

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

ANNUAL REPORT 1984-1985



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

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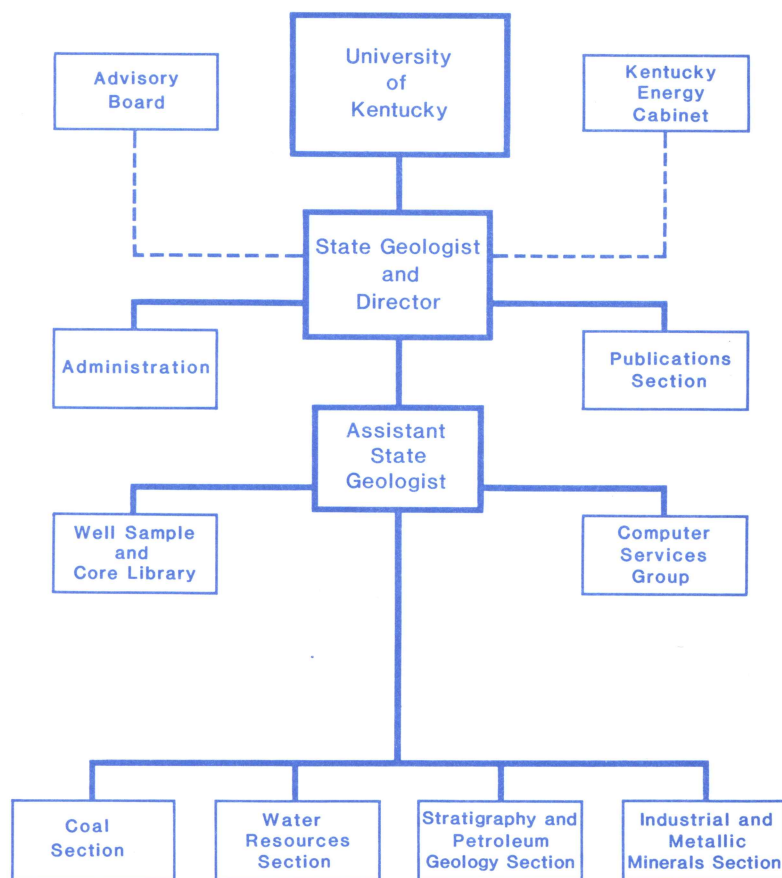
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ORGANIZATION OF THE KENTUCKY GEOLOGICAL SURVEY



FOREWORD

The Kentucky Geological Survey was established in 1854 as the official geologic research organization for the Commonwealth. Since that time the Survey, which is part of the University of Kentucky, has continued to build its data base and perform basic research in a number of geologic areas such as energy (coal, petroleum, and natural gas), applied geology, mineral resources, hydrogeology, and geologic and topographic mapping.

Some of the Survey's ongoing and future research objectives are: a major hydrogeology study involving the quantity and quality of ground water and surface water in the Kentucky River drainage, including a project to study the content of barium and other trace elements in selected smaller watersheds; a strategic and critical mineral study of the Jackson Purchase Region in western Kentucky; a major study of limestone resources in eastern Kentucky; a survey of the sand and gravel resources along the Ohio River in northern Kentucky; subsurface investigations of structure and stratigraphy related to the occurrence of oil and gas, including special projects on tar sands and eastern gas shales; studies of coal quality and compliance coal in both the Eastern and Western Kentucky Coal Fields; a major coal sampling project in the Western Kentucky Coal Field; stratigraphic studies in the Eastern Kentucky Coal Field; and continuous updating and review of coal resources data in both coal fields.

As an ex-officio member of the Kentucky Energy Cabinet, the Survey serves in an advisory capacity to local, regional, and various State and Federal agencies. Additionally, the Survey places great emphasis on public service activities. Close cooperation with industry and with the general public, and input from both sectors, are essential to the Kentucky Geological Survey in attaining its goals of defining, understanding, and properly utilizing the natural resources of the Commonwealth of Kentucky. Members of the Survey staff are actively involved in special committees and public service groups dealing with coal, water, oil and gas, 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, 1984-June 30, 1985).

PUBLIC SERVICES

Well Record Library

The Stratigraphy and Petroleum Geology Section of the Kentucky Geological Survey is the official repository for records of all 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 175,000 wells. Records for approximately 6,000 new wells are processed and recorded annually by the Survey. In addition, the Kentucky Geological Survey staff reviews and enters onto the computerized data base as many of the older well records as time permits.

The Survey is obligated to make all such data and records available and open to the public. Facilities in the Well Record Library for examination of records are used daily by representatives of industry, government, academic institutions, and the general public. An estimated 60,000 records are duplicated annually in reply to mail orders, telephone requests, and walk-in requests.

Well Sample and Core Library

Well cuttings and cores provide the best source of information concerning the nature and occurrence of rocks beneath the earth's surface. These materials are of great value for exploration and development in all areas of Kentucky's mineral industry, including oil, gas, coal, lignite, tar sands, oil shale, limestone, and other industrial and metallic minerals. The benefits from well samples and cores are timeless, because as new geological and engineering concepts evolve, and as new analytical techniques are developed, there is a constant need to go back and re-examine samples.

Samples and cores submitted to the Survey are processed, cataloged, and made available for inspection by researchers from industry, government, academic institutions, and the general professional community. Space and facilities are provided in the library for examination of these materials. Sampling of cuttings and cores is permitted under very strict controls, provided sufficient quantities of the required samples are available. Persons permitted to sample must sign an agreement to return all samples not destroyed, including thin sections, polish slabs, and plugs, and to turn in a bound copy of their reports to the Library. This policy allows the Survey to build on the information it can make available to others.

Results of specific studies will be held confidential for 1 year, if requested.

The Kentucky Geological Survey Well Sample and Core Library is centrally located near the University of Kentucky campus and provides easy access and permanent storage. In addition, the library has the advantage of storing materials from several sources in one place. The ultimate objective of the Survey is to selectively provide, wherever possible, a representative set of well cuttings or core samples for every Carter coordinate section (approximately 1 square mile) in the State. The library occupies a total area of about 21,000 square feet and has over 15,500 well sample sets and 900 cores on file.

Over 605,000 feet (335 sample sets) and about 90,000 feet (50 cores) have been added to the collection during the fiscal year. An Information Circular (ser. 11, IC 3), "Catalog of Well Samples, Cores, and Auger Samples on File at the Kentucky Geological Survey," is available for purchase through Publication Sales, and updates can be provided upon request. The Survey anticipates moving into a new facility soon, which will enhance our storage and service capabilities. The Library is currently located at 670 South Broadway in Reynolds Building No. 1, and is open from 8:00 a.m. to 4:30 p.m., Monday through Friday. For information, call (606) 257-1677.

National Cartographic Information Center

The Kentucky Geological Survey is the State affiliate of the National Cartographic Information Center (NCIC). NCIC was established by the U.S. Geological Survey in 1974 as the national repository for information regarding maps, charts, aerial photography, space imagery, digital map data, and geodetic control. Its mission is to organize cartographic data of national significance into a usable information system while the actual data remain with the original holder.

The Kentucky Geological Survey-National Cartographic Information Center office responded to a total of 749 individual inquiries for information during the 1984-85 fiscal year. Of these requests, 163 were for some type of remote-sensing or aerial-photography data, and 127 were for geodetic-control information.

The first phase of a computer-accessible, geodetic control information system was completed; more than 2,500 horizontal control points were cataloged and added to the Kentucky Geological Survey

computer system. These data included all of the National Geodetic Survey horizontal control in the State.

The KGS-NCIC office, in cooperation with the Kentucky Natural Resources and Environmental Protection Cabinet, presented a short course on topographic map interpretation as part of the certification training for sanitary-landfill operators. Three issues of the KGS-NCIC Newsletter were published during the year.

Publication Sales Office

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 many other sources, as well as open-file reports dealing with Kentucky geology, are also available.

The office is located in the basement of Breckinridge Hall on the University of Kentucky campus; convenient parking is located on the west side of Breckinridge Hall for customers who would like to visit the sales office.

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 equals 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 published by the U.S. Geological Survey, are also kept in stock. In addition, numerous other geological, geophysical, structure, hydrologic, and mineral-resource maps are available from the KGS sales office.

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 35,000 maps and 6,000 reports, resulting in income of more than \$145,000. Staff members who work in Publication Sales take great pride in assisting customers with finding needed information and offering prompt and efficient service. Most mail orders are shipped out the next 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.

Public Information General Information

Questions concerning various aspects of Kentucky geology come in to the Survey almost daily. These questions come from landowners, teachers, businessmen, farmers, students, spelunkers, rock and mineral collectors, persons planning vacations in Kentucky, and many others residing within the Commonwealth and outside the State. Most inquiries are answered by providing leaflets, maps, and pamphlets designed for this purpose, or by recommending available publications and maps that deal with the topic of interest.

Services include identification of rock, mineral, and fossil specimens and the distribution of rock and mineral sample sets to students. Displays are prepared for professional meetings, conferences, fairs, rock and mineral shows, and other public functions. These exhibits are designed to inform people about the many interrelationships of geology to everyday life and educate them in the use of maps and other geologic publications.

Coal Section

The Coal Section is responsible for providing information about Kentucky's coal resources. These requests come from many sources, including landowners, coal mining companies, land development companies, financial institutions, and all levels of government from local to State and Federal.

The maintenance of geologic records and specific data bases is a very important public service function of the Coal Section. Geologic records, which include core and outcrop descriptions, field notes, and chemical analyses, are archived in files for permanent storage. Most records are microfilmed to safeguard original copies. These records are constantly expanded and updated with data from ongoing research projects. The application of computer technology allows easier access, updating, and retrieval of data. Computer data sets currently being developed in the Coal Section are: an index of Coal Section information, coal-thickness records, coal quality and geochemical information, and stratigraphic and rock engineering data. When fully implemented, these data sets, along with other

coal-related data at the Kentucky Geological Survey, will be easily accessible to KGS research geologists and the general public.

Another important aspect of Coal Section public service is geologic consultation about the geology of coals in the Eastern and Western Kentucky Coal Fields. These consultations may be with landowners interested in the geology of their property, or with government agencies dealing with problems of concern to Kentucky.

Nearly 1,000 requests for coal geology information are received by the Coal Section each year. Coal Section personnel are involved in professional meetings, seminars, and short courses each year that reach hundreds of professionals who are involved with Kentucky's mineral industries.

Industrial and Metallic Minerals Section

The Industrial and Metallic Minerals Section provides assistance to industry representatives seeking information on mineral resources in Kentucky. Requests about resources commonly concern limestone, dolomite, clay, shale, sand and gravel, sandstone, barite, fluorspar, zinc, and lead. The Industrial and Metallic Minerals Section also answers more general inquiries concerning Kentucky geology from the general public, students, teachers, collectors, landowners, and persons planning vacations in the State. Services include the identification of rock, mineral, and fossil specimens. The Section prepares a set of three rock and mineral samples for distribution, upon request, to school children.

Stratigraphy and Petroleum Geology Section

The primary function of the Stratigraphy and Petroleum Geology Section is public service. Two of the Kentucky Geological Survey's major public service areas, the Oil and Gas Well Record Library and the Well Sample and Core Library, fall under the purview of the Stratigraphy and Petroleum Geology Section; these two areas provide services to more than 2,500 individuals, companies, and agencies annually. In addition, the Stratigraphy and Petroleum Geology Section answers more than 2,000 telephone and personal visit requests annually on subjects relating to a broad range of questions on the oil and gas resources of the Commonwealth.

The tremendous increase in drilling activity, from approximately 1,350 drilling permits issued in 1978 to a peak of 7,000 permits issued in 1983, and 6,250 issued in 1984, has severely taxed the Survey's resources and greatly limits the time available for needed research projects. Although permitting for 1985 continues to run at about the same rate as 1984, the staff of the Stratigraphy and Petroleum Geology Section strives to serve the public and the petroleum industry to the best of its ability. Major efforts to computerize additional records and the development of the capability to produce computer-plotted oil and gas well location maps highlight accomplishments of the past year.

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 300 requests for surface-water and ground-water information from industry, municipalities, State regulatory agencies, and private citizens.

Most requests can be answered through a search of available literature, although a field visit may be made when necessary. Funding limitations prevent extensive field investigations; however, these visits frequently provide valuable data for the Survey, as well as for the person making the request.

Literature containing water-resource data for specific regions of the State may be obtained from Publication Sales.

Committees, Boards, and Advisory Activities

National

ASSOCIATION OF AMERICAN STATE GEOLOGISTS LIAISON COMMITTEE

Dr. Donald C. Haney continues to serve on the Liaison Committee of the Association of American State Geologists. Eight State Geologists comprise the AASG Liaison Committee. The Committee visits Washington, D.C., twice annually to confer with officials of Federal agencies, members of Congress, and staff members of Congressional committees that have interest in matters relating to mineral, water, energy, and environmental resources.

COMMITTEE ON HIGHWALLS AND APPROXIMATE ORIGINAL CONTOUR

Dr. Donald C. Haney served as Chairman of the Committee on Highwalls and Approximate Original Contour of the National Academy of Sciences. In June 1984 the Committee completed an 18-month study of the requirements of the Surface Mining Control and Reclamation Act of 1977 (PL 95-87), which pertained to elimination of highwalls and return to approximate original contour of mined lands. The study, sponsored by the U.S. Office of Surface Mining and the U.S. Bureau of Mines, focused on concepts, technologies, and philosophies associated with reclamation practices in areas that have been surface mined. Major considerations of the Committee included geotechnical, socioeconomic, and esthetic issues; the rationale for statutory requirements; and whether existing requirements are flexible enough to achieve environmentally sound reclamation and post-mining land-use objectives. Work of this committee resulted in an extensive analysis of the impact of PL 95-87 on mining, reclamation, and the interests of the general public. Dr. Haney has made several presentations based on the findings of the study, which were published in July 1984.

COUNCIL OF STATE GOVERNMENTS ADVISORY COMMITTEE ON EARTH SCIENCE

Dr. Donald C. Haney is serving on the Advisory Committee on Earth Science of the Council of State Governments. The Council is under contract to the U.S. Geological Survey to assess the "Hazardous Waste Siting Needs" of the United States. Siting criteria include scientific and socioeconomic aspects of a particular area; however, geologic and engineering suitability must be addressed before other parameters can be considered. An advisory committee was established by the Council of State Governments to review and make recommendations concerning the data collected during the project and to review the final report.

INTERSTATE OIL COMPACT COMMISSION RESEARCH COMMITTEE

Dr. Donald C. Haney serves as chairman of the Research Committee of the Interstate Oil Compact Commission, which conducts research activities for the 33 member states. The Committee addresses research issues, including geology, engineering, and management problems, related to exploration, development, and production of petroleum.

Dr. John Kiefer is serving on the Environmental Affairs Committee of the Interstate Oil Compact Commission. This committee

represents the member states and assists the IOCC in developing positions on matters of environmental policy. The purpose is to develop policies that will insure continued development of our national resources, while insuring adequate protection of the environment.

Martin C. Noger was appointed a member of the Enhanced Recovery Committee of the Interstate Oil Compact Commission, which conducts research activities for the member states. The Committee addressed the technical progress of research efforts to recover heavy oil from tar-sand deposits and tertiary oil from depleted reservoirs.

Dr. Haney and Dr. Kiefer attended the IOCC Annual Meeting in Santa Fe, New Mexico, in December 1984, and Mr. Noger attended the IOCC Mid-Year Meeting in Austin, Texas, in June 1985.

NATIONAL COAL RESOURCES DATA SYSTEM COMMITTEE OF THE ASSOCIATION OF AMERICAN STATE GEOLOGISTS

Dr. Donald C. Haney is one of three State Geologists chosen to represent the Association of American State Geologists in an advisory capacity to the National Coal Resources Data System, which is operated by the U.S. Geological Survey. The committee members are selected from major coal-producing states to assist the U.S. Geological Survey with the development of a program to collect and disseminate coal-related information on a nationwide basis, using computer methods.

1984 EASTERN OIL SHALE SYMPOSIUM

Martin C. Noger was appointed a member of the Technical Program Advisory Committee and Chairman of the Tar-Sand Session of the Symposium sponsored by the Commonwealth of Kentucky, the Kentucky Energy Cabinet, and the University of Kentucky Institute for Mining and Minerals Research. The Committee was responsible for developing the format of the technical program, contacting and inviting speakers, and assisting in promoting the Symposium.

State

CITIZENS WATER TASK FORCE

Dr. John Kiefer serves as chairman of the Citizens Water Task Force (CWTF). This group is an outgrowth of the original State Water Management Task Force, which had been established by Kentucky House Joint Resolution 62, enacted by the 1982 General Assembly; the original task force functioned under the auspices of the

Legislative Research Commission until June 1984. The CWTF consists of most of the members of the original Water Management Task Force, plus several members who were added to broaden the areas of interest covered. The CWTF is sponsored by the Mountain Association for Community Economic Development (MACED) and the Environmental Quality Commission, and received clerical support from MACED.

The purpose of the task force is to work with State and Federal agencies to promote the proper protection, development, and utilization of Kentucky's water resources and to seek consensus among a broad range of Kentucky's citizens on priorities and strategies for addressing the State's present and future water needs.

The CWTF has held a series of meetings and field trips where legislators, citizens, administration officials, and industry representatives discuss and search for solutions to Kentucky's water problems. One of the major accomplishments of the task force during the past year was an in-depth review of the Governor's Water Management Plan. Meetings have been held with Secretary of Natural Resources and Environmental Protection Charlotte Baldwin and her staff to discuss the results of that review and to discuss ways in which the task force might assist the cabinet in meeting the State's water needs.

GOVERNOR'S EARTHQUAKE HAZARDS AND SAFETY TECHNICAL ADVISORY PANEL

Dr. John Kiefer serves on the Governor's Earthquake Hazards and Safety Technical Advisory Panel. This 15-member panel was appointed by the Governor in June 1984 to replace the Governor's Task Force on Earthquake Hazards and Safety. The panel was asked to expand on earlier efforts to improve earthquake preparedness in Kentucky. Legislation passed in spring 1984 laid the groundwork for the panel. In addition, financial support has been obtained from the Kentucky Division of Disaster and Emergency Services through the Federal Emergency Management Agency.

The Advisory Panel was directed to analyze data regarding seismic risks in Kentucky and to make specific recommendations for hazard mitigation, public education and awareness, emergency response planning in government and the private sector, and development of codes and policies to promote public health and safety. The panel, which is made up of members appointed by the Governor and associate members selected to advise in specialized areas, has met several times as a body and in committee. Dr. Kiefer also serves as chairman of the Seismic Probability Assessment Committee.

The panel has sponsored public meetings in association with the Central United States Earthquake Consortium, an organization of states most immediately threatened by the New Madrid tectonic activity (Kentucky, Tennessee, Missouri, Mississippi, Arkansas, Illinois, and Indiana). The panel, in association with the Division of Disaster and Emergency Services, has developed a 5-year seismic safety plan to guide Kentucky activities. In addition, the first annual report to the Governor is being prepared and should be available by August 1985.

KENTUCKY HAZARDOUS WASTE SITING BOARD

Dr. Donald C. Haney is serving on the Kentucky Regional Integrated Waste Treatment and Disposal Facility Siting Board. The board consists of nine permanent members and is made up of the Secretary of the Human Resources Cabinet and eight other members appointed by the Governor.

The Kentucky Hazardous Waste Siting Board was established by the 1983 General Assembly to investigate the need for an integrated hazardous waste processing facility landfill for the Commonwealth of Kentucky. The Board has been active for 3 years and will continue its work until a determination of need is established, and, if necessary, a site is located.

KENTUCKY ON-SITE SEWAGE DISPOSAL ADVISORY COMMITTEE

James Kipp is serving on the Kentucky On-Site Sewage Disposal Advisory Committee. The 1983 General Assembly transferred the responsibility of regulating on-site sewage disposal systems from the Department of Housing, Buildings, and Construction to the Cabinet for Human Resources. The program is now being administered by the Department for Health Service and local health departments. The Secretary of the Cabinet for Human Services established the advisory committee to assist the Department for Health Services with technical review and to make recommendations on matters relating to the regulation of such systems. Appointments are for 2-year terms.

KENTUCKY WATER-WELL DRILLERS CERTIFICATION BOARD

Dr. James Dinger was appointed by the Governor to serve a 2-year term on the initial Kentucky Water-Well Drillers Certification Board. The seven-member board was established by the 1984 General Assembly to regulate water-well drilling in an effort to protect the ground-water resource of the State. The board has developed

regulations concerning the qualifications for those people wishing to become certified water-well drillers in Kentucky and has implemented water-well record forms to be completed for wells drilled under the certification program. Those wells include all commercially constructed wells except those used for watering livestock and general farm use. Records will be kept at both the Division of Water and the Kentucky Geological Survey.

Local

LEXINGTON-FAYETTE URBAN COUNTY GOVERNMENT TECHNICAL ADVISORY COMMITTEE

Several members of the KGS staff have served in an advisory capacity to the Lexington-Fayette Urban County Government Division of Planning. Activities include reviews of planning documents and subdivision plans. During the past year, members of the KGS Water Resources Section and the Assistant State Geologist have assisted the Division of Planning in the development of a sinkhole ordinance. The development of sinkholes and other solution features in the limestones of the Lexington area poses a potentially serious problem for contractors, developers, and homeowners, and must be taken into consideration in planning and development. The final version of the regulations were adopted by the Lexington-Fayette County Planning Commission in June 1985.

RESEARCH ACTIVITIES

Basic research in geology and hydrology has formed the cornerstone of the Kentucky Geological Survey since its inception. This dedication to the identification and characterization of the Commonwealth's vast natural resources has continued throughout the Survey's 131 years of service to the people of Kentucky.

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, there are a number of energy-related special projects that are funded by grants or contracts. Projects in all of these areas of research are described in greater detail in the following sections.

Although research at the Kentucky Geological Survey covers a wide variety of subjects, it has a unified goal: a better understanding of the geology of the Commonwealth and utilization of the State's resources for the greatest benefit to the citizens of Kentucky and the Nation.

Coal

Coal is Kentucky's most valuable mineral resource; it is used to generate more than half of our nation's electrical power. Preliminary estimates from the Kentucky Department of Mines and Minerals show a large increase in coal production for 1984, to nearly 171 million tons, an increase of 30 percent over the 1983 production. Kentucky's coal production reached a peak in 1981 with production of 157.6 million tons; 1982 saw a 4 percent decline to 151.3 million tons, followed by a drastic 13 percent decline to 131.6 million tons in 1983.

The Coal Section conducts a variety of research projects designed to add vital information to its current data set. These projects involve coal-resource estimation, coal-bed mapping, coal-quality characterization and mapping, stratigraphy, mined-out area mapping, coal-bed methane studies, and overburden characterization for surface mining. Results of these projects are published or placed on open file for use by the public. Original information sources are archived.

One of the major efforts undertaken during the year was the identification of mining-related subsidence in a five-county area in the Western Kentucky Coal Field. This new project is funded by the Division of Abandoned Mine Lands of the Kentucky Natural Resources and Environmental Protection Cabinet. This project will provide valuable information for the recently enacted State Subsidence Insurance Program.

COAL RESOURCES OF THE EASTERN KENTUCKY COAL FIELD BRANT, Russell A., CHESNUT, Donald R., Jr., and COBB, James C.

One of the major research efforts of the Kentucky Geological Survey is the identification, characterization, and estimation of the Commonwealth's coal resources. Detailed knowledge about Kentucky's resources is essential for industrial development, expansion, government planning, and policy-decision making. Detailed knowledge about these resources is also vital because Kentucky's tax revenues are in very large part dependent upon coal production. Therefore, trends in resources and production must be identified in order to make projections on the economy of the State.

Kentucky's largest coal resource is in the Eastern Kentucky Coal Field. Before commercial mining, this field contained approximately 64 billion tons of coal greater than 14 inches in thickness. Since

large-scale commercial mining began in the last century, nearly 3.8 billion tons of coal have been produced from eastern Kentucky, and another 3.8 billion tons have been lost during the mining process, leaving approximately 56 billion tons of resources remaining.

Of the original 64 billion tons of resources, about 17 percent are greater than 42 inches in thickness, and 45 percent are greater than 28 inches in thickness. It is estimated that about 2 billion tons of production has been from surface mines and about 1.8 billion tons was from underground mines.

Kentucky now has one of the largest coal-resource data bases in existence. This data base serves industry, landowners, and government, and is itself a major resource for future investigations and production of Kentucky coal. Collecting additional coal-related data, maintaining the coal-resource data base, and disseminating information are the primary objectives of this project. Nearly 25,000 coal-thickness measurements, geographic and stratigraphic descriptions, 4,000 coal-bed isopach maps, and 200 core descriptions are currently in the computer data base. During fiscal year 1984-85, approximately 1,500 requests for coal information were answered.

COLLECTION OF DATA FOR THE NATIONAL COAL RESOURCES DATA SYSTEM (NCRDS)

BRANT, Russell A., COBB, James C., GROSSNICKLE, Effie Ann, and MATTHEWS, Neffra A.

Kentucky is the number one coal-producing state in the country. Coal plays a preeminent role in Kentucky's economy, and it is vital that accurate, up-to-date information about coal resources in Kentucky be readily available on a national level. To provide this type of nationwide network of coal information, the U.S. Geological Survey formed the national Coal Resources Data System (NCRDS). The purpose of this project is to supply relevant coal data to NCRDS, so that it may be computerized and made available nationally. In addition, this project has allowed the Kentucky Geological Survey to refine data management techniques and accelerate computerization of coal records, thus enhancing public service and research capabilities. Kentucky has participated in this program for 5 years, with funding from the U.S. Geological Survey. Funding for KGS participation in the project is scheduled to continue for one more year; however, the USGS will continue to maintain a National data base.

During the past year, 127 geologic descriptions of cores drilled in Kentucky were submitted for inclusion in the stratigraphic data base of NCRDS. Data to be entered into the NCRDS data set must

follow strict guidelines for submittal and must undergo many levels of verification. Kentucky is currently one of the largest contributors of data for NCRDS. Participation in the NCRDS program has resulted in many valuable exchanges of information between federal agencies and Kentucky.

ASSESSMENT OF DEEP COAL RESOURCES IN THE EASTERN KENTUCKY COAL FIELD

CHESNUT, Donald R.

Considerable research has been completed on the assessment of surface and near-surface coal resources in the Eastern Kentucky Coal Field. Rugged topography and extensive surface mining provide numerous exposures of most major eastern Kentucky coal beds. However, little is known about deeply buried coal beds, which makes assessing these resources difficult. The objective of this project is to collect core and well-log data on deeply buried coals so that their resources may be estimated. More than 1,500 drilling records containing coal information have been collected and are currently being analyzed. An estimate of deeply buried coal resources and their potential mineability will be the final result of this project.

STRATIGRAPHIC, PALEONTOLOGIC, AND STRUCTURAL INVESTIGATIONS OF THE COAL-BEARING ROCKS IN THE EASTERN KENTUCKY COAL FIELD

CHESNUT, Donald R.

Coal exploration, resource estimates, and exploitation of coal reserves depend upon detailed knowledge of the coal beds and the associated rock units above and below them. Much of the currently available information about the geology of coals occurring in Kentucky was obtained from rock strata at or near the surface. These data were compiled during the Statewide mapping program, the coal resources program, and other previous investigations. More information is still needed about coal-bearing rock strata in the subsurface. This information can only be obtained by drilling core holes across the Eastern Kentucky Coal Field. The expense of conducting such a coring project would be prohibitive to the Survey; however, this type of coring is being conducted locally by coal companies throughout eastern Kentucky. The Kentucky Geological Survey is attempting to solicit cores and coring records, make geophysical logs of selected holes, and compile stratigraphic information contained in these privately held coring records. These records then become

permanent additions to the coal data set and are available for public use.

Nearly 1,500 drilling records and core descriptions have been collected from various sources for this project. These records in conjunction with data already in the KGS coal data set are being used to construct detailed cross sections. These cross sections are essential to analyze the structural features and stratigraphic relationships in the coal field. A major goal of this project is to determine the utility of key stratigraphic horizons such as marine deposits and certain coal beds for regional correlations. Also being studied are the relationships between the Lee and Pennington Formations in the deeper parts of the coal basin in order to determine the potential for deeply buried coal resources in eastern Kentucky.

Valuable data can come from many sources. The Kentucky Geological Survey is frequently asked to identify curious rock specimens found in the Commonwealth. While these requests are usually routine, they sometimes prove to be significant geologic discoveries. One such case gained national and international attention during the past year because of its importance to the science of paleontology. The fossilized footprints of a four-legged animal in a Pennsylvanian sandstone were brought to the attention of the Kentucky Geological Survey by Mr. Roy Hines of Somerset, Kentucky. Working in conjunction with vertebrate paleontologists, Survey geologists tentatively identified this specimen as a reptile, which would make it the oldest known reptile fossil in the world. The specimen was donated to the University of Kentucky geology collection by Mr. Hines. To commemorate this outstanding contribution to the natural history of Kentucky, the University of Kentucky commissioned a painting of the reconstructed fossil, which the Survey presented to the University of Kentucky Geology Department for display with the fossil specimen.

GEOPHYSICAL WELL LOGGING

BRANT, Russell A., COBB, James C., and SMATH, Richard A.

Geophysical well logging is an important and relatively inexpensive method for collecting subsurface geologic data. The Kentucky Geological Survey has logged nearly 200 bore holes, and, as a result, has gained important data on coal, industrial and metallic minerals, ground-water, and oil and gas resources throughout the Commonwealth. Copies of the geophysical logs run by the Survey are available for public use.

The Kentucky Geological Survey works with other government agencies and private companies to interpret geophysical logs, and will log any test holes that serve the scientific interests of the State. Geophysical logging has been and will continue to be an integral part of numerous research projects conducted by the Survey. The logging capabilities of the Survey have been extremely cost-effective in the conduct of research projects funded by outside agencies.

Geophysical logging requires the use of low-level radioactive materials. Handling these materials requires extensive training and a State license. To this end, the Survey has organized a training course that fully complies with State licensing requirements for personnel from the Kentucky Geological Survey and private companies.

FEASIBILITY ASSESSMENT OF UNCONVENTIONAL GAS IN KENTUCKY, PHASE II—WESTERN KENTUCKY COAL BED METHANE STUDY

COBB, James C., SMATH, Richard A., WILLIAMS, David A., and WILLIAMSON, Allen D.

A major research project to determine gas content of selected coal beds in the Western Kentucky Coal Field was completed during the year. This investigation was supported by the Kentucky Energy Cabinet with funding from the U.S. Department of Energy's Unconventional Gas Program. Although methane gas in coal beds presents a danger to mining, it is also a potential energy resource if recovered prior to mining activities. This geological investigation is the first to examine the potential of coal-bed gas in Kentucky.

Eleven diamond drill cores were drilled, providing approximately 10,000 feet of core for examination. Twenty-five coal beds were sampled for analysis of their gas content and chemical composition. Gas volumes from the various coal beds ranged from 45 cm³ to nearly 9,000 cm³. In general, the composition of this gas is approximately 60 percent hydrocarbon and 40 percent nitrogen.

A complete report of research activities and results was submitted to the funding agencies. This report, which will be placed on open file by the Kentucky Geological Survey, describes the project activities and contains seven appendices of volumetric calculations of gas, detailed geologic descriptions of the cores drilled, lithologic logs, and geophysical logs. Rock cores from the project may be examined at the Kentucky Geological Survey Well Sample and Core Library. This report is valuable not only for its analysis of coal-bed gas, but also for its detailed geologic data, which are essential to

coal-resource and exploration programs. Likewise, analysis of the chemistry of the coals encountered in the coring contributed a great deal to the "Coal Sampling in Western Kentucky" project, discussed later in this report.

SAMPLING, ANALYSIS, AND COMPILATION OF DATA FROM EASTERN KENTUCKY COALS

CURRENS, James C., and COBB, James C.

Scores of different coal beds are being mined in eastern Kentucky. These coals can differ significantly in chemical characteristics such as amount of ash, sulfur content, percentage of moisture, Btu's per pound, and others. These coal-quality characteristics determine to a large extent the marketability of the coal bed and therefore are a major consideration in the characterization of coal resources.

The Kentucky Geological Survey was awarded a multi-year grant from the U.S. Geological Survey in 1979 to sample coal beds in eastern Kentucky in order to determine variations in quality within and between specific coal beds. Since 1979, a total of 700 coal samples have been taken and analyzed. Reports and maps outlining the results of these sampling activities are currently being prepared. They will be published or placed on open file as soon as they are completed.

Coal-quality maps are being constructed for selected coal beds. These maps show trends for Btu, moisture, ash, and sulfur. To date, coal-quality maps have been completed for the Upper Elkhorn No. 3, Lower Elkhorn, Fire Clay, Amburgy, and Manchester coal beds. These maps are available on open file.

A manuscript on the coal quality of the Princess Reserve District has been completed, and reports for the Big Sandy, Hazard, Licking River, Southwestern, and Upper Cumberland Reserve Districts are in progress. These coal-quality reports will supplement district reports on coal resources and provide Kentucky with excellent detailed information about its coal resources. In addition to these reports, coal-quality data have been entered into the KGS computer. These data can then be retrieved and manipulated to provide easy access to the coal-quality information.

This project has resulted in a large file of coal-quality information that is important for both public and private uses. It has also improved understanding of the distribution and geology of high-quality coals. Future work will include the completion of coal-quality maps for four additional coal beds and publication of the remaining district reports.

COAL SAMPLING IN THE WESTERN KENTUCKY COAL FIELD

CURRENS, James C., and ROBERTSON, Scotty E.

The quality of coal is a major factor in its marketability and value. In order to thoroughly characterize the quality of coal resources in Kentucky, the Kentucky Geological Survey was awarded a 2-year grant from the U.S. Geological Survey to sample coal beds in western Kentucky for chemical analyses. This coal sampling program requires the collection of 200 coal samples from strategic locations in the Western Kentucky Coal Field in order to determine their proximate, ultimate, and other associated analyses. Valuable data such as Btu's per pound, ash and moisture content, and percent sulfur were compiled during the course of this project. Detailed geologic descriptions of sampled coal seams are also included. This information will be made available to the public through published and open-file reports.

A total of 85 coal samples were described and collected for chemical analysis during the year. In conjunction with the coal sampling, a computerized data file containing results of all publically available coal analyses for Kentucky coals from the U.S. Bureau of Mines, U.S. Geological Survey, and U.S. Department of Energy is being compiled. This file will make coal-quality information readily available for both KGS coal-research projects and the general public. Initially, this file is helping to locate new coal-bed sampling sites by using the distribution of previous samples to determine where new samples are needed. Coal sampling and analysis of western Kentucky coal beds will continue through September 1986.

DELINEATION AND DOCUMENTATION OF MINING-RELATED SUBSIDENCE IN MUHLENBERG, HOPKINS, UNION, OHIO, AND WEBSTER COUNTIES, KENTUCKY

SERGEANT, Richard E., SMATH, Richard A., STICKNEY, John F., and COWAN, April L.

Coal has been mined underground in western Kentucky since 1820; despite this long history of mining activity, estimated remaining coal resources indicate production will continue well into the twenty-first century. A coal-resource study by the Kentucky Geological Survey estimates original coal resources in the Western Kentucky Coal Field exceeded 40 billion short tons, and remaining resources exceed 38 billion short tons. It is essential to the Commonwealth and the Nation that this coal resource be developed to full potential. This development, however, should not be at the ex-

pense of the citizens living over or adjacent to areas where the coal resource has been or is being extracted.

One of the ways citizens can be and are now adversely affected by underground coal mining is surface subsidence or ground failure over abandoned mines. This subsidence results when rock strata above a mined-out coal bed collapse into the void caused by extraction of the coal. When subsidence occurs in undeveloped areas such as pastures, fields, and woodlands, there may be little or no damage. But if surface subsidence occurs in urban areas such as subdivisions or shopping centers, property loss can be substantial.

In beginning to address the problem of subsidence in western Kentucky, the Kentucky Geological Survey has initiated a project to identify and delineate areas of subsidence in a five-county area of western Kentucky, consisting of Hopkins, Muhlenberg, Webster, Union, and Ohio Counties. This 2-year project is funded by the Division of Abandoned Mine Lands of the Kentucky Natural Resources and Environmental Protection Cabinet. Data relevant to suspected subsidence-affected areas are being organized into comprehensive "Subsidence Catalogs." Information contained in these catalogs will be used to determine the magnitude of existing subsidence problems and to outline areas of potential concern. In addition, information developed for the catalogs will be useful during implementation of the recently established "Subsidence Insurance Program." This insurance program provides protection for citizens of Kentucky residing in coal-producing areas by allowing them to insure their homes against subsidence damage. Therefore, it is imperative that county officials charged with evaluating county participation in this insurance program have available to them as much information about known and potential subsidence areas in their counties as is possible, so they will be able to make the necessary informed decisions.

MINEABILITY OF WESTERN KENTUCKY COALS, PHASE I—PALEOCHANNEL STUDIES

WILLIAMS, David A.

Geologic factors that adversely affect underground mining include roof-rock and floor-rock instability, coal continuity, excessive non-coaly material, and invasion of water. All of these problems are associated with the occurrence of paleochannels (usually sandstone-filled) in the coal-bearing strata. Mines have been abandoned or prematurely closed in the Western Kentucky Coal Field because of

the presence of paleochannels. This project is using drilling records and field geology to collect data on the occurrence of paleochannels associated with the Springfield (W. Ky. No. 9) coal bed. The Springfield coal bed was selected because it is the most productive coal bed in western Kentucky.

During fiscal year 1984-85, segments of paleochannels in McLean and Webster Counties were delineated. Efforts will continue to locate and define paleochannels in other areas of the coal field.

COAL RESOURCES OF THE WESTERN KENTUCKY COAL FIELD WILLIAMS, David A., and WILLIAMSON, Allen D.

The Western Kentucky Coal Field contained estimated original resources of nearly 41 billion tons of bituminous coal before mining began in the last century. Since commercial mining began, nearly 3.1 billion tons of coal has been mined and used or lost during the mining process. This loss constitutes less than 8 percent of the total coal resource for western Kentucky. About 47 percent of this coal was produced from surface mining, and 53 percent from underground mining. With approximately 38 billion tons of coal resources remaining, western Kentucky will be an important source of coal well into the next century. To properly develop this resource, it is necessary to understand the physical characteristics of the coal beds in western Kentucky and how they relate to other rock units within the coal measures.

The principal objectives of this project are to collect and update coal-resource data and to identify trends in remaining resource development and production. A computer data base of coal-resource information has been constructed. This data base will be useful in disseminating coal information to the general public, industry, and government agencies. During the last fiscal year, coal-resource data were added to the data base from 25 coal test holes described by Survey geologists. Drilling records from 3,500 oil and gas tests were analyzed for coal data and added to the data base.

Because of a number of physical, political, and economic factors, significant amounts of coal in western Kentucky cannot be produced, and must therefore cease to be considered a resource. Information collected during this project will expand our knowledge of the coal resource in western Kentucky and enable us to delimit unrecoverable coal and ensure the most efficient use of the remaining coal resource.

STRATIGRAPHIC, PALEONTOLOGIC, AND STRUCTURAL INVESTIGATIONS OF COAL-BEARING ROCKS IN THE WESTERN KENTUCKY COAL FIELD

WILLIAMSON, Allen D., and WILLIAMS, David A.

The Kentucky Geological Survey collects and disseminates geologic and stratigraphic information for the benefit of landowners, industry, and government agencies. Coal-resource estimates and industrial developments rely on information about the structure and stratigraphy of the coal-bearing rocks. One important objective of this project is the establishment of a well-defined stratigraphic classification for the Western Kentucky Coal Field. To this end, a series of cross sections were constructed to establish stratigraphic correlations within the coal measures. Many important coal beds demonstrated lateral continuity into Indiana and Illinois, and much of the correlation work on these coal beds was done in conjunction with similar efforts in these neighboring states.

Rock cores drilled in conjunction with the Western Kentucky Coal Bed Methane Study (discussed earlier in this report) provided a considerable amount of new subsurface stratigraphic data that were extremely important in determining stratigraphic correlations. A byproduct of this research is a report on the stratigraphy of the Sturgis Formation, which is currently being written.

The main objective of this project was compiling coal-resource, stratigraphic, and structural data into a single, comprehensive report that covers the entire Western Kentucky Coal Field. This report, which is currently undergoing editorial review, will contain general geology of the region, structural features of the region, isopach maps and cross sections of the major rock-stratigraphic units, and a discussion of the economic geology of the area. Publication of this report is anticipated in early 1986.

Industrial and Metallic Minerals

Industrial and metallic minerals furnish essential raw materials for agricultural, ceramic, chemical, construction, energy-related, metallurgical, and manufacturing industries. Current resource projects concern construction raw materials, metallic ores, and carbonate rocks for coal-related uses.

SAND AND GRAVEL RESOURCES OF THE OHIO RIVER VALLEY

AMARAL, Eugene J.

Sand and gravel constitute Kentucky's second most important source of mineral construction material and thus play a vital role

in the growth and future development of the Commonwealth. Production of sand and gravel in Kentucky, by both dredging and surface mining, is primarily confined to fluvio-glacial deposits along the Ohio River Valley and its major tributaries. There is an urgent need to determine the areal extent and characteristics of these deposits in order to facilitate resource potential and multiple land-use planning for the region. Potential aggregate sources are being removed from the resource base by expanding urban areas and industrial-plant construction. In addition to being a major source of construction aggregate, these deposits also form the principal aquifer of the region and underlie prime agriculture land.

To determine the physical, textural, and mineralogical properties of Kentucky's fluvio-glacial deposits, one of the main objectives of this project, a laboratory for sediment analysis, was established in 1984. A detailed investigation of the grain size distribution and shape, and compositional variation of sand and gravel deposits sampled in a three-county area of north-central Kentucky, is half completed. Subsurface information, the other prime objective of the study, is being obtained from various sources to help delineate the thickness and geometry of these deposits.

MIDCONTINENT STRATEGIC AND CRITICAL MINERALS PROGRAM ANDERSON, Warren H.

The U.S. Geological Survey, Branch of Central Mineral Resources, initiated and funded a program to evaluate the potential for strategic and critical mineral deposits in sedimentary and basement rocks of the Midcontinent United States. During Phase I of the program, completed in 1984, the focus was directed toward data inventory. Well- and mineral-location maps, cross sections, and an isopach-lithofacies map of the Sauk Sequence (Lower Ordovician-Upper Cambrian in Kentucky) were compiled. Lithologic and stratigraphic data were assembled into a cross section of Phanerozoic rocks along the 88°00'W longitude in western Kentucky. This cross section is available as a KGS open-file report. The work was based on a study of well records and samples, and available geologic reports and maps. During Phase II, a tectonic map of western Kentucky (west of 88°00'W longitude) will be compiled.

ZINC DEPOSITS OF SOUTH-CENTRAL KENTUCKY ANDERSON, Warren H.

An investigation of the stratigraphy, petrography, mineralization, and spectrography of the Mascot Dolomite (upper Knox Group) and

the erosional unconformity at the top of the Knox Group is near completion. The Mascot is a host rock for zinc and petroleum deposits. A manuscript and accompanying maps and plates have been completed and submitted for review. This report will include contributions from mining company geologists who conducted exploration for zinc deposits in the Cumberland Saddle area during the 1970's. Several of these core descriptions have been released as KGS open-file reports.

A detailed east-west cross section was constructed to show the stratigraphy of the Mascot Dolomite across Monroe, Cumberland, and Clinton Counties. Evidence from the cross section indicates Early Ordovician uplift on the Cincinnati Arch. Petrographic analysis of Mascot dolomites shows that parental Knox sediments were primarily oolitic limestones and contained evaporites. A paleotopographic map of the top of the Knox shows several linear trends that may have controlled zinc mineralization and petroleum accumulation. Zinc mineralization, ore controls, and trace-element content of the sphalerite will be discussed in the report.

LIMESTONE AND DOLOMITE RESOURCES FOR COAL-RELATED INDUSTRIES

DEVER, Garland R., Jr.

Coal producers and coal-consuming industries employ limestone and dolomite in environmental-control measures to meet Federal and State standards for mine safety and reclamation, water quality, and air quality. Carbonate rocks are utilized in underground-mine explosion abatement, surface-mine reclamation, acid-drainage neutralization, and sulfur oxide emission control through flue-gas desulfurization and fluidized-bed combustion systems. This resource study is directed toward providing information on the availability of stone that meets the specifications for these coal-related uses. Samples taken during the project are being analyzed by the University of Kentucky Institute for Mining and Minerals Research (IMMR) at the Kentucky Center for Energy Research Laboratory (KCERL).

The Survey assisted IMMR in selecting and obtaining dolomites and limestones for testing in the atmospheric fluidized-bed-combustion pilot plant at KCERL. Geologic factors that controlled the thickness and lithology of carbonate-rock deposits in eastern Kentucky are being investigated.

NONFUEL MINERAL STATISTICS

DEVER, Garland R., Jr.

Under a Memorandum of Understanding, the Kentucky Geological Survey assists the U.S. Bureau of Mines in collecting and compiling information on nonfuel-mineral production and industry activities in the State. Resulting data are disseminated through Bureau publications, principally the "Minerals Yearbook," "Mineral Industry Surveys," and commodity reports.

The Bureau of Mines 1983 "Minerals Yearbook" was published during 1984-85. The Kentucky chapter ("The Mineral Industry of Kentucky") was issued as Kentucky Geological Survey Reprint 19.

In 1984, the value of nonfuel-mineral production in the State was \$259.7 million, based on preliminary data received by the Bureau of Mines. Crushed stone was the leading nonfuel-mineral commodity, accounting for nearly half of the total value. Kentucky ranked second in the Nation in ball clay production and aluminum shipments, and fourth in lime and synthetic graphite output. Cement, construction sand and gravel, industrial sand, common and fire clays, and zinc ore also were produced. Other commodities processed or manufactured in the State included perlite, vermiculite, pig iron regenerator iron oxides, and synthetic mullite.

FLUORSPAR DEPOSITS OF WESTERN KENTUCKY

TRACE, Robert D. (retired)

This report on ore deposits, geologic setting, and mining history of the Tabb area, Crittenden and Caldwell Counties, has been released as a KGS open-file report. For many years, the Western Kentucky Fluorspar District of Crittenden, Livingston, and Caldwell Counties was the second largest fluorspar-producing district in the United States. The area of largest production within the district was along the Tabb Fault System in Crittenden and Caldwell Counties. Parts of the Tabb area are still considered to have potential for the production of substantial tonnages of fluorspar and byproduct lead and zinc, under favorable economic conditions. The report and accompanying mine maps were placed on open file in order to make the information more readily available to the mining industry and public.

Stratigraphy and Petroleum Geology

With more than 20,000 producing oil wells and over 8,500 producing gas wells, Kentucky ranks as a major producer of oil and

gas. Oil and gas rank third as a mineral resource in the State and provide an important source of revenue. Approximately 6,200 sites were permitted for drilling in 1984, about a 9 percent decrease from 1983, and 3,304 new wells were reported as successful. Discoveries included 48 oil pools, 23 gas pools, 49 deeper oil pools, 15 deeper gas pools, four shallower gas pools, 31 shallower oil pools, and 305 extensions to existing producing areas.

The most significant new discovery reported in 1984 was the Teges Creek Gas Field, located in north-central Clay County, north of the Oneida Gas Field. The field produces gas and oil from five separate zones; the Newman Limestone (Mississippian, "Big Lime") produces gas, the Lexington Limestone (Ordovician, "Trenton") produces oil, the Black River and Murfreesboro Limestones (Ordovician) produce oil, and the Knox Dolomite (Cambro-Ordovician) produces oil and gas. In addition, shows of gas have been reported from the Borden Formation (Mississippian) and the "Corniferous" (Silurian).

The most significant developments in western Kentucky have occurred in Henderson County and are related to production from various zones of Middle Mississippian age. Numerous wells have been completed in the Aux Vases and O'Hara Formations in the Hebbardsville Pool in the eastern portion of the county. In the western portion of Henderson County the Anthoston Pool was extended by production from several zones in the "McClosky" (Ste. Genevieve Formation) and the Aux Vases. Future new discoveries are anticipated in western Kentucky as more exploration to zones in the Salem-Warsaw Formations (Mississippian) develops.

Crude oil production was 7,787,513 barrels, a very slight decrease from 1983. Natural gas production was 61,518,251 mcf, an increase of 24 percent over 1983.

A primary responsibility of the Kentucky Geological Survey is to provide industry, government agencies, academic institutions, and the general public with information pertinent to the exploration for and development of oil and gas in Kentucky. The Survey, as the official repository for oil and gas well records, maintains a library for public use that contains more than 180,000 well records. The Survey also maintains a Well Sample and Core Library with more than 15,000 sample sets and 850 cores on file. In addition, Survey files contain such information as cumulative annual oil production, oil and gas pool maps (1:250,000 scale), pool indexes, geologic quadrangle indexes, oil and gas well maps of some counties, and bibliographies. Since a primary tool of the petroleum geologist is stratigraphy and subsurface geology, and since the well records and

the Well Sample and Core Library comprise the major pool of stratigraphic and subsurface information in the State, the name of the section was officially changed from the Oil and Gas Section to the Stratigraphy and Petroleum Geology Section in 1983.

At present, the Survey is committed to two major efforts to reorganize its files and improve its service to the public. The first effort is a reorganization and updating of files in the Henderson Field Office. This project is now nearly complete. When finished, the Henderson Office will have complete files for western Kentucky organized similarly to those of the Lexington Office. The second effort is computerization of all well records, which will make it possible to retrieve records in virtually any useful format. The Survey now has information on approximately 55,000 wells entered on the computer.

In addition to providing a public service, the Stratigraphy and Petroleum Geology Section is involved in basic geologic research such as structural and stratigraphic studies on local and regional scales.

GEOLOGIC CHARACTERISTICS OF SELECTED OIL AND GAS RESERVOIRS IN MISSISSIPPIAN-AGE ROCKS IN WESTERN KENTUCKY

BEARD, John G., and KIEFER, John D.

The objective of this study is to investigate the depositional environments and stratigraphic framework of Mississippian-age reservoir rocks in relation to known stratigraphic units in the outcrop belt of western Kentucky. Special emphasis is given to rocks of lower Meramecian and Osagean age.

The study focuses on the regional aspects of the stratigraphy, lithology, and depositional environments of these units, especially the location and geometry of petroleum reservoirs. All available information is being collected on selected reservoirs. Samples and cores, where available, are requested and examined in detail. Maps and cross sections of the stratigraphic interval encompassing the productive zones are constructed. Production data will also be compiled to the extent that they are available.

The study will assist the petroleum industry in focusing exploration activities on some of the less frequently tested and deeper objectives of the Eastern Interior Basin.

This project is being carried out by KGS staff as time permits. Much of the work during the past year has focused on reviewing historical data available from KGS and other files and comparing surface stratigraphy with units previously defined in the subsurface. Various

stratigraphic marker zones are being defined, and several stratigraphic cross sections have been prepared.

Complex facies relationships make it difficult to establish lateral continuity of Mississippian units; particular difficulty is encountered when outcrop data are related to the subsurface. Subsurface stratigraphy is extremely important to the petroleum industry in establishing depth to known or potential pay zones.

During the coming year, additional data and samples will be acquired in order to better delineate stratigraphic marker horizons and producing zones.

THE STUDY OF HYDROCARBON PRODUCTION FROM THE DEVONIAN SHALE IN LETCHER, KNOTT, FLOYD, MARTIN, AND PIKE COUNTIES, EASTERN KENTUCKY

FRANKIE, Wayne T., MOODY, Jack R., and KEMPER, Julie R.

The Kentucky Geological Survey initiated a 2-year cost-sharing project with the Gas Research Institute (GRI) in July 1984 to study the hydrocarbon production from the Devonian shale in eastern Kentucky. The primary objectives are to develop an understanding of relationships between stratigraphy and hydrocarbon production from the Devonian shales in eastern Kentucky, to create a comprehensive data base on the Devonian shale, and to prepare a geologic report for each county in the study area. Data for the investigation have been obtained from the KGS oil and gas well record files, company files, and from existing literature.

Despite a long history of exploration and production in eastern Kentucky, very little is known about the relationship of structure and stratigraphy to hydrocarbon accumulation. As a result, exploration has been extremely speculative. A better understanding of the geologic parameters controlling the occurrence of hydrocarbons and the best techniques to be used in the exploration and development of wells is needed.

The purpose of this research is to provide the oil and gas industry with information that can be used as exploration tools, which will, in turn, reduce the cost of future exploration, increase the chances for a successful well, and optimize production from that well.

Reports on the individual counties will summarize the results of the study and provide detailed information about the Devonian shale in each county. Research for Letcher County has been completed, and publication of the county report is anticipated in July 1985.

The first Devonian drilling activity in Letcher County was in 1939; it peaked during 1960-69. A 279-well data base for Letcher County has been collected and entered into the KGS computer. The Letcher County report will consist of a detailed summary of relationships between production, stratigraphy, structure, and stimulation techniques; statistical summaries; and locations of areas known to produce gas from the Devonian black shales. It will contain nine stratigraphic cross sections; a fence diagram of the Mississippian-Devonian black-shale stratigraphy in Letcher County; a series of four 1:100,000-scale structure, isopach, isoproduction, and location base maps of all Devonian wells in the KGS data base; and a summary of statistics run on the Letcher County data base.

Temperature logs were used to determine locations of gas-producing intervals. Gamma-ray logs were used to determine the individual stratigraphic units between the Mississippian Sunbury Shale and the Devonian Rhinestreet Shale. The stratigraphic cross sections show information on the type of well, amount of production, zone of treatment, and location of gas shows. The isoproduction map was constructed using initial production figures.

During the first contract year, July 1, 1984, to July 1, 1985, work concentrated on (1) gathering data from the KGS oil and gas files, (2) developing computer programs to store the data and plot wells onto computer-generated base maps, (3) conducting a literature search of previous work, (4) analyzing Devonian stratigraphy (correlation), (5) determining relationships between stratigraphy and production, and (6) constructing isopach, structure, isoproduction, and well-location maps.

The following conclusions for Letcher County may be drawn from the first year's work. (1) The only reliable and reasonably consistent correlation of the Devonian black-shale sequence in Letcher County is from gamma-ray logs. (2) Changes in thickness of each individual stratigraphic unit within the Devonian black-shale sequence are fairly uniform, with general thinning to the west. (3) The thickness of the Devonian black-shale sequence (top of the Cleveland Member to the base of the Olentangy Shale) increases from less than 450 feet in the west to more than 750 feet in the east. (4) The structure drawn on top of the Devonian black-shale sequence (Cleveland Member of the Ohio Shale) dips to the south from an elevation of less than -1,800 feet to an elevation of more than -2,200 feet, a dip of approximately 33 feet per mile. The structural strike is parallel to the Pine Mountain Thrust Fault and trends slightly north of east to south of west; dip is to the south and perpendicular to

the Pine Mountain Thrust Fault. (5) Relationships between local structural variations and production are indicated from cross sections. (6) Three areas of Devonian black-shale production greater than 200 mcf/gpd, outlined by the Devonian shale isoproduct map, correlate with the location of gas pools that produce from overlying (younger) formations. A correlation also exists between areas of production and some of the linear features determined from land-sat imagery. (7) The Lower Huron Shale has more shows of natural gas, as determined from temperature logs, than other stratigraphic units in the Devonian shale sequence.

GEOLOGY AND RESERVOIR PROPERTIES OF THE LOWER ORDOVICIAN MASCOT DOLOMITE, CENTRAL KENTUCKY

Gooding, Patrick J.

Oil and gas are being produced from Cambro-Ordovician rocks throughout the United States; central Kentucky is no exception. In this area, the Knox is of major economic significance. Production is generally associated with rocks directly below a regional unconformity.

The purpose of this investigation is to determine the depositional and diagenetic history of the Lower Ordovician Mascot Dolomite, the uppermost formation of the Knox Group. Source-rock and migration trends will also be studied. This investigation will aid in developing a model of the geologic characteristics of hydrocarbon reservoirs in the Knox and aid in oil and gas exploration.

In the eastern United States the Cambro-Ordovician Knox Group, predominantly composed of carbonate rocks, was deposited in shallow hypersaline waters that were 2,000 miles long (north-south) and 100 to 1,000 miles wide (east-west). The water attained thicknesses in excess of 3,000 feet. A regional unconformity occurs at the top of the Knox Group. In central Kentucky the paleotopographic surface of the Knox is characterized by extensive paleokarst developed on the upper Mascot Dolomite.

THE UNCONFORMITY AT THE TOP OF THE KNOX GROUP (CAMBRIAN-ORDOVICIAN) IN THE SUBSURFACE, SOUTH-CENTRAL KENTUCKY

GOODING, Patrick J.

The paleotopographic surface of the Cambro-Ordovician Knox Group is of major economic significance. A regional unconformity occurs at the top of this group, resulting in a surface with relief of nearly 400 feet. This surface is typified by large sinkholes and

residual hills. The Wells Creek Dolomite, an impermeable formation, seals the unconformable surface. It is present everywhere in the area studied, and fills depressions in the truncated surface of the Knox Group. The Wells Creek is 10 to 90 feet thick in this area. The Pencil Cave bentonite is easily recognized in gamma-ray logs, and was used as a stratigraphic marker. A previously unrecognized subsurface fault has been documented during the course of this study.

The area of study includes all or part of Adair, Cumberland, Clinton, Casey, Monroe, Metcalfe, Green, Taylor, Russell, and Wayne Counties in south-central Kentucky. Approximately 550 sets of cores and well cuttings, more than 1,000 geophysical logs, and approximately 200 drillers' logs were examined during the course of the study. A total of 1,725 control points were used.

Shallow drilling depths of generally less than 2,000 feet, combined with the potential for significant production, have made the Knox in this area a prime exploration target. Many areas are sparsely drilled, and deeper Knox strata remain untested. Hydrocarbons may occur in structures associated with the erosional highs or in permeable and porous zones that occur at or below the unconformable surface.

INVESTIGATION OF SUBSURFACE TAR-SAND DEPOSITS IN WESTERN KENTUCKY

NOGER, Martin C.

The Kentucky Geological Survey initiated a project in 1981 to inventory and evaluate the oil resource potential of asphaltic sandstones in the subsurface of Kentucky. A preliminary study (ser. 11, IC 7) suggested that major heavy oil resources were present in the Big Clifty Sandstone of Late Mississippian age in parts of Butler, Edmonson, Grayson, Logan, and Warren Counties.

In 1982, a project to catalog and evaluate the tar-sand resource potential of the United States was initiated by the Interstate Oil Compact Commission (IOCC). Lewin and Associates, Inc., of Washington, D.C., was selected to compile the data. The Kentucky Geological Survey, working in conjunction with Lewin and Associates, has confirmed that major tar-sand deposits are present in western Kentucky.

The report "Major Tar Sands and Heavy Oil Deposits of the United States" was published in January 1984 and is available from the IOCC. The Kentucky portion of the report contains maps delineating prospective resource areas, maps showing probable richness (in barrels per acre), and tables listing estimates of resources in place for

the Caseyville (Kyrock and Bee Spring Sandstones combined), Big Clifty, Hardinsburg, and Tar Springs Sandstones. The in-place tar-sand resource of these units is calculated to be 3.41 billion barrels (1.72 billion measured, 1.69 billion speculative). Measured resources were determined primarily from core analyses, and speculative resources were determined from drillers' logs of oil and gas exploration test holes. Additional evaluation of areas of speculative resource by core drilling and sample studies is needed. Results of drilling activities for conventional oil and gas resources in the area of the asphaltic sandstone deposits are being monitored, and the data derived used to update tar-sand resource maps.

Two projects in Logan and Edmonson Counties are currently recovering heavy oil from the Big Clifty Sandstone. Westken Petroleum, operator for the Kensyntar Partnership that successfully completed a 1-acre thermal fireflood pilot in Edmonson County in 1983, has been reorganized as KENOCO, Inc. A 4-acre commercial module project to recover heavy oil from the Big Clifty Sandstone by a thermal fireflood process has been activated in Edmonson County.

Tarco, Inc., has been reorganized as Kentar, Ltd. The pilot plant in Logan County has been reopened, and heavy oil is being extracted from surface-mined tar sands of the Big Clifty Sandstone, using a solvent process.

TXG Resources has closed its pilot plant in Logan County and withdrawn its proposal to the Synthetic Fuels Corporation.

COMPUTERIZATION OF OIL AND GAS WELL RECORDS

NUTTALL, Brandon C.

The purpose of this project is to provide a unified storage and retrieval system for oil and gas well records on file at the Kentucky Geological Survey. The computerization of the well-record library is expected to greatly enhance the speed and efficiency of data retrieval.

Approximately 55,000 well completions have been encoded, entered, and proofread to date. Data on current completions are being reported monthly to the American Petroleum Institute. By the end of 1985, records for approximately 75,000 wells should be available.

Data on approximately 175 new injection wells were gathered, entered, and reported to the U.S. Environmental Protection Agency as part of another KGS project. As injection wells are completed, the information will be compiled and reported semi-annually.

Well data for Leslie, Pike, Hopkins, Webster, and Butler Counties, generated by the Oil and Gas Base Map Project, are being gathered and processed at an average rate of 1,300 wells per month. Data for approximately 4,000 wells on the Mazie, Redbush, and Oil Springs Quadrangles that were the result of the completion of the Yatesville and Paintsville Reservoir Studies were processed. In addition, the Study of Hydrocarbon Production from the Devonian Shale in Letcher, Knott, Floyd, Martin, and Pike Counties, Eastern Kentucky is generating data on several hundred wells per month.

Three data sets have been created to support efficient access and internal consistency of the main data set. A file of data describing each county has been compiled. This file contains the county name, county seat, Carter coordinate boundaries, and a list of topographic maps. A file of data for each pool, containing pool name, discovery date, discovery well, and pays, is being completed. Finally, a standardized list of operator names has been compiled to aid in checking data at time of entry for consistent spelling.

THE CAMBRIAN SYSTEM OF KENTUCKY

WALKER, Frank H.

Interest in the Cambrian System is increasing, as evidenced by the inquiries received at the Kentucky Geological Survey and the number of permits being issued for wells proposed to be drilled to or through that system.

This program is a maintenance program that assists in the identification of those wells drilled to the Cambrian. An open-file map at a scale of 1:500,000 shows the location and total depth of formation for each well. A computer printout is available that gives details on each well.

As completion records are received, data are added to the map and to the computer printout. As of July 1, 1985, 173 wells had been identified.

OIL AND GAS WELL RECORD LIBRARY

WALKER, Frank H.

In 1960, the Kentucky Geological Survey was designated the State repository of geologic records of wells drilled for oil and gas purposes. Prior to 1960, the Survey collected, where possible, records on wells, but the files were, and are still, incomplete for those years. The file is, however, quite extensive, consisting of 345 file-cabinet drawers of information. Expansion amounts to about 6,000 new wells a year. The records are filed by location, first by county, and

then by Carter coordinate. It has been estimated that there may be information on as many as 200,000 wells on file at the Kentucky Geological Survey.

The library is located in the basement of Breckinridge Hall, and is open from 10:00 a.m. until noon, and 1:00 p.m. until 4:30 p.m. each working day. Students, industry representatives, government agencies, and the general public make extensive use of the files. In an average year 2,500 persons visit the record room. Record room personnel answer 1,350 telephone requests for information, and 60,000 copies are made of the well records by request.

Copies are limited to 50 wells per person by telephone or written request in a 30-day period. Visitors to the library may have 100 copies of wells per person in a 30-day period. Requests are usually filled within 24 hours of receipt. No electric logs are copied; however, a source of logs is provided to interested parties.

OIL AND GAS BASE MAPS

WALKER, Frank H., and NUTTALL, Brandon C.

The Kentucky Geological Survey has been engaged in the past 5 to 6 years in the preparation of oil and gas well location maps. These maps are available on a planimetric base at a scale of 1:48,000. The maps are accompanied by an index (that varies in completeness for each map) and in some cases a generalized columnar section. The maps, once prepared, were seldom, if ever, updated, and as a result were soon outdated. In the interest of efficiency, the Survey is now using a well-location map system based entirely on the 1:24,000 (7.5 minute) scale topographic map series.

The demand for up-to-date maps, coupled with the acquisition of a proper computer and the development of certain software, has allowed a substantial change in the material that may now be presented for use by industry, government, educational institutions, and the general public. Computer-plotted maps are now available for the entire State. The maps are plotted on good-quality tracing paper at a scale of 1:24,000. The maps may be used as overlays for topographic maps, geologic quadrangle maps, or may be used alone. The maps use standard symbols to show the locations of the wells and the type of completion. A computer-generated list of wells may be obtained for each map that lists the well identification, location, total depth, elevation, total depth formation, producing horizon, and reported initial production or open flow.

Maps are available for each quadrangle, but some areas have been more completely mapped than others. At present there

are approximately 55,000 wells in the computer data base, and an average of 10,000 wells a year are added to the system. All of the wells will appear on the correct map or maps.

Conversion of the records from the 1:48,000-scale county maps to the 1:24,000-scale quadrangle maps is progressing. As the wells in a county are converted, the county map will be withdrawn from distribution, since the county maps are severely out of date, and up-to-date maps are available. Previously listed county maps that are no longer available are Letcher, Montgomery, Clark, and Grayson. Quadrangles that have been completed are the Leslie and Logan County portions of all quadrangles, and the Hanson, Horton, Sugar Grove, Madisonville West, Blackford, Wofford, Williamsburg, Saxton, Oneida, Bar Creek, Mistletoe, Oil Springs, Redbush, and Sitka Quadrangles.

Staff personnel involved in the preparation of well-location maps are Patricia Ann Anderson, Timothy S. Barnett, John G. Beard, Jean Kelly, Martin C. Noger, Brandon C. Nuttall, and Timothy J. Young.

Water Resources

Over the past several decades, a new awareness of the tremendous potential and the overall critical importance of the Nation's water resource has been generated. With that awareness has come the realization of the difficult problems associated with the management and the protection of that resource. If one considers the basic needs of modern civilization—food, clothing, shelter, and energy—virtually nothing can be produced without large quantities of water. In addition, the large quantities of waste water our system generates must be disposed of.

The Kentucky Geological Survey plays an important role in the development, protection, and management of water resources in the Commonwealth. It is the charge of the Water Resources Section to collect data and to conduct research in hydrology and hydrogeology in order to provide for the optimum development, utilization, and management of the State's water resources. As has been the case of the past several years, many of our projects are carried out in cooperation with the U.S. Geological Survey Water Resources Division.

This past year has seen the completion of two projects funded by the U.S. Environmental Protection Agency, increased field work for projects in the Kentucky River basin, and elimination of the ground-water monitoring network due to curtailment of State funds.

On a day-to-day basis the section provides information to municipalities, industry, and private citizens concerning water resources in the State. Specifically, work for the Kentucky Natural Resources and Environmental Protection Cabinet included serving on a technical committee to review criteria for ground-water monitoring required by the Federal Office of Surface Mining for coal-mine permits. The section head was also appointed by the Governor to serve on the Water Well Drillers Certification Board, which is responsible for developing regulation and construction standards for that industry. In addition, the section head served as the chairman of the Technical Committee of the Louisville Ground-Water Development Task Force, which has been charged by the mayor to develop a management plan for the prolific sand and gravel aquifer underlying most of the city for use in geothermal heating and cooling.

AREA OF REVIEW AND INJECTION PRESSURE ASSESSMENT OF OIL AND GAS INJECTION WELLS IN KENTUCKY

SMALLEY, Richard C., and DINGER, James S.

The purpose of this U.S. Environmental Protection Agency-sponsored research is to test the applicability of several analytical subsurface flow models in predicting radius of influence and pressure buildup from injection wells used for enhanced petroleum production.

By using data on file in the Survey's Oil and Gas Records Library and data from industry, stratigraphic and structural features were studied to characterize petroleum-producing provinces within the State. Principal injection zones within each province were characterized with regard to their hydraulic properties, including porosity, permeability, and storage coefficient, for use in analytical flow models.

The project developed computer programs to process operational records submitted by producing companies and to combine these data with hydraulic properties of reservoirs for reservoir pressure response simulations. Pressure response simulations were performed on operating leases in nine different formations. Sensitivity analyses identified the most significant parameters for area-of-review assessments. This study concluded that the 1/4-mile radius of influence is generally valid for area-of-review assessments, but that the analytical model listed in the Federal regulations is inappropriate for calculation of area of review under the hydrogeologic conditions in Kentucky's oil fields.

Two significant groups of maps were produced during this project. The first group shows injection well locations color coded according to depth. These maps were produced because extensive, stringent data requirements mandated that analyses for this project be performed where data were most available, which is not necessarily where environmental sensitivity is greatest. These color-coded maps identify the areas of greatest potential environmental sensitivity, the shallow injection zones. The second group of maps is a structure-contour and an isopach map of the second Weir sand on the scale of 1:250,000. Assessments have been completed and the final report has been approved and submitted. The completion report is on file at the office of the U.S. Environmental Protection Agency, Region IV, Atlanta, Georgia.

BARIUM CONCENTRATIONS IN GROUND WATER IN EASTERN KENTUCKY

TOWNSEND, Margaret A., and KIPP, James A.

Water sampling in 1980 by the Kentucky Natural Resources and Environmental Protection Cabinet indicated the presence of dissolved barium above the presently recommended Federal drinking-water standard (1.0 mg/L) in scattered public and private water-supply wells in Perry County, Kentucky. The purposes of this Kentucky Geological Survey- U.S. Geological Survey cooperative study are to (1) determine the geographical extent of elevated levels of barium contamination in ground and surface water in the vicinity of Perry County, (2) determine the possible geologic and other sources for the barium ions in ground water in this region, (3) assess the possible occurrence of barium in ground water for other areas in eastern Kentucky, and (4) recommend remedial measures for water users in the affected areas.

Water samples were obtained from approximately 160 sites, most of which were domestic wells in the towns of Buckhorn, Chavies, and Jeremiah. All samples were analyzed in the field for temperature, pH, and specific conductivity. Analyses for barium, and in some cases for sulfate, were made in the laboratory. Preliminary results indicate that high barium concentrations are restricted to ground water and may be caused by specific rock units, bacteria, or mixing with more saline ground waters. Statistical analysis of collected data indicates a strong relationship between concentration of barium, depth of well, and type of well (dug or drilled). Barium/chloride ratios suggest that mixing with saline ground waters may occur in some areas. Additional sampling and

statistical analyses will be performed in an effort to link barium with geologic units and other hydrochemical variables.

HYDROGEOLOGY OF BRINE OCCURRENCE IN THE KENTUCKY RIVER BASIN

KIPP, James A.

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. The majority of petroleum wells in this region currently produce less than 10 barrels of oil per day, but they also produce approximately 10 barrels of brine for every barrel of oil. The intent of this Kentucky Geological Survey-U.S. Geological Survey cooperative study is to assess the occurrence, movement, and interaction of surface and ground water in this setting.

Water resources may be influenced by (1) injection of fluids into the producing zone for enhanced oil recovery, (2) brine disposal by injection, (3) upward leakage through inadequately plugged abandoned wells, (4) brine disposal into surface water, and (5) infiltration of brine from storage ponds. Characterization of existing water quality will be accomplished through the review of data from regulatory agencies' files and by additional sampling of water wells, springs, brine sources, and surface streams. The water-quality information will then be used to analyze ground water-surface water interaction in the region, and, it is hoped, brine loading rates for streams.

DEVELOPMENT OF A COMPREHENSIVE OIL AND GAS INJECTION WELL INVENTORY

WALKER, Frank H., and DINGER, James S.

In July 1983, the Kentucky Geological Survey contracted with the U.S. Environmental Protection Agency to inventory all active wells that are used for the injection of fluids in enhanced oil recovery operations or wells used for the disposal of produced fluid. The inventory was needed to assist in the implementation of the Clean Drinking Water Act of the U.S. Congress.

During the 1983-84 fiscal year, 5,291 wells were inventoried and reported. The basic well information was added to the data base maintained by the Kentucky Geological Survey.

The term of the grant was extended by the U.S. Environmental Protection Agency to update the inventory. During the 1984-85 fiscal year, 212 wells were corrected or added to the inventory.

Other Research

GEOLOGIC MAP OF KENTUCKY

NOGER, Martin C., and POTTS, Roger B

In 1984 the Kentucky Geological Survey began compilation of 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 map, which will be of a suitable size for display as a wall map, will be useful to government agencies, industry, the general public, and academic institutions.

Geologic units, columnar sections, cross sections, and stratigraphic diagrams to be shown on the 1:500,000-scale map have been selected. Geologic units shown on the published map will be combined where necessary to be compatible with the smaller scale map, and geologic contacts will be scribed at the reduced scale. After completion of cartographic work, the map will be published in color.

GEOLOGIC STUDIES OF THE FAULTS AND TERRACES OF CENTRAL AND WESTERN KENTUCKY

SERGEANT, Richard E., and VAN ARSDALE, Roy

This field-oriented research project attempts to identify areas demonstrating possible Recent seismic activity along the Kentucky River and Rough Creek Fault Systems in central and western Kentucky. Funded by the Nuclear Regulatory Commission, this research project began in July 1981 and will end in September 1985.

During the first two summers (1981-82), relationships between unconsolidated Tertiary-Quaternary high-level terrace deposits and known bedrock faults along the Kentucky River Fault System were examined in detail in selected areas of the Coletown, Ford, Hedges, Palmer, Richmond North, Union City, Valley View, and Winchester 7.5-minute quadrangles. Areas where terrace materials of sufficient thickness and areal extent overlay bedrock faults were identified for detailed field analysis, which included field mapping, electrical resistivity surveys, and the drilling of auger holes.

Where known bedrock faults were projected to extend beneath the terrace materials, electric resistivity profiles were conducted parallel and perpendicular to the projected fault trace. Subsequent augering, normal to and across the fault trace, provided accurate depth-to-bedrock thicknesses, which made possible geologic logging and sampling of terrace materials. Information obtained from the augering was used to construct detailed cross sections. Cross sections of terrace materials and related bedrock profiles were

carefully evaluated to determine if any bedrock "steps" or offset terrace strata (which could suggest possible Recent seismic activity) could be identified. A number of bedrock "steps" and cases of offset terrace materials were noted, but electrical resistivity surveys and auger holes alone are not accurate enough to properly document offset of terrace strata. It is essential that the offset be substantiated by the excavation of exploratory trenches in the terrace material.

During the summers of 1983 and 1984, nine exploratory trenches were excavated in selected areas of central Kentucky. One trench, on the Palmer 7.5-minute quadrangle, was excavated to the New Albany Shale bedrock, exposing the bedrock fault and associated folding; however, no evidence of post-terrace offset was noted.

Five trenches were excavated in the Winchester 7.5-minute quadrangle. The walls of one trench were unstable, and the trench had to be abandoned; two other trenches contained no evidence of strata offset. Two trenches on the same bedrock fault exhibited folding, faulting, and shearing in terrace and overlying colluvial material, indicating post-terrace activity.

Three trenches were excavated to bedrock in the Valley View 7.5-minute quadrangle. One trench was excavated in present-day Kentucky River alluvium, and it showed no indication of stratum flexure or offset. The remaining two trenches exposed bedrock faulting with associated folding, and contained flexures in terrace and colluvial deposits. These folds indicate possible post-terrace seismic activity.

A complete report of research activities in central Kentucky has been completed and is currently being reviewed for publication.

COMPUTER SERVICES

The primary responsibility of the Computer Services Group (CSG), which was established in 1983, is to assist the KGS staff in using computers to provide public services. CSG acquires, develops, modifies, and maintains software that enables users to store and manipulate data for reports, maps, charts, and other products for use by those in industry, government, education, and the private sector.

By teaching the professional staff how to properly use the equipment and software, efficiency and production have been greatly improved. Time requirements for tedious data searches and paperwork have been dramatically reduced, and the general public

benefits through better, more accurate, more timely reports. In addition, the KGS administrative staff uses the computer to manage the various and diverse projects undertaken by the Survey.

During the past year CSG personnel developed new software products to plot maps and overlays. This software is primarily used to spot locations of geologic information on 1:24,000- or smaller scale maps. The final products produced by the software are of publication quality and have been available to the general public since June 1985.

The CSG also worked with software known as MINEX, donated to KGS by Engineering Sciences Corporation. MINEX was developed primarily for the surface-coal mining industry, but its various components, especially the geologic modeling and contouring packages, are useful in all areas of geology. This product is used by the Survey only, and has enabled KGS geologists to look at regional and site-specific geologic trends on a very timely basis.

Growth in the use of the computer by the KGS staff has been phenomenal. We are presently using more resources than we had anticipated for 1988. The staff is doing more varied work on the computer—more data analysis, modeling, report writing, and sharing of information with users on other systems. Requests for data printouts by the public have far exceeded expectations. Demands for additional capabilities and resources are increasing, thus keeping CSG staff busy answering the many day-to-day requests for services.

COOPERATIVE PROGRAMS

Topographic Mapping

The Kentucky Geological Survey participates in an ongoing cooperative program with the U.S. Geological Survey for topographic map revision in the Commonwealth. This program has been active since Kentucky became the first major state to be entirely mapped topographically at a scale of 1:24,000 nearly 30 years ago, and it is designed to maintain revised and up-to-date maps for all areas of the State.

Twenty-six 7.5-minute quadrangles were revised during the 1984-85 fiscal year. Five of these maps were limited revisions, which involve recontouring in areas where changes have been made in the topography. The remaining maps were photorevisions on which changes are shown in a purple overprint on the original map. These

changes are compiled from 1:80,000-scale aerial photographs and are not field checked.

Four new 1:100,000-scale topographic maps were received from the U.S. Geological Survey during the year. Each of these maps covers an area that includes 30 minutes of latitude and 60 minutes of longitude; topographic contours are shown in meters. The new quadrangles are Madisonville, Beaver Dam, Beckley, and Corbin.

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

Water Resources

The cornerstone of the Kentucky Geological Survey Water Resources Program is our cooperative agreement with the U.S. Geological Survey Water Resources Division. Water-related cooperative programs with the U.S. Geological Survey date back to as early as 1920. The cooperative programs have covered a wide range of needs on both Federal and State levels and have provided data for more than 200 maps, publications, and open-file reports, most of which are currently available from the Kentucky Geological Survey. These data provide the basis for answering several hundred requests annually from individuals, industry, and State and Federal agencies. Most of the current information is summarized in an annual report, "Water Resources Data for Kentucky," published yearly by the U.S. Geological Survey. This report combines streamflow data, water-quality data for surface and ground water, and ground-water-level data from the basic network of observation wells, which is funded under the cooperative agreement. Unfortunately, State budget cuts necessitated the elimination of the ground-water network in the fall of 1984. Prior to 1975, ground-water levels and artesian pressures in observation wells in Kentucky were reported in the 5-year U.S. Geological Survey Water-Supply Paper series, "Ground-Water Levels in the United States, Southeastern States." Records since 1975 are found in the U.S. Geological Survey annual publication, "Water Resources Data for Kentucky." Additional information on ground water can be found in the 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 a 963-page document entitled "A Compilation of Ground Water Quality Data for Kentucky." Published in 1980, it lists all ground-water data for Kentucky, including chemical analyses, in the files of the U.S. Geological Survey through 1979. All of the publications

noted above are available from the Kentucky Geological Survey, Publication Sales Division.

The present cooperative program for water resources calls for a total funding of about \$700,000. Following are brief descriptions of individual projects active or in the publication process during the 1985 cooperative agreement.

1. *Surface-Water Stations*—A Statewide network to collect 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 publication, "Water Resources Data for Kentucky."

2. *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."

3. *Ground-Water Resources of the Mississippian Plateau Area*—This project is designed to provide information on water levels, directions of ground-water movement, and ground-water quality in order to aid in locating additional ground-water supplies and to guide planning decisions regarding the conflicting uses of karst regions. This project has been reoriented to some extent in order to place more emphasis on the aspect of ground-water quality, particularly in the area of trace elements. The project area coincides with the area of outcrop of Mississippian-age rocks in central and western Kentucky. The first report resulting from this project, U.S. Geological Survey Water-Resources Investigation 78-25, by R. O. Plebuch, was published in 1980 and encompasses most of Trigg County and parts of Lyon, Caldwell, and Christian Counties. A comprehensive final report covering the entire Mississippian Plateau

region is in press. It will be published as U.S. Geological Survey Water-Resources Investigations Report 84-4102, "Potentiometric Surface and Water Quality in the Principal Aquifer, Mississippian Plateaus Region," by R. O. Plebuch, R. J. Faust, and M. A. Townsend.

4. *Flow Model of the Kentucky River*—The purpose of this project is to develop a flow model of the Kentucky River between lock 2 and lock 10. This model will be useful in evaluating real and hypothetical stresses on the river for planning and prediction purposes. U.S. Geological Survey model J351 has been calibrated and verified, and the final report is in press as U.S. Geological Survey Water-Resources Investigation 85-4052, "Calibration and Verification of a Streamflow Simulation Model for the Kentucky River near Lexington and Frankfort, Kentucky," by C. J. Sholar.

5. *Reaeration Coefficients and Travel Times for Kentucky River Basin Streams*—Oxygen depletion caused by an increase in water temperature and the introduction of pollutants such as sewage effluent and chemicals has adverse effects upon Kentucky River water quality. Downstream movement of pollutants and the ability of the water to absorb oxygen to correct the adverse effects is difficult to predict. The overall objectives of this project are to develop techniques by which time-of-travel characteristics for streams may be reliably estimated and to develop techniques and quantitative models to measure reaeration coefficients for streams in the Kentucky River Basin. This project is scheduled for completion in 1986.

6. *An Evaluation of Water-Quality Data for the Kentucky River*—The purposes of this study are to describe and explain variations in water quality, to assess trends in water quality over time, to delineate reaches of poor water quality, and to outline major deficiencies in available data for this basin. This project is scheduled for completion in 1986.

7. *Hydrogeologic Investigation of Stress-Relief Fractures of a Valley in the Appalachian Plateaus*—The primary focus of this study is to investigate ground-water movement in steep hillslope topography of the Eastern Kentucky Coal Field where stress-relief fractures may constitute the most transmissive part of the aquifer. Examination of core, surface and downhole geophysics, downhole packer testing, dye tracing, and monitoring wells will be used to describe ground-water movement. Results may prove useful in developing ground-water supplies, in monitoring the hydrologic effects of surface and deep coal mining, and in understanding rela-

tions between surface water and ground water in small valleys. Field work for this project took place in 1985.

8. *Barium Concentrations in Ground Water in Eastern Kentucky*—The principal goals of this study are to determine the geographic, geologic, and hydrologic occurrence of barium in water supplies in eastern Kentucky where barium has been reported above the U.S. EPA recommended safe drinking water concentration of 1 mg/L. Water samples have been collected from both ground-water and surface-water supplies at approximately 160 sites and analyzed for common cations and anions, barium, pH, temperature, specific electrical conductance, and sulfate bacteria. Preliminary results indicate that high barium concentrations are restricted to ground water. This project is scheduled for completion in 1986.

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. The majority of petroleum wells in this region currently produce less than 10 barrels of oil per day, but they also produce approximately 10 barrels of brine for every barrel of oil. The intent of this Kentucky Geological Survey-U.S. Geological Survey cooperative study is to assess the occurrence, movement, and interaction of surface and ground water in this setting.

Water resources may be influenced by (1) injection of fluids into the producing zone for enhanced oil recovery, (2) brine disposal by injection, (3) upward leakage through inadequately plugged abandoned wells, (4) brine disposal into surface water, and (5) infiltration of brine from storage ponds. Characterization of existing water quality will be accomplished through the review of data from regulatory agencies' files and by additional sampling of water wells, springs, brine sources, and surface streams. The water-quality information will then be used to analyze ground water-surface water interaction in the region, and, it is hoped, brine loading rates for streams. The project is scheduled for completion in 1988.

PUBLICATIONS

Making the results of research projects and field investigations available to the public is one of the major functions of the Kentucky Geological Survey. These publications serve to disseminate

geologic information generated by Survey staff, members of cooperating agencies, and other earth scientists doing research on Kentucky's geology and mineral resources. The Survey also publishes the proceedings of technical sessions and symposia, and guidebooks for geologic field conferences.

Publications of the Kentucky Geological Survey are made available to the public at a nominal cost and have received widespread distribution. Maps and reports are available for purchase from the Publication Sales office, which is located in the basement of Breckinridge Hall on the University of Kentucky campus. Total sales for the 1984-85 fiscal year amounted to more than \$146,000.

KGS maintains an open file of reports, maps, manuscripts, theses, and other material including coal-thickness data, logs of core holes, sample descriptions, and gravity base station networks. Some of this material will eventually be published but has been placed on open file to make the data available for public use prior to publication.

The Survey's Stratigraphy and Petroleum Geology Section maintains an open file of oil and gas base maps for selected areas. Some of these maps are available as computer-generated plots and are always as up to date as the information in our files. KGS also maintains copies of most open-file reports dealing with Kentucky geology prepared by the U.S. Geological Survey.

Open-file reports are available for inspection at Survey offices in Breckinridge Hall on the University of Kentucky campus during regular office hours. Copies of reports that consist of page-size material or for which the Survey has reproducible copy are available for purchase.

The following publications were issued by the Kentucky Geological Survey during the past fiscal year.

Information Circulars

Information Circular 14. The *Chaetetetella* Zone in the Kinkaid Limestone (Mississippian): A Useful Stratigraphic Marker Along the Southern Rim of the Eastern Interior (Illinois) Basin, by Robert D. Trace and Preston McGrain, 9 p.

A thin zone in the Kinkaid Limestone (Mississippian) containing the coelenterate *Chaetetella* is a little known but extremely useful stratigraphic marker along the southern rim of the Eastern Interior (Illinois) Basin in western Kentucky, southern Illinois, and southern Indiana. Rounded and layered colonies of *Chaetetella* occur only

within a 5- to 10-foot-thick zone beginning approximately 5 to 10 feet above the base of the lower member (Negli Creek Member) of the Kinkaid. Because of its narrow stratigraphic range, its common although not abundant presence, and its ease of identification in the field, the fossil zone is an extremely useful horizon marker for surface investigations in the geologically complex Illinois-Kentucky fluorspar mining region, along the Rough Creek Fault System, and along the irregular Mississippian-Pennsylvanian boundary.

Information Circular 15. Oil and Gas Drilling Activity Summary for Kentucky, 1983, by Kentucky Geological Survey, 243 p.

Information Circular 16. Oil and Gas Drilling Summary for Kentucky, 1984, by Kentucky Geological Survey, 358 p.

Reprints

Reprint 18. Oil and Gas Developments in East-Central States in 1983, by Jacob Van Den Berg, Ray C. Gilbert, G. L. Carpenter, and Frank H. Walker, 10 p.

In Kentucky, 6,779 permits were issued in 1983, an increase of 3 percent from 1982. Reported completions totalled 2,771, which were 406 fewer than in 1982. The success rate was 43.2 percent, with 1,196 producers, 1,585 less than in 1982. There were 870 exploratory tests, with a success rate of 20.6 percent. Discoveries included 21 oil pools, three gas pools, 20 deeper oil pools, four deeper gas pools, four shallower oil pools, two shallower gas pools, and 125 extensions to pools. The Knox (Ordovician) play in south-central Kentucky continued to dominate drilling activity. Oil production in that area, however, declined slightly. An increase in drilling activity in Muhlenberg and Warren Counties resulted in fair success in Muhlenberg County and limited success in Warren County.

Reprint 19. The Mineral Industry of Kentucky, 1983, by Donald K. Harrison, 10 p.

The value of Kentucky's nonfuel mineral production in 1983 was \$224.5 million, \$17.6 million more than that of 1982. Crushed stone was the leading nonfuel mineral produced and accounted for more than 52 percent of the total value; it has accounted for more than one-half of the total value of minerals produced in the last 10 years. The State ranked second in ball clay production, after Tennessee; third in primary aluminum output; and fourth in synthetic graphite production and lime output. Leading commodities in terms of value

were crushed stone, lime, and portland cement. Other nonfuel minerals produced included construction sand and gravel, industrial sand, common and fire clay, masonry cement, and zinc.

Other commodities processed or manufactured included ferroalloys, perlite, vermiculite, pig iron, regenerator iron oxides, and synthetic mullite. In 1983, about 2,000 people were employed in Kentucky in the extraction and processing of nonfuel minerals.

Special Publications

Special Publication 11. Proceedings of the Technical Sessions, Kentucky Oil and Gas Association Forty-Fifth Annual Meeting, June 10-12, 1981, ed. by Margaret K. Luther, 74 p.

Contains "Subsurface Stratigraphy of the Corniferous (Silurian-Devonian) of Eastern Kentucky," by Michael T. Currie and William C. MacQuown, "Geology of the Eastern Overthrust," by John M. Dennison, "How to Raise Capital in the Oil and Gas Business under Federal and State Securities Laws," by Howard Z. Gopman, "Comparative Analysis of Stimulations in the Eastern Gas Shales," by Andrea I. Horton, "An Evaluation of Acid Gelling Agents for Use in Well Stimulation," by Kevin Hudock and Homer Skelton, "Update on Oil and Gas Regulations and Planning Ahead," by Henry M. Morgan, and "Fracturing: Mechanism for Secondary Hydrocarbon Migration and Influence on Production Patterns in the Illinois Basin of Western Kentucky and Southern Indiana," by Michael P. Sanders.

Special Publication 12. Caves and Karst of Kentucky, ed. by Percy H. Dougherty, 196 p.

The goals of this publication are (1) to provide a state-of-the-art approach to what has been done in Kentucky cave and karst research, written by people who are doing the work, (2) to accumulate diverse materials about Kentucky caves and karst in one publication, making available a quick and easy reference and research volume, (3) to fill a gap in the professional literature, for no single statewide reference to Kentucky caves and karst exists, although the Kentucky Geological Survey has published several good case studies on caves, (4) to use the regional approach to compare and contrast various cave and karst regions in Kentucky, enabling the reader to appreciate karst processes and understand how regional differences create unique landscapes, (5) to show the status of Kentucky cave and karst research in applied areas, including paleontology, archeology, history, and biology, (6) to present extensive bibliographic material, and (7) to discuss gaps in the

literature, thereby possibly stimulating further research in Kentucky cave and karst environments.

To meet these goals, this publication was divided into three parts. Section I introduces two chapters of background information necessary to understand the caves and karst of Kentucky. Section II divides the State into several cave and karst regions. Each region is discussed by an individual who has done substantial research in the area. Section III focuses upon the applied research that has taken place on the caves and karst of Kentucky.

Thesis Series

Thesis Series 3. Relationship of Possible Silurian Reef Trend to Middle Paleozoic Stratigraphy and Structure of the Southern Illinois Basin of Western Kentucky, by Gary L. Seale, 63 p.

The stratigraphic nomenclature used in the study area is a hodgepodge of the nomenclatures used in Indiana, Illinois, and Tennessee. The various lithostratigraphic units of the study area are not present throughout the entire area. Thus, construction of the maps of the Silurian in the study area required simplification of the confusing nomenclature by (1) grouping of units by practical subsurface intervals (A, B, C, D) mappable over the entire study area, and (2) subdivision of the study area into three generalized depositional areas (1, 2, 3) where the respective nomenclatures of Tennessee, Indiana, and Illinois are used.

Paleotectonic interpretations, based on isopachous maps of the four subsurface intervals and the character of sediments deposited in the three depositional areas, indicate that Area 1 and Area 2 are sites where shallower water sediments were deposited on relatively stable shelves and Area 3 is a site where deeper water sediments were deposited within a subsiding basin.

No evidence was found for extension of the Terre Haute Bank (southwestern Indiana reef trend) into Kentucky. However, several reefs were found in the Silurian of western Kentucky and western Tennessee. These reefs are located within a broad reef trend established by mapping the lithofacies of the uppermost Silurian Interval "D."

Miscellaneous

Annual Report, 1983-1984, 67 p.
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In Press or Editing Completed

Information Circular 17. Analysis of Coal Samples from the Princess District, Kentucky, by James C. Currens, Linda Jean Bragg, and James C. Hower.

Report of Investigations 2. Structure and Thickness of the Devonian-Mississippian Shale Sequence in and near the Middlesboro Syncline in Parts of Kentucky, Tennessee, and Virginia, by Paul Edwin Potter, Edward Norman Wilson, and Jaffrey S. Zafar.

Report of Investigations 3. Pennsylvanian Plants of Eastern Kentucky: A Flora from the Breathitt Formation near Grannies Branch and Rocky Branch of Goose Creek, Clay County, Kentucky, by Paul A. Spurgeon and James R. Jennings.

Report of Investigations 4. Study of the Unconformity at the Top of the Knox Group (Cambrian-Ordovician) in the Subsurface in South-Central Kentucky, by Patrick J. Gooding.

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