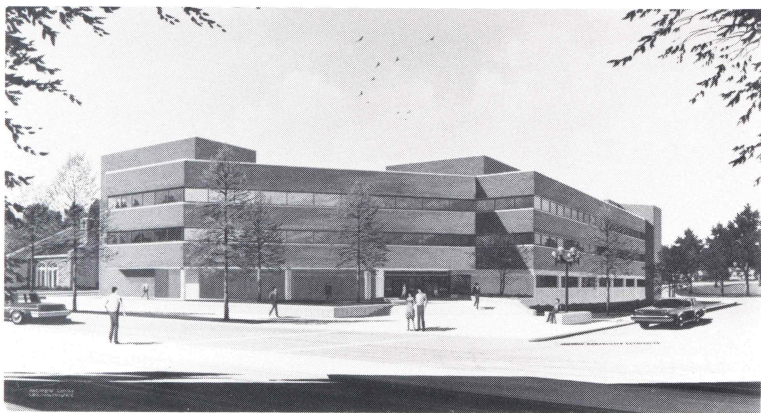


**KENTUCKY GEOLOGICAL SURVEY**  
**Donald C. Haney, State Geologist and Director**  
**UNIVERSITY OF KENTUCKY, LEXINGTON**



**ANNUAL**  
**REPORT**  
**1986-1987**

**1986-1987  
ANNUAL REPORT**

**KENTUCKY GEOLOGICAL SURVEY  
UNIVERSITY OF KENTUCKY**

**LEXINGTON, KENTUCKY**

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

**RESEARCH AND ADMINISTRATIVE OFFICES**

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Cover illustration:

Architect's depiction of Mining and Mineral Resources Building.



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# **IN MEMORIAM W. J. Reynolds, Jr. 1920-1987**

W. J. "Bill" Reynolds, member of the Kentucky Geological Survey Advisory Board, passed away June 21, 1987, at Allen, Kentucky, after an extended period of illness.

Bill was born January 15, 1920, at Martin, Kentucky, the son of the late William James and Rebecca Mayo Reynolds. He is survived by his wife, Ruth Virginia Skaggs Reynolds, of Allen; one son, William James Reynolds, III, of Martin; two daughters, Patricia Ann Reynolds of Martin, and Joyce Reynolds of Betsy Lane; two brothers; two sisters; and a grandson.

He graduated from Martin High School in 1938, and he later attended both Morehead State University and the University of Kentucky. He served in the U.S. Army during World War II and was a member of the Disabled American Veterans.

Bill had a genuine interest in people and the political process. He was elected to the Kentucky House of Representatives from the 95th District for six terms. He served with distinction as State Representative from 1963 to 1975 and was chosen to be Chairman of the Democratic Caucus during his last 6 years in the House. He also served on the Rules Committee and the Legislative Research Committee.

He worked extensively for the cause of education in Kentucky, especially Floyd County. While he was serving as President of the Floyd County PTA, he became acutely aware of the educational needs of the area and was determined to improve the situation. He was instrumental in the establishment of Prestonsburg Community College, serving as Chairman of the Fund-Raising Committee, and was also a leader in establishing the Garth Vocational School. He was very proud of his work in establishing these schools because he believed that getting an education was the best way of preparing for the future. He felt that although it was important to provide additional job opportunities for the people of eastern Kentucky, it was equally important that people receive adequate training to ably perform the tasks that will be needed by modern society.

Bill had a lifelong interest in helping the disadvantaged and trying to improve the quality of life for all citizens of Kentucky. He

worked to accomplish this by improving education and providing people with greater opportunities. In recognition of his work in the 1986 Legislative Session to increase appropriations for the Kentucky Office of Vocational Rehabilitation Services, he was awarded a plaque by the Kentucky Rehabilitation Association commending his efforts to improve services to the disabled citizens of the Commonwealth.

Bill was employed by Columbia Gas Company for 42 years, spending the first 32 years as a right-of-way supervisor and the last 10 years as a legislative liaison with special responsibility for the State of Kentucky. During his employment with Columbia Gas, he developed a strong appreciation of the importance of coal and oil and gas to the economy of eastern Kentucky. He became very aware of, and concerned about, Kentucky's natural resources during his years in the Legislature and time spent as a lobbyist.

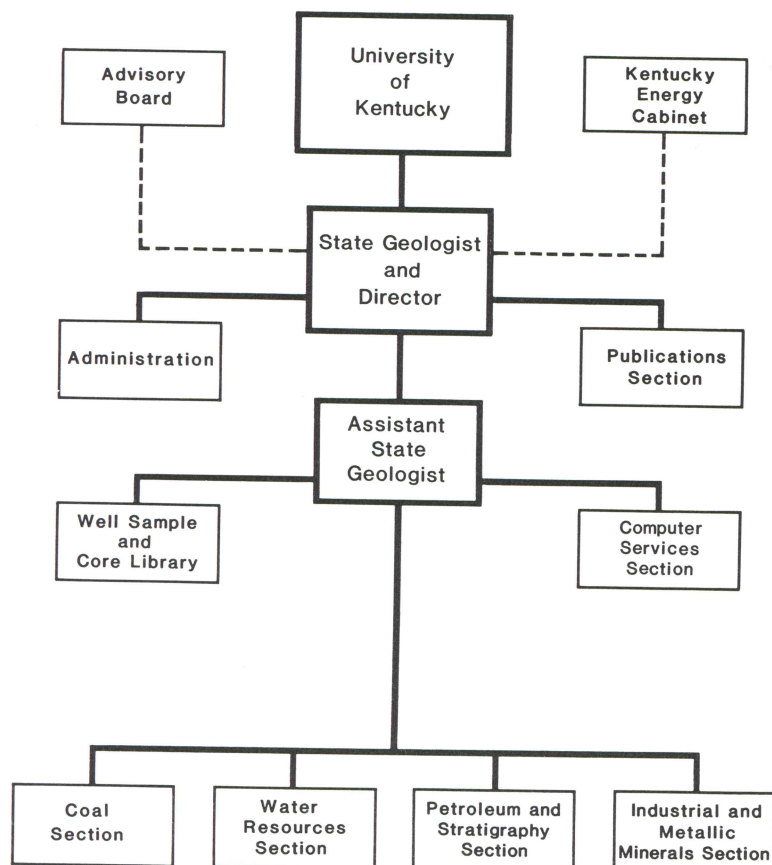
He was appointed to the Kentucky Geological Survey Advisory Board by former Governor Julian Carroll in 1976. He immediately took a great interest in the Survey's work and gave his undivided assistance in helping to acquire needed funding and other support for projects that would benefit the citizens of Kentucky. He was instrumental in obtaining legislative approval for the Mining and Mineral Resources Building that is now under construction on the University of Kentucky campus. Upon completion of this building, scheduled for the late fall of 1987, it will provide excellent facilities for the Kentucky Geological Survey and the Department of Mining Engineering. Without Bill's resourcefulness and unfailing support, this building might never have become a reality. Never ostentatious, he worked effectively behind the scenes and accomplished things that others would have thought impossible. This is because he had gained the reputation of being fair and honorable, and his counsel was well respected and much sought after by those who knew him.

Bill Reynolds was a thoughtful, considerate man who liked people and enjoyed interacting with them. The Kentucky Geological Survey and all Kentuckians have lost a good friend. He will be sorely missed by all.

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## ORGANIZATION OF THE KENTUCKY GEOLOGICAL SURVEY



## FOREWORD

The first official geological and mineralogical survey of Kentucky was made in 1838. Since that time, the Kentucky Geological Survey, which is presently 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, and a complementary project, a major national pilot study on the Kentucky River basin in cooperation with the U.S. Geological Survey; a major study of limestone resources in eastern Kentucky; a survey of the sand and gravel resources along the Ohio River in northern Kentucky; sub-surface 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 in both the Eastern and Western Kentucky Coal Fields; a pilot study in cooperation with the U.S. Geological Survey that may lead to a major revision of the manner in which national coal reserves are calculated; a preliminary study of the geology of roof control in coal mines, in cooperation with the U.S. Mine Safety and Health Administration, which will have national impact on mine planning and mine safety; 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, 1986-June 30, 1987).

## **PUBLIC SERVICES**

### **Well Record Library**

The Petroleum and Stratigraphy Section of the Kentucky Geological Survey is the official repository for records of all oil and gas wells drilled in the State. A variety of records, such as drillers' logs, wireline logs, well-location survey plats, plugging affidavits, and completion reports, are on file for an estimated 225,000 wells. Records for approximately 2,500 new wells were processed and recorded by the Survey last year. In addition, the Kentucky Geological Survey staff reviews and enters into the computerized data base as many of the older well records as time permits. A major long-term project to electronically store and preserve the well-record files was begun during 1986.

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 25,000 records were duplicated in reply to mail orders, telephone requests, and walk-in requests in fiscal year 1986-87.

### **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, polished slabs, and plugs, and to turn in bound copies 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 Kentucky Geological Survey Well Sample and Core Library is the fifth largest repository of its type in the country, and contains over 15,500 sets of well cuttings and in excess of 1,200 cores on file. Over 210,000 feet of sample sets (190 sets) and about 400,000 feet of cores (325 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 University recently purchased a warehouse from the American Tobacco Company adjacent to the main campus. In July 1986, after the University made moving funds available to the Survey, the Well Sample and Core Library began moving out of the Reynolds Building into the American Building. Of the total 54,000 square feet allotted to the Survey, approximately 44,000 square feet will be used for storage of rock materials, and 10,000 square feet will be used for examination areas, a rock processing laboratory, and office space. The Library currently occupies about 21,000 square feet.

The Well Sample and Core Library so far has moved about 70 percent of all rock materials from the Reynolds Building. The move will not be completed until renovation of the American Building is completed. This move was probably the most ambitious ever undertaken on campus. The following major jobs have been accomplished: 91 units of pallet racking have been disassembled, transported, and re-erected; over 215,000 boxes of core have been hand-loaded on

the pallet racking; over 30,000 feet of core have been reboxed; and 3,500 boxes have been repaired. In total, over 900 pallets of rock material, each weighing about 4,500 pounds, have been transported to the American Building.

The Library is still 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-National Cartographic Information Center (KGS-NCIC) provides a focal point for all types of cartographic information in Kentucky. Since 1980, KGS has been affiliated with the U.S. Geological Survey National Cartographic Information Center, which serves as the national repository for information concerning maps, aerial photography, space imagery, digital map data, and geodetic control.

Inquiries regarding the availability of aerial photographs, satellite imagery, current and historic geodetic control, current and historic map information, or digital cartographic data are handled by the KGS-NCIC office in Lexington. Resources available for answering requests include a file of more than 5,700 microfiche indexes to aerial photography projects, satellite data, and historical maps; a microfilm file containing 37,400 historical topographic maps of Kentucky and surrounding states; and online access to Federal government data bases at the EROS Data Center in Sioux Falls, South Dakota, and the USGS Branch of Global Seismology and Geomagnetism in Denver, Colorado.

Close coordination between KGS-NCIC and the KGS Publication Sales Office makes it possible for many persons to obtain the desired materials or information in response to a single visit or inquiry to the Kentucky Geological Survey. In some cases a user may be referred to another State or Federal agency or a private firm as the source for a particular product. A custom-tailored response from KGS-NCIC assures that each map user receives the best information for a particular problem or application.

A total of 456 individual inquiries for cartographic information were answered by KGS-NCIC during the 1986-87 fiscal year. Of these requests, 170 were for information about currently available maps and publications, 116 were for aerial photography or remote sensing data, 112 were for geodetic-control information, and 58 were

for historical or archival cartographic data. Ordering assistance to obtain the desired materials was provided on 161 of the requests.

During the year, a computer listing of approximately 1,600 historical photographs related to Kentucky geology or the Kentucky Geological Survey was completed. The KGS-NCIC Newsletter was issued three times during the year. Also, a Kelsh stereoplottter was donated by a Lexington consulting firm to the Survey.

## **Publication Sales and Data Distribution**

The Publication Sales Office of the Kentucky Geological Survey makes published information about Kentucky's mineral and water resources available to thousands of customers each year. Maps and reports published by the Kentucky Geological Survey and U.S. Geological Survey account for most of the materials sold, but publications from 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. Open-file maps indicating landslide susceptibility are available for most quadrangles in eastern Kentucky at a scale of 1:24,000. 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 21,000 maps and 3,000 reports, as well as 24,000 copies of well records and other miscellaneous items,



resulting in income of approximately \$100,000. Staff members who work in Publication Sales take great pride in helping customers find 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.

In order to further our goal of information dissemination, the Survey played a lead role in organizing and presenting a major Energy and Minerals Conference sponsored by the University of Kentucky and President Otis Singletary, which was held at the University September 18- 19, 1986. The KGS also sponsors an Annual Project Review of Survey research, which is open to the public. This year's review is tentatively scheduled for December 4, 1987.

### ***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 to 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 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.

One of the primary responsibilities of the Coal Section is to provide information about Kentucky's coal resources to the public. To facilitate this task, a new Coal Resources Information Office was opened at the Kentucky Geological Survey's main office. This office contains all publically available coal data at the Kentucky Geological Survey, and has a computer link to the Kentucky Coal Resources Information System (KCRIS), which contains thousands of coal-thickness measurements and coal-quality analyses.

### ***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.

### ***Petroleum and Stratigraphy Section***

The primary function of the Petroleum and Stratigraphy 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 Petroleum and Stratigraphy Section; these two areas provide services to more than 2,100 individuals, companies, and agencies annually. In addition, the Petroleum and Stratigraphy 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 during 1986 decreased to approximately 2,400, the staff of the Petroleum and Stratigraphy Section continues to serve the public and the petroleum industry to the best of its ability. Major efforts to computerize additional records and to develop the capability to produce computer-plotted oil and gas well location maps highlight accomplishments of the past year. A long-term project to electronically store and preserve the paper well-record files was initiated during the last 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 500 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***

#### **AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS**

Dr. Ian M. Johnston, as chairman of District 8 (Kentucky) of the AAPG Committee on Statistics of Drilling (CSD), attended the CSD meeting on June 6, 1987, in Los Angeles, California. This committee is responsible for compiling drilling statistics for the entire on-shore and offshore United States.

#### **ASSOCIATION OF AMERICAN STATE GEOLOGISTS**

Dr. Donald C. Haney was elected vice president of the Association of American State Geologists in 1987. He 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.

Dr. Haney also serves on the Association of American State Geologists-U.S. Geological Survey Cooperative Planning Committee.

#### **GEOLOGICAL SOCIETY OF AMERICA**

In 1985, Dr. Ian M. Johnston was appointed the Geological Society of America Agency Representative for the Kentucky Geological Survey. As Agency Representative, Dr. Johnston will handle correspondence and requests for information regarding GSA membership and activities.

#### **INTERSTATE OIL COMPACT COMMISSION**

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.



Martin C. Noger is serving as a member of the Enhanced Recovery Committee and the Tar Sands Subcommittee of the Interstate Oil Compact Commission. The committee conducts research activities on the technical progress of efforts to recover heavy oil from tar-sand deposits, and tertiary oil from depleted reservoirs.

Dr. John Kiefer serves as a member of the IOCC Environmental Affairs Committee.

Dr. Haney participated in the IOCC Annual Meeting in Salt Lake City, Utah, in December 1986, and also attended and chaired the Research Committee session at the IOCC Mid-Year Meeting in Coeur d'Alene, Idaho.

### **MAXEY FLATS STEERING COMMITTEE**

Dr. Donald C. Haney was appointed to serve in an advisory capacity on the national Maxey Flats Steering Committee, which is developing plans and objectives for a remedial investigation and feasibility study on the closing of the Maxey Flats Low-Level Nuclear Waste Repository in Fleming County, Kentucky. This committee is composed primarily of representatives of "Probable Responsible Parties," who generated much of the waste now buried at Maxey Flats. Dr. Haney will be a representative of the Commonwealth of Kentucky, and will serve in an advisory capacity to the Steering Committee.

### **NATIONAL WATER QUALITY ASSESSMENT PROGRAM**

The U.S. Geological Survey Water Resources Division initiated in 1986 a National Water Quality Assessment Program (NAWQA). This program selected the Kentucky River basin as one of the four pilot projects in the Nation to be studied from 1986 through 1989. The Kentucky Geological Survey serves on the liaison committee for the Kentucky River basin study, and Dr. Haney serves on the National Coordinating Work Group, whose responsibility is to review all NAWQA projects across the Nation.

### **State**

### **EASTERN OIL SHALE SYMPOSIUM**

Martin C. Noger was appointed a member of the Technical Program Advisory Committee of the Eastern Oil Shale Symposium sponsored by the Commonwealth of Kentucky and the Kentucky Energy Cabinet in 1986. The Committee is responsible for developing the format of the technical program, contacting and inviting speakers, and assisting in promoting the Symposium. Mr. Noger, who served

as the Tar-Sand Program chairman for the 1985 and 1986 symposiums, has again been asked to serve in this capacity for the 1987 Symposium, and is presently finalizing plans for the session, to be held November 18-20, 1987.

### **GEOLOGICAL SOCIETY OF KENTUCKY**

Martin C. Noger was elected president of the Geological Society of Kentucky in January 1987. He is the presiding officer at all meetings of the Society and Executive Committee, and arranges the program for the fall and spring meetings.

Margaret Luther Smath was elected to a 2-year term as secretary of the Society in January 1986. She is in charge of all member records, minutes, and correspondence.

### **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 for the panel 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 for government and the private sector, and development of codes and policies to promote public safety. The panel, which is made up of members appointed by the Governor and associate members selected to advise in specialized areas, held meetings at Owensboro, Frankfort, and Hickman, Kentucky, during the past fiscal year. In addition, a number of special committee meetings were held at various sites throughout the State. 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 (CUSEC), an organization of states most immediately threatened by any New Madrid tectonic activity. The Consortium held its annual meeting in Collinsville, Illinois, in November, and Dr. Kiefer served as chairman of the

geology/seismology parallel disciplines session. In January the geology/seismology groups from Kentucky, Indiana, and Illinois met again in Bloomington, Indiana, to develop research programs of mutual interest.

Individual members of the panel presented numerous talks to civic groups, agency personnel, schools, and professional meetings. Proposals for seismic research have been prepared and submitted jointly by the KGS and the University of Kentucky Departments of Geological Sciences and Civil Engineering. Although a limited amount of seismic research is ongoing, and the Kentucky Seismic Network, a series of seismic stations, is in operation, a lack of funding has severely hampered research. The June 10, 1987, earthquake in southern Illinois has provided substantial new data, which must be analyzed to aid the panel in its earthquake-damage-mitigation studies during the coming year.

The panel, in association with the Division of Disaster and Emergency Services, has developed a 5-year seismic-safety plan to guide Kentucky activities, and prepares an annual report of its activities for the Governor.

### **GOVERNOR'S GROUND-WATER ADVISORY COUNCIL**

Dr. Donald C. Haney is serving on the Governor's Ground Water Advisory Council, which assists the Secretary of the Kentucky Natural Resources and Environmental Protection Cabinet with developing strategy for the management and protection of Kentucky's ground water. Dr. Haney is being assisted on the Council by Dr. James Dinger, Head of the Water Resources Section at KGS. The council has developed a ground-water protection strategy that has been released for public review. The strategy calls for the development of a repository for ground-water data, to be housed at the Survey.

### **KENTUCKY ANTHROPOLOGICAL RESEARCH FACILITY ADVISORY COMMITTEE**

Garland R. Dever, Jr., serves on the Advisory Committee for the Kentucky Anthropological Research Facility (KARF) at the University of Kentucky. KARF consists of four units: Department of Anthropology archeology program, Program for Cultural Resource Assessment, Museum of Anthropology, and Office of State Archeology. The advisory committee is concerned with supporting and promoting KARF's research activities and interests, and with inform-

ing the academic and public communities of the facility's goals and achievements.

### **KENTUCKY HAZARDOUS WASTE SITING BOARD**

Dr. Donald C. Haney continues to serve 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 1984 General Assembly to investigate the need for an integrated hazardous waste processing facility and landfill for the Commonwealth. The Board has completed its preliminary work and is currently inactive pending an application for a regional integrated facility.

### **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 re-appointed by the Governor to serve a 2-year term on the 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 commer-



cially 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. Driller certification tests are administered through the Natural Resources and Environmental Protection Cabinet, and at this time, approximately 165 drillers have been certified by the Commonwealth.

### **MAXEY FLATS ADVISORY TASK FORCE**

Dr. Donald C. Haney was appointed to the Governor's Maxey Flats Advisory Task Force, the purpose of which is to gather data concerning the overall conditions of the Maxey Flats Low-Level Nuclear Waste Repository in Fleming County, Kentucky, and to advise State officials and others on procedures and actions necessary for its closing. Dr. Haney is being assisted on the task force by Dr. John D. Kiefer, Assistant State Geologist.

### **STATE WATER MANAGEMENT TASK FORCE**

Dr. John Kiefer, Assistant State Geologist, completed a 2-year term as chairman of the Citizens Water Task Force in June 1986. The Task Force was successful in working for the passage of water-related legislation, including House Joint Resolution 81, which established a State Water Management Task Force through the Legislative Research Commission. State Representative Walter Blevins of Morehead has been named chairman of the new task force, and Dr. Kiefer continues to serve as the KGS representative and as chairman of the Groundwater and Infrastructure subcommittees. In May 1987, Dr. Kiefer represented Kentucky at the National Council of State Legislatures Conference on Wastewater Infrastructure Funding, held in Washington, D.C.

The purpose of the Task Force is to work with State and Federal agencies, industry, and with the general public to promote the proper protection, development, and utilization of Kentucky's water resources and develop priorities and strategies for addressing the State's present and future water needs.

### **UNIVERSITY OF KENTUCKY DEPARTMENT OF GEOLOGICAL SCIENCES**

Dr. Donald C. Haney, Dr. James C. Cobb, and Dr. James S. Dinger have been named Adjunct Associate Professors to the graduate

faculty of the Department of Geological Sciences, where they are supervising graduate students in hydrology, coal, and other programs.

### ***Local***

#### **GEOLOGICAL SOCIETY OF KENTUCKY, LEXINGTON CHAPTER**

Martin C. Noger was vice president of the Lexington Chapter of the Geological Society of Kentucky, and was responsible for arranging the technical program for chapter meetings.

Richard E. Sergeant was secretary-treasurer of the Lexington chapter, and was in charge of all member records, minutes, dues, and correspondence.

#### **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 to delineate hazards such as sinkholes, subsidence, and flooding.

Members of the Water Resources Section also attended meetings and served in an advisory capacity to the Lexington-Fayette Mayor's Committee on Water Quantity and Quality and the regional Kentucky River Users Group, an organization of municipalities and water companies dependant on the Kentucky River as their source of water. The group is currently in the formulative stages, but may play a very important part in the protection and management of water resources in the Kentucky River Basin.

#### **UNIVERSITY OF KENTUCKY BUILDING NAMING COMMITTEE**

Dr. Donald C. Haney was appointed to the University of Kentucky Building Naming Committee, which assists the President and the Board of Trustees in naming new buildings on the Lexington campus.



# 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 since the first official geological and mineralogical investigations 149 years ago.

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

In 1986 Kentucky again ranked first in the United States in the production of bituminous coal. The U.S. Department of Energy estimated that Kentucky produced about 162 million tons of coal in 1986, down 5 percent from the 170 million tons produced in 1985.

Although Kentucky has abundant coal resources for the near term, there is concern that economically mineable coal will not be readily available for the next generation. The Kentucky Geological Survey has geologically documented coal resources in Kentucky. However, the mineability and economics of these remaining resources are not known with sufficient detail to make predictions about future levels of coal production. Since Kentucky's economy depends upon high levels of coal production, detailed information is needed to assess how long the remaining coal resources can sustain these high production levels. One of the Coal Section's current projects will determine Kentucky's available mineable resources.

The geology of mining was another major topic of research for the year. The Kentucky Geological Survey worked closely with the Mine Safety and Health Administration (MSHA) to prepare a train-

ing program for miners, supervisors, and inspectors on the geology of coal-mine roofs. This program will be produced and distributed to mines in the Appalachian region by MSHA.

Other KGS research into various aspects of Kentucky's coal resources during the year included coal resource-estimation, documentation, and definition; stratigraphy and coal-bed correlation; coal-bed mapping; coal-quality characterization; basin analysis; coal-mining geology; and identification of possible mine-subsidence areas in Kentucky. Several of the projects were conducted cooperatively or under contract with other agencies such as the U.S. Geological Survey, the Division of Abandoned Mined Lands, the Kentucky Natural Resources and Environmental Protection Cabinet, and the Mine Safety and Health Administration.

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

**CHESNUT, Donald R., Jr.**

Coal and petroleum exploration, resource estimates, and surface and underground coal mining depend upon detailed knowledge of coal beds and the rocks that enclose them. Most of the available information about the geology of coals in Kentucky was obtained from rock strata at or very near the surface. More information is still needed about deeper coal-bearing rocks. The Kentucky Geological Survey is conducting analyses of Kentucky's deep coal resources and the rocks in which they occur.

Core descriptions, drillers' logs, and geophysical logs are being analyzed to establish a stratigraphic and geometric framework for the coal-bearing rocks of eastern Kentucky. Subsurface rocks more than a few hundred feet below the surface are not usually core-drilled by coal companies mining surface and near-surface coals. However, oil and gas records from wells that penetrate the deeper coal-bearing rocks can be used as a preliminary exploration tool for subsurface analysis and coal-resources estimation.

Several important relationships have been discovered from analyzing oil and gas records. Coal-bearing rocks can be divided into four major units: the Lee, Breathitt, Conemaugh, and Monongahela Formations. The Lee Formation is composed of thick, massive, very hard sandstones and conglomerates and minor amounts of coal and shale. Coals in the Lee are generally very limited in occurrence. The most significant, mineable resources of

coal occur in the Breathitt Formation, which is composed of shale, thinner sandstones, siltstones, and coal. The members of the Lee Formation occur in belts at various levels within the Breathitt Formation, at the expense of coal-bearing rocks. The distribution of Lee and Breathitt Formation rock strata in the subsurface has a great effect on the distribution of coal resources. The Breathitt Formation also contains four thick marine-shale beds, which are, in ascending order, the Betsie Shale, the Kendrick Shale, the Magoffin Member, and the Stoney Fork Member. Generally, these beds are easily recognized in subsurface records such as oil and gas logs. They can be used to subdivide the Breathitt Formation into five informal units useful for resource determination: the Grundy, Pikeville, Hyden, Four Corners, and Princess, in ascending order. Preliminary study indicates that most of the subsurface coal resources of eastern Kentucky occur in the Grundy and Pikeville units above the Lee Formation.

A pilot study was conducted to determine the available coal reserves of the Matewan Quadrangle, Pike County, Kentucky. Oil and gas records were used to construct three cross sections across the quadrangle. These cross sections show the occurrence and depth of the Lee Formation as well as the subsurface coal-bearing rocks of the Grundy unit. Coal thicknesses within the Grundy can only be determined by additional core drilling or by high-resolution density logging of oil and gas wells before they are cased. Gas shows recorded on drilling records suggest that a potential for coal-bed methane exists in deeper coals in southeastern Kentucky.

Another important relationship, the unconformable contact between the Mississippian and Pennsylvanian rocks in eastern Kentucky, has been demonstrated by the subsurface analyses. Progressive northwestward truncation of Mississippian strata below the unconformity, progressive northwestward overlap of Pennsylvanian units above the unconformity, and buried topography were discovered during construction of cross sections.

A preliminary interstate coal correlation chart has been constructed for eastern Kentucky, northern Tennessee, western Virginia, and southwestern West Virginia. Coal correlation was aided by the use of subsurface marine-shale marker beds such as the Betsie Shale, Kendrick Shale, and the Magoffin Member. This correlation chart and a series of cross sections across the Eastern Kentucky Coal Field with accompanying text are in press. In addition, the Kentucky Geological Survey and the West Virginia Geologic and Economic Survey have agreed to jointly compile a coal correlation chart across

the Kentucky-West Virginia border. West Virginia and Kentucky share much of the geology of the Central Appalachian Basin, and this cooperative work will help both states better understand their coal geology and resources.

## **COAL-QUALITY ANALYSES FOR THE EASTERN AND WESTERN KENTUCKY COAL FIELDS**

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

The quality of coal is a major factor in its marketability, value, and uses. Therefore, the Kentucky Geological Survey has conducted intensive investigations of the quality of Kentucky coals. There are scores of different coal beds in Kentucky. It would be exceedingly difficult or impossible to find an area in the world that produces coal from as many different seams as Kentucky. These coals can differ significantly in chemical and physical characteristics, although Kentucky is well known for its high-quality steam and metallurgical coals.

Six new reports about the quality of eastern Kentucky coals for each of the six coal-resource districts in the Eastern Kentucky Coal Field (Big Sandy, Hazard, Licking River, Princess, Southwestern, and Upper Cumberland) were published by the Kentucky Geological Survey during the year. These publications are intended to be used with the other available coal-resource and coal-thickness publications for independent analyses of the quantity and quality of Kentucky coal resources.

These new publications on coal quality contain information on the geographic and stratigraphic location of each sample and other relevant information about the collection of the sample; a detailed geologic description of each sample; analytical results for proximate and ultimate, calorific content, sulfur forms, ash fusion, free swelling index, and major-, minor-, and trace-elements; and petrographic analyses including macerals and reflectance.

These reports contain analyses of nearly 800 samples from about 35 eastern Kentucky coals. The publication of these data represents a tremendous new source of information for industry and government researchers. It is a major accomplishment for Kentucky and a successful cooperative effort of the KGS, the U.S. Geological Survey, and the Kentucky Energy Cabinet Laboratory.

Two new open-file reports on coal quality were also made available during the year. One report contains data about coals in the Eastern Kentucky Coal Field (Appalachian Basin coals) and the other contains data about coals in the Western Kentucky Coal Field



(Illinois Basin coals). Both reports list coal name, interval sampled, sampling method, total thickness, Carter coordinate location of sample, proximate analysis, sulfur content, Btu content, free-swelling index, and softening temperature. The reports are organized by area, and give the different beds analyzed for each 7.5-minute quadrangle. These reports are supplements to the published district reports discussed above, and contain several hundred additional analyses. They are produced directly from the Kentucky Coal Resources Information System (KCRIS) computer data base. This data base is constantly being updated, and as additions to the data base are made, new open-file reports will be compiled.

Blue-line copies of coal-quality work maps are currently available from the Kentucky Geological Survey for seven coal beds. A set of four maps is available for each of the coals, detailing sample location and identification, Btu content with total moisture, ash content with ash-softening temperature, and sulfur content with free-swelling index. Maps are currently available for the Fire Clay, Williamson-Amburgy, Upper Elkhorn No. 3, Upper Elkhorn No. 1, Lower Elkhorn, Manchester, and Springfield coal beds. Similar maps for other coal beds are being planned.

## **KENTUCKY GEOLOGICAL SURVEY COAL RESOURCE INFORMATION OFFICE**

**DAVIDSON, O. Barton, SERGEANT, Richard E.,  
COBB, James C., and CHESNUT, Donald R., Jr.**

The Kentucky Geological Survey has recently opened a Coal Resource Information Office. This office provides a work room for visitors seeking coal-resource information about the Eastern and Western Kentucky Coal Fields. Several types of coal-related information are currently available, including:

1. More than 22,000 open-file measurements of coal-thickness data for nearly 50 beds. These open-file reports are categorized by the six coal reserve districts in the Eastern Kentucky Coal Field.
2. Information on coal quality for both the Eastern and Western Kentucky Coal Fields. These records are available in open-file reports by district and coal field, as well as in computer printouts.
3. Field notes and sign-off reports by KGS geologists for most of the coal-bearing quadrangles in the Eastern Kentucky Coal Field. These data were obtained during the Survey's Eastern Kentucky Coal Resource Assessment Program (1978-83).

4. Coal-resource field maps (7.5-minute topographic base). These field maps should be used in conjunction with the sign-off reports and field notes mentioned above. They are available on microfiche.
5. Field notes from the USGS-KGS Geologic Mapping Program (1960-78). Nearly 300 quadrangles in Kentucky contain coal, and the field notes for many of these quadrangles contain references to coals encountered by geologists who mapped the quadrangles.
6. USGS-KGS geologic-quadrangle overlay maps (mylar copies). These maps show the locations of field stations referenced in the USGS-KGS field notes.
7. Geophysical and lithologic logs from various sources.

The Coal Resource Information Office is equipped with microfilm and microfiche readers, a microfiche duplicator, and a computer terminal through which the coal-quality and coal-thickness data bases of the Kentucky Geological Survey may be accessed with appropriate guidance by KGS staff. To date, several visitors have made use of the facilities, and numerous phone requests have been answered. The Coal Resource Information Office is designed to be a research tool for the public as well as members of the Kentucky Geological Survey. Further expansion of services and facilities is expected in the near future as new information becomes available. Visitors are requested to call ahead for appointments to use the Coal Resource Information Office because of space and equipment limitations.

## **GEOLOGY IN MINING EDUCATION SERIES (GIMES)**

**GREB, Stephen F., and COBB, James C.**

Roof control is one of the major problems facing the coal-mining industry in Kentucky. Annually, roof falls result in an average of 10 fatalities, as well as substantial costs in injuries, litigation, clean-up and removal costs, and economic loss due to down-time. Case studies of underground mines in eastern Kentucky by the Kentucky Geological Survey and others have illustrated the significance of geologic factors in roof control and accurate reserve estimation. Results of a case study by the KGS in which roof falls were classified, and then used to predict roof conditions in advance of mining are very encouraging. However, communication to the coal-mining industry of the geologic principles used to construct the predictive roof-fall model has proved difficult.

The GIMES program was developed to disseminate information about geology relevant to the coal-mining industry in Kentucky. GIMES is divided into four phases. Phase 1 is the collection of geologic data from mines. Phase 2 is the presentation of audio-visual programs, such as traveling slide presentations, seminars, and a safety training film produced in conjunction with the Mine Safety and Health Administration, U.S. Department of Labor. These audio-visual programs combine colorful illustrations with actual subsurface photographs to increase miner awareness of the geologic factors that influence roof control and seam mineability. Phase 3 is a roof-fall questionnaire, which will provide statistical information on roof control in Kentucky. Phase 3 is a cooperative effort between the KGS and the Mining Engineering Department of the University of Kentucky and will provide new, vital, previously unavailable information on mines. Phase 4 will integrate the results of the case studies and the questionnaires into a publication that will be made available to both the public and private sectors of the mining industry.

Public response to the first two phases of the Geology in Mining Education Series has been highly encouraging. The forthcoming implementation of Phases 3 and 4 will further increase the effectiveness of GIMES as a viable tool to increase mine safety awareness in the Commonwealth.

### **THE GEOLOGY OF ROOF FALLS: A MINE-SAFETY TRAINING PROGRAM**

**GREB, Stephen F., and COBB, James C.**

Case studies of roof instability in underground coal mines of the Eastern Kentucky Coal Field by the Kentucky Geological Survey and others have shown that coal-mine roof falls can be geologically classified. Because many roof falls are related to weaknesses in the roof rocks, geologic mapping of mine roofs can be used to develop mine-specific, roof-fall prediction models. The key to interpreting mine roofs is a better understanding of the geologic conditions that lead to unsafe roof conditions.

The Kentucky Geological Survey, in conjunction with the U.S. Department of Labor, Mine Safety and Health Administration (MSHA), is working on a mining-training program called "The Geology of Roof Falls." The program has been reviewed by MSHA and the U.S. Bureau of Mines, and the production of an audio-visual presentation has been approved. The purpose of the program is to

help miners and mine planners understand and identify rock weaknesses in underground mine roofs and other mineability problems. The program illustrates geologic conditions that lead to unstable roof conditions, including (1) weakly bedded shales, (2) shales with coal riders, (3) kettle bottoms, (4) slickensided shales beneath sandstone or limestone rolls, (5) weakly bedded stackrock, (6) weakly bedded sandstone, (7) fractures (hill seams) and faults, (8) rotated bedding (paleoslumps), and (9) clay veins. Each condition is described and illustrated with colorful graphics and photographs from underground mines.

The development of the program in conjunction with MSHA is significant because the program will reach a large audience in the coal-mining industry. The simplicity of the training program will help non-geologists to identify and understand some of the common weaknesses in coal-mine roof rocks, and will help to ensure a safer and more economic coal-mining industry.

### **COAL RESOURCES OF THE EASTERN KENTUCKY COAL FIELD: EVALUATION OF AVAILABLE COAL RESERVES**

**SERGEANT, Richard E., COBB, James C., DAVIDSON, O. Barton, and CHESNUT, Donald R., Jr.**

The determination of remaining coal reserves in Kentucky and in other coal-producing states has become increasingly important in the Nation's search for cost-efficient, environmentally safe energy sources. Coal-reserve information is crucial to local, state, and federal planning for utility fuel supplies, mining technology, combustion technology, retrofitting of power plants, environmental concerns, and economic conditions.

The Kentucky Geological Survey and the U.S. Geological Survey have undertaken a pilot project to calculate the total available coal reserves of the Matewan Quadrangle of eastern Pike County, Kentucky. This calculation will be accomplished by subtracting from the total such resource factors as mined-out coal, coal rendered unmineable due to past mining, coal unmineable because of poor quality and geologic conditions, coal too deep for economical recovery, coal too densely drilled with oil and gas wells, and coal in state, federal, or private lands that are therefore unsuitable for mining.

The Kentucky Geological Survey, assisted by the Kentucky Department of Mines and Minerals and the Natural Resources and Environmental Protection Cabinet, will supply information on 22 ma-



for coal beds in the quadrangle. The information will include coal-thickness data, coal-quality data, mined-out area maps (supplied in part by the Kentucky Department of Mines and Minerals for research purposes only and not for publication), cultural features, and maps of lands unsuitable for mining. The U.S. Geological Survey will evaluate these data using computer-assisted resource modeling and mining-cost analyses. The resulting estimates of available reserves will be broken down by type of mining required, depth of overburden, coal thickness, coal quality, approximate production cost, and mineability.

The Matewan pilot study is nearing completion, and detailed reserve analyses are forthcoming. For example, the Upper Elkhorn No. 2 coal bed in the Matewan Quadrangle had 30 million tons of surface-mineable resources and 76 million tons of deep-mineable resources before any mining began. Mining in this seam has produced 14 million tons, which leaves about 92 million tons of remaining resources. Further restrictions and obstacles to mining such as oil and gas wells, towns, rivers, roads, streams, pipelines, and power lines effectively remove 4 million more tons from the remaining surface-mineable coal and potentially 65 million tons from the deep-mineable coal. The available resource of the Upper Elkhorn No. 2 coal is therefore only 28 million tons. Recovery factors for surface and deep coal, as well as other economic and geologic factors, indicate that less than half of the 28 million tons of available resources in the Upper Elkhorn No. 2 coal is actually recoverable coal.

It is not yet known to what degree the findings from the Upper Elkhorn No. 2 coal can be extrapolated to other coals and other quadrangles; further work is needed. Kentucky's coal resources of 95 billion tons represent only the geologically documented *resources*, and not the economically and technically recoverable *reserves*. The results of this pilot study will be presented to federal authorities in an effort to secure further funding for continuing the reserve study both in Kentucky and in other coal-producing states.

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

**SERGEANT, Richard E., SMATH, Richard A., STICKNEY, John R., COWAN, April, CAREW, Mark B., and CAREW, Pamela L.**

Underground mining of coal by shaft, slope, or drift in eastern and western Kentucky began in the early 1800's. Currently, underground mining continues to supply more than 40 percent of the coal in Kentucky's Eastern and Western Coal Fields. Despite more than 150 years of underground mining activity, remaining coal resources will continue for many decades to come. Coal-resource estimates by the Kentucky Geological Survey indicate remaining resources in the Eastern and Western coal fields exceed 95 billion tons. It is essential that these coal resources be developed to their full potential. This development, however, should not have an adverse impact on citizens living above or adjacent to areas where the coal resources are being or have been extracted.

One of the problems associated with underground coal mining is surface subsidence or ground failure over abandoned mines. This subsidence results when rock strata above mined-out coal beds collapse into the void created by coal-bed extraction. Subsidence in undeveloped areas such as pastures, fields, and woodlands may cause little or no damage. But, if surface subsidence occurs in urban areas such as subdivisions or shopping centers, potential property loss can be substantial.

To help quantify the extent of suspected subsidence damage in parts of eastern and western Kentucky, the Kentucky Geological Survey in cooperation with the Division of Abandoned Lands, has initiated a project to delineate and catalog suspected subsidence damage in Hopkins, Muhlenberg, Webster, Union, Ohio, and Boyd Counties.

Field work on the five counties in western Kentucky began on September 1, 1984, while field work in Boyd County in eastern Kentucky began on February 1, 1987. Plans are to organize and computerize data relevant to suspected subsidence in the study area. These data will then be compiled into comprehensive subsidence catalogs for the six counties in the study area. To date, subsidence catalogs for Hopkins and Muhlenberg Counties have been completed, and the remaining catalogs will be completed by December



1987. Information contained in these subsidence catalogs will be used to determine the magnitude of existing subsidence problems and to outline areas of potential concern. In addition, information compiled in these catalogs will be useful during implementation of Kentucky's Subsidence Insurance Program, which began on November 1, 1986. This program will provide protection to citizens who reside in the coal-producing areas of Kentucky by allowing them to insure their homes against future subsidence damage. Participation in this program is on a county-by-county basis; 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 possible.

## **COAL RESOURCES OF THE WESTERN KENTUCKY COAL FIELD**

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

With an estimated 38 billion tons of remaining resources, the Western Kentucky Coal Field is an important asset in the Commonwealth's energy treasury. In 1985 the Western Kentucky Coal Field produced 44 million tons of coal, down slightly from the 46 million tons produced in 1984. An important, ongoing task of the Coal Section is to assist industry, the general public, and government agencies in understanding the coal resources of this coal field, where exploration and development have been complicated by structure and stratigraphy.

From 1984 to 1985 surface mining declined by 3 million tons, while underground mining increased by only 700,000 tons. Surface mining has been the principal type of mining in the Western Kentucky Coal Field for many years, and as a result large areas of surface-mineable coal have been depleted.

Exploration for coal reserves deeper than 1,000 feet and for reserves suitable for longwall mining has been underway for some time. As a result, the need for detailed structural and stratigraphic information has increased greatly in the past year. The collection, analysis, and dissemination of information on subsurface coal resources is the major emphasis of work in the Western Kentucky Coal Field. During the year more than 100 thickness measurements were obtained, and 25 coal samples were collected for chemical analysis. Core descriptions were made for 25 cores drilled in the coal field, and samples of coals and limestones from neighboring state surveys and cooperating universities were obtained for paleon-

tological research. The coal-resource data and stratigraphic records for the Western Kentucky Coal Field were used to answer several hundred requests for information.

During the past year the Coal Section completed two reports on the stratigraphy of the Western Kentucky Coal Field. One report concerns the coal beds of the Sturgis Formation, which contain the youngest coal-bearing rocks of western Kentucky. These coals have attracted interest for development because the deeper and more widespread coals of the Carbondale Formation are already in heavy production. The second report concerns coal beds of the Tradewater Formation in Ohio County, which are older than other coal beds mined in the region but of exceptionally high quality.

A comprehensive report on the regional stratigraphy of coal-bearing rocks in western Kentucky has been revised and is in review. Included in this report are structure and isopach maps, and cross sections of the Pennsylvanian strata of the region.

## **Industrial and Metallic Minerals**

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

## **SAND AND GRAVEL RESOURCES OF THE OHIO RIVER VALLEY**

**AMARAL, Eugene J.**

Sand and gravel are an important source of construction material in Kentucky, ranking second only to crushed stone. Most sand and gravel is obtained from dredging and open-pit operations in glacial outwash and alluvial deposits along the Ohio River Valley. Potential aggregate sources represented by these deposits are being removed from the resource base at an accelerating pace as they are covered by expanding urban areas and industrial-plant construction. Sand and gravel deposits also form the principal aquifer of the region and underlie prime agricultural land. Determining the distribution, volume, and physical and mineralogical character of

these deposits will aid in advance planning for multiple land use to permit recovery of these potential aggregate resources.

A study to determine the physical, textural, and mineralogical properties of sand and gravel deposits along the Ohio River Valley is in progress. During the first phase of the project, deposits in Boone, Carroll, and Gallatin Counties are being investigated. About 150 samples have been collected from more than 30 sites (active and abandoned pits, outcrops, and boreholes) in the three counties. Quantitative analyses of the grain-size, particle-shape, and compositional characteristics of these samples are in progress at the KGS sedimentology laboratory, and are about 50 percent completed. For most applications, construction raw material must meet specifications for size gradation, percentage of deleterious material, aggregate soundness, abrasion resistance, and other physical and chemical properties.

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

**ANDERSON, Warren H.**

The High Bridge Group (Middle Ordovician) is mined at seven sites in central Kentucky for the production of construction and agricultural stone, fertilizer filler, and low-silica rock dust for underground coal mines. In north-central Kentucky, two operations along the Ohio River mine High Bridge stone for the production of lime for flue-gas desulfurization, flux, chemical industries, and water treatment.

Work continues on a regional study of the High Bridge to determine chemical characteristics of the limestone and dolomite, and to outline the occurrence of deposits suitable for industrial uses that require carbonate rocks of high chemical purity. Cores donated to the Survey by private companies are being utilized for the project. Samples for major-element analysis are taken at 1-foot intervals from the entire High Bridge section.

A core from Mason County has been sampled and described, and 300 of the 680 samples have been analyzed. A Boyle County core has been selected for sampling during the next phase of the project. Compilation of a structure map contouring the top of the High Bridge (Tyrone Limestone) in central Kentucky is in progress. The Kentucky Energy Cabinet Laboratory is cooperating in the current study.

### **NONFUEL MINERAL STATISTICS**

**ANDERSON, Warren H.**

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' 1985 "Minerals Yearbook" was published during 1987. The Kentucky chapter ("The Mineral Industry of Kentucky") was also issued as Kentucky Geological Survey Reprint 24. A directory of industrial and metallic mineral producers in the State was compiled and will be published as a Kentucky Geological Survey Information Circular.

In 1986, the value of nonfuel-mineral production in the State was about \$259 million, based on preliminary data received by the Bureau of Mines. Crushed stone was the leading nonfuel-mineral commodity, accounting for almost 50 percent of the State's total value. Kentucky ranked thirteenth among the 50 states in crushed-stone output. The State was the Nation's second leading producer of ball clay and lime. Portland and masonry cement, common and fire clays, construction sand and gravel, and industrial sand also were produced. Commodities processed or manufactured in the State included aluminum, ferroalloys, synthetic graphite, pig iron and steel, perlite, slag, sulfur, and vermiculite.

### **TITANIUM-BEARING PLACER DEPOSITS IN THE McNAIRY FORMATION (CRETACEOUS), WESTERN KENTUCKY**

**ANDERSON, Warren H.**

Low-grade deposits of titanium are present in heavy-mineral placers of the McNairy Formation (Cretaceous) in western Kentucky. Based on recent geological reconnaissance of surface exposures in Marshall and Calloway Counties, heavy-mineral placers are estimated to comprise less than 2 percent of the sand deposits in the McNairy. The placers, which are very fine grained, contain the titanium minerals, ilmenite, leucoxene, and rutile.

This preliminary investigation suggests that the placer deposits presently are uneconomical as a source of titanium because of their low grade, small grain size, and discontinuous distribution. However, documentation of their mineral content and areal distribution is considered warranted. Samples have been collected from



outcropping placers at eight sites for mineralogic and chemical analysis. The analytical work will be conducted when KGS laboratory facilities become available in the new Mining and Mineral Resources Building, which currently is under construction. The distribution and mineral content of placers in the subsurface McNairy will be investigated, and additional surface deposits may be sampled.

## **ZINC DEPOSITS OF SOUTH-CENTRAL KENTUCKY**

**ANDERSON, Warren H.**

The Mascot Dolomite of the Knox Group (Cambrian-Ordovician) in south-central Kentucky was the subject of a research project that was completed during the 1985-1986 fiscal year. The project report and accompanying maps and cross sections have now been completed and currently are undergoing technical review.

Major conclusions of the project indicate that low-grade zinc deposits in Monroe, Cumberland, and Clinton Counties are related to solution-collapse breccia bodies and stromatolites, and in part are localized by minor positive structural features within the Knox. The top of the Knox is marked by a well-known regional unconformity; the associated aquifer system that developed in the upper Knox served as a conduit for migrating basinal fluids, including hydrocarbons. Paleotopographic lowlands on the unconformable Knox surface may reflect the presence of solution-collapse features in the Mascot and indicate possible sites of mineralization.

The Mascot Dolomite has had a complex diagenetic history involving several stages of dolomitization, which were interrupted by silicification, solution, and brecciation. The repetitive nature of carbonate lithologies, the presence of oolites and stromatolites, and the former presence of evaporitic minerals (indicated by half-moon oolites) suggest that the Mascot was deposited in shallow subtidal to supratidal environments. Oolite bars may have been present in the area.

Pronounced thinning and thickening in the interval between internal marker beds M-5 and TR across the Cincinnati Arch indicate Early Ordovician uplift and subsidence along the arch. The interval between these marker beds also thins northward along the arch into Adair County. The absence of the upper and middle Mascot rocks on the Jessamine Dome in central Kentucky may be related to a combination of depositional thinning and erosion.

The information developed on geologic controls for zinc mineralization may also aid in the exploration for petroleum in the

Knox of south-central Kentucky. Favorable reservoirs for hydrocarbons and sites for zinc mineralization are both related to features associated with the paleoaquifer: enhanced dolomite dissolution and porosity, and breccia bodies. Paleolinear trends on a map of the Knox unconformity show a relationship between fracture alignment and oil and gas fields.

## **LIMESTONE AND DOLOMITE RESOURCES FOR COAL-RELATED INDUSTRIES**

**DEVER, Garland R., Jr.**

Limestone and dolomite are employed by coal producers and coal-consuming industries in environmental-control measures to meet Federal and State standards for mine safety and reclamation, water quality, and air quality. The objective of this project is to provide industry with information on the availability of stone in Kentucky that meets the specifications for coal-related uses.

The Survey continued to work with the Kentucky Energy Cabinet Laboratory (KECL) on limestones and dolomites for fluidized-bed combustion systems. The investigation of potential sources of limestone in Kentucky that would have low attrition rates in fluidized-bed boilers continued. Micrograined and medium-grained limestones in western and north-central Kentucky were sampled for testing of their attrition characteristics. A deposit of Salem-Warsaw Limestone in south-central Kentucky, previously used in test runs at the KECL fluidized-bed-combustion pilot plant, was sampled at 1-foot intervals to determine its chemical characteristics.

## **Petroleum and Stratigraphy**

With more than 20,000 producing oil wells and over 9,200 producing gas wells, Kentucky ranks as a major producer of oil and gas. Oil ranks second and natural gas ranks fourth as mineral resources in the State, and they provide an important source of revenue. Approximately 2,413 sites were permitted for drilling in 1986, a decrease of 2,737 from 1985, and 1,132 new wells were reported as successful. Discoveries included seven oil pools, 20 gas pools, 11 deeper oil pools, six deeper gas pools, one deeper oil and gas pool, seven shallower oil pools, six shallower gas pools, and 102 extensions to existing producing areas.

Exploration in eastern Kentucky was again dominated by the search for and development of natural gas reserves. In Harlan County, four wells have been completed in the Weir sand (Mississippian)

and Ohio Shale (Upper Devonian) at the Looney Creek Field; this is the first significant production for this county. In Johnson County, the discovery of gas in the Rome Formation (Cambrian) at a depth of 6,150 feet confirmed the existence of deep gas in eastern Kentucky. Other parts of eastern Kentucky with major activity include Clay, Whitley, Pike, and Leslie Counties.

Central Kentucky has not generally been considered a promising area for natural gas exploration. However, several gas discoveries and the development of a marketing system resulted in reported sales of 439,388 mcf of gas in 1986. The amount of gas production in this area is expected to increase during the next few years. Conversely, the recent intense drilling activity for oil in the Cumberland Saddle area has abated.

Western Kentucky continued to be the dominant oil-producing area of the State. Four counties (Henderson, Union, Muhlenberg, and Hopkins) accounted for 36 percent of the total oil produced in 1986. The main drilling targets were Chesterian (Mississippian) sandstones and porous zones in Ste. Genevieve carbonates (Mississippian). Discoveries of both oil and natural gas were made in western Kentucky in 1986.

Crude oil production was 6,472,252 barrels, a 17 percent decrease from 1985. Natural gas production was 80,195,328 mcf, an increase of approximately 7 billion cubic feet from 1985.

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 225,000 well records. The Survey also maintains a Well Sample and Core Library with more than 15,500 sample sets and 1,200 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 source of stratigraphic and subsurface information in the State, the name of the section was officially changed from the Oil and Gas Section to the Petroleum and Stratigraphy Section in 1986.

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 75,000 wells entered on the computer.

In addition to providing a public service, the Petroleum and Stratigraphy 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. Literature on this part of the section has been collected and reviewed, and a list of all geophysical logs that penetrated the Salem-Warsaw Formations is currently being compiled. This list is complete for logs run from 1980 to date, but only partially complete for logs run prior to 1980.

The Salem-Warsaw produces in a number of scattered areas, and two pools have been described in the literature. Overlying the Salem-Warsaw is the "X" dolomite marker of Indiana, which can be correlated throughout Daviess and Ohio Counties in Kentucky.

Samples, cores, and geophysical logs are being used to delineate the top of the Meramecian Series; when the delineation is completed, cross sections will be constructed covering the top of the Meramecian Series through the Salem-Warsaw Formations. The cross sections will aid the petroleum industry in establishing deeper pay zones.



## **OIL AND GAS WELL RECORD LIBRARY**

**FRANKIE, Wayne T.**

The 1960 Oil and Gas Conservation Act designated the Kentucky Geological Survey as the official repository of geologic records of wells drilled for oil and gas. Prior to 1960, well records were collected from cooperative operators and from scouting services. The files were, and still are, incomplete for years prior to 1960.

Despite problems in the early years, the files are extensive, consisting of 367 file-cabinet drawers of information. Expansion in the 1986-87 fiscal year amounted to approximately 2,500 new wells. The records are filed first by county and then by Carter coordinate location. Well data are filed in envelopes, and all information on each well is combined in the envelope. It is estimated that information on as many as 225,000 wells will be found in the files.

The library is located in the basement of Breckinridge Hall, and is open from 8:00 a.m. until 4:00 p.m. each working day. Students, industry representatives, government agencies, and the general public make extensive use of the files. Last year Oil and Gas Well Record Library personnel assisted 1,151 visitors, answered 699 telephone requests, and supplied 25,000 copies of well records. Copies are limited to 50 wells per person by telephone or written request in a 30-day period. Visitors to the library may have copies made of up to 150 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 for logs is provided to interested parties.

## **RESERVOIR CHARACTERISTICS AND DEPOSITIONAL ENVIRONMENTS OF THE LOWER ORDOVICIAN KNOX GROUP, CENTRAL KENTUCKY**

**GOODING, Patrick J.**

In the eastern United States the predominantly carbonate rocks of the Cambrian-Ordovician Knox Group, which were deposited on a broad, gently sloping continental shelf in shallow hypersaline waters, attain thicknesses in excess of 3,000 feet. A major unconformity occurs at the top of this group. This regional unconformity developed when the Sauk Sea retreated at the close of Early Ordovician time. In south-central Kentucky the paleotopographic surface is characterized by extensive paleokarst developed on the upper Mascot Dolomite. The study area is located on the crest of the

Cincinnati Arch, a major structural feature that separates the Appalachian Basin to the east from the Illinois Basin to the west.

Oil and gas are being produced from Cambrian-Ordovician rocks throughout the United States, and in south-central Kentucky this is no exception. In the study area the Knox is of considerable economic importance. Major hydrocarbon entrapment occurs at or near the unconformity at the top of the Knox. Approximately 3,500 oil and gas wells and mineral exploration holes have penetrated the upper Knox Group in south-central Kentucky. Over 32 million barrels of oil have been recovered from 11 relatively shallow stratigraphic zones in 120 oil pools. These stratigraphic zones are generally encountered at depths of less than 2,000 feet from the surface. A substantial amount of oil has been recovered from pools that produce exclusively from the Knox. Brecciated and fractured zones at the top of the Knox have also served as the host for sulfide mineralization, and these deposits may contain significant amounts of lead, zinc, and barium resources for future exploitation.

The two primary objectives of this investigation are to determine, from geochemical analysis, the most likely source or sources of the hydrocarbons found in the Knox, and to determine the depositional and diagenetic history of the Lower Ordovician Mascot Dolomite, which is the uppermost formation of the Knox Group.

Methods of investigation to be used in this study include geochemical analysis of sample cuttings and cores, detailed oil characterization and classification of oil samples collected from producing wells, megascopic and petrographic examination of cores, preparation of structure, isopach, and facies maps, and identification and discussion of structures that may have influenced the migration of fluid hydrocarbons from the source to the trap.

To date, over 450 oil wells have been visited in 28 counties, and 160 fresh oil samples have been collected from the well head. These oils are being produced from 16 different stratigraphic zones. Sixty-three oils were geochemically analyzed; over 450 rock cuttings have also been analyzed. Twelve cores (over 14,000 feet) were slabbled in half in order to study stratigraphic marker beds. A map at a scale of 1:125,000, showing all producing wells in the study area, has been prepared. Over 400 Knox cores have been collected, and 105 thin sections prepared.



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

**MOODY, Jack R., KEMPER, Julie R., JOHNSTON, Ian M., ELKIN, Robert R., and FRANKIE, Wayne T.**

The Kentucky Geological Survey initiated a 2-year cost-sharing project with the Gas Research Institute (GRI) in July 1984 to study hydrocarbon production from the Devonian shale in the Big Sandy Gas Field. The contract has been extended to include 20 counties either partially within, contiguous to, or between the Big Sandy and Ashland Gas Fields.

The original project was completed in March 1987 with the publication of "Geologic and Hydrocarbon Report of Pike County," the fifth and final report. A data base containing information on 5,894 Devonian-shale wells in the original five-county area has been entered into the KGS computer. Data for each of the reports (one report for each county) were obtained from the KGS oil and gas well-record files, company files, and existing literature. Gamma-ray logs were used to determine the individual stratigraphic units between the Mississippian Sunbury Shale and the Devonian Rhinestreet Shale; information from the gamma-ray logs was used to construct isopach and structure maps and cross sections. Temperature logs were used to determine locations of gas-producing intervals, and initial open-flow information was used to construct an isopotential map.

The following conclusions were drawn from the study of the original five-county area: (1) the most productive interval is the Lower Huron Member of the Ohio Shale, (2) the best method to stimulate the interval is hydraulic fracturing, (3) the best production appears to be in areas with a high degree of natural fracturing, and (4) initial open flow generally correlates positively with high production.

Research in the extended area started in the third quarter of 1986. The first report, containing information on Bell, Harlan, Knox, and Whitley Counties, was completed in the fourth quarter of 1986. Information on 977 Devonian-shale wells was entered into the computer, and essentially the same information was distributed as for the original reports.

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

**NOGER, Martin C.**

The American Association of Petroleum Geologists (AAPG) has initiated a project to compile a five-volume Petroleum Basin Series that will provide data for use in analyzing potentially similar basins in other areas. The series is intended to give a broad overview of significant fundamental basin types, their evolution, their oil and gas plays, and the resulting distribution and size of oil and gas fields. Each fundamental basin type is to be analyzed to determine the significant factors that control the plays, resulting fields, and future potential.

The Illinois Basin was selected by AAPG as the type basin for the Interior Cratonic Sag Basin volume. The report for the Illinois Basin will include an introduction and chapters on regional setting, stratigraphy, structure, tectonics, basin evolution, and oil and gas systems.

Dr. Morris W. Leighton, Chief of the Illinois State Geological Survey, is the editor of this volume. The Kentucky and Indiana Surveys are also participating in the project, and Martin C. Noger was chosen coordinator for Kentucky.

Various KGS personnel have contributed geologic data and compiled maps for the different chapters of the manuscript. The report is being compiled by the Illinois State Geological Survey.

## **TAR-SAND DEPOSITS OF WESTERN KENTUCKY**

**NOGER, Martin C.**

In 1981, the Survey initiated a project to inventory and evaluate the oil resource potential of asphaltic sandstones in the subsurface of western Kentucky. In 1982, the project was combined with the Interstate Oil Compact Commission (IOCC) project to catalog and evaluate the tar-sand resource potential of the United States. In 1984 and 1985 IOCC published reports of these investigations; the in-place oil resource potential of subsurface and surface tar-sand deposits in western Kentucky was calculated to be 3.4 billion barrels.

The Survey is continuing to monitor drilling and other developmental activities in tar-sand areas. Data bases are revised annually in order to further delineate and evaluate the deposits when economic conditions are favorable for commercial development.

In 1986-87, samples were collected from surface exposures of the Caseyville Sandstone (Pennsylvanian) and Big Clifty Sandstone Member of the Golconda Formation (Mississippian) for analysis by the U.S. Geological Survey for clay and metal content and reservoir characteristics. Parts of the samples were retained by the KGS for hydrocarbon source-rock analyses.

## **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 75,000 well completions have been encoded, entered, and proofread to date. By the end of 1987, records for approximately 82,000 wells should be available.

Custom printouts based on user specifications can be made on request. Well-location base maps are available as overlays to the U.S. Geological Survey 1:24,000-scale 7.5-minute topographic quadrangle maps. Machine-readable data selected by county or topographic quadrangle are available on 5.25-inch flexible diskettes.

The data base is complete with all locations for which information is on file at the Survey for Adair, Anderson, Ballard, Bell, Bourbon, Boyd, Boyle, Breathitt, Caldwell, Calloway, Carlisle, Casey, Clark, Elliott, Fayette, Fleming, Floyd, Fulton, Garrard, Grant, Graves, Grayson, Greenup, Harlan, Hickman, Jessamine, Knott, Leslie, Letcher, Lewis, Logan, Madison, Magoffin, Martin, McCracken, Mercer, Montgomery, Nicholas, Pike, Pulaski, Rowan, Todd, Washington, Whitley, and Woodford Counties. In addition, work has been completed on 42 additional topographic quadrangles, and work has been started on approximately 50 quadrangles. For those areas that have not been completed, data are available for wells in the following categories: all wells reported complete since January 1, 1981; all locations for which a permit has been issued since January 1, 1984; all pre-Trenton wells; all Devonian and deeper wells of western Kentucky; and all Class II (injection and disposal) wells reported active in 1979 and completed since.

A file of data for each pool, containing pool name, discovery and pay information, and historical data, is being accumulated. A file of monthly production data by county is also being compiled.

## **THE CAMBRIAN SYSTEM OF KENTUCKY** **WALKER, Frank H.**

This project was commenced to answer the demand for information relating to deep drilling in Kentucky. The oil and gas well record files and the literature were searched for data, and as wells were identified, the locations were added to a 1:500,000-scale map. At the same time the basic well information was added to a master listing.

The creation, expansion, and refinement of the computerized oil and gas well record data base now permits a rapid retrieval of desirable information on wells that have penetrated the Cambrian and other systems. This ability made the above map and listing obsolete. The project was terminated December 31, 1986, with the entry into the data base of all Cambrian and deeper tests.

## **OIL AND GAS WELL RECORDS PRESERVATION PROJECT** **WALKER, Frank H.**

The oil and gas well record files of the Kentucky Geological Survey are used extensively by well operators, geologists, engineers, attorneys, representatives of local, State, and Federal government agencies, the general public, and staff members. As a result, the paper files are deteriorating rapidly, and it has become evident that the files must be made available by some alternative method. After several media were examined extensively, the decision was made to store the records electronically.

The first of the equipment needed for electronic storage is now in place, and operators have been properly trained. The maximum size record that can be handled with the present equipment is 8 1/2 X 14 inches, and it is estimated that 50 percent of the files is made up of paper this size or smaller. A unit that will accept the larger geophysical surveys has been ordered, and will allow more than 95 percent of the total record file to be stored.

To access one record from an estimated 1 million records, an extremely detailed indexing program is necessary. An indexing pro-



gram has been written and is now usable, but requires additional refinements, which are being prepared.

Storage has commenced, on a limited basis, and the volume of records processed depends on available personnel. Personnel assigned to the program have prepared records for 7,000 wells for electronic storage since July 1, 1986.

Paper records will continue to be used until funds are available to purchase the necessary equipment for public use. At that time the paper records will be placed in proper storage.

## OIL AND GAS BASE MAPS

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

Oil and gas well-location maps are a basic exploration tool in the search for hydrocarbons. The preparation of maps is time consuming and requires consistent effort to keep the information correct. The advent of the program in which incoming well information is entered into the Kentucky Geological Survey data base allows continual upgrading of maps of this type. The acquisition of a plotter and the development of proper software have allowed the printing on order of up-to-date maps. At the present time the Survey is using a well-location map system based entirely on the 1:24,000-scale (7.5 minute) topographic map series.

The maps are plotted on good-quality tracing paper and may be used as overlays for topographic or 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 production or open flow.

Maps are available for each quadrangle, but some areas have been more completely mapped than others. At present, approximately 75,000 wells are in the computer data base, and an average of 8,000 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 is withdrawn from distribution, since the county maps are severely out of date, and up-to-date quadrangle maps are now available. The only county map still available is for Barren.

Maps are complete for the quadrangle in 45 counties, and for 42 additional quadrangles. In addition, work has been started on approximately 50 quadrangles. For those quadrangles that have not been completed, the following well locations are available for plotting: all wells reported complete since January 1, 1981; all locations for which a permit has been issued since January 1, 1984; all pre-Trenton wells; all Devonian and deeper wells of western Kentucky; and all Class II (injection and disposal) wells reported active in 1979 and completed since.

## 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, there is the need to dispose of the large quantities of waste water our system generates.

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 in past years, several projects are carried out in cooperation with the U.S. Geological Survey Water Resources Division (see **Cooperative Programs, Water Resources**).

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, and serving on a technical advisory council concerning the classification, use, and protection of ground water in the State. The section head serves on the Water Well Drillers' Certification Board, which is responsible for developing regulation and construction standards for that industry. A section member also serves

on an advisory committee concerning the on-site disposal of sewage for the Cabinet for Human Resources.

## **DEVELOPMENT OF A GROUND-WATER DATA BASE FOR KENTUCKY**

**CURRENS, James C.**

The Kentucky Ground-Water Advisory Council, in a draft Ground-Water Protection Strategy released in February 1987, recognized the need for computerized management of ground-water data for Kentucky. The Council recommended the establishment of a ground-water data repository at the Kentucky Geological Survey. This data base would support aquifer, potentiometric-surface, and water-quality mapping, and would significantly aid in answering inquiries from industrial and private water users.

The development of the Kentucky Aquifer-Research Database (KARD) was begun at KGS in the spring of 1987. It will be designed to take advantage of current and past data-collection efforts, including water-well drilling logs, inspection reports for public and private wells, data generated from mining permits, and other sources. At the same time the data base will remain flexible to accommodate future data-management needs.

Accomplishments to date include an inventory of existing hydrogeologic data on file with various state agencies, in conjunction with the Kentucky Division of Water, Ground-Water Section; development of a conceptual design for the data base and for data acquisition; and the construction of a set of common data codes in order to compile various agencies' data into a common data file. Work continues on developing the central nodes of the data base and the peripheral nodes used for data acquisition. The pace of data entry will accelerate as various components of the data base are phased into operation.

## **HYDROGEOLOGIC INVESTIGATION OF STRESS-RELIEF FRACTURES OF A VALLEY IN THE APPALACHIAN PLATEAUS**

**DINGER, James S., and KIPP, James A.**

Between 1980 and 1983, the Kentucky Geological Survey conducted a hydrogeologic study on the occurrence and movement of ground water in the Eastern Kentucky Coal Field. Site-specific core drilling and down-hole packer testing in Knott County indicated that

shallow but widespread fractures exist in a sequence of rocks characterized by sandstone and coal.

The present project is a cooperative study with the U.S. Geological Survey, sponsored by the U.S. Office of Surface Mining. Its major objective is to examine ground-water movement in a claystone-siltstone-coal sequence in the coal field.

Examination of 1,700 feet of core from nine drill holes, down-hole packer tests, and dye traces, and the monitoring of multiple piezometers at a site in Pike County have indicated the presence of a shallow fracture system ascribed to stress relief, which produces rapid ground-water movement down the valley side walls and along the ridge.

Additional funds are being sought to continue dye-tracing experiments and to monitor ground-water-level fluctuations in the coming year.

## **HYDROGEOLOGY OF BRINE OCCURRENCE IN THE KENTUCKY RIVER BASIN**

**KIPP, James A.**

The interaction of surface- and ground-water resources and the impacts of petroleum production are being evaluated in the area between the Kentucky and Red Rivers in this Kentucky Geological Survey-U.S. Geological Survey cooperative study. Approximately 100 water samples were obtained and analyzed during a reconnaissance in 1985. Most of these samples were from streams, but domestic wells and springs were also tested. The results of this sampling were used to select several stream basins within the study area for further investigation.

Basins representing various degrees of influence by produced waters were studied during 1986. Sampling sites were visited approximately every 2 weeks from May to November, and less frequently during the winter months. Samples were analyzed for temperature, pH, specific conductance, and chloride. Stream discharge was also measured at the time of sampling. Water samples were collected during low-flow conditions in August 1986 for major cation, anion, and selected trace-element analysis. Samples from 12 springs in the region were also analyzed for the same parameters.

The Furnace Fork basin in Estill and Powell Counties was selected for a detailed study including shallow ground-water quality, ground-water/surface-water interaction, and brine-transport mechanisms. A gaging station with automatic recording of stage, water



temperature, and specific conductance was installed in the basin. Two other local basins, Cat Creek and Big Sinking Creek, were similarly equipped. Water-quality sampling is being coordinated with the U.S. Geological Survey Kentucky River NAWQA (National Water Quality Assessment) study. The resulting data will be used to develop a conceptual model of brine transport from tributary basins to the Kentucky River.

## **PRODUCTION OF FRESH WATER FROM THE KNOX GROUP IN CENTRAL KENTUCKY**

**KIPP, James A.**

Most domestic wells in the Blue Grass area of Kentucky produce water from shallow solution openings along joints and bedding planes in the Ordovician carbonate rocks. In many locations it is difficult to obtain reliable supplies because of insufficient porosity and permeability. Where significant water-bearing conduits are present, the quantity of water available may be adequate, but the potential for contamination is high. Polluted recharge can directly enter the solution cavities through sinkholes and swallets, and rapidly travel through the conduit system. As a result, the Water Resources Section frequently receives inquiries concerning the availability of fresh water in deeper formations that would be unaffected by surface recharge. Interests include sources of domestic drinking water, water for general farmstead use and livestock watering, and sources capable of supplying sufficient quantities of water for irrigation.

A few deep wells (800 to 1,000 feet) produce fresh water in Jessamine, Fayette, and Bourbon Counties. These wells are completed in the top of the Cambrian-Ordovician Knox Group. The primary objectives of this investigation are (1) to identify areas where the Knox contains potable water, (2) to determine aquifer characteristics so that the quantity of water available from the Knox can be established, and (3) to identify the flow regime, including areas of recharge and discharge, and direction and rate of movement.

The initial phase of the project consisted of compiling data from known Knox wells. From the available information it appears that fresh-water wells are limited to an area near the West Hickman Creek-Bryan Station Fault Zone. In other areas water from the Knox is generally too mineralized for most uses. Additional work is needed to determine the extent to which this fault zone controls the distribution of fresh water in the Knox.

Two new wells were completed in Bourbon County during 1986, and water samples from them were obtained and analyzed. Geophysical logs were also run in each well. As additional data become available, they are added to the project file. Individuals requesting information on deep aquifers in central Kentucky can then be informed on the possibility of obtaining fresh water from the top of the Knox Group.

## **BARIUM CONCENTRATIONS IN GROUND WATER IN EASTERN KENTUCKY**

**WUNSCH, David R.**

Since 1984 the Kentucky Geological Survey has been involved in research concerning the cause and occurrence in eastern Kentucky of dissolved barium concentrations above the U.S. EPA suggested drinking-water standard of 1.0 mg/l in ground water. Complete chemical analysis of 63 water samples drawn from the Buckhorn, Chavies, and Salyersville, Kentucky, areas has shown that 20 percent of the water samples had barium concentrations in excess of 1.0 mg/l.

A monitoring well was installed in each of the three villages in the study area for stratigraphic and hydrogeologic control. The three water-producing zones in the well at Buckhorn varied greatly in chemical character. Whole-rock analysis for barium from cores drilled adjacent to the monitoring wells indicated barium concentrations in the various rock types and coal varied from less than 50 parts per million in sandstones, up to 1,000 parts per million in shales.

Stable Isotope Ratio Analysis (SIRA) indicated a high degree of fractionation between  $^{34}\text{S}$  and  $^{32}\text{S}$  values, suggesting that sulfur-reducing bacteria may be present in the ground-water system. Water samples analyzed by the U.S. Forestry Service for sulfur-reducing bacteria confirmed the presence of these bacteria in the Buckhorn and Chavies areas. These data suggest that the consumption of sulfate by sulfur-reducing bacteria creates ground waters that are undersaturated with respect to barite ( $\text{BaSO}_4$ ), thus allowing high concentrations of barium in solution. High correlations with barium and sodium, and with chloride and specific conductance, suggest brines as a probable source of the barium.

Although most water softeners will remove excess barium from water, a thorough disinfection of newly installed and existing wells may greatly reduce the incidence of high barium in the ground

waters of eastern Kentucky by controlling the activity of sulfur-reducing bacteria.

## Other Research

### SELECTED GEOLOGIC FEATURES ALONG AND ADJACENT TO INTERSTATE HIGHWAYS AND PARKWAYS IN KENTUCKY

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

Numerous inquiries concerning the availability of publications related to geologic features along Kentucky highways have been received at the Survey. The construction of Interstate highways and parkways in Kentucky has exposed numerous new, interesting geologic features. Many prominent geologic structures are also exposed short distances from the highways and parkways, and some State and National parks have been built in the vicinity of some of these geologic phenomena. Although the Survey has publications covering some of the parks and professional excursions along parts of some of Kentucky's highways, manuscripts that delineate generalized continuous profiles showing geologic units and interesting features are not available. The objectives of this project are to prepare illustrations and generalized descriptions of prominent geologic features that will inform people traveling or planning vacations in Kentucky of interesting localities to visit or observe. The data will also provide background information for field studies by academic institutions and excursions by professional organizations.

Strip maps showing geologic units and interesting geologic features along Interstate Highway 75 have been completed. A publication format is being developed. Reports for other Interstate highways and State parkways will be compiled when the Interstate Highway 75 report is completed.

### CONTERMINOUS UNITED STATES MINERAL ASSESSMENT PROGRAM (CUSMAP): PADUCAH 2-DEGREE SHEET

**NOGER, Martin C.**

The CUSMAP program, initiated by the U.S. Geological Survey, is designed to assess the mineral-resource potential of 1:250,000-scale quadrangles. In 1976 the U.S. Geological Survey, in cooperation with the Missouri Division of Geology and Land Survey, started a CUSMAP program to determine the mineral-

resource potential of several quadrangles in Missouri. One of the completed quadrangles is the Rolla Quadrangle. The appraisal indicates that several areas in the quadrangle have a very high potential for undiscovered mineral deposits of major importance.

The Paducah Quadrangle, which joins the Rolla Quadrangle on the east, is covered in part by Illinois (56 percent), Missouri (24 percent), Kentucky (19 percent), and Indiana (1 percent). A CUSMAP project for the Paducah Quadrangle is a logical extension of the Rolla Quadrangle project, and will evaluate the significant mineralization in the Paducah Quadrangle area. The Illinois State Geological Survey, the Missouri Division of Geology and Land Survey, the Kentucky Geological Survey, and the Indiana Geological Survey officially began the Paducah CUSMAP program on October 1, 1986; it is scheduled to be completed by September 30, 1990.

The first phase of the program will be the compilation of published data and data in the files of the participating agencies. If available, information from mining companies, oil and gas producers, and coal companies will be used as well.

Various geologic, geophysical, and geochemical maps, and stratigraphic and structural cross sections will be constructed. Studies of sedimentary petrology, fluid inclusions, organic geochemistry, and light stable isotopes of carbonate rocks will be made, primarily by the U.S. and Illinois State Geological Surveys. These data will be combined to show the various geologic environments known or inferred to exist in the quadrangle.

Models will be developed for the various geologic parameters, geometric controls, and surface manifestations of all types of mineral deposits that may be expected to occur in the known or inferred geologic environments.

The results of the modelling studies will be applied to the results of the geologic studies in order to evaluate the mineral-resource potential of the quadrangle and to identify areas favorable for new exploration.

Publications issued by the participating agencies will show the geology of the Paducah Quadrangle; structure, isopach, and lithofacies maps of selected formations or stratigraphic intervals; geochemical-elemental and composite-elemental maps of the region; mineral-deposit probabilities; compilations of magnetic and gravity data; and site-specific geochemical information based on single hole or closely spaced drill-hole data.



An organizational meeting of the participants was held on April 16, 1986, at Carbondale, Illinois. Various personnel from the different agencies will contribute to different sections of the report.

## **HANDBOOK OF KENTUCKY STRATIGRAPHY**

**NOGER, Martin C., and DEVER, Garland R., Jr.**

Knowledge of the stratigraphy of Kentucky has been of great value in the exploration for and development of mineral resources. However, rules governing stratigraphic nomenclature have changed since many of the geologic units in Kentucky were classified. In many published reports, nomenclature for geologic units of the same rank includes both biostratigraphic and rock stratigraphic units. The objective of this project is to show the evolution of stratigraphic classification in Kentucky and provide a stable stratigraphic nomenclature.

Literature pertaining to the development of stratigraphic nomenclature in Kentucky will be reviewed. Published sample descriptions, cores, and geophysical logs will be studied to determine the thickness and distribution of geologic units. Stratigraphic studies being conducted by the Survey will be used to compile the report.

Data for compiling the Precambrian section of the report are being assembled. A report will be published by the Kentucky Geological Survey.

## **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, and units shown on the published sheets covering central and eastern Kentucky have been compiled. The 1:500,000-scale map will be published in color after completion of geologic compilation and cartographic work.

# **COMPUTER SERVICES**

The primary responsibility of the Computer Services Section (CSS) is to assist the KGS staff in using computers to provide public services. CSS acquires or develops and maintains software that enables users to store and manipulate data for reports, maps, charts, and other products for use by industry, government, and the private sector.

Almost 60 percent of the professional staff uses the computer in their daily activities. Requests for various software applications by the staff are increasing because of the greater variety of work being done on the computer: more data analysis, modeling, report writing, and sharing of information with users on other systems. Demands for additional capabilities and resources are also increasing, thus keeping CSS staff busy answering the many day-to-day requests for services.

The proper use of the computer equipment and software have greatly increased efficiency and production by the staff. Time requirements for tedious data searches and paper work have been dramatically reduced, and the general public benefits through better, more accurate, and more timely reports. In addition, use of the computer by KGS administration helps manage the various and diverse projects undertaken by the Survey.

During the past year the Computer Services Section has been investigating various methods to upgrade its mini-computer. The advent of the new building is the best time to implement such a change, and the networking capabilities of the building will give the Survey greater flexibility in providing computing services. We will be able to easily integrate all the laboratory equipment, specialized work stations, and peripheral equipment with the mini-computer. This networking will allow users, from any location within the building, to access any of this equipment. In addition, the network within the building will be connected to the campus network. This connection will give users access to campus-wide and world-wide computing resources.

The Computer Services Section also investigated and installed an image-capturing system to aid in the records preservation project (see **Petroleum and Stratigraphy Section**). This system affords a method to record, store, manipulate, and print images of the many types of official documents now kept as paper copies by the Survey. The image-scanning system "captures" the original documents, sometimes with better clarity than the original, and stores them elec-

tronically. These images will eventually be stored on optical disks and can be viewed at terminal screens or printed by laser technology. Our goal is to provide the general public access to terminals where they can interactively request documents and obtain unlimited copies.

## **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 State. This program, which has been active since Kentucky became the first major state to be entirely mapped topographically at a scale of 1:24,000 more than 30 years ago, is designed to maintain revised and up-to-date maps for all areas of the Commonwealth.

In July 1986, the recently established State Mapping Advisory Committee (SMAC) met for the first time. Presentations concerning the current status of the topographic-mapping revision program were made to the group, and there was a discussion of mapping requirements and specific problems that had been encountered. Committee members were asked to submit a list of quadrangles that were in immediate need of revision. From these responses, a ranked list was compiled and submitted to the USGS to be used in selecting areas for future revision. The next SMAC meeting is planned for the fall of 1987.

Kentucky topographic maps are currently undergoing rigorous testing by the U.S. Geological Survey for horizontal accuracy. After the results of this testing program become available, decisions can be made concerning the most appropriate course for future topographic mapping activities in Kentucky. Although the costs of map revision have been rising dramatically over the past two decades, new technologies that are being developed promise to improve the quality of new maps, and possibly lower some of the costs.

Six 7.5-minute quadrangle maps were revised during the 1986-87 fiscal year (Dexter, Hardin, Hickory, Mont, Murray, and Wheelersburg Quadrangles). All of these maps were photorevisions on which changes are shown in a purple overprint on the existing map. Seven

new 1:100,000-scale maps were received from the U.S. Geological Survey during the year (Campbellsville, Falmouth, Harrodsburg, Louisville, Maysville, Murray, and Tompkinsville). All of these maps were planimetric editions; topographic editions will be published later.

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

### **Water Resources**

Water-related cooperative programs with the U.S. Geological Survey Water Resources Division 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.

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 \$400,000. Following are brief descriptions



of individual projects active or in the publication process during the 1986 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. *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 completed, and a report is presently being reviewed for publication.

4. *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 1987.

5. *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. This research is being conducted in conjunction with the U.S. Geological Survey's National Water Quality Assessment (NAWQA) program on the Kentucky River basin. This brine project is scheduled for completion in 1991.

## PUBLICATIONS

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

Publications of the Kentucky Geological Survey are made available to the public at a nominal cost and have received widespread distribution. Maps and reports are available for purchase from the Publication Sales Office, which is located in the basement of Breckinridge Hall on the University of Kentucky campus. Total sales for the 1986-87 fiscal year amounted to approximately \$100,000.

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. Copies of most U.S. Geological Survey open-file reports dealing with Kentucky geology are also maintained. Some of the material will eventually be published but has been placed on open file in order to

make the data available for public use prior to publication. Open-file reports are available for inspection at Survey offices in Breckinridge Hall on the University of Kentucky campus during regular office hours. Copies of materials that can be reproduced are available for purchase.

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

The following publications were issued by the Kentucky Geological Survey during the 1986-87 fiscal year.

## **Guidebook**

**Stratigraphy, Structure, and Mineral Deposits of the Western Kentucky Fluorspar District and the Stevens Hill Roadcut (Guidebook and Roadlog for Geological Society of Kentucky 1986 Field Conference), by Robert D. Trace, F. Boyce Moodie, and David A. Williams, 11 p.**

## **Information Circular**

**Information Circular 19. Analysis of Coal Samples from the Hazard District, Kentucky: Breathitt, Knott, Leslie, and Perry Counties, and Parts of Letcher and Harlan Counties, by James C. Currens, Linda Jean Bragg, and James C. Hower, 381 p.**

Chemical and petrographic data are presented for 132 samples of coal collected in the Hazard District, eastern Kentucky. These data include sample-site locations, sampling conditions, stratigraphic position, megascopic description of the coal, air-drying loss, proximate and ultimate analyses, Btu content, forms of sulfur, initial deformation temperature, softening temperature, fluid temperature, free-swelling index, concentration of major, minor, and trace elements, and petrographic analyses.

**Information Circular 20. Analysis of Coal Samples from the Big Sandy District, Kentucky: Floyd, Johnson, Martin, and Pike Counties, by James C. Currens, Linda Jean Bragg, and James C. Hower, 421 p.**

Chemical and petrographic data are presented for 146 samples of coal collected in the Big Sandy District, eastern Kentucky. These data include sample-site locations, sampling conditions, stratigraphic position, megascopic description of the coal, air-drying loss, proximate and ultimate analyses, Btu content, forms of sulfur, initial deformation temperature, softening temperature, fluid temperature, free-swelling index, concentration of major, minor, and trace elements, and petrographic analyses.

**Information Circular 21. Analysis of Coal Samples from the Southwestern District, Kentucky (Clay, Jackson, Knox, Laurel, Lee, McCreary, Owsley, Whitley, and Parts of Bell, Clinton, Estill, Madison, Pulaski, Rockcastle, and Wayne Counties), by James C. Currens, Linda Jean Bragg, and James C. Hower, 338 p.**

Chemical and petrographic data are presented for 119 samples of coal collected in the Southwestern District, eastern Kentucky. These data include sample-site locations, sampling conditions, stratigraphic position, megascopic description of the coal, air-drying loss, proximate and ultimate analyses, Btu content, forms of sulfur, initial deformation temperature, softening temperature, fluid temperature, free-swelling index, concentration of major- and minor-oxides and trace elements, and petrographic analyses.

**Information Circular 22. Analysis of Coal Samples from the Upper Cumberland District, Kentucky: Parts of Bell, Harlan, Letcher, and Whitley Counties, by James C. Currens, Linda Jean Bragg, and James C. Hower, 178 p.**

Chemical and petrographic data are presented for 57 samples of coal collected in the Upper Cumberland District, eastern Kentucky. These data include sample-site locations, sampling conditions, stratigraphic position, megascopic description of the coal, air-drying loss, proximate and ultimate analyses, Btu content, forms of sulfur, initial deformation temperature, softening temperature, fluid temperature, free-swelling index, concentration of major- and minor-oxides and trace elements, and petrographic analyses.



**Information Circular 23. Analysis of Coal Samples from the Licking River District, Kentucky: Elliott, Magoffin, Morgan, and Wolfe Counties, and Parts of Menifee, Powell, and Rowan Counties, by James C. Currens, Linda Jean Bragg, and James C. Hower, 127 p.**

Chemical and petrographic data are presented for 41 samples of coal collected in the Licking River District, eastern Kentucky. These data include sample-site locations, sampling conditions, stratigraphic position, megascopic description of the coal, air-drying loss, proximate and ultimate analyses, Btu content, forms of sulfur, initial deformation temperature, softening temperatures, fluid temperature, free-swelling index, concentration of major- and minor-oxides and trace elements, and petrographic analyses.

**Information Circular 24. Oil and Gas Drilling Activity Summary for Kentucky, 1986, comp. by Brandon C. Nuttall, 365 p.**

## Reprints

**Reprint 23. The Mineral Industry of Kentucky, 1984, by Donald K. Harrison and Garland R. Dever, Jr., 12 p.**

The value of Kentucky's nonfuel mineral production in 1984 was nearly \$257 million, \$32.5 million more than that of 1983. Crushed stone was the leading nonfuel mineral produced, accounting for more than one-half of the State's total value. The State ranked second nationally in ball clay and primary aluminum production and fourth in synthetic graphite, expanded perlite, and lime output. Other nonfuel minerals produced, in order of descending value, included portland cement, construction sand and gravel, common and fire clays, masonry cement, zinc, and industrial sand. Mineral commodities processed or manufactured included ferroalloys, exfoliated vermiculite, pig iron, steel, iron and steel slag, and regenerator iron oxides. Nationally, Kentucky ranked 28th in the value of nonfuel minerals produced in 1984.

**Reprint 24. The Mineral Industry of Kentucky, 1985, by Donald K. Harrison and Garland R. Dever, Jr., 10 p.**

The value of Kentucky's nonfuel mineral production in 1985 was \$267.6 million, \$10.4 million more than that of 1984. Crushed stone

continued to be the leading nonfuel mineral produced and accounted for about 50 percent of the total value. The State ranked second in ball clay and lime production. Nationally, the State ranked twenty-seventh in the value of nonfuel minerals produced, up one place from that of 1984. Leading commodities produced in terms of value were crushed stone, lime, portland cement, and construction sand and gravel. Other nonfuel minerals produced included ball, common, and fire clay, industrial sand, masonry cement, and zinc. Commodities processed or manufactured included aluminum, ferroalloys, synthetic graphite, pig iron, steel, iron and steel slag, expanded perlite, recovered sulfur, and exfoliated vermiculite.

## Miscellaneous

**Annual Report, 1985-1986, by Kentucky Geological Survey, 66 p.**

**Kentucky Geological Survey: A Plan for the Future, by Kentucky Geological Survey, 83 p.**

This 5-year plan includes not only projects that are currently active or have already been approved, but also projects for which a definite need has been demonstrated and that could be accomplished within the next 5 years if sufficient funds to obtain personnel and facilities become available. The first part of the 5-year plan contains a discussion of the Kentucky Geological Survey's public service activities. This section is followed by research projects and activities, which are arranged according to the organizational framework of the Survey. Most sections of the report list individual projects with discussions of background, goals, implementation, and expected results. Charts showing the time framework for implementation of projects are included at the end of each section.

## In Press or Editing Completed

Information Circular 25. Directory of Industrial and Metallic Mineral Producers in Kentucky, 1984-1985, by Eugene J. Amaral and Garland R. Dever, Jr.

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.

Special Publication 13. Proceedings of the Technical Sessions, Kentucky Oil and Gas Association Forty-Fifth, Forty-Sixth, and Forty-Seventh Annual Meetings, ed. by Margaret Luther Smath.

Teaching and Field Trip Guide to Alluvial Processes and Sedimentation of the Mississippi River, Fulton County, Kentucky, and Lake County, Tennessee (Guidebook for 1984 Annual Field Conference of the Geological Society of Kentucky), by Paul Edwin Potter, Wayne A. Pryor, Lawson M. Smith, and David Rich.

## Papers By Staff Members in Outside Publications

**Anderson, W. H., 1986**, Investigation of the Mascot Dolomite (Knox Group) relating to zinc and petroleum resources in south-central Kentucky [abs.]: Society of Economic Paleontologists and Mineralogists Annual Midyear Meeting Abstracts, v. 3, p. 2.

**Anderson, W. H., contributor, 1986**, Kentucky, in Mugel, D. N., comp., Map showing availability of data for selected deep drill holes in the northern Midcontinent, U.S.A.: U.S. Geological Survey Miscellaneous Field Studies Map MF-1835-A, Scale 1:1,000,000.

**Anderson, W. H., contributor, 1987**, Kentucky, in Pratt, W. P., comp., Isopach and lithofacies map of the Sauk Sequence (excluding basal clastics) in the northern Midcontinent, U.S.A.: U.S. Geological Survey Miscellaneous Field Studies Map MF-1835-D, Scale 1:1,000,000.

**Cobb, J. C., Brant, R. A., and Chesnut, D. R., Jr., 1986**, Coal resources as a tool for basin analysis [abs.]: Geological Society of America Abstracts with Programs, v. 18, no. 6, p. 566.

**Dever, G. R., Jr., 1986**, Mississippian reactivation along the Irvine-Paint Creek Fault System in the Rome Trough, east-central Kentucky [abs.]: Society of Economic Paleontologists and Mineralogists Annual Midyear Meeting Abstracts, v. 3, p. 27-28.

**Dever, G. R., Jr., 1986**, Mississippian reactivation along the Irvine-Paint Creek Fault System in the Rome Trough, east-central Kentucky: Southeastern Geology, v. 27, no. 2, p. 95-105.

**Dever, G. R., Jr. [with Barron, L. S.], 1986**, Red River Gorge Geological Area (Daniel Boone National Forest) and Natural Bridge State Park, east-central Kentucky, in Neathery, T. L., ed., Centennial field guide: Geological Society of America, Southeastern Section, v. 6, p. 43-46.

**Dever, G. R., Jr. [with Harrison, D. K.], 1987**, The mineral industry of Kentucky: U.S. Bureau of Mines Minerals Yearbook 1985, v. 2, p. 237-246.

**Dever, G. R., Jr., and Moody, J. R. [with Robl, T. L., and Barron, L. S.], 1987**, Limestone resources for industry and market diversification: Two examples from Kentucky: Geological Society of America Abstracts with Programs, v. 19, no. 2, p. 82.

**Dinger, J. S. [with Rebmann, J. R.], 1986**, Ordinance for the control of urban development in sinkhole areas in the Blue Grass region, Lexington, Kentucky, in Environmental problems in karst terranes and their solutions: National Water Well Association, Bowling Green, Kentucky, October 28, 1986, p. 163-179.

**Frankie, W. T., Moody, J. R., Kemper, J. R., and Johnston, I. M., 1986**, Hydrocarbon production from the Devonian shale in Letcher, Knott, and Floyd Counties, eastern Kentucky: Proceedings, 1986 Eastern Oil Shale Symposium, Lexington, Kentucky, November 19-21, 1986, p. 301-302.

**Haney, D. C., 1986**, A national agenda for geological related coal research, symposium proceedings, in A national agenda for coal-quality research: U.S. Geological Survey Circular 979, p. 155-163.

**Johnston, I. M., and Nuttall, B. C., 1987**, Review of eastern Kentucky petroleum activities in 1986 [abs.]: 18th Appalachian Petroleum Geology Symposium, Morgantown, West Virginia, March 25, 1987, p. 32.

**Kemper, J. R., Frankie, W. T., Moody, J. R., and Johnston, I. M., 1986**, Hydrocarbon production from the Devonian shale in Letcher and Knott Counties, eastern Kentucky: Proceedings, Society of Petroleum Engineers Eastern Regional Conference, Columbus, Ohio, November 12-14, 1986, p. 151-158.

**Nuttall, B. C., 1986**, Annual review: Kentucky: Northeast Oil World, v. 7, no. 6, p. 10-11.

**Walker, F. H. [with Oltz, D. F., Carpenter, G. L., and Gilbert, R. C.], 1986**, Oil and gas developments in east-central states in 1985: American Association of Petroleum Geologists Bulletin, v. 70, no. 10, p. 1273-1279.



## TALKS BY STAFF MEMBERS TO PROFESSIONAL GROUPS

- Anderson, W. H., 1986**, Investigation of the Mascot Dolomite (Knox Group) relating to zinc and petroleum resources in south-central Kentucky: Presented at Kentucky Academy of Science—Geology Section annual meeting, Lexington, Kentucky, November 21, 1986.
- Anderson, W. H., 1986**, Investigation of the Mascot Dolomite (Knox Group) relating to zinc and petroleum resources in south-central Kentucky: Presented at Kentucky Oil and Gas Association annual meeting, Owensboro, Kentucky, June 13, 1986.
- Anderson, W. H., 1986**, Investigation of the Mascot Dolomite (Knox Group) relating to zinc and petroleum resources in south-central Kentucky: Presented at Society of Economic Paleontologists and Mineralogists Annual Midyear Meeting, Raleigh, North Carolina, September 27, 1987.
- Chesnut, D. R., Jr., 1986**, Geology of the Eastern Kentucky Coal Field: Poster presented at University of Kentucky Energy and Minerals Conference, Lexington, Kentucky, September 18-19, 1987.
- Cobb, J. C., 1986**, Coal resource and reserve estimates for Kentucky: Past research and future directions: Presented at University of Kentucky Energy and Minerals Conference, Lexington, Kentucky, September 18-19, 1987.
- Cobb, J. C., 1986**, The geology of Kentucky's coal resources: Presented at Indiana University Geology Seminar, October 1986.
- Cobb, J. C., 1987**, A national program for coal-resource assessments: The Kentucky pilot study: Presented at Association of American State Geologists-U.S. Geological Survey Eastern Cluster Meeting, March 1987.
- Cobb, J. C., Brant, R. A., and Chesnut, D. R., Jr., 1986**, Coal resources as a tool for basin analysis: Presented at Geological Society of America annual meeting, San Antonio, Texas, November 10-13, 1986.

- Cobb, J. C., Currens, J. C., and Sergeant, R. E., 1986**, Geology of Kentucky's coal resources: Poster presented at University of Kentucky Energy and Minerals Conference, Lexington, Kentucky, September 18-19, 1987.
- Cobb, J. C., and Greb, S. F., 1987**, Classification and geology of coal-mine roof rocks: Presented to University of Kentucky Department of Mining Engineering, May 1987.
- Cobb, J. C., Greb, S. F., and Davidson, O. B., 1987**, Coal geology in Kentucky: Presented at Union College Geology Seminar, Barbourville, Kentucky, March 1987.
- Cordiviola, S. J., 1986**, Computer use at the Kentucky Geological Survey: Poster presented at University of Kentucky Energy and Minerals Conference, Lexington, Kentucky, September 18-19, 1987.
- Cordiviola, S. J., 1986**, DATATRIEVE application design tutorial: Presented at Fall Digital Equipment Users Society U.S. Symposium, San Francisco, California, October 6-10, 1986.
- Cordiviola, S. J., 1987**, DATATRIEVE application design considerations and tutorial: Presented at Spring Digital Equipment Users Society U.S. Symposium, Nashville, Tennessee, April 27-May 1, 1987.
- Dever, G. R., Jr., 1986**, Limestone resources in Kentucky for industry: Poster presented at University of Kentucky Energy and Minerals Conference, Lexington, Kentucky, September 18-19, 1986.
- Dever, G. R., Jr., 1986**, Mississippian reactivation along the Irvine-Paint Creek Fault System in the Rome Trough, east-central Kentucky: Presented at Kentucky Academy of Science—Geology Section annual meeting, Lexington, Kentucky, November 21, 1986.
- Dever, G. R., Jr., 1986**, Mississippian reactivation along the Irvine-Paint Creek Fault System in the Rome Trough, east-central Kentucky: Presented at Society of Economic Paleontologists and Mineralogists Annual Midyear Meeting, Raleigh, North Carolina, September 27, 1986.
- Dever, G. R., Jr., and Moody, J. R. [with Robl, T. L., and Barron, L. S.], 1987**, Limestone resources for industry and market diversification: Two examples from Kentucky: Presented at Geological Society of America Southeastern Section Meeting, Norfolk, Virginia, March 27, 1987.
- Dinger, J. S., 1986**, Inventory and assessment of injection wells for enhanced recovery of petroleum, Kentucky: Presented at University of Kentucky Energy and Minerals Conference, Lexington, Kentucky, September 19, 1986.

- Dinger, J. S., 1987**, Federal and State legal issues concerning ground water: Presented at Eastern Kentucky Water Well Drillers' Workshop, Buckhorn, Kentucky, April 10, 1987.
- Dinger, J. S., 1987**, Federal and State legal issues concerning ground water: Presented at Western Kentucky Water Well Drillers' Workshop, Rough River, Kentucky, April 6, 1987.
- Dinger, J. S., 1987**, Ground water, the connecting link: Presented at American Institute of Professional Geologists, Kentucky Chapter, annual meeting, Lexington, Kentucky, April 25, 1987.
- Dinger, J. S. [with Rebmann, J. R.], 1986**, Ordinance for the control of urban development in sinkhole areas in the Blue Grass region, Lexington, Kentucky: Presented at Environmental Problems in Karst Terrains and Their Solutions: National Water Well Association Conference, Bowling Green, Kentucky, October 28, 1986.
- Dinger, J. S. [with Sendlein, L. V.], 1987**, Ground-water monitoring and sampling techniques: Presented at short course sponsored by the Kentucky Geological Survey and the University of Kentucky Institute for Mining and Minerals Research, Lexington, Kentucky, March 26-27, 1987.
- Dinger, J. S., and Cobb, J. C., 1987**, Coal geology, ground-water monitoring: Presented at short course sponsored by the Kentucky Geological Survey and the University of Kentucky Institute for Mining and Minerals Research, Lexington, Kentucky, March 4, 1987.
- Dinger, J. S., and Walker, F. H., 1987**, Enhanced recovery of petroleum and related problems in Kentucky: Presented at University of Kentucky Department of Geological Sciences Lectures Series, Lexington, Kentucky, January 29, 1987.
- Gooding, P. J., 1986**, Oil and gas possibilities in the Cambrian-Ordovician Knox Group in Kentucky: Poster presented at University of Kentucky Energy and Minerals Conference, Lexington, Kentucky, September 8, 1986.
- Gooding, P. J., and Daniel, R. R., 1986**, The Kentucky Geological Survey Well Sample and Core Library: Poster presented at University of Kentucky Energy and Minerals Conference, Lexington, Kentucky, September 8, 1986.
- Greb, S. F., 1987**, Geologic mapping for roof-fall prevention in Kentucky's underground mines: Presented to Southeast Community College, Harlan, Kentucky, March 1987.

- Greb, S. F., 1987**, Geology mapping in coal mines and the classification of roof falls: Presented at Coal Mining Seminar, Hazard Community College, Hazard, Kentucky, May 1987.
- Greb, S. F., and Cobb, J. C., 1986**, Geology of roof falls: Presented at Big Sandy-Elkhorn Coal Conference, April 9-10, 1987.
- Greb, S. F., and Cobb, J. C., 1986**, Geology of roof falls in eastern Kentucky: Poster presented at University of Kentucky Energy and Minerals Conference, Lexington, Kentucky, September 18-19, 1987.
- Greb, S. F., and Cobb, J. C., 1987**, The geology of coal-mine roof rocks: A training program for the coal industry: Presented at U.S. Department of Labor, Mine Safety and Health Administration, Mine Health and Safety Academy Seminar, Beckley, West Virginia, February 1987.
- Haney, D. C., 1986**, Kentucky Geological Survey—Past accomplishments, present activities, and future opportunities: Presented at University of Kentucky Energy and Minerals Conference, Lexington, Kentucky, September 18, 1987.
- Haney, D. C., 1986**, The relationship of synsedimentary tectonics to the evolution of the Kentucky Fault System: Presented at the Penrose Conference, Durango, Colorado, 1986.
- Johnston, I. M., 1987**, General background and recent exploration activities, Arabian Gulf/Arabian Peninsula area: Presented at Geological Society of Kentucky, Lexington Chapter, meeting, Lexington, Kentucky, February 12, 1986.
- Johnston, I. M., 1987**, Review of current and near-future activity—Kentucky Geological Survey: Presented at Kentucky Oil and Gas Association annual meeting, Lexington, Kentucky, June 11, 1987.
- Johnston, I. M., and Nuttall, B. C., 1987**, Review of eastern Kentucky petroleum activities in 1986: Presented at 18th Appalachian Petroleum Geology Symposium, Morgantown, West Virginia, March 25, 1987.
- Kiefer, J. D., 1986**, Devonian shale as a major energy resource in Kentucky: Presented at University of Kentucky Energy and Minerals Conference, Lexington, Kentucky, September 19, 1986.
- Kiefer, J. D., 1986**, Earthquake preparedness in the Midwest: Presented at Tri-State Disaster and Emergency Services Association Annual Meeting, Covington, Kentucky, September 20, 1986.
- Kiefer, J. D., 1987**, Naturally occurring indoor radon in Kentucky: Presented at Kentucky Health Association Annual Meeting, Louisville, Kentucky, April 1, 1987.



- Kiefer, J. D., 1987**, Potential geologic sources of naturally occurring radon in Kentucky: Presented at American Institute of Professional Geologists, Kentucky Chapter, annual meeting, April 25, 1987.
- Kiefer, J. D., 1987, convener of symposium and panel moderator**, New concepts in geology: University of Kentucky Department of Geological Sciences Symposium, Lexington, Kentucky, 1987.
- Kemper, J. R., Frankie, W. T., Moody, J. R., and Johnston, I. M., 1986**, Hydrocarbon production from the Devonian shale in Letcher and Knott Counties, eastern Kentucky: Presented at Society of Petroleum Engineers Eastern Regional Meeting, Columbus, Ohio, November 12-14, 1986.
- Kipp, J. A., 1987**, Effects of fracturing on shallow ground-water flow in eastern Kentucky: Presented at Kentucky Water Well Association, Eastern Section, Spring Meeting, Pine Mountain State Resort Park, Pineville, Kentucky, May 9, 1987.
- Kipp, J. A., and Dinger, J. S., 1986**, Stress-relief-fracture control of ground-water movement in the Eastern Kentucky Coal Field: Poster presented at University of Kentucky Energy and Minerals Conference, Lexington, Kentucky, September 18-19, 1986.
- McHaffie, P. H., 1986**, The Kentucky Cartographic Inventory: Presented at the Southeast Division of the Association of American Geographers annual meeting, Lexington, Kentucky, November 23, 1986.
- McHaffie, P. H., 1986**, Kentucky topographic mapping: An unmatched resource for energy and mineral development: Poster presented at University of Kentucky Energy and Minerals Conference, Lexington, Kentucky, September 18-19, 1987.
- McHaffie, P. H., 1987**, Base map accuracy and geodetic control data: Presented at Mine Map Accuracy Seminar, Pikeville College, Pikeville, Kentucky, March 4, 1987.
- McHaffie, P. H., 1987**, Base map accuracy and geodetic control data: Presented at Mine Map Accuracy Seminar, Harlan Community College, Harlan, Kentucky, March 26, 1987.
- McHaffie, P. H., 1987**, Base map accuracy and geodetic control data: Presented at Mine Map Accuracy Seminar, Hazard Community College, Hazard, Kentucky, May 27, 1987.
- Moody, J. R., Frankie, W. T., Kemper, J. R., and Johnston, I. M., 1986**, Study of hydrocarbon production from Devonian shale in Letcher, Knott, and Pike Counties, Kentucky: Poster presented at University of Kentucky Energy and Minerals Conference, Lexington, Kentucky, September 18-19, 1986.

- Moody, J. R., Kemper, J. R., Johnston, I. M., Frankie, W. T., and Elkin, R. R., 1986**, Hydrocarbon production from the Devonian shale in Letcher, Knott, Floyd, Martin, and Pike Counties, Kentucky: Presented at Kentucky Academy of Science—Geology Section annual meeting, Lexington, Kentucky, November 21, 1986.
- Noger, M. C., 1986**, Kentucky tar-sand deposits: Resource potential and developmental activities: Poster presented at University of Kentucky Energy and Minerals Conference, Lexington, Kentucky, September 18-19, 1986.
- Noger, M. C., 1987**, Use of topographic maps to select sites for radon detectors: Presented to Division of Radiation Safety, Department of Human Resources, Lake Cumberland State Resort Park, Jamestown, Kentucky, January 13, 1987.
- Sergeant, R. E., 1986**, Kentucky Geological Survey coal data management: Poster presented at University of Kentucky Energy and Minerals Conference, Lexington, Kentucky, September 18-19, 1987.
- Stickney, J. F., Smath, R. A., McHaffie, P. H., and Sergeant, R. E., 1986**, Delineation and documentation of coal-mine-related subsidence in Madisonville, Kentucky: Poster presented at University of Kentucky Energy and Minerals Conference, Lexington, Kentucky, September 18-19, 1987.
- Walker, F. H., and Nuttall, B. C., 1986**, Oil and gas well record library: Poster presented at University of Kentucky Energy and Minerals Conference, Lexington, Kentucky, September 18-19, 1986.

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