

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



*William W. Mather
First State Geologist
of Kentucky—1838*

SESQUICENTENNIAL ANNIVERSARY
*of the
Kentucky Geological Survey
1838-1988*

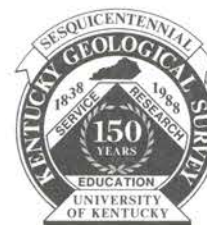
**ANNUAL
REPORT
1987-1988**

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

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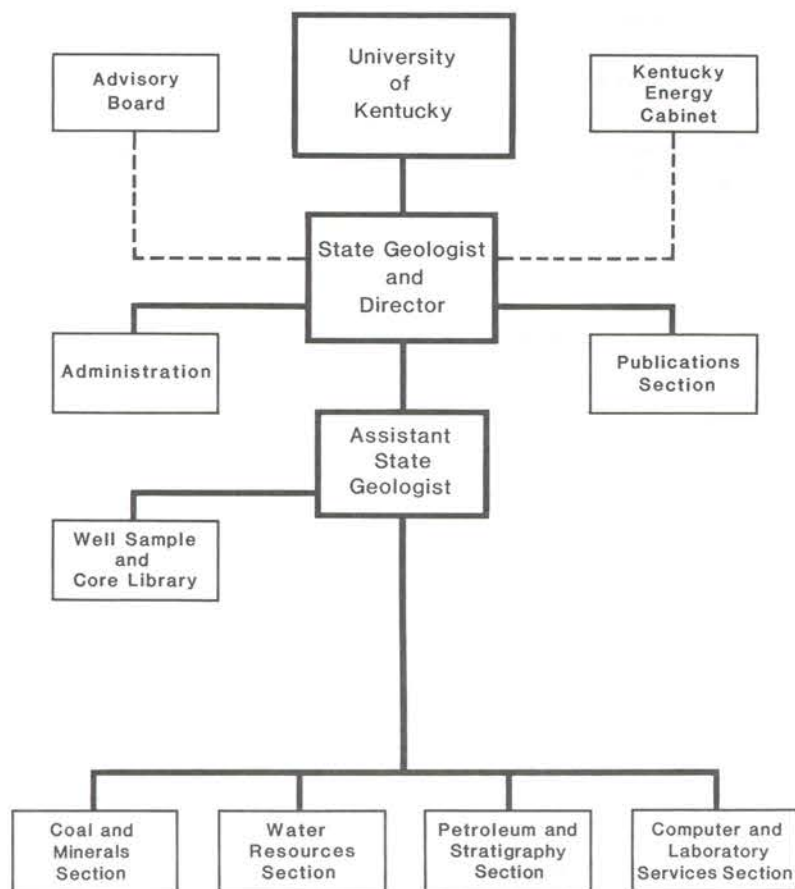
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CONTENTS

	Page
Foreword	1
Public Services	3
Well Record Library	3
Well Sample and Core Library	3
National Cartographic Information Center	5
Publication Sales and Data Distribution	6
Public Information	8
General Information	8
Coal	8
Industrial and Metallic Minerals	10
Petroleum and Stratigraphy	10
Water Resources	11
Committees, Boards, and Advisory Activities	12
National	12
State	14
Local	19
Research Activities	20
Coal	21
Industrial and Metallic Minerals	39
Petroleum and Stratigraphy	44
Water Resources	56
Other Research	64
Computer Services	68
Cooperative Programs	70
Topographic Mapping	70
Water Resources	71
Publications	75
Guidebooks	76
Information Circular	76
Reprint	76
Miscellaneous	76
In Press or Editing Completed	78
Papers by Staff Members in Outside Publications ..	78
Talks by Staff Members to Professional Groups	85
Personnel	91
Professional Staff	91
Clerical and Technical Staff	95
Student Assistants	96

ORGANIZATION OF THE KENTUCKY GEOLOGICAL SURVEY



FOREWORD

In 1988 the Kentucky Geological Survey celebrated its sesquicentennial anniversary: it was in 1838 that William W. Mather was commissioned by the Kentucky General Assembly to make the first official geological reconnaissance of Kentucky and became Kentucky's first State Geologist. He recognized the mineral districts in different parts of the State and generally delimited the coal fields of eastern and western Kentucky and the limestone areas of central and southern Kentucky. He identified established and potential mineral resources such as coal, iron ore, limestones, sandstones, clays and shales, and petroleum. Mather also noted the State's abundant surface-water resources and their potential to economically transport mineral, agricultural, and manufactured products.

Since Mather's day, 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 project to determine how much of Kentucky's 92 billion tons of coal is actually available for mining; a study of the limestone resources in eastern 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; an experiment to construct an artificial aquifer in coal-mine spoils to supply water for future industrial and residential development; a major hydrogeology study involving the quantity and quality of ground and surface water in the Kentucky River drainage basin; and stratigraphic studies in the Eastern and Western Kentucky 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.

In its sesquicentennial year, the Survey was fortunate to move into the new Mining and Mineral Resources Building on the University of Kentucky campus. The new building was dedicated April 8, 1988, and will provide the Survey with its own laboratory facilities for the first time, enlarge its computing capabilities, and increase space for the Well Record Library.

In celebration of its Sesquicentennial, the Survey held a series of seminars exploring the major areas of geologic research at the Kentucky Geological Survey. The speakers were nationally recognized authorities in their fields, and well versed in the broader aspects of geology's role in society and public policy. On June 16, 1988, the KGS held an open house at its new building, followed by a conference on the Survey's 150 years of service to the Commonwealth, and a banquet.

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, 1987-June 30, 1988).

PUBLIC SERVICES

Well Record Library

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

The Survey is obligated to make all such data and records available and open to the public. Facilities in the Well Record Library for examination of records are used daily by representatives of industry, government, academic institutions, and the general public. An estimated 28,000 records were duplicated in reply to mail orders, telephone requests, and walk-in requests in fiscal year 1987-88.

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 institu-

tions, and the general professional community. Space and facilities are provided in the library for examination of these materials. Sampling of cuttings and cores is permitted under very strict controls, provided sufficient quantities of the required samples are available. Persons permitted to sample must sign an agreement to return all samples not destroyed, including thin sections, polished slabs, and plugs, and to turn in bound copies of their reports to the Library. This policy allows the Survey to build on the information it can make available to others. Results of specific studies will be held confidential for 1 year, if requested.

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

The Kentucky Geological Survey Well Sample and Core Library is the fifth largest repository of its type in the country, and contains over 15,600 sets of well cuttings and in excess of 1,250 cores on file, representing over 19 million feet of vertical drilling. Over 197,000 feet of sample sets (101 sets) and about 42,000 feet of cores (45 cores) have been added to the collection during the fiscal year. An Information Circular (ser. 11, IC 3), "Catalog of Well Samples, Cores, and Auger Samples on File at the Kentucky Geological Survey," is available for purchase through Publication Sales, and updates can be provided upon request.

The University recently purchased a warehouse from the American Tobacco Company adjacent to the main campus. In July 1986, after the University made moving funds available to the Survey, the Well Sample and Core Library began moving out of the Reynolds Building into the American Building. Of the total 54,000 square feet allotted to the Survey, approximately 44,000 square feet will be used for storage of rock materials, and 10,000 square feet will be used for ex-

amination areas, a rock processing laboratory, and office space. The Library currently occupies about 21,000 square feet.

The Well Sample and Core Library so far has moved about 75 percent of all rock materials from the Reynolds Building. The move will not be final until renovation of the American Building is completed. This move was probably the most ambitious ever undertaken on campus. The following major jobs have been accomplished: 184 sets of well cuttings were picked up at collection stations statewide, 17,000 feet of core was cut in half and reboxed, and over 500 slabs of rock were cut and polished. In addition, 144 visitors, representing 92 organizations, visited the Library.

The Library is still located at 670 South Broadway in Reynolds Building No. 1, and is open from 8:00 a.m. to 4:30 p.m., Monday through Friday. For information, call (606) 257-1677.

National Cartographic Information Center

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

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

South Dakota, and the USGS Branch of Global Seismology and Geomagnetism in Denver, Colorado.

Close coordination between KGS-NCIC and the KGS Publication Sales Office makes it possible for many persons to obtain the desired materials or information as the result of a single visit or inquiry to the Kentucky Geological Survey. The Survey's move to new quarters in the Mining and Mineral Resources Building at the corner of Rose Street and Clifton Avenue on the University of Kentucky campus not only provided greatly improved facilities, but also allowed the Publication Sales Office and the KGS-NCIC Office to be located adjacent to each other, thereby providing better service to persons seeking maps or cartographic information. Although in some cases a user may be referred to another State or Federal agency or a private firm as the source for a particular product, a custom-tailored response from KGS-NCIC assures that each map user receives the best information for a particular problem or application.

A total of 429 individual inquiries for cartographic information were answered by KGS-NCIC during the 1987-88 fiscal year. Of these requests, 146 were for information about currently available maps and publications, 109 were for aerial photography or remote sensing data, 125 were for geodetic-control information, and 49 were for historical or archival cartographic data. Ordering assistance to obtain the desired materials was provided on 131 of the requests.

During the year, work was completed on mapping and field-checking subsidence features from satellite imagery for the western Kentucky subsidence project. Volume 17 of the KGS-NCIC Newsletter was issued in April.

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.

In January 1988, the Publication Sales Office moved to new quarters on the first floor of the newly constructed Mining and Mineral Resources Building, located at the corner of Rose Street and Clifton Avenue on the University of Kentucky campus. The new sales area, which was designed specifically for that purpose, offers much-improved facilities for serving the public. Convenient parking for customers is located in the University of Kentucky Faculty Club parking lot behind the Mining and Mineral Resources Building.

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

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

The Publication Sales Office handles a large volume of requests for maps and reports. During the past fiscal year, this office distributed approximately 20,000 maps and 3,000 reports, as well as 32,000 copies of well records and other miscellaneous items, resulting in income of approximately \$95,000. Staff members who work in Publication Sales take great pride in helping customers find needed information and offering prompt and efficient service. Most mail orders are shipped out the next day after they are received.

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

Public Information

General Information

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

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

In order to further our goal of information dissemination, the Survey sponsors an Annual Project Review of Survey research, which is open to the public. This year's review is tentatively scheduled for December 16, 1988.

Coal

The Coal and Minerals 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 Section. Geologic records, which include core and outcrop de-

scriptions, field notes, and chemical analyses, are archived in files for permanent storage. Most records are micro-filmed 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 and Minerals Section are: an index of 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 and Minerals Section public service is consultation about the geology of coals in the Eastern and Western Kentucky Coal Fields. These consultations may be with landowners interested in the geology of their property, or with government agencies dealing with problems of concern to Kentucky.

Nearly 1,000 requests for coal-geology information are received by the Coal and Minerals Section each year. 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. The International Carboniferous Congress, which meets every 4 years, convened in Beijing, China, during the summer of 1987, and the Kentucky Geological Survey was represented by four talks. Three of the papers will be published in the proceedings of the Congress. Two field trips were attended during this Congress. One investigated the coal-bearing rocks of north-central China, and the other investigated the Carboniferous deposits in south-central China. Cooperative research with specialists on the geology of Kentucky's coal-bearing rocks from around the world was promoted.

The International Geological Congress will meet in Washington, D.C., in 1989. As part of this meeting the Carboniferous geology of Kentucky will be presented for 5 days of a 10-day field trip from St. Louis, Missouri, to Washington,

D.C. The route will traverse the Eastern and Western Kentucky Coal Fields and the Mississippian Plateaus region of Kentucky. A manuscript describing the Carboniferous geology along the route in Kentucky has been submitted for review and will be published as a guidebook by the Congress.

Work has also begun for the 1989 Geological Society of America Coal Division field trip. This field trip will traverse both coal fields of Kentucky. Geological sites are being described, and a few chapters of the manuscript have been written.

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

Industrial and Metallic Minerals

The Coal and Minerals Section also provides assistance to industry representatives seeking information on nonfuel mineral resources in Kentucky. Requests about resources commonly concern limestone, dolomite, clay, shale, sand and gravel, sandstone, barite, fluorspar, zinc, and lead. The Coal and 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

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 2,000 individuals, companies, and agencies annually. In addition, the Petroleum and Stratigraphy Section answers more than 1,800 telephone and walk-in requests annually on a broad range of subjects relating to 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, has severely taxed the Survey's resources and greatly limits the time available for research projects. Although permits issued during 1987 decreased to approximately 1,800, the staff of the Petroleum and Stratigraphy Section continues to serve the public and the petroleum industry to the best of its ability. Major efforts to computerize additional records and to develop the capability to produce computer-plotted oil and gas well-location maps highlight accomplishments of the past year. A long-term project to electronically store and preserve the paper well-record files was initiated in 1986, and progress continues to be made.

Water Resources

The Water Resources Section provides daily consultation on both water quality and quantity to the public. During the past year the Section answered approximately 500 requests for surface-water and ground-water information from industry, municipalities, State regulatory agencies, and private citizens.

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

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

Committees, Boards, and Advisory Activities

National

AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS

Patrick J. Gooding is an alternate delegate to AAPG.

Dr. Donald C. Haney is a member of the AAPG Governmental Affairs Committee.

Dr. Ian M. Johnston served as chairman of District 8 (Kentucky) of the AAPG Committee on Statistics of Drilling (CSD). This committee is responsible for compiling drilling statistics for the entire onshore and offshore United States.

ASSOCIATION OF AMERICAN STATE GEOLOGISTS

Dr. Donald C. Haney was elected vice president of the Association of American State Geologists in 1987 and is currently president elect. He continues to serve on the Liaison Committee of the Association of American State Geologists, which is comprised of eight State Geologists. The Committee visits Washington, D.C., twice annually to confer with officials of Federal agencies, members of Congress, and staff members of Congressional committees that have interest in matters relating to mineral, water, energy, and environmental resources.

Dr. Haney also serves on the Association of American State Geologists-U.S. Geological Survey Cooperative Planning Committee and is chairman of the AASG National Geologic Mapping Steering Committee.

The 1988 Annual Meeting of AASG was held in Lexington from June 12-15 in conjunction with the KGS Sesquicentennial Celebration. Geologists from 43 states and several Federal agencies attended the meeting hosted by the KGS, which was one of the organization's most successful ever. The meeting included an open house in KGS's new building and a field trip to Natural Bridge State Park. The entire KGS staff contributed to the meeting's success.

GEOLOGICAL SOCIETY OF AMERICA

James C. Cobb is Vice Chairman of GSA's Coal Geology Division, and Donald C. Haney is a member of the GSA Council.

Dr. John D. Kiefer has been appointed the Geological Society of America Agency Representative for the Kentucky Geological Survey. As Agency Representative, Dr. Kiefer handles correspondence and requests for information regarding GSA membership and activities.

INTERSTATE OIL COMPACT COMMISSION

Dr. Donald C. Haney served as chairman of the Research Committee of the Interstate Oil Compact Commission, which conducts research activities for the 33 member states, from 1984 to 1987. The Committee addresses research issues, including geology, engineering, and management problems, related to exploration, development, and production of petroleum.

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

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

MAXEY FLATS STEERING COMMITTEE

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

NATIONAL WATER QUALITY ASSESSMENT PROGRAM

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

State

EASTERN OIL SHALE SYMPOSIUM

Martin C. Noger was appointed a member of the Technical Program Advisory Committee of the Eastern Oil Shale Symposium, sponsored by the Commonwealth of Kentucky and the Kentucky Energy Cabinet in 1987. The Committee is responsible for developing the format of the technical program, contacting and inviting speakers, and assisting in promoting the Symposium. Mr. Noger, who served as the Tar-Sand Program chairman for the 1985, 1986, and 1987 symposiums, has again been asked to serve in this capacity for the 1988 Symposium, and is presently finalizing plans for the session, to be held November 30-December 2, 1988.

GEOLOGICAL SOCIETY OF KENTUCKY

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

Margaret Luther Smath completed her 2-year term as secretary of the Society in December 1987. She was in charge of all member records, minutes, and correspondence.

David A. Williams was elected president for 1988, and Patrick H. McHaffie was elected to a 2-year term as secretary, beginning in 1988.

James S. Dinger is Chairman of the Membership Committee, which verifies potential members' credentials.

GOVERNOR'S EARTHQUAKE HAZARDS AND SAFETY TECHNICAL ADVISORY PANEL

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

The advisory panel was directed to analyze data regarding seismic risks in Kentucky and to make specific recommendations for hazard mitigation, public education and awareness, emergency response planning for government and the private sector, and development of codes and policies to promote public safety. The panel, which is made up of members appointed by the Governor and associate members selected to advise in specialized areas, held meetings at Louisville, Lexington, and Elizabethtown, Kentucky, during the past fiscal year. In addition, a number of special committee meetings were held at various sites throughout the State. Dr. Kiefer also serves as chairman of the Seismic Probability Assessment Committee.

The panel has sponsored public meetings in association with the Central United States Earthquake Consortium (CUSEC), an organization of states most immediately threatened by any New Madrid tectonic activity. The Consortium held its annual meeting in Collinsville, Illinois, in November, and Dr. Kiefer served as chairman of the geology/seismology parallel disciplines session. In January the geology/seismology groups from Kentucky, Indiana, and Illinois met again in Bloomington, Indiana, to develop research programs of mutual interest.

Individual members of the panel presented numerous talks to civic groups, agency personnel, schools, and professional meetings. Proposals for seismic research have

been prepared and submitted jointly by the KGS and the University of Kentucky Departments of Geological Sciences and Civil Engineering. Although a limited amount of seismic research is ongoing, and the Kentucky Seismic Network, a series of seismic stations, is in operation, a lack of funding continues to severely hamper research.

The panel, in association with the Division of Disaster and Emergency Services, has developed a 5-year seismic-safety plan to guide Kentucky activities, and prepares an annual report of its activities for the Governor. The next meeting of the Panel is scheduled for Owensboro, Kentucky, November 15-17, 1988.

GOVERNOR'S GROUND-WATER ADVISORY COUNCIL

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

KENTUCKY ANTHROPOLOGICAL RESEARCH FACILITY ADVISORY COMMITTEE

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

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 serves on the Kentucky Water-Well Drillers' Certification Board. The seven-member board was established by the 1984 General Assembly to regulate water-well drilling in an effort to protect the ground-water resource of the State. The board has developed regulations concerning the qualifications for those people wishing to become certified water-well drillers in Kentucky and has implemented water-well record forms to be completed for wells drilled under the certification program. Those wells include all 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.

MAXEY FLATS ADVISORY TASK FORCE

Dr. Donald C. Haney was appointed to the Governor's Maxey Flats Advisory Task Force, the purpose of which is to gather data concerning the overall conditions of the Maxey Flats Low-Level Nuclear Waste Repository in Fleming County, Kentucky, and to advise State officials and others

on procedures and actions necessary for its closing. Dr. Haney is being assisted on the task force by Dr. John D. Kiefer, Assistant State Geologist.

STATE WATER MANAGEMENT TASK FORCE

The resolution establishing the State Water Management Task Force was renewed by the 1988 General Assembly. The purpose of the Task Force is to work with State and Federal agencies, industry, and with the general public to promote the proper protection, development, and utilization of Kentucky's water resources and develop priorities and strategies for addressing the State's present and future water needs.

Representative Walter Blevins has again been named Chairman of the Task Force, and Dr. John Kiefer, Assistant State Geologist, will continue to serve as the KGS representative.

The Task Force was instrumental in developing and securing the passage of a bill establishing a revolving loan fund to construct and upgrade wastewater treatment facilities. The State will put up 20 percent of this fund, which will receive an 80 percent match from the U.S. Environmental Protection Agency. A second revolving loan fund will be used for a variety of other water infrastructure projects.

The Task Force also developed and sponsored legislation that would have required each county to develop an alternative water-supply plan. Although the legislation failed, its timeliness was underscored by the 1988 drought, and similar legislation will probably be prepared for introduction during the 1990 legislative session.

UNIVERSITY OF KENTUCKY DEPARTMENT OF GEOLOGICAL SCIENCES

Dr. Donald C. Haney, Dr. James C. Cobb, and Dr. James S. Dinger have been named Adjunct Associate Members of the graduate faculty of the Department of Geological Sciences, where they are supervising graduate students in hydrology, coal, and other programs.

Local

GEOLOGICAL SOCIETY OF KENTUCKY, LEXINGTON CHAPTER

Richard E. Sergeant is President, James S. Dinger is Vice President, and Robert R. Elkin is Secretary-Treasurer of the Lexington Chapter of the Geological Society of Kentucky.

LEXINGTON-FAYETTE URBAN COUNTY GOVERNMENT TECHNICAL ADVISORY COMMITTEE

Several members of the KGS staff have served in an advisory capacity to the Lexington-Fayette Urban County Government Division of Planning. Activities include reviews of planning documents and subdivision plans to delineate hazards such as sinkholes, subsidence, and flooding.

Members of the Water Resources Section also attended meetings and served in an advisory capacity to the Lexington-Fayette Mayor's Committee on Water Quantity and Quality.

NATIONAL SPELEOLOGICAL SOCIETY, BLUE GRASS GROTTO

James C. Currens is a member of the Board of Directors of the Blue Grass Grotto of the National Speological Society.

UNIVERSITY OF KENTUCKY BUILDING NAMING COMMITTEE

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

RESEARCH ACTIVITIES

Basic research in geology and hydrology has formed the cornerstone of the Kentucky Geological Survey since its inception. This dedication to the identification and characterization of the Commonwealth's vast natural resources has continued since the first official geological and mineralogical investigations 150 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, a number of energy-related special projects are funded by grants or contracts. Projects in all of these areas of research are described in greater detail in the following sections.

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

When W. W. Mather was commissioned by the Kentucky General Assembly in 1838 to conduct the first geological survey of Kentucky, nearly one-third of the report was about Kentucky's coal resources. Mather conducted the first coal-resource investigation for Kentucky. He recognized the general boundaries of the Eastern and Western Kentucky Coal Fields and the rocks making up the coal fields. He correctly identified Kentucky's coal resources as bituminous in rank and of three types: (1) common bituminous caking (coking), (2) bituminous noncaking, and (3) cannel. He also recognized steamboats, sugar refining, and iron furnaces as the biggest future markets for Kentucky coal.

Mather's philosophy and scientific observations on coal geology are still of great interest to today's coal geologists. Mather gave us the benefit of his philosophy about natural resources in Kentucky when in 1838 he wrote:

During the reconnaissance of the past season, I had occasion to examine many of the coal mines which are now wrought in Kentucky. The system generally pursued is a very defective one, and must eventually cause a great expense to be incurred, or result in the abandonment of the mines.

Mines and beds of minerals are of public utility, and when exhausted they cannot be renewed; hence it becomes a matter of moment, not only to the proprietor, but to the people, State, and the Nation, that they should be wrought in such a manner as shall produce the greatest quantity and best quality of the materials with the least waste and expenditure of labor, time, and money.

Mather understood at the beginning of Kentucky's great rise to leading the Nation in coal production that care must be taken to use these resources wisely. These same resources are even more important in today's society because coal now produces more than 60 percent of the electrical power used in this country. It generates more than 20 percent of Kentucky's general revenue fund.

Most of the previous 150 years of geological work on Kentucky's coal has been to locate and characterize these resources. A new question is now posed for research to

unravel: how much of Kentucky's coal is available for mining and what are the principal obstacles to future production? A related question is how long will Kentucky's resources be of sufficient mineability to allow the high levels of current coal production? There will probably never be a precise answer to this question, but estimates based upon realistic data can be made. These estimates will be important in planning Kentucky's economic future.

In 1987, Kentucky achieved an all-time record coal production of 177.3 million tons, according to the Kentucky Department of Mines and Minerals Annual Report. The Eastern Kentucky Coal Field produced 126.4 million tons of coal; 53.6 million tons of this total were from surface mines and 72.8 million tons from underground mines. The Western Kentucky Coal Field produced 50.9 million tons of coal; 20.6 million tons of this total were from surface mines and 30.2 million tons from underground mines. Kentucky's total underground coal production was 103.1 million tons, and total surface production was 74.2 million tons. Kentucky's 1987 coal production was up 11.7 million tons from 1986. The average price per ton in 1987 was \$24.8 per ton, down from \$26 per ton in 1986.

Production statistics are a direct indication of the general condition of resources in the Commonwealth. The record high coal production for 1987 during a year of lower coal prices and a declining work force suggests for the near term favorable availability, mineability, and recoverability of Kentucky coal resources.

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

CHESNUT, Donald R., Jr.

The study of Kentucky's most economically important rocks, the coal-bearing strata, often involves many methods of investigation, such as stratigraphy, structural geology, and paleontology. One of the ultimate goals of these investigations is the development of useful lithostratigraphic, biostratigraphic, chronostratigraphic, and structural frame-

works for the coal-bearing rocks. These frameworks can then be used to predict such characteristics as coal resources, coal quality, and mining conditions.

A recently established lithostratigraphic and geometric framework for the coal-bearing rocks of eastern Kentucky was used in the Coal Availability for Economic Development project (*see below*) to describe the surface and subsurface coal resources of Noble Quadrangle in Breathitt, Perry, and Knott Counties, and Middlesboro North Quadrangle in Bell County. Four cross sections drawn across the Noble Quadrangle were constructed from oil and gas records. These cross sections show that in the subsurface massive sandstones of the Bee Rock Member of the Lee Formation occur at the expense of the coal-bearing Alvy Creek unit of the Breathitt Formation. Only minor coals were reported in the Bee Rock Member. The coal-bearing Grundy and Pikeville units of the Breathitt overlie the Bee Rock and occur in the subsurface throughout the quadrangle. Coal beds are commonly reported in these units, but thickness data are not available because of a lack of deep subsurface coreholes and high-resolution density logs. The coal-bearing Hyden, Four Corners, and Princess units of the Breathitt Formation occur at the surface and subsurface in the Noble Quadrangle. Most mining in the quadrangle in the past has occurred in the Four Corners and Princess units, but the near-surface coals of the Hyden unit may become more important in the immediate future as the upper coals are depleted.

Description of the coal resources of the Middlesboro North Quadrangle is complicated by geologic structure. This quadrangle is the most structurally complex area in the Eastern Kentucky Coal Field. It contains several major structural features, including the Pine Mountain Thrust Fault, Rocky Face Fault, Middlesboro Syncline, and Middlesboro Impact Structure. Many minor structural features, such as the Canada Mountain and Rocky Face Anticlines, as well as several unnamed faults, also occur. Research is made more difficult by the lack of subsurface data such as oil and gas logs and core descriptions. Three cross sections based on surface and subsurface data were constructed across

the Middlesboro North Quadrangle. The cross sections reveal that the Middlesboro North Quadrangle has fewer coal resources than adjacent coal-bearing quadrangles because (1) much of the quadrangle occupies a large topographic basin (not to be confused with the smaller Middlesboro Basin) situated between Pine, Cumberland, and Black Mountains and higher elevations of Log Mountain, thereby deleting the coal-bearing rocks of the upper half of the Breathitt Formation, and (2) the Lee Formation is close to the surface at this location because of the influence of the Canada Mountain and Rocky Face Anticlines and the Middlesboro Impact Structure. Most of the coal resources in this quadrangle occur in the Grundy and Pikeville units.

First steps toward developing a chronostratigraphic framework for the coal-bearing rocks of eastern Kentucky have been taken. A cooperative agreement with a research laboratory in West Germany has resulted in the first radiometric date for a Carboniferous rock in Kentucky, a flint-clay sample from the Fire Clay coal of eastern Kentucky. The flint clay represents a very extensive volcanic ash deposit that fell into the peat swamp of what is now the Fire Clay coal. Swamp conditions chemically altered the ash to a flint clay. Analysis of two volcanic minerals in the ash, sanidine and plagioclase, revealed an age of 311 million years for the volcanic ash deposit. The Fire Clay coal bed is therefore of a similar age. Flint clays from other coal beds are being sampled and analyzed for additional radiometric dating. The resulting dates will be used to establish a chronostratigraphic framework for the coal-bearing rocks.

Three manuscripts have been prepared and are being edited, while a fourth manuscript is in preparation. One manuscript concerns the stratigraphic and structural framework of the Carboniferous rocks of the Eastern Kentucky Coal Field. Discussions on the occurrence of surface and subsurface coal-bearing rocks are included in this paper, which will probably be published by the Survey as an Information Circular. Another manuscript describes the evidence for a regional unconformity between the coal-bearing rocks and the underlying Mississippian rocks, and will probably be

published in an outside journal. The third paper, also to be published in a journal, discusses how Appalachian mountain-building affected the Carboniferous rocks of the Eastern Kentucky Coal Field. The fourth paper, in preparation, interprets the depositional environments of the Carboniferous rocks in the coal field. This paper emphasizes the various controversial interpretations of environments of deposition for the Pennsylvanian coal-bearing rocks.

INVESTIGATING THE ORIGINS OF COMMERCIAL-QUALITY COAL DEPOSITS

COBB, James C.

In the search for additional scientific evidence about the origin of coal, much attention has recently been given to tropical peat swamps in Southeast Asia. During July and August of 1987 a group of geologists from the United States and Indonesia conducted an extensive field investigation of the coastal peat swamps of Sumatra, Indonesia. Samples of peat were collected from depths up to 50 feet from 21 sites on the domed coastal swamps. Also, samples of water and sediments were collected from these swamps and from rivers, lakes, and seas adjacent to the coastal swamps. Nearly 1,000 samples were collected for microscopic, mineralogic, chemical, and physical analyses for comparison with other peat swamps and with coal deposits.

The general origin of coal has been known since the middle of the last century. Although it is almost universally agreed that coal originates in peat swamps, there are differences of opinion regarding specific details about how commercial-quality coal is formed. A current geologic model explaining the origin of many commercial coals is based on peat forming in swamps in low-lying, deltaic environments. Most deltaic environments, however, have high sedimentation rates and high rates of peat destruction by erosion, which precludes the production of commercial coals. By comparison, the peats of Sumatra are very thick, extensive, and low in sulfur, ash, and other contaminants. The Sumatra peat swamps are possible modern equivalents to

the Pennsylvanian coal swamps that existed 300 million years ago.

The specific characteristics of the Sumatra peat swamps that make them so interesting to coal geologists are their equatorial location, extremely high rainfall, domed geometry, great thickness (greater than 50 feet), extensive distribution (covering thousands of square miles), very low ash content (less than 2 percent), and very low sulfur content. In other words, if the Sumatra peat deposits were buried and preserved for coalification, they would make excellent commercial-quality coals.

Investigations into the origin of the Sumatra peat swamps and the geologic processes at work are giving geologists a greater understanding about the origin of coal. This knowledge of present-day peat deposits will provide coal geologists with a valuable tool for interpreting data from drill cores and chemical analyses of coals that formed under similar conditions in the geologic past.

LABORATORY FACILITIES FOR COAL ANALYSIS

COBB, James C., AMARAL, Eugene J., and CHESNUT, Donald R., Jr.

The Kentucky Geological Survey published the first analyses of Kentucky coal in 1856 in the "Report of the Geological Survey in Kentucky, Made During the Years 1854 and 1855." Dr. Robert Peter was the chemical assistant to the Survey and was responsible for the first chemical analyses of Kentucky coal by the Survey. Included in these early analyses were total volatile matter, total coke, moisture, combustible volatile matter, fixed carbon in coke, ashes, and specific gravity. Within the next few months the Kentucky Geological Survey will once again have the ability to perform not only the analyses done 150 years ago but also the advanced analyses required in today's world.

New and well-equipped laboratories are being set up at the Mining and Mineral Resources Building for the characterization of Kentucky coal resources. The new facilities include laboratories for chemical, petrographic, and paleontologic analysis of coal and coal-bearing rocks. Laboratories

for the preparation of samples for analysis are also being set up. Equipment includes a Leco MAC-400 to determine moisture, ash, fixed carbon, and volatile matter of coal and coke; a Leco CHN-600 to determine carbon, hydrogen, and nitrogen in solid or liquid organic matter; a Leco SC-132 to determine total sulfur in coke, coal, and petroleum; a Leco AF-600 to determine the various deformation temperatures of ash from coal and coke; and a Leco AC-300 to determine the calorific value of coal, coke, and petroleum.

Coal petrography is an important tool for geologic and geochemical characterization of coal resources. A Zeiss UEM reflectance microscope equipped with camera, photometry, grating monochromator, automated stage, and computer automation has been installed in the new petrography lab. The microscope is programmed for the following computer-automated procedures:

Manual Photometry Program: Allows the measurement of reflectance intensity of a coal sample from a number of different spots on the sample or the measurement of reflectance intensity of a single spot on the sample over a defined period of time. Results are used to characterize coal by rank.

Vitrinite Reflectance Program: Allows computer-automated vitrinite-reflectance analysis of coal samples. Results are used to characterize coal by rank.

Coal Analysis Program: Allows the rapid collection of petrographic data using automated reflectance microscopy. It was designed to evaluate coal for coke making but also has several geologic applications. The program gives a rapid and statistically significant maceral analysis and the rank maturity of these macerals.

Lambda Scan Program: Allows the collection of light-intensity photometric data (transmission, reflection, or fluorescence) from samples at selected points, within a selectable spectral range, at fixed wavelength intervals.

Support equipment purchased for the coal laboratories includes a Holmes Pulverizer Model 350, a Holmes Crusher Model 201xL, a Riffle Splitter Model 15xL, a Riffle Splitter

Model 70xL, a Buehler Ecomet IV Polisher, a Buehler Euromet I Power Head, a Buehler Belt Grinder, and a Buehler Polisher/Grinder. New X-ray diffraction and fluorescence equipment is also available for mineral and trace-element analyses of coal and ash.

The setup of this equipment is expected to take several months, as some modification to the labs is required.

The Kentucky Geological Survey is grateful for the assistance of Dr. Susan Rimmer of the UK Department of Geological Sciences for her help in designing the coal laboratories and in the selection of equipment for the laboratories.

COAL AVAILABILITY FOR ECONOMIC DEVELOPMENT

COBB, James C., SERGEANT, Richard E., DAVIDSON, O. Barton, STICKNEY, John F., ANDERSON, Warren H., and SMATH, Richard A.

Kentucky's coal is a nonrenewable natural resource that has produced 6.148 billion tons over the past 200 years. Another estimated 6 billion tons were lost from future production because it was left in pillars and barriers, and lost in cleaning. Since the United States consumes about 900 million tons of coal per year, the great magnitude of coal already produced causes concern about how much coal remains in Kentucky to be produced.

Few states are as dependent on a single natural resource for their economy as Kentucky is on coal. The value of Kentucky's 1987 coal sales was \$4.3 billion. Taxes from coal-related business generate 20 percent of the Commonwealth's general revenue fund. Therefore, it is vital for the future economic security of the Commonwealth to know how much coal remains to be mined. Since coal is an exhaustible resource, the time will come when constraints such as decreasing thickness, increasing depth, declining quality, and declining mineability will impede the growth in production by adding cost factors that cannot be overcome by technological advances. Such additional costs could prevent Kentucky coal from competing in national and international markets.

Kentucky is indeed fortunate to have coal resources within the Commonwealth in great abundance. In 1983, the

Kentucky Geological Survey estimated that Kentucky had an original resource of 105 billion tons of coal in the ground before any mining took place. In 1987, taking into account coal production and losses due to cleaning and underground pillars, the remaining resources for Kentucky were estimated to be 92 billion tons. Although important as a starting point for more detailed studies of the resources available for mining, the estimates for original and remaining resources are not good indicators of the resources actually available for future mining under the general constraints of today's technology and economy.

The Coal Availability Study was conceived by the Kentucky Geological Survey and the U.S. Geological Survey to estimate the amount of coal available for mining, and more importantly, available for mine development.

The Matewan Pilot Study was the first coal availability study undertaken. The area of study was the Matewan 7.5-minute quadrangle in Pike County, Kentucky, and a small part of Mingo County, West Virginia. The Matewan Quadrangle contains 21 mineable coal beds. The original resources of the Matewan Quadrangle before any mining took place were estimated at 987 million tons. Surface and underground mining have removed 11 million and 118 million tons of coal, respectively. Surface restrictions from towns, roads, protected rivers, cemeteries, power lines, pipelines, and oil wells remove, at least for the near future, 18 million tons, while underground restrictions from oil wells and previous mines remove another 228 million tons. It is estimated that Matewan has an available deep coal resource of 324 million tons and an available surface resource of 289 million tons. The available coal resources are only 62 percent of the original resources. Surface mining has removed about 1 percent, deep mining 12 percent, surface restrictions 2 percent, and deep restrictions 23 percent.

Two additional factors further severely reduce the amount of coal that can actually be produced in the Matewan pilot area. The first factor is recoverability. Recoverability factors vary according to mining method. In conventional room and pillar mines 50 percent recovery is

expected. Auger mining recovers only 28 percent of the coal, while mountaintop-removal and contour strip mining can achieve 95 and 80 percent recovery, respectively.

The second factor is mineability, of which geologic conditions such as roof control and seam continuity are a major part. So, although 62 percent of the original resources are available for development, both recoverability and mineability factors not accounted for in the Matewan study further reduce the actual amount of coal that can ultimately be produced.

The mining of deeper seams, particularly by long wall methods, could adversely affect the mineability of higher seams by severely disrupting roof and floor strata. Therefore, whenever possible, mining should be done in such a way as to minimize the adverse affects on unmined resources.

Extrapolation of the findings from the Matewan Pilot Study into other areas of Pike County and eastern Kentucky is still premature until other quadrangles are completed. Studies in the Noble Quadrangle in Perry, Breathitt, and Knott Counties, and the Middlesboro North Quadrangle in Bell County are currently underway. The findings from these quadrangles, when compared to the findings from Matewan, will help determine the extent to which results can be extrapolated.

Similar quadrangle studies are underway in West Virginia and Virginia. These investigations will give further evidence for the extrapolation of results from small quadrangle areas to entire counties, districts, and coal fields.

The current plan for eastern Kentucky is to complete 10 to 15 more quadrangles in the next 3 to 4 years, which should be sufficient to permit meaningful statistical extrapolation of results into the entire coal field. Since funding is currently on a year to year basis, it is difficult to predict if this goal will be achieved.

These studies would not be possible without the assistance of the U.S. Geological Survey Branch of Coal Geology, the Kentucky Department of Mines and Minerals, and the Kentucky Natural Resources and Environmental Protec-

tion Cabinet. The Kentucky Geological Survey is truly grateful for their help.

The computer software in use for this project was developed by the National Coal Resources Data System, which is part of the U.S. Geological Survey Branch of Coal Geology. We acknowledge the close cooperation of the National Coal Resources Data System personnel, which has made this program possible.

KENTUCKY COAL PRODUCTION STATISTICS DATA BASE **DAVIDSON, O. Barton, and COBB, James C.**

The Eastern Kentucky Coal Field is currently the focus of a joint cooperative effort between the Kentucky Geological Survey and the U.S. Geological Survey to determine the amount of coal available for future mining. A major part of this effort is calculating remaining resources by subtracting mined-out coal from original resource estimates. To facilitate this process, the computerization of Kentucky's coal production statistics from the late 18th century to the present was undertaken.

The information on Kentucky coal production was taken from the Kentucky Department of Mines and Minerals annual reports. Production figures are stored in the Kentucky coal production data base by year, county, and type of mining. The use of computer spreadsheets enables the compilation of graphs to illustrate production statistics for a specific area or time.

From 1981 to 1983, Kentucky coal production declined from 158 million tons to 131 million tons. By 1984, however, production had jumped to over 170 million tons, and had reached a record high of 177 million tons by 1987. Analyses of such production trends assist in determining the effects various factors such as advances in mining technology; changes in environmental laws, economic conditions, and political events; or the effects of resource depletion on coal production.

A manuscript outlining coal production statistics by year, county, and mining method is currently being prepared for the Eastern and Western Kentucky Coal Fields. It is anti-

pated that this manuscript will be published as a Kentucky Geological Survey Information Circular in late 1988.

KENTUCKY COAL RESOURCES INFORMATION SYSTEM AND PUBLIC INFORMATION OFFICE

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

The Coal Resource Information Office has proved to be an excellent tool for the public and Survey employees since it opened in 1986. Facilities at the new Mining and Mineral Resources Building include a centralized coal records room and public workroom, both of which have greatly enhanced the efficiency of the office. A tremendous amount of coal data is currently available, including: (1) over 25,000 open-file measurements of coal-thickness data for nearly 50 beds, (2) over 1,700 coal-quality records for both eastern and western Kentucky, (3) field notes and sign-off reports prepared by KGS geologists for most of the coal-bearing quadrangles in the Eastern Kentucky Coal Field, (4) field notes and geologic-quadrangle overlay maps from the USGS-KGS geologic mapping program (1960-78), (5) geophysical and lithologic logs from various sources, and (6) customized computer printouts of Kentucky coal-production statistics from 1790 to 1987.

The Coal Resource Information Office has complete access to the KCRIS (Kentucky Coal Resources Information System) computerized data base, which contains information on coal thickness, quality, and production statistics. It is now possible to download open-file coal information onto magnetic media (floppy disks, tapes, etc.) through the Coal Resource Information Office.

The Kentucky Geological Survey also maintains a field office in Henderson, Kentucky, to collect geologic data concerning the coal resources of the Western Kentucky Coal Field and to provide information to the public. The Henderson field office personnel respond to telephone, written, and walk-in requests.

THE PROGRESSION OF LIFE

GREB, Stephen F.

In commemoration of the sesquicentennial anniversary of the Kentucky Geological Survey, an 18 X 22 inch color poster called "The Progression of Life" was printed. The poster is a full-color mosaic of 150 animals and plants designed to be used as a teaching tool and to be visually appealing. An index for the 150 fossils shown on the poster is printed on the reverse side, along with a brief introduction and geologic time scale. The poster follows the progression of life on earth from simple cells in the Precambrian Period, through Paleozoic marine invertebrate life, the rise of Paleozoic vertebrates, the first terrestrial plants and animals, the dinosaurs and other Mesozoic life, and ends with Cenozoic mammals and man.

Accompanying the poster is an open-file guidebook that presents short explanations for each of the creatures on the poster and special notes on the plants and animals that have lived in Kentucky throughout time. Of specific interest are some of the world-famous fossils these animals have left behind in Kentucky, such as (1) the Devonian-age fossil reef at the Falls of the Ohio, which has been preserved as a world historic site, (2) the first evidence of reptilian life, which was found in Early Pennsylvanian rocks of McCreary County, and (3) one of the largest finds of Ice Age mammal bones in the world at Big Bone Lick State Park.

SEDIMENTOLOGICAL INVESTIGATIONS OF THE CARBONIFEROUS ROCKS IN KENTUCKY

GREB, Stephen F.

As part of several ongoing projects in the Coal and Minerals Section of the Kentucky Geological Survey, especially the planning for next year's field trips with the International Geologic Congress and Geological Society of America, several short sedimentological studies on Carboniferous rocks in both the Eastern and Western Kentucky Coal Fields were completed. These included: (1) mapping of a fault-bound, debris-flow deposit, informally called the Poison Honey beds, along the Rockcastle River, (2) analysis of giant

foreset-bedding structures in the Rockcastle Sandstone in the same area, (3) paleocurrent analysis of exposed bedding surfaces in the Lee Sandstone at Laurel River Dam, (4) investigations of kettlebottoms in Kentucky mines, and (5) study of measured sections in both coal fields, especially the newly completed roadcuts near Pikeville, representing more than a dozen economic coal seams.

These studies help in understanding the depositional environments in which the coals were deposited so that geological problems relating to coal resources, quality, and mineability can be better understood.

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

SERGEANT, Richard E., SMATH, Richard A., and STICKNEY, John F.

In Kentucky, the underground mining of coal by shaft, slope, or drift methods began in the early 1800's. Surface subsidence is a consequence of underground mining in any coal-producing region where extensive underground coal mining has taken place.

Surface subsidence or ground failure over abandoned mines results when the overlying rocks above a mined-out coal seam collapse into the space created by the extracted coal. Subsidence in undeveloped areas such as pastures, fields, and woodlands may cause little or no damage, but subsidence in urban areas such as subdivisions or shopping centers can cause great property loss.

In order to determine the extent of suspected subsidence damage in parts of eastern and western Kentucky, the KGS, in cooperation with the Kentucky Division of Abandoned Lands, has recently completed a 3-year study to delineate and catalog suspected subsidence damage in Hopkins, Muhlenberg, Webster, Union, Ohio, and Boyd Counties. Originally, the investigation was focused on the five leading coal-producing counties in western Kentucky. However, once the study began, it became apparent that the urban areas in and around Ashland in Boyd County were experi-

encing the same subsidence problems found in many western Kentucky cities. Subsequently, Boyd County was added to the study.

Information relevant to suspected subsidence in the study area has been compiled into comprehensive catalogs for the six counties. These catalogs will be used to determine the magnitude of existing subsidence problems and to outline areas of potential concern. Also, information compiled in these catalogs will be useful during implementation of Kentucky's Subsidence Insurance Program, which began November 1, 1986.

During the course of the subsidence project, coal-mine records were needed to determine areas of possible subsidence. Two large-scale maps of mined-out areas were made, one for the Western Kentucky Coal Field and one for Boyd County. The map of Boyd County was especially difficult to construct because of a lack of mine maps on file at the Kentucky Department of Mines and Minerals. After extensive research, over 50 mine maps for Boyd County and over 200 Statewide mine maps were found from private sources. These maps were photographed and are now on file at the Department of Mines and Minerals.

To disseminate general information on subsidence and its effects on Kentucky homeowners, two pamphlets have been produced. One deals with western Kentucky, and the other with Boyd County in eastern Kentucky. In addition to addressing mine subsidence and its effects, the pamphlets also deal with other causes of subsidence-like damages, coal mining, and the Kentucky Subsidence Insurance Fund.

COAL RESOURCES OF THE WESTERN KENTUCKY COAL FIELD

WILLIAMS, David A.

The economy in the Western Kentucky Coal Field has suffered greatly during the current "energy glut." The high-sulfur coals that typify this coal field have been difficult to a market for many of the operators, and only long-term contracts and the high efficiency of the mines have saved this area from economic desolation. Now the probability of even

more stringent environmental restraints paints an even more austere economic picture at a time when the easily extractable, thicker, near-surface coals are largely mined out.

Seventy years ago, Leonidas C. Glen, working for the Kentucky Geological Survey, predicted that the so-called "near worthless" coals of the upper coal measures in western Kentucky would be mined, and he has been proven correct. Up until recently it was considered unlikely that coal would ever be mined in western Kentucky at depths greater than 1,000 feet, but today mines exceed that depth.

The challenge before the coal industry of western Kentucky is to produce coal at competitive prices from less economical beds and to find local sources of low-sulfur coal for blending, producing a more environmentally acceptable product. To this end, the Kentucky Geological Survey collects and maintains coal-resource data for the Western Kentucky Coal Field, conducts geologic research on these resources, and provides these data to the public, industry, and government agencies. This past year the Kentucky Geological Survey has described 13 cores drilled in the Western Kentucky Coal Field, recorded over 125 new coal thickness points, and taken approximately 50 coal samples for analysis; many of the samples were taken from the Sturgis Formation, where we are searching for low-sulfur coal beds and coal beds that may in the future be useful for *in-situ* liquefaction and gasification.

This year the Survey has begun an intensive effort to add western Kentucky coal information to its computer data base. When this extensive and complicated job is complete, accurate updates of coal resources will be only seconds away.

MINEABILITY OF WESTERN KENTUCKY COALS: PHASE 1—PALEOCHANNEL STUDY

WILLIAMS, David A.

A multimillion-dollar investment is lost. Why? Because a paleochannel was encountered. Maybe the roof was terrible and so much water was coming in that pumps could not

keep the mine dry. Or perhaps a geologic fault was encountered and the mine was abandoned because of a lack of coal. As the depletion of western Kentucky's strippable coals becomes a fact instead of a prediction, mining is going deeper and becoming more expensive. There is no room for mistakes in a coal market already biased against the high-sulfur product of the Western Kentucky Coal Field. The documentation of hazards to underground mining becomes more important as mines go deeper and the costs of mining become higher.

This year the Kentucky Geological Survey has continued to work toward producing a comprehensive map of paleochannels within the Western Kentucky Coal Field and to assist the mining industry with mapping channels in specific areas. The Survey has inspected several thousand geophysical logs from oil and gas test holes and recorded approximately 3,000 data sheets for entry in a computer data base. In addition to the oil and gas tests, information such as cores and geophysical logs has been collected from coal companies, when possible, to augment the Survey's information. Several preliminary maps of sandstone distribution at several stratigraphic horizons within the coal field have been produced, and study has expanded into a greater portion of the coal field than originally intended.

The product of this study will be a set of sandstone-distribution maps that will enable the Survey to map the trends of paleochannels within the Western Kentucky Coal Field. The information is being compiled on the Survey's computer data base, which will make eventual maps convenient for reproduction and easy to be updated.

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

WILLIAMS, David A.

The Kentucky Geological Survey maintains an ongoing investigation of the stratigraphy of the Western Kentucky Coal Field. This year approximately 50 limestone samples from 13 cores were collected and sent off for paleontologic

analysis. Over 50 coal samples have been collected, for which palynological studies are possible. With the addition of new stratigraphic information, the Survey continually refines and updates the stratigraphic framework of the coal field and makes it readily available to any person, company, or agency that requests it.

A comprehensive report of the geology of the Pennsylvanian rocks of western Kentucky is in its final revision and will be an important contribution on the coal-bearing rocks of western Kentucky upon its publication.

The Survey continues to cooperate with other state surveys in conducting regional correlations of coal-bearing rocks and has been a significant force in developing a three-state regional investigation of the Springfield (Western Kentucky No. 9) coal bed's distribution, character, and quality. This project is the first of its kind, and the Kentucky Geological Survey intends to continue to be a driving force in developing the regional understanding of Pennsylvanian rocks in western Kentucky.

Industrial and Metallic Minerals

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

NEW LABORATORY FACILITIES FOR CHEMICAL AND MINERALOGICAL ANALYSES

COBB, James C., and AMARAL, Eugene J.

Detailed chemical and mineralogical analyses of Kentucky's natural resources are essential for their marketing and economic development. New laboratory equipment for the analysis of resource materials has been obtained in conjunction with the Survey's move into the new Mining and Mineral Resources Building at the University of Kentucky. The new laboratories are being set up and are expected to be in full operation within the next 12 months.

In this sesquicentennial year of the Kentucky Geological Survey, we are reminded of how early economic development in Kentucky depended on the development of natural resources in Kentucky. The Kentucky Geological Survey's first geochemist, Dr. Robert Peter, performed the first analyses of Kentucky minerals using the laborious wet chemical techniques of the mid-1800's. In today's modern analytical laboratory, the technological advances in quantitative X-ray methods, computerized data acquisition, and automated sample handling represent significant improvements over Dr. Peter's laboratory, yet the mission to assist in the economic development of Kentucky's resources remains the same.

With the new laboratory facilities, the mineralogy and chemical composition of Kentucky's natural resources will

be determined primarily using X-ray techniques. A fully computerized Siemens X-ray system, which includes the D-500 diffractometer and the SRS-303 wavelength fluorescence spectrometer, will assist in this task; it should be operational by the last quarter of 1988. Petrologic studies employing the polarizing optical microscope will supplement the X-ray analyses. A new, automatic-exposure camera attachment now in use has enabled photomicrographic documentation to become a routine procedure. Another new microscope attachment, the cathode luminescence stage, is especially helpful in petrographic studies of limestones, dolomites, and sandstone cements.

Some important physical properties of Kentucky's natural resources of interest to industry will be quantified in the newly equipped Mineral Aggregate Laboratory. Analyses of particle-size materials in the gravel to silt size range can now be run on the coarse and fine sieve shakers. Quantitative particle shape and soundness testing is also possible. The optical appearance of finely ground minerals is of special importance in a wide variety of applications, such as the manufacture of pigments and pharmaceuticals. The new HunterLab Color-Quest spectrophotometer will enable the KGS to very accurately quantify the brightness, opacity, and color of Kentucky's limestone, silica, and clay minerals, thus enhancing the marketability of these resources.

NONFUEL MINERAL STATISTICS

DEVER, Garland R., Jr.

Under a Memorandum of Understanding, the Kentucky Geological Survey assists the U.S. Bureau of Mines in collecting and compiling information on nonfuel-mineral production and industry activities in the State. Resulting data are disseminated mainly through Bureau publications, principally the "Minerals Yearbook," "Mineral Industry Surveys," and commodity reports. The Survey employed the data to compile and publish a directory of Kentucky's industrial and metallic mineral producers during the past fiscal year.

In 1987, the value of nonfuel-mineral production in Kentucky increased by \$25 million to more than \$292 million, based on preliminary data received by the Bureau of Mines. Production of crushed stone, the State's leading nonfuel-mineral commodity, increased by 6 million tons to 44.5 million tons. Kentucky's rank among the 50 states in crushed-stone output rose from thirteenth in 1986 to seventh in 1987. Portland and masonry cement; common, ball, and fire clays; quicklime and hydrated lime; construction and industrial sand and gravel; and crushed sandstone also were produced during the year.

Kentucky's fluorspar industry, after more than 5 years of inactivity, strongly revived in late 1987. The Kentucky-Illinois Fluorspar Corporation, a subsidiary of Diversified Minerals Corporation, acquired from USX Corporation all fluorspar reserves, mines, and processing facilities formerly owned by Marathon Oil, Cerro Corporation, and U.S. Steel. In December it reopened the former Cerro/Frontier flotation mill near Salem in Crittenden County, and is producing substantial quantities of high-purity, acid-grade fluorspar and zinc concentrates.

INVESTIGATION OF THE MASCOT DOLOMITE (KNOX GROUP) RELATING TO ZINC AND PETROLEUM RESOURCES

ANDERSON, Warren H.

The Mascot Dolomite of the Knox Group (Cambrian-Ordovician) in south-central Kentucky is the host rock for mineral deposits and petroleum accumulations. This investigation concluded that mineral deposits were influenced by (1) development of shallow marine algal structures and subsequent diagenetic changes, (2) solution-collapse brecciation and karst development, and are characterized on the surface by (3) curvilinear features. The development of algal stromatolite structures and breccia bodies created open space and vugular porosity suitable for precipitation of mineralizing fluids. The curvilinear features are a surface geomorphic expression of breccia system development in

the Mascot and can be used as an exploration guide for mineral deposits.

Pronounced thickening in the interval between internal marker beds M-5 and TR on the eastern flank of the Cincinnati Arch may indicate a depositional center. Early Ordovician uplift and subsidence along the arch is shown by thinning in the marker beds. The interval between these marker beds also thins northward along the arch into Adair County. The absence of the Upper and Middle Mascot on the Lexington Dome in central Kentucky may be related to a combination of depositional thinning and erosion. Petroleum accumulation in the Mascot is related to the development of the erosional unconformity and its associated paleoaquifer system near the M-5 marker bed. Numerous Knox oil fields are located along a regional northeast-trending fracture system in Cumberland and Clinton Counties.

This project was completed during the 1985-86 fiscal year, and the project report and accompanying maps are undergoing final technical review. Included in this report are a map of the top of the Knox in the study area, showing the paleotopography of the Knox surface, and a paleolineament map on the Knox. Cross sections show Mascot marker bed correlations across Cumberland, Clinton, and Monroe Counties and the Gradyville Oil Field in Adair County. Correlation of marker beds shows the position of ore horizons and petroleum reservoirs.

The information developed on geologic controls for zinc mineralization may also aid in the exploration for petroleum in the Knox of south-central Kentucky. Both favorable reservoirs for hydrocarbons and sites for zinc mineralization are related to features associated with the paleoaquifers, enhanced dolomite dissolution and porosity, and breccia bodies. Paleolinear trends on a map of the Knox unconformity show a relationship between fracture alignment and the location of oil and gas fields.

LIMESTONE AND DOLOMITE RESOURCES FOR COAL-RELATED INDUSTRIES

DEVER, Garland R., Jr.

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

Low-silica stone and high-calcium limestone on Pine Mountain will be described in a recently completed report that currently is being processed for publication as a KGS Information Circular. The Newman Limestone in Harlan County contains two thick deposits of low-silica stone, 64 and 25 feet thick, with average silica (SiO_2) contents of 0.82 and 1.01 percent, respectively. Intervals of high-calcium limestone occur within the low-silica deposits. The average calcium carbonate (CaCO_3) content of the upper low-silica deposit, 25 feet thick, is 96.37 percent. The upper 37 feet of the lower 64-foot low-silica deposit has an average calcium carbonate content of 97.33 percent. These deposits in the southeastern part of the Eastern Kentucky Coal Field are a potential source of stone for rock dusting underground coal mines, surface-mine reclamation, and acid-drainage control. Foot-by-foot chemical analyses and lithologic ledge descriptions will be published in the report.

Petroleum and Stratigraphy

With more than 20,000 producing oil wells and over 9,200 producing gas wells, Kentucky ranks as a major producer of oil and gas. Oil ranks second and natural gas fourth as mineral resources in the State, and they provide an important source of revenue. Approximately 1,833 sites were permitted for drilling in 1987, a decrease of 575 from 1986. A total of 1,587 new wells were reported successful, a 40 percent increase over 1986. Discoveries included 23 oil pools, 22 gas pools, 10 deeper oil pools, six deeper gas pools, three shallower oil pools, four shallower gas pools, and 153 extensions to existing producing areas.

In eastern Kentucky, exploration for natural gas dominated exploration and development drilling activity. In Whitley County in southeastern Kentucky, of 135 wells reported complete, 132 were reported successful, and 130 were completed as gas wells. For 123 gas wells with reported initial open flows, the minimum was 2 mcfg/d, the maximum 13,900 mcfg/d, and the average 712 mcfg/d. The primary target horizon in this area is the Mississippian Newman carbonate, the "Big Lime" of drillers.

In addition to gas, the Big Lime has proved to be a prolific oil producer. Exploration and development of Big Lime pools in eastern Kentucky, in conjunction with regulatory pressures associated with secondary recovery operations, have vaulted Leslie County over Lee County to become the second most prolific county in Kentucky, producing 440,659 barrels of oil.

In 1986, central Kentucky reported the first commercial gas produced since 1950. While the amount of gas produced decreased to 248 million cubic feet in 1987, a continued interest in gas production is indicated. For central Kentucky counties in the Cumberland Saddle part of the Cincinnati Arch, oil exploration and development remained moderately active, with the Lower Ordovician Knox Dolomite being the primary target. The most active counties in central Kentucky were Barren County, with tests of the Upper Ordovician Leipers and Lexington (Sunnybrook of drillers), and

Warren County, with tests of the Mississippian Salem and Warsaw Formations and the Devonian Clear Creek Formation. New exploratory drilling has been slated for the Knox Formation in Grant County of north-central Kentucky.

Western Kentucky dominates oil production in the State, with seven of the top 10 producing counties accounting for 49 percent of the total 1987 oil production. Henderson, Union, Webster, Muhlenberg, Daviess, Hopkins, and McLean Counties (in order of rank) produced a combined 2,767,482 barrels of oil. Main drilling targets continue to be Chesterian (Mississippian) sandstones and carbonates. Of 67 successful exploratory wells, 50 were drilled as extensions or outposts to existing fields.

Statewide, 5,752,011 barrels of oil were produced, representing a 12 percent decline from 1986. Gas production declined 13 percent to 70,125,200 thousand cubic feet. The decrease in natural gas production can probably be accounted for by decreased demand and sharply declining prices. As in 1986, oil production declined in all areas of the State. Large numbers of producing wells were plugged in response to Environmental Protection Agency Underground Injection Control Program requirements; it is not economical to bring marginal wells into compliance. In the Keaton-Mazie and Martha Pools of Lawrence and Johnson Counties in eastern Kentucky, approximately 500 of nearly 1,500 shut-in wells have been plugged. In 1985, these counties accounted for nearly 170,000 barrels of oil per year, compared to only 72,000 in 1987. Many secondary recovery operations in western Kentucky were also affected.

A primary responsibility of the Kentucky Geological Survey is to provide industry, government agencies, academic institutions, and the general public with information pertinent to the exploration for and development of oil and gas in Kentucky. The Survey, as the official repository for oil and gas well records, maintains a library for public use that contains more than 225,000 well records. The Survey also maintains a Well Sample and Core Library with more than 15,500 sample sets and 1,200 cores on file. In addition, Survey files contain such information as cumulative annual oil produc-

tion, oil and gas pool maps (1:250,000-scale), pool indexes, geologic-quadrangle indexes, oil and gas well maps of some counties, and bibliographies.

GEOLOGIC CHARACTERISTICS OF SELECTED OIL AND GAS RESERVOIRS IN MISSISSIPPIAN 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 reservoir rocks in relation to known stratigraphic units in the outcrop belt of western Kentucky. Special emphasis is given to rocks of lower Meramecian and Osagean age.

The study focuses on the regional aspects of the stratigraphy, lithology, and depositional environments of these units, especially the location and geometry of petroleum reservoirs. Literature on this part of the section has been collected and a bibliography prepared and computerized. In addition, all known data from test holes that penetrated the Salem-Warsaw Formations have been collected; of the approximately 50,000 oil tests drilled in western Kentucky, less than 4 percent penetrated below the Ste. Genevieve Limestone, which is the top of the Meramecian Series, and only 1 percent reached the New Albany black shale (Devonian).

The Salem-Warsaw has produced in scattered areas, and two pools have been described in the literature; in addition, the Fort Payne Formation often is petroliferous, and one uneconomic pool has been described in the literature.

The study is presently concentrating on the wells that penetrated the complete section, which, in descending order, consists of the Ste. Genevieve, St. Louis, Salem-Warsaw Formations of the Meramecian Series, and the Fort Payne, New Providence, and Rockford Formations of the Osagean Series. After identification, these formation tops are being computerized to be used in a regional study of the Lower Mississippian.

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

GOODING, Patrick J.

The primary objectives of this investigation are to determine from geochemical analysis the most likely source or sources of the hydrocarbons found in Kentucky, investigate structures that may have influenced the migration of fluid hydrocarbons from the source to the trap, and develop a model to explain hydrocarbon formation. Originally, this study was concerned only with the Cambrian-Ordovician carbonate rocks of central Kentucky. But after extensive sampling revealed that five different types of oil occur in the Lower Ordovician reservoirs in that area, the study was expanded to include all producing formations throughout the State.

The oil and gas industry in Kentucky cooperated in this project by allowing visits to over 530 oil wells throughout the State; fresh oil samples were collected from 210 of the wells. The oils were being produced from 40 different stratigraphic zones. Geochemical analyses have already been completed on 114 of the oils.

The oil samples have a wide range of color and odor. Some oils are almost colorless; others range from light yellow, to green, to brown, and black. The higher gravity crude oil is usually lighter in color, while the lower gravity crudes are darker. The odors range from sweet smelling to the odor of rotten eggs; generally, the more mature oils smell worse.

Source-rock evaluations have been made on over 8,000 rock samples ranging in age from Cambrian to Pennsylvanian. Geochemical analyses indicate that samples from several locations contain high to very high quantities of organic matter of variable composition, which would have been capable of generating hydrocarbons during burial.

The geochemical data generated from this study will allow for a detailed characterization and classification of Kentucky oils.

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

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

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

Data on 10,280 wells that penetrate Devonian shales in the 25-county study area have been entered into the KGS computer. This information was used to determine the individual stratigraphic units between the Mississippian Sunbury Shale and the Devonian Rhinestreet Shale, to construct isopach and structure maps and cross sections, to determine locations of gas-producing intervals, and to construct isopotential maps. The results of this study were published in March 1988 in five single-county reports. An additional report, covering nine counties, will be published in the first quarter of next year. A comprehensive report that assimilates all the information and interpretations from the previous county reports will be published sometime prior to 1989.

The following conclusions have been drawn from the study: (1) the best method of stimulating the shale interval is hydraulic fracturing, (2) the best production appears to be in areas with a high degree of natural fractures, (3) the most productive interval in the shale is the Lower Huron Member of the Ohio Shale, and (4) initial open flow generally has a positive correlation with high production.

AREAL AND STRATIGRAPHIC DISTRIBUTION OF OIL AND GAS PRODUCTION IN KENTUCKY

NUTTALL, Brandon C.

This project was initiated to provide a better understanding of the distribution of hydrocarbon production in Ken-

tucky. The result of the project will be a report including text and multi-color maps showing distribution of production for each major stratigraphic system and many individual pay zones, along with penetration maps, color-coded classification maps, and general geologic and physiographic maps. This publication will show locations of the major producing areas in Kentucky, as well as identify stratigraphic units from which hydrocarbons are produced. The project will utilize information that is already in the KGS oil and gas data base, and the maps will be updated as new data are entered. Digitizing of state and county outlines has been completed. Preliminary maps have been constructed for review and format design.

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 85,100 well records have been encoded, entered, and proofread to date. By the end of 1988, data for approximately 90,000 wells should be available.

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

The data base is complete for all locations for which information is on file at the Survey for 62 counties; Bullitt, Carter, Clay, Crittenden, Harrison, Johnson, Knox, Lawrence, Larue, Livingston, Lyon, Marshall, Morgan, Menifee, Nelson, Perry, and Trigg were completed this past fiscal year. Work continues on areas in Barren, Bath, Lee (not including the Zachariah Quadrangle), Powell, and Wolfe Counties. In western Kentucky, work is progressing to incor-

porate data for all Mississippian Salem/Warsaw and deeper penetrations. 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 EPA Class II (injection and disposal) wells reported active in 1979 and completed since.

Of 85,137 well-record entries on the computer, 81,733 have complete Carter coordinate locations. There are 56,827 entries with modern (since 1960) permit numbers. The data base contains entries for 21,967 oil wells, 14,014 gas wells, 506 combined oil and gas wells, and 25,422 dry holes. In the part of eastern Kentucky covered by the Devonian shale project (*see above*), 27,819 well entries are on the computer, with 12,137 from wells that penetrate the Mississippian/Devonian black shale, and 5,714 from shale gas producers. There are 9,848 pre-Trenton penetrations on the computer. Finally, 125 wells in the data base are from the Jackson Purchase Area of western Kentucky, 22,175 wells from the Eastern Interior Basin/Mississippian Plateau areas of western Kentucky, 28,666 wells from the central Kentucky/Cincinnati Arch area, and 33,550 wells from the eastern Kentucky portion of the Appalachian Basin.

Work continues on the pool names data base. Data for monthly oil production by county have been entered for January 1960 to March 1988, and data are being entered for the 1950's.

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 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 result-

ing distribution and size of oil and gas fields. Each fundamental basin type is to be analyzed to determine the significant factors that control the plays, resulting fields, and future potential.

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

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

Various KGS personnel have contributed geologic data and compiled maps for the different chapters of the manuscript. Chapters 1 through 4, which provide data on the regional setting, stratigraphy, structure, and tectonics and evolution of the Illinois Basin, have been compiled by the Illinois Survey and reviewed by the Kentucky and Indiana Surveys. Chapter 5, which analyzes the oil and gas fields and hydrocarbon potential of the basin, has not been completed.

TAR-SAND DEPOSITS OF WESTERN KENTUCKY

NOGER, Martin C.

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

In 1986-87, samples were collected from surface exposures of the Caseyville Sandstone (Pennsylvanian) and Big Clifty Sandstone Member of the Golconda Formation (Mississippian) for analysis by the U.S. Geological Survey for

clay and metal content and reservoir characteristics. Parts of the samples were retained by the KGS for hydrocarbon source-rock analyses. These analyses have not yet been completed.

The Survey continues to monitor drilling and other developmental activities in tar-sand areas. Data bases are revised annually to further delineate and evaluate the deposits so they will be up to date when economic conditions are favorable for commercial development.

HANDBOOK OF KENTUCKY STRATIGRAPHY

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

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

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

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

OIL AND GAS WELL RECORDS PRESERVATION PROJECT

WALKER, Frank H.

The oil and gas well-record files of the Kentucky Geological Survey are used extensively by well operators, geologists, engineers, attorneys, representatives of local, State, and Federal government agencies, the general public, and staff members. As a result, the paper files are deteriorating rapidly, and it has become evident that the files must be

made available by some alternative method. After several media were examined, it was decided to store the records electronically.

The first two items of scanning equipment have been received and placed in service. One unit is used to record documents up to 8 1/2 X 14 inches in size. The other unit is designed for scanning longer documents (electric logs). Malfunction of the smaller unit resulted in a loss of nearly 4 months time in the project. The long-document scanner has been used to record some page-size documents, but no appreciable progress can be expected until both units are on line.

It is estimated that the well-record files contain over 1 million page-size documents. To access one record from such a large volume requires extensive programming. Software is continually being developed to accomplish the desired result, but much is yet to be prepared. The recent move into new quarters also interrupted the program. Most, but not all, of the problems have been overcome, however.

Approximately 11,000 documents have been scanned and are stored on tape for later transfer to a more permanent medium.

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 constant 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 allow up-to-date maps to be printed on order. 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 stan-

dard symbols to show the locations of the wells and the type of completion. A computer-generated list of wells may be obtained for each map that lists the well identification, location, total depth, elevation, total depth formation, producing horizon, and reported initial production or open flow.

Maps are available for each quadrangle in the State, but some areas have been more completely mapped than others. At present, information on approximately 82,500 wells is in the computer data base, and an average of 7,000 to 8,000 wells a year are added to the system.

Conversion of the 1:48,000-scale county maps to the 1:24,000-scale quadrangle maps is nearly completed. As the wells in a county are converted, the county map is withdrawn from distribution, since the county maps are severely out of date, and up-to-date quadrangle maps are now available. The only county map still available is for Barren County.

Maps are complete for all quadrangles in 59 counties. A total of 353 quadrangles are completed. In addition, work has been started on approximately 251 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 the majority of eastern Kentucky; and all Class II (injection and disposal) wells reported active in 1979 and completed since.

OIL AND GAS WELL RECORD LIBRARY

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

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

Despite problems in the early years (including two fires), the files are extensive, consisting of 376 file-cabinet draw-

ers of information. Expansion in the 1987-88 fiscal year amounted to approximately 2,000 new wells. The records are filed first by county and then by Carter coordinate location. It is estimated that information on as many as 225,000 wells can be found in the files.

The library is located in Room 101 of the Mining and Mineral Resources Building, and is open from 8:00 a.m. until 4 p.m. each working day. Students, industry representatives, government-agency personnel, and the general public make extensive use of the files. Last year, Oil and Gas Well Record Library personnel assisted 687 visitors, answered 488 telephone requests, and supplied 28,263 copies of well records. Copies are limited to 50 wells per person by telephone or written request in a 30-day period. Visitors to the library may have copies made of up to 150 wells per person in a 30-day period. Requests are usually filled within 24 hours of receipt. No electric logs are copied; however, a source for logs is provided to interested parties.

Water Resources

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

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

On a day-to-day basis, the section provides information to municipalities, industry, and private citizens concerning water resources in the State. Specifically, work for the Kentucky Natural Resources and Environmental Protection Cabinet included serving on a technical committee to review criteria for ground-water monitoring required by the Federal Office of Surface Mining for coal-mine permits, and serving on a technical advisory council concerning the classification, use, and protection of ground water in the State. The section head serves on the Water Well Drillers' Certification Board, which is responsible for developing regulation and construction standards for that industry. A section member also serves on an advisory committee concerning the on-site disposal of sewage for the Cabinet for Human Resources.

GATEWAY AREA DEVELOPMENT DISTRICT, WATER WELL STUDY

CURRENS, James C.

The Kentucky Division of Water (DOW) and the Kentucky Geological Survey (KGS) initiated an analysis of data from samples collected by the Cabinet for Human Resources from domestic water wells in the Gateway Area Development District. Samples from 109 water wells, distributed among the five counties in the District (Bath, Menifee, Morgan, Montgomery, and Rowan), were analyzed for bacteria, primary and secondary water-quality constituents, radionuclides, and other constituents. The data were entered into the KARD data base at KGS, and descriptive statistics were calculated. A file was written for analysis by SAS software for multiple correlation coefficients, students t-test, and other statistical tests.

The study found only scattered occurrences of well contamination except in the case of bacteria. The wells that were improperly constructed or maintained, particularly hand-dug wells, were the most frequently contaminated with bacteria. There was no evidence of widespread aquifer contamination by any of the constituents tested. There is ambiguous evidence that the fractured bedrock aquifers may be occasionally contaminated with bacteria in the immediate vicinity of the wellhead. Previous hydrogeologic and microbiologic research confirms that under certain circumstances bedrock aquifers may be locally contaminated with bacteria. The data from the Gateway study suggests that further research into the susceptibility of bedrock aquifers in Kentucky to bacterial contamination may be warranted.

THE KENTUCKY AQUIFER-RESEARCH DATABASE (KARD)

CURRENS, James C.

The Kentucky Geological Survey has been charged by the Kentucky Ground-Water Advisory Council to act as a ground-water data repository. As a result, in the spring of 1987 the development of a data base for ground-water data was initiated. By the end of fiscal year 1986-87, the conceptual design of the data base was completed; various sup-

porting Datatrieve domains, record structures, and files had been written; and work was proceeding on programming for the central domains of the data base.

During 1987-88, significant progress has been made on the data base. Domains and supporting programs are now complete and in use for location, well construction, lithologic, water quantity, and water-quality data, including bacterial, on-site, and major- and minor-ion data. Approximately 220 well locations and related data have been entered into the data base. In addition, a data-transfer format for magnetic tape, and a major series of programs to translate data acquired from the Groundwater Branch of the Kentucky Division of Water (DOW) into the KARD format has been written. The data base is already in use, as wells completed in the Knox Formation in central Kentucky are being entered to be used for aquifer definition and water-quality mapping. In addition, work has been started on a users' guide for the KARD data base.

Work planned for the coming year includes continued data-base development and accelerated data entry. The domains for major-minor ions and on-site water-quality determinations will be revised to provide for values below detection limits. The domains and supporting programs for trace organics, trace elements, and radionuclides will be written. Some of this work has already been started within the domain developed for the Gateway Area report. Further work will be done to develop video forms to simplify interactive data entry. It is hoped that a part-time data-entry person can begin to enter the well records and other hydrogeologic data on file at KGS in the fall of 1988.

The transfer of new water-well records from DOW will have been attempted for the first time by the end of August 1988. This transfer is planned to take place quarterly and should be routine by the end of 1988. It is anticipated that some 2,000 to 3,000 wells will be added to the data base annually once the programming is complete.

STAR FIRE PROJECT

DINGER, James S., HANEY, D. C., and STRECKER, C. Todd

Present and predicted future conditions indicate that coal mining in the Eastern Kentucky Coal Field will provide fewer and fewer jobs in the coming years. At the same time, economic growth and diversity in the coal field are severely limited, in part by the steep topography and the lack of water resources. Most coal companies operating in this area have no real interest in these limiting factors because they generally own only the mineral rights to the properties they mine, not the land surface. Cyprus Mountain Coals, a subsidiary of Cyprus Minerals, Inc., is unique in that they own the 17,000 acres at the Star Fire surface mine, located in Knott, Perry, and Breathitt Counties, and, therefore, have considerable interest in post-mine development of the property to its highest and best use.

It is estimated that 10,000 acres of flat land will be created by the year 2010 through mountaintop removal techniques, thus providing a site for new land uses and future economic development. The Kentucky Geological Survey has been awarded a research grant to conduct initial feasibility studies for site development. These studies include the assessment of need for such development in southeastern Kentucky, the availability of infrastructures to support the site, inventory of and development plans for water resources, and development of land-use models.

Contact has been made with numerous industry representatives to inform them of the site potential, and presentations concerning the project goals and present research efforts have been made to over 3,000 people, both within and outside southeastern Kentucky.

Preliminary reports have been completed concerning the assessment of need for economic development, attitudes of the local people toward development of the property, and water resources at the site.

HYDROGEOLOGIC INVESTIGATION OF NEAR-SURFACE FRACTURES IN THE APPALACHIAN PLATEAUS

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

Between 1980 and 1983, the Kentucky Geological Survey conducted a hydrogeologic study on the occurrence and movement of ground water in the Eastern Kentucky Coal Field. Site-specific core drilling and down-hole packer testing in Knott County indicated that shallow but widespread fractures exist in a sequence of rocks characterized by sandstone and coal.

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

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

Funding was received from the U.S. Office of Surface Mining to conduct additional dye tracing of ground-water movement. Two dye injections were performed, and monitoring wells are being measured for dye concentration and water-level fluctuation.

HYDROGEOLOGY OF BRINE OCCURRENCE IN THE KENTUCKY RIVER BASIN

KIPP, James A.

A detailed hydrologic study, including water quality, ground-water/surface-water interaction, and brine transport mechanisms, is being conducted in the Furnace Fork Basin in Estill County. Since petroleum has been produced in the area for over 70 years, a review of files in the Oil and Gas Well Records Library yielded approximately 350 wells in the study basin.

A gaging station with automatic recording of stage, water temperature, and specific conductance was installed on

Furnace Fork during spring 1987. Monthly water-quality sampling is being coordinated with the U.S. Geological Survey's Kentucky River National Water Quality Assessment (NAWQA) study. Stream samples are collected at the gaging station and at six locations within the basin. Two other local streams, Cat Creek and Big Sinking Creek, are also being monitored to compare water quality between basins with varying degrees of petroleum production.

A survey of domestic wells and springs in the Furnace Fork Basin was completed in 1987. Information obtained during the survey was used to select a site for the installation of monitoring wells for a detailed ground-water investigation. Four wells will be drilled during summer 1988. Water-quality samples will be collected, and water-level recorders will be installed on each well. Results of the ground-water and surface-water portions of the study will be integrated and used to develop a conceptual model of brine transport from tributary basins to the Kentucky River.

PRODUCTION OF FRESH WATER FROM THE KNOX GROUP IN CENTRAL KENTUCKY

KIPP, James A.

A few deep wells (800 to 1,000 feet) produce fresh water in central Kentucky. These wells are generally completed in the top of the Cambrian-Ordovician Knox Group. The primary objectives of this investigation are: (1) to identify areas where the Knox contains potable water, (2) to determine aquifer characteristics, and (3) to identify the flow regime, including areas of recharge and discharge and direction and rate of water movement. Because of the great expense of drilling wells to the Knox, the Survey relies upon local well drillers and their customers to identify new wells that are available for sampling. In the past year, geophysical logs were obtained from new Knox water wells in Jessamine, Fayette, and Bourbon Counties. Water samples were also collected and analyzed. The additional data have been added to the project file.

The Water Resources Section has received numerous inquiries concerning the availability of fresh water from deep

formations during the recent drought. Interests include sources of domestic drinking water, water for livestock, and sources capable of supplying sufficient quantities of water for irrigation. The deep formations are of particular interest because water levels are often relatively unaffected by short-term reductions in rainfall and recharge. Individuals requesting information on deep aquifers in central Kentucky have been informed of the possibilities for obtaining fresh water from the top of the Knox Group. Additional work is needed to determine aquifer characteristics so that the quantity of water available from the Knox can be evaluated. Factors that affect the distribution of water quality in the Knox should also be investigated further to allow more reliable predictions of water quality for specific locations in central Kentucky.

BARIUM CONCENTRATIONS IN GROUND WATER IN EASTERN KENTUCKY

WUNSCH, David R.

The Kentucky Geological Survey recently completed a study that has helped delineate the cause and occurrence of anomalously high barium concentrations in shallow ground waters in eastern Kentucky. Chemical analyses of water samples from the Buckhorn, Chavies, and Salyersville, Kentucky, areas have shown that 20 percent of the water samples had barium concentrations in excess of the U.S. EPA suggested drinking-water standard of 1.0 mg/L.

Monitoring and domestic well data indicate that shallow, high-barium brines are encountered at shallow depths at each of the study areas and constitute a likely source of barium when they mix with shallow, fresh waters.

Stable Isotope Ratio Analyses (SIRA) indicated a high degree of fractionation between ^{34}S and ^{32}S in the sulfate molecule, suggesting that sulfur-reducing bacteria may be present in the ground-water system. The presence of sulfur-reducing bacteria (i.e., *Desulfovibrio*) was confirmed by bacteriological analysis of water samples by the U.S. Forestry Service. These data suggest that the consumption of

sulfate by the sulfur-reducing bacteria create ground waters that are undersaturated with respect to the mineral barite (BaSO_4), thus allowing high barium concentrations in solution.

Although most water softeners will remove excess barium from water, a thorough disinfection of newly installed and existing wells may reduce the incidence of high barium, as well as improve the general quality of ground waters in eastern Kentucky by reducing the effects of undesirable bacteria.

The results of this study were presented at the National Water Well Association's Ground Water Geochemistry Conference.

DEVELOPMENT OF THE WATER-QUALITY LABORATORY WUNSCH, David R., and DINGER, James S.

A water-quality laboratory is being established in the new Mining and Mineral Resources Building. The lab will house a wide range of state-of-the-art analytical equipment for the complete analysis of the dissolved organic and inorganic constituents in water samples. The goal of the lab will be to produce high-quality analyses for ongoing Water Resources Section research as well as other State and regulatory agency programs, and general public needs.

Inorganic constituents in ground water will be analyzed utilizing inductively coupled plasma emission spectroscopy (ICP), atomic absorption spectrophotometry, ion chromatography, and titrations using an autotitrator. Organic constituents will be identified by gas chromatography using Soxhlet extraction separation techniques. A total organic carbon analyzer will allow for quick screening of samples for potential pollution. Additional supporting equipment and glassware will complete the lab for total in-house analytical capabilities.

Laboratory modifications for the placement and operation of analytical equipment have been occurring since the relocation of the Kentucky Geological Survey into the Mining and Mineral Resources Building. It is anticipated that the Water Quality Laboratory will be operational in 1989.

Other Research

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

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

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

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

LINEAMENT ANALYSIS OF THE PAINT CREEK UPLIFT IN MAGOFFIN, JOHNSON, LAWRENCE, ELLIOTT, MORGAN, AND FLOYD COUNTIES, KENTUCKY

McHAFFIE, Patrick H.

The objective of this study is to produce lineament maps, analyses, and a report for the area covered by the Ivyton, Salyersville North, Salyersville South, Oil Springs, Dingus,

Redbush, Mazie, and Isonville 7.5-minute topographic quadrangles in Kentucky. The project, which is sponsored by the U.S. Army Corps of Engineers through Commonwealth Technology, Inc., of Lexington, Kentucky, will conclude August 31, 1988.

GEOLOGIC MAP OF KENTUCKY

NOGER, Martin C., and POTTS, Roger B

In 1984 the Kentucky Geological Survey began compiling a 1:500,000-scale geologic map of Kentucky, taken directly from the three-sheet, 1:250,000-scale "Geologic Map of Kentucky." The single-sheet, 1:500,000-scale 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 charts have been compiled. Preparation for publication of the color map by the U.S. Geological Survey is in progress.

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

NOGER, Martin C.

The CUSMAP program, initiated by the U.S. Geological Survey, is designed to assess the mineral-resource potential of 1:250,000-scale quadrangles. In 1976 the U.S. Geological Survey, in cooperation with the Missouri Division of Geology and Land Survey, started a CUSMAP program to determine the mineral-resource potential of several quadrangles in Missouri. One of the completed quadrangles is the Rolla Quadrangle. The appraisal indicates that several areas in the quadrangle have a very high potential for undiscovered mineral deposits of major importance.

The Paducah Quadrangle, which joins the Rolla Quadrangle on the east, is covered in part by Illinois (56 percent), Missouri (24 percent), Kentucky (19 percent), and Indiana (1 percent). A CUSMAP project for the Paducah Quadrangle is a logical extension of the Rolla Quadrangle project, and will evaluate the significant mineralization in the Paducah Quadrangle area. The Illinois State Geological Survey, the

Missouri Division of Geology and Land Survey, the Kentucky Geological Survey, and the Indiana Geological Survey officially began the Paducah CUSMAP program on October 1, 1986; it is scheduled to be completed by September 30, 1990.

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

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

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

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

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

Kentucky Geological Survey personnel have provided geologic maps for use in compiling a geologic map of the Paducah Quadrangle. Warren Anderson has compiled a map showing the occurrences of mines and ore minerals in Kentucky.

KENTUCKY RADON SURVEY

NOGER, Martin C.

The Kentucky Geological Survey and the Kentucky Department of Health Services, Radiation Control Branch (DHS), participated in a Statewide radon survey of 879 homes. In addition to placing charcoal canisters in homes, DHS personnel completed an in-depth questionnaire covering all of the structural characteristics commonly associated with elevated and nonelevated levels of radon, and plotted the location of survey sites on 1:24,000-scale topographic maps.

KGS personnel transferred the sites from the topographic maps to 1:24,000-scale geologic quadrangle maps. For each site, footage from quadrangle boundaries, site number, canister reading, geological province, system, unit, unit lithology, and structural setting were compiled on data sheets, which were then computerized by the DHS.

The data sheets will be divided into two groups: those whose canister readings were above and those whose canister readings were below 4 picocuries/liter. Each category will be related to the geologic parameters of province, age, unit, unit lithology, and structural setting.

COMPUTER SERVICES

The Computer Services Section (CSS) assists the KGS staff in using computers for their research and public-service responsibilities. CSS acquires or develops and maintains software and hardware, which enable users to store and manipulate data for reports, maps, charts, and other products for use by industry, government, and the general public.

The demands and types of computing needs of the KGS staff have changed dramatically in the past few years. The acquisition of laboratory facilities in the new building has necessitated different types of computing requirements. A computer network that was installed in the new building will enable CSS to meet the present and future requirements, because of its versatility and flexibility in enabling various types of computers and operating systems to communicate with each other.

The professional staff routinely uses the computer in its daily activities. The CSS upgraded its DEC VAX 11/750 computer to a DEC VAX 8550 computer. Applications such as data-base query, data analysis, map generation, geological modeling, and report writing are handled by the Survey's new Digital Equipment Corporation (DEC) VAX 8550 mini-supercomputer, a DEC MicroVax II/GPX color graphics workstation, and two DEC VAXstation 2000 workstations. In addition, various types of MS-DOS-based PC's handle the unusual tasks that cannot be accomplished on the bigger computers. A user can access any of the computers from the terminal on his desk, and most of the computers can easily share information with other computers.

A network link has been established between the Mining and Mineral Resources Building (MMnet) and the University of Kentucky Computing Center (UKnet). Access to UKnet is easy and provides unlimited computer resources since UKnet is linked to most of the national networks. Access to UKnet also provides an administrative link for the staff, making available electronic mail, accounting, and other services.

The KGS has greatly increased its efficiency and production by the staff's use of computers. Data queries from the general public are easily and quickly handled. Computers have helped curtail the staff's paper handling. The time to prepare reports and talks has been dramatically reduced, and the general public benefits through better, more accurate, and more timely reports. Additionally, use of the computer by KGS administration helps manage the various and diverse projects undertaken by the survey.

During the past year the KGS has acquired new or upgraded software, including Interleaf's desktop publishing, DEC's Spatial 2 spatial data-base software, DEC's relational data base (Rdb), and a suite of software for PC's.

The CSS staff continues to develop software needed in the Document Preservation project at KGS. Most of CSS's efforts have been optimizing the compression/decompression of the documents, regardless of what device was used to scan them.

COOPERATIVE PROGRAMS

Topographic Mapping

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

The State Mapping Advisory Committee (SMAC) met in Lexington in September 1987. At the meeting committee members were informed of the status of maps being revised by the U.S. Geological Survey's Mid-Continent Mapping Center in Rolla, Missouri. Members were told that 84 7.5-minute quadrangle topographic maps were being revised. All of these maps are scheduled for limited revision, which involves recontouring in areas where changes in the land surface have occurred and which are more desirable than photorevisions, which show changes by overprinting them on the existing map in purple ink. Of the 84 maps undergoing revision, 64 are part of the jointly funded program between the Kentucky Geological Survey and the U.S. Geological Survey and represent quadrangles that were given high priority for revision by the State Mapping Advisory Committee.

USGS personnel reported on the recently completed horizontal accuracy testing program that was conducted in Kentucky. This program was initiated because 90 percent of the 1:24,000-scale topographic maps of Kentucky were produced prior to 1958, and experience has shown that the horizontal components of many maps made during this period are inaccurate by present standards. Eighty-three maps were selected for testing. These maps were located in six test areas throughout the State in order to ensure that a typical cross section of Kentucky's topographic maps was represented. The testing process consisted of the following

steps: (1) establishing necessary basic field control to support the photogrammetric testing, (2) selecting a minimum of 20 test points on each quadrangle that are discrete and well defined, (3) establishing a horizontal position on each test point using photogrammetric control extension surveys and high-altitude photography, (4) determining the map position for each test point, (5) recording the computed geodetic position, the map position, the algebraic difference, and the root-mean-square summaries, and (6) interpreting the test results. Based on National Map Accuracy Standards, the maximum permissible horizontal error for 90 percent of the map features tested shall not exceed a 40-foot ground distance, or 0.02-inch map distance.

Results of the 83-quadrangle test indicates that 26 maps pass, 20 are borderline, and 37 fail. However, 83 percent of the more than 2,000 points in the six test areas met National Map Accuracy Standards after adjustment. Large parts of most of the maps meet National Map Accuracy Standards, and only the substandard areas should have to be remapped when the quadrangles undergo revision.

Seventeen 7.5-minute quadrangle maps were revised during the 1987-88 fiscal year: Bloomfield, Bobtown, Brooks, Canmer, Clementsville, Ellisburg, Frankfort, Gresham, Lexington East, Louisville West, Mount Eden, Nelsonville, New Haven, New Liberty, Newport, Sanders, and Shopville. All of these maps were photorevisions on which changes are shown in a purple overprint on the existing map. Seven new 1:100,000-scale planimetric maps were received from the U.S. Geological Survey during the year: Bowling Green, Cape Girardeau, Evansville, Lexington, Paducah, Sikeston, and Tell City.

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

Water Resources

Water-related cooperative programs with the U.S. Geological Survey Water Resources Division date back to as early as 1920. The cooperative programs have covered a

wide range of needs on both Federal and State levels, and have provided data for more than 200 maps, publications, and open-file reports, most of which are currently available from the Kentucky Geological Survey. These data provide the basis for answering several hundred requests annually from individuals, industry, and State and Federal agencies. Most of the current information is summarized in an annual report, "Water Resources Data for Kentucky," published yearly by the U.S. Geological Survey. This report combines streamflow data, water-quality data for surface and ground water, and ground-water-level data from the basic network of observation wells, which is funded under the cooperative agreement.

Prior to 1975, ground-water levels and artesian pressures in observation wells in Kentucky were reported in the 5-year U.S. Geological Survey Water-Supply Paper series, "Ground-Water Levels in the United States, Southeastern States." Records since 1975 are found in the U.S. Geological Survey annual publication, "Water Resources Data for Kentucky." Additional information on ground water can be found in the Hydrologic Atlases, which are available for all areas of Kentucky, including several detailed atlases for the Ohio River flood plain. One of the most important publications to evolve from the cooperative program is a 963-page document entitled "A Compilation of Ground Water Quality Data for Kentucky." Published in 1980, it lists all ground-water data for Kentucky, including chemical analyses, in the files of the U.S. Geological Survey through 1979. All of the publications noted above are available from the Kentucky Geological Survey Publication Sales Division.

State budget cuts have reduced available funds for the cooperative program by almost half in the past 6 years. The present funding for the program is approximately \$140,000. Following are brief descriptions of individual projects that are active or in the publication process during the 1987 cooperative agreement.

1. Surface-Water Stations—A Statewide network collects surface-water data for a variety of uses such as research and special studies, assessment of surface-water re-

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

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

3. Reaeration Coefficients and Travel Times for Kentucky River Basin Streams—Oxygen depletion caused by an increase in water temperature and the introduction of pollutants such as sewage effluent and chemicals has adverse effects upon Kentucky River water quality. Downstream movement of pollutants and the ability of the water to absorb oxygen to correct the adverse effects is difficult to predict. The overall objectives of this project were 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. The results of this work are reported in U.S. Geological Survey Water-Resources Investigation Report 87-4179, "Mean Velocity, Longitudinal Dispersion, and Reaeration Characteristics of Selected Streams in the Kentucky River Basin." A paper, "Effects of Streamflow Conditions on Gas-Transfer Coefficients," was also authored by James L. Smoot and pub-

lished in the Proceedings of the 1987 National Conference on Hydraulic Engineering, HY Division/ASCE, Williamsburg, Virginia, August 3-7, 1987.

4. *Barium Concentrations in Ground Water in Eastern Kentucky*—The principal goals of this study are to determine the geographic, geologic, and hydrologic occurrence of barium in water supplies in eastern Kentucky where barium has been reported above the U.S. EPA recommended safe drinking-water concentration of 1 mg/L. Water samples were 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, sulfate isotopes, and sulfate bacteria. Interpretation of these data indicate that barium may become dissolved in ground water because of the interaction of sulfur-reducing bacteria with the mineral barite (BaSO_4). Water softeners will remove excess barium from water, and a thorough disinfection of wells will reduce the incidence of high barium by killing off the bacteria. The results of this study are presented in a paper, "High Barium Concentrations in Ground Water in Eastern Kentucky," published in the Proceedings of the National Water Well Association's Ground Water Geochemistry Conference.

5. *Hydrogeology of Brine Occurrences in the Kentucky River Basin*—The effects of petroleum production on surface- and ground-water resources are being evaluated in a 600-square-mile area centered between the Kentucky and Red Rivers in parts of Estill, Powell, Wolfe, and Lee Counties. The majority of petroleum wells in this region currently produce less than 10 barrels of oil per day, but they also produce approximately 10 barrels of brine for every barrel of oil. The intent of this Kentucky Geological Survey-U.S. Geological Survey cooperative study is to assess the occurrence, movement, and interaction of surface and ground water in this setting. This research is being conducted in conjunction with the U.S. Geological Survey's National Water Quality Assessment (NAWQA) program on the Kentucky River basin. This brine project is scheduled for completion in 1991.

PUBLICATIONS

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

Publications of the Kentucky Geological Survey are made available to the public at a nominal cost and have received widespread distribution. Maps and reports are available for purchase from the Publication Sales Office, which is located in the new Mining and Mineral Resources Building at the corner of Rose Street and Clifton Avenue on the University of Kentucky campus. Total sales for the 1987-88 fiscal year amounted to approximately \$95,000.

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 the Mining and Mineral Resources Building on the University of Kentucky campus during regular office hours. Copies of materials that can be reproduced are available for purchase.

Computer-plotted overlay maps showing the locations of oil and gas wells are available by 7.5-minute quadrangle. These maps are plotted on 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 1987-88 fiscal year.

Guidebooks

Stratigraphy, Sedimentology, and Paleontology (Upper Ordovician) and Glacial and Engineering Geology of Northern Kentucky and Southern Ohio (Guidebook and Roadlog for Geological Society of Kentucky 1987 Field Conference), by Roy C. Kepferle, Martin C. Noger, David L. Meyer, and Gregory A. Schumacher, 18 p.

Teaching and Field Guide to Alluvial Processes and Sedimentation of the Mississippi River, Fulton County, Kentucky, and Lake County, Tennessee (Guidebook and Roadlog for Geological Society of Kentucky 1984 Field Conference), by P. E. Potter, W. A. Pryor, L. M. Smith, and David Rich, 46 p.

Information Circular

Directory of Industrial and Metallic Mineral Producers, by Eugene J. Amaral and Garland R. Dever, Jr., 25 p.

Reprint

Report on the Geological Reconnaissance of Kentucky, Made in 1838, by W. W. Mather (Reprinted from the Journal of the Senate of the Commonwealth of Kentucky, 1839), p. 253-292.

Miscellaneous

Geologic and Hydrocarbon Report of Floyd County, Part 3 of 5: Hydrocarbon Production from the Devonian Shale in Letcher, Knott, Floyd, Martin, and Pike Counties, Eastern Kentucky: by Wayne T. Frankie, Jack R. Moody, Julie R. Kemper, and Ian M. Johnston, 52 p.

Geologic and Hydrocarbon Report of Knott County, Part 2 of 5: Hydrocarbon Production from the Devonian Shale in Letcher, Knott, Floyd, Martin, and Pike Counties, Eastern Kentucky: by Wayne T. Frankie, Jack R. Moody, Julie R. Kemper, and Ian M. Johnston, 94 p.

Geologic and Hydrocarbon Report of Letcher County, Part 1 of 5: Hydrocarbon Production from the Devonian Shale in Letcher, Knott, Floyd, Martin, and Pike Counties, Eastern Kentucky, by Wayne T. Frankie, Jack R. Moody, and Julie R. Kemper, 59 p.

Geologic and Hydrocarbon Report of Martin County, Part 4 of 5: Hydrocarbon Production from the Devonian Shale in Letcher, Knott, Floyd, Martin, and Pike Counties, Eastern Kentucky: by Jack R. Moody, Julie R. Kemper, Ian M. Johnston, Wayne T. Frankie, and Robert R. Elkin, 50 p.

Geologic and Hydrocarbon Report of Pike County, Part 5 of 5: Hydrocarbon Production from the Devonian Shale in Letcher, Knott, Floyd, Martin, and Pike Counties, Eastern Kentucky: by Jack R. Moody, Julie R. Kemper, Ian M. Johnston, and Robert R. Elkin, 51 p.

The Geology and the Drilling and Production History of the Upper Devonian Shale of Breathitt, Clay, Johnson, Leslie, Magoffin, Perry, and Wolfe Counties, East-Central Kentucky, by Jack R. Moody, Julie R. Kemper, Ian M. Johnston, Robert R. Elkin, and Richard A. Smath, 50 p.

The Geology and the Drilling and Production History of the Upper Devonian Shale of Whitley, Knox, Bell, and Harlan Counties, Southeastern Kentucky, by Jack R. Moody, Julie R. Kemper, Ian M. Johnston, and Robert R. Elkin, 30 p.

The Progression of Life, by Stephen F. Greb (Special Sesquicentennial Poster).

In Press or Editing Completed

Information Circular 26. Oil and Gas Drilling Activity Summary for Kentucky, 1987, compiled by Brandon C. Nuttall.

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

Reprint 26. The Mineral Industry of Kentucky, 1986, by L. J. Prosser, Jr.

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

Special Publication 14. Proceedings of the Technical Sessions, Kentucky Oil and Gas Association Forty-Eighth and Forty-Ninth Annual Meetings, ed. by Margaret Luther Smath.

Special Publication 15. Proceedings of the Technical Sessions, Kentucky Oil and Gas Association Fiftieth and Fifty-First Annual Meetings, ed. by Margaret Luther Smath.

Special Publication 16. The History of the Kentucky Geological Survey, by Preston McGrain.

Papers by Staff Members in Outside Publications

Chesnut, D. R., 1987, Structural and stratigraphic framework of the Carboniferous rocks of the Central Appala-

chian Basin, eastern U.S.A. [abs.]: Eleventh International Congress of Carboniferous Stratigraphy and Geology, August 30-September 5, 1987, Beijing, China, Abstracts of Papers, v. 1, p. 276-277.

Chesnut, D. R. [with Ettensohn, F. R.], 1987, Nature and probable origin of the Mississippian-Pennsylvanian unconformity in eastern United States [abs.]: Eleventh International Congress of Carboniferous Stratigraphy and Geology, August 30-September 5, 1987, Beijing, China, Abstracts of Papers, v. 1, p. 280-281.

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