of the Rough Creek Graben to a total depth of 14,202 feet in McLean County, Kentucky.

scriptions, source-rock analyses, and stratigraphic interpretations will be published at the end of 1993 in a KGS publication.

It is anticipated that significant reflection seismic data for the Rome Trough will become available to KGS within the year. With this eventuality, the eastern Kentucky part of this project will begin again.

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

DRAHOVZAL, James A.

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

This project is Phase I of a proposed ongoing project with the Illinois Basin Consortium sponsored by the U.S. Geological Survey's Earthquake Hazards Reduction

Program. Phase I is designed to assess the reflection seismic data available for the area and acquire as many data as possible. During the year, consortium members met with various oil and gas industry and seismic acquisition representatives to review available seismic surveys of the Illinois Basin. Many of the former companies that acquired these data are now out of business or have sold their interests in the data, but contacts have been made with representatives of more than 30 companies or former companies. A number of significant seismic surveys for the basin, and particularly the Rough Creek Graben of Kentucky, have been acquired. Because of the ongoing nature of the negotiations for additional data, Phase I of the project has been extended. Preliminary interpretations of many of the data have been made, and a generalized top of Precambrian basement map has been developed.

Regional Geology

GEOLOGIC MAP OF KENTUCKY

NOGER, Martin C., and POTTS, Roger, B

In 1984 the Kentucky Geological Survey began compiling a 1:500,000-scale geologic map of Kentucky, based on the 1:250,000-scale "Geologic Map of Kentucky." The single-sheet, 1:500,000-scale color map will be useful to government agencies, industry, energy and mineral producers, the general public, and academic institutions.

The map was printed in December 1992, and was a cooperative effort between KGS and the U.S. Geological Survey.

GEOLOGY ALONG KENTUCKY HIGHWAYS

HANEY, Donald C., and NOGER, Martin C.

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

Two reports, "Roadside Geology Along Interstate Highway 75 in Kentucky" and "Roadside Geology Along Interstate Highways 71 and 65 in Kentucky," have been published. Reports on Interstate Highway 64, the Bluegrass Parkway, the Western Kentucky Parkway, and part of Interstate Highway 24 west of Princeton, Kentucky, have been compiled and are in preparation for printing. Future plans call for similar reports for the Alexandria-Ashland (AA) Highway, the Cumberland Park-

way, Kentucky Highway 80, and the Daniel Boone Parkway.

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

MEGLEN, Joseph F., and NOGER, Martin C.

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

A study is underway that includes (1) a regional pre-Devonian subcrop map, (2) a Silurian-Devonian oil and gas pool overlay map, (3) regional stratigraphic and structural interpretation, with particular attention paid to the multiple unconformities present, (4) sedimentology and depositional history of each sequence, (5) structure and isopach maps, (6) stratigraphic nomenclature of the Corniferous section, including drillers' terms, (7) detailed reservoir studies, including an analysis of fractured reservoirs, and (8) specific studies of the Greensburg and Big Sinking Oil Fields and the Creekville-Hyden/Oneida/ Burning Springs Gas Field Complex.

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

REGIONAL STRUCTURAL CROSS SECTIONS, ILLINOIS BASIN, WESTERN KENTUCKY

NOGER, Martin C., and DRAHOVZAL, James A.

This project to compile structural cross sections continues in cooperation with the Illinois Basin Consortium (IBC). The Illinois Basin, which covers parts of western Kentucky, southwestern Indiana, and southern Illinois, is a sedimentary, interior cratonic sag basin that has produced some 4 billion barrels of oil from its shallow parts. The potential exists for large accumulations of hydrocar-

bons in deeper pre-Upper Mississippian strata. Construction of a network of structural cross sections from available data will provide an understanding of the regional structural geology, stratigraphy, and evolution of the basin and illustrate known and potential hydrocarbon sources, traps, reservoirs, and seals. The cross sections, in addition, provide a geologic framework for future geologic and mineral-resource and environmental studies.

Preliminary copies of two west-east sections across Illinois and Indiana and one north-south section across Illinois have been printed. A cross section from Pope County, Illinois, through Crittenden County, Kentucky, and south to Tennessee has been printed. A west-east cross section from Illinois to central Kentucky, three north-south cross sections from Indiana across Kentucky into northern Tennessee, and one north-south cross section from Illinois to Webster County, Kentucky, have been assembled. The compilation of the Kentucky portion of the west-east cross section and north-south cross sections have been delayed until data from Conoco for a recently completed Precambrian well in McLean County and proposed Precambrian test in Grayson County are available for incorporation in the sections. KGS personnel are responsible for structural and stratigraphic correlations for the Kentucky portion of these sections.

Preliminary blackline copies of the printed cross sections are available from each of the member surveys. The IBC will publish the final editions of the cross sections in color.

TAR SANDS OF WESTERN KENTUCKY

NOGER, Martin C., and HAMILTON-SMITH, Terence

Through this study, industry's interest in tar sands continues to be monitored and stimulated. The in-place oil-resource potential of subsurface and surface tar-sand deposits in western Kentucky is calculated to be 3.4 billion barrels. Since 1980, the Survey has coordinated the program of the Tar Sands/Heavy Oil sessions of the Eastern Oil Shale Symposium, which meets annually in Lexington, Kentucky. In 1992 these sessions included 21 research papers and one poster session. The 1993 symposium will be held November 17-19.

This ongoing project is designed to keep the Survey up to date with industry activity associated with the tar-sand deposits of western Kentucky. Maintaining data bases ensures that necessary information will be accessible when economic conditions warrant commercial development of tar-sand resources.

Hydrocarbon Resources

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

HAMILTON-SMITH, Terence, NUTTALL, Brandon C., and DRAHOVZAL, James A.

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

To date, a regional New Albany Shale well data base with over 2,000 entries from western Kentucky alone has been compiled, and stratigraphic cross sections have been completed across the basin. Final maps of major structural features in the Illinois Basin, and of New Albany Shale gas production, structure, thickness, core locations, and reflectance of shale vitrinite have been completed. Project results have been presented at talks and poster sessions in Lexington, Owensboro, Bloomington, Indiana, and Champaign, Illinois. The final report has been written, and will be published in late 1993 by the Indiana Geological Survey on behalf of the Gas Research Institute and the Illinois Basin Consortium.

GAS RESERVOIR CHARACTER OF DEVONIAN SHALES OF KENTUCKY

HAMILTON-SMITH, Terence

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

A paper describing the regional geologic context of the Devonian shales has been recently published by the Geological Society of America. "Gas Exploration Strategy for Fractured Devonian Shales of Kentucky" will be published by KGS in late 1993. A reservoir study of New Albany Shale gas production in the Shrewsbury Consolidated Field in Grayson, Butler, and Edmonson Counties has been initiated, and preliminary results have been presented at professional and industry meetings in Lexington, Owensboro, and Champaign, Illinois. Publication of this field study by KGS is anticipated for 1994.

CARBONIFEROUS OIL FIELDS OF KENTUCKY (ILLINOIS BASIN)

HAMILTON-SMITH, Terence, and HARRIS, David C.

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

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

A reservoir evaluation of the Antioch Field of Hopkins County is in progress, using proprietary data provided by Ashland Exploration and Har-Ken Oil Company. TERRASTATION log analysis and mapping software installed on a Sun workstation at KGS is being used for the analysis. This field study will be completed in 1993, and will result in a subsequent publication by the KGS.

Agreement has also been reached with Har-Ken Oil Company to conduct a reservoir evaluation of the New Cypress NE Field in Muhlenberg County. To date, a data base has been prepared and cores collected. This field study will result in a publication by KGS.

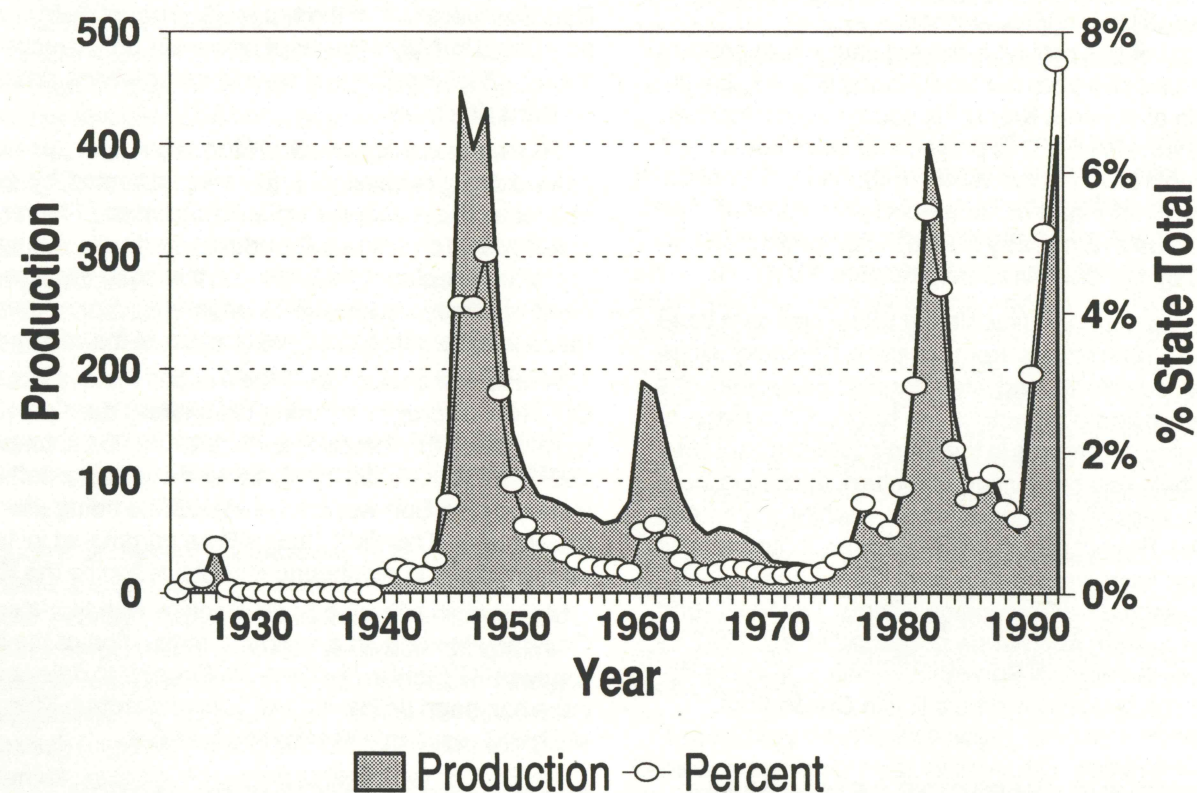
RESERVOIRS OF THE CINCINNATI ARCH, CENTRAL KENTUCKY

HAMILTON-SMITH, Terence, HARRIS, David C., NUTTALL, Brandon C., and ANDERSON, Warren H.

Upper Ordovician oil reservoirs in south-central Kentucky are attracting national attention because of continuing high-volume production in southern Clinton County. Deepening of an abandoned well in 1990 resulted in record-setting initial production for the region of 3,500 b/d from fractured limestones of the High Bridge Group. Additional high-volume wells drilled in the vicinity of the discovery well established the existence of a large and productive reservoir, with uncertain character and distribution. Recently, a new field discovery has been made in the High Bridge Group in northern Clinton County, with an initial production rate of 2,950 b/d.

This project will reduce exploration risk by improving prediction of the distribution of major tectonic fracture systems responsible for high-volume production. A paper summarizing the play was published in the *Oil and Gas Journal* in 1992. A presentation was made at the 1992 Eastern Section Meeting of the American Associa-

Clinton County Oil Production by Year 1924 to 1992 in Thousands of Barrels



tion of Petroleum Geologists and a paper based on this presentation will be published by KGS in 1993; the publication will include new structure and thickness maps of the discovery area.

KGS recently assisted staff of the Los Alamos National Laboratory in a microseismic research project in Clinton County, which has the potential to image the reservoir fracture system. KGS is also supporting geochemical analysis of Clinton County oils by the U.S. Geological Survey, the objective being to identify hydrocarbon source rocks and migration pathways.

PETROLEUM GEOCHEMISTRY AND SOURCE-ROCK EVALUATION OF HYDROCARBON RESERVOIRS IN KENTUCKY

GOODING, Patrick J.

Hydrocarbons in Kentucky are produced from many stratigraphic horizons in a variety of rock types ranging in age from Early Cambrian to Early Pennsylvanian. The purpose of this study is to determine source-rock poten-

tial, crude-oil characteristics, and oil source-rock correlations by utilizing geochemical analyses, and to investigate the influence of geologic structures and tectonics on the maturation, migration, and accumulation of hydrocarbons in Kentucky.

KGS is currently compiling the geochemical analyses of oils and source-rock evaluations for public release during 1993. The interpretation of these data is the subject of a dissertation being completed at the University of Kentucky Department of Geological Sciences.

Geophysics

OPERATION OF THE KENTUCKY SEISMIC AND STRONG MOTION NETWORKS

HARRIS, James B.

Operation of the Kentucky Seismic Network began in late 1980 following the 5.2 m_b July 27, 1980, Sharpsburg, Kentucky, earthquake. The network is designed to monitor seismicity in and around the State, and has produced over 1,000 recordings of regional earthquakes

since it began operation. The network presently consists of 11 borehole-mounted, short-period seismometers deployed across the State from Grayson, in the east, to Clinton in the west. The seismic data are transmitted to the UK campus via the state KEWS (Kentucky Early Warning System) microwave network. Continuous drum recordings of seismic activity are used for visual analysis, and the data are digitized and stored on computer for advanced processing and display.

The Kentucky Strong Motion Network consists of five surface-mounted, three-component accelerographs, and two vertical (surface and borehole instruments) accelerometer arrays, located in western Kentucky and northwestern Tennessee, in the vicinity of the New Madrid Seismic Zone. The data are transmitted by telephone modem links between the individual stations and

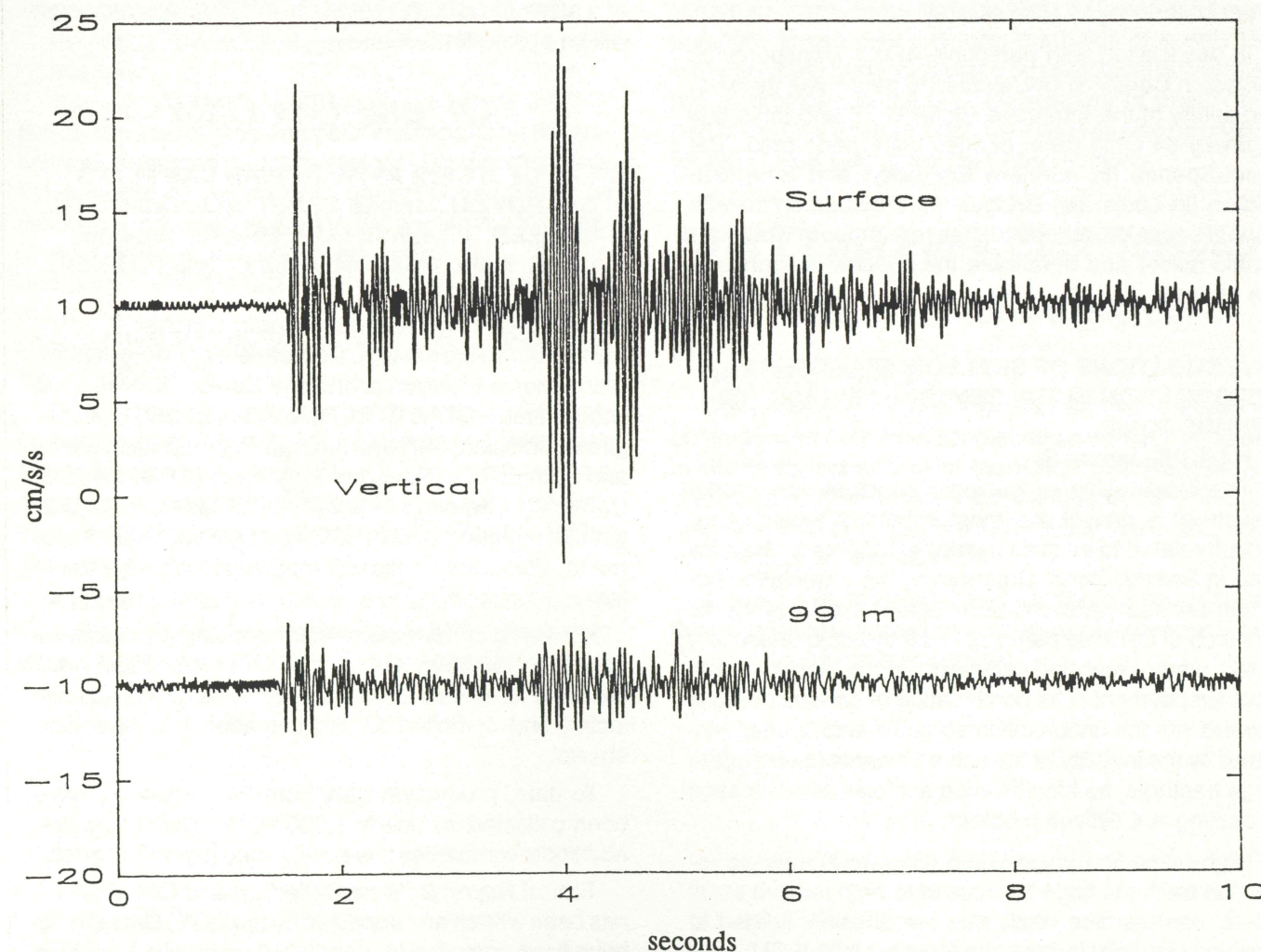
the Seismic Lab at UK. The strong-motion network is designed to investigate the effects of thick sequences of unconsolidated sediments associated with the Lower Ohio River Valley, the Central Mississippi River Valley, and the Mississippi Embayment on earthquake ground motions, and provide engineers with high-quality data that can be used in the design and construction of safer structures. Since it began operation in 1990, the Kentucky Strong Motion Network has provided over 20 digital recordings, and the data are compiled in a KGS open-file report.

SEISMIC HAZARD ANALYSIS IN KENTUCKY

HARRIS, James B.

Amplification of earthquake ground motions by near-surface geologic conditions has been recognized as a major cause of damage in areas underlain by deep,

MARCH 02, 1993; VSAB



March 2, 1993, Henderson Mound, Missouri, earthquake ($m_b=3.0$) recorded at vertical strong-motion array VSAB, located in Fulton County, Kentucky. Note the change in amplitude, frequency, and duration as the earthquake propagates upward through the unconsolidated near-surface sediments.

poorly consolidated sediments. Several Kentucky communities along the lower Ohio River are at risk to severe earthquake damage because of their foundation on deep alluvial material and their proximity to the New Madrid and Wabash Valley Seismic Zones. Microzonation studies of the Paducah and Henderson areas have been undertaken in order to estimate the potential for soil-column amplification. In both studies, surface seismic (refraction and reflection) methods, integrated with available geotechnical data, were used to characterize site conditions and determine material properties.

An associated study to determine site conditions at strong-motion stations in the central United States, operated by the Seismic Lab at UK and the Lamont-Doherty Earth Observatory at Columbia University, is underway. This research is important in defining the effects of the soil column on earthquake records, and in correcting the records for site effects so they can be used in site-response modeling studies at other locations.

In association with personnel at the Transportation Research Center at UK, studies to determine the seismic safety of the Interstate Highway 75 and Interstate Highway 64 Ohio River bridges were performed. The Brent-Spence (in northern Kentucky) and Sherman-Minton (in Louisville) Bridges were instrumented with portable accelerographs to measure random vibrations (traffic noise) and determine the spectral response of the bridges.

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

HARRIS, James B.

The relationship of geologic structure and recent seismicity is one of the most important topics of research related to seismic hazard evaluation in the New Madrid Seismic Zone. Determining the association between seismicity and structural deformation is hindered by much of the area being covered by thick, unconsolidated, water-saturated sediments of the Upper Mississippi Embayment. The continuation of basement faults upward into the unconsolidated sediments is often hindered by the inability of the soft sediments to propagate large fractures, so identification and age determination of faulting is a difficult problem.

High-resolution shear-wave (SH-wave) seismic reflection methods have been used to help resolve small offset, near-surface faults that are possibly related to current seismicity in the Lake County Uplift (LCU) area of Kentucky, Tennessee, and Missouri. Preliminary results indicate that shallow faulting along the crest of the LCU, a Holocene flexure, is predominantly normal. This

finding suggests that the faults are secondary features related to tensional stresses across the LCU and are not directly related to local seismicity, which indicates that the area is under compressive stress.

Continuing research, supported in part by the U.S. Geological Survey, will attempt to determine the relationship between these shallow structural features and previously identified deeper deformation.

GRAVITY MAP OF KENTUCKY

HARRIS, James B.

In 1978, the western sheet of the Bouguer gravity map of Kentucky was published by the Kentucky Geological Survey at a scale of 1:250,000. Because of difficulties in matching contours across map boundaries, the central and eastern sheets were never published. However, recent work has succeeded in joining the sheets together. The entire gravity map will be published at a scale of 1:500,000, and the 1:250,000-scale sheet will be placed on open file.

Oil and Gas Data

ATLAS OF MAJOR APPALACHIAN GAS PLAYS

DRAHOVZAL, James A., NUTTALL, Brandon C., MEGLLEN, Joseph F., HUMPHREYS, Matthew, CHEN, Mara, WATSON, Anna E., and WALKER, Dan

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

A catalog of formation-water resistivity for eastern Kentucky has been compiled. Gas analyses and pressure and temperature data on gas fields have been collected and compiled for incorporation into field data sheets.

To date, production data from 12 companies have been collected for nearly 1,300 wells in Kentucky. Ten additional companies have committed to providing data.

Topical Report 2, "Data Collection and Compilation," has been written and accepted by the DOE. Data sheets have been compiled for nearly 250 reservoirs in various plays. Data are being collected for several plays: the Lower Devonian–Upper Silurian Unconformity ("Corniferous"), the Upper Silurian Lockport-Big Six, the Upper

Ordovician "Trenton" Limestone, the upper to lower Trenton to Knox fractured carbonates, and the Lower Ordovician–Upper Cambrian Knox Unconformity.

Additional funding has been obtained to compile Tertiary Oil Recovery Information System (TORIS) data sheets for the Appalachian Basin. This new task will supply oil reservoir data and extend the project an additional year. Data have been gathered to target 23 Appalachian Basin oil fields representing 135 separate pools; 39 different stratigraphic intervals from the Pennsylvanian to the Cambrian are included. These fields and their associated pools are estimated to have originally in excess of 1.2 billion barrels of oil in place in eastern Kentucky.

RESERVOIR CLASSIFICATION OF TERTIARY OIL RECOVERY INFORMATION SYSTEM (TORIS) IN KENTUCKY

DRAHOVZAL, James A., MEGLLEN, Joseph F., NUTTALL, Brandon C., and HUMPHREYS, Matthew

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

DOE is considering a proposal to compile TORIS information sheets as part of a larger oil and gas play atlas for the Illinois and Michigan Basins. The project will be a cooperative effort of the Illinois, Indiana, Ohio, and Kentucky geological surveys together with Western Michigan University.

A proposal to extend the Atlas of Major Appalachian Gas Plays Project by compiling TORIS information sheets for the Appalachian Basin has been funded.

OIL AND GAS MAPS OF KENTUCKY

WILLIAMS, David A., NUTTALL, Brandon C., MEGLLEN, Joseph F., HUMPHREYS, Matthew, CHEN, Mara, WATSON, Anna E., and WALKER, Dan

The various 1:250,000-scale sheets of the "Oil and Gas Map of Kentucky" are out of date and are being updated. Sheets 3 and 4 are currently being generated at a scale of 1:100,000; the first map, the Pikeville Quadrangle, is expected to be published as part of the Map and Chart Series in 1993. The Williamson Quadrangle is currently being compiled. Sheets 1 and 2, which show the location and areal extent of oil and gas in western Kentucky, have been revised at the scale of 1:250,000 and will also be made available during the year. All oil and gas maps will ultimately be incorporated into the 1:500,000-scale State map.

The index to field names that was compiled and published as Information Circular 27 is being revised and updated. These data will form the basis of a pool information data base, organized by geological plays, that will be provided to the U.S. Department of Energy as part of the Gas Atlas Project. The data will also be useful for the TORIS part of the Gas Atlas Project.

Drill Cutting and Core Samples

COMPUTERIZATION OF CORE REPOSITORY DATA

GOODING, Patrick J.

The primary goal of this project was to establish a computerized data base containing an index of all cores available for public use at the KGS Core Repository. Over 70,000 core boxes, representing about 700,000 feet of vertical drilling, were individually inspected, and an inventory list was compiled.

A catalog of cores available for public inspection at the Core Repository will be published as an Information Circular during the coming year.

Water Resources

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

Over the past 20 years not less than 10 Federal acts have been enacted to protect water. During this time, State regulatory agencies developed programs dealing with mining and mine reclamation, solid and liquid waste disposal, sewage disposal, water supply, oil and gas recovery, and agricultural practices. Over this past year, the State has concentrated on developing ground-water regulations to protect this vital resource. An understanding of the geology and hydrogeology of Kentucky is essential for development of these regulations and the optimum development, utilization, and management of the State's water resources. The Water Resources Section provides information to municipalities, industry, State and Federal agencies, and private citizens concerning the occurrence, movement, quantity, and quality of surface and ground water in the State.

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

Urban and rural economic development is tied to the availability of water. The effect of land use on water quality and quantity is also an important factor in economic development because of regulatory policies. Therefore, basin-hydrology research is essential for future economic development in the Commonwealth. This type of research requires comprehensive data bases for both ground water and surface water. Data for surface water are collected in a cooperative program with the Kentucky Division of Water and the U.S. Geological Survey (*see* Cooperative Programs, Water Resources); development of a ground-water data repository was in its initial stage during this past year.

In order to achieve its mission during the past year, the Water Resources Section has conducted research in cooperation with the Kentucky Cabinet of Natural Resources and Environment Protection; various groups within the University of Kentucky including the College of Agriculture, Institute for Mining and Minerals Research, College of Engineering, and Department of Geological Sciences; and several Federal agencies including the Soil Conservation Service and the U.S. Geological Survey.

Water Resources programs can be divided into four areas: Coal-Field Hydrology, Karst Hydrology, Water Quality, and Basin Hydrogeology. The following summaries describe the results of research projects conducted during the 1992-93 fiscal year.

Coal-Field Hydrology

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

WUNSCH, David R., DINGER, James S., CAREY, Daniel I., and GRAHAM, C. Douglas R.

The economy of eastern Kentucky is highly dependent on the coal-mining industry. Coal production in the Eastern Kentucky Coal Field has increased, while mining-related jobs have declined 30 percent during the past decade. Cyprus Mountain Coals, a subsidiary of Cyprus Minerals, Inc., owns the 17,000 acres at the Star Fire surface mine, located in Knott, Perry, and Breathitt Counties. The company has an interest in the post-mine development of the property and is presently planning for alternative land uses after mining has been completed.

Economic growth and diversity in the coal field are severely limited, in part by the steep topography and the lack of water resources. An estimated 10,000 acres of usable flat land will be created by the year 2010 at the Star Fire site through mountaintop-removal techniques, thus providing a site for new land uses and future economic development. KGS has been awarded a research grant to conduct ongoing studies for definition and development of the water resources at the site, which will be vital for the successful development of the site.

Data collected from surface-water monitoring stations, infiltration/percolation tests, and precipitation at the site have been collected to aid in the calibration of the surface hydrology model SEDIMOT II. Better calibrated models will help the mining industry with reclamation and compliance plans.

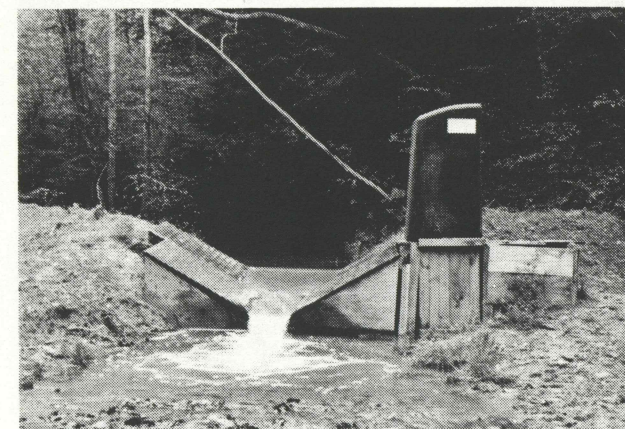
Spring and surface-water discharges have been measured using weirs and hand-held flow meters. A v-

notch weir equipped with digital data-recording capabilities was installed to monitor continuous surface-water outflow from the mine site, which will aid in determining the hydrologic budget. Data collected over 255 days showed an average mine discharge of 6.6 cubic feet per second, which is equivalent to about 4 million gallons per day.

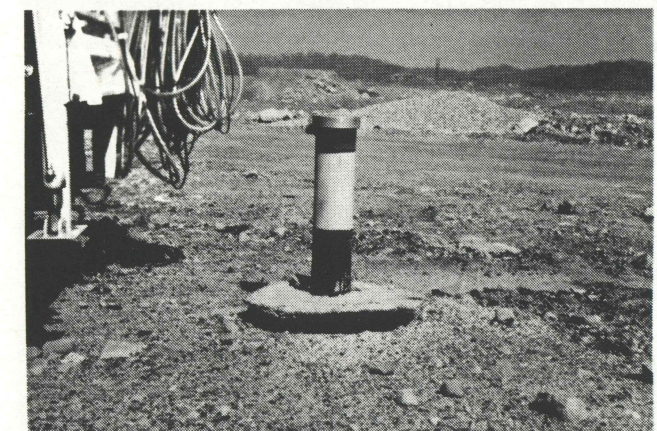
Data interpreted from the 14 monitoring wells at the site indicate a zone of saturation exists at the base of the spoil that averages 21 feet in thickness and stores an estimated 1.4 billion gallons. Slug tests were performed in individual wells to determine the hydraulic characteristics of the saturated portion of the spoil. Hydraulic conductivity (K) values ranging from 2.0×10^{-6} to more than 2.9×10^{-5} were calculated for the spoil surrounding the wells.

Spoil surface subsidence measured around the surface seals of the monitoring wells reveals that subsidence is occurring throughout the spoil area. Some areas are subsiding at a maximum rate of 0.4 foot per year.

Water samples are collected for chemical analysis on a semi-annual basis from the monitoring wells and major springs that crop out at the spoil's periphery. Wells located in the hollow-fill areas were found to be more responsive to precipitation events and contain water that is less concentrated in dissolved constituents compared to wells located in the main spoil body. The analysis of water samples from all areas of the site reveal that the major dissolved constituents are calcium, magnesium, and sulfate. Geochemical data reveal that the ground water in the interior of the spoil is near equilibrium or saturated with respect to gypsum. Ground water in the hollow-fill areas is undersaturated with respect to gypsum, probably because of dilution.



Flume on Long Branch at Star Fire site.



Separation between cement seal and ground surface is evidence of mine-spoil subsidence.

The interpretation of hydrological, hydrogeological, and geochemical data has led to the construction of a conceptual model of ground-water flow at the site. Future plans call for verifying the model with mass-balance calculations of geochemical and hydrological data. Plans for the implementation of a spoil surface subsidence monitoring network are also being initiated.

A report titled "Design, Construction, and Monitoring of the Ground-Water Resources of a Large Mine-Spoil Area: Star Fire Tract, Eastern Kentucky" was published in 1992. Concepts and findings to date have been published in this report and in several symposium proceedings. A manuscript titled "The Hydrogeology and Hydrogeochemistry of a Large Mine-Spoil Area: Star Fire Site, Eastern Kentucky" has been prepared and is expected to be published by KGS in 1993.

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

WUNSCH, David R., KIPP, James A., CONRAD, Phillip G., KEAGY, Dwayne M., and DINGER, James S.

The Water Resources Section is conducting research to define natural background flow and chemical characteristics of ground water in the Eastern Kentucky Coal Field. Industries that operate in eastern Kentucky, including mining, oil and gas, and landfill operations, are in need of this information for permit applications. Therefore, the State must define ground-water flow and quality so that this resource may be monitored and used efficiently.

Previous ground-water-quality studies conducted in eastern Kentucky suggest that distinct geochemical facies are related to specific zones of ground-water flow. The Kentucky Geological Survey is searching for suitable sites in which to conduct hydrogeochemical studies

in order to interpret and define the interaction between ground-water occurrence and natural water quality. The objectives of this study are to (1) correlate the hydraulic characteristics of coal-bearing rocks with site geology, (2) characterize the occurrence, movement, and quality of ground water, (3) document the occurrence of trace elements and their relationship to specific ground-water types, and (4) gain a better understanding of the hydrogeologic characteristics of the area in order to initiate a meaningful ground-water monitoring scheme.

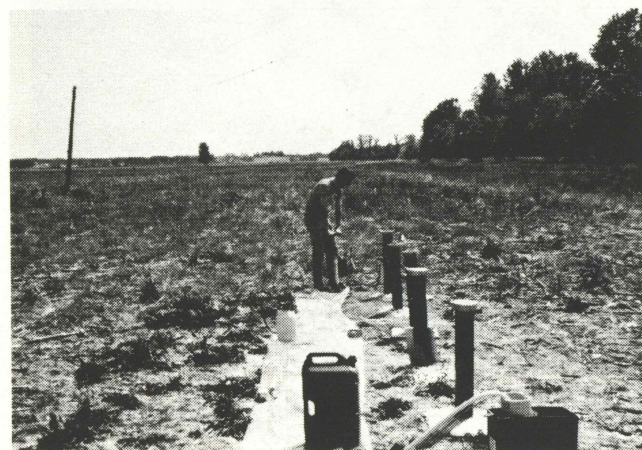
Data collection has been continuing at a site located approximately 1 mile south of the Star Fire Mine in Perry County. Sixteen piezometers have been installed to obtain ground-water head measurements and water samples from units at various depths. Monthly water-level measurements and bi-annual collection of water samples for chemical analysis has been continuing. Data collected at this site will augment our knowledge of the geochemistry of ground water in eastern Kentucky and supplement data necessary for the creation of conceptual ground-water geochemical models for the Eastern Kentucky Coal Field.

Monthly water-level data and water-quality samples were taken from the monitoring wells installed at the University of Kentucky's Robinson Forest. Robinson Forest contains some of the largest undisturbed tracts of land in eastern Kentucky. Ten piezometers have been installed to augment other ongoing data-collection programs. These data will also be used to validate the interpretations and conceptual models derived from data collected at other sites.

Constant-head pressure-injection tests were performed at several sites in the Eastern Kentucky Coal Field. These detailed tests document the ability of rock



Field sampling and analysis at ground-water monitoring wells.



Collecting ground-water samples.

units to transmit water. These data are currently being summarized to describe the hydraulic characteristics of Pennsylvanian rocks and provide insights into the complex movement and occurrence of ground water in the region. A draft report describing these conditions is currently in preparation.

The Kentucky Geological Survey, supported by the Kentucky Division of Abandoned Lands, conducted studies from 1989 to 1992 to evaluate the impact of past mining on ground-water resources at three locations in eastern Kentucky. The nature and extent of the perceived water-quality and -quantity changes were documented through literature review, resident interviews, and water-sample collection and analysis. Project completion reports were subsequently prepared and provided to the Division of Abandoned Lands. Detailed evaluations of these data were beyond the scope of the original contract with the Division of Abandoned Lands. As a result, descriptive reports of the comprehensive data-collection efforts for these studies are currently being planned. It is anticipated that a more thorough analysis of the data will supplement the information used to create conceptual models for natural and mine-influenced ground-water conditions in eastern Kentucky.

Data and models generated from these ground-water studies will be valuable to regulatory agencies and the industries they regulate for permit requirements, definition and protection of aquifers, and will add to the knowledge concerning evolution of ground-water types in the Eastern Kentucky Coal Field.



Collecting ground-water samples from monitoring wells in Robinson Forest.

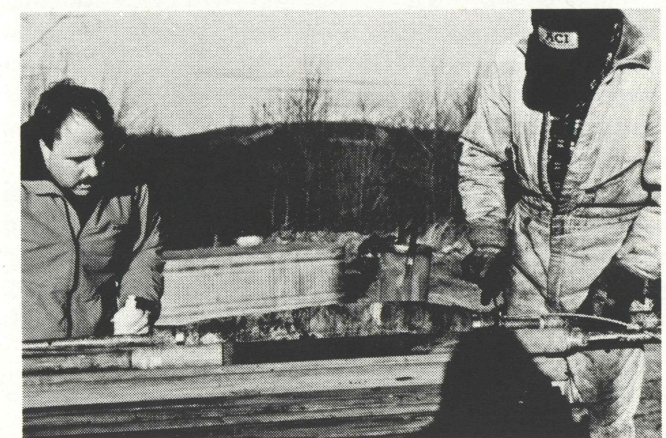
EFFECTS OF DEEP COAL MINES ON HYDROGEOLOGY

KIPP, James A., MINNS, Shelley A., DINGER, James S., and CAREY, Daniel A.

The purpose of this project is to evaluate subsidence-related deformation and associated hydrologic changes that occur at an active longwall coal mine in rugged eastern Kentucky. In longwall mining, a working face several hundred feet in width is advanced between parallel headings, producing a series of large, rectangular, mined-out panels. The face is temporarily supported during extraction of the coal by movable hydraulic jacks. As these supports advance with the face, the beam strength of the immediate roof and the stable arch width of the main roof are deliberately exceeded. The unsupported roof normally fractures into blocks that collapse into the mined-out area. The remaining overburden then settles onto this rubble. The ground subsides over the mine if the ratio of extracted area to depth is high enough to transmit strata movement to the surface.

The study site selected for this investigation is located on Edd Fork near Helton in Leslie County. Three cores were initially drilled (ridge-top, valley-side, and valley-bottom positions) to provide stratigraphic information for the site. Pressure-injection testing was also conducted in each core hole in 10-foot intervals using inflatable packers to isolate the test sections. The resulting data provide documentation of the pre-mining hydraulic characteristics of the rocks over the area to be mined. Coaxial cables were later grouted into the three core holes. These cables will be monitored using Time Domain Reflectometry to evaluate rock deformation that occurs in response to mining and subsidence.

Information from the core holes was also used to design 24 ground-water monitoring wells that were installed during the summer of 1992. Initial water-level data from these wells and the results of water-quality sampling indicate the presence of complex ground-wa-



Testing for packer leaks.

ter flow and hydrogeochemical systems. These conditions are commonly encountered throughout the Eastern Kentucky Coal Field. A flume and rain gage were also installed to measure the discharge of Edd Fork and to collect precipitation data in the study basin. All of the instrumentation was in place in time to collect at least 1 year of data prior to mining of the selected panel in 1994. Current plans are to continue monitoring prior to, during, and after mining of the coal. Installation of monuments to measure surface subsidence is also planned for the coming year.

This study is a cooperative effort with the U.S. Office of Surface Mining, the Kentucky Department of Surface Mining Reclamation and Enforcement, the UK Department of Geological Sciences, the UK Institute for Mining and Minerals Research, and the coal industry. A doctoral dissertation entitled "Conceptual Model of Local and Regional Ground-Water Flow in the Eastern Kentucky Coal Field" was completed using data gathered in this project and data collected from other projects over the past 10 years.

Karst Hydrogeology

KARST HYDROGEOLOGY

CURRENS, James C., KEAGY, Dwayne C., HARMON, David L., GRAHAM, C. Douglas R., and DINGER, James S.

Karst areas of the State constitute one of the most important hydrogeologic provinces in Kentucky because over half of the Commonwealth is underlain by carbonate rocks with some karst development, and approximately 25 percent of the State can be characterized as having well-developed karst ground-water flow. Most of the karst areas are rural, where most residents depend on wells for their individual water supplies, and many community supplies in this region are dependent upon large springs that are a result of karst hydrology. Karst conditions also exist under several of our metropolitan areas, including Louisville, Lexington, and Bowling Green. A thorough understanding of the hydrogeology of these regions is essential for protection of those water supplies because aquifers in karst terrane are easily contaminated by pollutants flowing into sinkholes and moving quickly through open conduits and discharging into streams and rivers. Such rapid movement also leads to flooding, which can cause considerable damage in urban areas.

During the past year work has continued on entering published and new data into the KGS Hydrologic Data Base (formerly known as the Kentucky Aquifer Research Data Base [KARD]). Such data include ground-

water dye traces, potentiometric surface maps, water-quality data, cave maps, and water levels in wells. The eventual products of this work will include ground-water basin maps, flow analyses, and water-quality maps. The ground-water basin maps are being compiled in cooperation with the Kentucky Division of Water, Ground-Water Branch.

Monitoring-equipment installation, data collection, and data analysis have continued from last year at non-point-source pollution studies in several unique karstic hydrogeologic settings. Field work is in coordination with the other nonpoint-source pollution studies being conducted in granular and bedrock aquifers, and is being conducted in cooperation with the University of Kentucky's College of Agriculture, Institute for Mining and Minerals Research, and Department of Geological Sciences, and the Kentucky Natural Resources and Environmental Protection Cabinet. Intensive field work has been conducted in Logan, Jessamine, Bourbon, and Woodford Counties:

A study in *Jessamine County* was prompted by severe flooding that occurred throughout Kentucky in February 1989. The flooding of sinkholes and karst valleys was widespread, and Sinking Creek karst valley in northwestern Jessamine County remained flooded through late March and early April. One home was damaged extensively, roads were blocked for extended periods of time, and other property was threatened. A report on the flooding of Sinking Creek karst valley in the Garretts Spring drainage basin, Jessamine and Woodford Counties, was completed in the late fall of 1992 and submitted for review. The report explains the hydrology of the cave conduits carrying water from Sinking Creek to Garretts Spring and the conditions leading to flooding in Sinking Creek karst valley. A computer model predicts flood response of the area under varying land-use and precipitation conditions. Relative merits of several possible solutions to flooding are discussed. Although KGS has continued to monitor stream and spring flow in the basin, no further studies are planned. Because this project is in cooperation with the University of Kentucky College of Agriculture, plans are being made for the College to continue the operation of stream-gaging equipment installed by the Geological Survey.

The *Bourbon County* study area is unique in that two different karst systems are suspected to be controlling ground-water movement. One system may be related to conduit flow, while the other may represent epikarst ground-water movement where the majority of flow takes place along the soil-bedrock interface. One site is a cattle pasture area and the other is a corn field. Ground-water dye tracing continued at both sites. At the pasture site, water-quality monitoring has been initiated

at two springs, five lysimeters have been installed to bedrock, 10 shallow monitoring wells have been installed into bedrock, and one deep monitoring well has been installed in a sinkhole drilled to local stream base level. At the corn field, three springs are being monitored in conjunction with nine lysimeters installed to bedrock and 14 shallow monitoring wells drilled into bedrock. Both sites are being monitored for pesticides, nutrients, and cations and anions associated with natural ground water.

The goal of the *Logan County* study is to determine the current level of pesticides and nitrate discharging from the karst aquifer at Pleasant Grove Spring. Based upon results obtained from this study, a variety of agricultural changes in the basin will be recommended. Then, expected improvements in water quality resulting from the new practices will be monitored. If improvement in the ground-water quality cannot be demonstrated on a basinwide scale in a real-world setting, then the effectiveness of the implemented practices will be re-evaluated. Mapping of the drainage basin by ground-water dye tracing was delayed another season because of continuing dry conditions from spring 1992 into winter 1992-93 (8-inch deficit for 1992 and 2.8-inch deficit for first 3 months of 1993). However, a water hauler was hired, and with the help of some late winter storms, 14 traces have been conducted since December. This completes the ground-water dye tracing except for some optional traces and two to four quantitative traces planned for late spring and next fall. In addition to defining the karst ground-water basin, the tracing has revealed a trellis pattern to the underground drainage network, which will be defined in detail by the quantitative traces. This information is extremely valuable for interpreting the chemical data being gathered at Pleasant Grove Spring. A rain gage and other meteorological monitoring equipment are now in place at Pleasant Grove Spring. Additional equipment installation at two to four upstream sites, and the resumption of sampling at these sites is planned for summer and fall of 1993. The water-quality and discharge monitoring equipment at Pleasant Grove are working well. The quantities of data generated by this equipment are massive, and they will be entered into a special data base so they may be easily reviewed and interpreted. Detailed mapping of crops in the basin, and an inventory of domestic water wells is planned. The synoptic monthly sampling of six sites in the study area ended in June 1991. Monthly sampling at Pleasant Grove Spring will continue until June 1993. In

addition, samples are being gathered for analysis of less extensive suites of constituents at Pleasant Grove Spring during storm events and between monthly samples. Since July 1, 1992, eight monthly, 13 semi-weekly, 76 storm-event, and two rain-water samples have been collected. In the Pleasant Grove Spring drainage basin, atrazine herbicide is used extensively and is the most common pesticide found in the ground water. Other pesticides are found occasionally at low concentrations. The highest atrazine concentrations occur a few weeks after application and peak during spring storm events. Although concentrations are generally below standards for drinking water, not enough samples have been obtained during spring storms to set an upper limit on possible concentrations. Nitrate continues to be the most ubiquitous contaminant, and concentrations are above values reported for non-agricultural areas. Although the nitrate concentrations are also below drinking-water limits, they do not seem to significantly decrease in the winter. This observation needs further investigation. Other analytical work is planned, including additional bacteriological studies, and possibly nitrogen isotope analysis to identify the source of the nitrate.

The *Woodford County* site is a farm that belongs to the University of Kentucky. As such, farm practices can be controlled to facilitate research goals and at the same time provide for developing effective agricultural practices. Initial reconnaissance indicates that this site is hydrologically unique in that two predominant karst systems seem to be operating at the farm. One system, perched on the Brannon Member, causes many springs to exist on the valley walls above regional base level. The second is a deeper, more highly developed karst system with larger conduits, represented by fewer but higher capacity springs. The sources of these springs are off the farm, as indicated by dye tracing and their different water quality. Complete background analyses have been run on 13 springs and two streams on the farm property. Sampling has been predominantly for pesticides applied to the corn and tobacco that have been raised on the property prior to this year. Thirteen monitoring wells and eight lysimeters have been installed to study ground water in corn-field, tobacco-field, and pasture settings. Nine weirs have been installed to measure stream flow on the farm and as points to sample surface-water quality. This research is being carried out in direct cooperation with the Kentucky Division of Conservation and the U.S. Soil Conservation Service.

Water-Quality Research

IMPACT OF NONPOINT-SOURCE POLLUTION ON AQUIFERS AND SURFACE WATER

CAREY, Daniel I., CONRAD, Philip G.,
CURRENS, James C., DINGER, James S.,
HARMON, David L., and KEAGY, Dwayne C.

Section 319 of the 1987 Federal Clean Water Act regulates a large variety of pollutants that enter waters by sources other than single-point discharges. This type of pollution is called nonpoint-source (NPS) pollution and includes contaminants from sources such as agriculture, construction, forestry, mining, septic-tank wastes, and urban storm runoff. In response to the Federally mandated program to measure and mitigate the effects of NPS pollution, the Kentucky Division of Water has developed a program, and the Kentucky legislature has provided funds to the University of Kentucky College of Agriculture to investigate the effects of agricultural practices on ground water in Kentucky. The Kentucky Geological Survey is participating in both of these programs by conducting hydrogeologic investigations.

Modern agricultural practices rely on the use of pesticides, herbicides, and insecticides to increase crop yields. In addition, agricultural practices such as the construction of feed lots and waste lagoons concentrate animal wastes, leading to potential contamination of aquifers. In many instances these aquifers are potable water for the region and serve as sources for irrigation and livestock watering. At present, KGS is investigating 10 sites in coordination with the University of Kentucky's College of Agriculture, Department of Geological Sciences, and Institute for Mining and Minerals Research, and the Kentucky Natural Resources and Environmental Protection Cabinet. Major emphasis this past year has been placed on sites in the counties of Jessamine, Woodford, Bourbon (see Karst Hydrogeology above), Daviess, Hopkins, Logan, and Hickman Counties (see below for details). These sites represent diverse hydrogeologic settings, in which the movement and fate of agricultural chemicals may vary greatly. In addition, Survey staff members serve as technical representatives to the Ground-Water Education and Rural Water Testing Program, which is co-sponsored by the UK College of Agriculture, Kentucky Divisions of Water and Conservation, and Kentucky Farm Bureau Federation, Inc.

The Ground Water Education and Testing Program was conducted from 1989 to 1992; 4,862 wells in 108 of Kentucky's 120 counties were tested. Samples were tested for ammonia, nitrite-nitrogen, nitrate-nitrogen, chloride, sulfate, conductivity (dissolved solids), ala-

chlor (Lasso), and triazine (atrazine). A summary of the data will be presented in the KGS publication "Quality of Domestic Well Water in Kentucky," which is being prepared for publication.

Ground-water quality is being studied in a small drainage basin (approximately 1 square mile in area) in Hickman County. This site was chosen because of its extensive cultivation with row crops and use of fertilizers and pesticides, its geology (loess, continental deposits, and semi-consolidated sandstone, which is representative of much of the Jackson Purchase Region), and the use of ground-water supplies by residents. Samples from domestic wells collected on a monthly basis have been analyzed for standard ions, nitrate, and pesticides. Four domestic wells have been instrumented with air lines to measure water levels. Eleven 1-inch-diameter wells have been installed ranging in depth from 5 to 75 feet to measure ground-water levels and sample soil water and ground water. Two 4-inch-diameter monitoring wells have been installed to depths of 27 and 119 feet, the deeper of which is typical of the depth and construction of most local domestic wells. Two suction lysimeters have been installed to collect ground water from above the saturated zone. Samples from the monitoring sites have been collected on a bi-monthly basis from October to April, with twice-monthly sampling beginning in May, to record changes during the growing season when nutrients and pesticides are applied. Pressure transducers have been installed in the 4-inch-diameter wells to measure water-level fluctuation on a continuous basis. A chloride tracer was used to study the timing of surface recharge to the soil- and ground-water systems.

Ground-water quality is being studied in a tilled farm field in Hopkins County that has been planted in corn for most of the last 30 years. This farm represents outlying areas of the Western Kentucky Coal Field, while the Da-

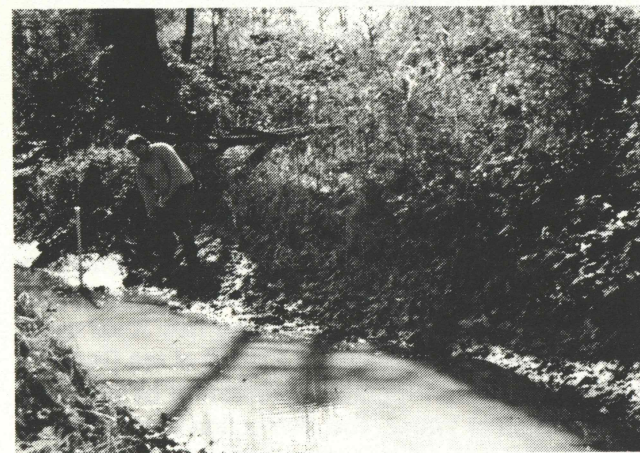


Well nest and rain gage in Hickman County.

viess County site (see below) represents farms nearer the center of the coal field. The geology of the site consists of lacustrine deposits of silt and clayey silt above a sandstone, shale, and coal bedrock at a depth of 28 feet. Tile drains discharge into a local creek whose bottom is approximately 10 feet below the farmed-land surface. Nine ground-water-monitoring points, ranging in depth from 5 feet to 28 feet, and one suction lysimeter were installed. Water samples were collected twice per month from mid-May through June and were analyzed for nutrients, pesticides, and common ions found in ground water. Samples were collected bi-monthly during the non-growing season.

Ground-water quality is being studied in a no-till farm field and a nearby wooded lot in Daviess County. This is one of two farm sites currently studied that represent the Western Kentucky Coal Field, the other site being in Hopkins County (see above). The geology of the farm and wooded sites consists of lacustrine deposits of clayey silt and clay above a shale, sandstone, and coal bedrock that lies 23 to 40 feet below the surface. The farm is tile drained and local drainage ditches are about 6 feet deep. Eleven ground-water-monitoring points were sampled on a bi-weekly basis during the growing season and a bi-monthly basis during the remainder of the year. Depths of the nine monitoring wells range from 2 to 70 feet, and one suction lysimeter was installed at a depth of 5 feet. Six additional monitoring wells and a suction lysimeter are monitored in the center of a nearby wooded area for comparison with ground-water quality at the farm field.

Water-quality sampling and analyses are being conducted in Fleming, Russell, and Shelby Counties by the University of Kentucky Agronomy Department, and the data are being evaluated by the study team.



Sampling ground-water quality below a stream in the Jackson Purchase Region.

See Karst Hydrogeology above for information on Bourbon, Jessamine, Logan, and Woodford Counties.

EFFECTS OF RIPARIAN VEGETATION ON WATER QUALITY: MODELING AND EXPERIMENTAL STUDIES

FOGLE, Alex W., and CAREY, Daniel I.

Riparian vegetative filter strips (VFS's) are one of the most frequently cited technologies to control nonpoint-source pollution of surface waters resulting from agricultural practices. Recent studies show that trapping of sediment and dissolved solids is much less than would be expected according to existing idealized VFS models. Part of this discrepancy can be attributed to the channelization of flow in the VFS. Physically based models that can be translated from one physiographic and climatic region to another are needed to predict the impact of channelized flow in VFS's on trapping of sediment, nutrients, and agricultural chemicals.

The objectives of this project are to (1) characterize the movement of sediment and dissolved solids through naturally occurring VFS's, accounting for natural variation in microtopography and channelized flow, (2) characterize the movement of dissolved solids into the vadose zone of VFS's in karst regions, and (3) develop predictive models to evaluate the impact of VFS's on water quality.

Six test filter strips located on UK's Spindletop Farm were selected for study in 1990. These filter strips were located immediately downslope of erosion plots established in 1989. The erosion plots were identical in size and consisted of three conventional tillage plots and three no-till plots. The filter strips ranged in length from 15 to 45 feet, with each length of strip duplicated below a conventional and no-till plot. Each filter strip's microtopography was determined over a 6 inch by 1 foot grid.

Twelve test runs were conducted on the six plots in 1991. Each test was designed to simulate natural rainfall occurring on a field subjected to common agricultural practices. Rainfall was applied at a rate of 2.5 inches per hour for a long enough period to produce 2 hours of runoff from the erosion plots to the grass filters.

Runoff onto and from the VFS's was sampled approximately every 5 minutes. These samples were analyzed to determine runoff rate, sediment concentration, sediment particle-size distribution, and concentrations of atrazine, ammonium nitrogen, nitrate nitrogen, and phosphorus. Inflow and outflow hydrographs and sediment graphs were also developed.

All filter strips trapped more than 90 percent of the sediment introduced to the filters, regardless of filter length and tillage practice. The filters also trapped more

than 90 percent of atrazine and nitrogen introduced from the erosion plots. Phosphorus trapping efficiency exceeded 85 percent for all filters. The best control was obtained with 30-foot filter strips below no-till plots. It was expected that the 45-foot strips would perform better than the 30- and 15-foot strips, but extreme channelization was observed on the 45-foot strips, which considerably reduced the area subjected to runoff.

A model of filter-strip channelization, sediment transport, and trapping has been developed. The model performs very well in predicting the trapping efficiencies of the six test filter strips.

This project is being conducted in cooperation with the departments of Agricultural Engineering and Agronomy at the University of Kentucky. A KGS publication is currently under review, and a journal article entitled "A Low Head Loss Sampling Device for Monitoring Inflow to Natural Vegetated Filter Strips" is in press in the Transactions of the American Society of Agricultural Engineers.

DETERMINISTIC MODEL OF CHANNEL HEADWALL EROSION: INITIATION AND PROPAGATION

FOGLE, Alex W.

Upland erosion from rill and inter-rill areas has been the subject of intensive investigations in the past. These investigations have been both empirical and physically based. To date, however, no complete channel erosion models have been developed for small upland streams. The emphasis in this project was on modeling the initiation and propagation of headcut erosion on small upland streams with intermittent or small base flows.

Models were developed or gleaned from the literature that predict channel erosion resulting from shear in gradually varied flow, shearing forces resulting from submerged and partially submerged jets, and shearing forces resulting from free jets impinging upon a plunge pool. These models were linked with a runoff routing algorithm and a pseudo-three-dimensional channel geometry model to develop the CHANNEL model. CHANNEL predicts general channel erosion resulting from time-varying flow, as well as the development and propagation of channel headwalls.

Development of all algorithms of the CHANNEL model was completed. CHANNEL has been alpha-level tested to some degree, but model testing was halted due to lack of funding. The free-jet profile and overfall shear stress distribution components of the model were tested with data collected both here at the University of Kentucky and at the U.S. Department of Agriculture Plant Science and Water Conservation Laboratory in

Stillwater, Oklahoma. These components appeared to perform well in comparison with the data.

The CHANNEL model makes predictions of changing channel geometry due to erosion and deposition. It also predicts stream-flow sediment load with space and time. The model works reasonably well in scenarios where the headwall is forming or after the headwall is formed and begins to propagate upstream. The model has problems with numerical difficulties in cases where the scour hole is in transition from a submerged jet to a free jet. These difficulties were not resolved before funding ended.

A paper detailing the free-jet profile and overfall shear stress distribution components of the CHANNEL model is currently in review for publication in Transactions of the American Society of Agricultural Engineers. The project final report has been submitted to the Kentucky Water Resources Research Institute for publication, and upon publication the project will be ended.

The project was conducted cooperatively with the University of Kentucky Department of Agricultural Engineering and was funded by the U.S. Army Research Office.

PRODUCTION OF FRESH WATER FROM THE KNOX GROUP IN CENTRAL KENTUCKY

KIPP, James A.

A few deep wells (800 to 1,000 feet deep) produce fresh water in central Kentucky. These wells are generally completed in the top of the Cambrian-Ordovician Knox Group. The purpose of this investigation is to describe the Knox aquifer in central Kentucky, and to identify areas where it may represent a potential source of rural domestic drinking water. The primary objectives are to (1) identify areas where the Knox has been demonstrated to contain potable water, (2) review available information on hydraulic characteristics so that the quantity of water potentially available from Knox wells can be estimated, and (3) evaluate water movement in the Knox, including the identification of possible recharge and discharge areas and the direction and potential rate of water movement.

The Kentucky Geological Survey, because of the great expense of drilling wells to the Knox, has historically relied upon well drillers and their customers to identify Knox water-supply wells for testing and water-quality sampling. Since 1985, data for new Knox wells have also become available as a result of the Certified Water Well Drillers Program administered by the Kentucky Division of Water. The distribution and quality of the available information is still quite limited, but interest in the Knox aquifer remains because short-term variations in quantity and quality are less likely in this deep

formation than in the near-surface karst aquifer that is more commonly used for rural domestic water supplies in central Kentucky. A summary of the currently available information is being developed into a KGS report titled "The Knox Aquifer in Central Kentucky." The preliminary draft of this report has been completed, and preparation of the final document is in progress.

Basin Hydrogeology

RECONNAISSANCE OF GROUND WATER IN THE KENTUCKY RIVER BASIN

CAREY, Daniel I., CURRENS, James C., DINGER, James S., KIPP, James A., WUNSCH, David R., and CONRAD, Philip G.

A number of studies on ground water in the Kentucky River Basin have been completed in recent years. These studies have covered such diverse topics as the effects of oil production on water quality, the occurrence of high barium concentrations in ground water of eastern Kentucky, ground-water geochemistry in Eastern Kentucky, a reconnaissance of ground-water supply resources, production of fresh water from the Knox Group, and the quality of domestic well water. A summary of KGS research and data from local, State, and Federal sources is being developed into a KGS report, "Ground Water in the Kentucky River Basin." The report will provide a comprehensive look at what we know about ground water in the basin. It will provide up-to-date information on ground-water use and the potential for developing additional ground-water supplies. The report will also overview ground-water quality, and include an examination of human activities that may threaten ground-water resources, and discuss contaminants that occur naturally in the basin.

The report is nontechnical, but will contain an extensive bibliography of ground-water references for technical readers. A draft report is currently in preparation.

WATER RESOURCES PLANNING AND MANAGEMENT IN THE KENTUCKY RIVER BASIN

CAREY, Daniel I.

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

Spatial data at a Statewide and basin level on soils, hydrology, water quality, demographics, oil production, and political subdivisions were entered into the GRASS 4.0 geographic information system at the Survey. These data and the GIS were used in support of two ground-water studies. The development of a spatial data base using existing sources will continue.

HYDROLOGY OF MINED WATERSHEDS

CAREY, Daniel I.

Surface-water monitoring stations have been installed in four watersheds in different areas of eastern Kentucky in support of basin hydrogeology studies. The station on Edd Fork in Leslie County, a watershed of less than 200 acres, provides data to support hydrogeologic studies on the impact of underground mining. The station on Long Fork in Knott County provides data to support evaluations of water resources and post-mining development.

Two monitoring stations have been installed on adjacent small watersheds in the University of Kentucky's Robinson Forest. These stations will collect flow and water-quality data to support an evaluation of the impacts of mining on surface water and ground water in the area.

COMPUTER AND LABORATORY SERVICES

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

Computer Services

A building-wide network allows KGS to connect various mini-, desktop, and personal computers. This versatility allows many types of operating systems to exchange information. The network in the building has also been bridged to the UK Network (UKnet), which, in turn, is linked to most of the National networks.

KGS's six-node Local Area VAXcluster (LAVc), which is an operating environment specific to Digital Equipment Corporation's (DEC) VAX computers, consists of a VAX 8550, MicroVax II/GPX color-graphics workstation, VAXstation 4000 model 60, VAXstation 4000vlc, VAXstation 2000 workstation, and VAXstation 3100. In addition, various MS-DOS-based personal computers perform functions such as Computer Aided Design (CAD), presentation graphics, scanning, and other extraordinary tasks that cannot be accomplished on other computers. Peripheral equipment includes large-format plotters and digitizers, high- and medium-speed printers, and long-document scanners. Software includes data-base and report-writing facilities, wordprocessing and desktop publishing, geologic modeling, and computer-aided drafting and presentation graphics.

CONFIGURATION OF A PERSONAL COMPUTER LOCAL AREA NETWORK

During the year, KGS began fully integrating its growing number of personal computers into the Local Area Network (LAN). Because KGS primarily uses DEC equipment, DEC's PathWorks LAN was chosen; it also had the advantage of being compatible with several server and desktop client operating systems (i.e., DEC VMS and ULTRIX, SUN UNIX, PC DOS, UNIX, OS/2, and MACINTOSH OS).

The LAN was implemented in 5 months, and although still being tested, works well. Users can access the various PC products from any networked PC, and at the same time obtain data from the KGS data base on the VAX. Windows technology allows users to operate multiple sessions at once and copy data from one window to another with the click of a mouse button. In addition, future upgrades will enable users to automatically

transfer data. The PC user also has access to all peripheral equipment (printers and plotters) connected to the network.

DEVELOPING A GRAPHICAL INTERFACE WITH THE KGS DATA BASE

To improve the general public's access to KGS data, KGS is experimenting with a PC-based graphical user interface. Using a software called SPASE, licensed from GEOTech Computers, KGS is building a simple interface that will allow the public to quickly find the information they need with little or no help from KGS staff.

SPASE uses maps that are linked to the data base. Users can "click" on an area of interest, enlarge it, and see the details of that area. They can also zoom in on a particular data point, from which a corresponding list of information can be shown on the screen. Conversely, they can search the data base for specific information, get a list, then use the map to graphically view those data's areal distribution. Users can also view and print scanned images of the archived well records associated with the data. A public demonstration of this software is scheduled in July 1993.

A side benefit of SPASE is that it can create very accurate base maps, at any scale, which can be used in other applications. Researchers at KGS have been able to incorporate these base maps into their research projects.

A COMPREHENSIVE PUBLIC DOMAIN GEOLOGIC/HYDROLOGIC DATA BASE

The Survey has used relational data bases to provide the general public, researchers, government agencies, and consultants easier access to extensive computerized geologic/hydrologic data sets. This storage and retrieval system efficiently manages, retrieves, and manipulates these ever-expanding and diverse public-domain data sets.

Information on coal, ground water, surface water, and limestone is currently online and available for use. Extensive stratigraphic and petroleum data sets will be added during 1993. In addition, existing data sets continue to be enhanced and updated as a result of ongoing KGS research projects and solicited information from private industry and government agencies.

A major objective is to provide the public and KGS staff with a relatively simple method to access and use these data. To this end, a menu-driven, query-by-form user interface has been designed and implemented. It allows users to select various options from a series of menus. Data searches can be made by typing parameters directly onto a form and striking a single retrieve, or

"hot," key. Other hot keys link data on the current form to other forms (e.g., linking coal-thickness data to coal-quality data). Hard-copy reports and ASCII files can be generated easily by selecting the appropriate records and striking a single defined key. This easy-to-master interface allows users with little or no computer expertise to access and manipulate large, complex data sets without having to know programming languages, syntax, or formatting codes.

Laboratory Services

The KGS Laboratory facilities analyze the chemical and physical characteristics of water, rock, coal, oil and gas, and other natural resources. The laboratories make use of state-of-the-art automated equipment to provide researchers with the necessary data to complete their geologic and hydrogeologic reports. A detailed analysis of data files and available software has led to the development of a general-purpose Laboratory Information Management System (LIMS). LIMS was designed to meet the information-processing requirements of the laboratory, and keeps track of information such as sample login, data storage, quality assurance, auditing, and reporting of results.

The laboratory facilities at KGS include:

(a) for metals:

Inductively Coupled Argon Plasma (ICAP)
Flame Atomic Absorption (FAA) and Graphite
Furnace Atomic Absorption (GFAA)
X-Ray Fluorescence Spectrometry (XRF)

(b) for organics and pesticides:

Gas chromatographs with mass selective, flame ionization, electron capture, photoionization, electrolytic conductivity, and nitrogen-phosphorus detectors

Immunoassay for pesticides

Total Organic Carbon

(c) for mineralogy:

X-Ray Diffraction Spectrometry (XRD)

(d) for coal quality:

Proximate analysis—Leco MAC 400 Determinator

Ultimate analysis—Leco CHN 600

Total sulfur—Leco SC-444

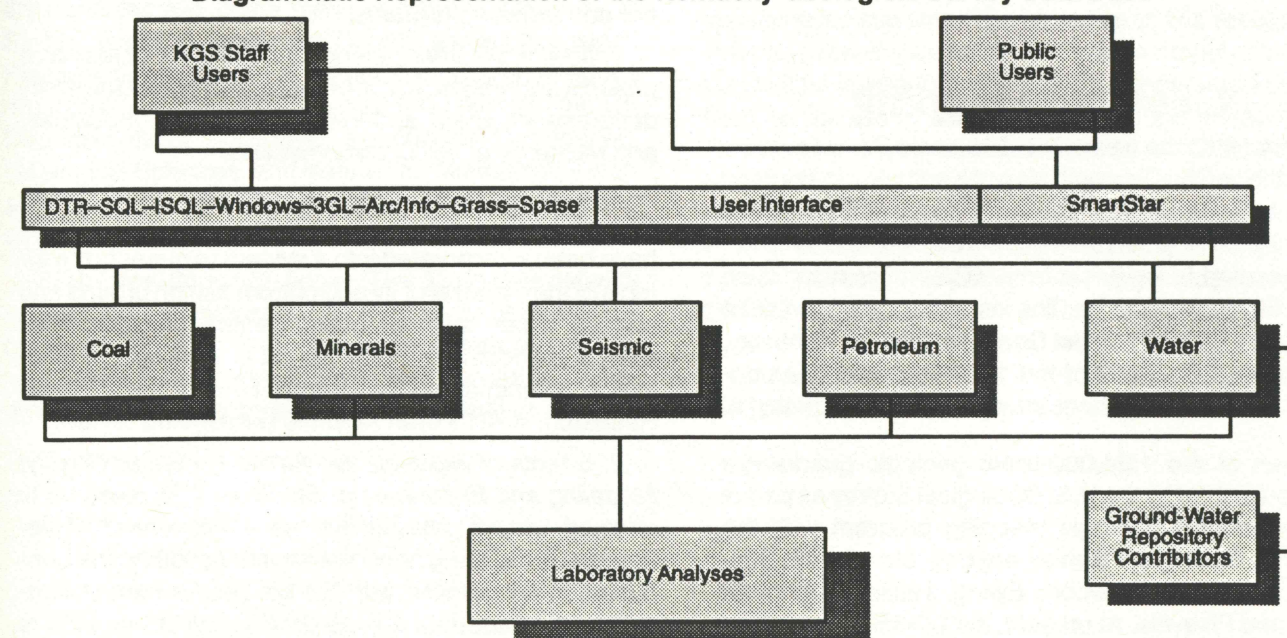
Calorimeter—Leco AC 300

Ash fusibility—Leco AF 600

During 1993, the Fuels Division of the Laboratory Services Section analyzed over 400 coal and mineral samples for coal quality and mineralogy. The laboratory also participates in the Interlab Network, a round-robin program operated by Standard Laboratories, Inc.

During the year over 500 water samples were received in the Water Division for the analysis of metals and other water-quality parameters such as acidity, hardness, inorganic anions, and dissolved and suspended solids. Over 50 samples were analyzed for pesticides by gas chromatography and immunoassay. The Water Laboratory participates in both the USGS Standard Reference Sample Program and the EPA Water Supply Laboratory Performance monitoring programs.

Diagrammatic Representation of the Kentucky Geological Survey Data Base



COOPERATIVE PROGRAMS

Topographic Mapping

The Kentucky Geological Survey has participated in an ongoing cooperative program with the U.S. Geological Survey for topographic map revision in the State since Kentucky became the first major state to be entirely mapped topographically at a scale of 1:24,000 more than 35 years ago. This program is designed to maintain revised and up-to-date maps for all areas of the Commonwealth.

Revision of the Elizabethtown Quadrangle in 1991 marks the first topographic map in Kentucky to be reproduced from digital data. This quadrangle was completely revised, the separated map components were digitized, and new maps were printed using the digital information.

Fifty-one newly revised 7.5-minute-quadrangle topographic maps were received during the 1992-93 fiscal year. Of these, 48 maps were standard updates, which include field checking and limited revisions of contours. Three maps were limited updates, which involve making changes that can be observed on aerial photographs, but no contours are changed and no field checking is done.

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

Geologic Mapping

In late 1992, the new 1:500,000-scale Sesquicentennial Edition of the Geologic Map of Kentucky was printed by the U.S. Geological Survey in cooperation with the Kentucky Geological Survey. This colorful and informative new map is available from KGS Publication Sales for \$6.00, plus postage. The new map was compiled from the 1:250,000-scale Geologic Map of Kentucky, printed in 1981. Stock of the 1981 map has been depleted, and currently there are no plans for reprinting it.

Seven of the 1:24,000-scale geologic quadrangle maps published by the U.S. Geological Survey as part of the cooperative geologic mapping program with the Kentucky Geological Survey are now out of print: Bristow, Cranston, Crestwood, Ewing, Hellier, Mammoth Cave, and Pikeville. At present, the USGS has no plans to reprint these maps.

Water Resources

As part of the University of Kentucky, KGS cooperates with many other academic departments and institutes, State and Federal agencies, private companies and corporations, and many citizens of the Commonwealth. These efforts range from participation in short courses, seminars, and professional presentations for specific educational programs to long-term research projects. In the past year, the Water Resources Section has participated in University programs in the environmental systems curriculum, hydrogeology, water resources research, agricultural engineering, agronomy, aquiculture, geological sciences, and with UK's Institute for Mining and Minerals Research. Since 1920, the Survey has conducted cooperative programs with the U.S. Geological Survey Water Resources Division. This cooperation has produced more than 200 maps, publications, and open-file reports. Additional information on ground water can be found in the USGS's hydrologic atlases, which are available for all areas of Kentucky, including several detailed atlases for the Ohio River floodplain and Mississippi Embayment regions. Unfortunately, State budget cuts over the past 10 years have forced the elimination of the water-resources cooperative agreement with the USGS. However, the Kentucky Geological Survey is developing computer capabilities that should allow direct access to computerized hydrologic data bases maintained by the USGS, thereby allowing the Commonwealth to access data collected under cooperative programs.

Following are brief descriptions of the major research projects undertaken in cooperation with other University departments, State and Federal agencies, industries, and residents of the Commonwealth:

1. East Kentucky Power Cooperative Plant Waste-Disposal Site Analysis—Monitoring wells and springs have been incorporated into a system to quantify the effects of the disposal of fly and bottom ash on ground and surface water at three power-generation sites. This work is in cooperation with the UK Department of Geological Sciences and Institute for Mining and Minerals Research. A KGS draft report is undergoing review.

2. Effects of Riparian Vegetation on Water Quality: Modeling and Experimental Studies—This research is directed toward determining the effectiveness of vegetation in reducing nonpoint-source pollution. It is conducted in cooperation with the UK Department of Agricultural Engineering. A KGS draft report of this work is undergoing review.

3. Effect of Infiltration Basins on Mine Spoil Hydrology—In an effort to enhance the development of a ground-water resource in a mine spoil, an artificial infiltration basin has been installed at the Star Fire surface mine, located in Knott, Perry, and Breathitt Counties, in the Eastern Kentucky Coal Field. Discharge measurements, along with water-quality variables, have been collected at the site and are being analyzed. This work is in cooperation with the Cyprus Mountain Coal Company, and the UK Departments of Agricultural Engineering and Horticulture and Landscape Architecture.

4. Ground-Water Education and Rural Water Testing—A water-quality inventory of domestic wells and springs is being carried out in all counties in Kentucky. Educational materials consisting of brochures, a slide show, and videotape have been prepared and distributed to agencies dealing with the rural areas of the State. This work is done in cooperation with thousands of rural landowners, the Kentucky Natural Resources and Environmental Protection Cabinet, the UK Departments of Agronomy and Agricultural Engineering, the University Agricultural Extension Service, and Kentucky Farm Bureau Federation, Inc.

5. Nonpoint-Source Assessment of Ground Water in Agricultural Areas—Efforts have begun to study the effects of agricultural practices on nonpoint-source pollution of ground-water resources. Land use, land treatments, and ground-water resources are being assessed in Bourbon, Fleming, Henderson, Hickman, Hopkins, Jessamine, Logan, Russell, Shelby, and Todd Counties. Water-quality samples have been collected monthly at most sites, and dye tracing and water-quality and -quantity variables are being measured more frequently in Sinking Creek in Jessamine County and in the basin of Pleasant Grove Spring in Logan County. These efforts are in cooperation with individual farm owners, the UK Departments of Agronomy, Agricultural Engineering, Geological Sciences, and Institute for Mining and Minerals Research, and the Kentucky Natural Resources and Environmental Protection Cabinet.

6. Surface-Water Stations—This Statewide network collects surface-water data for a variety of uses such as research and special studies, assessment of surface-water resources, waste disposal, pollution control, planning and design of facilities, and forecasting of water

levels. The program, in cooperation with the U.S. Geological Survey, has been in operation since 1938; however, several major budget cuts over the past 10 years have forced the Kentucky Geological Survey to withdraw from this program during this year.

7. Water-Quality Stations—This Statewide network of approximately 70 sites where water quality is monitored on a regular basis provides data for broad Federal and State planning and for the management of waterways. This program has been continuous since 1949; however, several major budget cuts over the past 10 years have forced the Kentucky Geological Survey to withdraw from this program, which was in cooperation with the U.S. Geological Survey, during this year.

9. Effects of Deep Coal Mines on Hydrogeology—The goal of this project is to determine what effects high-extraction deep mining might have on ground and surface water in a drainage basin in eastern Kentucky. Effects on both water quality and quantity will be investigated. This research is in cooperation with Shamrock Coal Company, the U.S. Office of Surface Mining, the Kentucky Department for Surface Mining Reclamation and Enforcement, and the University of Kentucky Department of Geological Sciences and Institute for Mining and Minerals Research. A doctoral dissertation, "Conceptual Model of Local and Regional Ground-Water Flow in the Eastern Kentucky Coal Field," was completed using the preliminary data from this and other projects.

10. Deterministic Model of Channel Headwall Erosion: Initiation and Propagation—Eroded soil and the chemicals attached to it represent serious pollution problems for streams. The objective of this research is to develop predictive channel-erosion computer models that will be linked to runoff models. These models can then be utilized to describe the pollution phenomena. Results of this work will be published as "CHANNEL, a Model of Channel Erosion by Shear, Scour, and Channel Headwall Propagation: Part 1. Model Development," by the University of Kentucky Water Resources Research Institute. This project was completed in cooperation with the University of Kentucky Department of Agricultural Engineering and was funded by the U.S. Army Research Office and the Water Resources Research Institute at the University of Kentucky.

PUBLICATIONS

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

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

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

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

The following publications were issued by the Kentucky Geological Survey during the 1992-93 fiscal year.

Bulletins

- B 2. Geology and Stratigraphy of the Western Kentucky Coal Field, by S. F. Greb, D. A. Williams, and A. D. Williamson, 77 p.

- B 3. Stratigraphic and Structural Framework of the Carboniferous Rocks of the Central Appalachian Basin in Kentucky, by D. R. Chesnut, Jr., 42 p.

Information Circulars

- IC 40. Kentucky Coal Production, 1790-1990, compiled by J. A. Cecil, 248 p.
- IC 41. Low-Silica and High-Calcium Stone in the Newman Limestone (Mississippian) on Pine Mountain, Letcher County, Southeastern Kentucky, by G. R. Dever, Jr., T. L. Robl, J. R. Moody, F. H. Walker, G. W. Ellsworth, Jr., and L. S. Barron, 73 p.
- IC 42. Available Coal Resources of the Booneville 7.5-Minute Quadrangle, Owsley County, Kentucky, by G. A. Weisenfluh, R. E. Andrews, J. K. Hiett, S. F. Greb, R. E. Sergeant, and D. R. Chesnut, Jr., 26 p.

Map and Chart Series

- MCS 3. Geologic Highway Cross Sections, Interstate Highway 75—Conway, Kentucky, to Jellico, Tennessee, by D. R. Chesnut, Jr., 1 sheet.
- MCS 4. Geologic Highway Cross Sections, Interstate Highway 64—Farmers to Catlettsburg, by D. R. Chesnut, Jr., 1 sheet.

Reprint

- R 35. The Mineral Industry of Kentucky, 1990, by L. J. Prosser, Jr., and G. R. Dever, Jr., 7 p.

Report of Investigations

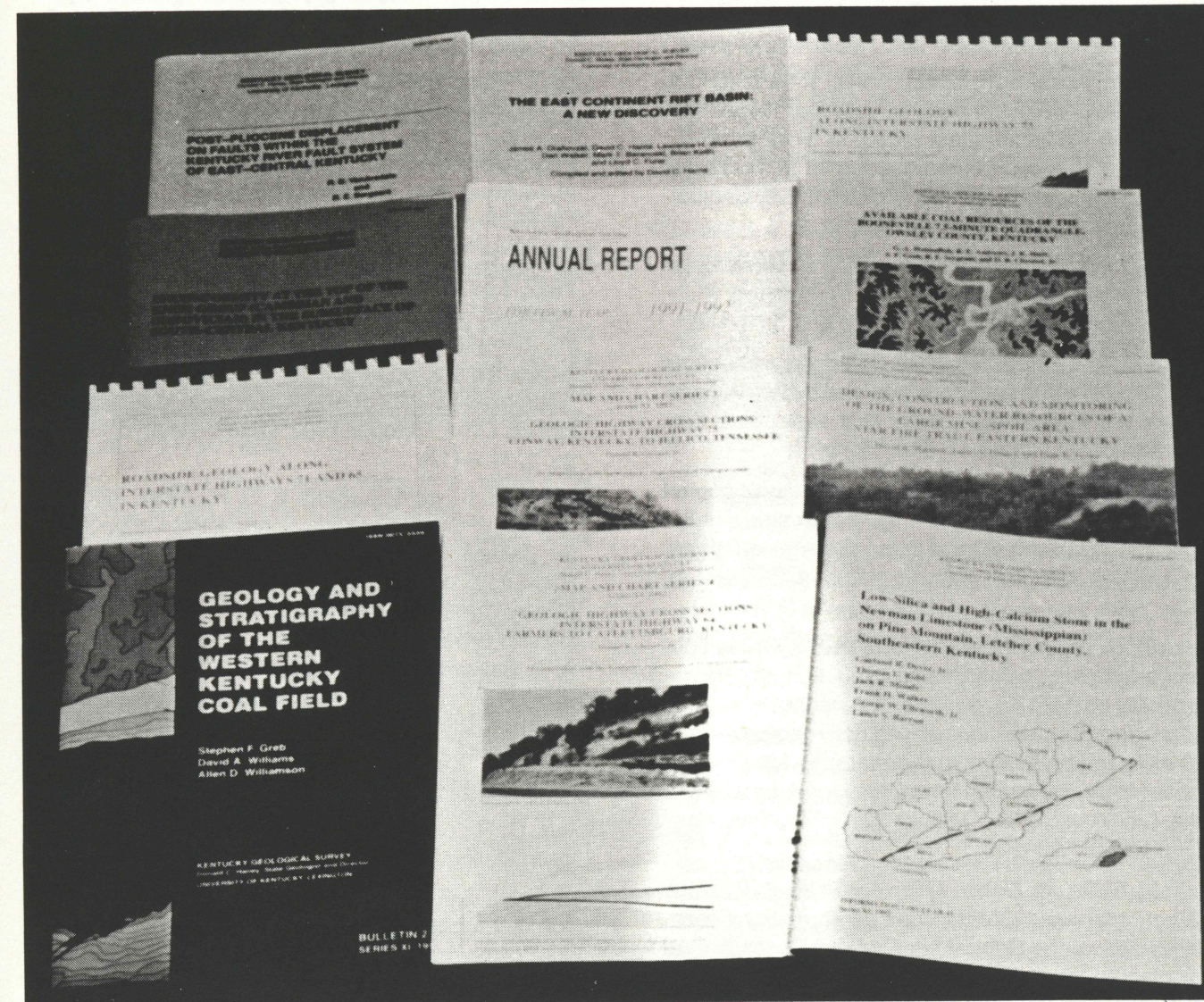
- RI 6. Design, Construction, and Monitoring of the Ground-Water Resources of a Large Mine-Spoil Area: Star Fire Tract, Eastern Kentucky, by D. R. Wunsch, J. S. Dinger, and P. B. Taylor, 16 p.

Special Publications

- SP 15. A Guide to Kentucky Place Names [rev. ed.], by T. P. Field, 268 p.
- SP 16. Roadside Geology Along Interstate Highway 75 in Kentucky, by D. C. Haney and M. C. Noger, 46 p.

Miscellaneous

- KGS Annual Report, 1991-1992, 50 p.
- Kentucky Ground-Water Data Repository, by O. B. Davidson: 1 p.
- Kentucky Water Fact Sheet, by D. R. Wunsch: 1 p.
- Sesquicentennial Edition of the Geologic Map of Kentucky (scale 1:500,000), compiled by M. C. Noger. Published by the U.S. Geological Survey in cooperation with the Kentucky Geological Survey.



PAPERS BY STAFF MEMBERS IN OUTSIDE PUBLICATIONS

Anderson, W. H., 1992, Present and potential mineral resources in the Paducah 2-degree quadrangle and rift related mineralization in central Kentucky [abs.], in Goldhaber, M., and Eidel, J., eds., Mineral resources of the Illinois Basin in the context of basin evolution: U.S. Geological Survey Open-File Report 92-1, p. 1.

Baxter, J. W., Anderson, W. H., Hayes, T. S., and Pool, R. R., 1992, Vein and bedded fluor spar mineralization in the Paducah sheet [abs.], in Goldhaber, M., and Eidel, J., eds., Mineral resources of the Illinois Basin in the context of basin evolution: U.S. Geological Survey Open-File Report 92-1, p. 2.

Carey, D. I., 1993, Development based on carrying capacity: A strategy for environmental protection: Global Environmental Change, v. 3, no. 2, p. 140–148.

Cecil, C. B., and Eble, C. F., 1992, Paleoclimate controls on Carboniferous sedimentation and cyclic stratigraphy in the Appalachian Basin: U.S. Geological Survey Open-File Report 92-546, 182 p.

Chesnut, D. R., Jr., 1992, Eustatic and tectonic control of sedimentation in the Pennsylvanian strata of the Central Appalachian Basin [abs.]: Geological Society of America Abstracts with Programs, v. 24, no. 7, p. 32.

Chesnut, D. R., Jr., 1992, General Pennsylvanian paleogeographic, paleoclimatic, and tectonic framework for eastern Kentucky, in Ettensohn, F. R., ed., Changing interpretations of Kentucky geology—Layer-cake, facies, flexure, and eustasy: Fieldtrip Guidebook for Geological Society of America Annual Meeting, Cincinnati, Ohio, October 1992: Ohio Division of Geology, p. 100–105.

Chesnut, D. R., Jr., Cobb, J. C., and Greb, S. F., 1992, "Pipe-organ structures" in the Lee Formation (Pennsylvanian) of the Central Appalachian Basin: Animal or plant? Journal of Paleontology, v. 66, no. 1, p. 148–155.

Chesnut, D. R., Jr., and Greb, S. F., 1992, Lowstand versus highstand eustatic models for peat preservation: The coal-bearing rocks of the Breathitt Group, eastern Kentucky [abs.]: Geological Society of America Abstracts with Programs, v. 24, no. 7, p. 163–164.

Chesnut, D. R., Jr., Greb, S. F., and Eble, C. F., 1992, Breathitt Formation and coal-forming environments,

in Ettensohn, F. R., ed., Changing interpretations of Kentucky geology—Layer-cake, facies, flexure, and eustasy: Fieldtrip Guidebook for Geological Society of America Annual Meeting, Cincinnati, Ohio, October 1992: Ohio Division of Geology, p. 119–120.

Chesnut, D. R., Jr., Greb, S. F., Eble, C., and Rice, C. L., 1992, Stop 9: Gregoryville exposure on I-64 in Kentucky—An examination of two middle Carboniferous depositional models, in Rice, C. L., Martino, R. L., and Slucher, E. R., eds., Regional aspects of Pottsville and Allegheny stratigraphy and depositional environments, Ohio and Kentucky: U.S. Geological Survey Open-File Report 92-558, p. 47–55.

Chesnut, D. R., Jr., Greb, S. F., and Ettensohn, F. R., 1992, Lee Formation and the Mississippian–Pennsylvanian contact, in Ettensohn, F. R., ed., Changing interpretations of Kentucky geology—Layer-cake, facies, flexure, and eustasy: Fieldtrip Guidebook for Geological Society of America Annual Meeting, Cincinnati, Ohio, October 1992: Ohio Division of Geology, p. 113–118.

Currens, J. C., and Graham, C. D. R., 1993, Flooding of Sinking Creek, Garretts Spring karst drainage basin, Jessamine and Woodford Counties, Kentucky, in Beck, B. F., ed., Proceedings of the Fourth Multidisciplinary Conference on Sinkholes and the Engineering and Environmental Impacts of Karst: Rotterdam, A. A. Balkema, p. 145–156.

Dever, G. R., Jr., 1993, Current use of carbonate rocks and lime for controlling emissions from coal-fired plants in Kentucky [abs.]: Geological Society of America Abstracts with Programs, v. 25, no. 3, p. 16.

Dever, G. R., Jr., 1993, Kentucky, in 1992 annual review: Mining Engineering, v. 45, no. 5, p. 472.

Drahovzal, J. A., 1992, The origin and geologic evolution of the East Continent Rift Basin [abs.]: Geological Society of America Abstracts with Programs, v. 24, no. 7, p. A330.

Drahovzal, J. A., and Harris, D. C., 1993, A billion-year-old sedimentary basin discovered in central North America: University of Kentucky Institute for Mining and Mineral Research, Highlights, v. 12, no. 2, p. 1–2.

Drahovzal, J. A., and Nuttall, B. C., 1992, Kentucky Geological Survey is working on a major Appalachian gas plays atlas: University of Kentucky Institute for

Mining and Mineral Research, Highlights, v. 11, no. 5, p. 1, 4.

Drahovzal, J. A., Wickstrom, L.H., and Towey, P.E., 1992, Lower Paleozoic and shallow Proterozoic structural geology of western Ohio as interpreted from the reprocessed COCORP seismic profile [abs.]: American Association of Petroleum Geologists Bulletin, v. 76, no. 8, p. 1290.

Eble, C. F., 1992, Controls on Middle Pennsylvanian peat-forming floras in the eastern United States [abs.]: Geological Society of America Abstracts with Programs, v. 24, no. 7, p. 50.

Eble, C. F., 1992, Lower Breathitt Formation (Lower Pennsylvanian) coal geology, eastern Kentucky [abs.]: American Association of Petroleum Geologists Bulletin, v. 76, p. 1275.

Eble, C. F., Fedorko, N., and Grady, W., 1992, Paleocology and paleoenvironments of peat formation in the Pittsburgh coal bed, northern Appalachian Basin, U.S.A. The Euramerican Coal Province: Controls on Tropical Peat Accumulation in the Late Paleozoic, a symposium held in conjunction with the annual meeting of the Geological Association of Canada, May 1992: Geological Association of Canada Abstracts, v. 17, p. 1275.

Eble, C. F., Grady, W. C., and Ashton, K. F., 1992, Coal supplies for the 1990's: A reevaluation of Kanawha Formation splint coals in central and southern West Virginia, in Platt, J., Price, J., Miller, M., and Suboleski, S., eds., 1.2: New perspectives on Central Appalachian low-sulfur coal supplies: Fairfax, Virginia, TechBooks, p. 77–101.

Eble, C. F., Grady, W., and Blake, W. B., 1992, Relationships of coal beds and strata of the Allegheny Formation and Pottsville Group of northern and central West Virginia and the proposed Pennsylvanian System stratotype of southern West Virginia [abs.]: Geological Society of America Abstracts with Programs, v. 24, no. 3, p. 25.

Eble, C. F., Hower, J. C., and Andrews, D., 1992, Paleocology of the Fire Clay coal bed in a portion of the Central Appalachian Basin, U.S.A., in The Euramerican Coal Province: Controls on tropical peat accumulation in the Late Paleozoic, a symposium held in conjunction with the annual meeting of the Geological Association of Canada: Geological Association of Canada Abstracts, v. 17, p. A30.

Eble, C. F., Hower, J. C., and Rathbone, R., 1992, No. 5 Block coal, northeastern Kentucky [abs.]: Geological Society of America Abstracts with Programs, v. 24, no. 3, p. 24.

Eble, C. F., Pierce, B. S., and Stanton, R. W., 1993, Comparison of petrography, palynology and paleobotany of the Stockton coal bed, West Virginia, and implications for paleoenvironmental interpretations: Organic Geochemistry, v. 20, no. 2, p. 149–166.

Eidel, J. J., Baxter, J. W., Hughes, R. E., Masters, J. M., Pool, R. R., Smith, L. R., Stiff, B. J., Anderson, W., Dever, G. R., Jr., Olive, W. W., McFarland, M. C., Reuff, A., Hayes, T. S., and Berg, R. B., 1992, Economic potential for industrial minerals in the Paducah 1° x 2° quadrangle in southern Illinois and adjacent Kentucky and Missouri: The results of CUSMAP assessment [abs.], in Sidder, G. B., Sims, P. K., Chadima, Sarah, and Biek, R. F., eds., Industrial minerals, today and tomorrow: The raw materials to build the upper Midwest: U.S. Geological Survey Open-File Report 92-0514, p. 22–23.

Ettensohn, F. R., and Chesnut, D. R., Jr., 1992, Nature and probable origin of the Mississippian–Pennsylvanian unconformity in the eastern United States: Eleventh International Congress of Carboniferous Stratigraphy and Geology, August 30–September 5, 1987, Beijing, China, Comptes Rendus, v. 4, p. 145–159.

Ettensohn, F. R., Chesnut, D. R., Jr., Eble, C. F., Pashin, J. C., and Barnett, S. F., 1992, The Slade and Paragon Formations and Pennsylvanian slumping, in Ettensohn, F. R., ed., Changing interpretations of Kentucky geology—Layer-cake, facies, flexure, and eustasy: Fieldtrip Guidebook for Geological Society of America Annual Meeting, Cincinnati, Ohio, October 1992: Ohio Division of Geology, p. 56–59.

Fogle, A. W., and Barfield, B. J., 1992, CHANNEL, a model of channel erosion by shear, scour, and channel headwall propagation: Part 1. Model development: University of Kentucky Water Resources Research Institute, Research Report 186, 92 p.

Greb, S. F., 1992, Heterogeneity in seam and roof related to mineability prediction—Hazard No. 8 coal, a case study, in Platt, J. E., Price, J., Miller, M., and Suboleski, S., eds., 1.2—New perspectives on Central Appalachian low-sulfur coal supplies: Fairfax, Virginia, TechBooks, p. 102–124.

Greb, S. F., 1992, Sedimentology of a Pennsylvanian sandstone (lower Breathitt Formation) from bedding-plane exposures, Laurel River Dam spillway, Whitley County, Kentucky: Lexington, University of Kentucky, Ph.D. Dissertation, 364 p.

Greb, S. F., and Chesnut, D. R., 1992, Trace fossil zonation in regressive sequences in the lower Breathitt Formation (Pennsylvanian), Central Appala-

- chian Basin [abs.]: Geological Society of America Abstracts with Programs, v. 24, no. 7, p. A43.
- Greb, S. F., Chesnut, D. R., Jr., and Eble, C. F.**, 1992, Coastal and terrestrial environments of the lower Breathitt and Lee Formations (lower Middle Pennsylvanian), near Frenchburg, Kentucky, *in* Cecil, C. B., and Eble, C. F., eds., Paleoclimate controls on Carboniferous sedimentation and cyclic stratigraphy in the Appalachian Basin: U.S. Geological Survey Open-File Report 92-546, p. 90-101.
- Greb, S. F., Chesnut, D. R., Jr., and Eble, C. F.**, 1992, Lower Breathitt Formation (Lower Pennsylvanian) coal geology, eastern Kentucky [abs.]: American Association of Petroleum Geologists Bulletin, v. 76, p. 1275.
- Greb, S. F., Eble, C. F., and Chesnut, D. R., Jr.**, 1992, Coal-bottomed channels in the Breathitt Formation (Pennsylvanian), eastern Kentucky [abs.]: American Association of Petroleum Geologists Bulletin, v. 76, p. 1275-1276.
- Hamilton-Smith, Terence**, 1992, Gas production from the New Albany Shale [abs.]: American Association of Petroleum Geologists Bulletin, v. 76, no. 8, p. 1276-1277.
- Hamilton-Smith, Terence**, 1992, Kentucky exploration targets oil in fractured High Bridge, Knox zones: Oil and Gas Journal, v. 90, p. 102-104.
- Hamilton-Smith, Terence**, 1993, Stratigraphic effects of the Acadian Orogeny in the autochthonous Appalachian Basin, *in* Roy, D. C., and Skehan, J. W., eds., The Acadian Orogeny: Recent studies in New England, Maritime Canada, and the Autochthonous Foreland: Geological Society of America, Special Paper 275, p. 153-164.
- Haney, D. C.**, 1992, The geologic mapping of Kentucky—A success story: GSA Today, v. 2, no. 12.
- Haney, D. C.**, 1993, Wake up, geologists!: Geotimes, January 1993.
- Haney, D. C.**, and Mankin, C. J., 1992, Geologic mapping: A national issue: Geotimes, v. 37, no. 11, p. 5.
- Harris, D. C.**, 1992, Petrology of the Middle Run Formation (Precambrian), East Continent Rift Basin, western Ohio and north-central Kentucky [abs.]: Geological Society of America Abstracts with Programs, v. 24, no. 7, p. A231.
- Harris, D. C., Anderson, W. H., and Nuttall, B. C.**, 1992, Exploration potential of fractured Ordovician carbonates, Cincinnati Arch, south-central Kentucky [abs.]: American Association of Petroleum Geologists Bulletin, v. 76, p. 1277.
- Harris, J. B., Higgins, B. A., and Street, R.**, 1993, Site amplification of earthquake ground motions in unconsolidated sediments: Henderson, Kentucky: EOS, Transactions, American Geophysical Union, v. 74, no. 16, p. 289.
- Harris, J. B., Kiefer, J. D., Street, R. L., Allen, D. L., and Wang, Z. M.**, 1993, Microzonation and site amplification of seismic ground motions in the Paducah, Kentucky, area: Proceedings, 1993 National Earthquake Conference, Earthquake Hazard Reduction in the Central and Eastern United States: A time for examination and action: Memphis, Tennessee, v. 1, p. 215-224.
- Harris, J. B., Mullins, T., Woolery, E., Wang, Z., and Street, R.**, 1992, Near-surface faulting on the Tiptonville dome as documented by shear-wave seismic investigations [abs.]: Geological Society of America, Abstracts with Programs, v. 24, no. 7, p. A153.
- Harris, J. B., Wang, Z. M., Street, R., and Woolery, E. W.**, 1992, Q(s) estimates for unconsolidated sediments in the Upper Mississippi Embayment: Seismological Research Letters, v. 63, p. 613.
- Harris, J. B., Wang, Z. M., Street, R., and Woolery, E. W.**, 1993, Site conditions and response of weak ground motion in western Kentucky: EOS, Transactions, American Geophysical Union, v. 74, no. 16, p. 289.
- Harris, J. B., Woolery, E. W., Street, R. L., and Wang, Z.**, 1992, Investigation of structural deformation in unconsolidated sediments using high-resolution SH-wave seismic methods [abs.]: 62nd Annual International Meeting of the Society of Exploration Geophysicists, Expanded Abstracts, p. 291-294.
- Hayes, T. S., and Anderson, W. H.**, 1992, Regionwide correlation of the hydrothermal paragenesis of the Illinois-Kentucky Fluorspar District [abs.], *in* Goldhaber, M., and Eidel, J., eds., Mineral resources of the Illinois Basin in the context of basin evolution: U.S. Geological Survey Open-File Report 92-1, p. 19.
- Hughes, R. E., Olive W. W., Reuff, A., Baxter, J. W., Anderson, W. H., McFarland, M., and Stiff, B. J.**, 1992, Assessment of clay and shale resources of the Paducah Quadrangle [abs.], *in* Goldhaber, M., and Eidel, J., eds., Mineral resources of the Illinois Basin in the context of basin evolution: U.S. Geological Survey Open-File Report 92-1, p. 28.
- Jones, H. D., Kesler, S. E., Spry, P. G., Richardson, C. K., Kyle, J. R., Anderson, W. H., and Furman, C. C.**, 1992, Determination of the limits of Mid-Continental brine flow by sulfur isotopes from Mississippi Valley-type deposits [abs.], *in* Goldhaber, M., and Eidel, J., eds., Mineral resources of the Illinois Basin in the

- context of basin evolution: U.S. Geological Survey Open-File Report 92-1, p. 32.
- Masters, J. M., Olive, W. W., Reuff, A., Baxter, J. W., Anderson, W. H., McFarland, M., and Stiff, B. J.**, 1992, Assessment of the construction sand, gravel and industrial sand resources of the Paducah 2-degree quadrangle [abs.], *in* Goldhaber, M., and Eidel, J., eds., Mineral resources of the Illinois Basin in the context of basin evolution: U.S. Geological Survey Open-File Report 92-1, p. 38.
- Minns, S. A., Sahba, A. M., Sendlein, L. V. A., Currens, J. C., and Dinger, J. S.**, 1993, Hydrogeology and ground-water monitoring of a coal-ash-disposal site at the Cooper power station, south-central Kentucky: East Kentucky Power Cooperative, Project Completion Report, 120 p.
- Nuttall, B. C.**, 1992, Annual review: Kentucky, 1991: Northeast Oil World, v. 12, no. 6, p. 16-17.
- Nuttall, B. C.**, 1992, Oil and gas developments in eastern Kentucky, 1991 [abs.]: Program and Abstracts of the Twenty-Third Annual Appalachian Petroleum Geology Symposium, West Virginia Geologic and Economic Survey, Morgantown, West Virginia, I. C. White Memorial Fund Publication 4, p. 45-47.
- Nuttall, B. C., and Drahovzal, J. A.**, 1993, Oil and gas developments in Kentucky, 1992 [abs.]: Program and Abstracts of the Twenty-Fourth Annual Appalachian Petroleum Geology Symposium, West Virginia Geologic and Economic Survey, Morgantown, West Virginia, I. C. White Memorial Fund Publication 5, p. 66-68.
- Patchen, D. G., Nuttall, B. C., Baranoski, M. T., Harper, J. A., Schwietering, J. F., Van Tyne, A., Aminian, K., and Smosna, R. A.**, 1992, Gas atlas and data base of major Appalachian Basin gas plays, *in* Malone, R. D., Shoemaker, H. D., and Byrer, C. W., eds., 1992, Proceedings of the Natural Gas Research and Development Contractors Review Meeting: U.S. Department of Energy, Morgantown, West Virginia, DOE/METC-92/6125, p. 337-344.
- Patchen, D. G., Nuttall, B. C., Baranoski, M. T., Harper, J. A., Schwietering, J. F., Van Tyne, A., Aminian, K., and Smosna, R. A.**, 1992, Selecting major Appalachian Basin gas plays, *in* Malone, R. D., Shoemaker, H. D., and Byrer, C. W., 1992, Proceedings of the Natural Gas Research and Development Contractors Review Meeting: U.S. Department of Energy, Morgantown, West Virginia, DOE/METC-92/6125, p. 19-28.
- Prosser, L. J., Jr., and Dever, G. R., Jr.**, 1992, The mineral industry of Kentucky: U.S. Bureau of Mines Annual Report, 1990, 7 p.
- Prosser, L. J., Jr., and Dever, G. R., Jr.**, 1993, The mineral industry of Kentucky: U.S. Bureau of Mines Annual Report, 1991, 7 p.
- Sendlein, L. V. A., Dinger, J. S., Conrad, P. C., and Armstrong, J. A.**, 1992, Ground-water monitoring for a non-point source agricultural setting [abs.]: Geological Society of America Abstracts with Programs.
- Taraba, J., Ilvento, T., Dinger, J., Coleman, S., Boone, R., and Knoth, L.**, 1992, Kentucky results: Private drinking water source testing program: American Society of Agricultural Engineers, Paper 922505, 34 p.
- Walker, Dan, Hamilton-Smith, Terence, and Drahovzal, J. A.**, 1992, Structure and stratigraphy of the Rome Trough [abs.]: American Association of Petroleum Geologists Bulletin, v. 76, no. 8, p. 1288-1289.
- Walker, Dan, and Misra, K. C.**, 1992, Tectonic significance of basalts of the Middle Run Formation (Upper Proterozoic) of the East Continent Rift Basin [abs.]: Geological Society of America Abstracts with Programs, v. 24, no. 7, p. A231.
- Williams, D. A., and Greb, S. F.**, 1992, Plant origin for unusual "pipe-organ" structures of the Curlew Sandstone, Tradewater Formation (Pennsylvanian), Western Kentucky Coal Field [abs.]: Geological Society of America Abstracts with Programs, v. 24, no. 7, p. A105.
- Wunsch, D. R., Dinger, J. S., Taylor, P. B., and Carey, D. I.**, 1992, The hydrogeology and hydrogeochemistry of a large mine-spoil area: Star Fire Tract, eastern Kentucky [abs.]: Proceedings, West Virginia Surface Mining Task Force Symposium, 2 p.

TALKS BY STAFF MEMBERS TO PROFESSIONAL AND CIVIC GROUPS

- Berg, Thomas, **Dever, G. R., Jr.**, Hester, Norman, and Eidel, James, 1992, Limestone resources and availability—Panel discussion by state geological surveys: Limestone and Lime for SO₂ and Pollutant Control in the Ohio Valley, Lexington, Kentucky, November 30, 1992.
- Chesnut, D. R., Jr.**, 1992, Dinosaurs and fossils in Kentucky: Lexington Children's Museum, November 22, 1992.
- Chesnut, D. R., Jr.**, 1992, Eustatic and tectonic control of sedimentation in the Pennsylvanian strata of the Central Appalachian Basin: Geological Society of America Annual Meeting, Cincinnati, Ohio, October 26, 1992.
- Chesnut, D. R., Jr.**, 1992, The project to build the Kentucky Museum of Natural History: Kentucky Academy of Science Annual Meeting, Ashland, Kentucky, October 29, 1992.
- Chesnut, D. R., Jr., and Greb, S. F.**, 1992, Lowstand versus highstand eustatic models for peat preservation: The coal-bearing rocks of the Breathitt Group, eastern Kentucky: Geological Society of America Annual Meeting, Cincinnati, Ohio, October 27, 1992.
- Cobb, J. C.**, 1993, Modern analogues of coal formation: Purdue University, West Lafayette, Indiana, March 14, 1993.
- Cobb, J. C., and Dever, G. R., Jr.**, 1992, Introduction: Limestone and Lime for SO₂ and Pollutant Control in the Ohio Valley Conference, Lexington, Kentucky, November 30, 1992.
- Conrad, P. C.**, 1993, Agricultural non-point source pollution at the Daviess County study site, Kentucky: University of Kentucky College of Agriculture, Nonpoint-Source HB 271 Second Year Executive Summary Seminar, Lexington, Kentucky, March 1, 1993.
- Conrad, P. C.**, 1993, Agricultural non-point source pollution at the Hickman County study site, Kentucky: University of Kentucky College of Agriculture, Nonpoint-Source HB 271 Second Year Executive Summary Seminar, Lexington, Kentucky, March 8, 1993.
- Conrad, P. C.**, 1993, The origin, use, and properties of rocks: Tates Creek Elementary School, Lexington, Kentucky, March 5, 1993.
- Conrad, P. C., Dinger, J. S., and Sendlein, L. V.**, 1992, Study of an agricultural non-point source pollution site in Hickman County, Kentucky: Geological Society of America Annual Meeting, Cincinnati, Ohio, October 19, 1992.
- Currens, J. C.**, 1993, Characterization and quantification of nonpoint-source pollutant loads in a conduit-flow dominated karst aquifer underlying an intensive use agricultural region: University of Kentucky College of Agriculture, Nonpoint-Source HB 271 Second Year Executive Summary Seminar, Lexington, Kentucky, March 29, 1993.
- Currens, J. C., and Graham, C. D. R.**, 1993, Flooding of Sinking Creek, Garretts Spring karst drainage basin, Jessamine and Woodford Counties, Kentucky: Fourth Multidisciplinary Conference on Sinkholes and the Engineering and Environmental Impacts of Karst, Panama City, Florida, January 19, 1993.
- Dever, G. R., Jr.**, 1993, Current use of carbonate rocks and lime for controlling emissions from coal-fired plants in Kentucky: Geological Society of America North-Central Section meeting, Rolla, Missouri, March 30, 1993.
- Dinger, J. S.**, 1992, Need for and elements of monitoring a mid-sized watershed with respect to agricultural pollution and implementation of BMPs: Mammoth Cave Resource Conservation and Development Area Committee, Barren River Area Development District, Bowling Green, Kentucky, December 1, 1992.
- Dinger, J. S.**, 1992, Striking a balance between use of mineral resources and water resource problems: Environmental Day Program, Lansdowne Elementary School, Lexington, Kentucky, September 24, 1992.
- Dinger, J. S.**, 1992, Water resources related to mine spoil: Environmental Systems Seminar Course, University of Kentucky, Lexington, Kentucky, September 22, 1992.
- Dinger, J. S.**, 1993, Geology's role in today's world, and dinosaurs of long ago: Lansdowne Elementary School, Lexington, Kentucky, March 24, 1993.
- Dinger, J. S.**, 1993, Status of the ground-water repository and Kentucky Geological Survey research programs: Kentucky Groundwater Consensus Group, Frankfort, Kentucky, March 2, 1993.
- Drahovzal, J. A.**, 1992, The geology of the Clinton County play and fracture prediction: Clinton County

- Oil and Gas Steering Committee, Albany, Kentucky, September 16, 1992.
- Drahovzal, J. A.**, 1992, The East Continent Rift Basin: Lexington Torch Club, Lexington, Kentucky, November 19, 1992.
- Drahovzal, J. A.**, 1992, The origin and geologic evolution of the East Continent Rift Basin: Geological Society of America Annual Meeting, Cincinnati, Ohio, October 30, 1992.
- Drahovzal, J. A.**, 1993, Kentucky Geological Survey programs with DOE: DOE Workshop for Independent Oil and Gas Producers in Appalachian and Illinois Basins, Lexington, Kentucky, June 4, 1993.
- Drahovzal, J. A.**, 1993, Oil and gas development in Kentucky, 1992: 24th Annual Appalachian Petroleum Geology Symposium, Morgantown, West Virginia, April 30, 1993.
- Drahovzal, J. A.**, 1993, The origin and geologic evolution of the East Continent Rift Basin: Ohio Geological Society, Columbus Ohio, January 18, 1993.
- Drahovzal, J. A., Wickstrom, L. H., and Towey, P. E.**, 1992, Lower Paleozoic and shallow Proterozoic structural geology of western Ohio as interpreted from the reprocessed COCORP seismic profile: Eastern Section Meeting of the American Association of Petroleum Geologists, Champaign, Illinois, September 21, 1992.
- Frankie, W. T., and **Hamilton-Smith, Terence**, 1993, Gas potential of the New Albany Shale (Devonian-Mississippian) of the Illinois Basin: Illinois Basin Consortium Workshop, Bloomington, Indiana, March 15, 1993.
- Greb, S. F.**, 1992, Sedimentology of a Pennsylvanian sandstone (lower Breathitt Formation) from bedding-plane exposures, Laurel River Dam spillway, Whitley County, Kentucky: Lexington, University of Kentucky, Ph.D. Dissertation Defense, November 6, 1992.
- Greb, S. F., and Chesnut, D. R., Jr.**, 1992, Trace fossil zonation in regressive sequences in the lower Breathitt Formation (Pennsylvanian), Central Appalachian Basin: Geological Society of America Annual Meeting, Cincinnati, Ohio, October 26, 1992.
- Hamilton-Smith, Terence**, 1992, New Albany Shale gas from the Shrewsbury Field: Eastern Section Meeting of the American Association of Petroleum Geologists, Champaign, Illinois, September 22, 1992.
- Haney, D. C.**, 1992, Geologic mapping, a success story: Geological Society of America Annual Meeting, Cincinnati, Ohio, October 29, 1992.
- Haney, D. C.**, 1992, The role of geologists in the siting and cleanup of waste disposal sites: American Institute of Professional Geologists Annual Meeting, Lake Tahoe, Nevada, September 28, 1992.
- Harris, D. C.**, 1992, Petrology of the Middle Run Formation (Precambrian), East Continent Rift Basin, western Ohio and north-central Kentucky: Geological Society of America Annual Meeting, Cincinnati, Ohio, October 29, 1992.
- Harris, D. C., Anderson, W. H., and Nuttall, B. C.**, 1992, Exploration potential of fractured Ordovician carbonates, Cincinnati Arch, south-central Kentucky: Eastern Section Meeting of the American Association of Petroleum Geologists, Champaign, Illinois, September 22, 1992; Illinois Geological Society Monthly Meeting, Grayville, Illinois, October 20, 1992.
- Harris, J., Kiefer, J. D., Street, R. L., Allen, D. L., and Wang, Z. M.**, 1993, Microzonation and site amplification of seismic ground motions in the Paducah, Kentucky, area: 1993 National Earthquake Conference, Memphis, Tennessee, May 3-5, 1993.
- Keagy, D. M.**, 1993, Agricultural non-point source pollution at the Hickman County study site, Kentucky: University of Kentucky College of Agriculture, Nonpoint-Source HB 271 Second Year Executive Summary Seminar, Lexington, Kentucky, February 22, 1993.
- Kiefer, J. D.**, 1992, Earthquake-induced landslides along the bluffs of the Mississippi River in western Kentucky: Geological Society of Kentucky Annual Field Conference, Reelfoot Lake State Park, Tennessee, September 26, 1992.
- Kiefer, J. D.**, 1992, The importance of observation in geotechnical studies: Kentucky Geological Survey Seminar, Lexington, Kentucky, October 15, 1992.
- Kiefer, J. D.**, 1993, The East Continent Rift Basin and its possible relationship to seismic activity in the eastern United States: Governors Earthquake Hazards and Safety Technical Advisory Panel Meeting, University of Louisville, Louisville, Kentucky, June 23, 1993.
- Kiefer, J. D.**, 1993, The Kentucky Seismic and Strong Motion Network and seismic zonation, their importance to Kentucky: Central United States Earthquake Consortium State Geologists Group and U.S. Geological Survey joint research conference, Memphis Tennessee, February 4, 1993.
- Kipp, J. A.**, 1992, Effects of deep coal mines on hydrogeology: Fifth Annual Kentucky Professional Engineers in Mining Seminar, University of Kentucky, Lexington, Kentucky, August 14, 1992.

Nuttall, B. C., 1992, The formation of a natural oil seep at Vaughn Creek, south-central Kentucky: Ohio Geological Society, Columbus, Ohio, November 16, 1992.

Nuttall, B. C., 1992, Review of eastern Kentucky drilling and development, 1991: Twenty-Third Annual Appalachian Petroleum Geology Symposium, Morgantown, West Virginia, April 1, 1992.

Sendlein, L. V. A., and Dinger, J. S., 1993, Ground-water monitoring principles and sampling techniques: Short course sponsored by the University of Kentucky Institute for Mining and Minerals Research and the Kentucky Geological Survey, University of Kentucky, Lexington, Kentucky, June 8-9, 1993.

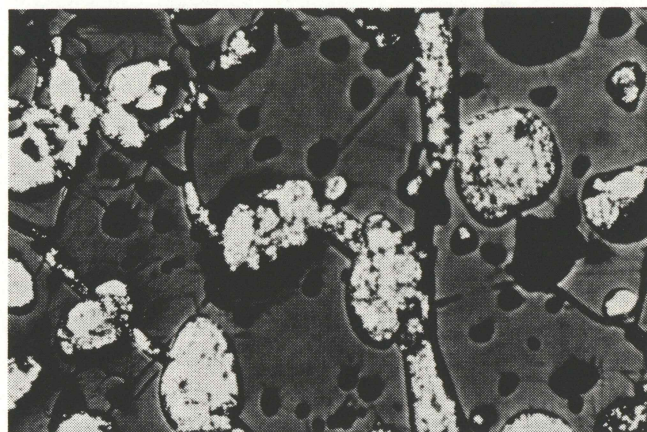
Smath, R. A., 1992, ESIC: Organization, resources, and unique services: Annual Conference of the Southeastern Division of the Association of American Geographers and Committee on Southern Map Libraries, Louisville, Kentucky, November 22, 1992.

Taraba, J., Ilvento, T., Dinger, J., Coleman, S., Boone, R., and Knoch, L., 1992, Kentucky results: Private drinking water source testing program: American Society of Agricultural Engineers Winter Meeting, Nashville, Tennessee, December 15-18, 1992.

Walker, Dan, Hamilton-Smith, Terence, and Drahovzal, J. A., 1992, Structure and stratigraphy of the Rome Trough: Eastern Section Meeting of the American Association of Petroleum Geologists, Champaign, Illinois, September 21, 1992.

Williams, D. A., and Greb, S. F., 1992, Plant origin for unusual "pipe-organ" structures of the Curlew Sandstone, Tradewater Formation (Pennsylvanian), Western Kentucky Coal Field: Geological Society of America Annual Meeting, Cincinnati, Ohio, October 28, 1992.

Wunsch, D. R., Dinger, J. S., Taylor, P.B., and Carey, D. I., 1992, The hydrogeology and hydrogeochemistry of a large mine-spoil area: Star Fire Tract, eastern Kentucky: West Virginia Surface Mining Task Force Symposium, Morgantown, West Virginia, April 28, 1993.



Pyrite in fusinite.



Cell patterns in etched semifusinite.

KENTUCKY GEOLOGICAL SURVEY DISTINGUISHED LECTURE SERIES

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

The second Distinguished Lecture, in honor of David Dale Owen, was presented in 1989 by Hermann W. Pfefferkorn, whose topic was "The Orinoco Delta in Tropical South America as a Model for Coal-Bearing Strata in the United States." Aureal T. Cross presented the Nathaniel S. Shaler Distinguished Lecture in 1991; the title of his presentation was "Aspects of Plants in Coal and the Coalification Process." In 1992, Paul Edwin Potter was chosen as the John R. Procter Distinguished Lecturer in honor of Kentucky's fourth State Geologist. The title of Dr. Potter's lecture was "Contributions to Sedimentology—Geology from the North American Heartland."

The 1993 KGS Distinguished Lecture was presented by Philip E. LaMoreaux, who spoke on "The Importance of Environmental Geology." Mr. LaMoreaux has occupied a central role in the development of hydrogeology into perhaps the most dynamic discipline in geology. He has made major contributions in the areas of hydrogeology and environmental geology, and has had a distinguished career in positions with both state and Federal governments, in academia, and in consulting. He has also served as Director of the Environmental Institute for Waste Management Studies at the University of Alabama and Editor in Chief of the International Journal of

Environmental Geology and Water Science, and was the 1990 recipient of the Ian Campbell Medal.

This year's Distinguished Lecture honored Dr. Wallace W. Hagan, who retired as State Geologist and Director of the Kentucky Geological Survey in 1978. Dr. Hagan is the recipient of many awards, among them the John Wesley Powell Award, presented by the U.S. Geological Survey in 1972 in recognition of Dr. Hagan's contribution to the furtherance of USGS missions. But his most noted accomplishment during his tenure from 1958 to 1978 was the initiation and completion of a Statewide areal geologic mapping project in cooperation with the U.S. Geological Survey. Dr. Hagan's vision, perseverance, and untiring effort to ensure completion of this monumental program resulted in the publication of 707 detailed geologic maps, making Kentucky the first state to have such coverage, and the best mapped state in the Nation. This accomplishment has served as a significant base for future geologic research and mineral exploration and development in the State.

DISTINGUISHED LECTURES

William W. Mather—1988

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

David Dale Owen—1989

Hermann W. Pfefferkorn

Nathaniel S. Shaler—1991

Aureal T. Cross

John R. Procter—1992

Paul Edwin Potter

Wallace W. Hagan—1993

Philip E. LaMoreaux

PUBLIC SERVICES

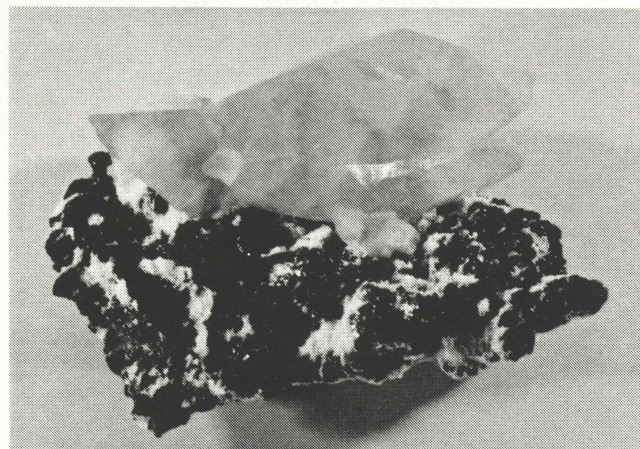
Coal and Minerals Section

EARTH SCIENCE EDUCATION MATERIALS

A Special Publication describing the rocks and minerals of Kentucky is currently in the final stages of preparation. "Rocks and Minerals of Kentucky" will also include photographs of minerals in Kentucky including calcite, barite, gold, meteorites, and other unusual minerals.

An Information Circular entitled "The Fossil Beds at the Falls of the Ohio" is being prepared to help visitors to the Falls interested in the natural history and scientific importance of this unique fossil locality. The Falls of the Ohio, on the Ohio River at Louisville, Kentucky, and Clarksville, Indiana, is world famous for its fossil beds. Because of the fossil beds' proximity to major metropolitan areas, they have been a favorite for school field trips and tourists. A visitors center planned to be completed in 1993 should only increase the number of visitors.

"The Fossil Beds at the Falls of the Ohio" is an overview of the geologic history of the Falls. It contains maps that show where Silurian and Devonian limestones outcrop at the Falls, and where different types of fossils can be seen in the bedrock along the Ohio River. It also contains more than 60 photographs of fossil corals, stromatoporoids, brachiopods, bivalves, echinoderms, and fish remains found at the Falls. These photographs can be used to aid in identifying the different types of fossils exposed in the bedrock. But more than just identifying fossils, this publication also explains what types of animals the fossils came from, and how those animals lived in the ancient seas. Twenty-two illustrations show what many of the sea creatures looked like during the Devo-



Calcite scalenohedron on sphalerite, from vein in Lexington Quarry, Jessamine County (from "Rocks and Minerals of Kentucky," by Warren H. Anderson).

nian Period. Illustrations also show the various geologic processes that led to the fossils being preserved at the Falls. The publication can be used to compare creatures living in the seas today with creatures that lived in the seas nearly 400 million years ago. It is hoped that this publication will help all who read it appreciate the importance of preserving this unique natural historic site.

PUBLIC ACCESS TO COAL INFORMATION AND COAL-DATA MANAGEMENT

The most important mission of the Kentucky Geological Survey is to provide information to the public on mineral resources. Coal information is available to the public through formal publications, open-file reports, presentations to groups, and computerized data bases. The Kentucky Coal Resources Information System (KCRIS) was established to provide coal-related data to the public. KCRIS maintains computerized and open-file data including coal quality, thickness, resources, core descriptions, and coal-related engineering data. These data have been collected by the Survey for the last two decades, and the data bases are continually being updated with new information. The computerized data bases have been transformed into a relational data base (RDB), which combines all the relevant coal data

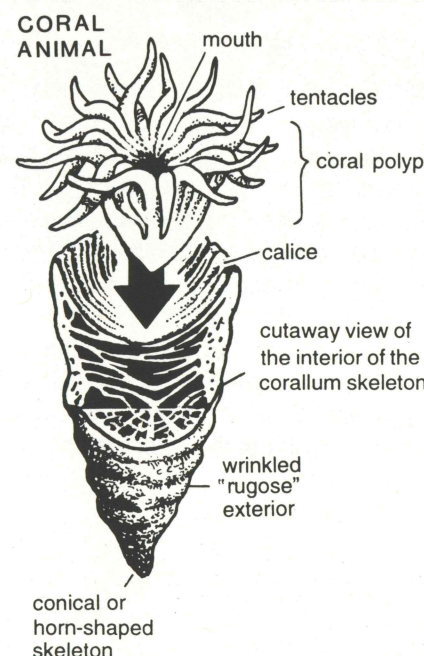


Diagram of rugose coral, showing the parts of the living coral animal and its skeleton (from "The Fossil Beds of the Falls of the Ohio," by Stephen F. Greb, Richard Todd Hendricks, and Donald R. Chesnut, Jr.).

into a single integrated data base. Public requests for information will be more efficiently fulfilled using RDB.

Data entry and management are the primary responsibilities of this project. The new data that are constantly being collected through the efforts of research projects must be added to the data bases. Public requests must be answered from the data in the system. Analytical data from the KGS coal laboratory must be added to the data base. KGS personnel work continuously to code and enter data into the computer system, and KGS geologists travel throughout the State to sample coal beds, measure coal-bearing outcrops, collect core descriptions, and describe core. All coal data must be located stratigraphically, topographically, and geographically before they can be entered into the data base.

Each member of the section responds to requests from the public, which are generally in one or more of the following categories: coal resources, coal quality, coal-mining geology, stratigraphy and subsurface geology, or coal data. Answering requests from the public is a major emphasis for the entire staff. Each year the section responds to more than 1,000 requests for assistance.

Petroleum and Stratigraphy Section

WELL RECORD LIBRARY

The Petroleum and Stratigraphy Section of the Kentucky Geological Survey is the official repository for records of all oil and gas wells drilled in the State. The public has access to well records in two locations—the Lexington office, where a complete set of records is maintained, and the Henderson office, where records for the western Kentucky oil and gas fields are maintained. A variety of records, such as drillers' logs, wireline logs, well-location survey plats, plugging affidavits, and completion reports, are on file for an estimated 225,000 wells.

Records for 1,270 new wells were processed and recorded by the Survey last year. The Kentucky Geological Survey staff also reviews and enters into the computerized data base as many of the older well records as time permits; 2,210 new records were added to the data base in 1992. The computerization of the Well Record Library and the expanded supporting data sets are expected to greatly enhance the speed and efficiency of data retrieval. By the end of 1993, data for approximately 110,000 wells should be available.

Last year, 2,345 visitors were assisted and 2,676 phone requests for information were processed at the

Lexington and Henderson locations. A total of 35,200 copies of well records were supplied. A log-copying service is available to the public at the Lexington office. More than 34,000 feet, representing logs for more than 2,500 wells, were copied for the public in 1992.

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's 1:24,000-scale 7.5-minute topographic quadrangle maps. More than 600 computer-generated overlays to topographic maps were made.

Stratigraphic and production significance has become the criteria for inclusion of wells in the data base. Stratigraphic tops data entry continues for the Cambrian and deeper penetrations. Ordovician Knox and Pencil Cave bentonite tops for nearly 500 wells in south-central Kentucky were entered, bringing the total post-Knox tops in the data base to nearly 6,000.

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

Machine-readable data selected by county, topographic quadrangle, and other parameters are available on 5.25-inch flexible diskettes or magnetic tape. One hundred floppy diskette requests were processed last year.

OIL AND GAS WELL-RECORD PRESERVATION

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

To date, records for nearly 30,000 wells have been scanned, resulting in one of the largest data bases of its kind in the country. In 1991, records selected for scanning were ranked according to stratigraphic and production significance to better meet the increasing research

and public needs. There were 14,000 documents scanned in 1992 for 4,000 wells.

WELL SAMPLE AND CORE REPOSITORY

The Repository, which is the fifth largest in the country, contains data from over 22,400 locations, valued at over \$535 million. In the last year, 366 sets of well cuttings and cores representing about 1 million drilled feet have been added to the collection.

The Well Sample and Core Repository provides easy access and permanent storage for well samples and cores from Kentucky. These materials are the greatest single source of information for subsurface investigation. Both professionals and the public used the Repository to study the surface and subsurface geology of Kentucky. During the year, 293 persons visited the facility and over 842 individual inquiries for information were answered by telephone. Twenty-three visitors to the Repository were assisted in identifying stratigraphic contacts in rock core and cuttings. In addition, 157 well cuttings and cores from nine wells were sampled for research. An index of all cores available for public use at the Repository was computerized and will be made available to the public as an Information Circular. Numerous tours of the facility, demonstrations, and displays were given to interested groups and individuals.

Repository personnel regularly visit collection stations located Statewide to collect samples and meet with representatives of industry. This interaction helps to maintain good working relationships between industry and the Survey. Two collection stations were relocated during the past fiscal year.

Over 151,700 feet of well samples were processed and added to the collection at the Repository last year. More than 30,500 boxes of core were sorted and inventoried, and 1,150 boxes of core were repaired. More than 26,600 feet of core was reboxed, and 21,860 boxes of cores were sorted and shelved onto pallet racks at the Repository. Several companies and government agencies were solicited for cores, including Dravo Lime Company, U.S. Army, Oryz Energy, Cyprus Minerals, Vulcan Materials, Exxon Minerals, City Services Oil Company, and three engineering companies. As a result, 172 cores and well cuttings representing more than 100,000 feet of vertical drilling were donated to the University. Two cores, representing over 1,300 feet of vertical drilling, were boxed and retrieved from UK's Robinson Forest.

During the past several years the repository has undergone major reorganization, including construction of new pallet racking and improvements in lighting and utilities. Computer linkage with KGS and the University of

Kentucky network was established, and computer terminals were installed.

Unfortunately, on the evening of June 17, 1992, Lexington received 7 inches of rain in 1 hour, and extensive flooding occurred. The American Building, in which the Repository is housed, was flooded with up to 3 feet of water and was the most heavily damaged structure on campus. Over 630,000 sample envelopes and 1,200 core boxes were damaged beyond use and will have to be replaced. Much of the KGS map and publication inventory also received heavy damage. Much of the damage was covered by insurance, and a moisture-control company spent over 6 months dehumidifying the facility. Although the facility was reopened for public use just 1 month after the flood, much of the progress made in remodeling over the past several years has been lost.

The flooding, besides causing delays and making major renovations necessary, points up the need for a new facility. KGS is currently working with its Advisory Board to draft plans and a proposal for a new facility.

Publications Section

PUBLICATION SALES AND DATA DISTRIBUTION

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

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

The office stocks 7.5-minute-quadrangle topographic and geologic maps for the entire State. These maps are at a scale of 1:24,000 (1 inch on the map represents 2,000 feet on the ground) and depict in great detail Kentucky's topography and geology. All available 1:250,000- and 1:100,000-scale topographic maps of Kentucky, as well as complete coverage of Hydrologic Atlases and a number of 7.5-minute-quadrangle, flood-prone-area maps published by the U.S. Geological Survey, are also kept in stock. In addition, numerous other geologic, geophysical, structure, hydrologic, and mineral-resource maps are available from the KGS sales of-

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

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

The Publication Sales Office handles a large volume of requests for maps and reports. During the past fiscal year, this office distributed approximately 20,000 maps and 4,000 reports, as well as 27,000 copies of well records and other miscellaneous items. Most mail orders are shipped out the day after they are received.

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

EARTH SCIENCE INFORMATION CENTER

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

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

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

refer persons to another State or Federal agency, or private firm, as the source for a particular product.

Approximately 500 individual inquiries for information were answered by KGS-ESIC during the 1992-93 fiscal year. Of these requests, 36 percent were for map-related information, 24 percent were for geodetic control data, 13 percent were for aerial photography or space imagery, 5 percent concerned digital map products, and 22 percent were for information about available publications. Ordering assistance to obtain the desired materials was provided for many of the requests.

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

Water Resources Section

The Water Resources Section provides daily consultation to the public on both water quality and quantity. During the past year the Section answered approximately 500 requests for surface- and ground-water information.

Most requests can be answered through a search of available literature and maps, although a field visit may be made when necessary. Although manpower limitations prevent extensive field investigations, these investigations frequently provide valuable data for KGS as well as for the person making the request.

THE KENTUCKY GROUND-WATER DATA REPOSITORY

In 1990, the Kentucky General Assembly mandated that the Kentucky Geological Survey establish a repository for all ground-water data collected by State agencies (KRS 151:035). In 1992 the Legislature provided funding for continued development of the repository. A data base manager and assistant were hired in late 1992 and early 1993 to develop and maintain the repository.

A relational computer data base for the repository is nearing completion. This data base will enhance the retrieval of ground-water data from other agencies, as well as improve the efficiency of data retrieval and manipulation for agencies, industry, and the general public.

Also included in the repository are hard-copy map files, field notes, ground-water publications, and other related information. The collection of ground-water data from State agencies and other sources in the industrial, academic, public health, and research sectors is underway, and will be an ongoing task for the repository.

The permanent home for the Kentucky Ground-Water Data Repository is now Room 101 of the Kentucky Geological Survey. The various types of ground-water data mentioned above are currently available for public use. It is expected that the repository will play an increasingly important role in ground-water planning for the Commonwealth in the future.

THE KENTUCKY HYDROLOGIC DATA BASE

The Kentucky Hydrologic Data Base, formerly known as the Kentucky Aquifer Research Data Base (KARD), is a comprehensive, interactive data base containing many types of ground-water data covering the entire Commonwealth of Kentucky. These data include information on water wells, well construction, water quality, springs, dye traces, discharge and water level, and lithology derived from well logs. To date, the data base contains 13,676 site records. This number will more than double during the current fiscal year as new data from various State agencies and other contributors are added to the data base.

The data base is dynamic, and is constantly being updated, modified, and expanded to meet the growing demand for ground-water information from KGS researchers, State and Federal workers, industry personnel, and the general public. The Kentucky Hydrologic Data Base is also a part of the Kentucky Ground-Water Data Repository discussed above.

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

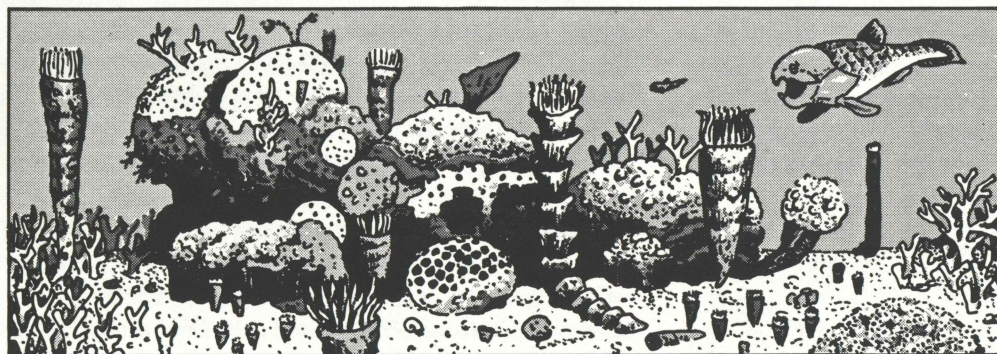
This cooperative project has proceeded as time per-

mits, without additional funding, for the past 2 years. Substantial effort was made to enter the available tracing records into the ground-water data base. Some additional data remain to be entered, and proofreading and error checking are underway. Rough drafts of several karst ground-water basin maps have been completed and are under review. Tracing data, such as injection and recovery location and dates, will be summarized in a listing that will accompany the basin maps, providing the first Statewide delineation of karst basins in Kentucky. The value of such maps and data for water supply, ground-water protection, and general economic development is significant.

SURFACE-WATER DATA BASE

A surface-water data base for Kentucky is being developed for use in research and to provide data for public inquiries. With the addition of this information to the KGS data bases, users can obtain geologic, topographic, and surface- and ground-water data at the same location. Providing easily accessible data in a centralized location will encourage greater efficiency and utilization of data by consultants, agencies, local governments, and citizens groups.

Currently the surface-water data base includes historical daily average flow data for all (about 257) surface water stations in Kentucky (either ongoing or discontinued). Low-flow and flood statistics and selected water-quality data will be incorporated on a priority basis. The availability of the data base greatly enhances KGS's ability to respond to public requests, and facilitates planning and research for water resources.



Part of the coral ecosystem that existed at the Falls of the Ohio (from "The Fossil Beds of the Falls of the Ohio," by Stephen F. Greb, Richard Todd Hendricks, and Donald R. Chesnut, Jr.).

AWARDS

Dr. Donald C. Haney, State Geologist and Director of the Kentucky Geological Survey, was awarded the prestigious Ian Campbell Medal for outstanding contributions to the profession of geology as an educator, administrator, and public servant. Dr. Haney was presented the award at the Geological Society of America annual meeting in Cincinnati, Ohio, in October 1992. The medal is named in memory of Ian Campbell, former State Geologist of California, who was noted for his candor and integrity.



Dr. Haney received the Ian Campbell Medal for outstanding contributions to the profession of geology in 1992. Photograph copyright Mayhew and Peper. Used with permission.

COMMITTEES, BOARDS, AND ADVISORY ACTIVITIES

National

American Association of Petroleum Geologists

Donald C. Haney—Representative of the Association of American State Geologists; David C. Harris—Eastern Section Membership Committee. James A. Drahovzal—Delegate of the Geological Society of Kentucky to House of Delegates; Research Committee

American Geological Institute

Donald C. Haney—President; Chairman, Ian Campbell Medal Award Committee; nominating Committee; Chairman, Search Committee for Executive Director. James C. Cobb—Editorial Advisory Committee

American Society for Testing and Materials

Cortland F. Eble—Task group leader for updating microscopic standards for coal. Henry E. Francis, Subcommittee D-5 on Coal and Coke; Subcommittee D-19 on Water; Subcommittee E-11 on Quality and Statistics.

Appalachian Oil and Natural Gas Research Consortium

James A. Drahovzal—KGS Research Coordinator.

Association of American State Geologists

Donald C. Haney—Liaison Committee; Chairman, Cooperative Planning Committee.

Central United States Earthquake Consortium

John D. Kiefer—State Geologists Committee.

Cincinnati Arch Consortium

James A. Drahovzal—KGS Research Coordinator.

Digital Equipment Computer Users Society

Steven Cordivola—Vice Chairman, Communications Committee; editor, Transactions of DECUS; coordinator, On-Demand Print Project.

Eastern Oil Shale Symposium

Terence Hamilton-Smith—Technical Advisory Committee; Chairman, Tar Sands/Heavy Oil Subcommittee. Martin C. Noger—Technical Advisory Committee; Chairman, Tar Sands/Heavy Oil Subcommittee.

Energy Advisory Board

Donald C. Haney—Secretary, Fuel Cycle Peer Review Panel.

Geological Society of America

Donald C. Haney—Geology and Public Policy Committee. John D. Kiefer—Chairman, Southeastern Section Committee on Geology and Public Policy. Cortland F. Eble—Secretary/Treasurer, Coal Geology Division.

Geology Alumni Advisory Board for the Department of Geology, University of Iowa

James A. Drahovzal.

Illinois Basin Consortium

James A. Drahovzal—Chairman; KGS Research Coordinator; Seismic Task Force Advisor. Stephen F. Greb, Cortland F. Eble, David A. Williams, James C. Cobb—Tradewater Working Group.

Interstate Oil and Gas Compact Commission

John D. Kiefer—Environmental Affairs Committee. Martin C. Noger—Enhanced Recovery Committee.

National Research Council

Donald C. Haney—Board on Earth Sciences and Resources.

National Stone Association

Garland R. Dever, Jr.—Program Committee for 1993 SO₂ Capture Conference.

National Water Quality Assessment Program

Donald C. Haney—Kentucky Liaison Committee; National Liaison Committee.

Ohio River Basin Consortium for Research and Education

John D. Kiefer—Board of Directors; Representative for the University of Kentucky.

Smartstar Midwest Users Group

Richard E. Sergeant—Treasurer, Steering Committee.

Tri-State Correlation Committee

Cortland F. Eble, Stephen F. Greb, David A. Williams.

U.S. Geological Survey

James C. Cobb, Cortland F. Eble—Adjunct Research Scientists.

U.S. Secretary of the Interior National Geologic Mapping Advisory Committee

Donald C. Haney.

State

American Institute of Professional Geologists, Kentucky Section

David A. Williams—President.

Geological Society of Kentucky

David C. Harris—President. Anna E. Watson—Secretary. James S. Dinger—Membership Secretary.

Governor's Council on Nonpoint Source Pollution

Donald C. Haney.

Governor's Earthquake Hazards and Safety Technical Advisory Panel

John D. Kiefer—Chairman, Technical Subcommittee.

Governor's Groundwater Advisory Council

Donald C. Haney. James S. Dinger—Chairman, Data Management Committee; Groundwater Monitoring Committee. James C. Currens—Data Management Committee. Richard E. Sergeant—Data Management Committee. James A. Kipp—Groundwater Monitoring Committee.

Kentucky Board of Registration for Professional Geologists

Donald C. Haney.

Kentucky Center for Energy Research Advisory Board

Donald C. Haney

Kentucky Geographic Information Systems Advisory Council

Donald C. Haney. Richard E. Sergeant—Standards Committee; Chairman, Base Map Subcommittee.

Kentucky Groundwater Management Data Committee

Richard E. Sergeant.

Kentucky Information Systems Commission on Geographic Information Systems

Richard E. Sergeant, Steven Cordivola, Donald C. Haney.

Kentucky Museum of Natural History

Donald R. Chesnut, Jr.—President, Board of Directors.

Kentucky On-Site Sewage Disposal Advisory Committee

James A. Kipp.

Kentucky Stratigraphic Nomenclature Committee

Donald R. Chesnut, Jr., Stephen F. Greb, Garland R. Dever, Jr.

Kentucky Water Availability Advisory Council

James S. Dinger.

Kentucky Water Management Task Force

John D. Kiefer.

Kentucky Water-Well Drillers' Certification Board

James S. Dinger.

State River Basins Policy Study Committee

John D. Kiefer.

State Water Management Task Force

John D. Kiefer (assisted by James S. Dinger, James A. Kipp, and David R. Wunsch).

University

Building Naming Committee

Donald C. Haney.

Department of Geological Sciences

James C. Cobb, James S. Dinger, James A. Drahovzal—Adjunct Associate Professors. James A. Drahovzal—Graduate Faculty. Martin C. Noger—Centennial Committee.

Environmental System Committee

Donald C. Haney.

Environmental Systems Program

James C. Cobb—Coordinator.

Groundwater Center Committee

Donald C. Haney.

Self-Study Committee

Donald C. Haney.

Local

Kentucky River Authority

Donald C. Haney. Daniel I. Carey—Policies and Procedures Subcommittee.

Lexington-Fayette County Quarry Ordinance Committee

John D. Kiefer.

Lexington-Fayette County Urban County Government Environmental Commission

John D. Kiefer.

Lexington-Fayette County Urban County Government Greenspace Committee

John D. Kiefer.

Lexington-Fayette County Urban County Government Stormwater Flooding Study Committee

John D. Kiefer.

Living Arts and Science Center

Stephen F. Greb—Science Advisory Board.

Mammoth Cave Karst Area Water-Quality Oversight Committee

James C. Currens.

National Speleological Society, Blue Grass Grotto

James C. Currens—President.

PERSONNEL

Professional Staff

Warren H. Anderson, M.S.
Geologist IV, Coal and Minerals Section

Daniel I. Carey, Ph.D.
Hydrologist IV, Water Resources Section

Mara Chen, Ph.D.
Post-Doctoral Scholar, Petroleum and Stratigraphy Section

Donald R. Chesnut, Jr., Ph.D.
Geologist V, Coal and Minerals Section

James C. Cobb, Ph.D.
Assistant State Geologist and Head, Coal and Minerals Section

Philip G. Conrad, M.S.
Geologist II, Water Resources Section

Steven Cordiviola, M.S.
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