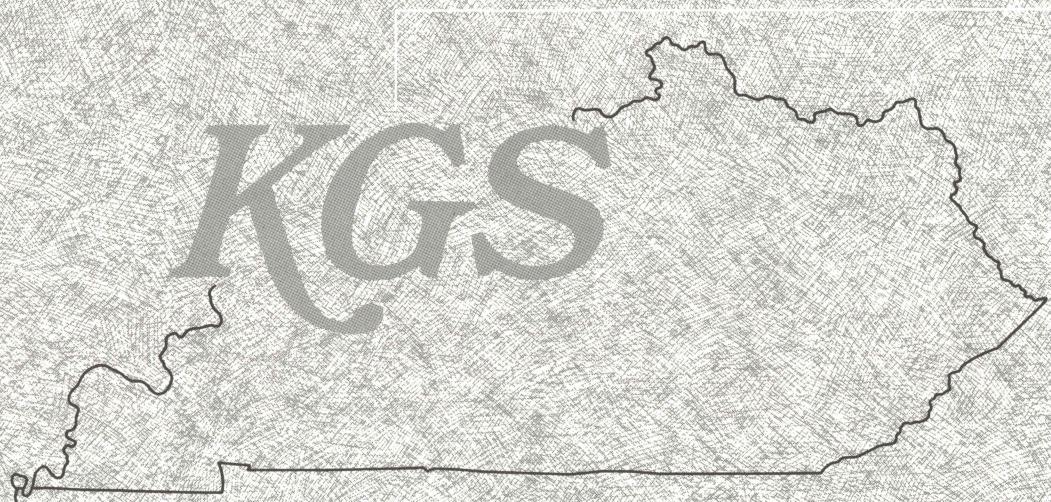


Annual Report



1990–1991

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

1990–1991 ANNUAL REPORT

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

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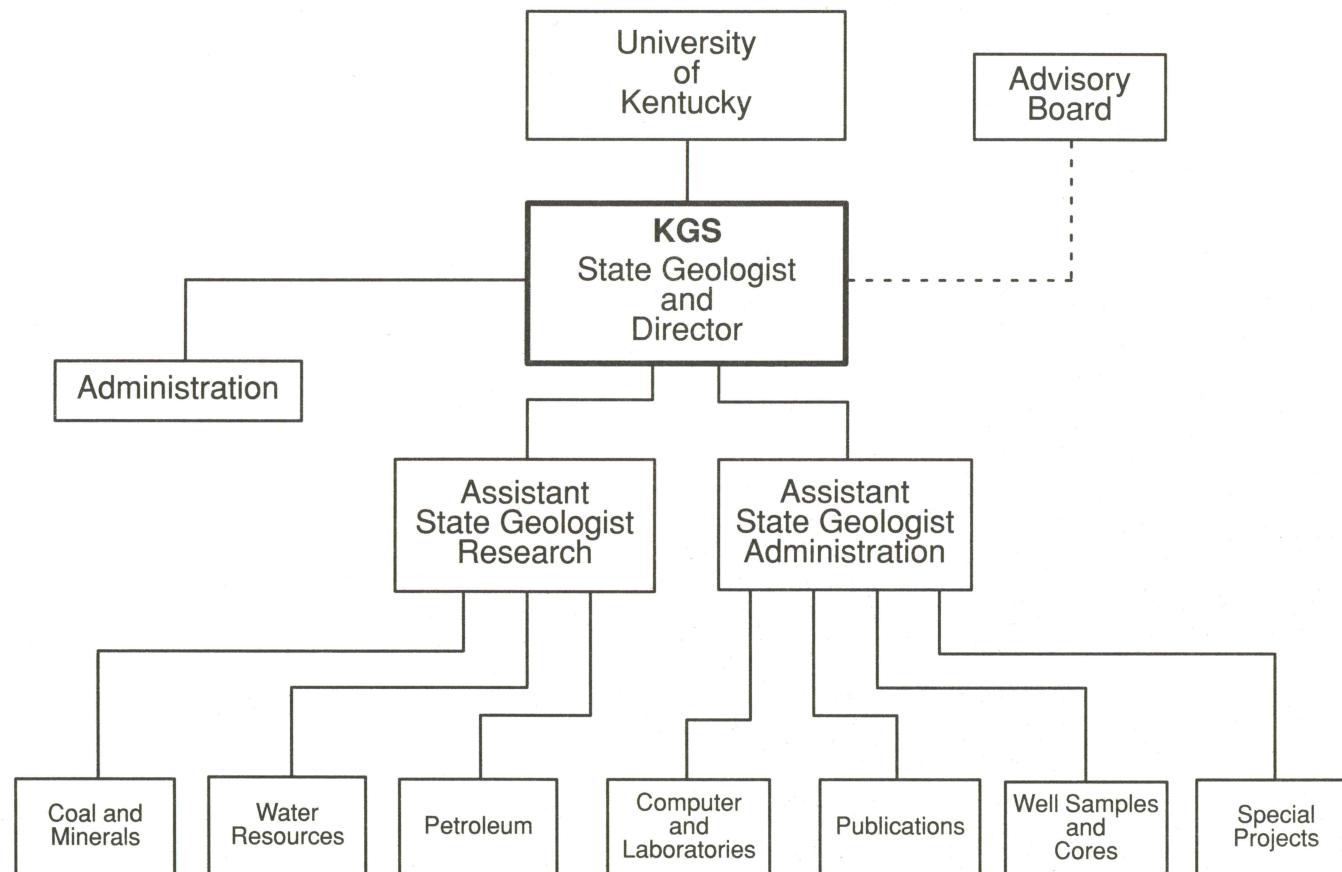
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ORGANIZATION OF THE KENTUCKY GEOLOGICAL SURVEY



FOREWORD

The Kentucky Geological Survey has conducted research on the mineral and water resources of Kentucky for the past 150 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.

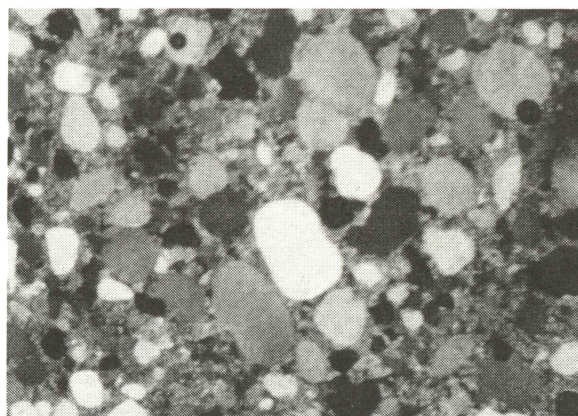
The objective of this annual report is to provide a brief summary of the activities of the Kentucky Geological Survey during the past fiscal year (July 1, 1990–June 30, 1991).



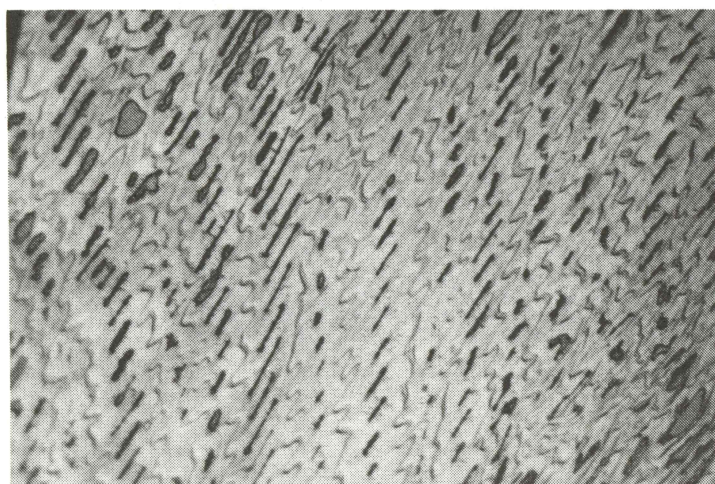
Dr. Donald C. Haney, State Geologist and Director.

RESEARCH ACTIVITIES

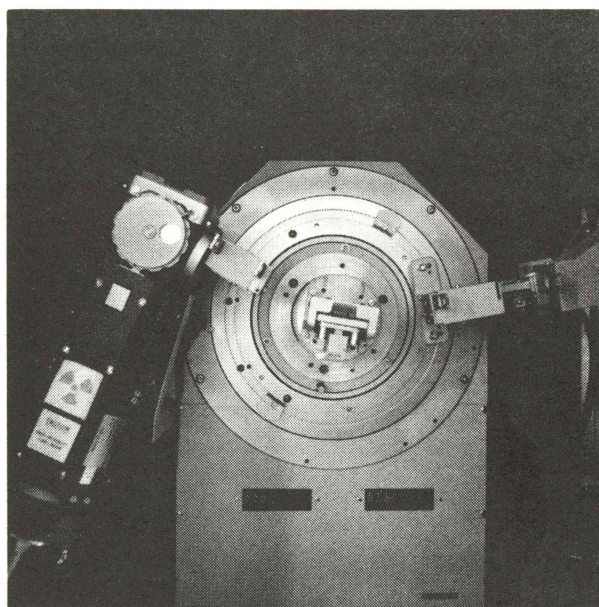
Basic research in geology and hydrology has formed the cornerstone of the Kentucky Geological Survey since its inception. The Kentucky Geological Survey maintains a diversified and comprehensive research program into the fields of coal geology, industrial and metallic minerals, oil and gas, and hydrology. 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.



Photomicrograph of quartz sand grains in dolomite.



Photomicrograph showing cellular structure of a lycopsid, a common constituent in Kentucky coal.



The X-ray Diffractometer determines the mineralogy of rock samples.

Coal

Coal is Kentucky's most important mineral resource. The value of Kentucky's annual coal production to the Commonwealth's economy surpasses all other segments of the economy. In 1990, Kentucky produced 179.3 million tons of coal, with a value to the economy of the State of about \$4.5 billion.

Coal production in the United States reached a record high of 1.03 billion tons in 1990, and is expected to reach 1.05 billion tons in 1991. Coal has not only maintained its position as the mainstay of national energy production, but has done so by a wide margin. Fifty-seven percent of the electrical power generated in this country is from coal-burning power plants. Coal is the most abundant fossil fuel in this country, but its future is clouded with uncertainty, primarily because of environmental concerns. Energy forecasters generally agree that the current trend of *increasing coal utilization will continue at least for the next 20 years*.

This is a time of many concerns for the coal industry in Kentucky, despite the apparently optimistic outlook for coal in general. These concerns stem from the passage of the Clean Air Act Amendments by Congress in 1990 (acid-rain legislation), generally low market prices for coal, economic recession, declining prime coal reserves, increased competition from other foreign and domestic coal regions, and a successful conclusion to the Persian Gulf War, which appears to guarantee plentiful oil supplies for the near term. Although Kentucky's coal industry produced a record amount of coal, there is great concern over how Kentucky's coal production will be affected by compliance with the amendments to the Clean Air Act. It is possible that the Clean Air Act could cause significant problems for Kentucky's coal industry.

The news media, industry personnel, and government agencies have shown much concern lately over Kentucky's coal resources. Although it is well known that Kentucky's coal resources are extremely abundant, it is less well known how much of these abundant resources are economically recoverable under current or future economic conditions. Presently, research is being conducted to identify the restrictions on the original resources such as land-use restrictions, mined-out coal, required mine barriers and buffers, coal too thin for underground mining, and coal-quality considerations. It appears from preliminary results that thin coal, coal-quality considerations, and mined-out coal account for the largest amount of coal not available for future production, with thin coal being the largest category. The ability to mine thinner seams is a technological factor that could greatly extend the productive life of Kentucky's coal fields.

In order to meet the demands for coal resource information, the Coal Section conducts projects in four broad areas: (1) coal-resource assessments, (2) public service and coal data management, (3) coal-mining geology, and (4) coal quality and petrology. This annual report gives the results of projects underway in 1990-91.

COAL AVAILABILITY FOR ECONOMIC DEVELOPMENT

DAVIDSON, O. Barton, ANDERSON, Warren H., HIETT, John K., CHESNUT, Donald R., Jr., GREB, Stephen F., SERGEANT, Richard E., and COBB, James C.

The amount of coal resources in Kentucky and other coal-producing states that are available for mining has been highly debated. Previously, estimates for original

resources and in some cases original resources modified by thickness and reliability classifications have been used to reflect the magnitude and future potential of coal fields. These estimates are quite large, in the hundreds of billions of tons, for several states, including Kentucky, giving the impression that the Nation's coal supply is more than adequate for even centuries of production. However, important technological and land-use factors were not taken into account by the previous resource es-

timates. Current research shows a very significant part of the coal resource is affected by these technological and land-use factors.

The use of computers employing digitizing and geographic-information-system 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, towns, and streams. Assessments for five 7.5-minute quadrangles have been completed to date in Pike, Perry, Bell, and Leslie Counties, and two more are underway for Boyd and Owsley Counties.

The coal resources available for mining in the areas investigated to date are only 50 percent of the original resources and may be as low as 25 percent of the original if strict sulfur limitations for compliance with the Clean Air Act are required. Technological factors restrict about 35 percent of the original resources, land-use factors restrict about 6 percent of the original resources, and mined-out areas account for about 10 percent of coal not available for mining. The available resource for the quadrangles investigated varied from 41 to 62 percent of the original resources. The available resource is further reduced by the sulfur-emissions regulations in the acid-rain legislation passed by Congress in 1990. Coal quality, which requires further investigation, appears to reduce the available resource in half. Preliminary findings suggest that only one-quarter of the original resource is available for mining when technological, land-use, and coal-quality factors are considered. Furthermore, engineering and economic modeling of the available resources suggests that only 8 to 20 percent of this coal may be *economically recoverable* under certain market conditions.

It is therefore imperative that projects such as this one be conducted to enable State and Federal planners, mining industry personnel, and utility companies to make meaningful assessments of coal fuel supplies for the future. Passage of the 1990 Amendments to the Clean Air Act in Congress, known as the Acid Rain Bill, which is intended to reduce sulfur dioxide emissions for coal-burning power plants, has brought much attention to the question of how much low-sulfur coal is available for mining and is economically recoverable. The Kentucky Geological Survey, in conjunction with the U.S. Geological Survey, West Virginia Geological Survey, Virginia Geological Survey, Illinois State Geological Survey, and Ohio Geological Survey has been conducting research into the availability of coal resources for mining over the past 5 years. The results of this study have been

the focus of much media attention, and have been presented to industry officials and government agencies. The Coal Availability Program will eventually be implemented in all major coal-producing states of the Nation.

SPRINGFIELD COAL STUDY

WILLIAMS, David A., SERGEANT, Richard E., and COBB, James C.

The Springfield coal (Western Kentucky No. 9) is Kentucky's largest producing seam and is one of the largest resources in a single seam in the world. The annual production in Kentucky is 33 million tons. This seam accounts for 75 percent of the coal mined in the Western Kentucky Coal Field and 20 percent of the coal produced in the State. When the production of Springfield coal is totaled for the entire Illinois Basin (covering Illinois, Indiana, and Kentucky), the amount is over 52 million tons, making the production from this single coal bed equal to the entire production of the sixth largest producing state, Texas. The remaining resources for this coal in Kentucky alone are more than 10 billion tons. However, because of the Clean Air Act Amendments of 1990, production of coal from this high-sulfur coal bed is expected to decline over the next 5 to 10 years.

Comparisons such as these help to put in perspective the importance of coals such as the Springfield. For the most part, coals are not viewed in the context of the geologic basin in which they occur; rather, they are viewed from the context of the state in which they occur. The basin approach helps to demonstrate better the magnitude of the resource and puts the resource in its proper geologic context.

The state geological surveys of Illinois, Indiana, and Kentucky have been involved in a cooperative project on the Springfield coal for the past 3 years. The purpose of this project is to demonstrate the geology and resources of this significant coal over the entire basin. Computerized data on coal thickness, elevation, mined-out areas, and coal quality have been combined into a common data base. The products from this work include thickness, structure, quality, and mined-out-area maps. The results of this work will provide energy and resource planners and policy makers with the most up-to-date and complete overview possible of this energy resource. It is important to direct positive attention to this important energy resource at this time because of the impact the Acid Rain Bill is having on the economy of this coal-producing region. Also, the Springfield coal needs to be put forward as a prime candidate for clean coal technologies: coal scrubbing, liquefaction, and gasification.

COAL-QUALITY, PETROGRAPHIC, AND PALYNOLOGIC ANALYSES OF KENTUCKY COAL BEDS

EBLE, Cortland F.

Knowledge of the quality of Kentucky's remaining coal resources is important in coal exploration and development, resource assessment and evaluation, coal-cleaning plant design and operation, environmental protection and regulation, and energy policy decision making. Each year the Kentucky Geological Survey receives hundreds of requests for information about the quality of Kentucky's coal resources. Because of this interest, a coal-quality research program is of the utmost importance for the Commonwealth of Kentucky.

The Kentucky Geological Survey's coal analytical laboratories became operational in 1989 to satisfy a rapidly growing demand for knowledge about the quality of Kentucky's coal resources. The quality of Kentucky coals, notably the ash yield, sulfur content, and calorific value, have become of greater importance because of the Acid Rain legislation passed in 1990. By the year 1995, when phase I of the legislation takes effect, *nearly all* coal-burning facilities *must* adopt strategies to reduce sulfur dioxide (SO₂) emissions by using scrubber technologies or by burning low-sulfur coal. Consequently, more research is needed to characterize better Kentucky's low-sulfur coal resources.

Currently, the Kentucky Geological Survey is performing coal analyses to meet this challenge. Routine analyses are proximate, ultimate, total sulfur, Btu, ash fusion, petrography, and palynology. Plans are being made to do mineral and elemental analyses.

A special effort is being made to coordinate the analytical program with resource mapping; special emphasis is being placed on not only determining which coal beds are higher in ash yield and sulfur content, but where in the coal bed, both vertically and regionally, the ash and sulfur tend to be concentrated. A good example of this approach is a pilot study on the Fire Clay coal bed that was undertaken to determine coal-quality variations in a low-sulfur coal in an area of eight 7.5-minute quadrangles in eastern Kentucky. This pilot study will help determine the variability in coal quality on a small to medium scale. This study will serve as a predictive model for understanding other low-sulfur coal reserves, and enhance resource recovery in the future.

SEDIMENTOLOGICAL INVESTIGATIONS OF THE CARBONIFEROUS ROCKS IN KENTUCKY

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

To understand coal resources, attention must also be given to the interburden, or non-coal rocks between

seams. In the Eastern Kentucky Coal Field the interburden is composed of shales, siltstones, sandstones, conglomerates, and limestones. Sometimes the interburden strata are thick and extensive for miles. In other cases the interburden strata are thin and change laterally over very short distances. Each of the rock types has different properties that can affect coal mining and reclamation. Interburden strata directly affect mine-roof stability, roof-support planning, and, potentially, acid-mine drainage. Some interburden rocks were deposited in channels where the coal was removed, causing coal "wants" or washouts. The type of rock in the floor also affects mine planning, because soft floor rock causes mining problems. By understanding the manner in which the rocks enclosing the coal can affect mining, models can be made to help predict various aspects of coal reserve estimates, roof support, and coal quality in advance of mining.

Sedimentological investigations of interburden strata examine the geologic characteristics of rocks, including grain size, bedding, contacts, and lateral and vertical relationships of rock. Research has shown that sediments deposited in river channels form different rocks with different properties than the sediments deposited on floodplains, lakes, bays, and swamps. Mappable trends of interburden strata can be used to predict mining problems, problems in coal quality, and reserves. This type of modeling is a powerful tool that allows geologists to predict changes in rock character based on limited information.

Several projects are underway at the Kentucky Geological Survey to characterize the different types of rock units in the coal field. Studies of roof and floor rocks of the Hazard No. 4 (Fire Clay) coal bed indicate that rocks were deposited in a variety of depositional environments ranging from river channels to marine bays. These rocks are being mapped to determine regional trends in roof character and their implications. Comparisons between coal thickness, coal quality, and the type of roof rock are also underway to determine any correlations that might prove to be useful in future mining. Trends that are noted above the Fire Clay coal may then be extrapolated to other seams with similar roof conditions.

CONSTRUCTION OF GEOLOGIC CROSS SECTIONS

CHESNUT, Donald R., Jr.

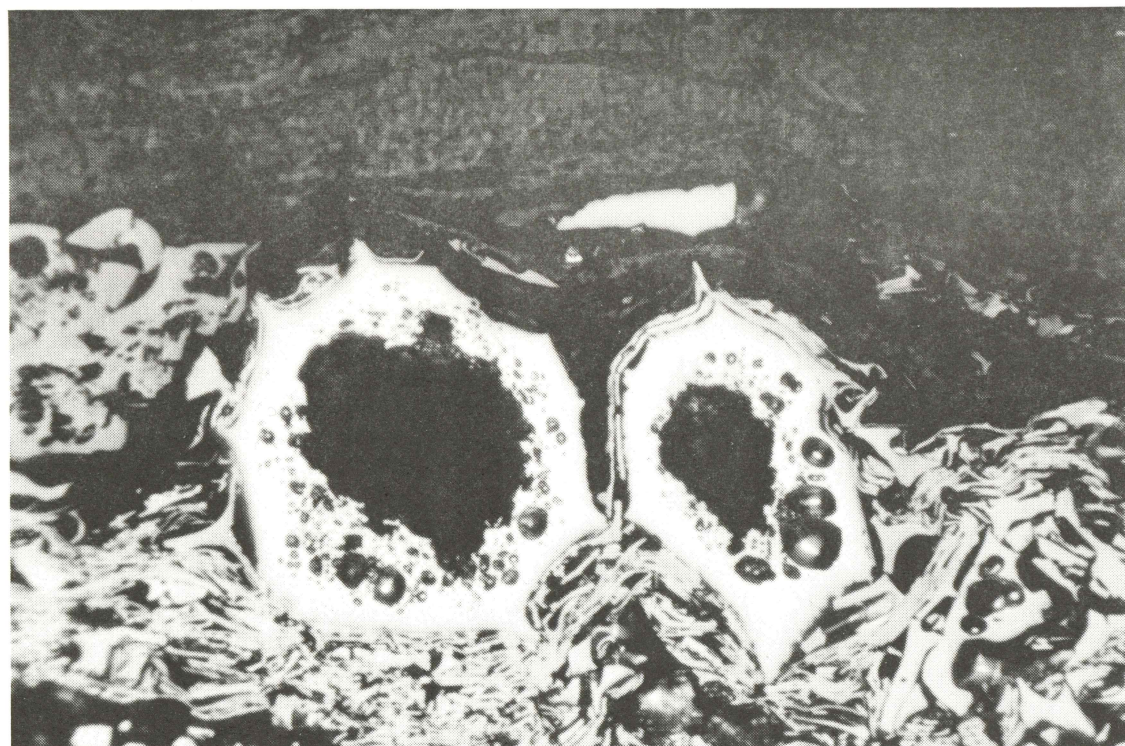
The identification of named stratigraphic units often must rely upon the construction and interpretation of detailed geologic cross sections. For this reason, a series of cross sections based on surface and subsurface data are being developed.

Outcrop sections along three major eastern Kentucky highways have been constructed and are being digitized for final publication using the AUTOCAD computer software. These highway cross sections illustrate the geology along Interstate Highway 64, Interstate Highway 75, and Kentucky Highway 80 in eastern Kentucky. These cross sections identify coal beds and show highway topography, outcrop location, mile markers, and exits. They will be used by persons interested in geology, resources, environmental concerns, and other engineering and construction issues.

In addition, seven regional cross sections across the Eastern Kentucky Coal Field have been constructed and

are in the final stages of preparation for publication. Two additional cross sections along the western belt of outcrop are being constructed and should prove helpful in identifying strata in the heavily forested Daniel Boone National Forest.

Detailed cross sections have been made for coal-availability studies of the Hoskinston, Matewan, Middlesboro North, Millard, and Noble Quadrangles in eastern Kentucky. These cross sections are used to demonstrate the surface and subsurface occurrence of coal beds and to examine the potential for deep subsurface coal resources.



Photomicrograph of sclerotinite, an inertinite maceral found in Kentucky coal.

Industrial and Metallic Minerals

Industrial and metallic minerals furnish essential raw materials for agricultural, ceramic, chemical, construction, energy-related, metallurgical, and manufacturing industries. The Kentucky Geological Survey conducts resource investigations to determine the compositional and physical properties, geologic setting, and geographic distribution of industrial and metallic minerals in the State.

INDUSTRIAL AND METALLIC MINERAL RESOURCES AND MINERAL INDUSTRIES MAP OF KENTUCKY

DEVER, Garland R., Jr., AMARAL, Eugene J., and ANDERSON, Warren H.

The Kentucky Geological Survey is preparing a new map of industrial and metallic mineral resources and mineral industries in Kentucky. The 1:500,000-scale map will show (1) limestone, dolomite, clay, shale, sand, gravel, and sandstone resources, (2) metallic and non-metallic mineral deposits, (3) active quarries, mines, and pits, and (4) mineral-industry plants. Compilation of the areal distribution of resources will be based mainly on the geologic mapping done in the State during the Kentucky Geological Survey-U.S. Geological Survey cooperative mapping program (1960-78).

Resource overlays have been prepared for mapped deposits of various thicknesses and in various topographic settings in order to evaluate compilation and reduction techniques. The new geologic map of Kentucky (scale 1:500,000), prepared by the Kentucky Geological Survey, will serve as the principal framework for resource compilation, and will be supplemented by compilations from geologic-quadrangle maps (scale 1:24,000) where required.

LIMESTONE AND DOLOMITE RESOURCES FOR COAL-RELATED INDUSTRIES

DEVER, Garland R., Jr.

Carbonate rocks are used by coal producers and coal-burning industries in environmental-control measures to meet Federal and State standards for mine safety and reclamation, air quality, and water quality. In order to determine the availability of stone for industry requirements, the Kentucky Geological Survey is investigating the chemical and lithologic characteristics of the State's limestones and dolomites.

With enactment of the Clean Air Act Amendments of 1990, the demand for limestone for SO₂ emission control is expected to increase sharply. Under provisions of the legislation, prompt installation of emission-reduction technology, such as limestone- and lime-based

wet-scrubbing systems, will enable coal-burning utilities to earn emission allowances and to extend compliance deadlines. Using information generated by its limestone investigations, KGS has been able to provide utilities and stone producers with quality, thickness, and geographic data for potential limestone sources.

Geologic features found during KGS limestone and coal investigations in south-central Kentucky were the focus of the 1990 field conference of the Geological Society of Kentucky. Variations in Mississippian limestones of the area indicate that the quality and thickness of the deposits were affected by fault-controlled uplift and subsidence during the time of deposition.

NONFUEL MINERAL STATISTICS

DEVER, Garland R., Jr.

The Kentucky Geological Survey and U.S. Bureau of Mines collect and compile information on the State's nonfuel mineral industry and on government actions affecting mineral industries. Data are shared by both 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 compile a mineral-producer directory, to prepare reviews of industry activities, and to answer public-service inquiries.

The value of Kentucky's nonfuel-mineral production in 1990 was \$334 million, based on preliminary data compiled by the Bureau of Mines. Crushed stone, with production of 44.4 million tons valued at \$183 million, was the leading commodity, accounting for 55 percent of the State's nonfuel-mineral value. Lime; cement; common, ball, and fire clay; construction and industrial sand and gravel; fluorspar; and zinc ore were produced in Kentucky during 1990.

CHEMICAL CHARACTERISTICS OF CARBONATE ROCKS IN THE HIGH BRIDGE GROUP (MIDDLE ORDOVICIAN) OF CENTRAL AND NORTH-CENTRAL KENTUCKY

ANDERSON, Warren H.

The High Bridge Group (Middle Ordovician) is mined at seven sites in central Kentucky and two sites in north-

ern Kentucky for various limestone products. Budget constraints caused work to be temporarily suspended on this project from 1988 to 1990, but the project was resumed in 1991 as a continuation of a regional study of the High Bridge Group to determine chemical characteristics of the limestone and dolomite.

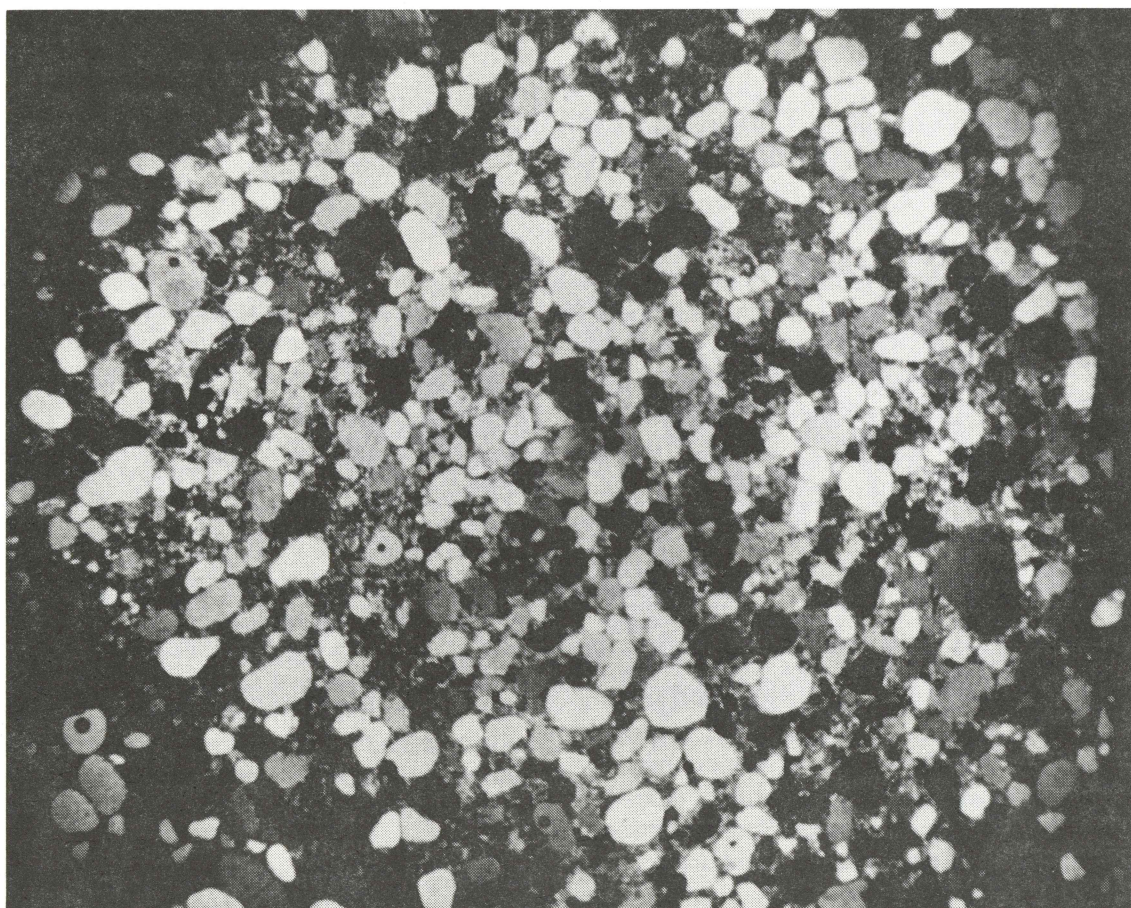
A lithostratigraphic description of a core from Mason County has been completed, the core has been sampled at 1-foot intervals, and 530 of the 680 samples have been analyzed. The remaining 150 samples are being prepared for analysis. The entire High Bridge section in the Mason County core will be analyzed for major elements.

REVISION OF "KENTUCKY'S ROCKS AND MINERALS"

ANDERSON, Warren C.

The popular booklet, "Kentucky's Rocks and Minerals" has recently gone out of print, and a new booklet is needed to satisfy the demand by rock collectors, teachers, naturalists, and amateur geologists. The KGS receives over 300 requests annually on rocks and minerals. Two major goals of the project are to expand the list of minerals included in the report, and provide color photographs (including microphotographs).

New specimens have already been obtained, and some photography has been concluded. A new text will be written, numerous new minerals will be photographed, and locations will be discussed. This report will be another Special Publication published by the KGS.



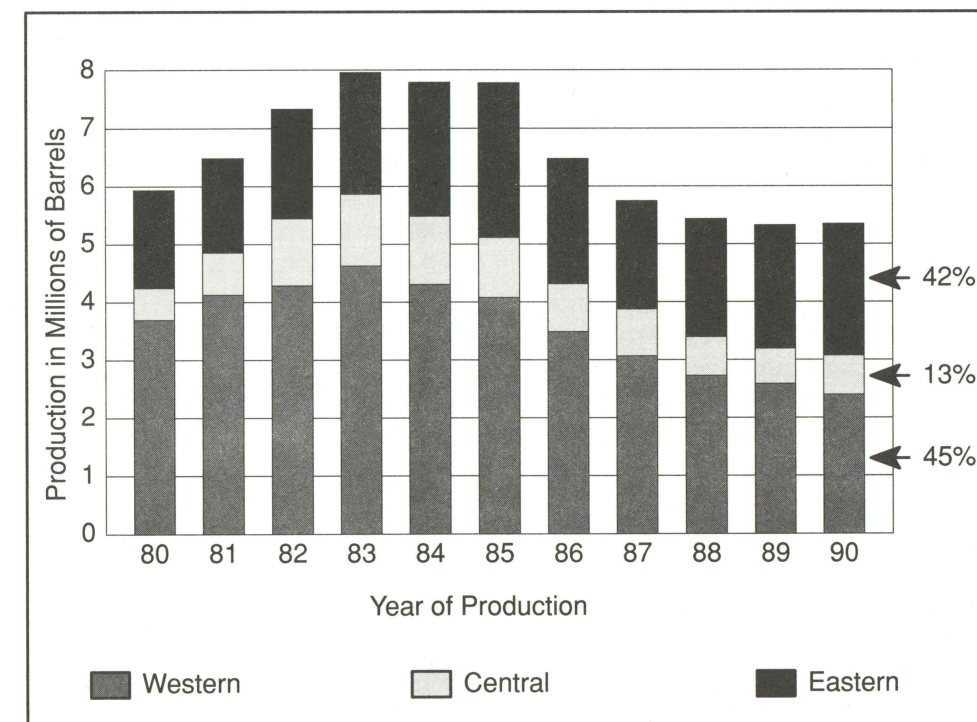
Photomicrograph of quartz sand grains in dolomite.

Petroleum and Stratigraphy

The responsibility of the Petroleum and Stratigraphy Section is twofold: to conduct research and provide services relating to the exploration and development of oil and gas resources in Kentucky, and to carry out research on the regional geology of the Commonwealth. On-going research activities are designed to stimulate hydrocarbon exploration and production. Regional geologic research is vital to the continued development of the stratigraphic and structural framework of the State; integration of subsurface information with the well-known surface geology is especially important. Regional studies are critical in understanding the character and distribution of mineral resources as well as the geologic aspects of environmental concerns and issues.

Oil and natural gas are important commodities for Kentucky's economy, ranking second and fourth, respectively, in value of natural resources produced in the State. In 1989, oil- and gas-wellhead value of production was nearly \$300 million. Currently, the industry nationwide, as in Kentucky, remains somewhat depressed. Most observers, however, are convinced that oil and natural gas will remain the core of the United States' energy base well into the twenty-first century. With careful planning and commitment, this sector of the State's economy could grow in the future, providing the Commonwealth with a strong energy base, a vital industry, and increased oil and gas revenues.

During 1990, Kentucky's drilling activity matched the current national trend with a continued decline. Only 1,053 well completions were reported for the year, compared to 1,265 for 1989. The success rate in these wells was 74 percent. Two hundred forty-five exploratory wells were drilled, resulting in the discovery of 26 new fields and pools, 15 deeper pools, 5 shallower pools, and 85 extensions of existing pools. Total footage drilled during the year was 2,389,171 feet, with an average well depth of 2,277 feet. In spite of the decreased drilling, production for both oil and natural gas was slightly higher than last year, by a little more than 1 percent and 2 percent, respectively.



The Appalachian Basin of eastern Kentucky was the most active area with 606 wells reported completed. Four hundred seven wells were successfully completed as gas wells within the shale, with an average initial open flow of 524 million cubic feet of gas per day.

Leslie County overtook Henderson County as the top oil producer in the State, with a total of 926,243 barrels of oil produced during the year. The primary drilling target is the Mississippian Newman Limestone ("Big Lime" of drillers), with an average initial potential of 78 barrels of oil per day.

In Pike County, the most active county in Kentucky, 181 wells were reported complete; all were successful. Gas production in Pike County totaled more than 20.3 billion cubic feet.

Of the gas wells reported, the maximum initial open flow was 6,037 million cubic feet per day from the Columbia Natural Resources, Inc., No. 21820 Pocahontas Development Corporation well in Martin County. Columbia also drilled the State's first horizontal hole in the Lower Huron Member of the Ohio Shale.

On the eastern flank of the Cincinnati Arch, the Syndicated Options Limited of Austria No. 9372 Ferguson Brothers well, Clinton County, made national headlines and spurred area exploration activity with an initial reported rate of 400 barrels of oil per hour. Cumulative production for the first 6 months was estimated to be nearly 200,000 barrels.

In western Kentucky, Henderson County was the highest oil producer, but activity and production continued to decline.

In response to changing national and local energy priorities, the Petroleum and Stratigraphy Section is carefully examining future research and service efforts. Details of these trends and our plans can be found in the 1991-96 KGS 5-Year Plan.

Nationally, the consensus is that natural gas will play a significant role in the future domestic energy mix because of the environmental acceptability of natural gas, its low cost, and its domestic availability. Kentucky has large untapped natural-gas resources, and KGS research will continue to aid private industry in its exploration and production.

Recovery of oil and gas from known domestic reservoirs is also being recognized as an important source of future domestic supply. Compilation of 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 development of exploration and development strategies. Kentucky's known oil and gas fields represent a significant resource, and research efforts in this area will continue and likely grow in the future.

The recent Congressional extension of the energy tax credits for the production of unconventional energy resources has already spurred interest in these resources in Kentucky. Devonian black shale, tight sands, tar sands, and coal-bed methane are all considered unconventional resources and represent significant hydrocarbon resources in Kentucky. The research in these areas will expand in the near future.

Horizontal drilling is becoming a more commonly applied technology and one that promises to result in increased production. The first horizontal hole was successfully completed in Kentucky this year, and several others are currently planned. To be successful, this technology requires detailed subsurface geologic information. KGS will continue to provide this information and increase the research and service efforts needed to support this and other new technologies.

Environmental problems are becoming more important in Kentucky as well as in the Nation. Subsurface geologic information is key to several of these areas of study,

including earthquake risk, potential deep-well disposal efforts, and ground-water pollution studies.

In addition to changes in research direction, the Petroleum and Stratigraphy Section has made several organizational changes to reflect the new environment in which it is operating. For several years we have been involved in fostering the development of regional research consortia. These consortia include the Illinois Basin Consortium (IBC), made up of the geological surveys of Kentucky, Indiana, and Illinois in cooperation with the U.S. Geological Survey, and the Cincinnati Arch Consortium (CAC), made up of the geological surveys of Kentucky, Ohio, and Indiana in cooperation with six oil companies. Earlier this year we joined the Appalachian Oil and Natural Gas Research Consortium made up of the state surveys of Kentucky, West Virginia, Ohio, and Pennsylvania, and the University of West Virginia.

All three of these consortia were developed because the research efforts deal with large geologic provinces that extend beyond an individual state's boundaries. These consortia are extremely valuable because they promote the integrated study of major geologic features. Consortia have the added advantage of sharing research and laboratory facilities as well as geologic expertise.

The Section, being charged with both applied research and service in areas of hydrocarbon and regional geology, is currently carrying out a number of projects and activities designed to serve the petroleum industry and the general public. Results in many of the existing projects already reflect the refocusing of research and the enhanced services that are now required. In addition, we are planning to initiate new projects that will address future needs. This redirection of effort will be necessary to increase the oil and gas production in Kentucky, develop a better geologic framework for the State, stimulate mineral-resource exploration, and provide geologic input to an increasing number of environmental issues. The following summaries review the status of currently active projects.

CINCINNATI ARCH CONSORTIUM: REGIONAL GEOLOGIC STUDIES

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

The Cincinnati Arch Consortium (CAC), consisting of the Kentucky, Ohio, and Indiana Geological Surveys, was formed in 1989 to carry out joint geologic research in the tri-state area. The CAC's initial project, funded by six oil and mineral exploration companies, is a detailed study of a previously unrecognized sedimentary basin lying below the Cincinnati Arch. The project, which will evaluate the basin's potential for economic petroleum and mineral resources, began in September 1990, and the initial phase is for 1 year. Follow-up efforts are dependent on Phase I results.

Results to date show that the basin, termed the "Kentucky-Ohio Trough," extends from southwestern Ohio and southeastern Indiana into central Kentucky. The trough was formed by faulting of basement rocks, and is filled with more than 5,000 feet of lithic sandstone (the Middle Run Sandstone) and basalts. The sandstones may provide reservoirs for oil, gas, or mineral deposits. Integration of regional gravity, magnetic, and seismic

data as well as petrologic and geochemical analyses of basement rocks will help formulate possible theories for basin development. The results of the study will be released in 1992.

ILLINOIS BASIN CONSORTIUM: GAS POTENTIAL OF THE NEW ALBANY SHALE, ILLINOIS BASIN HAMILTON-SMITH, Terence, WALKER, Dan, NUTTALL, Brandon C., and DRAHOVZAL, James A.

The purpose of this research is to assess the gas potential of the Devonian New Albany Shale of the Illinois Basin. The project is being carried out by the Illinois Basin Consortium (IBC), composed of the Kentucky, Illinois, and Indiana geological surveys. The project is being funded by the Gas Research Institute (GRI).

Final agreement on the project contract and subcontracts was reached in April 1991. To date, a New Albany Shale well data base with over 1,800 entries has been compiled, gas production and organic geochemical data have been recovered, and stratigraphic cross sections have been constructed. Preliminary maps have been made of New Albany Shale structure, thickness, gas

production, and thermal maturity of shale kerogen. The project will be concluded in March 1992.

HIGH-VOLUME OIL DISCOVERY IN CLINTON COUNTY, KENTUCKY

HAMILTON–SMITH, Terence, NUTTALL, Brandon C., GOODING, Patrick J., WALKER, Dan, and DRAHOVZAL, James A.

On September 25, 1990, the Syndicated Options Limited of Austria No. 9372 Ferguson Brothers well began production at rates as high as 400 barrels of oil per hour. After 8 weeks of operation, the well was reported to have produced nearly 150,000 barrels of oil from a depth of just over 1,000 feet. This well set a new American record for oil production for this depth, and initiated a great deal of leasing and drilling activity in the area.

The purpose of this project was to compile all available information about this well, to develop the basic geologic framework of the area, and to present it to the public in a timely fashion so as to encourage effective exploration and development of this significant resource. The result was Information Circular 33, which was published at the end of December 1990.

ILLINOIS BASIN CONSORTIUM: REGIONAL GEOLOGIC STUDIES

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

The Illinois Basin is an interior cratonic sag basin covering an area of some 60,000 square miles and containing about 100,000 cubic miles of Paleozoic sedimentary rocks in parts of Kentucky, Illinois, and Indiana. Four billion barrels of oil have been produced from reservoirs primarily in the Upper Mississippian. The potential exists for large accumulations of hydrocarbons in pre-Upper Mississippian strata. The Kentucky, Illinois, and Indiana geological surveys formed the Illinois Basin Consortium (IBC) in 1989 as a cooperative effort to study the geologic evolution of the Illinois Basin and to ensure wise decisions regarding the use and development of the basin's wealth of energy, mineral, and water resources.

The initial project of the consortium is the construction of a network of structural cross sections from geophysical logs, cuttings or cores, and seismic data where available. The sections 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-related 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 is being printed. A west–east cross section from Illinois to Lincoln County, Kentucky, is being constructed, and two north–south cross sections from Indiana through Breckinridge County, Kentucky, and south to Tennessee, and from Illinois to Webster County, Kentucky, are in the planning stage. KGS personnel are responsible for structural and stratigraphic correlations for the Kentucky portion of these sections.

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

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, taken directly from the three–sheet, 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 has been compiled and submitted to the U.S. Geological Survey for printing. Estimated publication date is either late 1991 or early 1992.

GEOLOGY ALONG KENTUCKY HIGHWAYS

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

The construction of highways in Kentucky has resulted in roadcuts that display numerous 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. A report about the geology along Kentucky's major interstate highways for professionals and the public at large will fill a definite need.

The first report, for Interstate Highway 75 in Kentucky and part of Tennessee, has been completed and is being published. Future plans call for preparation of similar reports along Interstate Highways 64, 71, and 65, as well as the Bluegrass and Western Kentucky Parkways and the Alexandria–Ashland (AA) Highway.

UPDATE, SHEET TWO, "OIL AND GAS MAP OF KENTUCKY"

WILLIAMS, David A., and NUTTALL, Brandon C.

The various sheets of the "Oil and Gas Map of Kentucky" are out of date. This project is part of an effort to update these maps. Current work is concentrated on Sheets 1 and 2, which show the location and areal extent of oil and gas fields in western Kentucky. The two maps were published in 1971 and 1972, respectively.

Sheets 1 and 2 have been updated to show the location and areal extent of new fields, extensions, and consolidations since 1972. The explanatory text is being prepared. Upon completion, Sheets 1 and 2 will be combined into a single overlay that will be sold as an open–file supplement to the printed Sheets 1 and 2. Information from the update will be stored in a computer data base for eventual output on demand. Sheets 1 and 2 are designed to be used in conjunction with the recently printed "Index of Oil and Gas Fields of Kentucky," which replaces the information listed on the back of the individual sheets of the "Oil and Gas Map of Kentucky."

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

NUTTALL, Brandon C., and DRAHOVZAL, James A.

The U.S. Department of Energy (DOE) 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. The Interstate Oil Compact Commission (IOCC) and the Geoscience Institute for Oil and Gas Recovery Research were charged with analysis and validation of TORIS. IOCC made TORIS data base information sheets available to regional coordinators. The objective of the regional review was to classify regional TORIS reservoirs, identify plays, and update reservoir engineering data. Kentucky was included in the northeast region.

For Kentucky, TORIS contains data for only five oil reservoirs, all located in the Illinois Basin. Using data available at KGS, each reservoir was classified according to the TORIS criteria, and geologic play names were assigned. Deficiencies in the TORIS data base were found during this research. Reservoirs were improperly identified, and reservoir engineering data were not accurate. In addition, multiple stacked pays were not identified, and a significant number of reservoirs and plays throughout Kentucky were not included in TORIS. Appropriate corrections were made to the existing TORIS entries, and they were submitted to IOCC for inclusion in the final regional summary report.

Current efforts focus on the development of a multi-state proposal to DOE to enhance the TORIS data base for the Appalachians. Currently, TORIS contains no data for oil fields in the Appalachian part of Kentucky. Correc-

tion of the TORIS data base for Kentucky would have positive economic consequences for the State.

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 (570 million years old) to Early Pennsylvanian (315 million years old). The purpose of this study is to determine source–rock potential, 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.

Geochemical analyses of oil samples using liquid chromatography and gas–chromatography mass spectrometry techniques show the oils to be generally mature and probably derived from two major sources in Ordovician and Devonian rocks.

Source–rock evaluations were determined by Rock–e–Val pyrolysis and total organic carbon analysis. Results indicate that samples from the Devonian black shales contain high to very high quantities of organic matter of variable composition. These samples fall within the oil window and were capable of generating hydrocarbons during burial.

A model explaining generation and migration of the hydrocarbons is being developed. Oil generated could migrate considerable distances by travelling through faults, fractures, joints, pores, and cavities, and along bedding planes to accumulate in the reservoirs where they now are found.

AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS PETROLEUM BASIN SERIES—INTERIOR CRATONIC SAG BASIN VOLUME

NOGER, Martin C.

The American Association of Petroleum Geologists (AAPG) is compiling a five–volume World Petroleum Basin Series that will provide oil and gas explorationists with information on the types of basins that hold the best promise for future hydrocarbon resources. Each volume contains a detailed description of one maturely explored "type" or "model" basin. The Illinois Basin was selected as the type basin for interior cratonic basin classification. Because the southwestern limits of the Illinois Basin extend into western Kentucky, KGS has taken an active role in contributing to this new volume. In addition to

Kentucky, the Illinois and Indiana geological surveys were part of the project; Illinois acted as principal coordinator. Various KGS personnel contributed geologic data and compiled maps for various chapters of the volume.

The Interior Cratonic Basin volume was published in May 1991. In addition to the Illinois Basin, the report includes information on the Williston and Michigan Basins, United States; Paris Basin, France; Baltic Basin, Soviet Union; Parana Basin, Brazil; and Carpentaria Basin, Australia. The volume is available through the American Association of Petroleum Geologists in Tulsa, Oklahoma.

TAR-SAND DEPOSITS OF WESTERN KENTUCKY **NOGER, Martin C., and HAMILTON-SMITH, Terence**

In 1981, the Survey initiated a project to inventory and evaluate the oil-resource potential of asphaltic sandstones of western Kentucky. In published reports (1984–85), the in-place oil-resource potential of sub-

surface and surface tar-sand deposits in western Kentucky was calculated to be 3.4 billion barrels. A 1990 report published by the U.S. Geological Survey listed the chemical composition and the sediment residue of the bitumen, and the trace-element composition of the reservoir rock.

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 1990 these sessions included 20 research papers and one poster session. The 1991 symposium will be held November 13–15 at the Hyatt Regency Hotel in Lexington.

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



Drilling in eastern Kentucky.

Water Resources

If one considers the basic needs of modern society—food, clothing, shelter, and energy—virtually nothing can be produced without large quantities of water. The drought of 1988 pointed out the stress of urban demands on water supplies and the importance of ground water for smaller communities, agriculture, and rural domestic water supplies.

Over the past 15 years not less than 10 Federal acts have been passed aimed at protecting 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. It is essential to understand geology and hydrogeology for the optimum development, utilization, and management of the State's water resources. The KGS 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. In addition, the 1990 State legislature (KRS 151:035) mandated that KGS establish a repository for all ground-water data collected by State agencies.

The following represent the major research efforts of the section over the past year (*see also Cooperative Programs, Water Resources*).

IMPACT OF NONPOINT-SOURCE POLLUTION ON AQUIFERS AND SURFACE WATER

DINGER, James S., CURRENS, James C., CONRAD, Philip G., and KEAGY, Dwayne C.

Section 319 of the 1987 Federal Clean Water Act deals with 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 land-use activities 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 providing 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 College of Agriculture, Department of Geological Sciences, In-

stitute for Mining and Minerals Research, and the Kentucky Division of Water. Major emphasis this past year has been placed on sites in Jessamine, Logan, and Hickman Counties (*see projects below for details*). In addition, Survey staff 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. During the past year, this group has made presentations to agricultural representatives in 46 counties and collected and analyzed water samples from wells and springs in these counties for pesticides and fertilizer components. During the next year, it is anticipated that the State's other 74 counties will be similarly tested.

HYDROGEOLOGY OF HICKMAN COUNTY

CONRAD, Phillip G., and DINGER, James S.

Soil moisture and ground water are 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 attending use of fertilizers and pesticides, its geology (consisting of loess, continental deposits, and semi-consolidated sandstone), which is representative of much of the Jackson Purchase Region, and the use of ground water for drinking-water supplies by the local residents.

Samples of water from domestic wells collected on a monthly basis have been analyzed for standard ions, nitrate, and pesticides. Four domestic wells have been in-

strumented with air lines to measure water levels, and several lysimeters have been installed to measure water quality in the unsaturated zone beneath a corn field. More lysimeters and several monitoring wells will be installed during the next year to sample water quality, and the ground-water flow system will be mapped using water-level measurements in both the domestic and monitoring wells.

This project is a cooperative effort with the University of Kentucky College of Agriculture, Department of Geological Sciences, and Institute for Mining and Minerals Research.

HYDROGEOLOGY OF THE GARRETTS SPRING (SINKING CREEK) DRAINAGE BASIN

CURRENS, James. C., and GRAHAM, Douglas C.

During February 1989, severe flooding occurred throughout Kentucky, and the flooding of sinkholes was widespread. The Sinking Creek karst valley in northwestern Jessamine County remained flooded through the end of March and early April. One home was almost submerged, and others were damaged extensively. Ground-water dye-tracing experiments were conducted from the fall of 1989 through the spring of 1990 to define the Sinking Creek ground-water basin divide. During the winter of 1989-90, three stage recorders were installed at critical sites in the basin. Discharge measurements are being made at these sites and others to use in conjunction with the stage data to develop a continuous discharge record.

During the 1990-91 Christmas holiday season, two storms yielding over 2 inches of precipitation each provided data on discharge rates and conduit dimensions. Monitoring will continue through another major storm to confirm and extend these data. Discharge data will be used to develop an understanding of the hydrology of the karst system and a procedure to forecast the effects of both larger storms and land-use changes in the drainage basin.

This project is in cooperation with the University of Kentucky College of Agriculture, which is monitoring ground-water quality to assess nonpoint-source pollution in the basin. Study of the relationship between ground-water discharge, water quality, and land use will provide information concerning source, mechanisms, and contaminant transport in a karst basin.

NONPOINT-SOURCE POLLUTION ASSESSMENT OF THE PLEASANT GROVE SPRING DRAINAGE BASIN, LOGAN COUNTY, KENTUCKY

CURRENS, James. C., KEAGY, Dwayne M., and GRAHAM, Douglas C.

In recent years concern has grown about the occurrence of pesticides and fertilizers in ground water in agricultural areas. Little data exist in Kentucky to establish whether or not agricultural chemicals are a significant threat to ground-water supplies in the State. Because karst areas are especially vulnerable to ground-water contamination and also represent some of the most valuable farm land in the State, a project was initiated by KGS to study a karst ground-water basin over several years. Field reconnaissance during the summer of 1989 located a prospective study area, the Pleasant Grove Spring drainage basin, in Logan County.

Preliminary work began on this project in the summer of 1990, and concentrated effort began in February 1991. Current efforts are centered on four activities: field reconnaissance, evaluation of selected sites for instrumentation, ground-water dye tracing, and synoptic sampling of springs. The three latter activities depend on labor-intensive reconnaissance. Reconnaissance activity reached a peak in April of 1991, continued through the summer, and will intensify again in the fall. Four locations have been partially evaluated as potential instrumentation sites.

At this time instrumentation is being chosen for Pleasant Grove Spring that will monitor water depth, water-flow velocity, temperature, and conductivity. Probes for dissolved oxygen, pH, and turbidity are also being considered. Another labor-intensive activity is the ground-water dye tracing. Eight traces have been completed, and sites for many more traces have been identified. Each ground-water dye-tracing experiment requires a month to complete, but four traces are run simultaneously. Results to date include a partial delineation of the drainage basin and the collection of 14 water samples. Analyses for eight water-quality samples show only slight nitrate contamination and occasional high bacteria counts. Pesticides have not been found in detectable quantities by Heidelberg Laboratory or the Kentucky Geological Survey laboratory at this time.

This project is being conducted in coordination with the University of Kentucky College of Agriculture and the nonpoint-source pollution program of the Kentucky Division of Water.

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

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

Riparian vegetative filter strips (VFS's) are one of the most frequently cited control technologies for nonpoint-source pollution of surface and ground water by agricultural chemicals. Recent studies show that trapping of sediment and dissolved solids is much less than would be expected according to existing idealized models, because of channelized flow. 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.

An initial rainfall simulation data run was conducted in 1990, and the grass filter plot was surveyed with grid spacings ranging from 2 inches to 1 foot. Computer programs for geostatistical analysis and simulation of microtopographic data (ZKRIP and TUBA) were installed and tested. Using parameters obtained from field data, statistically similar microtopographic data were generated to provide simulated grass plot digital elevation models (DEM). These DEM data were input into a geographical information system (GIS) preprocessor to determine subwatersheds and rill networks, and these results were entered into the raster-based GIS called GRASS for display and further analysis. The simulated grass plots will be used to develop statistics for sediment transport and deposition as a function of microtopography.

DETERMINISTIC MODEL OF CHANNEL HEADWALL EROSION: INITIATION AND PROPAGATION

FOGLE, Alex W.

Entry of sediment into the waterways of the Nation and Kentucky is a serious pollution problem, intensified by the chemicals adsorbed on the exchange phase of clay particles in the sediment. The topic of upland erosion from rill and inter-rill areas has been the subject of intensive investigations, both empirically and physically based. To date, however, no complete channel erosion

models for upland streams have been developed. The emphasis in this project is the initiation and propagation of headcut erosion on small upland streams with intermittent or small base flows.

Models were developed to 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 to a runoff routing algorithm to develop the CHANNEL model, which predicts general channel erosion resulting from time-varying flow, as well as the development and propagation of channel headwalls. Model algorithms will be validated using data collected from a channel built in a research flume. It is anticipated that the results of this study can be used to study erosion from agricultural and mined lands.

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

EFFECTS OF DEEP COAL MINES ON HYDROGEOLOGY

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

Deep mining is the principal method of coal production in Kentucky; approximately 60 percent is extracted from deep mines. Deep mining, and in particular pillar extraction and longwall mining techniques, will become more important because of the highly competitive nature of the coal industry today. These techniques remove structural support for the mine roof, producing deflection, fracturing, and total collapse of overlying strata. Collapse zones and fractures that commonly rise vertically toward the land surface alter ground-water flow and water quality in the area of the mine. High-extraction mining techniques also affect surface- and ground-water systems.

The goal of this project is to determine what effects high-extraction mining have on ground and surface water in a drainage basin in eastern Kentucky. Effects on both water quality and quantity will be investigated.

A study site has been selected in the Eastern Kentucky Coal Field, and field reconnaissance has begun. Monitoring wells will be installed above and adjacent to future longwall panels. Stress gages will be installed in the overlying rock strata to detect changes caused by mining. Springs, streams, and wells will be monitored for both water quality and quantity prior to, during, and after mining of the coal.

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, Institute for Mining and Minerals Research, and the coal industry.

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

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

Coal-related jobs in the Eastern Kentucky Coal Field have declined by 30 percent over the past decade. This trend is not expected to reverse in the future. Economic growth and diversity in the coal field are severely limited, in part by the steep topography and the lack of water resources. The coal industry, which is the principal economic force in the region, is concerned with the efficient extraction of coal. Since mineral ownership and extraction have in many cases been legally separated from land ownership, post-mining land use has not been the concern of the mining company. Cyprus Mountain Coals, a subsidiary of Cyprus Minerals, Inc., is unique in that it owns the 17,000 acres at the Star Fire surface mine, located in Knott, Perry, and Breathitt Counties, and, therefore, has considerable interest in post-mine development of the property.

An estimated 10,000 acres of usable flat land will be created by the year 2010 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 initial feasibility studies for water-resource development.

To date, 11 monitoring wells have been completed, which brings the total to 14 at the site. Well depths range from as shallow as 50 feet in hollow fills on the perimeter of the main spoil body to as deep as 244 feet in the spoil interior.

Water samples are collected for chemical analysis on a quarterly basis from the monitoring wells and major springs that crop out at the spoil's periphery. Presently, seven of the 14 wells at the site have been instrumented with digital data loggers in order to compile continuous water-level readings. Spring and surface-water discharges have been measured using weirs and hand-held flow meters. Plans are being drawn to perform a large-scale pumping test at the site to determine the hydraulic characteristics of the saturated portion of the spoil.

Dye traces have traced the path of surface water from its entry point at the specially designed infiltration basin into the spoil's saturated zone. The SEDIMOT II surface

hydrology modeling program has been used to estimate anticipated peak runoff for a 10-year period in order to aid in the development and design requirements for monitoring the mine site.

Concepts and findings to date have been published in symposium proceedings.

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.

Industries that operate in eastern Kentucky, including mining, oil and gas, and landfill operations, may affect the quality and quantity of ground water. Therefore, ground-water monitoring programs are required of these industries to obtain operational licenses and permits.

Presently, the complex chemical and physical relationships that are associated with ground water of the Eastern Kentucky Coal Field are not well understood. Initial 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 actively searching for suitable sites 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 meaningful ground-water monitoring scheme.

A site chosen this past year for intensive study is located approximately 1 mile south of the Star Fire Mine in Perry County. Eight monitoring wells housing 16 piezometers have been installed to obtain ground-water head measurements and water samples from units at various depths. Geologic cores, geophysical logs, packer tests, and downhole camera examinations have been used to gather hydrogeologic information of the hydros-tratigraphic units that underlie the site.

Weekly water-level measurements and monthly collection of water samples for chemical analysis have been initiated. A one-time sample collection for tritium analysis has been performed to determine the relative age of ground water and to aid in the definition of the flow system. Data obtained from this study will provide need-

ed information on the geochemistry of ground water in eastern Kentucky and provide the data necessary for the creation of a conceptual ground-water geochemical model for the Eastern Kentucky Coal Field. These data and models will be valuable to regulatory agencies and the industries they regulate for permit requirements and protection of aquifers.

HYDROGEOLOGY OF BRINE OCCURRENCE IN THE KENTUCKY RIVER BASIN

KIPP, James A.

A detailed hydrologic investigation was initiated in Estill, Powell, and Lee Counties in 1987 in cooperation with the U.S. Geological Survey. Cat Creek, Furnace Fork, and Big Sinking Creek were monitored to compare water quality in basins with varying degrees of petroleum production. A gaging station with automatic recording of stage, water temperature, and specific conductance was installed on each stream. In addition, monthly water-quality sampling was conducted in conjunction with the U.S. Geological Survey's Kentucky River National Water Quality Assessment study. Stream samples were collected at the gaging stations and at six locations within the Furnace Fork Basin from March 1987 through March 1989.

Oil-production activities were apparently the source of many dissolved constituents including barium, boron, bromide, chloride, magnesium, sodium, and strontium in water from Big Sinking Creek and Furnace Fork. The release of oil-production brines converts water in the receiving streams from the natural calcium bicarbonate type to the sodium chloride type. The greatest constituent transport in all of the basins occurred during flushing of the watersheds by initial high-flow events following the low-flow summer and fall seasons.

Four monitoring wells were completed in the Furnace Fork Basin during summer 1989 to gather information on long- and short-term fluctuations of water levels in the producing formation (Corniferous) and overlying strata. Water samples were collected from these monitoring wells, domestic wells, springs, and brines discharging from oil separators. Shallow ground water in the valley alluvium and near-surface bedrock does not appear to be widely affected by oil-production activities. Total-dissolved-solids content of water from the producing zone is less than water from the overlying New Albany Shale. This discrepancy is probably because of dilution that occurred in the producing zone as a result of the secondary recovery of oil by water flooding.

A report summarizing the results of this cooperative effort was recently published as U.S. Geological Survey Water-Resources Investigations Report 90-4191.

PRODUCTION OF FRESH WATER FROM THE KNOX GROUP IN CENTRAL KENTUCKY

KIPP, James A.

A few deep wells (800 to 1,000 feet) produce fresh water in central Kentucky. These wells are generally completed in the top of the Cambrian-Ordovician Knox Group. The primary objectives of this investigation are to (1) identify areas where the Knox contains fresh water, (2) determine the amount of water available from the Knox, (3) locate recharge and discharge areas, and (4) determine the direction and rate of water movement in the Knox. Because of the great expense of drilling these deep wells, the Survey has relied upon well drillers and their customers to identify new wells for testing and water-quality sampling.

Two new Knox wells were visited and sampled during the past year in Grant and Owen Counties. These wells were reported to be producing fresh water, but samples indicated a total dissolved solids concentration of approximately 4,000 milligrams per liter. This concentration is consistent with other wells in the area.

Information on the availability and quality of water from the Knox was supplied to the Kentucky State University aquaculture program during the past year. A section on the Knox was also included in the Kentucky River Basin ground-water report described below.

HYDROGEOLOGIC ASSESSMENT OF WATER SUPPLIES TO DETERMINE THE EFFECTS OF ABANDONED MINE LANDS

KIPP, James A., DINGER, James S., CONRAD, Philip G., and KEAGY, Dwayne M.

The Kentucky Abandoned Mine Land (AML) Reclamation Program, administered by the Kentucky Natural Resources and Environmental Protection Cabinet, is charged with reclaiming and restoring lands and waters adversely affected by mining that took place prior to the enactment of the Surface Mining Control and Reclamation Act (Public Law 95-87, enacted on August 3, 1977). The Kentucky Geological Survey, supported by the Kentucky Division of Abandoned Lands, initiated studies in June 1989 to evaluate the impact of past mining on ground-water resources in selected parts of the Commonwealth.

The nature and extent of perceived water-quantity and -quality changes are determined through literature review, resident interviews, and water-sample collection and analysis. The evaluations are then used by the Division of Abandoned Lands to determine where the AML program should assist with restoration or replacement of affected water resources. During the past year draft reports were completed by KGS for Pathfork in Har-

Ian County and Nevisdale in Whitley County. A final report was also prepared for the Nevisdale study. In addition, technical review was provided for a report prepared for the Division of Abandoned Lands by an independent consultant.

This project has been hindered by the lack of a comprehensive data base on ground–water quality for Kentucky. As a result, it is often difficult to differentiate between normal background and mining–affected water supplies. Ground–water–quality data from previous studies, theses, and dissertations have been entered into a computerized data base so that baseline conditions can be established as standards for comparison for future studies. Such a data base should facilitate creation of a more complete conceptual model of the occurrence of natural and mine–influenced water quality.

RECONNAISSANCE OF THE GROUND–WATER RESOURCES OF THE KENTUCKY RIVER BASIN

CURRENS, James C., CAREY, Daniel I., and DINGER, James S.

This project is an outgrowth of the 1988 drought and the subsequent organization of the Kentucky River Basin Steering Committee, which is staffed by concerned public officials and citizens and whose goal is to plan for water supply during future droughts. Under contract by the steering committee and the Lexington–Fayette Urban County Government, work began on this project in July 1990 and was completed in January 1991. A report was prepared based on questions posed by the Steering Committee. The methodology of the study was to assemble as much data as possible on the hydrogeology of the basin and synthesize it into a comprehensive report. No additional data were collected in the field because of time and funding constraints.

The most important conclusion of the project is that ground water is an important resource for domestic and small public and industrial water users, but probably cannot meet the needs of the large municipal users in the basin. A more comprehensive report for the public is planned for the coming year.

THE KENTUCKY AQUIFER–RESEARCH DATA BASE (KARD) AND GROUND–WATER DATA REPOSITORY

CURRENS, James C., SERGEANT, Richard C., and DINGER, James S.

KGS began developing the Kentucky Aquifer Research Data Base (KARD) for ground–water data in the spring of 1987. By the end of fiscal year 1986–87, the conceptual design of the data base was completed and programming was underway. During 1987–88 many new data sets and supporting programs were completed, and the data base was first used for storage and retrieval. During 1988–89 efforts were more focused on data entry, although considerable effort was also made on data–base development and refinement. During the 1989–90 fiscal year, development work on the data base was completed. Data sets for isotopic and trace–organic analyses were written. Also, sets for data specific to springs, discharge measurements, and ground–water tracing experiments were completed.

During 1990–91, effort continued to focus on data entry, with minor improvements being made to data storage and retrieval programming. To date, KARD contains approximately 13,343 site records, including 6,500 hydrogeologic sites from the U.S. Environmental Protection Agency's STORET data base and about the same number from the certified water well drillers' program administered by the Kentucky Division of Water. In addition, water–quality data were also obtained from STORET and various research projects being carried out by University personnel. These data continue to be entered. Significant progress has also been made on entering ground–water dye–trace data. A large file of dye–trace records has been accumulated, and 131 records are now in the data base.

The 1990 Kentucky Legislature mandated that KGS develop a ground–water–data repository for data collected by all State agencies (KRS 151:035). Although no funds were allocated, KGS has hired a data base programmer who has begun developing a relational data base and has developed plans for computer hardware and software to operate the system. The Groundwater Data Management Committee of the Governor's Groundwater Advisory Council is coordinating issues related to the creation and operation of the data repository.

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 computer network allows KGS to interconnect 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 University of Kentucky 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 series of computers, consists of a VAX 8550, MicroVax II/GPX color–graphics workstation, two VAXstation 2000 workstations, and a 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 (DEC Rdb, VAX DATATRIEVE, and SMARTSTAR), wordprocessing and desktop publishing (MASS–11 and INTERLEAF Desktop Publishing System), geologic modeling (MINEX and SURFACE III), and computer–aided drafting and presentation graphics (AutoCAD, FreeLance Plus, Harvard Graphics, etc.).

To enhance public–service and research capabilities at the Kentucky Geological Survey, it was decided to convert existing data sets into a comprehensive relational data base. Use of relational data–base management software will provide state–of–the–art data storage and retrieval technology and facilitate management of large public–domain data bases at the Survey. To accomplish this conversion it was necessary to catalog the contents of current and proposed data sets. Once this information was gathered, a theoretical data–base model was developed. The data–base model will then be used in a manner similar to a blueprint to design the actual data–base structures (i.e., tables, relations, indexes, etc.) and data–storage strategies. To insure data–base continuity

and compatibility, all design and implementation activities are being done using the Common Data Dictionary (CDD) software. CDD contains a compendium of data–base elements and serves to document physical data–base design as it proceeds. To date, the theoretical data–base model has been completed, and data–base structures are being designed and implemented for all of the coal data sets. Data conversion will be completed and the relational data base will be fully operational by January 1992.

Virtually all state geological surveys use computers in their day–to–day public service and research activities. Such things as public–service requests, data management, geologic and hydrologic modeling, wordprocessing, map making, and desktop publishing are being done with computers. Since most surveys conduct similar activities, they would benefit by sharing with other state surveys the experiences and insights they have gained in their computer–related activities. Shared information of this nature helps eliminate duplication of effort and makes surveys more productive and efficient. To provide state surveys with a vehicle to exchange experiences and information, an annual meeting for computer users at state geological surveys was proposed. A prototype meeting was held last year in conjunction with the annual meeting of the American Association of State Geologists. At this meeting the association agreed to co–sponsor (with the Kentucky Geological Survey) the first of these meetings in Lexington. A successful first meeting was recently completed, and plans were made for the 1992 meeting in Butte, Montana.

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. Most instruments have autosamplers and dedicated computers to help generate a complete set of analyses in the shortest time possible.

The laboratory facilities at KGS include the following analytical equipment:

- (a) for metals:
 - Inductively Coupled Argon Plasma (ICAP)
 - Atomic Absorption (AA) and AA with Graphite Furnace
- (b) for organic compounds and pesticides:

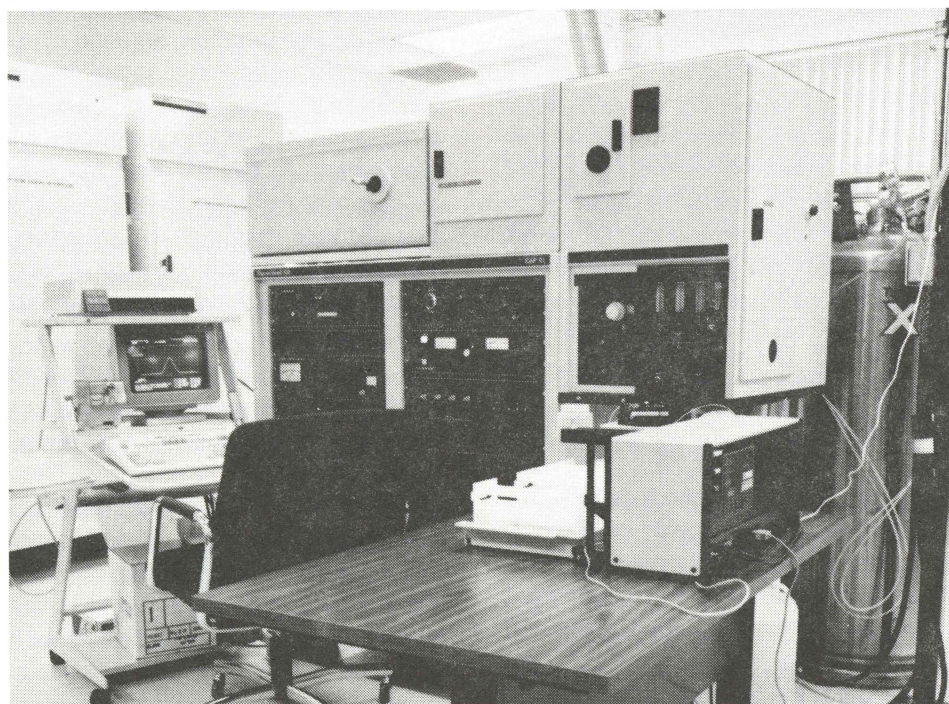
- gas chromatographs with Mass Selective, Flame Ionization, and Electron Capture detectors
- DELSI Rock-e-Val chromatograph
- (c) X-Ray Diffraction and X-Ray Florescence
- (d) UV-visible spectrophotometers
- (e) Leco instrumentation for coal analyses:
 - Proximate; MAC-400 Determinator
 - Ultimate; CHN-600 and SC-132
 - Total Organic Carbon
 - Ash Fusion; AF-600
 - Calorimeter; AC-300
- (f) Zeiss Incident and transmitted-light microscope UEM

The Fuels Division of the Laboratory Services Section analyzed over 700 coal samples for coal quality and 68 soil samples by X-ray diffraction. In addition, X-ray diffraction is now being used for the qualitative analysis of soils and rock minerals.

During the year over 500 water samples were re-

ceived in the Water Laboratory for the analysis of metals and other water-quality parameters such as acidity, hardness, inorganic anions, ammonia, and dissolved and suspended solids. The Water Laboratory analyzed over 350 samples from a variety of in-house and outside agencies.

The Organic Division began instrumental analysis of pesticides and volatile organic carbons; routine quantitative sample analysis is being carried out for pesticides. The Organic Division was involved in two research projects during the year: a plot study in cooperation with the University of Kentucky Department of Geological Sciences to perform headspace analysis for light hydrocarbons in soil samples from oil producing areas, and a project in cooperation with Dr. Alan Thio of the University of Kentucky Department of Regulatory Services to develop a new method for rapid screening for and identification of phenols and chlorated phenols via PID-ELCD gas chromatography. The results of these research projects are being submitted to refereed journals and presented at national meetings and workshops.



The ICAP-61 (Inductively Coupled Argon Plasma) analyzes up to 30 metals simultaneously.

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.

Three revised 7.5-minute-quadrangle maps were received during the 1990-91 fiscal year: Derby (Indiana-Kentucky), Metropolis (Illinois-Kentucky), and Shawneetown (Illinois-Kentucky). Four new 1:100,000-scale topographic maps were received: Cincinnati, Falmouth, Lexington, and Louisville.

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

Water Resources

As part of the University of Kentucky, KGS cooperates with many other academic departments and institutes, as well as State and Federal agencies. 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 flood plain. One of the most important publications to evolve from the cooperative program is the 963-page "A Compilation of Ground Water Quality Data for Kentucky." Reports such as these form the basis for answering several hundred requests annually from individuals, industry, and State and Federal agencies.

Following are brief descriptions of the major research projects undertaken in cooperation with other university departments and State and Federal agencies.

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. Part of this research resulted in the completion of a M.S. thesis by Arsin Sahba entitled "The Effects of Coal-Fired Power Plant Ash Disposal Upon the Groundwater Quality of an Alluvial System."

2. *Hydrogeology of the Western Kentucky Coal Field*—The hydrogeology of the Anvil Rock Formation and associated coal zones in the vicinity of the Ohio No. 11 and Hamilton No. 2 Mines operated by Island Creek Coal Company in Union County is being studied in cooperation with the UK Department of Geological Sciences and Institute for Mining and Minerals Research. It culminated in a M.S. thesis by Todd Fickle entitled "A Hydrogeologic Investigation of the Anvil Rock Sandstone in Parts of Union County, Kentucky."

3. *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.

4. *Effect of Infiltration Basins on Mine Spoil Hydrology*—In an effort to enhance the development of a ground-water resource in a mine spoil, artificial infiltration basins are being installed at the Star Fire surface mine, located in Knott, Perry, and Breathitt Counties, in the Eastern Kentucky Coal Field. This work is in cooperation with the UK Departments of Agricultural Engineering and Geological Sciences (see **Water Resources, Star Fire Project**).

5. *Ground-Water Education and Rural Water Testing*—A water-quality inventory of domestic wells and springs is being carried out in a pilot study of nine counties. Educational materials consisting of brochures, a slide show, and videotape are being prepared for distribution to agencies dealing with the rural areas of the State. The inventory and distribution of materials will be extended to all 120 counties in the coming years. This work is done in cooperation with 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.

6. 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 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.

7. 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 has been in operation since 1938. Prior to 1960, information from this program was published annually in the U.S. Geological Survey Water-Supply Paper series, "Surface Water Supply of the United States." Daily streamflow records for Kentucky from 1961 to 1974 were also published in annual U.S. Geological Survey open-file reports. Since 1975 all surface-water data are found in the annual USGS publication, "Water Resources Data for Kentucky."

8. 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. Prior to 1971 these data were published annually in the

U.S. Geological Survey Water-Supply Paper series. For the years 1964–74, these data for Kentucky were also released annually in open-file U.S. Geological Survey reports. Records since 1975 are found in the U.S. Geological Survey annual report, "Water Resources Data for Kentucky."

9. Hydrogeology of Brine Occurrences in the Kentucky River Basin—The effects of petroleum production on surface- and ground-water resources are being evaluated in a 600-square-mile area centered between the Kentucky and Red Rivers in parts of Estill, Powell, Wolfe, and Lee Counties. This research was conducted in conjunction with the U.S. Geological Survey's National Water Quality Assessment program on the Kentucky River Basin. The results of this study are presented in U.S. Geological Survey Water-Resources Investigations Report 90-4191, "Effects of Oil Production on Water Resources in the Kentucky River Basin, Kentucky," by Ronald D. Evaldi and James A. Kipp.

10. 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 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 the Institute for Mining and Minerals Research.

11. Deterministic Model of Channel Headwall Erosion: Initiation and Propagation—Eroded soil and the chemicals attached to it represent serious pollution problems to 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. The models will be verified through flume studies. This project is in cooperation with the University of Kentucky Department of Agricultural Engineering and is funded by the U.S. Army Research Office.

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 costs 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 printed publications, 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 1990–91 fiscal year.

Guidebook

Tectonic Implications of Depositional and Erosional Features in Carboniferous Rocks of South-Central Kentucky (Guidebook and Roadlog for Geological Society of Kentucky 1990 Field Conference), by Garland R. Dever, Jr., Stephen F. Greb, Jack R. Moody, Donald R. Chesnut, Jr., Roy C. Kepferle, and Richard E. Sergeant, 53 p.

Information Circulars

- IC 33.** High-Volume Oil Discovery in Clinton County, Kentucky, by Terence Hamilton-Smith, Brandon C. Nuttall, Patrick J. Gooding, Dan Walker, and James A. Drahovzal, 13 p.
- IC 34.** Low-Silica and High-Calcium Stone in the Newman Limestone (Mississippian) on Pine Mountain, Harlan County, Southeastern Kentucky, by Garland R. Dever, Jr., Jack R. Moody, Thomas L. Robl, and Lance S. Barron, 34 p.
- IC 35.** Oil and Gas Drilling Activity Summary for Kentucky, 1990, comp. by Brandon C. Nuttall, 158 p.

Maps

- Generalized Geologic Bedrock Conditions as Related to Solid-Waste Landfills in Kentucky, comp. by Martin C. Noger, scale 1:500,000.
- Status of Topographic Mapping Revision Program in Kentucky: 7.5-Minute Quadrangles (September 1, 1990), scale 1:100,000.

Report of Investigations

- RI 4.** Mineralization and Hydrocarbon Emplacement in the Cambrian-Ordovician Mascot Dolomite of the Knox Group in South-Central Kentucky, by Warren H. Anderson, with contributions by Peter Price, 31 p.

Reprints

- R 28.** Geology of Six Kentucky Carbonates: Sulfur Sorbents for AFBC, by Lance S. Barron, Garland R. Dever, Jr., and Thomas L. Robl, (reprinted from Proceedings of the 23rd Forum on the Geology of Industrial Minerals, May 11–15, 1987; Illinois State Geological Survey Industrial Mineral Notes 102), p. 11–20.

- R 29.** Ordinance for the Control of Urban Development in Sinkhole Areas in the Blue Grass Karst Region, Lexington, Kentucky, by James S. Dinger and James R. Rebmann, (reprinted from Proceedings of the Conference on Environmental Problems in Karst Terranes and Their Solutions, October 28–30, 1986, Bowling Green, Kentucky, published by the National Water Well Association), 14 p.
- R 30.** Stress–Relief Fracture Control of Ground–Water Movement in the Appalachian Plateaus, by James A. Kipp and James S. Dinger, (reprinted from Proceedings of the Fourth Annual Eastern Regional Ground Water Conference, Focus on Eastern Regional Ground Water Issues, July 14–16, 1987, Burlington, Vermont, published by the National Water Well Association), 11 p.

- R 31.** High Barium Concentrations in Ground Water in Eastern Kentucky, by David R. Wunsch, (reprinted from Proceedings of the Ground Water Geochemistry Conference, February 16–18, Denver, Colorado, published by the National Water Well Association), 14 p.

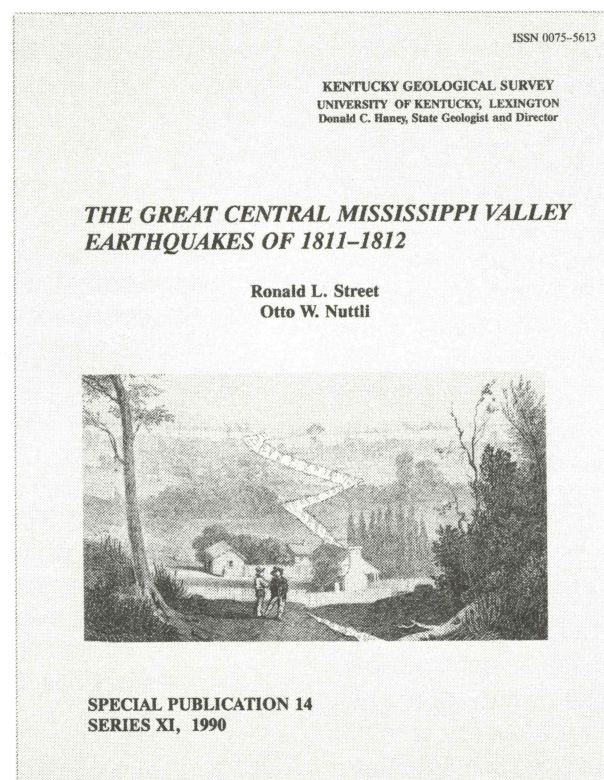
Special Publication

- SP 14.** The Great Central Mississippi Valley Earthquakes of 1811–1812, by Ronald L. Street and Otto W. Nuttli, 15 p.

Miscellaneous

Annual Report, 1989–1990, 58 p.

Generalized geologic map of Kentucky: Postcard.



PROFESSIONAL PRESENTATIONS BY STAFF MEMBERS

Carey, D. I., 1990, Solid waste management in Kentucky: Presented to Area Development District Executive Directors, Lexington, Kentucky, July 12, 1990.

Chesnut, D. R., Jr., 1991, Eustatic and tectonic control of sedimentation in the Pennsylvanian strata of the Central Appalachian Basin [abs.]: Geological Society of America Abstracts with Programs, v. 23, no. 1, p. 16; presented at Joint Meeting, Northeastern and Southeastern Sections, Geological Society of America, Baltimore, Maryland, March 16, 1991.

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Dever, G. R., Jr. [with Sable, E. G.], 1990, Mississippian rocks in Kentucky: U.S. Geological Survey Professional Paper 1503, 125 p.

Dinger, J. S., 1990, Definition, management, and special problems of aquifers in Kentucky: Presented at Kentucky Conservation Foundation's Center for Environmental Policy Symposium on the Unfinished Agenda: Protecting Kentucky's Groundwater, Frankfort, Kentucky, August 15–16, 1990.

Dinger, J. S., 1990, Kentucky geology; effects on pesticide movement in ground water, in Protecting Kentucky's groundwater, a grower's guide: University of Kentucky College of Agriculture, Cooperative Extension Service Publication IP–13, p. 9–10.

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Spencer, Bullitt, and Nelson Counties: Presented at University of Kentucky College of Agriculture Leadership Conference, Louisville, Kentucky, August 15, 1990.

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Warren Anderson, Coal and Minerals Section, identifies fossils for elementary students.

PUBLIC SERVICES

Coal and Minerals Section

Coal and Minerals Section personnel respond to over 150 questions per month from industry personnel, State and Federal agencies, researchers, and the general public. Coal-related inquiries concerning coal resources, thickness, quality, petrography, production, and general geology are addressed with the help of the Kentucky Coal Resources Information System (KCRIS). KCRIS is a computer-based system of indexes, geologic data, chemical analyses, microfiche records, core descriptions, field notes, and maps. KCRIS contains an interactive, on-line data base in which various types of coal-related information are stored, searched, retrieved, and manipulated. Customized computer output of most types of information requested by the public is possible. These data can be provided in hard copy or magnetic format, depending on the needs of the customer.

Types of coal data currently available through the Kentucky Coal Resources Information Office include: (1) 40,000 measurements of coal-thickness for approximately 120 beds in eastern and western Kentucky, (2) 1,311 coal chemical analyses for eastern Kentucky and 435 analyses for western Kentucky, (3) field notes and resource reports for most of the 7.5-minute quadrangles in the Eastern Kentucky Coal Field, (4) field notes and geologic quadrangle maps from the USGS-KGS geologic mapping program (1960-78), (5) 3,000 core descriptions from the Eastern and Western Kentucky Coal Fields, (6) 350 engineering records for the Eastern Kentucky Coal Field, (7) over 600 coal petrology records containing maceral and reflectance data for the Eastern Kentucky Coal Field, (8) coal production statistics by county, year, and type of mining for both coal fields from 1790 to 1990, and (9) 200 geophysical logs from both coal fields.

KCRIS is constantly being updated through the many ongoing projects at the Survey. A primary objective of Coal and Minerals Section personnel is to incorporate these data into this, one of the Nation's most comprehensive, publicly accessible coal-resource data bases.

As part of our commitment to earth-science education, members of the Kentucky Geological Survey gave presentations on geology, fossils, and dinosaurs in several civic forums. Slide shows on dinosaurs and fossils were presented at Lexington branch libraries throughout the summer of 1990, and were well attended. Staff members also visited local elementary schools to talk about

many different earth-science topics, including dinosaurs, fossils, and earthquakes. The earthquake scare in December 1990, prompted by a prediction of a quake along the New Madrid Fault generated many requests for information. Presentations were made via television, radio, print media, and personal appearances to calm fears and educate the public on the realistic dangers from earthquakes in Kentucky.

For the second year in a row the Survey hosted a University of Kentucky Saturday Seminar. This year's topic was "Mammoths, Mastodons, and Ancient Coral Reefs—Kentucky's Fossil Heritage." The presentation consisted of several slide shows on fossils and dinosaurs as well as a hands-on exhibit in the lobby of the Mining and Mineral Resources Building featuring hundreds of fossils collected in Kentucky. Graduate students from the Department of Geological Sciences were on hand to identify fossils that visitors brought to the presentation. More than 300 people attended the seminar, breaking all attendance records for the University of Kentucky Saturday Seminar program.

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. 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 approximately 2,000 new wells were processed and recorded by the Survey last year. In addition, the staff reviews and enters into the computerized data base as many of the older well records as time permits; 3,162 records were added to the data base in 1990. The computerization of the Well Record Library is expected to greatly enhance the speed and efficiency of data retrieval. By the end of 1991, data for approximately 102,000 wells should be available.

In addition to public access to oil and gas records, the staff provides a number of other services to the public. Services include custom well-list printouts based on user specifications (also available on 5.25-inch diskettes or magnetic tape), computer-generated well-location base map overlays for 1:24,000 topographic quadrangle maps (also may be plotted on user-supplied base maps), and well-record copying service. In addition, a personal-computer routine is available for con-

verting Carter coordinate locations to latitude and longitude.

Facilities in the Well Record Library are used daily by representatives of industry, government, academic institutions, and the general public. Last year, 1,228 visitors were assisted and 1,778 phone requests for information were processed. A total of 22,251 copies of well records were supplied and 89 floppy diskette requests were processed last year. Eight hundred quadrangle overlay well-location maps were sold to the public last year.

Because the oil and gas well-record files of the Kentucky Geological Survey are used extensively by the public and staff, the paper files are deteriorating rapidly, and it has become evident that the files must be made available by some alternate method. After several media were examined, it was decided to store the records electronically. Nearly 22,000 documents were scanned in 1990 for 7,377 wells. Data for 54 counties have been stored in this manner to date.

To meet the changing needs of the industry and our refocused research priorities, several new initiatives were instituted in the Library this year. A new program of entering stratigraphic information into the data base was started. The program necessitated a revision of the coding scheme used for stratigraphic data. The revisions enable sorting and comparisons with much more stratigraphic detail than the previous code. Current emphasis is on the wells of greatest stratigraphic and production significance, starting with the deepest tests in the State. As a result, data for the 183 Cambrian or deeper penetrations have been reviewed and stratigraphic tops from surface to total depth have been entered. The data base now contains more than 20,000 stratigraphic tops for wells in the State.

To further meet the needs of industry, a new log-copying service was initiated in May 1991 on a trial basis. Continuation of the service will depend upon the response of the petroleum industry.

Well Sample and Core Repository

The KGS Well Sample and Core Repository is the fifth largest facility of its type in the United States and contains cores and cuttings representing over 20 million feet of drilling. These cores and cuttings provide a valuable resource for the exploration and development of Kentucky's energy and mineral resources. They are the best source of information on the nature and occurrence of rocks in the subsurface.

The Survey is currently in the process of relocating the repository to the American Building on South Upper Street adjacent to the main campus in Lexington. It is

hoped that this move can be completed by midsummer 1991. The new facility contains 54,000 square feet of space. Approximately 44,000 square feet will be used for storage of rock materials, and 10,000 square feet for examination areas, rock processing, and offices. Centrally located, the repository will provide easy access and permanent storage for cuttings and cores from over 19,000 locations throughout the State and will greatly facilitate public service.

The benefits of the Core Repository are perpetual because as new geologic and engineering concepts evolve, new analytical techniques are developed, and as economic conditions change, these samples must be constantly reexamined.

Oil and Gas Newsletter

A newsletter designed to update the public on significant oil- and gas-related subjects was initiated in 1988. The latest edition was published and distributed in the spring of 1991.

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 1:100,000-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 office. Open-file maps showing landslides and related features are available for approximately 250 quadrangles in eastern and south-

central Kentucky; blueline 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 30,000 maps and 5,000 reports, as well as 20,000 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.

Since 1980, KGS has been affiliated with the U.S. Geological Survey's National Cartographic Information Center (changed to Earth Science Information Center in 1989 when it merged with USGS's Public Inquiry Office). The USGS center serves as a national repository for information concerning maps, aerial photography, space imagery, digital map data, and geodetic control, as well as information about earth–science publications.

Resources available to the KGS–ESIC office for answering requests include a file of more than 5,700 microfiche indexes to aerial photography (soon to be 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 infor-

mation about 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 460 individual inquiries for cartographic information were answered by KGS–ESIC during the 1990–91 fiscal year. Of these requests, 28 percent were for map–related information, 37 percent were for geodetic–control data, 22 percent were for aerial photography or space imagery, 4 percent concerned digital map products, and 9 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 working with the State Mapping Advisory Committee.

Water Resources Section

The Water Resources Section provides daily consultation on both water quality and quantity to the public. During the past year the Section answered approximately 700 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.

Recent State legislation (KRS 151:035) mandates that KGS establish a ground–water–data repository for data gathered by all State agencies. At present, a relational data base is being developed, and data from the Kentucky Division of Water are being stored in a computerized format. In addition, the U.S. Environmental Protection Agency STORET data base is being downloaded into the Survey's computer.

COMMITTEES, BOARDS, AND ADVISORY ACTIVITIES

National

American Association of Petroleum Geologists

James A. Drahovzal—District 8 (Kentucky) Committee on Statistics of Drilling (Chairperson), Acting Delegate of the Geological Society of Kentucky to the House of Delegates

American Geological Institute

Donald C. Haney—Vice President (1991), Ian Campbell Metal Award Committee (Chairman, 1991–92), Nominating Committee

American Society for Testing and Materials

Cortland F. Eble—Standardization Committee

Association of American State Geologists

Donald C. Haney—Liaison Committee, National Geologic Mapping Steering Committee (Chairman), Cooperative Planning Committee (Chairman)

Eastern Oil Shale Symposium

Martin C. Noger—Technical Program Advisory Committee (Chairman), Tar Sands/Heavy Oil Subcommittee; James A. Drahovzal—Technical Program Advisory Committee, Tar Sands/Heavy Oil Subcommittee

Geological Society of America

Donald C. Haney—Governing Council

Interstate Oil Compact Commission

Martin C. Noger—Enhanced Recovery Committee, Tar Sands Subcommittee

National Symposium on Mining

James A. Kipp—Program Advisory Committee

National Water Quality Assessment Program

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

State

Geological Society of Kentucky

Garland R. Dever, Jr.—Western Vice President, 1990; O. Barton Davidson—Secretary, 1989; Richard E. Sergeant—Secretary, 1990; James S. Dinger—Membership Chairman

Governor's Groundwater Advisory Council

Donald C. Haney; James S. Dinger, Data Management Committee (Chairman), Groundwater Monitoring Committee; James C. Currens, Data Management Committee; Richard E. Sergeant, Data Man-

agement Committee; James A. Kipp, Groundwater Monitoring Committee

Kentucky Center for Applied Energy Research

Donald C. Haney—Advisory Board

Kentucky Encyclopedia

Garland R. Dever, Jr.—Consulting Editor for Geology

Kentucky General Assembly

James C. Cobb—Task Force on Coal Revenue Allocation; Donald C. Haney, Richard E. Sergeant, John D. Kiefer, Steven Cordiviola—Interim Committee on Geographic Information Systems/Global Positioning Systems

Kentucky Information Systems Commission on Geographic Information Systems

Richard E. Sergeant, Steven Cordiviola—Executive Committee

Kentucky Museum of Natural History

Donald R. Chesnut, Jr.—Founding Director

Kentucky Nonpoint Source Technical Advisory Committee

Donald C. Haney, James S. Dinger, James C. Currens

Kentucky Oil and Gas Association

David C. Harris—1991 Technical Sessions (Co–Chairman); Terence Hamilton–Smith—1991 Technical Sessions (Co–Chairman)

Kentucky On–Site Sewage Disposal Advisory Committee

James A. Kipp

Kentucky Water Availability Advisory Council

James S. Dinger

Kentucky Water–Well Drillers' Certification Board

James S. Dinger

Living Arts and Science Center

Stephen F. Greb—Science Advisory Board

State Water Management Task Force

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

Tradewater Working Group, Illinois Basin Consortium

Stephen F. Greb, Cortland F. Eble, David A. Williams, James C. Cobb

Local

Kentucky River Basin Steering Committee

Donald C. Haney; Daniel I. Carey, Technical Advisory Subcommittee; John D. Kiefer, Technical Advisory Subcommittee (Chairman)

Kentucky River Authority

Donald C. Haney; Daniel I. Carey, Policies and Procedures Subcommittee

University of Kentucky Building Naming Committee

Donald C. Haney

University of Kentucky Department of Geological Sciences

Donald C. Haney, James C. Cobb, James S. Dinger, Adjunct Associate Members

University of Kentucky Environmental System Committee

Donald C. Haney

University of Kentucky Groundwater Center Committee

Donald C. Haney (assisted by James S. Dinger)

University of Kentucky Self-Study Committee

Donald C. Haney

University of Kentucky Solid Waste Management Study Group

John D. Kiefer (Chairman); Daniel I. Carey

Mammoth Cave Karst Area Water-Quality Oversight Committee

James C. Currens

National Speleological Society, Blue Grass Grotto

James C. Currens (Board of Directors)

Lake Cumberland Area Development District Environmental Committee for Solid Waste Management

Daniel I. Carey



David Wunsch, Water Resources Section, monitors a water-quality test in the field.

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