Kentucky Geological Survey

Earth Resources—Our Common Wealth

Annual Report 1999–2000

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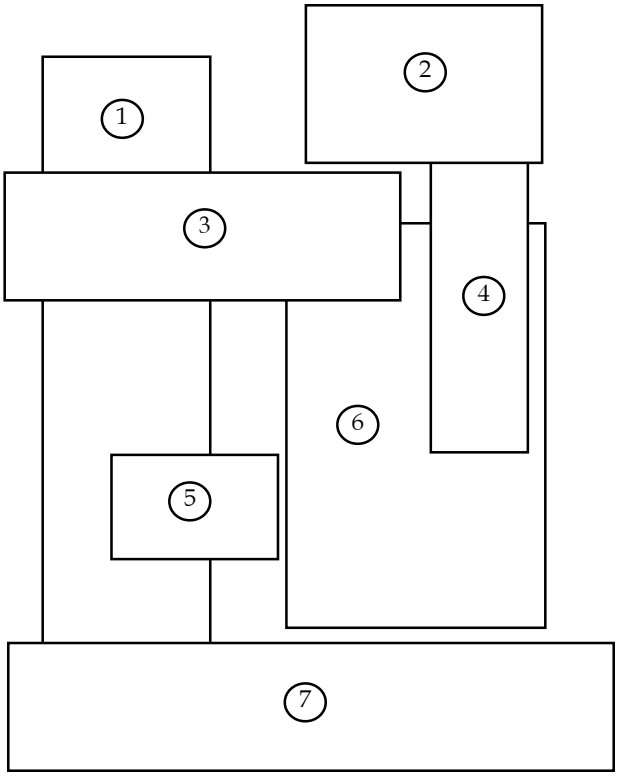
1999–2000

Cover Illustrations



① Quartz-pebble conglomerate from Cumberland Falls. Photo by Stephen Greb. ② Portion of geologic map of Harrodsburg 30 x 60 minute quadrangle, by Thomas Sparks, Garland Dever, and Warren Anderson. ③ Karst landscape in central Kentucky. Photo by Deanna Davis, Barry's Photography. ④ Polished core from the Cambrian–Ordovician Knox Group in Cumberland County. Photo by Lyle VanHorne and Patrick Gooding. ⑤ Kentucky agate. Photo by Collie Rulo. ⑥ Sandstone bluff in Carter Caves State Park. Photo by Douglas Reynolds Jr. ⑦ Big South Fork of the Cumberland River, McCreary County. Photo by Brandon Nuttall.

Earth Resources—Our Common Wealth

Kentucky Geological Survey Annual Report 1999–2000

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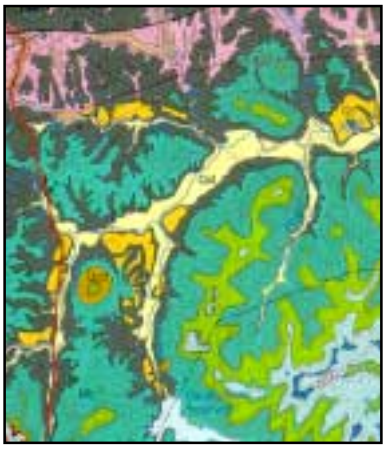

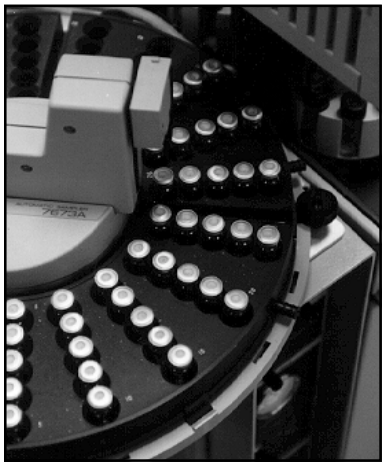

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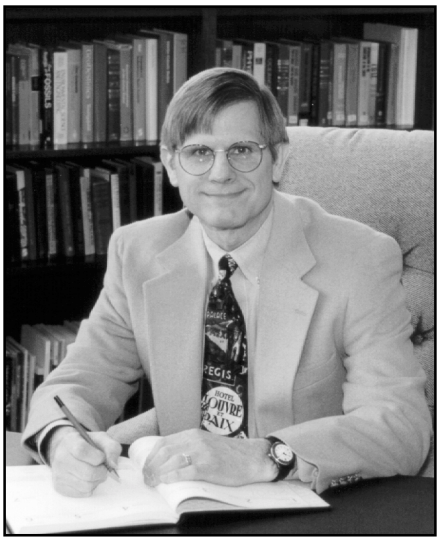
State Geologists
1838–2000

1838:	William W. Mather, State Geologist. No organizational structure.
1839–53:	No organizational structure; no State Geologist.
1854–60:	First Survey. David Dale Owen, State Geologist, 1854–57; Robert Peter, State Chemist, supervised the activities of the office from 1857–60.
1860–73:	No organizational structure; no State Geologist.
1873–93:	Second Survey. Nathaniel S. Shaler, State Geologist and Director, 1873–80; John R. Proctor, State Geologist, 1880–93.
1893–1904:	No organizational structure; no State Geologist.
1904–12:	Third Survey. Charles J. Norwood, State Geologist and Director.
1912–18:	Fourth Survey. Joseph B. Hoeing, State Geologist.
1918–19:	Fifth Survey. J.E. Barton, Commissioner of Geology and Forestry. No State Geologist, 1918–19. Willard R. Jillson, Deputy Commissioner and State Geologist, 1919–20.
1920–32:	Sixth Survey. Willard R. Jillson, Director and State Geologist.
1932–34:	Seventh Survey. Arthur C. McFarlan, Director and State Geologist.
1934–48:	Eighth Survey. Daniel J. Jones, State Geologist.
1948–58:	Ninth Survey. Arthur C. McFarlan, Director; Daniel J. Jones, State Geologist.
1958–78:	Tenth Survey. Wallace W. Hagan, Director and State Geologist.
1978–1999:	Eleventh Survey. Donald C. Haney, Director and State Geologist.
1999–present:	Twelfth Survey. James C. Cobb, Director and State Geologist.

Director's Desk



On October 1, 1999, I was appointed State Geologist and Director of the Kentucky Geological Survey (KGS). It is a privilege and challenge for me to follow in the footsteps of my predecessors who have served as State Geologist of Kentucky since 1838. All 50 states, Puerto Rico, and almost every country in the world have geological surveys. Many state geological surveys were created in the mid to late 1800's and were vital to the settlement and industrial development of the 19th and 20th centuries. In recent decades the research of geological surveys has expanded from mineral and resource development to include water-resource assessment and environmental research. State geologists and their staff share a common goal of wise and prudent use of mineral and water resources and respect for the environment.

The study of earth science is the foundation for understanding the interaction of our land, water, mineral resources, and society to stimulate economic development, promote environmental protection, minimize the risk of geologic hazards, protect public safety, and improve our standard of living. To reflect this idea, we have adopted a new motto: "Earth Resources—Our Common Wealth."

As a result of the outstanding vision and leadership provided by previous state geologists in Kentucky, and strong support from the State and Federal governments, our survey has been a national leader in geologic mapping. My goal for the Twelfth Survey is to have Kentucky be the first state in the country to be completely digitally mapped. To date, we have completed the digital conversion of more than half of the geologic maps for Kentucky. We are building the foundation for a statewide geographic information system (GIS) of digital geologic maps and associated data sets. This GIS product will be interactive with other KGS databases and enable users of KGS information to be able to access, manipulate, retrieve, and display this information for their own purposes, 7 days a week, 24 hours a day, using the information highway provided by the Internet.

Several achievements have served to make this a year distinguished by excellence in research and public service. We have completed a new digital coal atlas and a digital water-resources atlas. A major study of agricultural pollution of ground water was published. The results of a comprehensive investigation of the geology, quantity, and quality of the Fire Clay coal in eastern Kentucky were published in three research reports. The addition of new data, maps, geologic information, and publications online on our Web site has enhanced public access to information and research expertise available at KGS. These and other achievements are highlighted in this annual report for fiscal year 1999–2000 (July 1, 1999, to June 30, 2000).

Since I began working at the Kentucky Geological Survey 20 years ago, I have seen great advancements in our knowledge and ability to serve the people of Kentucky. As the State Geologist of the Twelfth Survey, I am pleased to uphold a 160-year tradition of excellence in research and public service in the geosciences. I remain committed to making this survey outstanding in the research it conducts and the public service it renders to meet the challenges of the 21st century.

James C. Cobb

Energy and Mineral Resources for Our Economy

Better use of our resources will stimulate economic development and provide fuel for society.

Resource issues

- Complex relationships between global resource economics and environmental protection
- Deregulation of the natural gas and electric-utility industries nationwide
- Environmental protection and global climate change
- Rising dependence on imported oil
- Increasing prices for gasoline, heating oil, natural gas, and coal

Research challenges

- Exploring the geologic structure of the deep subsurface in Kentucky for resource potential
- Understanding the geology and chemical properties of coal from the Eastern and Western Coal Fields of Kentucky to promote its increased use
- Finding innovative, economic ways to reduce atmospheric emissions of carbon dioxide to promote clean air

Opportunities for Kentucky

- Untapped resources of deep natural gas in eastern Kentucky
- Recent discoveries of natural gas resource potential in Kentucky
- Significant reserves of coal in the Eastern and Western Coal Fields of Kentucky
- Coal-bed methane as an alternative fuel for the future

Assisting the public

- Oil and natural gas well-location maps
- Digital coal atlas for Kentucky

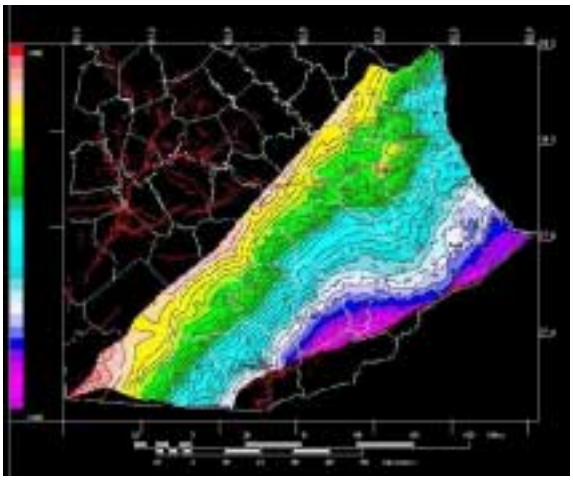
Heating fuel for homes and industry—developing strategies to recover deep natural gas in eastern Kentucky

With funding from four energy companies and the U.S. Department of Energy, **James Drahovzal** and **David Harris** are leading a natural gas research consortium formed in 1998, the Rome Trough Consortium. The study area consists of eastern Kentucky, southern Ohio, and northern West Virginia. Researchers from the geological surveys of Ohio and West Virginia are also contributing to the investigation. Recent discoveries have included the Homer Field, which produces natural gas in **Elliott County,** Ky., and in the Cottontree Field in Roane County, W.Va. This research will provide a model to improve exploration for natural gas in the study area. This exploration activity will stimulate economic development and provide natural gas as a heating fuel for homes, schools, businesses, and industries across the state and provide opportunities to export natural gas to markets outside of Kentucky.

Imagine deep below the surface the rising and falling structures of an ancient eroded mountain belt that today may have "pockets" that hold natural gas.

Uncovering the secrets of the deep subsurface

James Drahovzal has been leading a team of geologists at KGS studying the deep subsurface of central and western Kentucky. This research began with the discovery in 1990 of the East Continent Rift Basin, a basin filled with sediments and buried volcanic rocks believed to be 950 to 1,020 million years old. The basin is buried in the deep subsurface of central and western Kentucky, southern Indiana, and western Ohio. An understanding of this basin is critical for developing models of the early geologic evolution of the eastern Midcontinent. Drahovzal and a team of geologists from several states also discovered the Hoosier Thrust Belt, a previously unknown ancient eroded mountain belt in the deep subsurface of southern Indiana and northern Kentucky. This discovery could stimulate natural gas exploration and development in the Illinois Basin, which is one of the oldest oil- and gas-producing areas in the United States.



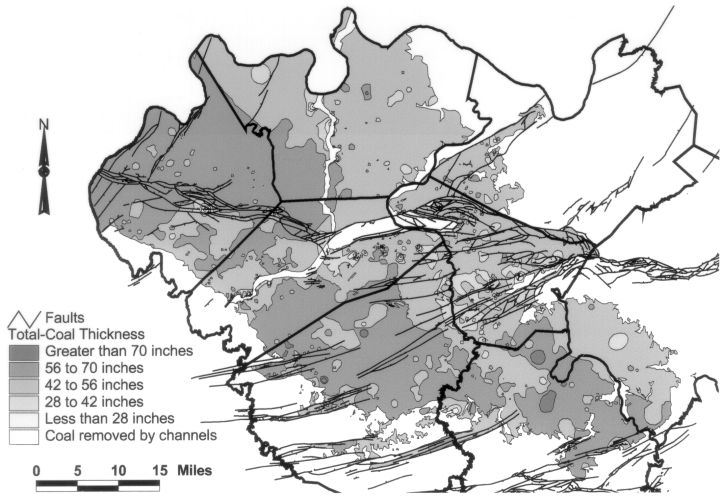
Helping oil and natural gas producers in Kentucky

Brandon Nuttall is using geographic information system (GIS) software to illustrate petroleum drilling activity and results.

The location of oil and natural gas wells is shown on maps. To date, oil and gas well-location maps have been released for the **Tompkinsville, Evansville, Hazard, Corbin,** and **Williamson** quadrangles. A printed copy of the **Pikeville** quadrangle map was released in 1994. These maps are useful for oil and gas exploration and development and are becoming increasingly important in assessing environmental issues. The maps, which integrate information from the U.S. Geological Survey and oil and gas well records at KGS, will be periodically updated to track petroleum activity. Paper maps are available or electronic versions of the maps can be retrieved at www.uky.edu/KGS/emsweb/ogmap/ogmaps.html. Persons who want to compile their own maps may also download individual map components to use on their own computers.

Helping coal producers—digital coal atlas for Kentucky

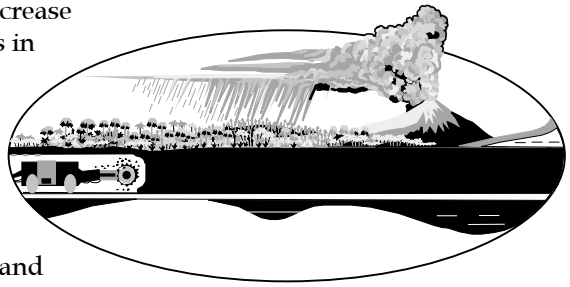
A team of coal geologists at KGS led by **Gerald Weisenfluh** has completed a digital coal atlas consisting of 12 maps and charts with data for the most important coal beds in Kentucky. The authors of the atlas have identified the factors that significantly affect the potential for future mining of coal. Maps in the coal atlas illustrate coal thickness, mined-out areas, elevation, coal quality, and the extent of each major coal bed in the state. The estimated tons of original and remaining coal for eastern and western Kentucky is provided. Factors that restrict mining and can affect the future availability of coal will be calculated in the near future. The maps also illustrate patterns of development on a regional basis in both coal fields and identify areas with the greatest potential for future mining. Paper maps showing the results of the assessment, as well as a CD-ROM containing the digital data sets used to compile the maps, are available to the public. The atlas may be viewed online at www.uky.edu/KGS/coal/webcoal/pages/coal/nca_refs.htm.



Example of data and a map included in the Kentucky digital coal atlas – total coal thickness of the Springfield coal in western Kentucky. This illustration is a gray-scale rendition of the original color version in the digital coal atlas.

The digital atlas and accompanying data sets provide a valuable tool to help the coal industry identify future opportunities for economic coal mining in Kentucky. The data are also useful in identifying high-quality coal to assist electric utilities in complying with Federal clean air regulations governing atmospheric emissions from burning coal.

A powerful tool to aid future exploration of the Fire Clay coal of eastern Kentucky

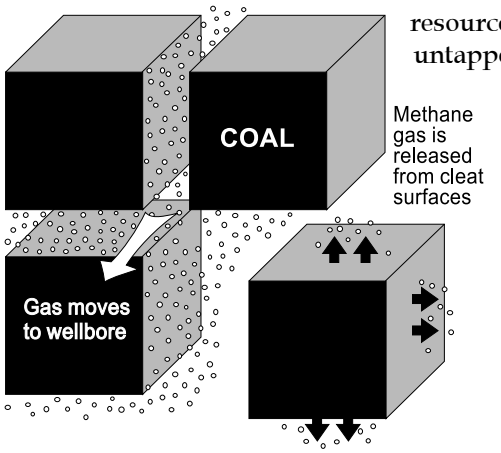


A priority for coal geologists at KGS has been to increase our understanding of the major mineable coal beds in Kentucky. The results of a multi-year research project have been published in a three-part study representing the most comprehensive single investigation undertaken to date that explains the geology, chemistry, and quality of the Fire Clay coal bed. Detailed mapping of the coal bed has identified distinct trends in thickness and quality. The results of this research provide a powerful tool to aid in future coal exploration. The results are published in three scientific reports available at www.uky.edu/KGS/pubs/kgspublications.html.

Coal-bed methane—an alternative fuel for the future

Coal-bed methane is a gas that occurs in association with coal. When coal is formed, large amounts of gas (mainly methane) are produced—more gas than the coal can hold. Some of this gas escapes into other rocks or into the atmosphere, but some of it remains in the coal. Coal-bed methane is produced in association with mining in many states, but little has been done to date in Kentucky to explore this energy alternative.

Brandon Nuttall, Donald Chesnut, and **Cortland Eble** are assessing the potential for coal-bed methane and development of deep coal resources in an area north of **Pine Mountain** and in western Kentucky. Previous mining in the Eastern Kentucky Coal Field has concentrated on areas where the coal is most accessible, resulting in the easily recovered resources being developed. Deeper, harder-to-recover coal deposits are becoming increasingly important for future economic opportunities. Research at KGS indicates that methane gas contained in deep coal resources in the Eastern Kentucky Coal Field may also be recoverable. Recovery of methane from Kentucky coal beds may be advantageous for several reasons. First, it uses an energy resource that would otherwise go untapped. Second, it would help supplement a rapidly growing demand for natural gas, both within the Commonwealth and across the Nation. Third, removal of coal-bed methane has none of the risks to humans associated with underground mining, nor does it disturb the earth's surface, as is the case with surface mining.



Technology transfer—sharing what we know

On September 16, 1999, KGS geologists held a workshop to discuss coal-bed methane potential in the eastern United States. The workshop, sponsored by the Petroleum Technology Transfer Council and the Kentucky Society of Professional Geologists, was attended by 112 registrants. Workshop topics included coal-bed methane research; the geology of the Black Warrior, Appalachian, and Illinois Basins; field operations in Virginia; and a summary of evidence for coal-bed methane in Kentucky.

A 1-day coal-assessment seminar was held on March 8, 2000, in **Madisonville**, Ky., for personnel from coal and natural gas companies and consultants. Each participant was provided information and data on all aspects of coal in the major beds of western Kentucky (for example, coal structure, outcrops, mining history, areas that have been mined, coal thickness and quality, and the potential for developing coal-bed methane). The seminar was part of a series of biannual technology-transfer seminars on coal resources taught by KGS coal geologists **Stephen Greb, Cortland Eble, David Williams, Donald Chesnut, Brandon Nuttall,** and **William Andrews.**

Experienced coal geologists at KGS are available to respond to inquiries and can assist the public in locating relevant information.

Do you need data on the coal resources of Kentucky? We can help you.

KGS manages the largest publicly available database in Kentucky on the coal resources of Kentucky. Data in the **Kentucky Coal Resources Information System** (KCRIS) include coal-thickness measurements and descriptions of coal at natural outcrops, roadcuts, and mine exposures in eastern Kentucky; analyses of coal quality in samples from mines, natural outcrops, and cores from both eastern and western Kentucky; and records of holes drilled for coal exploration and development. These data, which are provided on request as paper printouts or on computer diskettes and CD-ROM, are available to coal-industry personnel, consultants, government agencies, researchers, students, and other interested persons.

A research library for resource development

Since 1960, KGS has had a legislative mandate to review applications to drill oil and natural gas wells that are filed with the State. KGS can request samples and cores from selected sites. These samples and others donated to KGS by industry are housed at the **Well Sample and Core Library**. The samples and cores illustrate different characteristics of rock in the earth's subsurface and are of interest to geologists exploring for oil, natural gas, and coal.

Although outcrops offer opportunities for studying the geology of the landscape, samples and cores such as those stored at the library are the best source of information about the nature and occurrence of coal, minerals, oil, and natural gas found below the earth's surface. A computer database is being constructed to provide information about the samples and cores. The materials are used by industry personnel for exploration and development; researchers; graduate students for theses and dissertations; and by other students for term papers and laboratory assignments.

Each year the library hosts a regional meeting in which middle-school teachers teach their students about energy use and development in Kentucky. The 48,000-square-foot facility is used to host the KGS annual seminar, as well as workshops by the Kentucky Society of Professional Geologists and others.

Housing the fifth largest collection of its type in the United States, the Well Sample and Core Library has more than 22,000 sets of well samples from 120 counties.

Clean Air and Water to Enhance Our Quality of Life

The benefits of economic growth must be balanced with the need for environmental protection.

Clean air and water issues

- Clean air and water are an important part of our quality of life and are essential for our health.
- Kentucky's water resources, both surface and ground water, must be protected for the benefit of human health, vital ecosystems, and a growing population and economy.
- The quality of Kentucky's ground water must be studied to establish long-term policy and develop strategies for managing watersheds.
- Kentucky must plan for increasing use of its water resources, both surface and ground water.
- The effects of land use and pollution on water quality need to be understood.
- The benefits of economic growth need to be balanced with the need for environmental protection.

Research challenges

- Assessing water quality and supply for Kentucky homes, farms, and businesses
- Applying research tools to locate affordable, high-yield water wells
- Developing strategies to minimize pollution of ground and surface water
- Reducing carbon dioxide emissions in the atmosphere
- Assessing coal quality to reduce air pollutants from burning coal

Opportunities for Kentucky

- Achieving Governor Paul Patton's goal that every Kentucky household have access to drinkable water by 2020
- Protecting the quality of ground and surface water for the health of all residents of Kentucky

Assisting the public

- Transferring technology to local communities for locating affordable, high-yield water wells
- Publishing data and maps of water quality for Kentucky

Reducing emissions of carbon dioxide for clean air

Throughout the past 100 years, the use of coal, oil, and natural gas for electric power plants, industrial activities, vehicles, and other purposes has significantly increased carbon dioxide levels in the atmosphere. This increase may be contributing to climate change, including global warming. With funding from the U.S. Department of Energy, KGS geologists are participating in a 3-year research project to investigate methods to reduce concentrations of carbon dioxide, a greenhouse gas.

Water vapor, carbon dioxide (CO_2), and methane trap heat in the earth's atmosphere. Without these gases, the earth would be too cold to sustain life as we know it. If human activities introduce more greenhouse gases into the atmosphere than the land and oceans can absorb, however, more warming than is natural may occur. This is known as the "greenhouse effect."

Geologic sequestration—a process of injecting CO_2 into underground geologic formations—may be one way to manage CO_2. Geologists at KGS will be investigating places beneath the earth's surface in Kentucky where CO_2 can be safely contained for long periods of time. For example, depleted and underproduced oil and gas reservoirs could be excellent storage sites for CO_2 if they are needed in the future. Deep, thin, unmineable coals, which Kentucky has in abundance in both the eastern and western parts of the state, have the potential for sequestering CO_2, as do some producing oil fields.

Geologists at KGS, led by **James Drahovzal,** will be cooperating with researchers from Illinois, Indiana, Kansas, and Ohio to develop a computer database that will integrate regional information on CO_2 sources with potential sites for geologic sequestration. The project will create a planning tool for sequestering CO_2 in the central United States.

Geologic sequestration would be an environmental and economic win-win situation in which CO_2 would be injected in underground reservoirs, and natural gas and oil could be produced at higher rates and in larger quantities.

Clean coal for a clean environment

Sulfur and other chemicals found in coal may be released into the atmosphere when coal is burned. Several provisions in the Federal Clean Air Act Amendments of 1990 have implications for the coal industry in Kentucky and elsewhere. Of particular interest are Federal regulations governing the emission of sulfur dioxide and nitrogen oxides during the burning of coal and the regulation of hazardous air pollutants. Fifteen of the trace elements of concern for hazardous air pollutants commonly occur in very small quantities in coal. **Cortland Eble,** in his study, "Overview of Environmental Regulations That Affect Coal Combustion," has assessed the implications of these Federal regulations for the coal industry in Kentucky. Eble's study is available at www.uky.edu/KGS/pubs/.

By-products of burning coal: what are they and why do they matter?

Utilities that burn coal to generate electricity need to know what the quality of the coal available for them to use will be in the next 5 to 15 years. This information is important for assessing the environmental implications of burning specific coals. Although data on coal quality are available, most of these data are for coals that were mined decades ago. Coal geologists at KGS maintain a comprehensive, computerized database of records on coal quality that includes measurements of trace elements (for example, mercury, lead, arsenic, nickel, and cadmium) occurring in more than 700 samples of coal. With funding from the Electric Power Research Institute and the U.S. Geological Survey, **Cortland Eble** and **Stephen Greb** are sampling coals in Kentucky to analyze the quality of coal as a fuel source for boilers used by electric utilities. This research will assist utilities in determining whether hazardous air pollutants are washed out of the coal before it is shipped to the utilities or if environmentally harmful products are generated as a by-product of burning the coal.

Contributing to a water resources development plan for Kentucky

In 1999, Governor Paul Patton created the Water Resource Development Commission, whose goal is to develop plans to provide drinkable water and modern sewer service to every household in Kentucky by 2020. **Daniel Carey,** a hydrologist at KGS, assisted the commission by preparing strategic plans on water resources and sewer systems in the state. An inventory of public and private water and sewer systems was prepared, the strengths and weaknesses of the systems were assessed, and strategies to build on the strengths and eliminate the weaknesses were recommended. A series of technical committee meetings with Federal, State, and local officials was held to consider infrastructure, financial, managerial, and other factors. The statewide water-resources plan was completed in October 1999, and the wastewater-treatment plan was completed in March 2000.

Protecting the quality of drinking water in rural areas

In Kentucky and elsewhere, good water supplies in many rural communities come from sources of ground water in limestone rock referred to as "karst aquifers." In areas with a lot of limestone, the rock is porous enough that ground water can flow through the rock and provide significant quantities of water to wells and springs. Unfortunately, karst aquifers can also be sensitive to pollution from agricultural activities because runoff from fields and animal feedlots can enter the ground water directly through streams that enter the

ground and sinkholes. Pesticides, fertilizers, soil eroded from fields, and animal waste washed from pastures and feedlots can all contribute to contamination of ground water. Agricultural producers can voluntarily take steps to minimize such pollution of ground water. Whether or not such voluntary measures can protect the quality of ground water in karst aquifers is a question of both environmental and economic importance. **James Currens** published the findings of the first of two reports in a multi-year investigation of these issues in his report, "Mass Flux of Agricultural Nonpoint-Source Pollutants in a Conduit-Flow-Dominated Karst Aquifer," which is available at www.uky.edu/KGS/pubs/.

Currens tested the effectiveness of the voluntary adoption of practices to protect ground-water quality in a karst aquifer in southwestern Kentucky, the **Pleasant Grove Spring Basin**. His results demonstrated that ground water was adversely affected by contamination from soils, chemicals used in agricultural activities, and waste from animal feedlots. Currens says that the protection of ground-water quality will require reducing pollution from crop-field runoff, using safer methods for disposal of animal waste, and applying agricultural chemicals more efficiently to limit contaminants entering ground water. The report's findings are relevant for geologists, soil scientists, agricultural extension agents, farmers, landowners using domestic water wells, municipal water companies, and government agencies responsible for monitoring ground-water quality.

Assessing the quality of our ground water

The Kentucky Ground-Water Data Repository housed at KGS has data on ground-water quality from springs and wells across the state. These data are being used by **Stephen Fisher** to assess the quality of ground water for basins of the Tennessee, Mississippi, upper and lower Cumberland, Tradewater, and Green Rivers, and tributaries to the Mississippi River in the **Jackson Purchase Region.** The chemistry of the ground water is being studied to determine the extent to which ground water and surface water interact with each other and to identify possible sources of pollution. This investigation is being conducted in cooperation with the Groundwater Branch of the Kentucky Division of Water.

The chemistry of ground water is being studied to identify possible sources of pollution.

The Kentucky Division of Water monitors the quality of ground water four times a year at approximately 70 sites across the state. A project led by **Stephen Fisher** will expand this effort by collecting water samples quarterly at 30 springs or wells and analyzing them. Monitoring sites will be established in the basins of the upper and lower Cumberland River, lower Tennessee River, and tributaries of the Ohio and Mississippi Rivers. The goals of the project are to better understand the quality of the ground water at these sites, locate pristine supplies of ground water, and identify the impacts of pollution on the ground water of these river basins. The results of the water analyses will be added to the Kentucky Ground-Water Data Repository.

Protecting well-water supplies from nitrate contamination

Ground water is used by more than 75 percent of the residents in the **Jackson Purchase Region** in western Kentucky. Approximately 60 public water utilities provide water from wells to residents, businesses, schools, and industry. A greater proportion of private wells in the Jackson Purchase Region have water with nitrate levels above the U.S. Environmental Protection Agency's maximum contaminant level for nitrate than wells in other parts of Kentucky. The presence of nitrate in drinking water is of concern for human health.

Glynn Beck, a geologist in the KGS field office in **Henderson,** Ky., is studying the sources of the elevated nitrate in the Jackson Purchase Region. Beck, along with agronomists and agricultural engineers in the UK College of Agriculture, has found that the possible sources of nitrate are chemical fertilizers, leaky septic tanks, and active or abandoned animal feedlots, in possible combination with poor (leaky) construction of water wells. To help protect the quality of well water in this region, Beck will explain the findings of his research in public presentations and outreach programs for citizens.

Finding new water supplies in eastern Kentucky

Robert Andrews is developing methods to identify locations where water wells can be drilled to yield large water supplies in eastern Kentucky. He is using satellite imagery, aerial photography, hydrogeologic information, and innovative drilling techniques to locate water wells yielding greater than 30 gallons per minute. The results have been positive. As of June 2000, KGS has worked at six locations. Four of the six sites **(Oakdale** in **Breathitt County, Creekville** in **Clay County, Isom** in **Letcher County,** and **Vest** in **Knott County)** had water yields, measured in gallons per minute, that were greater than 95 percent of all wells drilled within their respective counties.

Abandoned underground coal mines often contain enough water to provide an economic source of water for small municipal communities in eastern Kentucky. Whether or not these water supplies can be developed depends upon the capacity of the abandoned mine to store water, the rate at which the abandoned mine is recharged with water, the quality of the water, and the distance to the nearest communities that could use the water. **Dennis Cumbie** is assessing the potential to use water from abandoned underground coal mines at three sites near **Whitesburg** in **Letcher County** and one site near **Manchester** in **Clay County.** Many of these mines contain millions of gallons of water that can be used as a principal or backup source of ground water for communities and industry.

Does the way we use our land affect the quality of our surface and ground water?

Carlos Galcerán and **James Dinger** are assessing the quality of surface water at the **Wendell H. Ford, Artemus,** and **Clay City** training sites operated by the Kentucky Army National Guard in western Kentucky. Activities that occur on the surface of the land can have an impact on the quality of water that drains from the land surface. The impacts of current activities on surface water at the sites and surface water exiting from the sites to surrounding areas are being studied, and a long-term plan for monitoring the quality of the surface water is being developed.

Environmental research laboratory

Research on water and coal quality conducted by KGS geologists is made possible by the expertise of the professional staff of the KGS laboratory, which specializes in environmental analysis of water, coal, rocks and minerals, and other natural resources. Although this service is provided primarily to researchers at KGS, it is also available to representatives of academia, government, and industry who study the environment and natural resources of Kentucky. The laboratory has state-of-the-art equipment and a quality-control program to assure reliable results.

Helping Our Communities Become More Resistant to Natural Disasters

Geologic expertise can improve design codes for buildings, highways, dams, and bridges.

Research challenges

- As our country's economy and population expand, new construction is increasingly occurring in less desirable locations that may be more prone to geologic hazards.
- Although scientists' understanding of geologic hazards has greatly increased, there has not been a corresponding increase in public awareness of steps that can be taken to minimize the risks associated with geologic hazards such as earthquakes, flooding, subsidence, landslides, and sinkholes.

Opportunities

- Provide geologic expertise to improve emergency-response planning
- Provide geologic expertise to improve design codes for buildings, highways, dams, and bridges to make them more resistant to natural disasters
- Provide technical advice for local initiatives to build communities more resistant to natural disasters

Assisting the public

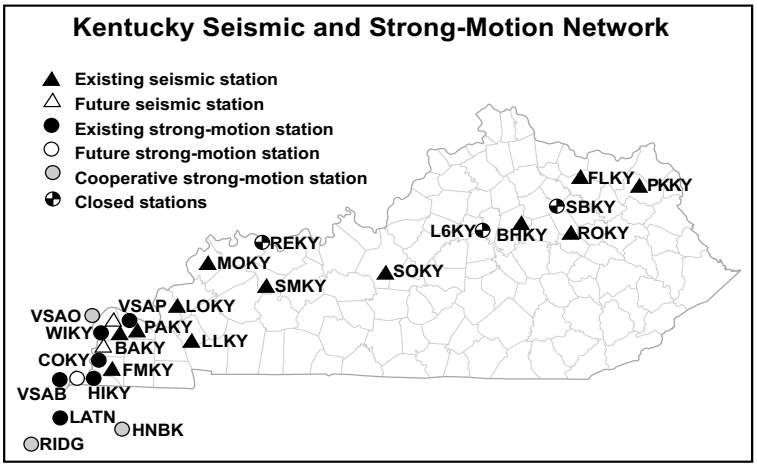
- Public education to help minimize the loss of property and life that may result from geologic hazards

Understanding earthquake activities in Kentucky

For the past 20 years, KGS and the University of Kentucky (UK) Department of Geological Sciences have jointly operated the Kentucky Seismic and Strong-Motion Network. The network has 20 stations across the state—12 weak-motion and six strong-motion—that monitor earthquake activity. KGS continues to extend and upgrade the network.

KGS has established a cooperative agreement with the U.S. Army Corps of Engineers to operate a vertical strong-motion seismic array at the **Olmsted Locks and Dam** on the lower Ohio River bordering **Ballard County.** The seismic array measures earthquake activity in soil above bedrock. These real-world measurements are used to refine computer models that predict what effects an earthquake may have at the dam site. In addition, the station at this site is providing valuable data for understanding earthquake hazards in the Southern Illinois and Wabash Valley Seismic Zones.

Helping to minimize damage from potential earthquakes in Kentucky



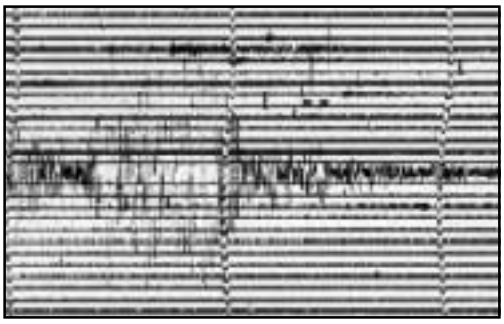
Edward Woolery of KGS and **Ron Street** of the UK Department of Geological Sciences are studying ways to minimize damage from potential earthquakes in Kentucky. Six seismic source zones, areas from which earthquake activities originate, have historically resulted in earthquake activities felt in Kentucky. Knowledge of these seismic source zones is being used to build statistical models to estimate earthquake hazards that might occur in any 250-year period and what implications this has for engineering design. The results of this study will be used by the Kentucky Transportation Center for the design of the next generation of transportation systems (highways, bridges) in Kentucky.

Edward Woolery and **Ron Street** are also measuring soil properties (such as soil thickness) that are responsible for the amplification of earthquake motions (waves) in western Kentucky, southeastern Missouri, northeastern Arkansas, and northwestern Tennessee. As more is known about these soil properties, appropriate recommendations can be made for engineering designs that reduce the risk of damage from earthquake activity. Engineering designs are often conservative to build in safety features. It is important not to overestimate the risk of damage from earthquakes, since this will unnecessarily escalate building costs. At the same time, it is also

important not to underestimate the risk of damage from earthquakes so there will not be loss of life or property should an earthquake occur.

Was this really an earthquake?

Blasting in mineral quarries, coal mines, and highway roadcuts; collapses of roofs in coal mines; and mining-related disturbances can register as magnitudes 2 or 3 on the Richter scale, a numerical scale used to measure the magnitude of earthquakes. These events can mistakenly be considered earthquake events. If such incorrect interpretations are used when designing structures (for example, buildings and bridges), unnecessary and expensive over design can result. It is important to be able to know whether a recorded event is a genuine earthquake. The difference between the typical recordings of genuine earthquake activities and other blasts is easy for seismologists to recognize and distinguish. To address this concern, **Ron Street, Edward Woolery,** and **Gil Bollinger** (a retired professor from Virginia Polytechnic Institute) are reviewing the national earthquake catalog to eliminate the seismic disturbances recorded in Kentucky that are not genuine earthquake events. The revised catalog will provide a more accurate, reliable reference resource for use in Kentucky.



Creating geologic maps to improve our understanding of earthquake risks

Since the Central United States Earthquake Consortium (CUSEC) was founded in 1983, **John Kiefer** has been active in the organization. This consortium of emergency-management agencies in a seven-state region (Arkansas, Illinois, Indiana, Kentucky, Mississippi, Missouri, and Tennessee) strives to improve earthquake awareness and education, coordinate multistate planning for earthquake preparedness, and encourage research in efforts to reduce hazards to infrastructure and people resulting from earthquakes.

In 1992, state geologists representing the state geological surveys of the CUSEC region organized CUSEC State Geologists (CUSEC-SG). In cooperation with the U.S. Geological Survey, CUSEC-SG is coordinating efforts to develop earthquake-hazards maps. The maps are useful for guiding decisions about how best to use land. For example, hospitals and schools should not be built on land classified as being at high risk for earthquake activity. The maps are also being used to increase an understanding among Federal,

State, and local government officials, media, and the public about the nature, extent, and likelihood of earthquake events. Maps describing soil type and characteristics, referred to as soil-profile maps, have been completed for the New Madrid and Wabash Valley Seismic Zones; both seismic zones are areas of relatively high seismic risk. **John Kiefer, Steven Cordiviola,** and **James Drahovzal** contributed to the development of these maps.

Another outgrowth of CUSEC has been the Central United States Partnership (CUSP), which is a coalition of national organizations and agencies that are cooperating to produce and implement a long-term strategic plan to reduce risks associated with damaging earthquakes. **John Kiefer** played a key role in founding CUSP. He also played a central role in organizing a conference at Kentucky Dam Village State Resort Park, May 22–24, 2000, where officials from agencies throughout the central United States that address geologic hazards and emergency-response planning were brought together to discuss strategies for living with earthquakes, building for earthquakes, and learning about earthquakes.

Earthquake-hazard maps are being used to increase understanding about the nature, extent, and likelihood of earthquake events.

Planning for safer communities

John Kiefer is providing technical assistance to the Project Impact Program for the **Lexington-Fayette Urban County Government**. This program, an initiative of the Federal Emergency Management Agency, is designed to help local communities become more prepared to respond to disasters and reduce the risk of damage that may result from natural disasters. Kiefer is also active in the Governor's Earthquake Hazards and Safety Technical Advisory Panel.

Enhancing Access to Geologic Maps and Data for Our Citizens

Geologic maps are the cornerstone of geologic research.

Research challenges

- Using 21st century information technology to enhance public access to geologic maps and data
- Developing cost-effective methods for efficient public distribution of geologic maps and data
- Converting geologic maps and data into computer format to address issues and problems that require the expertise of geologists

Opportunities for Kentucky

- Using the World Wide Web to deliver geologic maps and information to citizens 24 hours a day, 7 days a week
- Providing national leadership in digital geologic map technology

Assisting the public

- Providing citizens with information to protect the quality of surface and ground water, minimize the damage from potential natural hazards, and develop energy and mineral resources

Meeting citizens' needs for geologic information

To support research and respond to questions from the public, KGS has a state-of-the-art computerized database of information on the oil, natural gas, coal, water, and mineral resources of Kentucky. The database is accessed thousands of times each year, and information is provided to the public, consultants, industry and government personnel, researchers, and students.

KGS is dedicated to creating digital geologic maps for the entire state by 2004 and becoming the first state in the Nation to achieve such a hallmark.

Creating digital geologic maps for 21st century information technology

Since 1996, geologists at KGS have been converting Kentucky's geologic maps into computer format. In the first 4 years of this major undertaking, approximately 50 percent of the digital conversion of the maps has been completed. The geologic information found on the paper maps is being put into computer files so that the information can be used in projects around the state. This information will guide coal, mineral, and petroleum resource assessment; rural and urban development; engineering, planning, and reclamation projects; and water-supply and waste-disposal studies.

Providing national leadership in digital geologic mapping

An essential part of the National Geologic Mapping Act of 1992 and its subsequent reauthorization in 1997 was the establishment of a national database of geologic maps. The U.S. Geological Survey is building the database. The project's first product was an Internet-based, searchable catalog of available geologic maps for the country (ncgmp.usgs.gov/ngmdbproject/). The second phase will implement digital geologic maps in a database so that the map contents can be viewed using the Internet. **Gerald Weisenfluh** is leading a team of KGS geologists to supply data for 64 geologic maps for a prototype of the national database. KGS geologists are also cooperating with the U.S. Geological Survey and authors of the North American Data Model, the database structure for geologic maps, to design and test the database methodology.

Ground-water resource reports for each of Kentucky's 120 counties are available from the Kentucky Geological Survey in a digital ground-water atlas.

Digital atlas of ground water in Kentucky

KGS hydrologist **Daniel Carey** developed a digital ground-water atlas for Kentucky to support the water-resources planning activities of the Kentucky Water Resource Development Commission created in 1999 by Governor Paul Patton in support of his goal that every household have access to drinkable water and acceptable sewage disposal by 2020 (see "Contributing to a Water Resources Development Plan for Kentucky" above). The hydrologic atlases for Kentucky, paper maps previously published by the U.S. Geological Survey, have been converted into computer files and placed in a geographic information system. Geologic information found on the maps was updated, and data from water wells were added. The atlas will be used to evaluate the quality and supply of ground water throughout the state, particularly for areas in which public water supplies may not be available. The digital ground-water atlas is found at www.uky.edu/KGS/water/library/webintro.html.

Ensuring future availability of geologic maps for the public

Steven Cordiviola directed a project to archive and preserve 707 geologic maps for Kentucky using a color scanner that creates computer files and color copies of large documents. At the present time, the U.S. Geological Survey has no plans to reprint these maps in the future; therefore, this archive will eventually become the only source of the original maps. The Survey can plot color copies of the maps for the public, and they will eventually also be made available for public access on the Internet.

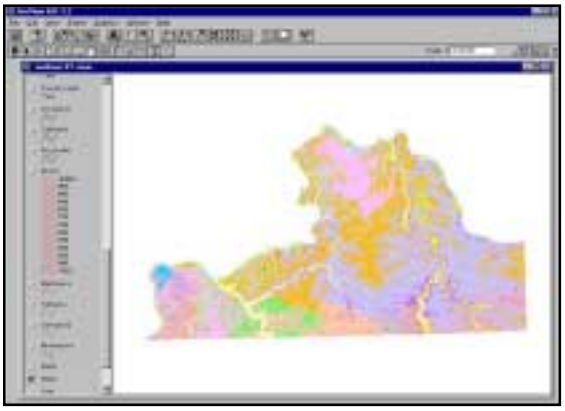
Providing geologic information to aid interstate transportation planning

KGS geologists developed a transportation planning model for the proposed Interstate 66 corridor in the **London-Corbin-Somerset** area of southern Kentucky. In cooperation with the Kentucky Transportation Center at the University of Kentucky, **Gerald Weisenfluh, Warren Anderson, Xin-Yue Yang,** and **Ernest Thacker** integrated geologic data in a geographic information system to provide information for the planning and design phases of the proposed highway. Weisenfluh and Anderson provided information about the geologic impacts of the corridor. Of particular interest were karstic limestone

formations in the vicinity of Somerset. Karstic limestone formations often have caves, which may house bats and endangered species. Caves are also of research interest and recreational value to speleologists, or persons who explore caves. Information on geologic maps can identify areas with caves that could be affected by road construction. Other geologic factors examined were formations that had steep slopes, which could lead to rock falls, and possible subsidence in areas with historical coal mining. Information prepared by KGS was used by planning staff of the Kentucky Department of Transportation to assist in making final decisions about route alignments in the region.

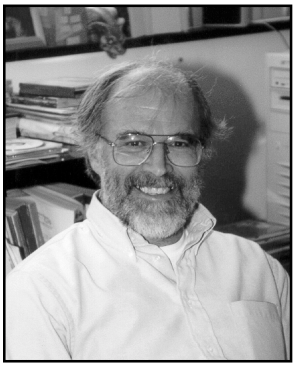
Digital mapping techniques

KGS hosted Digital Mapping Techniques 2000, a national workshop, May 20–24, 2000, at the University of Kentucky. The workshop attracted more than 200 Federal, State, and industry personnel. The technical program and demonstrations focused on methods of data capture, three-dimensional data visualization, digital map production, and progress toward building a national geologic map database.



Teaching 21st century information technology

KGS is an authorized Environmental Systems Research Institute, Inc. (ESRI) instruction center for geographic information system software. **Daniel Carey** has taught numerous classes on ArcView 3.1 and ArcView Spatial Analyst for KGS, University of Kentucky, and other groups in the Commonwealth.



Daniel Carey

Upholding a Tradition of Quality Public Service

KGS staff members responded annually to approximately 10,000 questions from the public.

Do you want to know about water wells in Kentucky?

Created in 1990, the **Kentucky Ground-Water Data Repository** is an archive of ground-water data collected by more than 15 State and Federal government agencies, research organizations, and independent researchers. Data are provided to the public on paper printouts, diskettes, and CD-ROM's. Data may also be transferred electronically by e-mail or FTP (file transfer protocol). The repository database currently contains information on more than 50,000 water wells, 4,000 springs, 350 dye traces, and 40,000 water-quality analyses. Information is also available on the location of public, domestic, and industrial water wells. Well-location overlay maps can be provided at a scale of 1:24,000 on vellum paper or on a scanned topographic map. These data are useful to industry personnel, environmental geologists and engineers, regulatory agencies, land-use planners, agricultural producers, and others. **Bart Davidson** and **Richard Smath** respond to between 50 and 100 requests for ground-water data each month.

Do you want to learn more about ground-water quality?

The **Kentucky Interagency Groundwater Monitoring Network** was created in 1998 to facilitate research on the quality, quantity, and distribution of Kentucky's ground-water resources. The network is operated at KGS in coordination with a technical advisory committee composed of representatives from numerous State and Federal government agencies. The network provides information that can be used to develop community water supplies, address resource-allocation concerns, outline ground-water flow systems, identify areas of unclean and pristine ground water, and monitor long-term changes in ground-water quality.

Stephen Fisher is leading efforts to map and summarize the concentrations of three groups of chemicals: (1) those having health implications (such as nitrate, fluoride, and barium), (2) those having primarily natural sources (such as sodium, calcium, bicarbonate, and chloride), and (3) those resulting primarily from urban or agricul-

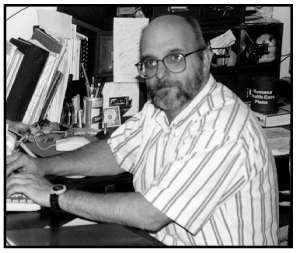
tural activities (such as fertilizers, pesticides, and insecticides). Maps showing statewide concentrations of these and other chemicals present in ground water and statistical summaries of concentrations are being prepared and distributed to the public. Maps of statewide concentrations of nitrate and fluoride in ground water have been published and are available at www.uky.edu/KGS/pubs/.

Are you interested in information about oil and natural gas wells in Kentucky?

KGS is the official repository for records of all oil and natural gas wells drilled in the state. The records are housed in the **Kentucky Oil and Gas Data Repository.** These records, which are available to the public, include drillers' logs, wireline logs, well-location survey plats, plugging affidavits, and completion reports for approximately 175,000 wells. In addition, files for wells drilled in western Kentucky are available at the KGS field office in **Henderson.** These records are being scanned and preserved in electronic files to archive the well records. The number of well records available in the computerized database as of June 30, 2000, is 155,000, constituting almost 90 percent of the well records.

Do you want to know about the wetlands of Kentucky?

Wet areas such as marshes, swamps, ponds, and bogs are commonly referred to as "wetlands." The protection of wetlands is of environmental interest because they support migratory birds, fish, and aquatic plants, and provide natural flood and erosion control. Each year, 458,000 acres of wetlands across the country are lost to development, drainage, and agriculture. In 1977, the Fish and Wildlife Service of the U.S. Department of the Interior began the National Wetlands Inventory, a systematic effort to classify and map the remaining wetlands in the United States. In the spring of 2000, KGS acquired the complete set of maps for Kentucky from the national wetlands inventory. Copies of these maps are available to the public for a nominal fee. The maps are useful for land-use planning, town planning, project-siting studies, zoning, permit reviews, water-quality planning, flood-hazard planning, flood controls, research, waste treatment, and wildlife habitat management.



Richard Smath

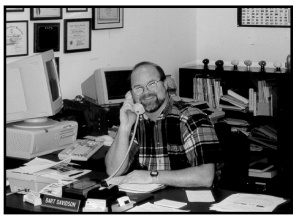
Do you have questions about the geology of Kentucky?

Richard Smath, coordinator of the **Earth Science Information Center,** responds daily to questions on a diverse range of subjects pertaining to the geology of Kentucky, geologic maps, aerial photographs, geodetic control points (horizontal and vertical benchmarks used by surveyors), publications on geology, and identification of rocks and minerals. KGS also maintains a listserv in which persons can submit by e-mail questions on the geology of Kentucky or questions pertaining to earth-science topics for kindergarten through grade 12. Information about this listserv is found at www.uky.edu/KGS/education/education.html.

Theola Evans

Do you need maps on the geology of Kentucky or publications about the geology of Kentucky?

The **Publication Sales** office has available for the public all the publications of the Kentucky Geological Survey, all the 7.5-minute, 1:24,000-scale topographic and geologic maps for Kentucky, and many other maps published by the U.S. Geological Survey. Numerous other geologic, geophysical, hydrologic, and mineral-resource maps are also available. During fiscal year 1999–2000, staff in the Publication Sales office assisted more than 3,000 customers, and sold 5,445 publications, 7,950 topographic maps, and 2,158 geologic maps. Many of the KGS publications and maps are now available for browsing online on the KGS Web site at www.uky.edu/KGS/pubs. To assist customers living outside of Lexington, Ky., a toll-free telephone number has been established (1-877-778-7827). An online, searchable list of publications is being constructed, and our goal is to have it available on the KGS Web site in 2001.



Bart Davidson

Public Service Activities

Grants and contracts in effect—25

Committees, boards, and societies on which KGS staff serve

- International—4
- National—25
- Regional—15
- State—38
- Local—12
- University of Kentucky—20

Kentucky Geological Survey publications completed—12

Geologic Data Center

- Oil and gas permit applications processed—1,036
- Oil and gas completions, terminations, drilling affidavits, and changes processed—1,211
- Well records copied—14,075
- Electronic-data disks and well lists—132
- Computer-generated overlays to topographic maps—299
- Data entry or new records received for oil and gas well records—2,594

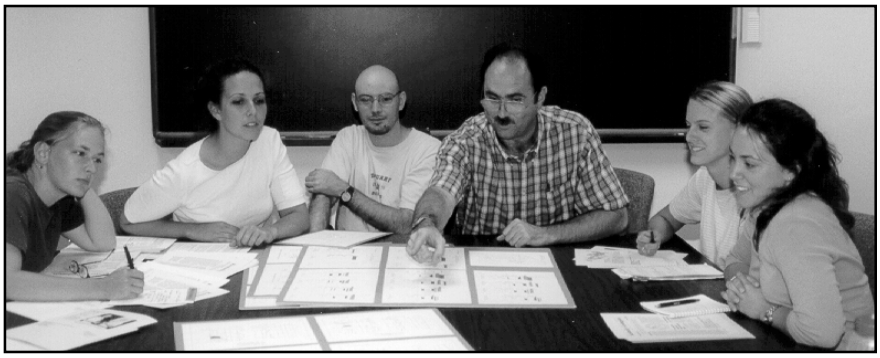
Mentoring Future Geologists

"I consider my internship at KGS this summer a chance of a lifetime." – Hannah Harbin

Chance of a Lifetime: Summer Internship at KGS

In the spring of 2000, an independent studies course was created at the University of Kentucky to enable geology students to earn credit for participation in a newly established internship. Four students participated: **Bethany Overfield** of Western Kentucky University; **Hannah Harbin** of Hanover College in Hanover, Ind.; **Matt Crawford** of Eastern Kentucky University; and **Sarah Hawkins** of the University of Kentucky. The interns worked on a diverse range of research activities. They were introduced to digital geologic mapping; the use of Global Positioning System (GPS) equipment; seismic research for oil and natural gas exploration; palynology and coal-quality studies; geologic sequestration of carbon dioxide gas; hydrogeology; minerals and geologic mapping; curation of mineral and fossil collections; fellowship opportunities in Congress, career opportunities in general, and professional registration for geologists; and earth-science education and public outreach. Every Friday afternoon was devoted to a mentoring session in which a KGS staff member shared his or her expertise and current research interests. The interns conducted field work and research to write articles for the county geology project featured on the KGS Web site. Field trips organized for the interns included tours of two underground quarries, the Ghent coal-fired electric power plant, and the Star Fire coal-mine operation. Students employed at KGS also participated in the mentoring sessions and field trips.

"My experience as an intern at the Kentucky Geological Survey has been unprecedented in my collegiate career. I have been given a most helpful perspective of geology at the state level." – Bethany Overfield



Left to right: Bethany Overfield, Sarah Hawkins, Mark Tyra, Doug Reynolds, Kristin Toth, Hannah Harbin.

Earth Science Week 1999

During the second annual Earth Science Week, October 11–15, 1999, **John Kiefer** and **Stephen Greb** gave presentations on hydrogeology and guided tours for elementary and middle-school students at McConnell Springs, an environmental and educational park in Lexington. Earth Science Week kits were distributed to every elementary and middle school in Fayette County. A rock and mineral display was arranged by Richard Smath and Collie Rulo and exhibited at the Lexington Public Library.

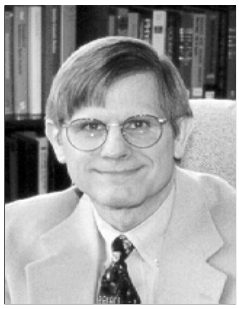
Earth science for Kentucky's virtual high school

Stephen Greb, the science education coordinator at KGS, is developing the earth-science content for the curriculum of a high-school course for the Kentucky virtual high-school program. This pilot program, sponsored by the Kentucky Department of Education, is being developed to assist schools that do not have teachers for the core content areas of earth and space science.

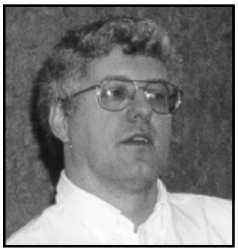
Creating adventures for earth-science learning

The Earth Science Education Network, created in 1996, continues to attract interest from teachers and students from across the Commonwealth and Nation. The popular site at www.uky.edu/KGS/education/education.html, which has information for teachers and students, has received four awards. New features include a geologic and paleontologic cookbook of recipes that use food to demonstrate earth-science concepts, an art project to make masks based on drawings of trilobites, and an art project in which students use knowledge of modern animals to draw the dinosaur *Tyrannosaurus rex*. These classroom activities and other information available on the network provided the focus of two popular workshops taught by **Stephen Greb** at the 1999 annual conference of the Kentucky Science Teachers Association in Lexington in November.

Recognizing Excellence in Research and Public Service

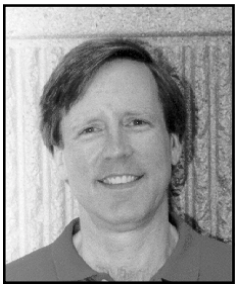


James Cobb

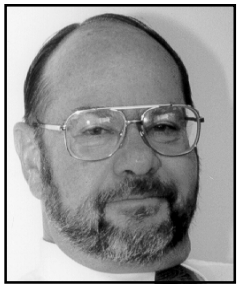


Stephen Greb

David Williams



David Harris



John Kiefer

James Cobb, State Geologist and Director of the Kentucky Geological Survey, was presented the annual Outstanding Kentucky Geologist Award from the Kentucky Chapter of the American Institute of Professional Geologists (May 13, 2000).

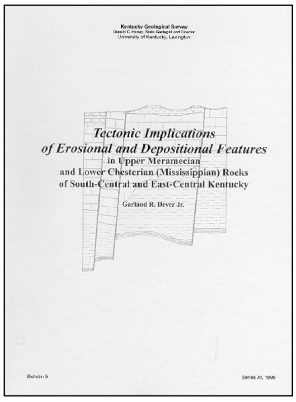
Stephen Greb and **David Williams** were awarded the Ralph L. Miller Memorial Award of the Eastern Section of the American Association of Petroleum Geologists for their paper, "Mining Geology of Western Kentucky Coals," published in 1999 in the AAPG Bulletin. This is the third time Greb has won the award; he also received the award in 1996 and 1998.

David Harris received the Distinguished Service Award from the Eastern Section of the American Association of Petroleum Geologists (September 1999).

John Kiefer received the annual Distinguished Service Award from the Kentucky Society of Professional Geologists (May 5, 2000).

John Kiefer was awarded the Top Dawg Award by the Association of American State Geologists (June 20, 2000). The award is presented annually to a member of the Assistant State Geologists Caucus in recognition of years of service and guidance to the caucus. Kiefer was recognized for 18 years of faithful and loyal support for the association's mission and activities.

New Publications Fiscal Year 1999–2000

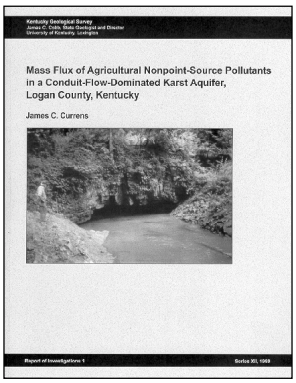


Bulletin

Bulletin 5. *Tectonic Implications of Erosional and Depositional Features in Upper Meramecian and Lower Chesterian (Mississippian) Rocks of South-Central and East-Central Kentucky,* by Garland R. Dever Jr., 1999, 67 p.

Information Circular

Information Circular 1. *Ground-Water Quality in Kentucky: Fluoride,* by Philip G. Conrad, Daniel I. Carey, James S. Webb, R. Stephen Fisher, and Matthew J. McCourt, 1999, 4 p.

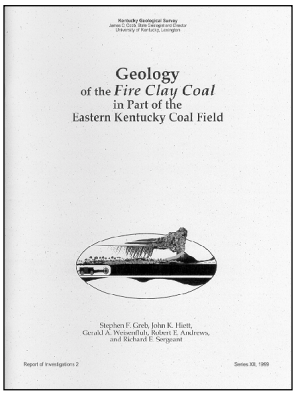


Map and Charts

Map and Chart 1. *Cambrian and Deeper Tests of Kentucky, 1999,* compiled by Brandon C. Nuttall, 1999, scale 1:1,000,000.

Map and Chart 20. *Geologic Map of Kentucky,* compiled by Martin C. Noger and Garland R. Dever Jr. , 2000, scale 1:1,000,000.

Map and Chart 21. *Generalized Geologic Bedrock Conditions as Related to Solid-Waste Landfills in Kentucky,* compiled by Martin C. Noger, 2000, scale approximately 1:560,000.



Reports of Investigation

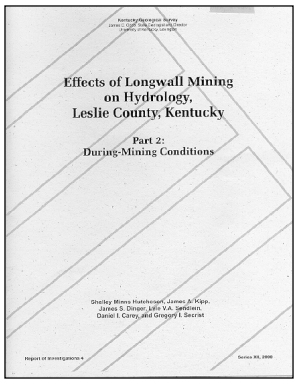
Report of Investigations 1. *Mass Flux of Agricultural Nonpoint-Source Pollutants in a Conduit-Flow-Dominated Karst Aquifer, Logan County, Kentucky,* by James C. Currens, 1999, 151 p.

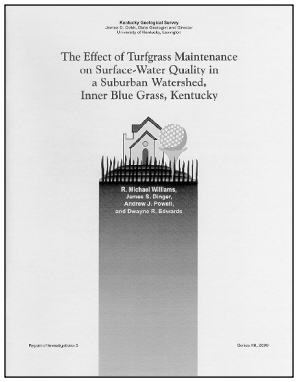
Report of Investigations 2. *Geology of the Fire Clay Coal in Part of the Eastern Kentucky Coal Field,* by Stephen F. Greb, John K. Hiett, Gerald A. Weisenfluh, Robert E. Andrews, and Richard E. Sergeant, 1999, 37 p.

Report of Investigations 3. *Available Resources of the Fire Clay Coal in Part of the Eastern Kentucky Coal Field,* by Stephen F. Greb, Gerald A. Weisenfluh, Robert E. Andrews, John K. Hiett, James C. Cobb, and Richard E. Sergeant, 1999, 18 p.

Report of Investigations 4. *Effects of Longwall-Mining on Hydrology, Leslie County, Kentucky; Part 2: During-Mining Conditions,* by Shelley Minns Hutcheson, James A. Kipp, James S. Dinger, Lyle V.A. Sendlein, Daniel I. Carey, and Gregory I. Secrist, 2000, 34 p.

Report of Investigations 5. *The Effect of Turfgrass Maintenance on Surface-Water Quality in a Suburban Watershed, Inner Blue Grass, Kentucky,* by R. Michael Williams, James S. Dinger, Andrew J. Powell, and Dwayne R. Edwards, 2000, 10 p.



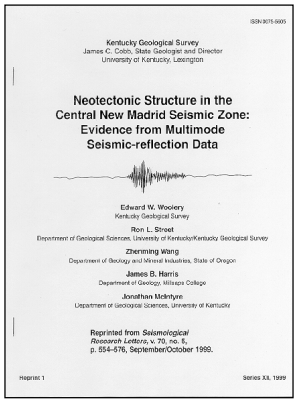


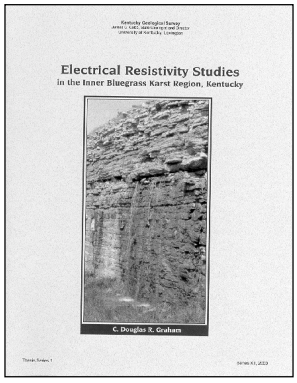
Reprint

Reprint 1. *Neotectonic Structure in the Central New Madrid Seismic Zone: Evidence from Multimode Seismic-Reflection Data,* by Edward W. Woolery, Ron L. Street, Zhenming Wang, James B. Harris, and Jonathan McIntyre, 1999, p. 554–576.

Thesis

Thesis 1. *Electrical Resistivity Studies in the Inner Bluegrass Karst Region, Kentucky,* by C. Douglas R. Graham, 1999, 92 p.





Active Research Projects

During fiscal year 1999–2000, the Kentucky Geological Survey received $1.4 million in external grant funding. The following research projects were active.

Grants and Contracts Funded by State and Federal Agencies

Communications

1. "Communications Coordinator for the Kentucky Board of Registration for Professional Geologists." Funding agency: Kentucky Board of Registration for Professional Geologists.

Coal Resources

2. "Computerized Coal Resources Data for the National Coal Resources Data System." Funding agency: U.S. Geological Survey.
3. "Estimation of Future Mountaintop Removal Areas in the Eastern Kentucky Region." Funding agency: U.S. Office of Surface Mining.

Energy and Minerals

4. "Rome Trough Consortium–U.S. Department of Energy." Funding agency: U.S. Department of Energy.
5. "Rome Trough Consortium–Private." Private industry support.

Geologic Hazards

6. "Seismology Hazard Mitigation." Funding agency: Kentucky Division of Emergency and Disaster Services/Federal Emergency Management Agency Hazard Mitigation Grant Program.

Geologic Mapping

7. "Generation of 1:100,000 Geologic Maps from Digital 1:24,000 Geologic Quadrangle Maps in the Kentucky River Basin, Kentucky." Funding agency: U.S. Geological Survey.
8. "Availability of Coal Resources for the Development of Coal." Funding agency: U.S. Geological Survey.

Water Resources

9. "Development of a Long-Term Land Use Plan for the Star Fire Area." Funding agency: Cyprus Coal Southern Realty Company.
10. "Robinson Forest Trust Project for the Investigation of Mine Spoil." Funding agency: University of Kentucky, Robinson Forest Trust Allocation.
11. "Chemical Analysis of Groundwater Samples Taken from the Kentucky Groundwater Network." Funding agency: Kentucky Natural Resources and Environmental Protection Cabinet.

12. "Water Quality Survey for Kentucky Army National Guard Training Sites." Funding agency: Kentucky Department of Military Affairs.
13. "Identification and Prioritization of Karst Groundwater Basins in Kentucky for Targeting Nonpoint Source Pollution and Abatement—Analytical Services." Funding agency: Kentucky Natural Resources and Environmental Protection Cabinet.
14. "Water Resources Development Commission Phase II Strategic Plan Document." Funding agencies: Kentucky Department for Local Government and Water Resource Development Commission.
15. "Water Resource Development Commission Phase II Strategic Plan Groundwater Atlas." Funding agencies: Kentucky Department for Local Government and Water Resource Development Commission.
16. "Hydrogeologic Evaluation of High Yield Well Potentials in the Upper Kentucky River Basin." Funding agencies: Kentucky River Authority and Kentucky Natural Resources and Environmental Protection Cabinet.
17. "Water Supplies from Underground Coal Mines in the Eastern Kentucky Coal Fields." Funding agencies: Kentucky River Authority and Kentucky Natural Resources and Environmental Protection Cabinet.
18. "Mapping Karst Groundwater Basins as a Nonpoint-Source Pollution Management Tool in the Inner Bluegrass." Funding agency: Kentucky Natural Resources and Environmental Protection Cabinet.
19. "Expanded Groundwater Monitoring for Nonpoint-Source Pollution Assessment of Watersheds in Kentucky Basin Management Unit Three." Funding agency: Kentucky Natural Resources and Environmental Protection Cabinet.
20. "Evaluation of Existing Groundwater Quality in the Tennessee, Mississippi, Upper and Lower Cumberland, Tradewater, and Green River Basins." Funding agency: Kentucky Natural Resources and Environmental Protection Cabinet.

Grants Administered by Other Units of the University of Kentucky

Geologic Mapping

1. "Development of a Transportation Planning Model for Interstate 66 Corridor in the London-Corbin-Somerset Area." Funding agency: Kentucky Transportation Cabinet. Cooperative study with the University of Kentucky Transportation Center.

Water Resources

2. "Nonpoint-Source Assessment of Groundwater." Funding agency: Commonwealth of Kentucky. Cooperative study with the University of Kentucky College of Agriculture.
   (A) "Western Kentucky Coal Field."
   (B) "Animal Research Center—Woodford County."
   (C) "High Nitrate Wells."
3. "Federal Facilities Oversight Unit—Paducah Gaseous Diffusion Plant." Funding agency: Kentucky Cabinet for Health Services. Cooperative study with the Kentucky Water Resources Research Institute.
4. "Maxey Flats Technical Assistance Oversight Program." Funding agency: Kentucky Cabinet for Health Services. Cooperative study with Kentucky Water Resources Research Institute.

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