

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

ANNUAL
REPORT
1985-1986



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**KENTUCKY GEOLOGICAL SURVEY
UNIVERSITY OF KENTUCKY**

LEXINGTON, KENTUCKY

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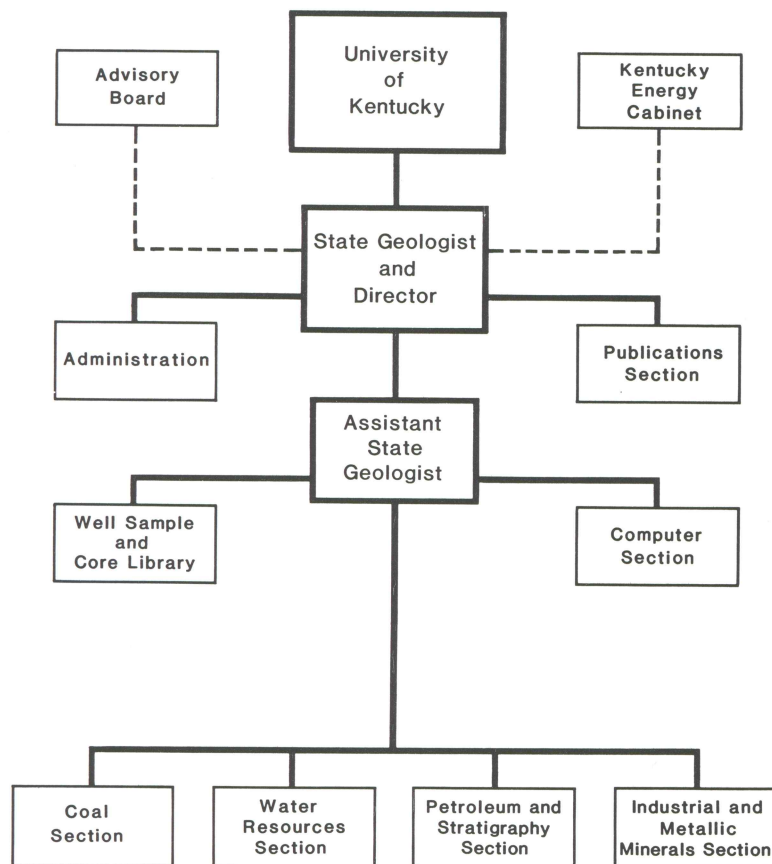
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CONTENTS

	Page
Foreword.....	1
Public Services.....	2
Well Record Library.....	2
Well Sample and Core Library.....	2
National Cartographic Information Center.....	3
Publication Sales and Data Distribution.....	4
Public Information.....	5
General Information.....	5
Coal Section.....	5
Industrial and Metallic Minerals Section.....	6
Petroleum and Stratigraphy Section.....	6
Water Resources Section.....	7
Committees, Boards, and Advisory Activities.....	7
National.....	7
State.....	8
Local.....	12
Research Activities.....	12
Coal.....	13
Industrial and Metallic Minerals.....	22
Petroleum and Stratigraphy.....	25
Water Resources.....	36
Other Research.....	39
Computer Services.....	41
Cooperative Programs.....	41
Topographic Mapping.....	41
Water Resources.....	42
Publications.....	45
Guidebook.....	46
Information Circulars.....	47
Reports of Investigations.....	47
Reprints.....	48
Miscellaneous.....	50
In Press or Editing Completed.....	50
Papers by Staff Members in Outside Publications.....	52
Talks by Staff Members to Professional Groups.....	55
Personnel.....	60
Professional Staff.....	60
Clerical and Technical Staff.....	65
Student Assistants.....	66

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; a strategic and critical mineral study of the Jackson Purchase Region in western Kentucky; a major study of limestone resources in eastern Kentucky; a survey of the sand and gravel resources along the Ohio River in northern Kentucky; subsurface investigations of structure and stratigraphy related to the occurrence of oil and gas, including special projects on tar sands and eastern gas shales; studies of coal quality and compliance coal in both the Eastern and Western Kentucky Coal Fields; a major coal sampling project in the Western Kentucky Coal Field; stratigraphic studies in the Eastern Kentucky Coal Field; and continuous updating and review of coal resources data in both coal fields.

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

The objective of this annual report is to provide a brief summary of the activities of the Kentucky Geological Survey during the past fiscal year (July 1, 1985-June 30, 1986).

PUBLIC SERVICES

Well Record Library

The Petroleum and Stratigraphy Section of the Kentucky Geological Survey is the official repository for records of all wells drilled in the State. A variety of records, such as drillers' logs, wireline logs, well-location survey plats, plugging affidavits, and completion reports are on file for an estimated 200,000 wells. Records for approximately 5,000 new wells are processed and recorded annually by the Survey. In addition, the Kentucky Geological Survey staff reviews and enters onto the computerized data base as many of the older well records as time permits.

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

Well Sample and Core Library

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

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

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

The Kentucky Geological Survey Well Sample and Core Library is centrally located near the University of Kentucky campus and provides easy access and permanent storage. In addition, the Library has the advantage of storing materials from several sources in one place. The ultimate objective of the Survey is to selectively provide, wherever possible, a representative set of well cuttings or core samples for every Carter coordinate section (approximately 1 square mile) in the State.

The Kentucky Geological Survey Well Sample and Core Library is the fifth largest repository of its type in the country and contains over 15,000 sets of well cuttings and in excess of 1,000 cores on file. Over 602,000 feet of sample sets (423 sets) and about 152,000 feet of cores (135 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. The Library has begun moving into this new facility, where it will occupy approximately 59,000 square feet. Presently, the Library occupies a total area of about 21,000 square feet. The move, which will enhance our storage and service capabilities, will not be completed until the summer of 1987. The Library is currently located at 670 South Broadway in Reynolds Building No. 1, and is open from 8:00 a.m. to 4:30 p.m., Monday through Friday. For information, call (606) 257-1677.

National Cartographic Information Center

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

The Kentucky Geological Survey National Cartographic Informa-

tion Center office responded to a total of 466 individual inquiries for information during the 1985-86 fiscal year. Of these requests, 131 were for some type of remote-sensing or aerial-photography information, and 132 were for geodetic-control data. Assistance in ordering materials to supply the needed information was provided for 101 of the requests.

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. In addition, numerous other geological, geophysical, structural, 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 25,000 maps and 6,000 reports, resulting in income of more than \$100,000. Computer programs for the handling of KGS mailing lists and charge accounts were developed and implemented during the year. Staff members who work in Publication Sales take great pride in assisting customers with finding needed

information and offering prompt and efficient service. Most mail orders are shipped out the next day after they are received.

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

Public Information

General Information

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

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

Coal Section

The Coal Section is responsible for providing information about Kentucky's coal resources. These requests come from many sources, including landowners, coal-mining companies, land-development companies, financial institutions, and all levels of government from local to State 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 geologic consultation about the geology of coals in the Eastern and Western Kentucky Coal Fields. These consultations may be with landowners interested in the geology of their property, or with government agencies dealing with problems of concern to Kentucky.

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

Industrial and Metallic Minerals Section

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

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 2,300 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 1985 decreased 18 percent to

5,138, 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 the development of the capability to produce computer-plotted oil and gas well location maps highlight accomplishments of the past year.

Water Resources Section

The Water Resources Section provides daily consultation on both water quality and quantity to the public. During the past year the Section answered approximately 400 requests for surface-water and ground-water information from industry, municipalities, State regulatory agencies, and private citizens.

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

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

Committees, Boards, and Advisory Activities

National

ASSOCIATION OF PETROLEUM GEOLOGISTS

Dr. Ian M. Johnston was appointed chairman of District 8 (Kentucky) of the AAPG Committee on Statistics of Drilling (CSD), replacing Dr. John D. Kiefer. Dr. Johnston attended the CSD meeting on June 14, 1986, in Atlanta, Georgia. This committee is responsible for compiling drilling statistics for the entire onshore and offshore United States.

ASSOCIATION OF AMERICAN STATE GEOLOGISTS LIAISON COMMITTEE

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

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 Program Steering Subcommittee of the Interstate Oil Compact Commission. The committee conducts research activities on the technical progress of efforts to recovery heavy oil from tar-sand deposits, and tertiary oil from depleted reservoirs.

Dr. Haney, Dr. Kiefer, and Mr. Noger participated in the IOCC Annual Meeting in New Orleans, Louisiana, in December 1985. Dr. Haney chaired the Research Committee session and Mr. Noger attended the IOCC Mid-Year Meeting in Anchorage, Alaska.

State

CITIZENS WATER TASK FORCE

Dr. John Kiefer served as chairman of the Citizens Water Task Force (CWTF) through June 1986. This group is an outgrowth of the original State Water Management Task Force, which had been established by Kentucky House Joint Resolution 62, enacted by the 1982 General Assembly; the original task force functioned under the auspices of the Legislative Research Commission until June 1984. The CWTF consists of most of the members of the original Water Management Task Force, plus several members who were added to broaden the areas of interest covered. The CWTF has been sponsored by and received clerical support from the Mountain Association for Community Economic Development (MACED).

The purpose of the task force is to work with State and Federal agencies to promote the proper protection, development, and utilization of Kentucky's water resources and to seek a consensus

among a broad range of Kentucky's citizens on priorities and strategies for addressing the State's present and future water needs.

The CWTF held a series of meetings and field trips in which legislators, citizens, administration officials, and industry representatives discussed and searched for solutions to Kentucky's water problems. Field trips and public meetings were held in Bowling Green, the central Kentucky karst area, the oil and gas fields in eastern Kentucky, and coal-mining areas in eastern Kentucky.

The CWTF also successfully supported several pieces of water-related legislation during the recently completed session of the Kentucky General Assembly. The key piece of legislation is House Joint Resolution 81, which re-establishes a State Water Management Task Force through the Legislative Research Commission under guidelines similar to the original Water Management Task Force. Representative Walter Blevins has been named chairman of the new task force, and Dr. Kiefer has been named as the KGS representative. The task force will hold its first meeting in August 1986.

The CWTF concluded its work with a meeting on April 18, 1986, at which recommendations were formulated to be passed on to the new task force.

GOVERNOR'S EARTHQUAKE HAZARDS AND SAFETY TECHNICAL ADVISORY PANEL

Dr. John Kiefer, Assistant State Geologist, 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 Paducah, Owensboro, and Frankfort during the past fiscal year. In addition, a number of special committee meetings were held at

various sites throughout the State. Dr. Keifer also serves as chairman of the Seismic Probability Assessment Committee. The panel has sponsored public meetings in association with the Central United States Earthquake Consortium, an organization of states most immediately threatened by any New Madrid tectonic activity. The panel also participated in a Federal Emergency Management-U.S. Geological Survey workshop on earthquake preparedness in Nashville, Tennessee, in March. 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 their activities for the Governor.

Individual members of the panel present numerous talks to civic groups, agency personnel, schools, and professional meetings. Several proposals for seismic research have been prepared and submitted jointly by the KGS and the University of Kentucky Departments of Geology and Civil Engineering.

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.

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 appointed by the Governor to serve a 2-year term on the initial Kentucky Water-Well Drillers' Certification Board. The seven-member board was established by the 1984 General Assembly to regulate water-well drilling in an effort to protect the ground-water resource of the State. The board has developed regulations concerning the qualifications for those people wishing to become certified water-well drillers in Kentucky and has implemented water-well record forms to be completed for wells drilled under the certification program. Those wells include all commercially constructed wells except those used for watering livestock and general farm use. Records will be kept at both the Division of Water and the Kentucky Geological Survey. 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.

1985 EASTERN OIL SHALE SYMPOSIUM

Martin C. Noger was appointed a member of the Technical Program Advisory Committee, and Chairman of the Tar-Sand Session of the 1985 Eastern Oil Shale Symposium sponsored by the Commonwealth of Kentucky and the Kentucky Energy Cabinet. The Committee was responsible for developing the format of the technical program, contacting and inviting speakers, and assisting in promoting the Symposium. Mr. Noger has again been asked to serve as the Tar Sand Program Chairman for the 1986 Symposium, and is presently finalizing plans for the session.

Local

LEXINGTON-FAYETTE URBAN-COUNTY GOVERNMENT TECHNICAL ADVISORY COMMITTEE

Several members of the KGS staff have served in an advisory capacity to the Lexington-Fayette Urban-County Government Division of Planning. Activities include reviews of planning documents and subdivision plans. During the past year, members of the KGS Water Resources Section and the Assistant State Geologist have assisted the Division of Planning in the development of a sinkhole ordinance. The development of sinkholes and other solution features in the limestones of the Lexington area poses a potentially serious problem for contractors, developers, and homeowners, and must be taken into consideration in planning and development. The final version of the regulations was adopted by the Lexington-Fayette County Planning Commission in June 1986.

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 with the naming of new buildings on the 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 148 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

The Eastern Kentucky Coal Field is the most productive coal-producing area in the United States and probably the world. This coal field produces one-fifth of the coal mined in the United States and has half of the United State's operating coal mines. Kentucky produced a near-record 169.6 million tons of coal in 1985, which was second only to the 170.7 million tons produced in 1984. To date, nearly 10 billion tons of coal have been mined and lost from this coal field. Remaining resources estimated by the Kentucky Geological Survey are 56.6 billion tons; however, some authorities suggest that as little as 10 billion tons of economically recoverable coal remain.

Important questions about the economics, recoverability, and quality of remaining resources are still unanswered. Generally, it has been assumed that the Central Appalachian Coal Field, of which Kentucky is the largest producer, can supply the East and South with competitively priced compliance coal. However, the basic research necessary to establish if this is possible for 5, 10, or 15 years into the future has not been done. Therefore, the Survey has undertaken new research to determine remaining mineable reserves in the Eastern Kentucky Coal Field.

The Kentucky Geological Survey continues its research into various aspects of coal resources in Kentucky. These projects involve coal-resource estimation, coal-bed correlations, coal-bed mapping, coal-quality characterization and mapping, stratigraphy, evaluation of mined-out areas, and overburden characterization for surface mining.

One of the Coal Section's most important functions is providing public access to coal-resource information. This information is used by the general public, consultants, educators, industry, and govern-

ment agencies. Annually, members of the Coal Section respond to more than 1,000 requests for coal-resource information.

To assist with storage and retrieval of data for public service and research, use of computers has increased tremendously. New coal-resource data bases have recently been created, and the ability to disseminate this computer-formatted data in the most useful way is a key element in planning Coal Section activities for the next 5 years. The goals and objectives for Public Service and Coal-Data Management have been combined to emphasize the close relationship and importance of these two functions. One of the major efforts completed during the year was the release to the public of coal-resource information in both electronic format for computer use and hard copy. Kentucky now has one of the largest publically available data sets for coal resources in the Nation.

ASSESSMENT OF DEEP COAL RESOURCES IN THE EASTERN KENTUCKY COAL FIELD

CHESNUT, Donald R.

The steep topography and gentle dip of coal-bearing strata in the Eastern Kentucky Coal Field cause a great many of the major producing coal seams to occur at or near the land surface. A recently completed estimate of coal resources for eastern Kentucky by the Kentucky Geological Survey indicates that a large portion of the coal-resource base is concentrated in these surface and near-surface coal beds. Eastern Kentucky's large coal resources, and relatively easy access through drift and slope mines have meant that in the past it has not been necessary to develop the shaft mines that are so common in other coal fields. Coal mines in Alabama operate at depths of 2,000 feet below the surface, for example. However, as mineable surface coal resources become depleted and cost factors become favorable, shaft mines will be needed to utilize the deeper subsurface coal resources in eastern Kentucky. Before companies can make the large-scale commitments required for shaft mining, a great deal of information must be available about rocks deeper in the subsurface. This project was initiated to collect data on deeply buried coal and assess eastern Kentucky's deep-coal resources.

Approximately 2,500 core descriptions have been collected for this project. The descriptions have been inventoried, and a structural and stratigraphic framework is being completed, from which the coal resource data will be compiled.

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

CHESNUT, Donald R.

The Eastern Kentucky Coal Field occupies approximately 10,000 square miles in the Appalachian Coal Basin. Coal-bearing rocks extend from the surface to depths as great as 4,000 feet below the surface. Knowledge about the structure, stratigraphy, and paleontology of coal-bearing rocks in eastern Kentucky is particularly important because of the vast mineral resources contained in these rocks. Accurate resource estimates and the success of future exploration depend upon the information derived from studies of subsurface geology. This project was initiated to collect additional information pertaining to the subsurface geology of the coal field, to compile this information for public use, and to analyze the structural and stratigraphic relationships of the Pennington, Lee, and Breathitt Formations.

Several thousand core descriptions have been collected for this project. These descriptions, together with oil and gas well logs, were used to construct cross sections through the basin. Analyses of these cross sections, which were oriented parallel and perpendicular to the axis of the Appalachian Basin, reveal thickening and thinning of coal-bearing rocks; structural features such as anticlines, synclines, and faults; and relationships between the coal-bearing formations. Stratigraphic markers, which are distinctive, recognizable beds, are essential in studying the regional stratigraphic framework and in correlating coal beds in Kentucky, Tennessee, West Virginia, and Virginia. Several regional stratigraphic marker beds have been identified as a result of these analyses.

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

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

More than 40 different coal beds are currently being mined in eastern Kentucky. The chemical characteristics of these coals can differ significantly from coal to coal, and can be different in the same coal from one locality to another. Such things as the amount of ash, sulfur content, percentage of moisture, Btu's per pound, and trace-element constituents can be different. Coal-quality char-

acteristics such as these are critical in determining the marketability of a coal bed.

Since 1979 the Kentucky Geological Survey, in cooperation with the U.S. Geological Survey, has been sampling coal beds in eastern Kentucky to determine variations in coal quality within and between specific coal beds. To date, more than 700 coal samples have been collected and analyzed. A series of reports for the Princess, Licking River, Big Sandy, Southwestern, Hazard, and Upper Cumberland coal resource districts have been prepared, using the data compiled during this research project. A report for the Princess District has been published, and the reports for the other districts are currently in press. An open-file report of coal-quality data collected by various agencies, chiefly the U.S. Bureau of Mines, has been compiled. This report contains data from all of the resource districts and supplements the published reports. Coal-quality maps showing trends for Btu, moisture, ash, and sulfur have been prepared for selected major coal beds in eastern Kentucky. These maps are also available on open file.

The sampling, analysis, and compilation of coal data have resulted in a large file of coal-quality information for eastern Kentucky that is important for both public and private uses. Considerable effort has been given to entering the coal-quality data into the Kentucky Geological Survey computer system. These data can now be readily searched, modified, updated, manipulated, and retrieved, providing easy access and expanded research capabilities to the coal-quality information. The project has also improved understanding of the distribution and geology of high-quality coals.

COAL SAMPLING IN THE WESTERN KENTUCKY COAL FIELD

CURRENS, James C.

The quality (chemical characteristics) of coal reserves is as important to marketing Kentucky's coal as the quantity of these reserves. The Kentucky Geological Survey's efforts to characterize the quality of the State's coal resources has continued under a grant from the U.S. Geological Survey (USGS). Efforts were concentrated on making the findings available to industry, researchers, and the general public.

Field work in western Kentucky was curtailed because of a loss of funding for coal analysis. However, 35 coal samples were collected during the summer and fall of 1985. Since the beginning of the program, 119 coal samples have been collected from the

Western Kentucky Coal Field. These samples have been analyzed, and the data are now in the Kentucky Geological Survey's coal-quality data set. In addition, field assistance was given to USGS research geologists studying the Herrin (No. 11) coal bed. Coal-quality data collected by the U.S. Bureau of Mines for the Western Kentucky Coal Field were organized into an open-file report for distribution to the public. These data are from sampling programs conducted years ago, and the results of the analyses were not made available to the public before. The value of these data is in assessing trends in coal quality and comparing coal quality from one area to another. There are 435 coal-quality records in the western Kentucky data base. Work has begun on preparing coal-quality maps for the Western Kentucky Coal Field.

In addition to the work directly related to western Kentucky, the coal-quality data base has developed rapidly during the year. Besides the western Kentucky data, there are 1,243 records for eastern Kentucky, 23 out-of-state records, and one analysis for a Jackson Purchase lignite sample. The data set has been highly effective in making data on the quality of Kentucky's coal available to industry and the general public. Currently, the data base is one of the largest in the Nation and has significant potential to expand in size and usefulness in the next year.

GEOLOGY OF THE HAZARD COAL

DAVIDSON, Oscar B., and COBB, James C.

The Hazard coal is extensively mined throughout the Eastern Kentucky Coal Field. It ranks eighth in remaining resources, with an estimated 3.7 billion tons. It also ranks fourth in potential low-sulfur, compliance resources. Because the Hazard coal is such an important resource, knowledge about its geology, quality, and mineability is important to coal producers and resource planners. Therefore, this project was undertaken to describe the geology of the coal across the coal field.

The Kentucky Geological Survey-U.S. Geological Survey Cooperative Geologic Mapping Program, the Eastern Kentucky Coal Resources Program, and recent field work have accumulated a substantial amount of data about the Hazard coal. This information was used to construct isopach maps, coal-quality maps, split maps, and cross sections for the coal. These geologic tools were used to infer depositional conditions during accumulation of peat in the Hazard swamp, and a regional interpretation was created for the origin of this coal.

The Hazard peat swamp covered about 5,000 square miles in what is now eastern Kentucky. This swamp had an area of well-protected peat accumulation, which produced high-quality, thick coal; an area of a poorly protected peat accumulation, which produced poorer quality, split coal; and an area of marine-influenced peat accumulation, which produced higher sulfur, thin coal. These swamp environments for the Hazard coal have been mapped, and the maps used to predict in general what coal quality, thickness, and mineability factors might be encountered in the Hazard coal in the Eastern Kentucky Coal Field.

GEOLOGY OF ROOF FALLS IN EASTERN KENTUCKY COAL MINES

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

Roof-control problems in the Eastern Kentucky Coal Field are a major cost of mining in terms of death and injury to miners, clean-up operations, and lost reserves. Twenty deaths were attributed to roof falls in 1984, and an average of 10 deaths occur each year because of roof falls in eastern Kentucky. There are nearly 1,000 underground mines in eastern Kentucky, so the potential for future disasters is also great. Therefore, a geological analysis of roof falls was conducted in several eastern Kentucky mines to identify geological characteristics of roof falls.

Six types of roof falls were identified. These six types consistently occurred in similar strata, which indicates that geologic mapping of roof rocks can aid in predicting roof conditions. The roof strata were broadly categorized as channel, channel margin, and floodplain/bay deposits. Core and outcrop descriptions were used to map these deposits in the mine area. Mine records and observations made in the mines verified that falls had occurred in areas where the geological conditions indicated a potential for roof-control problems.

Several geologic characteristics of roof falls that contributed to stability problems were identified. They include joints and tension fractures, coal riders and splits, disturbed and slumped bedding, channel-erosion scours, and contacts between lithologies of different grain sizes and types. These characteristics can be recognized by nongeologists if they are properly instructed in their identification.

The results of this investigation are preliminary, but highly encouraging, and indicate that the application of geology can greatly benefit mining in Kentucky.

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

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

The deep mining of coal by shaft, slope, or drift in western Kentucky began in the early 1800's and continues to supply more than 40 percent of the coal mined in the Western Kentucky Coal Field. Despite this long history of underground mining, estimated remaining coal resources will support the mining of coal well into the twenty-first century. Coal-resource estimates by the Kentucky Geological Survey indicate original coal resources in the Western Kentucky Coal Field exceeded 40 billion short tons, and the coal still remaining is estimated to exceed 38 billion short tons. It is essential to develop this coal resource to its full potential. This development, however, should not have an adverse impact on citizens living over 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 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 western Kentucky, the Kentucky Geological Survey, in cooperation with the Division of Abandoned Mine Lands, has initiated a project to delineate and catalog suspected subsidence damage in Hopkins, Muhlenberg, Webster, Union, and Ohio Counties. This project, which began in September 1984, will attempt to organize and computerize data relevant to suspected subsidence. These data will then be compiled into comprehensive "Subsidence Catalogs" for the five counties in the study area. Information contained in these Subsidence Catalogs will be used to determine the magnitude of existing subsidence problems and to outline areas of potential concern. The information compiled in these catalogs will also be useful when Kentucky's Subsidence Insurance Program is implemented. This program will provide protection to citizens who reside in Kentucky's coal-producing areas 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 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.

In 1912, Leonidas C. Glenn, a geologist with the Kentucky Geological Survey working in Webster County, stated in his report that thin coals present in what is now called the Sturgis Formation were uneconomical for mining at that time; but he foresaw that someday, as coal resources were depleted, these coals would be mined. Seventy years later, Glenn's prediction has been fulfilled, and these coals are now being extracted. Similar predictions can be made today for the Western Kentucky Coal Field. Future mining will be in deeper, thinner seams.

An important function of the Kentucky Geological Survey is to maintain an accurate estimate of the total coal resources of the Western Kentucky Coal Field. Data are accumulated for individual coal beds so that estimates can be made for reserves, under current economic and technological constraints. The Survey's computer capabilities are instrumental in this project. During the past fiscal year, approximately 25 drill-hole descriptions and 100 new data points were added to the coal data set.

The object of this project is to collect and maintain coal-resource data for the Western Kentucky Coal Field, to conduct geologic research on these resources, and to provide these data to the public, industry, and government agencies.

MINEABILITY OF WESTERN KENTUCKY COALS: PHASE 1, PALEOCHANNEL STUDY

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

The Kentucky Geological Survey estimates that the Western Kentucky Coal Field contains approximately 38 billion tons of coal, the majority of which is accessible only through underground methods. As strippable coal reserves near depletion, the documentation of geologic features affecting underground mining becomes vital. Both faults and paleochannels have a profound effect on the safety and production of an underground mine. Lack of awareness of

paleochannels has caused mines to alter their mine plans, abandon large blocks of coal, jeopardize the safety of miners, and in extreme cases, abandon the mine. Identifying sandstone-filled channels of ancient streams formed during peat deposition should be a primary factor in mine planning and development. Problems associated with paleochannels are: (1) local and regional coal cut-outs, (2) water seepage affecting both the floor (wet clay, standing water) and the roof (decreased friction along joints and fractures), (3) sharp contact between thin shale and sandstone bodies, causing poor roof conditions, and (4) slumps in roof strata, which cause unstable roofs and missing coal.

The Kentucky Geological Survey is mapping paleochannels by using core descriptions, and drillers' logs provided by the coal industry, field mapping, and geophysical logs from oil and gas drilling. Significant progress has been made in the past fiscal year in tracing paleochannels above the Springfield (W. Ky. No. 9) coal bed. The study has been expanded to other paleochannel systems.

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

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

The Kentucky Geological Survey is responsible for supplying geologic data to the general public, industry, and government agencies. For this reason, the Survey maintains and makes available coal-resource estimates, coal analyses, and other coal information, including stratigraphic and structural data. The ability to accurately predict the position and depth of economic coal beds is essential to coal-resource estimates and the mining industry.

This fiscal year the Kentucky Geological Survey has put special emphasis on correlating coal beds of the Sturgis Formation. The Sturgis Formation is the shallowest coal-bearing rock unit in western Kentucky, and contains significant deposits of low- to medium-sulfur coal. The Kentucky Geological Survey has continued to work with neighboring state surveys to correlate coal beds and develop a unified nomenclature.

A comprehensive report of coal-bearing rocks in western Kentucky is being reviewed and prepared for publication. This report will contain isopach maps and cross sections of coal-bearing rocks and will discuss the economic geology of the Western Kentucky Coal Field. A thorough review of the general geology of the Western Kentucky Coal Field will also be contained in this report.

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, distribution, and geologic setting of industrial and metallic minerals in the State. Current resource projects concern construction raw materials, metallic ores, 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 of the 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. The 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.

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. A study to determine the physical, textural, and mineralogical properties of sand and gravel deposits along the Ohio River Valley is in progress. Investigation of the grain-size distribution, particle shape, and compositional characteristics of surface deposits in Boone, Carroll, and Gallatin Counties is now three-fourths completed. The scarcity of available subsurface data for the study area is restricting three-dimensional mapping of the thickness and geometry of the deposits.

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

ANDERSON, Warren H.

In 1986, work resumed on a regional study to determine the chemical characteristics of limestone and dolomite in the High Bridge Group (Middle Ordovician) and to outline the occurrence of deposits suitable for industrial uses that require carbonate rocks of high chemical purity. The High Bridge Group 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. Chemically pure stone is mined from the High Bridge at two sites in north-central Kentucky along the Ohio River for the production of lime for flue-gas desulfurization, flux, chemical industries, and water treatment.

Cores donated to the Survey by private companies have been utilized for the project. Samples for major-element analysis were taken at 1-foot intervals from the entire High Bridge section. A core from Mason County was sampled and described, and analysis is in progress. The Kentucky Center for Energy Research Laboratory is cooperating in the current study.

MIDCONTINENT STRATEGIC AND CRITICAL MINERALS PROGRAM

ANDERSON, Warren H.

The U.S. Geological Survey, Branch of Central Mineral Resources, initiated and funded a program to evaluate the potential for strategic and critical mineral deposits in sedimentary and basement rocks of the Midcontinent United States. Several state geological surveys, including the Kentucky Geological Survey, have cooperated in the program. In Phase I of the program, completed in 1984, the focus was directed toward data inventory. Well- and mineral-location maps, cross sections (including a section showing Phanerozoic rocks along the 88°00'W longitude), and a Sauk Sequence isopach-lithofacies map were compiled.

During Phase II, completed in 1985, a tectonic map of western Kentucky (west of 88°00'W longitude) was compiled. This map shows the location of the Reelfoot Basin, Pascola Arch, the eastern limit of the Reelfoot Rift, and other tectonic features in western Kentucky.

Maps, cross sections, and data prepared by participating state geological surveys are currently being compiled by the U.S. Geological Survey for publication.

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' 1984 "Minerals Yearbook" was published during 1985-86. The Kentucky chapter ("The Mineral Industry of Kentucky") will be issued as a Kentucky Geological Survey Reprint.

In 1985, the value of nonfuel-mineral production in the State was \$262.3 million, based on preliminary data received by the Bureau of Mines. Crushed stone was the leading nonfuel-mineral commodity, accounting for more than 50 percent of the total value. Kentucky ranked second in the nation in ball clay production and aluminum shipments, and fourth in lime, synthetic graphite, and expanded perlite output. Portland and masonry cement, common and fire clays, construction sand and gravel, industrial sand, and zinc ore also were produced. Other commodities processed or manufactured in the State included vermiculite, pig iron, and regenerator iron oxides.

ZINC DEPOSITS OF SOUTH-CENTRAL KENTUCKY

ANDERSON, Warren H.

The investigation of zinc mineralization in the Mascot Dolomite of the Knox Group (Cambrian-Ordovician) in south-central Kentucky was completed during the fiscal year. The project report and accompanying maps and cross sections are in the final stages of preparation.

The Mascot Dolomite has had a complex diagenetic history involving several stages of dolomitization, silicification, solution, and brecciation. It was influenced by tectonic activity and the development of a regional unconformity at the top of the formation. Pronounced thinning in the interval between internal marker beds M-5 and TR across the Cincinnati Arch indicates Early Ordovician uplift along the arch. The position of a paleoaquifer associated with the erosional unconformity was influenced by the M-5 marker bed, a

relatively impermeable cherty dolomite. The paleoaquifer enhanced (1) dissolution and development of breccia bodies, and (2) porosity of the dolomite, creating a favorable reservoir rock. Zinc mineralization is associated with stromatolites and solution-collapse breccia bodies, where localized by minor structural features. The information developed on geologic controls for zinc mineralization may also aid in the exploration for petroleum in the Knox of south-central Kentucky.

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 the project is to provide industry with information on the availability of stone in Kentucky that meets the specifications for coal-related uses. A report on the chemical quality of limestone resources along Pine Mountain, in southeastern Kentucky, was published in the Proceedings of the Twentieth Forum on the Geology of Industrial Minerals, and will also be available through the Survey's Reprint series. Pine Mountain is in the southeastern part of the Eastern Kentucky Coal Field, and this report outlines the availability of low-silica stone suitable for use as rock dust for explosion abatement in underground coal mines. An investigation of variations in the distribution and thickness of chemically pure limestones in west-central Kentucky is in progress.

The Survey continued to work with the Kentucky Center for Energy Research Laboratory (KCERL) on limestones and dolomites for fluidized-bed combustion systems. A deposit of Lexington Limestone used in test runs at the KCERL fluidized-bed-combustion pilot plant was sampled to determine its chemical characteristics. An investigation of potential sources of limestone that would have a low rate of attrition in a fluidized-bed boiler is in progress.

Petroleum and Stratigraphy Section

With more than 20,000 producing oil wells and over 9,200 producing gas wells, Kentucky ranks as 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 5,150 sites were permitted for drilling in 1985, a decrease of 1,050 from 1984, and 2,372 new wells were reported as successful. Discoveries included 22 oil pools, 26 gas pools, one oil and gas pool, 18 deeper oil pools, 14 deeper gas pools, one deeper oil and gas pool, eight shallower oil pools, four shallower gas pools, and 217 extensions to existing producing areas.

Eastern Kentucky continued to be dominated by discoveries and developments in gas-producing areas. Deeper gas was found in the Rose Run (Ordovician) in Lee County and in the Rome (Cambrian) in Johnson County. On the northern flank of the Rockcastle River Uplift, wells are being completed in the Trenton, Stones River, Murfreesboro, and Beekmantown (Ordovician). In addition, significant production from the Borden (Mississippian) has been encountered in both Clay and Leslie Counties.

In western Kentucky, extensions of many known pools were of major interest. The majority of these extensions were Chesterian and upper Meramecian (Mississippian). Forty-four such extensions were reported, mainly in Christian, Henderson, Hopkins, and Muhlenberg Counties. In addition, the New Albany (Devonian) is being listed as the pay for numerous proposed gas-well completions in Butler, Edmonson, and Grayson Counties. The New Albany equivalent in eastern Kentucky (Brown shale or Ohio Shale) is a well-known gas-producing unit. Improved completion techniques are making it possible to establish gas production from the much thinner New Albany Shale in western Kentucky.

Crude oil production was 7,784,334 barrels, a very slight decrease from 1984. Natural gas production was 73,126,200 mcf, an increase of approximately 12 billion cubic feet from 1984.

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 200,000 well records. The Survey also maintains a Well Sample and Core Library with more than 15,000 sample sets and 1,000 cores on file. In addition, Survey files contain such information as cumulative annual oil production, oil and gas pool maps (1:250,000 scale), pool indexes, geologic quadrangle indexes, oil and gas well maps of some counties, and bibliographies. Since a primary tool of the petroleum geologist is

stratigraphy and subsurface geology, and since the well records and the Well Sample and Core Library comprise the major pool of stratigraphic and subsurface information in the State, the name of the section was officially changed from the Oil and Gas Section to the 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 70,000 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. All available information is being collected on selected reservoirs. Samples and cores, where available, are requested and examined in detail. Maps and cross sections of the stratigraphic interval encompassing the productive zones are constructed. Production data will also be compiled to the extent that they are available.

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

This project is being carried out by KGS staff as time permits. Much of the work during the past year has focused on reviewing historical data available from KGS and other files, and comparing surface

stratigraphy with units previously defined in the subsurface. Various stratigraphic marker zones are being defined, and several stratigraphic cross sections have been prepared.

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

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

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

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

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

The major goals of this project are (1) to create a comprehensive data base of Devonian-shale well information, (2) to develop an understanding of relationships between local geology and Devonian-shale production, and (3) to prepare an oil and gas report for each county in the study area.

The Kentucky Geological Survey initiated a 2-year cost-sharing project with the Gas Research Institute (GRI) in July 1984 to study the hydrocarbon production from the Devonian shale in the Big Sandy Gas Field. The present contract was extended until January 31, 1987; KGS is currently in the process of submitting a new proposal for a 3-year project to continue work in the remaining counties of the Big Sandy Gas Field.

The initial phase of the project involves compiling a well data base. All wells available in the Kentucky Geological Survey oil and gas well-record files are being entered into the Survey's computer. From this data base, cross sections and structure, isopach, and initial open-flow potential maps have been constructed. In addition,

statistical analyses and comparison of different stimulating techniques are being conducted.

The first county report, on Letcher County, has been completed and submitted to GRI; it will be available as a KGS open-file report during the third quarter of 1986. The Knott County report is in preparation and should be completed by July 31, 1986. The three remaining county reports (Floyd, Martin, and Pike) are expected to be completed during the fourth quarter of 1986 and the first and second quarters of 1987. The Kentucky Geological Survey plans to compile all five county reports into a single report at the conclusion of the project.

This research project is providing industry with information and maps that can be used as exploration tools, reducing the cost of future exploration and increasing the chances of a successful well. A data base of 4,839 Devonian shale wells in the five-county area has been collected and entered into the KGS computer.

The Letcher County report includes a summary of relationships between production, stratigraphy, structure, stimulation techniques, and location of areas known to produce gas from the Devonian black shales. The report contains nine cross sections, a series of 1:100,000-scale base maps showing structure, thickness, potential, and location of all Devonian wells in the KGS data base, and a summary of statistics run on the Letcher County data base.

Temperature logs have been used to determine locations of gas-producing intervals. Gamma-ray logs were used to determine the individual stratigraphic units between the Mississippian Sunbury Shale and the Devonian Rhinestreet Shale. The cross sections show individual stratigraphic units within the Mississippian-Devonian shale sequence, and contain information on the type of well, amount of initial open-flow potential, zone of treatment, and location of gas shows. The isopotential map was constructed using initial open-flow potential figures. Statistics for Letcher County were calculated using DATATRIEVE software.

Data for the investigation have been obtained from the KGS oil and gas well-record files, company files, and existing literature.

The following conclusions may be drawn: (1) the only reliable and reasonably consistent correlation of the Devonian black-shale sequence in the subsurface of eastern Kentucky is from gamma-ray logs, (2) change in thickness of each individual stratigraphic unit within the Devonian black-shale sequence is fairly uniform, with a general thinning to the west, (3) relationships between local structure variations (flexures) and production are indicated from cross

sections, (4) the Letcher County Devonian shale isopotential map outlines 11 areas of Devonian shale initial open-flow potential greater than 200 mcf/d and seven areas of initial open-flow potential greater than 300 mcf/d, (5) wells situated close to local structural features generally exhibit relatively high initial open-flow potential compared to wells located farther away, and (6) analysis of Letcher and Knott County temperature logs indicates that the greatest number of natural gas shows occur in the Lower Huron Member of the Ohio Shale.

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 were deposited on a broad, gentle slope 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, 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, a map showing all producing wells in the study area has been generated at a scale of 1:125,000, 30 maps showing all oil and gas tests drilled in the study area have been prepared at a scale of 1:24,000, and 12 cores have been obtained to be described; one core has already been described. Well data have been entered into the computer and will be used to generate isopach maps. In addition, well samples from 30 deep wells were collected.

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, and basin evolution and oil and gas systems.

Dr. Morris W. Leighton, Chief of the Illinois State Geological Survey, has agreed to be editor of this volume. On October 2, 1985, Dr. Leighton organized a meeting at Bloomington, Indiana, with representatives of the Kentucky and Indiana Geological Surveys to discuss the proposed project. Dr. Donald C. Haney, State Geologist and Director of the Kentucky Geological Survey, and Dr. John B. Patton, Director of the Indiana Geological Survey agreed to par-

ticipate in the project. Coordinators were chosen for each state; Martin C. Noger was chosen coordinator for Kentucky. Various Survey personnel will contribute to different chapters of the manuscript.

CORRELATION OF STRATIGRAPHIC UNITS OF NORTH AMERICA (COSUNA)

NOGER, Martin C.

In 1981, the Kentucky Geological Survey COSUNA Committee completed seven stratigraphic columns covering western and central Kentucky for inclusion in the Midwestern Basins and Arches Region Correlation Chart, and three columns covering eastern Kentucky for inclusion in the Southern Appalachian Basin Region Correlation Chart. The charts were published in 1985 by the American Association of Petroleum Geologists. Stratigraphic data sheets were completed for each unit and submitted to the project coordinator for inclusion in a central data bank.

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 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 is 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.

Kenoco, Inc., which was organizing a 4-acre commercial model in Edmonson County to produce heavy oil from the Big Clifty Sandstone using a thermal fireflood process developed during their pilot project, has stopped operations because of the drastic drop in the price of crude oil. However, they have extended the term of lease holdings for 10 years, and plan to renew operations when economic conditions are more favorable.

Kentar, Ltd., which was extracting heavy oil in Logan County from surface-mined tar sands in the Big Clifty using a solvent process, has discontinued operations.

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 68,000 well completions have been encoded, entered, and proofread to date. Data on current completions are being reported monthly to the American Petroleum Institute. By the end of 1986, records for approximately 75,000 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 Anderson, Ballard, Bell, Bourbon, Boyle, Caldwell, Calloway, Carlisle, Casey, Clark, Fayette, Fleming, Fulton, Garrard, Grant, Graves, Grayson, Greenup, Harlan, Hickman, Jessamine, Knott, Leslie, Letcher, Logan, Madison, McCracken, Mercer, Montgomery, Nicholas, 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.

Interest in the Cambrian System continues to increase. The successful gas-well completions in the Rome Formation in Johnson and

Lee Counties, coupled with excellent shows of gas in the same geologic unit in Garrard and Morgan Counties, have stimulated inquiries to the Kentucky Geological Survey.

This project continues to be a maintenance program to assist those persons requiring identification of wells penetrating the Cambrian. An open-file map at a scale of 1:500,000 shows the location and total depth formation for each well. The accompanying computer printout has been expanded to give additional details on each well.

As completion records are received, data are added to the map and computer printout. As of June 30, 1986, 179 wells have been identified.

OIL AND GAS WELL RECORD LIBRARY

WALKER, Frank H.

The 1960 Oil and Gas Conservation Act designated the Kentucky Geological Survey as the official repository of geologic records of wells drilled for oil, gas, and other purposes. Prior to the designation, 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 1985-86 fiscal year amounted to approximately 4,000 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 200,000 wells will be found in the files.

The library is located in the basement of Breckinridge Hall, and is open from 10:00 a.m. until noon, and from 1:00 p.m. until 4:30 p.m. each working day. Students, industry representatives, government agencies, and the general public make extensive use of the files. In an average year, 2,200 persons visit the Record Room. Record Room personnel answer 1,550 telephone requests for information, and 42,000 copies are made of the well records by request. Copies are limited to 50 wells per person by telephone or written request in a 30-day period. Visitors to the library may have copies made of up to 100 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.

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 70,000 wells are in the computer data base, and an average of 10,000 wells a year are added to the system. All of the wells will appear on the correct map or maps.

Conversion of the records from the 1:48,000-scale county maps to the 1:24,000-scale quadrangle maps is progressing. As the wells in a county are converted, the county map 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 maps available are Barren, Carter, Lewis, and Rowan.

Maps are complete for the quadrangle in 34 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—there is virtually nothing that 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 of the past several years, many of our 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 also 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.

In the past year, a project funded by the U.S. Environmental Protection Agency concerning an inventory of injection wells used for enhanced petroleum recovery was completed.

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 mudstone-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.

BARIUM CONCENTRATIONS IN GROUND WATER IN EASTERN KENTUCKY

WUNSCH, David R.

Analysis of water samples collected by the Kentucky Natural Resources and Environmental Protection Cabinet in 1980 indicates that dissolved barium in concentrations above the suggested drinking-water standard of 1.0 mg/L exists in eastern Kentucky. The Kentucky Geological Survey, in cooperation with the U.S. Geological Survey, is presently conducting a study to (1) determine the extent of anomalous barium concentrations in ground water in part of eastern Kentucky, and (2) investigate the geologic and other sources of barium in ground water.

At present, complete chemical analysis has been performed on 63 samples drawn from wells located in the vicinity of Buckhorn, Chavies, and Salyersville, Kentucky. Several wells have been re-sampled periodically to check annual chemical variations.

Results show that barium in concentrations as high as 15 mg/L exist in water samples from the study area. Calculations using the WATEQ computer program show that 16 percent of the samples analyzed are saturated with respect to barite (BaSO_4). Statistical analysis indicates the occurrence of barium is related to different geochemical parameters at each of the three study areas, suggesting that different hydrochemical mechanisms may be occurring at each site. The possibilities include (1) solution and leaching of barium-enriched minerals in aquifers, (2) cation-exchange reactions, (3) contamination from brines or mixing with saline connate waters, and (4) combinations of the aforementioned mechanisms.

Monitoring wells at each location were completed in 1985 to allow more detailed testing. Whole-rock analyses were performed on cores drilled near the monitoring wells for stratigraphic control. Additional water sampling, along with stable-isotope analysis, will be performed to evaluate the significance of barite solubility as a result of sulfate-reducing bacteria. Further geochemical and statistical analysis will be conducted to identify other geochemical relationships that may be related to high barium concentrations in ground water.

HYDROGEOLOGY OF BRINE OCCURRENCE IN THE KENTUCKY RIVER BASIN

KIPP, James A.

The intent of this Kentucky Geological Survey-U.S. Geological Survey cooperative study is to assess the occurrence, quality, movement, and interaction of surface and ground water in a petroleum-producing region. The area under study is located between the Kentucky and Red Rivers in Estill, Powell, Wolfe, and Lee Counties, where petroleum production has occurred for 70 years.

Water samples were collected at approximately 100 sites. Most of the samples were from streams, but domestic wells and springs were also tested. Samples were analyzed in the field for temperature, pH, specific conductance, and chloride. Preliminary results indicate that high chloride concentrations (greater than 600 mg/L) are common in headwater reaches of streams draining basins with active production. Additional sampling will be conducted to assess shallow ground-water quality, ground water-surface water interaction, and the impact of petroleum production on water resources in this region.

DEVELOPMENT OF A COMPREHENSIVE OIL AND GAS INJECTION WELL INVENTORY

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

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

During the 1983-84 fiscal year, 5,291 wells were inventoried and reported. During the 1984-85 fiscal year, 212 wells were corrected or added to the inventory. In the final year of this contract, the 1985-86 fiscal year, approximately 200 well-status corrections or new wells were added to the inventory. The basic well information was added to the data base maintained by the Kentucky Geological Survey.

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. 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.

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.

Maps in color with brief descriptions will be published for individual Interstate highways and parkways by the Kentucky Geological Survey.

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.

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 sheet covering central 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 is to assist the Survey staff in using computers in order to provide public service. The Computer Services Section acquires, 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 daily. Staff requests for various software applications are increasing because of the greater variety of work being done with 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 Computer Services Section staff busy answering the many day-to-day requests for services.

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

During the year, various programs have been added to the system, including a water-chemistry graphics package (PIPER), a general geologic-modeling package (SURFACE II), and a water-chemistry analysis program (WATEQ). In addition, several smaller programs have been written to display geologic map information such as bore holes, oil and gas tests, and coal-mining areas.

COOPERATIVE PROGRAMS

Topographic Mapping

The Kentucky Geological Survey participates in an ongoing cooperative program with the U.S. Geological Survey for topographic map revision in the Commonwealth. This program is designed to maintain revised and up-to-date maps for all areas of

the State, and has been active since Kentucky became the first major state to be entirely mapped topographically at a scale of 1:24,000 30 years ago.

In January 1986, Governor Martha Layne Collins established the State Mapping Advisory Committee (SMAC). This committee consists of 12 members selected to represent the mapping interests of State and local government, industry, professional groups, and the academic community. The main function of the committee will be to identify areas in the State that need map revisions, assign priorities, and send recommendations through KGS to the U.S. Geological Survey. The first SMAC meeting is scheduled for July 1986.

Five 7.5-minute quadrangles were revised during the 1984-85 fiscal year. All of these maps were photorevisions, on which changes are shown in a purple overprint on the original map. These changes are compiled from 1:80,000-scale aerial photographs and are not field checked.

Seven new 1:100,000-scale topographic maps were received from the U.S. Geological Survey during the past year. Each of these maps covers an area that includes 30 minutes of latitude and 60 minutes of longitude; topographic contours are shown in meters. The new quadrangles are West Frankfort, Dyersburg, Ironton, Morehead, Huntington, Hopkinsville, and Pikeville.

During the year, responsibility for the Kentucky cooperative topographic mapping revision program was transferred from the U.S. Geological Survey's Eastern Mapping Center in Reston, Virginia, to the Mid-Continent Mapping Center in Rolla, Missouri. A meeting with representatives of the Mid-Continent Mapping Center was held in April 1986, and plans are currently being formulated for expanded work in the revision program. Input from the newly formed State Mapping Advisory Committee will be extremely valuable in making decisions concerning future directions of the program.

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

Water Resources

The cornerstone of the Kentucky Geological Survey Water Resources Program is our cooperative agreement with the U.S. Geological Survey Water Resources Division. Water-related cooperative programs with the U.S. Geological Survey date back to as early as 1920. The cooperative programs have covered a wide

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

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

1. Surface-Water Stations—A Statewide network to collect surface-water data for a variety of uses such as research and special studies, assessment of surface-water resources, waste disposal, pollution control, planning and design of facilities, and forecasting of water levels. The program has been in operation since 1938. Prior to 1960, information from this program was published annually in the U.S. Geological Survey Water-Supply Paper series, "Surface Water Supply of the United States." Daily streamflow records for Kentucky from 1961 to 1974 were also published in annual U.S. Geological Survey

open-file reports. Since 1975 all surface-water data are found in the annual publication, "Water Resources Data for Kentucky."

2. *Water-Quality Stations*—This Statewide network of approximately 70 sites where water quality is monitored on a regular basis provides data for broad Federal and State planning and for the management of waterways. This program has been continuous since 1949. Prior to 1971 these data were published annually in the U.S. Geological Survey Water-Supply Paper series. For the years 1964-74, these data for Kentucky were also released annually in open-file U.S. Geological Survey reports. Records since 1975 are found in the U.S. Geological Survey annual report, "Water Resources Data for Kentucky."

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

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

5. *An Evaluation of Water-Quality Data for the Kentucky River*—The purposes of this study are to describe and explain variations in water quality, to assess trends in water quality over time, to delineate reaches of poor water quality, and to outline major deficiencies in available data for this basin. This project was scheduled for completion in 1986, but the work was discontinued because of inadequate State funds. However, a U.S. Geological Survey proposal has been funded at the Federal level, which will lead to a 3-year study of the effects of various land uses on the water quality in the Kentucky River.

6. *Hydrogeologic Investigation of Stress-Relief Fractures of a Valley in the Appalachian Plateaus*—The primary focus of this study is to investigate ground-water movement in steep hillslope topography of the Eastern Kentucky Coal Field, where stress-relief fractures may constitute the most transmissive part of the aquifer. Results may prove useful in developing ground-water supplies, in monitoring the hydrologic effects of surface and deep coal mining, and in understanding relations between surface water and ground water in small valleys. Examination of 1,700 feet of core, downhole packer testing, dye tracing, and monitoring wells were used to describe ground-water movement. Additional funds are being sought from the U.S. Office of Surface Mining for continuation of this project.

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

8. *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 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 on Kentucky's geology and mineral resources. The Survey also publishes the proceedings of technical sessions and symposia, and guidebooks for geologic field conferences.

Publications of the Kentucky Geological Survey are made available to the public at a nominal cost and have received widespread distribution. Maps and reports are available for purchase from the Publication Sales Office, which is located in the basement of Breckinridge Hall on the University of Kentucky campus. Total sales for the 1985-86 fiscal year amounted to more than \$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.

Recent additions to the Survey's open-file materials are computer-plotted overlay maps showing the locations of oil and gas wells. These maps are available by 7.5-minute quadrangle, and 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 1985-86 fiscal year.

Guidebook

Stratigraphy Along and Adjacent to the Bluegrass Parkway (Guidebook and Roadlog for Geological Society of Kentucky 1985 Field Conference), by Martin C. Noger and Roy C. Kepferle, 24 p.

Information Circulars

Information Circular 17. Oil and Gas Drilling Summary for Kentucky, 1985, by Kentucky Geological Survey.

Information Circular 18. Analysis of Coal Samples from the Princess District, Kentucky: Boyd, Carter, Greenup, and Lawrence Counties, and Part of Lewis County, by James C. Currens, Linda Jean Bragg, and James C. Hower, 128 p.

Chemical and petrographic data are presented for 42 samples of coal collected in the Princess 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.

Reports of Investigations

RI 2. Structure and Thickness of the Devonian-Mississippian Shale Sequence in and Near the Middlesboro Syncline in Parts of Kentucky, Tennessee, and Virginia, by Paul E. Potter, Edward N. Wilson, and J. S. Zafar, 15 p.

The Devonian-Mississippian shales of eastern Kentucky are significant producers of natural gas. Hence, their equivalents in the Middlesboro Syncline south of Pine Mountain should also have a rich potential, judging by the lithologic similarity of the shale within the syncline to that in surrounding areas and by the occurrence of gas fields in rocks of Mississippian age within it. The maps in this report complement and extend to the southeast the structure and thickness map of the shale sequence made by Provo (1979), which covers all of eastern Kentucky northwest of Pine Mountain. Subsurface mapping and study of outcrop patterns revealed six major segments of the Middlesboro Syncline. The volume of shale in each segment is estimated, and its petroleum potential is assessed.

RI 3. Pennsylvanian Plants of Eastern Kentucky: A Flora from the Breathitt Formation Near Grannies Branch and Rocky Branch of Goose Creek, Clay County, Kentucky, by Paul A. Spurgeon and James R. Jennings, 34 p.

This study of fossil plants is intended to provide a basis for more detailed biostratigraphic dating of Pennsylvanian-age strata. The determination of biostratigraphic correlations based upon fossil plants will assist in the correlation of coal beds in eastern Kentucky.

A flora collected from strata associated with a coal described as the Jellico coal, in Clay County, Kentucky (Ogle 7 1/2-minute quadrangle) consists of *Lepidodendron* cf. *L. aculeatum*, *Lepidophylloides longifolium*, *Lepidostrobophyllum lanceolatum*, *Lepidostrobos ornatus*, *Bothrodendron minutifolium*, *Ulodendron minus*, *Asolanus* sp., *Calamites cisti*, *C. undulatus*, *Annularia galioides*, *Asterophyllites longifolius*, *A. charaeformis*, *Paleostachya* sp., *Sphenophyllum cuneifolium*, *Bowmanites* sp., *Pecopteris* cf. *P. plumosa*, *Alethopteris decurrens*, *Alethopteris* cf. *A. lonchitica*, *Neuropteris* cf. *N. tenuifolia*, *N. heterophylla*, *N. gigantea*, *Mariopteris nervosa*, *Eremopteris gracilis*, *Sphenopteris amoena*, *Sphenopteris* sp., *S. obtusiloba*, and *Trigonocarpus* sp.

Correlative strata were examined in several areas, and each area yielded substantially different plant assemblages. Vertical and lateral changes in floral assemblages in the study area, often accompanied by shifts in lithofacies, suggest that sedimentological factors influenced fossil plant distribution significantly. The magnitude of lateral variation in the flora underscores the importance of collecting at a number of sites at a given stratigraphic horizon in order to obtain a representative flora and in order to derive more reliable paleobotanical correlations.

Reprints

Reprint 20. Kentucky Coal, by James C. Cobb, Russell A. Brant, James C. Currens, and Allen D. Williamson, [19] p.

Covers the coal resources of Kentucky, coal production of Kentucky, compliance-coal resources of Kentucky, coal quality of the Hazard District, eastern Kentucky, stratigraphy of the Western Kentucky Coal Field, structure of the Western Kentucky Coal Field, coal resources of the Western Kentucky Coal Field, coal quality in the Western Kentucky Coal Field, stratigraphy of the Eastern Kentucky

Coal Field, structure of the Eastern Kentucky Coal Field, coal resources of the Big Sandy District, coal quality in the Big Sandy District, coal resources of the Hazard District, coal resources of the Licking River District, coal quality of the Licking River District, coal resources of the Princess District, coal quality in the Princess District, coal resources of the Southwestern District, coal quality in the Southwestern District, coal resources of the Upper Cumberland District, and coal quality in the Upper Cumberland District.

Reprint 21. Oil and Gas Developments in East-Central States in 1984, by Ray C. Gilbert, G. L. Carpenter, Frank H. Walker, and Jacob Van Den Berg, p. 1534-1542.

In Kentucky, drilling activity declined significantly in 1984. Permits issued were down from 6,779 in 1983 to 6,258 in 1984, and 2,671 of those issued in 1983 were allowed to expire without drilling. Late reporting of 1983 completions and improved reporting of 1984 completions resulted in a statistical increase of 129 percent in exploratory tests and 151 percent in development wells reported. Of a total of 1,994 exploratory tests in 1984, 559 (28 percent) were successful. The intense drilling activity of the past few years in the Cumberland Saddle has diminished. Increased drilling for gas in eastern Kentucky resulted in a number of gas producers in the "Big Lime" (Mississippian) in Whitley County and in the "Big Lime" and Devonian shale of Leslie County, and in the discovery of both oil and gas in Middle and Lower Ordovician beds in Clay County. In south-central Kentucky, the main emphasis has been on extensions of oil production from the "Corniferous" (Clear Creek) in Warren County. The most significant developments in western Kentucky occurred in Henderson County, where numerous wells have been completed producing from various zones in the Middle Mississippian. Kentucky produced 7,787,513 bbl of oil in 1984, 1.3 percent less than in 1983.

Reprint 22. Limestone Resources for the Coal Industry: An Evaluation of the Newman Limestone (Mississippian) on the Cumberland Overthrust Block, Southeastern Kentucky, by Garland R. Dever, Jr., Thomas L. Robl, and Jack R. Moody, 13 p.

The Eastern Kentucky Coal Field is one of the major coal-producing regions of the world. With 1,240 underground mines and 1,800 surface mines active in 1982, the region is a large market for limestone

products: rock dust for explosion abatement in underground coal mines; agricultural stone for surface-mine reclamation; construction stone for haulage roads; and, to a lesser extent, high-calcium limestone for acid-drainage control.

Movement of the Cumberland Overthrust Block has brought the Newman Limestone (Mississippian) to the surface on Pine Mountain in the southeastern part of the coal field, a region otherwise generally devoid of operable limestone deposits. To evaluate the Newman as a potential source of low-silica stone ($<4\% \text{ SiO}_2$) for rock dust, 2,736 foot-by-foot samples for major-element analysis have been taken at 10 sites along the 125-mile length of Pine Mountain.

Analytical results show that thick deposits (41-64 feet) of low-silica stone are present in the lower Newman of Harlan and Letcher Counties. These deposits in the central part of the outcrop belt may be sufficiently thick to produce by selective quarrying or underground mining. Production, however, will be complicated by the steep dip of the beds and by displacement along small-scale faults within the Newman. In the northeastern and southwestern parts of Pine Mountain, low-silica zones range from 10 to 28 feet in thickness, but probably are too thin to produce economically from the dipping beds.

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Information Circular 20. 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.

Information Circular 21. 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.

Information Circular 22. 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.

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