

Annual Report 2002-03

Kentucky Geological Survey



2003

1875



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Director's Report

Building a solid foundation for understanding Kentucky's geology

As depicted on the cover of this report, geologists still use surveying equipment, rock hammers, compasses, and magnifying lens, just as their predecessors did in the late 1880's. The last century has seen tremendous scientific, technological, and social change in geological surveys, however, and the scope of research by geologists has greatly expanded. Geologists now also use infinitely more complex tools, and the resulting research and products they generate are much more sophisticated.

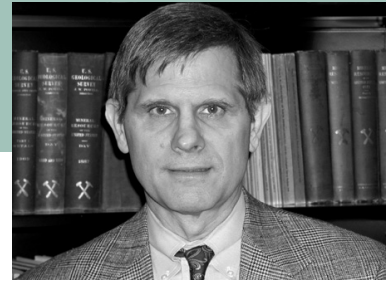
We have the good fortune of being able to build on the solid foundation of our predecessors. Thousands of maps and reports published by the Kentucky Geological Survey and geologic maps for the entire state have provided the foundation for mineral and fuel resource development, water-supply and -quality studies, environmental protection, mitigation of geologic hazards, and much more. Powerful computers and sophisticated software have allowed us to archive and analyze vast amounts of data. Internet access has enabled unprecedented distribution of our data, maps, and publications

to geologists and the general public.

The past year has been a landmark in Kentucky geology. We launched an exceptionally comprehensive database that provides free access to oil and gas well records, water well and spring records, coal information, and well sample and core records. The quality of public service and quantity of data we provide to industry, government, and the general public increased dramatically.

People who require our data, maps, and publications now make between 150 and 200 searches a day on our Web site. This is approximately four times the number of inquiries and requests for data we have traditionally received in the past by telephone, fax, and e-mail or from customers visiting our offices. We will continue to enhance our online system as we dedicate ourselves to improving the quality of our public service.

In the past year we had 20 active research projects and \$1.2 million in external grant funding. We made significant



advances in the investigation of coalbed methane resources, carbon sequestration, deep natural gas resources, earthquakes, and karst-related geologic hazards in Kentucky. By the end of fiscal year 2002-03, we had completed the digital conversion of 80 percent of the geologic quadrangle maps for Kentucky. We had released 19 publications, including six new 30 x 60 minute, 1:100,000-scale geologic maps. The details of these achievements are discussed in this report.

At first glance, it may look like not much has changed since the photograph of our predecessors was taken in 1875. But, like our predecessors, we are committed to building a solid foundation for our understanding of the geology of Kentucky for the benefit of future generations. We are using tools and achieving results that could not have even been imagined by our predecessors, however.

James C. Cobb

State Geologist and Director

On the cover:

1875 (Second Kentucky Geological Survey, Nathaniel S. Shaler, State Geologist): William B. Page, Phillip N. Moore, Charles J. Norwood, John R. Procter

2003 (Twelfth Kentucky Geological Survey, James C. Cobb, State Geologist): Zhenming Wang (Geologic Hazards), Douglas C. Curl (Geospatial Analysis), John B. Hickman (Energy and Minerals), Leslie K. Russo (Water Resources)

Environmental Protection

Kentucky karst atlas

Since the mid-1990's **Jim Currens** and **Randy Paylor**, along with **Joe Ray** of the Kentucky Division of Water, have conducted dye-trace experiments and compiled data to prepare a series of maps that outline the boundaries of drainage basins for groundwater in areas with a concentration of karst. The first map, for the Lexington 30 x 60 minute quadrangle, was published in 1996. Since then, maps for five other quadrangles (Beaver Dam, Bowling Green, Campbellsville, Harrodsburg, and Somerset) have been published, all at a scale of 1:100,000. In March 2003, Currens and Paylor completed mapping karst groundwater basins in the Inner Bluegrass, resulting in a substantial revision of the Lexington and Harrodsburg maps. The Lexington revision was published in 2002.

The maps were used by **Jerry Weisenfluh** to explain karst features (such as sinkholes and caves) relevant to the construction of the proposed I-66 highway near Mammoth Cave National Park. His presentations were made at public meetings held in Bowling Green and Brownsville by the Kentucky Department of Transportation.

In August 2002, a new map by Paylor and Currens, "Karst Occurrence in Kentucky," was published. The color map shows areas with high, moderate, and no potential for karst development. Persons concerned about sinkhole collapse, sinkhole flooding, and groundwater pollution of springs in karst areas will find this map useful. The map will also be useful to persons interested in the rare biological communities and endangered species found in the fragile underground environments developed in karst landscape.

Also in August 2002, a new map by Currens and **Qianhong**

A new color map documents karst springs in Fayette County and provides a resource to help citizens avoid the geologic hazards associated with building near springs during future urban development.

Wu of KGS and **Ken Pidgeon** of the Kentucky Division of Water, "Inventory of Karst Springs of Fayette County, Kentucky," was published. It serves as a historical record of springs in the county and provides a foundation for

future studies of the hydrology and karst geology of the Inner Bluegrass Region. The 1:62,500-scale map (1 inch equals 1 mile) can be used as an aid in locating potential groundwater discharge points in case of hazardous materials spills.

All of these maps can be downloaded as PDF files from the KGS Web site at www.uky.edu/KGS/pubs/lop.htm, or they can be purchased from the Public Information Center.

These maps are attracting attention outside the water resources community as well. An image from the groundwater basin map of the Campbellsville quadrangle is featured on the ESRI (Environmental Systems Research Institute) Web site as an example of the application of ArcView, a geographic information system software; see www.esri.com/industries/cavekarst/examples3.html. This will provide considerable publicity for the maps, because ESRI has 11 regional offices in the United States, more than 75 international distributors, and users in more than 220 countries.

Maps ideal for protecting water quality

The Kentucky Groundwater Data Repository has a wealth of data that are useful for environmental consultants, engineers, and citizens. Since the spring of 2002, **Bart Davidson**, manager of the repository, has compiled these 13 maps showing the distribution and location of water wells and springs in 30 x 60 minute quadrangles:

- ◆ Harrodsburg
- ◆ Lexington
- ◆ Somerset
- ◆ Bowling Green
- ◆ Campbellsville

- ◆ Beaver Dam
- ◆ Evansville
- ◆ Louisville
- ◆ Falmouth-Cincinnati-Madison
- ◆ Murray
- ◆ Corbin
- ◆ Morehead
- ◆ Madisonville

Davidson will compile maps for the entire state by the end of 2003.

Each map, at a scale of 1:100,000, covers an area of

approximately 31 by 54 miles, and displays the locations of springs and four types of water wells (domestic or private, industrial, public, and monitoring). Detailed information about the wells and springs identified on the maps is available from the Kentucky Groundwater Data Repository, which is maintained by KGS. Each map is available as a PDF file at www.uky.edu/KGS/pubs/lop.htm, or can be purchased from the Public Information Center.

Protecting community water quality

Several communities in Kentucky depend on karst springs for their water supply. George-

town, in central Kentucky, is one such community; it depends upon Royal Spring.



Royal Spring, the water supply for the city of Georgetown, in central Kentucky. Photo by Jim Currens.

The groundwater basin of Royal Spring receives drainage from southern Scott County and northern Fayette County, which are largely urbanized areas. In the spring of 2003, with funding from the Georgetown Water and Sewer Service, **Jim Currens** and **Randy Paylor** began developing a set of maps depicting the time a pollutant takes to reach Royal Spring, and thus the intakes for the water treatment plant in Georgetown. To prepare the maps, multiple groundwater dye traces were completed. The maps and final report for the project will be completed in the fall of 2003.

Informing the public about water quality

The Kentucky Geological Survey manages a long-term groundwater monitoring network to characterize groundwater resources in the state, in cooperation with an inter-agency technical advisory committee. Since its establishment in 1998, data on groundwater resources have been made available to the public and are widely distributed.

In November 2002, **Steve Fisher** published a study of pH concentrations in groundwater in Kentucky. pH is a fundamental property that describes acidity or alkalinity and largely controls the amount and chemical form of many organic and inorganic substances dissolved in groundwater. Fisher's study summarizes statewide data for pH in groundwater and includes a map showing pH values in wells and springs. This is the latest study in a series of reports that KGS is publishing to assess the quality of groundwater throughout the state.

Fisher and other geologists at KGS previously published studies on nitrate-nitrogen, fluoride, and arsenic concentrations in groundwater in Kentucky. He will be completing future studies for almost 30 additional quality parameters in groundwater. Identifying regions of similar groundwater quality helps citizens, resource managers, and environmental planners anticipate the conditions they will encounter when new groundwater supplies are developed.

The publications are a product of the Kentucky Interagency Groundwater Monitoring Network and are available as PDF files at www.uky.edu/KGS/pubs/lop.htm or can be purchased from the Public Information Center.

A report by Fisher describing general water-quality properties, inorganic anions, metals, nutrients, pesticides, and volatile organic chemicals in the

southwestern half of Kentucky is in review. A similar summary of groundwater quality in northeastern Kentucky is in progress.

In the spring of 2003, the Survey began providing online access to public information about water wells and springs. The information can be searched online at no charge at kgsweb.uky.edu/DataSearching/Water/WaterWellSearch.asp. A tutorial to guide users is also available online. Users can search by county, 7.5-minute quadrangle, or radius from latitude and longitude coordinates. The information, which can be viewed in tables or on an interactive map, is valuable to anyone interested in water supply and quality.

Understanding regional patterns of groundwater quality is important because many citizens and municipalities rely on wells and springs for drinking water.

Carbon sequestration: a strategy to address global warming

Hydrocarbon fuels (oil, natural gas, and coal) are expected to be the primary source of energy for the United States for the next 50 years or more. Many scientists believe that increasing concentrations of carbon dioxide (CO₂) in the atmosphere, released when hydrocarbons are burned, are contributing to global climate change. Innovative application of technology can significantly reduce the amount of pollutants introduced into our atmosphere. One such technol-

Database (MIDCARB). The database can be used to estimate the amount of CO₂ emitted by a source (for example, electric power plants) and evaluate how close these sources are to reservoirs in five Midcontinent states that can provide safe and secure, long-term storage. In the other project, Nuttall and his colleagues at KGS are investigating a possible, but untested, strategy for geologic sequestration of CO₂ in which CO₂ is injected into organic-rich shales.

tested, and data for CO₂ emissions were updated.

With funding from the U.S. Department of Energy, Nuttall is performing adsorption analyses to determine the potential for long-term storage of CO₂ in the Ohio Shale of eastern Kentucky. The shale contains adsorbed gas, which is analogous to coalbed methane. In coal, CO₂ is preferentially adsorbed and displaces methane to produce coalbed methane. If CO₂ adsorption in shale is similar, the shale may be an excellent subsurface reservoir for storing CO₂ (a "geologic sink").

Nuttall and his colleagues are trying to determine if Devonian black shale can be used to sequester CO₂ and enhance the production of natural gas as a beneficial by-product of the sequestration procedure. The black shale, which underlies approximately two-thirds of Kentucky, is generally thicker and deeper in the Illinois (western Kentucky) and Appalachian (eastern Kentucky) Basins, and it is the largest source of natural gas production in the state. If such shales prove to be a viable geologic sink for CO₂, their extensive occurrence would make them an attractive option for carbon sequestration and enhanced natural gas production. More information is available at www.uky.edu/KGS/emsweb/devsh/devsh-seq.html.

The MIDCARB Internet mapping site has the first database system developed for the U.S. Department of Energy that successfully links and integrates data and maps from five states for assessment of potential carbon sequestration.

The MIDCARB Internet mapping site, launched in 2002, integrates maps and databases from the geological surveys of Kentucky, Illinois, Indiana, Kansas,

and Ohio into a single Web portal (www.midcarb.org). It provides public access to data and maps useful for industry and government decision-makers. The MIDCARB database and the maps show information about potential sequestration targets: oil and gas reservoirs, coal beds, and saline aquifers, as well as carbon sources in the region. During fiscal year 2002-03, several new components were compiled for the MIDCARB database, public access to the database was

ogy is "carbon sequestration," a process in which CO₂ emitted in the atmosphere is captured and securely stored in subsurface reservoirs.

Geologists at KGS are evaluating the potential of carbon sequestration in two research projects. **Brandon Nuttall** and colleagues at KGS and four other state geological surveys have built an integrated database of information, called the Midcontinent Interactive Digital Carbon Atlas and Relational

Energy Production

Enhancing natural gas production

Dave Harris and his colleagues at KGS are conducting research in Clark County to help oil and gas companies investigate the potential for finding natural gas reservoirs. KGS is a partner with a gas exploration company, Triana Energy of Charleston, W.Va., in a 2-year study to examine geologic features in central Kentucky, in order to better understand how natural gas reservoirs form in the eastern United States.

In June 2002 Harris taught a workshop to examine well cores and led a field trip to several localities in Clark County with unusual structures that indicate Ordovician limestone (440 to 470 million years old) has been converted to dolomite

near faults and fractures. Unlike the host limestone, dolomite commonly has excellent pore space, where natural gas and oil can accumulate. Hot fluids moving up from deeper sources in the subsurface formed these unusual structures. This process, referred to as "fault-controlled dolomitization," has resulted in the formation of prolific oil and gas reservoirs.

The core workshop, sponsored by the Petroleum Technology Transfer Council, introduced participants to outcrop exposures of dolostone bodies that are analogs to subsurface natural gas reservoirs in Michigan, New York, Ohio, and Ontario,



Participants examined hundreds of feet of core at the workshop. Photo by Brandon Nuttall.

Canada, where the same rocks are buried 5,000 to 8,000 feet deep. Seismic data were collected to create a three-dimensional image of the dolostone bodies and determine the best location for two coreholes, which were drilled during the summer of 2003. The New York Energy Research and Development Authority, Triana Energy, the U.S. Department of Energy, and KGS are funding the study.

Deep natural gas in eastern Kentucky: the Rome Trough

The Rome Trough is a deep Cambrian sedimentary basin that produces natural gas from several fields in eastern Kentucky. In a study initiated in 1998, **Dave Harris** and **John Hickman** collaborated with colleagues from the state geological surveys of Ohio and West Virginia and four energy companies to evaluate the potential for natural gas discoveries in the Rome Trough. The final report from KGS for the industry-government consortium was completed and submitted to participants in August 2002. Most of the

results of the research remain confidential to the consortium members for 2 years, after which KGS will publish the results. Results are available to the public for geochemical analysis of source rocks performed by the U.S. Geological Survey to determine the source of the hydrocarbons.

Cambrian shales sampled in several wells in the Rome Trough yielded surprising results. Previous studies of Cambrian pre-Knox Group shales in the Appalachian Basin indicated poor hydrocarbon source

potential, but analyses done in the KGS study found good hydrocarbon potential. The results suggest that natural gas and oil produced in the Homer Field in Elliott County were derived from Cambrian source rocks in the Rome Trough. This research has important implications for future exploration for deep natural gas in pre-Knox Cambrian rocks in the Rome Trough and Appalachian Basin. More information is available at www.uky.edu/KGS/emsweb/rome/rome.html.

Coalbed methane in western Kentucky

Coalbed methane could provide a significant future energy resource. If captured and economically produced, it could be used as a fuel similar to natural gas. The potential demand for coalbed methane gas could be great: nearly all of the new electricity gen-

eration capacity proposed for Kentucky will be powered by natural gas. Coalbed methane gas is also attractive because it is a clean fuel, and drilling and mining it causes relatively little disturbance of the local environment. A fact sheet on coalbed methane is available on the KGS Web site at www.uky.edu/KGS/education/methane.pdf.

The Western Kentucky Coal Field, extending across all or parts of 19 counties, is esti-

ated to have 36 billion tons of remaining coal, which may contain economically recoverable quantities of methane gas. With funding from the Kentucky Consortium for Energy and the Environment, KGS coal geologist **Cortland Eble** is assessing the potential to develop the coalbed methane. Eble's work is initially focused in Ohio County and will be expanded later to other parts of the coal field. It will identify specific areas with the greatest cumulative thickness of coal at sufficient depth for economic production. Mine maps will also be analyzed to determine if any structural trends, such as regional flexure patterns of faulting, can be identified, because these areas can greatly enhance the natural permeability of the coal and the potential for coalbed methane production.

Development of coalbed methane would provide a new use for the abundant coal resources of western Kentucky and revitalize economic development in the region. Coal production has declined almost 40 percent in the last decade, in large part as a result of stringent sulfur dioxide emission limits, which have decreased the demand for western Kentucky coal.

Coalbed methane, previously considered a nuisance and hazard in some Kentucky coal mines, may be an important future energy resource. Geologists at KGS are investigating the potential for developing coalbed methane gas from seams in the Western Kentucky Coal Field.

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Assessing Kentucky's coal resources

Under the direction of **Jerry Weisenfluh**, coal geologists at KGS continue to contribute to the National Coal Resource and Coal Quality Assessment project of the U.S. Geological Survey (energy.usgs.gov/coal.html). **Bethany Overfield** and **Mike Schultz** completed a CD-

ROM that contains comprehensive coal resource information, including general background information, database descriptions, and results of research on Kentucky coal. They prepared a regional assessment of original and remaining Amburgy coal resources, which will be

added to the KGS Coal Atlas (www.uky.edu/KGS/coal/webcoal/pages/coal/coalatlas.htm). They also prepared regional coal assessment maps for eastern Kentucky; the maps will be used in future coal recoverability studies by the USGS.

Land Use and Planning

Digital geologic mapping

In the spring of 2003, KGS received a 1-year, \$224,000 grant from the USGS for digital compilation of geologic maps. This was the eighth consecutive year that KGS received funding from the USGS for the Digital Geologic Mapping Program, which has generated more than \$1.3 million in extramural funding for the Survey. This USGS funding for the STATEMAP component of the National Cooperative Geologic Mapping Program (ncgmp.usgs.gov) is enabling KGS to convert all 707 geologic quadrangle maps for Kentucky into digital format. Eighty percent of the maps for the state had been converted by the end of fiscal year 2002-03.

In fiscal year 2002-03, Principal Investigator **Warren Anderson** and other geologists at KGS completed maps for the Hopkinsville, Madisonville, Bowl-

ing Green, Beaver Dam, Pikeville, and Middlesboro 30 x 60 minute quadrangles (1:100,000 scale). Funding from the most recent grant is being used to complete the Campbellsville and Morehead quadrangle maps. Other products completed included GIS data sets in ESRI shapefile format, county

geologic maps, and derivative map products for a variety of applications. More information is available on the KGS Web site at www.uky.edu/KGS/mapping/mapping.html.

A comprehensive set of digital maps and databases for the entire state of Kentucky is being developed by KGS. This will provide an extremely valuable tool for project planning and analysis by geologists in the energy and mineral industries, rural and urban planners, environmental consultants, engineers, and others.

Internet mapping site

In fiscal year 2002-03, KGS launched an Internet mapping site (kgsweb.uky.edu/arcims-Search.asp), which contains links to a number of mapping services that provide data about oil and gas, water, coal, core and sample holdings, geology, and land-use planning. Each map service allows users to view data locations

on a variety of topographic or aerial photographic base maps. Descriptive information about locations or map areas can be viewed and downloaded. The map services complement the KGS database search services by allowing users to browse for information in a geographic context. The maps are also linked from the results pages of

the database search functions.

The oil and gas mapping service was reported to be one of the two most popular sites on the Kentucky Geography Network's Web site in the February 2003 issue of *Techline*, the online technology news service of the Commonwealth of Kentucky.

Introducing geology to community planners

Digital geologic data sets and land-use planning maps developed by KGS are new products that are ideal for communicating information about geology to users in other professions.

The land-use planning maps, which are being produced for each Kentucky county at a scale of either 1:48,000 or 1:63,360, interpret the local geology in nontechnical language for homeowners, developers, planners, and others. The maps, prepared by **Dan Carey** and other KGS staff, provide information on how the underlying rock in an area affects excavation and foundations, on-site wastewater treatment systems, residential and industrial developments, highway and street development, and pond and reservoir construction. Tables provide information about a variety of development issues, and diagrams and photographs illustrate the technical concepts. The first

map, "Simplified Geologic Map for Land-Use Planning: Lexington and Fayette County, Kentucky," by Carey, **M.C. Noger**, and **Paul Howell**, was published in 2002. The map can be downloaded as a PDF file from the KGS Web site at www.uky.edu/KGS/pubs/lop.htm or purchased from the Public Information Center. Maps for Anderson, Butler, Edmonson, Henderson, Jessamine, Madison, McCracken, Scott, Warren, and Woodford Counties are undergoing final review. Maps for Boyd, Calloway, Graves, Greenup, Hardin, Hopkins, Livingston, Marshall, and Pulaski Counties are under development.

In the spring of 2003, a new initiative was launched to explain to professionals in the planning community how digital geologic maps and data are essential for planning decisions about land use, environmental protection, and mitigation of

natural hazards in urban and rural areas. This initiative was undertaken by KGS in cooperation with the NewCities Foundation Leadership Center Program (www.newcities.org) of the Kentucky League of Cities. **Drew Andrews**, **Carol Ruthven**, **Dave Williams**, and **Jim Cobb** taught seminars in this leadership program in Berea, Elkton, LaGrange, and Mount Sterling. The seminars will be offered in other communities in the future.

A workshop demonstrating the use of digital geologic data in land-use planning and GIS applications was presented by Cobb and Ruthven at the spring conference of the Kentucky Chapter of the American Planners Association. The conference was held at Rough River Dam State Resort Park in western Kentucky on May 23, 2003.

Bringing geology to area development districts

In November 2002, **Glynn Beck** and **Bart Davidson** gave 10 presentations to Federal and State officials of Area Development Districts, Resource Conservation and Development Councils, and Natural Resources Conservation Service offices in Bowling Green, Elizabethtown, Hopkinsville, Mayfield, and Owensboro. They demonstrated new digital geologic map products and online data- and map-serving capabilities available at the Survey.

Accessing Kentucky mine map information

On October 11, 2000, a coal slurry impoundment in Martin County failed, releasing more than 300 million gallons of viscous coal waste into Wolf Creek and Coldwater Creek. It affected water utilities on the Big Sandy River as far as 80 miles downstream. In the period following the accident, many groups expressed concern about impediments to obtaining mine map information. In response to these concerns, in September 2001 KGS hosted a meeting of State and Federal agency representatives to discuss the creation of an information system for accessing Kentucky mine map information. As a result of the meeting, teams were formed to explore legal and technical solutions for providing mine map information to government personnel, as well as the general public.

The legal team proposed changes to Kentucky law regarding accessibility of mine maps. Statutory revisions were

approved to permit public access to mine maps held by the Kentucky Department of Mines and Minerals. The revisions facilitated exchange of information among agencies that need this information for regulatory or safety concerns. The technical team reviewed existing information systems and holdings of the Kentucky Department of Mines and Minerals, Kentucky Department of Surface Mine Reclamation and Enforcement, Kentucky Revenue Cabinet, U.S. Office of Surface Mining, and KGS.

An Internet map service is now being developed that will provide access to information about Kentucky's mines. The primary developer works in the Natural Resources

and Environmental Protection Cabinet, and the service will be hosted by the Governor's Office of Technology.

Jerry Weisenfluh, head of the Geospatial Analysis Section at KGS, is participating in the design effort. A draft is expected to be released in the summer of 2003.

A project to provide public access to mine map information is an exemplary model of interagency cooperation in Kentucky State government. Products created by the project staff will greatly benefit the citizens of the Commonwealth.

Public access to mine maps will help prevent damage to streams like this one, the Big South Fork of the Cumberland River, near the mouth of Oil Well Creek. Photo by Brandon Nuttall.



Mitigation of Natural Hazards

Kentucky Seismic and Strong-Motion Network

Geologists who study earthquakes (geophysicists and seismologists) face a great challenge, because earthquakes happen infrequently and without advance warning. This makes estimating earthquake hazards and risk difficult. The task is further complicated by engineering and economic factors that need to be considered. An important resource geologists and others use is the Kentucky Seismic and Strong-Motion Network, jointly operated by KGS and the UK Department of Geological Sciences.

The strong-motion network is designed to record ground motion from strong earthquakes in the New Madrid Seismic Zone, which stretches from just west of Memphis, Tenn., into southern Illinois. It has 21 stations that can monitor any earthquake occurring in or around Kentucky with a magnitude greater than 2.0, as well as major earthquakes in the central United States and many around the world.

Cover-collapse sinkholes

As part of the Kentucky Karst Atlas project, **Jim Currens** initiated a pilot study to develop a methodology for determining the frequency of occurrence of cover-collapse sinkholes. Currens is using historical aerial photography to document the episodes of cover collapse. He also initiated an online system to allow people from across the state to report cover-collapse sinkholes, using a form available on the KGS Web site (www.uky.edu/KGS/water/research/kasinkreport.html). As the Web site has become more widely indexed by major search engines, inquiries and reports have become more frequent.

Since March 2002, seismic records for 10 stations have been made available to the public, virtually on a real-time basis, on the KGS Web site at www.uky.edu/KGS/geologichazards/geologichazards.html. This online access to seismic records is valuable to researchers, as well as the general public. Its value became apparent on June 18, 2002, as hundreds of people visited the site at the time of the magnitude 5.0 earthquake, whose epicenter was in Darmstadt, Ind. The network's strong-motion recordings for the Darmstadt earthquake were published in the March/April 2003 issue of *Seismological Research Letters* in an article by **Zhenming Wang, Ed Woolery, and Jeffrey Schaefer**. The Web site was frequented again when a magnitude 2.9 earthquake struck on January 3, 2003; its epicenter was in New Haven, about 30 miles west of Henderson, Ky., and 25 miles northeast of Harrisburg, Ill.

Landfills at the Paducah Gaseous Diffusion Plant

The U.S. Department of Energy has proposed expanding an existing landfill and building a new landfill at one of its facilities, the Paducah Gaseous Diffusion Plant in McCracken County. When taking into account Federal seismic safety regulations, which are based on USGS seismic hazard maps, State officials in the Division of Waste Management and the Cabinet for Health Services have had difficulty issuing permits for the landfills.

Ed Woolery and Zhenming Wang were asked to serve as experts for the State to address issues related to seismic hazard assessments and the selection of design ground motion for the landfills at the plant. They are responsible for evaluating and ensuring the completeness of geologic and seismologic data, evaluating and ensuring that the method and assumptions used are thoroughly justified by DOE, and providing expertise and guidance to ensure that DOE can resolve potential conflicts in such a manner that the final design will protect the citizens of Kentucky.

Improved understanding of seismic risk

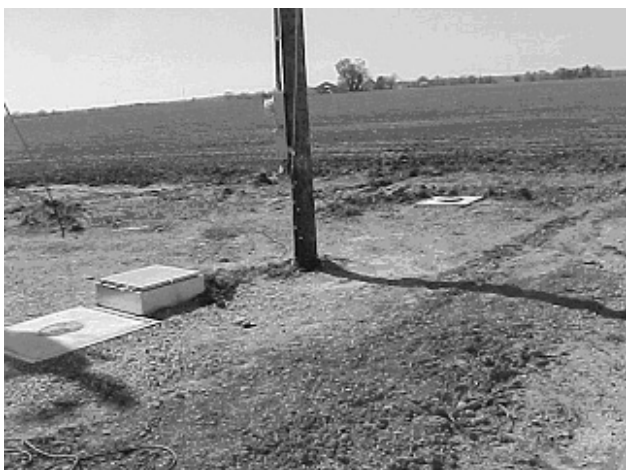
The Kentucky Seismic and Strong-Motion Network is unique: it has the only vertical arrays east of the Rocky Mountains. A vertical array has a seismometer at the surface, another at the bottom of the hole, and at least one more somewhere in between. The Kentucky network produced the first recording from a vertical array in the eastern United States in 1994.

The network was expanded in fiscal year 2002–03 to help seismologists improve their un-

derstanding of seismic risk in the New Madrid Seismic Zone. In November 2002, a new vertical strong-motion array was installed to a depth of 850 feet at Sassafras Ridge in Fulton County. It will provide information on changes such as amplification or

Another strong-motion station was installed in Maysville in cooperation with the USGS and the Center for Earthquake Research and Information at

A new vertical strong-motion array at Sassafras Ridge, Fulton County, in western Kentucky is the deepest vertical strong-motion array east of the Rocky Mountains.



The vertical array at Sassafras Ridge. Photo by John Kiefer.

damping of seismic waves as they travel from the bedrock to the surface. This is information that no one else has the capability of recording. It will provide new data vital for an improved understanding of the central New Madrid Seismic Zone. The array has been in operation since late March 2003.

the University of Memphis; the station will be part of the Advanced National Seismic System (www.anss.org). In total, five new seismic stations were installed in fiscal year 2002–03 with funding provided by the Commonwealth of Kentucky through the Western Kentucky Consortium for Energy and the Environment. Two seismic stations are under construction in the Jackson Purchase Region of western Kentucky.

KGS hosts seismic hazards workshop

Scientific assessment of seismic risks in western Kentucky is subject to considerable debate among seismologists. At a workshop hosted by KGS in Lexington on November 18, 2002, seismologists and others met to discuss seismic hazards, risk, and design maps in the central United States, especially western Kentucky. More than 100 geologists, seismologists, engineers, emergency managers, and others from Federal, State, and local government agencies, consulting firms, and universities attended the workshop. Many of the persons attending were among the most outstanding in their fields. The proceedings of the workshop were published in 2003 as KGS Special Publication 5, "Kentucky NEHRP Seismic Hazard and Design Maps Workshop Proceedings," edited by **Zhenming Wang**. The publication is available on the KGS Web site at www.uky.edu/KGS/lop.htm or can be purchased from the Public Information Center.

Advising the Commonwealth on seismic issues

Building codes include guidelines designed to minimize damage from earthquakes. Seismic hazard maps are a key reference used by decision-makers to update these codes. **Zhenming Wang** and **Ed Woolery** provided technical advice and expertise to the Kentucky Natural Resources and Environmental Protection Cabinet; Kentucky Department of Housing, Buildings, and Construction; State Building Commissioner; Structural Engineering Association of Kentucky; Kentucky Transportation Cabinet; and others to develop a scientifically sound seismic hazard map for western Kentucky.

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Wang, Woolery, and **Baoping Shi** published a preliminary assessment of earthquake activity in the Jackson Purchase Region of western Kentucky for a 6-month period following the installation of a dense seismic network in late December 2002 and early January 2003. The network of closely spaced

seismometers collects data from an area covering the northern boundary of the New Madrid Seismic Zone. This area is of scientific interest because previous seismic hazard assessments have been based on the assumption that the active faults of the New Madrid Seismic Zone extend into the Jackson Purchase Region of western Kentucky. This extension is one of the reasons that western Kentucky, the Jackson Purchase Region in particular, has more rigorous seismic design standards than anywhere in California, even though it is well documented that California has greater seismic hazards and risk.

Wang, Woolery, and Shi found that the earthquake activity observed between January and June 2003 indicates that most recorded seismicity in the central United States reflects the active faults of the New Madrid Seismic Zone. They also found that in the Jackson Purchase Region characteristics of earthquakes, such as focal depth, are different from those of earthquakes in the central New Madrid Seismic Zone. Although 6 months of seismic monitoring is not long enough to make a scientifically defensible conclusion, the observed seismicity suggests that the active faults of the New Madrid Seismic Zone may not extend into the Jackson Purchase Region, and the current seismic safety regulations and building codes in that region may need to be reexamined. The details of their study are published in KGS Special Publication 6, "Observed Seismicity (Earthquake Activity) in the Jackson Purchase Region of Western Kentucky: January through June 2003."

Seismic design of highway bridges in Kentucky

In a cooperative research project in 1996, geologists and engineers at KGS, the UK Department of Geological Sciences, and the Kentucky Transportation Research Center developed seismic hazard maps and ground-motion time histories for seismic design of highway bridges in Kentucky. Bridge engineers and State and local officials interested in seismic design, retrofitting substandard bridges, and mitigation of other problems with highway bridges use the maps. In response to new seismic design specifications that are under consideration by the American Association of State Highway and Transportation Officials for highway bridges, KGS seismologists are working with researchers and engineers in the Kentucky Transportation Research Center and the Kentucky Transportation Cabinet to revise the seismic hazard maps and ground-motion time histories for Kentucky. This work is being funded by the Federal Highway Administration through the Kentucky Transportation Cabinet. A preliminary report and the maps were completed in July 2003. The final report will be submitted to the Kentucky Transportation Cabinet.

Seismic hazard mapping in metropolitan Louisville

Seismic hazards associated with local geology, such as ground-motion amplification, liquefaction, and earthquake-induced slope failure, can result in great damage during earthquakes. The Louisville metropolitan area along the Ohio River is underlain by thick and soft soils that are prone to amplification and liquefaction. Even if earthquakes occur far away, the amplification and liquefaction by the near-surface soft soils could be devastating. For example, in a 1985 earthquake in Mexico City, severe damage

was caused by ground-motion amplification of soft lake deposits underneath the city, even though the earthquake epicenter was 200 kilometers away.

Seismic hazards can be assessed if soil properties and groundwater levels are known. **Zhenming Wang** and **Steve Cordivola** are evaluating geologic, geotechnical, geophysical, and water-well data to assess the ground-motion amplification hazard based on the average shear-wave velocity of the top 30 meters of soil. They

are developing seismic hazard maps that will be completed in the summer of 2003. Emergency managers, planners, and the general public can use the maps for seismic hazard mitigation. The maps will also be used by Wang and Cordivola to augment a database and assess seismic risk for the Louisville metropolitan area using HAZUS99, a software package for seismic risk evaluation developed by the Federal Emergency Management Agency.

Landslide inventory in northern Kentucky

Landslides occur frequently throughout Kentucky. The Greater Cincinnati–Northern Kentucky region has long been recognized as having unstable slopes. A USGS publication (Fleming, R.W., and Taylor, F.A., 1980, Estimating the costs of landslide damage in the United States: U.S. Geological Survey Circular 832, 21 p.) estimated that the area may have the highest per capita loss resulting from slope failure in the United States. As the metropolitan region has expanded onto the unstable slopes, landslides have become an increasingly significant problem that has an impact on economic development and the welfare of citizens. Quantifying the cost of landslide damage has been difficult, however, because of the variety and degree of applicability of records about the extent of repair and replacement costs and the costs of stabilizing hillslopes to pre-

vent future damage. The USGS report estimated the annual cost in Hamilton County, Ohio, alone at over \$5 million, and added that this was probably greatly underestimated.

With support from the USGS, geologists at KGS and Northern Kentucky University conducted a pilot study to document landslide damage and investigate the feasibility of collecting accurate and reliable data on the cost of landslides. The results provide the basis for identifying the most fruitful methods of collecting these data regionally and nationally. Using these insights, future national as-

sessments can more successfully quantify the annual extent of loss and better establish future research priorities by convincingly documenting landslide risk and consequences.



Landslides, like this one on Magnolia Street in Hickman, Ky., threaten property. Photo by John Kiefer.

Serving the Public

Enhanced access to KGS databases and map information

A major legislative mandate of KGS is maintaining public repositories of oil, natural gas, coal, and water data. Historically, the public accessed these data through direct contact with KGS personnel (telephone, fax, e-mail, or office visit), which limited access to normal business hours. To enhance public access, in the summer of 2002 KGS launched a comprehensive Web-based system to make its data available online.

The system, accessible at www.uky.edu/KGS/pubs/lop.htm, provides efficient access 24 hours a day, 7 days a week, from the convenience of a user's office or home, or any place with access to the Internet. Online tutorials demonstrate how to access information. Interactive map services and text-based forms enable users to locate data by query or map searches, perform spatial analysis, print maps, download data, and link to related data sources.

KGS has placed a priority on providing user-friendly public access and presenting data in a

format readily understood by the general public.

The news that KGS was launching the nation's first free, statewide, Web-accessible database of oil and gas well records was welcomed by the oil and gas industry and the Kentucky Division of Oil and Gas. Rick Bender, director of the Division, said, "With the Survey's new implementation of online access to oil and gas records and data, KGS's excellent service continues. The Division ... staff must frequently review past records in order to perform our duties. The online access allows the staff to perform this task quickly and efficiently, thereby reducing costs and saving taxpayer dollars. Our field inspectors, located throughout the state, now have direct access to the records and no longer need to contact the Frankfort office for paper copies."

In the winter of 2002, the system was enhanced to allow searching for publications by map areas. For example, a user can specify a quadrangle name and find all publications or

maps that exactly match that area or overlap it. Index maps on the data search pages provide an alternative way of selecting geographic areas for search criteria.

In the spring of 2003, a feature was added that automatically converts map coordinates and allows persons to download data in the coordinate system and geographic datum of their choice. Full lithology reports and coal seam summary reports were added to pages that display the results of coal borehole data searches. Spring information was added to the water well search page, as well as extended lithology and casing reports. Information about core and cutting samples available at the **Well Sample and Core Library** was added to the core borehole and oil and gas results page.

These enhancements significantly increased the use of the Web site. In July 2002 there were 81,618 hits on the KGS Web site. By June 2003, that number had more than doubled to 184,352 hits. Among more than 50 Web sites at the University of Kentucky, the rank of the KGS Web site increased from 22 in July 2002 to 14 in June 2003.

"The new online database is a Godsend to our industry, as it will assist not only small operators who now do not have to travel to Lexington to retrieve data, but large operators as well, who can easily access large volumes of data."

**—D. Michael Wallen, president,
Kentucky Oil and Gas Association**

New Public Information Center enhances public access and service

Throughout fiscal year 2002–03, the former Publication Sales office was renovated to enhance access to geologic data, maps, and publications available at KGS, as well as provide products and services in a user-friendly way to a broader and more diverse customer base. Its name was changed to the **Public Information Center** to reflect this new focus.

Particular emphasis was placed on providing access to the rapidly expanding resource of data, maps, and publications available online on the KGS Web site. Staff have been trained to provide customer service and technical assistance, in order to guide the public in the use of these extensive online resources. The center has computers for

customers to access online oil and gas, water, and coal records from KGS databases (www.uky.edu/KGS/pubs/lop.htm). The computers are also used to access seismic recordings from 10 seismic stations across Kentucky (www.uky.edu/KGS/geologichazards/equake3.HTM).

A grand reopening of the center was held on October 16, 2002, in conjunction with KGS's celebration of Earth Science Week.



Apollo astronaut and geologist visits KGS

To celebrate the 30th anniversary of the Apollo 17 mission to the Moon, KGS invited Apollo astronaut and geologist **Harrison "Jack" Schmitt** to the University of Kentucky as a distinguished lecturer. More than 1,200 adults and children came to the Singletary Center for the Arts at the University of Kentucky in Lexington to hear Schmitt's keynote address, "A Trip to the Moon," on October 11, 2002. Schmitt also met with faculty and students in the College of Arts and Sciences and College of Engineering.



Left to right: Apollo astronaut Harrison Schmitt, State Geologist Jim Cobb, and UK President Lee Todd. Photo by Brandon Nuttall.



Shelves of core samples at the Well Sample and Core Library. Photo by Patrick Gooding.

Well Sample and Core Library

Throughout the fiscal year, **Patrick Gooding** and the staff at the Well Sample and Core Library provided assistance to researchers and consultants, as well as public seminars for students and others. The library was also used for core workshops taught by KGS geologists.

The section of the KGS Web site devoted to the Well Sample and Core Library was significantly expanded in May 2003. In addition, information about all cores and well cuttings available for inspection at the library was added to the comprehensive KGS database of geologic information.

KGS annual seminar

The 43rd annual KGS seminar on May 16, 2003, featured keynote speaker **John Steinmetz**, state geologist and director of the Indiana Geological Survey. The seminar also featured numerous technical presentations and poster displays by KGS geologists to highlight research achievements during the past year. In the afternoon, a workshop provided an online demonstration of the use of KGS digital data and maps in GIS applications. More than 120 geologists, engineers, and environmental experts from Federal, State, and local government, industry, and consulting firms attended the seminar.

KGS physiographic map exhibited at Kentucky State Fair

An updated map of the physiographic regions of Kentucky prepared by geologist **Drew Andrews** and cartographer **Terry Hounshell** was a popular interactive, educational exhibit at the Kentucky State Fair in Louisville in August 2002. The

map fit in perfectly with the theme of the fair, "This Land Is Our Land—2002: A Land Odyssey." More than 300,000

schoolchildren, adults, and families came to view the exhibit and explore the 32 x 16 foot floor map. The map also

attracted the attention of almost 200 visitors who attended the Earth Science Week open house hosted by KGS in Lexington on October 16, 2002.



Visitors explore the physiography of Kentucky at the State Fair. Photo by Carol Ruthven.

Easy access to KGS publications

As part of its continued commitment to excellent public service, KGS improved access to its publications by publishing them on a CD-ROM. "Selected Kentucky Geological Survey Publications, 1999-2002," by **Meg Smath, Terry Hounshell, and Steve Cordiviola**, contains PDF files of all KGS maps, charts, and reports published in the last 4 years that are available in electronic format. The PDF's can be viewed on most personal computers using the free copy of Acrobat Reader included on the CD-ROM. A searchable index to the publications is also included. Free copies of the CD-ROM were distributed to geologic and regional libraries.

Summer interns immersed in geology

Debbie Criss and **Eric Robinson** of Morehead State University and **Brent Wilhelm** of Eastern Kentucky University participated in the third annual KGS Summer Internship Program. The students worked with staff of the Digital Geologic Mapping Program to learn how to create digital geologic maps, use ARC/INFO and ArcView GIS software, and apply digital geologic map data. With **Steve Greb**, the students did field mapping in eastern Kentucky; they described rock units, prepared scaled sketches, and correlated coal beds. With **Jim Currens** and

Randy Paylor, they went on a karst hydrogeology field trip to identify springs and sinkholes. The interns used their GIS skills to digitize the boundaries of karst basins and trace

groundwater flow paths. They also worked with the Coalmaster database at KGS, learned standard lithologic descriptions of cored rocks, worked with geophysicists in the Geologic Hazards Section, and

"What I learned as an intern over the summer is far more valuable than any of my experiences as a student in geology. I view this experience as both educational and, most importantly, a feel for ... what it takes to be a geologist in the world today."

—Brent Wilhelm

completed detailed mapping of Inner Bluegrass rock units for use in an outcrop database. The students acquired excellent hands-on experience and new skills for applied research in

Helping citizens understand geologic maps

Geologic maps are an extremely valuable source of information used by geologists, engineers, consultants, planners, property owners, and others. Many citizens are unfamiliar with geologic maps, however, and do not understand how the information on them is used to address such common problems as flooding, sinkholes, cracked foundations,

landslides, and water quality in wells. To help citizens understand geologic maps, in the spring of 2003 KGS published "Geologic Maps and Geologic Issues in Kentucky: A Citizen's Guide," by **Carol Ruthven, John Kiefer, Steve Greb, and Drew Andrews**. The citizen's guide has colorful illustrations and photos that complement a simple, easy-to-understand

explanation of geologic issues and how geologic map information is used to address these common problems. The publication explains what geologists do, how geologists can help citizens, and includes a free geologic map. To enhance public access to the citizen's guide, it was also made available as a PDF file on the KGS Web site at www.uky.edu/KGS/pubs/lop.htm.



Left to right: KSPG President David Jackson, Jessamine County Judge-Executive Neal Cassity, State Rep. Robert Damron, State Geologist Jim Cobb, and State Geologist Emeritus Don Haney during the ceremony designating Camp Nelson as Distinguished Geologic Site 2. Photo by Brandon Nuttall.

Increasing public awareness of unique geology in Kentucky

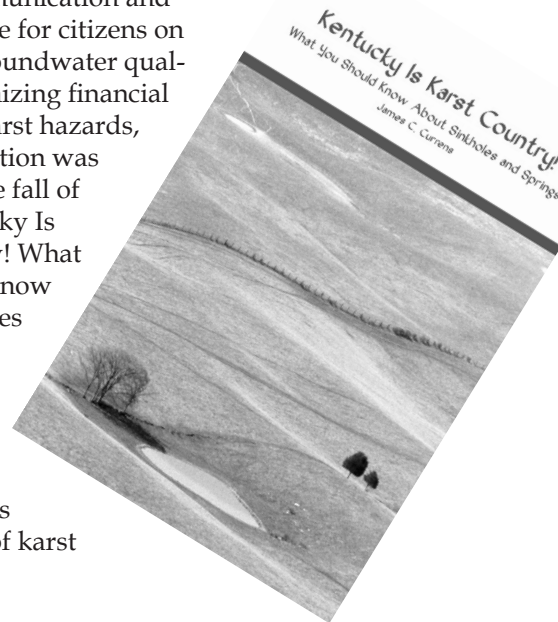
In conjunction with its 2002 fall field trip, the Kentucky Society of Professional Geologists designated the Camp Nelson area in Jessamine and Garrard Counties as Distinguished Geologic Site 2 in Kentucky. **Drew Andrews** and **Patrick Gooding** coordinated research for the designation and led the field trip, in which KSPG members explored the geologic and historic importance of the site. Experts from the University of Kentucky, Eastern Kentucky University, University of Cincinnati, KGS, Shaker Village at Pleasant Hill, and the Camp Nelson Foundation contributed to the trip. State and local officials, geologists, and students attended the event.

Understanding water resources and karst

The theme of Earth Science Week 2002 was "Water Is All Around You." As an extension of this theme, KGS offered its very popular guided tours of McConnell Springs Park in Lexington. The tours, which focused on explaining karst geology, groundwater resources, and protection of groundwater quality, were provided for 225 elementary students. On October 16, 2002, KGS and the UK Department of Geological Sciences, the Kentucky Water Resources Research Institute, and the Tracy Farmer Center for the Environment jointly hosted an open house that showcased water resource and other earth science activities. More than 200 children and adults attended the fun and educational open house.

Communicating to the public the importance of protecting water quality and mitigating geologic hazards in areas with karst landscape continued as a priority for KGS. To facilitate this communication and provide advice for citizens on protecting groundwater quality and minimizing financial losses from karst hazards, a new publication was released in the fall of 2002. "Kentucky Is Karst Country! What You Should Know about Sinkholes and Springs," by hydrogeologist and karst expert **Jim Currens**, provides color photos of karst

features, explains how water flows underground, and describes some of the geologic hazards associated with building on karst landscape.



Awards and Appointments

Jim Drahovzal, head of the Energy and Minerals Section, was appointed to the Kentucky Height Modernization Subcommittee of the Geographic Information Advisory Board.

Assistant State Geologist **John Kiefer** received the George Cohee Public Service Award from the Eastern Section of the American Association of Petroleum Geologists. The award is issued for a career of outstanding service and achievement in public affairs.

At the 2002 annual meeting of the Eastern Section of the American Association of Petroleum Geologists, **Jim Drahovzal** received the A.I. Levorsen Memorial Award for the best paper presented at the 2001 meeting. The award was for his paper on carbon sequestration, "Midcontinent Interactive Digital Carbon Atlas and Relational Database (MIDCARB)." His coauthors were Lawrence Wickstrom, Timothy Carr, John Rupp, Beverly Seyler, and Scott White. Drahovzal also received this award in 1997.

John Kiefer and **Zhenming Wang** were invited speakers at the National Conference of States on Building Codes and Standards annual meeting in Louisville. This organization, a subcommittee of the National Governors Conference, provides a forum for coordinating building codes, regulations, and public safety interests in construction. Kiefer and Wang spoke on seismic- and earth-

quake-related issues pertaining to the new International Building Code and International Residential Code, which are having a significant impact throughout the nation, and particularly western Kentucky.

At the 2002 annual meeting of the Geological Society of America in Denver, Colo., **John Hickman, John Kiefer, Ed Woolery, and Drew Andrews** received awards for serving in the Roy J. Shlemon Mentor Program in Applied Geology. In this program, professional geologists mentor undergraduate and graduate students, providing advice to assist them in preparing for careers in applied geology.

Richard Smath, Earth Science Information Center Coordinator, was elected president-elect of the Kentucky Society of Professional Geologists for 2003. He will serve as president in 2004.

Jerry Weisenfluh, head of the Geospatial Analysis Section, was reappointed to the Governor's Geographic Information Advisory Council for a 3-year term. He represents the Kentucky Society of Professional Geologists on this committee.

The American Institute of Professional Geologists-Kentucky Section honored **Brandon Nuttall** and **Steve Cordiviola** as joint recipients of the Kentucky Geologist of the Year

award. They were recognized for their outstanding contributions to the Commonwealth of Kentucky by developing the Web-accessible database of oil and gas well records and geophysical logs.

Patrick Gooding, manager of the Well Sample and Core Library, was appointed by the Kentucky Society of Professional Geologists to serve as a delegate to the American Association of Petroleum Geologists for a 3-year term. The AAPG House of Delegates is composed of delegates from affiliated professional societies and regional representatives from around the world. Gooding was subsequently appointed by AAPG to serve on its National Core and Sample Preservation Committee. The mission of the committee is to promote collection, preservation, and use of samples and cores, as well as those data directly attributable



to this rock material, including analyses, descriptions, and stratigraphic assignment. Gooding's appointment was most appropriate, considering the Survey has the fifth largest core and sample library in the country.

Chad Willis, an agricultural producer who lives in Wil-lisville in western Kentucky, received an award to recognize his outstanding contributions to the University of Kentucky and the Kentucky Geological Survey. The award was presented by Assistant State Geologist John Kiefer at the 43rd annual meeting of the Survey in Lexington. In the past 10 years, Willis has cooperated with UK and KGS seismologists who set up a seismic station on his property in Fulton County. His cooperation and assistance facilitated the seismic research conducted by UK and KGS.

This research is of interest to seismologists in Federal and State government and universities, and consultants studying seismic activity in the New Madrid Seismic Zone.

John Kiefer was selected as the first chair of the national Division for Earth Science and Society. This new division of the Geological Society of America was created by the GSA national Committee on Geology and Public Policy, of which Kiefer is a member. He also serves as the chair of the Southeastern Section GSA Committee on Geology and Public Policy. He is a member of the Joint Technical Program Committee for GSA, and is also chair-elect of the Southeastern Section of GSA; he will take office at the spring meeting in Washington, D.C., on March 25, 2004.

In addition, Kiefer was named a charter member of the Central U.S. Seismic Advisory Council and is a member of the Central U.S. Committee for the U.S. Geological Survey's Advanced National Seismic System. And he was elected chair-elect of the Association of American State Geologists' Associates Caucus; he has been acting chair, and will serve as chair for 2004-05.

Carol Ruthven, Manager of Communications and Technology Transfer, was elected vice president of the Association of Earth Science Editors for 2002-03. She will serve as president for 2003-04. AESE members are from Canada, the United States, and Europe.

Fiscal year 2002-03 highlights

Number of active projects:	20
Amount of external funding:	\$1,223,816
Number of publications:	19
Responses to technical inquiries or requests for information:	12,503*
Number of professional presentations by KGS staff:	191

*telephone, fax, e-mail, and office visits

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www.uky.edu/KGS

Earth Science Education Network

www.uky.edu/KGS/education/education.html

KGS Online List of Publications

www.uky.edu/KGS/pubs/lop.htm

Mission statement

Our mission is to increase knowledge and understanding of the mineral, energy, and water resources, geologic hazards, and geology of Kentucky for the benefit of the Commonwealth and Nation.

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