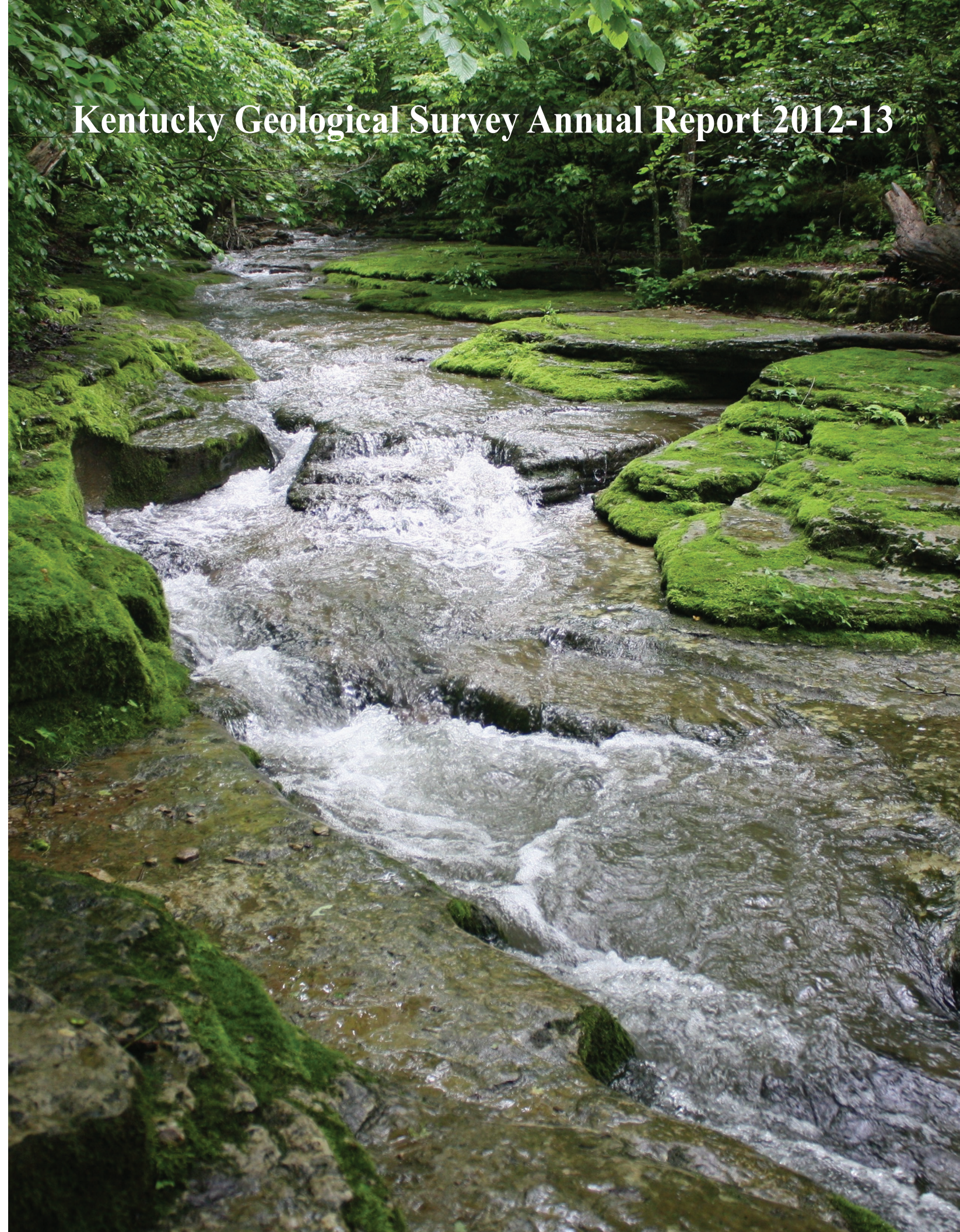


**Kentucky Geological Survey**  
228 Mining & Mineral Resources Bldg.  
University of Kentucky  
Lexington, KY 40506-0107

*Address service requested*

Nonprofit Organization  
US Postage  
**PAID**  
Lexington, KY  
Permit No. 51

# Kentucky Geological Survey Annual Report 2012-13



# Contents

- 2 Letter from the Director
- 5 KGS Advisory Board
- 6 Energy and Minerals
- 11 Water Resources
- 14 Geologic Hazards
- 16 KGS: Research, Collaboration, and Education
- 19 Geologic Mapping
- 20 Well Sample and Core Library
- 21 Archaeopteris Tree
- 22 Western Kentucky Office in Henderson
- 23 KGS Laboratory
- 24 Geologic Information Management
- 25 KGS Publications 2012-13
- 26 Public Outreach
- 28 Research Projects, Fiscal Year 2012-13
- 29 Staff Awards, Recognitions, Committee Assignments
- 30 KGS Staff 2012-13
- 31 KGS Organizational Chart
- 32 Feedback



# Letter from the Director

The Kentucky Geological Survey is a research center of the University of Kentucky under the vice president for research. A report is prepared each year to inform the public about the Survey's activities in support of its mission, specified in Kentucky statutes, to investigate the state's geology, minerals, groundwater, and hazards, and to report on them to the public. To accomplish its tasks, KGS emphasizes quality scientific investigations, timely and informative publications, engagement with other UK departments and outside agencies, and database building for preservation and distribution of information. Investigations by KGS during the 2012-13 fiscal year were aided by 18 projects funded by more than \$726,600 in grants. Much of the information from recent research is distributed on the KGS website, which is used by private citizens and landowners, business people, industries, and government agencies.

During the fiscal year, nearly 415,000 database searches were made online for oil and gas, coal, and water data, resulting in more than 13,000 downloads. These data were viewed on interactive maps, especially our signature interactive geologic map. An

average of 450 users access our data at [www.uky.edu/kgs](http://www.uky.edu/kgs) each weekday. The KGS website is one of the University's most active information providers. In addition, our Henderson office and Well Sample and Core Library provide access to geoscience information and samples to government agencies, researchers, professional geologists, faculty, and students. The Core Library acquired 100 new well samples and cores in 2012-13.

Chuck Taylor was named head of the KGS Water Resources Section in January 2013, replacing Jim Dinger, who retired the previous spring. Chuck was with the U.S. Geological Survey for 21 years, primarily with the Water Science Center in Louisville. At USGS, he conducted groundwater investigations, on topics such as flow in karst and fractured bedrock, contaminants in groundwater, and ground-water-surface water interactions.

KGS has nearly completed all phases of the research required under the Kentucky Energy Independence and Incentives Act of 2007. A tremendous amount of core and samples, geophysical well logs, seismic profiles, water monitoring data, reservoir testing, and engineering data that were acquired in the course of

the work will be available to the public as a result of this research. Technical reports covering the results of these projects are available from KGS. The Energy Independence and Incentives Act required KGS to perform research to test the potential for injecting and storing CO<sub>2</sub> in deep rock formations in the Eastern and Western Kentucky Coal Fields and the use of CO<sub>2</sub> for enhanced oil and gas recovery. This year, a 4,800-foot-deep well was drilled and tested in Carter County, and enhanced gas recovery data from Johnson County continue to be analyzed. All of the work mandated by the legislation on the feasibility of using and storing CO<sub>2</sub> has been successfully completed.

KGS added a new seismic station in Hazard to the Kentucky Seismic and Strong-Motion Network. The new station expands monitoring into the southeastern part of the state and will record events from the East Tennessee Seismic Zone. This is an active zone that typically generates small to moderate earthquakes, but large events are possible, although their pattern of occurrence is not well known. This station was prompted by a 4.2-magnitude earthquake near Blackey on Nov. 10, 2012. That

earthquake was widely felt across Kentucky, including very noticeable shaking in Lexington. This station was dedicated to the memory of Jonathan McIntyre, a KGS seismologist from Hazard who died in 2011.

The KGS laboratory has significant analytical capabilities for water, fuels, and minerals. It was started in 1988, and more than 200,000 individual analytical tests have been performed in it on more than 40,000 samples. Previously, it was a service center running samples for KGS researchers, outside organizations, and private companies, but is now a research unit under the KGS Water Resources Section. Although under the umbrella of the Water Resources Section, it will handle all of KGS's analytical needs.

Coal-fired power plants continue to be the principal source of electrical energy in the United States, but the majority of new plants use natural gas and renewable energy. As a result, Kentucky's coal production and workforce declined in 2012, especially in eastern Kentucky (Appalachian Basin). The high costs of producing coal from deep mines in eastern Kentucky is also a factor in declining production. Production of less

costly but higher-sulfur western Kentucky coal (Illinois Basin) has benefitted from expanding use of flue-gas desulfurization technology at existing electric power plants. Newly opened, high-capacity underground mines have added production and new jobs in western Kentucky.

In 2012, the total value of oil and gas produced in Kentucky was more than \$593 million; 3.2 million barrels of oil and 278 billion cubic feet of natural gas were produced. Since the first oil well in Kentucky was drilled near Monticello in 1815, more than 793 million barrels of oil and 6.9 trillion cubic feet of natural gas have been produced. In 2012, the total number of wells drilled annually declined to fewer than 900, but production continued to increase. The Kentucky Geological Survey is the public repository for drilling and production data and provides publicly available interactive services that support this vital industry.

KGS benefits a great deal from international partnerships. In July 2013, KGS and the Lanzhou Institute of Seismology renewed their partnership in seismology, which began in 2005. A new partner, the Institute of Engineering Mechanics of the



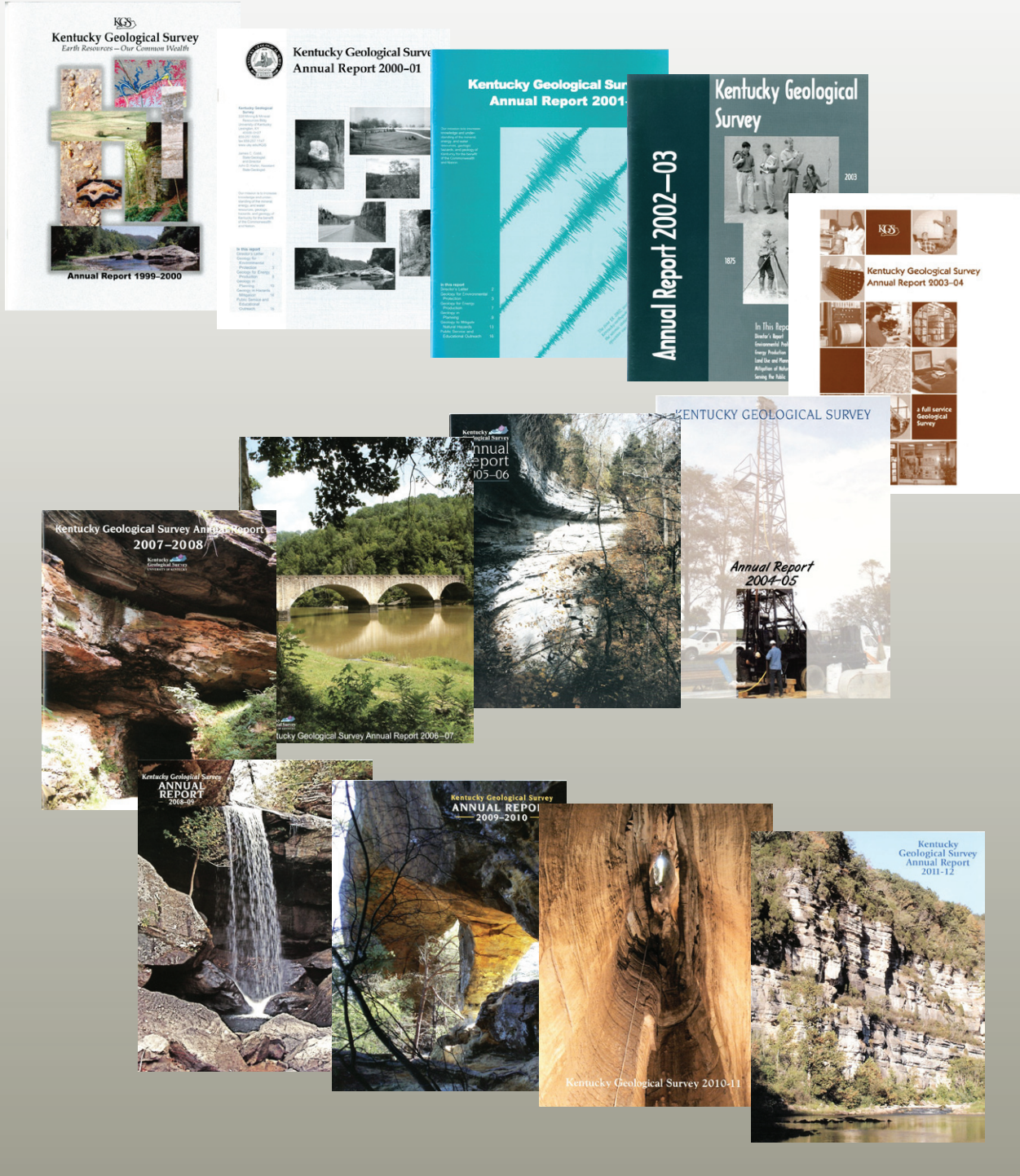
China Earthquake Administration in Harbin, was added. KGS is hosting students and visiting scholars from both of these organizations. During the 2013 exchange visit to Lanzhou in Gansu Province, a 6.6-magnitude earthquake struck a rural area of the province, inflicting 100 fatalities and displacing thousands from their homes. Although earthquakes are tragic events for people, the frequent earthquakes in Gansu Province provide valuable scientific data to seismologists at KGS, UK, and Gansu Province. It is our hope that these data will help mitigate future disasters in Kentucky and China.

I hope you find the information in this annual report useful. Please let me know if you have any questions or comments. □

*James C. Cobb*

During each of the 14 years of the Twelfth Survey, the cover of this annual report has depicted the research of our professional staff or some of the natural beauty of Kentucky's geology. The more recent photos gracing the covers were taken by KGS staff, their family members, or other friends of the Survey.

This annual report helps KGS meet the mandate of Kentucky Revised Statute 151.040 to "report periodically on its findings to the Governor and General Assembly, and such reports shall be available to the public."



# KGS Advisory Board

The KGS Advisory Board meets several times each year to hear updates on research projects and other activities of the Survey and to make recommendations for future directions. The members are appointed to 3-year terms by Kentucky's governor. The board also serves as the State Mapping Advisory Committee, to provide input and direction for mapping activities funded by the U.S. Geological Survey.



**Raymond R. (Rusty) Ashcraft**, chairman, is a registered professional geologist and manager of government affairs and environmental policy for Alliance Coal, with responsibility for Kentucky, Indiana, Illinois, and federal environmental issues.

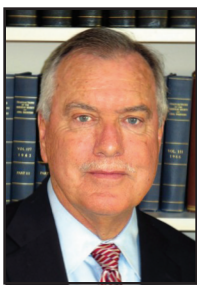


**Douglas W. Reynolds**, vice chairman, is a geologist and vice president for exploration and production of Reynolds Resources Inc. He works to identify locations and

opportunities for resource development and provides geologic support for new projects.



**J. Steven Gardner**, a licensed professional engineer, is president and CEO of ECSI, LLC, a consulting practice based in Lexington. He focuses on mining, natural resources, energy, environmental, health and safety, sensitive land-use issues, and industrial heritage projects.

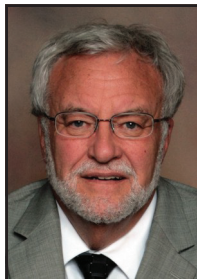


**Ron D. Gilkerson** is president of GRW, an engineering, architectural, and geospatial design consulting firm in Lexington. He has more than 40 years of industry experience in project management, quality and fiscal control, business development, division administration, and direction of corporate operations.

**Mark B. Mangun** does environmental assessment and remediation work with his company, Mangun Enterprises. He has over 30 years' experience related to contaminated soils, surface waters, and groundwater in a variety of locations, including karst and fractured hydrogeologic settings.



**Marco M. Rajkovich Jr.** is a member of the Lexington law firm of Rajkovich, Williams, Kilpatrick & True, PLLC, focusing in the areas of mine safety and health, mineral and energy, and administrative law. He was named in *Best Lawyers in America* as 2014 Lawyer of the Year, Energy Law, Lexington.



**Roger B. Recktenwald** serves as director of research and planning for the Kentucky Association of Counties, where he assists counties, cities, and their special purpose

government entities in development, project implementation, and consolidation of water and wastewater services.



**Stephen B. Sullivan** is the chief financial officer of the Corradino Group Inc. of Louisville, a professional consulting services firm providing transportation planning, engineering, and environmental services to clients throughout the Midwest and South.

**John F. Tate** works with James River Coal in Hazard, Ky. He has worked as a land agent, primarily in the East Kentucky Coal Field, for 30 years. He has also been active in elk restoration efforts in eastern Kentucky as well as projects to demonstrate that high-value commercial trees can be grown on reclaimed coal mine land.



**Chester M. Thomas**, is the Manager of Sunshine Oil & Gas, LLC, which is active in all aspects of exploration, developing, and producing oil and gas properties. He began his mining career in the late

70's. Thomas has owned and managed multiple successful mining operations in the West Kentucky Coal Field.



**Karen E. Thompson** is a geologist with Smith Management Group of Lexington. She has 20 years of experience in the environmental industry, specializing in hydrogeology. She was the 2011 Outstanding Kentucky Geologist for the Kentucky AIPG chapter.

**Gregory A. Yankey** has over 22 years of geotechnical engineering experience in complex civil, hydrology, and hydraulics projects across North America. His experience relates specifically to dam and levee design, construction, operation and inspection. He has worked on dam and levee safety programs with the U. S. Army Corps of Engineers and Tennessee Valley Authority. He is also skilled in forensic or failure analyses.

# Energy and Minerals

*Research continues on resources for an energy-hungry world, carbon storage, and strategic minerals.*

## CARBON STORAGE

### *Carbon-storage demonstrations*

Two carbon-storage projects funded by the Energy Independence and Incentives Act of 2007 were active during the year. Both involved field operations in the Eastern Kentucky Coal Field, marking a shift from the completed research in western Kentucky (Hancock County deep well and Hopkins County CO<sub>2</sub> enhanced oil recovery). Both projects were largely completed, and final results will be released later in 2013.

### *Devonian shale enhanced gas recovery demonstration using CO<sub>2</sub>*

**Brandon Nuttall** led a project in Johnson County to test the hypothesis that Devonian black shales beneath about two-thirds of Kentucky may serve for long-term

CO<sub>2</sub> storage and play a role in enhanced natural gas recovery. In addition to State funding, support for this project continued from the U.S. Department of Energy through a contract with Advanced Resources International. In September 2012, flow rates and pressures were tested under a variety of conditions. Three monitoring wells and downhole instruments recorded the data. Geophysical logs were acquired before and after the test for comparison. Eighty-seven tons of CO<sub>2</sub> were pumped into the shale of the test interval in three stages. Geophysical logs suggests CO<sub>2</sub> interacted with the shale and may have displaced additional natural gas, but the duration and small volumes of the test limited interpretation of the results. The pressure data acquired during the transient test are being analyzed.

### *Eastern Kentucky Coal Field deep saline injection well*

KGS drilled a 4,835-foot-deep stratigraphic research well in the Eastern Kentucky Coal Field for a project managed by **Steve Greb**, **Rick Bowersox**, and **Warren Anderson**. KGS partnered with Hanson Aggregates (a subsidiary of Lehigh Hanson Inc.) for access to property at their AA Limestone Quarry in northern Carter County in order to collect deep, subsurface data to assess potential reservoirs and seals for future carbon dioxide storage near the Ohio River industrial corridor. No carbon dioxide was injected in the well, but a large data set has been collected that will

Brandon Nuttall and Dave Harris check the pressure and temperature data from a surface readout gage at a monitoring well near the Devonian shale enhanced gas recovery demonstration.

aid in interpreting the potential for future carbon storage.

The KGS No. 1 Hanson Aggregates well penetrated the entire Paleozoic section and the top of Precambrian basement. An extensive suite of geophysical logs, including imaging logs, was recorded in the borehole. Eight cores totaling 453 feet were cut from the major porous formations and impermeable seals. An additional 30 rotary sidewall cores were cut to supplement whole-core data. Laboratory analysis planned for the collected core includes porosity and permeability measurements, rock strength, capillary-entry pressures, and 59 thin sections. Three intervals were selected for sampling formation water, testing step-rate pressure to determine in situ rock strength, and determining reservoir porosity and permeability parameters: the Mount Simon Sandstone through Maryville Sandstone section, a highly porous section in the middle Copper Ridge Dolomite, and the Rose Run Sandstone.

An unexpected outcome of the Carter County well has been cooperative work with the UK College of Pharmacy at the Center for Pharmaceutical Research and Innovation. Deep subsurface rock samples were collected by KGS and prepared by College of Pharmacy research staff hoping to isolate unique microbes. This work is still in progress.

Results from the data collected will be analyzed, and a final report will be completed later in 2013. This project is managed by the Kentucky Consortium for Carbon Storage ([www.kyccs.org](http://www.kyccs.org)), a KGS-industry partnership formed to carry out the CO<sub>2</sub>-storage





Bart Davidson and Steve Webb of the Water Resources Section take water samples from a well near the Carter County deep storage research well.



A drilling rig is set up on the Hanson Aggregates property in Carter County for the eastern Kentucky deep storage test project.



Rick Bowersox examines a piece of core that had just been pulled from the Carter County deep well.

research mandated in the Energy Independence and Incentives Act of 2007.

***Regional carbon storage partnerships***

The Energy and Minerals Section, led by **Steve Greb**, continued research in phase III of the Midwest Regional Carbon Sequestration Partnership funded by the U.S. Department of Energy. Managed by the Battelle Memorial Institute, the project covers Indiana, Kentucky, Maryland, Michigan, New Jersey, New York, Ohio, Pennsylvania, and West Virginia. Phase III research continues regional characterization of reservoirs and confining intervals, and injection testing (in other states) to help prepare for future commercialization of carbon storage. Information about the regional partnership (fact sheets, reports, presentations, etc.) can be found at [www.mrcsp.org](http://www.mrcsp.org).

Steve Greb also participated in

the multistate U.S. Department of Energy project, Simulation Framework for Regional Geologic CO<sub>2</sub> Storage Infrastructure Along the Arches Province of the Midwest United States. This effort, managed by the Battelle Memorial Institute, modeled CO<sub>2</sub> sequestration into the Mount Simon Sandstone in Indiana, Kentucky, Ohio, and Michigan to better evaluate the feasibility of CO<sub>2</sub> storage from multiple sources into a single regional reservoir. Advanced reservoir simulations of large-scale CO<sub>2</sub> storage were conducted, using a geologic model developed for the project. Computer simulations will help address technical and infrastructure questions about CO<sub>2</sub> transport, infrastructure needs, storage capacity, monitoring, and risk assessment in the region. The contract ended in September 2012, and a final report was submitted to the U.S. Department of Energy. UK Department of Earth and Environmental Sciences graduate student

**Ralph Bandy** worked on this project as part of his master's thesis.

***Evaluating deep CO<sub>2</sub> storage in the Illinois and Michigan Basins***

This project, funded by the U.S. Department of Energy beginning in 2010, is a collaborative effort of the state surveys of Illinois, Kentucky, and Indiana, and geologists at Western Michigan University. The carbon-sequestration potential of the Cambrian-Ordovician Knox Group and Ordovician St. Peter Sandstone of the Midwest is being studied. KGS is characterizing the potentially important Knox Group in western Kentucky.

This year, phase II CO<sub>2</sub> injection testing and 3D vertical seismic profile imaging at the KGS Marvin Blan No. 1 well was completed by **Rick Bowersox** and **John Hickman**, and a report was submitted to the U.S. Department of Energy. KGS publications based on this report are in preparation.



Knox reservoir characterization continued. An older Knox core from Trigg County was sampled for porosity and permeability analysis. Thin-section petrography of Knox core samples to document porosity types and diagenetic processes also continues.

Geochemical models to predict interactions among supercritical carbon dioxide, brines, and the minerals making up the Knox carbonate reservoir and seal rocks were completed by **Marty Parris** and **Junfeng Zhu**. A paper discussing geochemical modeling of the injected CO<sub>2</sub>-brine-reservoir rock system for the KGS Blan well by **Junfeng Zhu, Marty Parris,** and **Rick Bowersox** was accepted for publication by *Applied Geochemistry*. Parris and a colleague wrote a paper on reactive transport modeling in order to predict reactions between CO<sub>2</sub>-saturated brines and confining zones (shale or nonporous carbonates).

**Marty Parris** and **Steve Webb**, assisted by summer intern **Jerrad Grider**, sampled two Knox wells in Woodford and Bourbon Counties, to characterize the geochemistry and microbial communities in the Knox groundwater. The research is a collaborative effort with **Kevin Mandernack** of Indiana University–Purdue University Indianapolis. Historically, Knox groundwater in the Bluegrass Region often has had a sulfur smell, suggesting the presence of sulfate-reducing bacteria. Previous work suggested that, despite being relatively dilute, Knox groundwater in the Bluegrass could be older than 1 million years. The age estimates are based on measurements of 36-chlorine, which has a half-life of 301,000 years. The results of the research confirmed the presence of phospholipid fatty acids (components of cell mem-

branes), some of which are characteristic of sulfate-reducers. The evidence thus far suggests the presence of a viable but old bacterial community, and future work will investigate how the geochemistry and microbial community changes with increasing salinity in a downgradient direction. This research has several implications for CO<sub>2</sub> storage deeper in the Illinois Basin. Relatively dilute Knox waters could indicate active meteoric recharge along faults, which could also act as leakage pathways for injected CO<sub>2</sub>, and characterizing Knox groundwater geochemistry will allow modeling of CO<sub>2</sub> solubility and chemical reactions after injection.

## OIL AND NATURAL GAS RESOURCES

### *Evaluation of heavy oil and tar sand resources, western Kentucky*

**Rick Bowersox** initiated a project in mid-2011 to reevaluate western Kentucky tar sand resources, in response to increased interest. A belt of heavy oil- and bitumen-saturated zones in the Late Mississippian Hardinsburg and Big Clifty Sandstones and Early Pennsylvanian Caseyville Formation occurs primarily in Logan, Butler, Webster, Edmonson, and Grayson Counties.



A Big Clifty Sandstone tar seep—the type of resource Rick Bowersox is evaluating.

Such rock asphalt deposits were mined for use in road surfacing from the late 19th to mid-20th centuries, when shallow wells, less than 600 feet deep, yielded very low, noncommercial production of the tar-like oil.

As a starting point for a reevaluation of the western Kentucky tar sand resources, tar seeps, historical rock asphalt and bitumen mines and quarries, test pits, coreholes, enhanced oil recovery projects, and associated place names were compiled. A Google Earth project was constructed in which locations and details of these developments by geologic quadrangle were noted. This project is periodically updated as additional historical reports are uncovered and new information arrives.

In this reevaluation, oil-well data are being reviewed, and shows of shallow heavy oil mentioned in drillers' logs of the Caseyville, Hardinsburg, and Big Clifty formations are being compiled along with electric-log data and whole-core analysis into a petroleum reservoir analysis database. These data will be used to describe the extent of the tar sands and revise estimates of in-place heavy oil and bitumen resources.

### *Utica Shale Appalachian Basin Exploration Consortium*

KGS is participating in a five-state study of the geology, stratigraphy, and hydrocarbon potential of the Ordovician Utica Shale, an unconventional gas and oil reservoir in the Appalachian Basin. Research is being conducted by **John Hickman, Cortland Eble,** and **Jason Backus,** as well as researchers at the Pennsylvania, Ohio, and West Virginia geological surveys, Washington University, Smith Stratigraphic LLC of New York, and the U.S. Department of Energy's National Energy Technology Laboratory.

The research team at KGS analyzed 379 samples from project wells for total organic carbon content using a carbon/sulfur analyzer in the KGS laboratory during the year. **Cortland Eble** analyzed 83 samples for organic petrology and thermal maturity. Initial results indicate that although discrete vitrinite-like material is present, the bulk of the organic material in the source rocks is derived from amorphous marine algal material. The measured vitrinite reflectance (a measure of the thermal maturity of organic matter) seems to be consistent within individual wells, with relatively rapid increases in thermal maturity approaching eastern Ohio.

In addition to traditional stratigraphic tops from geophysical well logs, Upper Ordovician stratigraphy has been interpreted for three continuous cores from Kentucky. To aid in interpretation and future documentation, the Upper Ordovician intervals of two of these cores were photographed. These photographs will become part of the data distributed at the end of this project. Future integration of these interpretations with lab-derived total organic carbon analyses and thermal maturation data from well cuttings and cores may assist with identifying productive fairways for exploration drilling.

#### *Pennsylvanian marine shale beds as a potential oil and gas resource*

**Cortland Eble** and **Steve Greb** continued a project funded by the U.S. Geological Survey to document the organic composition of shale beds in both the Eastern and Western Kentucky Coal Fields, using petrographic, palynologic, and geochemical methods. The intent is a better evaluation of their potential as a future energy resource. Data from western Kentucky indicate that the marine shales are very organic-rich (15 to 44

percent) and contain adsorbed methane, but gas content is less than in adjacent coal beds. With current prices for natural gas, these shales are not economical to produce, but represent a future gas resource.

## COAL RESOURCES

### *Eastern Kentucky metallurgical coal*

Eastern Kentucky coal is mostly used for electric power generation because of its low sulfur content, and very little of it is used to produce metallurgical coke. The increasing use of scrubbers, which remove sulfur and allow the use of less-expensive, high-sulfur coal for power generation, will likely reduce utilities' demand for low-sulfur coal. Metallurgical coal may be an alternative market to avoid a further drop in production in eastern Kentucky.

The Kentucky Energy and Environment Cabinet funded a project to document the remaining eastern Kentucky coal resources with properties suitable for the domestic and international steel industry. **Cortland Eble**, **Jerry Weisenfluh**, and **Tom Sparks** developed maps showing remaining resources for beds that are known to be low in ash and sulfur, two important characteristics of metallurgical coal. Results indicate that many eastern Kentucky coals can be used as metallurgical feedstock, although primarily through blending with other (mainly low-volatile bituminous) coals. Furthermore, low-ash, low-sulfur eastern Kentucky coal appears to be of prime consideration for pulverized coal injection. PCI coal is primarily used as a heat source, and many samples analyzed during the course of this study had calorific values in excess of 14,000 Btu/pound. The final report was completed in November 2012, and was released as a KGS publication in 2013.

## MINERAL RESOURCES

### *Minerals database*

**Warren Anderson**, **Tom Sparks**, and **Richard Smath** continued to work on organizing a database on minerals such as ore minerals, fluorite, barite, sphalerite, and lead. A new map of the Western Kentucky Fluorspar District was published this year. "Mines and Minerals of the Western Kentucky Fluorspar District" (Map and Chart 201, series 12, 2012) by **Warren Anderson** and **Tom Sparks**, shows all the known mines, mineral prospects, and igneous intrusions (dikes or sills) of the Western Kentucky Fluorspar District in Caldwell, Crittenden, and Livingston Counties. Recent mining and exploration activity has renewed interest in the district, so the mineral industry will benefit from this map. In addition, the identified igneous rocks have the potential to host rare earth elements, an increasingly important strategic resource. Mineral specimen collectors and anyone wishing to locate sites of historical mining activity may also find the map of interest.

**Anderson**, **Sparks**, and **Smath** also developed a prototype database, which consists of a geospatial component along with a linked database of thousands of scanned mineral records, including core logs, cross sections, mine maps, chemical analyses, and reserve reports; the database should be publicly available and online by 2014. Final editing and consolidation of the image data are currently under way and will reduce the overall size of the database. KGS records are organized into a spatial and tabular database and are linked to cataloged images and documents for viewing in a geologic information system, providing easy access to the public through a new map service.

This service will provide access to thousands of in-house and donated files with information about mines and mining in Kentucky. With the opening of a new fluorite mine and additional fluorite exploration drilling in western Kentucky, this information should be valuable to the mining community.

**Rare earth element research**

Rare earth elements are considered strategic and critical minerals. They are used in a variety of applications, including cellphones, missiles, and lasers. Most of these metals come from China, which has reduced their export to the United States.

**Warren Anderson and Jason Backus** are investigating the geochemistry of ultramafic igneous rocks in the Western Kentucky Fluorspar District and other rock units in the state for their rare earth potential. Analysis of selected rock units has been completed and data interpretation has begun. Many of these rock units are enriched in rare earth elements, but the abundance and extent is not well understood; this investigation should enhance our knowledge of these rocks. KGS also investigated phosphatic rocks, western Kentucky sandstones, and Elliott County igneous rocks for their rare earth potential. This project should conclude in 2013 with a summary report.

**BRINES AND UNDERGROUND WASTE DISPOSAL**

**Mapping underground waste-disposal wells**

Disposal of oil-field brines and completion fluids by underground injection is increasing as shale-gas production expands in neighboring states. No cases of seismic activity related to underground fluid injection have been reported in Kentucky, but isolated cases in

other states have identified a need to document the location of underground injection wells permitted by the Environmental Protection Agency in Kentucky. **Tom Sparks, Dave Harris, and Rick Bowersox** completed a short-term project to identify and map permitted injection wells in the commonwealth. The publication, "Class I Waste-Disposal Wells and Class II Brine-Injection Wells in Kentucky" (Map and Chart 204, series 12, 2013), will be useful for the oil- and gas-production industry in Kentucky, as well as to anyone interested in safe underground waste disposal in the state.

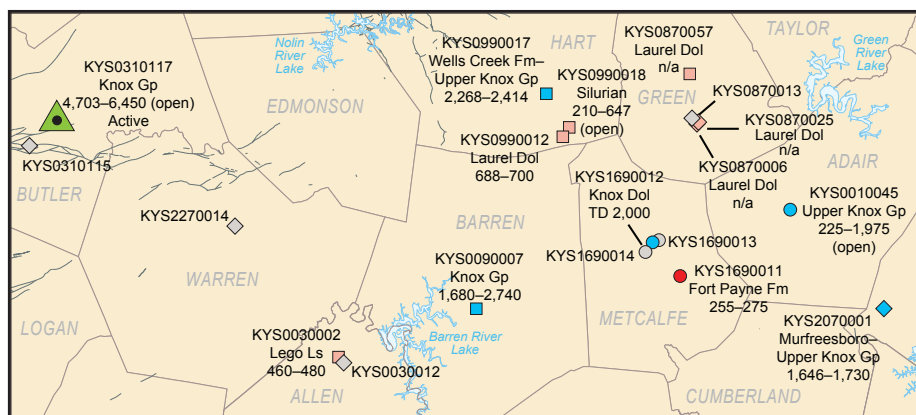
To make the map, locations of EPA-permitted Class I (hazardous

formations used for brine injection were displayed. The injection well map will be updated periodically, and is a key resource for a newly funded research project modeling brine disposal across the northern Appalachian Basin.

**Development of a brine disposal framework for the northern Appalachian Basin**

**Marty Parris and Tom Sparks** attended the kickoff meeting for a new project addressing the regional issues associated with brine disposal in the Appalachian Basin.

The project, Development of a Brine Disposal Framework for the Northern Appalachian Basin, is headed by Battelle Memorial



Detail from Map and Chart 204, series 12, 2013: "Class I Waste-Disposal Wells and Class II Brine-Injection Wells in Kentucky."

and nonhazardous) and Class II brine-injection wells were obtained from EPA Region 4, and matched with records in the KGS oil and gas well database. Since the state of Kentucky has no regulatory authority over underground injection, some of the wells used for injection had not been so identified in the KGS database. The remaining wells were successfully matched to wells in the KGS database. The map shows the well identification, injection zone, and depth.

This new map was a focal point of a core workshop held during the 2013 KGS annual seminar. Cores and data from several different

Institute and the state surveys of Kentucky, West Virginia, Pennsylvania, and Ohio. Goals of the project are to develop a regional geologic framework for brine injection zones, making use of reservoir properties such as injectivity and fracture strength, storage capacity, operations requirements, and potential costs under various combinations of brine source and injection sites. The deliverables are intended to provide guidance for oil and gas producers, regulatory agencies, and public stakeholders. □

# Water Resources

## *A Year of Transition*

The Water Resources Section conducts a variety of hydrogeologic investigations and acts as a scientific-technical resource to assist the groundwater data needs of State and federal agencies, other KGS sections and UK research faculty, professional geoscientists and engineers, and the general public. In addition, by legislative mandate, the section is responsible for maintaining the state's official groundwater data repository and for oversight of a statewide groundwater-monitoring network.

This fiscal year was one of transition for the Water Resources Section: In the spring of 2012, **Jim Dinger** retired as head of the section after 31 years of service. In January 2013, **Chuck Taylor** was selected as the new section head, coming to UK after 21 years with the U.S. Geological Survey.

### CDC PRIVATE WELL WATER INITIATIVE

**Bart Davidson** continued work on a third project with the Centers for Disease Control and Prevention in Atlanta. The CDC initiated a nationwide project to identify and characterize private drinking-water sources, primarily wells and springs, not covered by the Safe Drinking Water Act. Funded through the Kentucky Division of Water, KGS proposed a pilot study to review and compile bacteriological data collected from private wells by local and regional health departments in different geologic areas. In recent years, many Kentuckians have switched from wells to city or county water supplies as their primary drinking-water source. Most health departments continue to sample a few private wells per month at home-

owners' requests, however. More than 13 health departments and two State laboratories had been visited by the end of the fiscal year, as well as many telephone contacts made. Several hundred bacteria records will be added to the Kentucky Groundwater Data Repository as a result of this project and made available for public health research.

### KARST ACTIVITIES

The Water Resources Section remained active in karst hydrogeology research, and investigations were conducted in three areas.

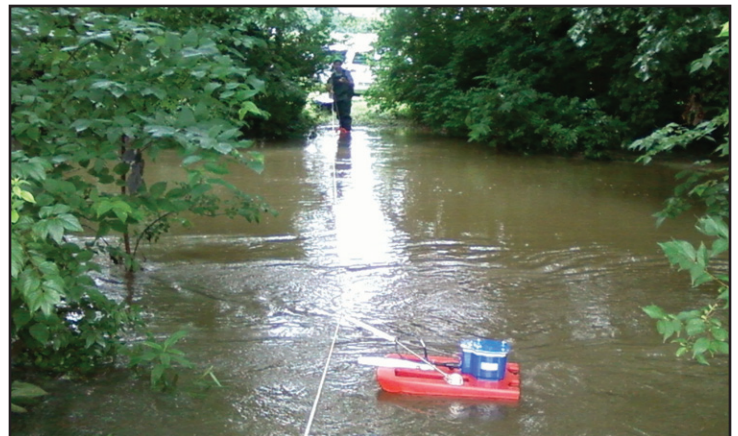
#### *Hydrology of the Cane Run karst watershed*

KGS staff and faculty in the UK College of Agriculture and Department of Earth and Environmental Sciences have collaborated to attempt to better quantify the discharge of water and concentrations and loads of fecal bacteria, nitrate, and suspended sediments through the Cane Run karst watershed. Cane Run, a surface stream that heads in east-central Fayette County and extends into Scott County, drains approximately 15,000 acres. Near the Scott-Fayette County line, the watershed's surface flow is pirated by a series of swallow holes that are

hydraulically connected to the main karst conduit of Royal Spring, the source of municipal water for Georgetown. KGS began monitoring flow conditions and water quality in the Royal Spring karst aquifer in May 2011, using a cluster of monitoring wells located at the Kentucky Horse Park drilled into the Royal Spring conduit and adjacent parts of the karst aquifer. The wells have been equipped with stage recorders, a velocity meter, a 12-volt pump to collect samples, and a water-quality testing device and data logger.

Karst hydrogeologist **Jim Currens** has been conducting research into methods to accurately measure the discharge of water and flux of potential contaminants through the Royal Spring conduit. Discharge and cross-sectional area are difficult to determine directly in underground conduits, unlike with surface streams, yet they are essential to calculating the flux of contaminants, as well as water-flow velocity distribution. Three methods have been used to calculate the cross section of the Royal Spring karst conduit: (1) downhole video, (2) Doppler sonar, and (3) quantitative groundwater tracing. The Doppler sonar was most useful in

Water Resources staff use an automated sonar device during a heavy rain at Cane Run Creek in the Kentucky Horse Park. The device uses global positioning and sonar to measure water depths and calculate water flow.





Jim Currens lowers instruments into a monitoring well for the Cane Run watershed project after calibrating them.

determining passage size. To analyze the sonar data, Currens performed vector analysis, which showed the direction of flow, the speed of the suspended material, and the coordinates of the location of the observation. The quantitative groundwater tracing has been the most effective tool for determining discharge because the data generated by it reflect the increasing width and depth of flow as the higher and normally air-filled conduits begin to discharge. Most of the current effort is focused on collecting discharge measurements under a variety of flow conditions to develop a more precise discharge-rating curve for the Royal Spring conduit and hence the entire Cane Run karst watershed.

In addition to enabling researchers to characterize the flux of nitrate and other potential contaminants through the Cane Run watershed, the results of this research are anticipated to result in a better understanding of the interaction of surface water and groundwater in the Inner Bluegrass karst region.

#### ***Inventory of sinkholes and sinkhole occurrences***

National news reports of several incidents in 2013 of large sinkhole

collapses in various parts of the United States, including one near Tampa, Fla., that resulted in a fatality, dramatically increased the public's awareness and concern about sinkhole occurrences in Kentucky. Water Resources Section staff responded to approximately 68 requests for information or field inspections of sinkholes occurring on private landowners' properties. Section personnel also gave several interviews about karst and sinkhole occurrence to local and regional news outlets. Since 1997, the section has collected information about the occurrence of cover-collapse sinkholes in Kentucky, maintaining an inventory of these features that describes their locations, physical characteristics, and topographic and geologic settings. A GIS file of sinkholes identified and mapped throughout the state at 1:24,000 scale was prepared in 2003 and is available for download at [www.uky.edu/KGS/gis/sinkpick.htm](http://www.uky.edu/KGS/gis/sinkpick.htm).

#### ***Using LiDAR to map karst sinkholes***

To investigate new methods to improve the ease and accuracy of sinkhole identification and mapping, **Junfeng Zhu** has been investigating the use of digital topographic data collected by using the remote sensing technology LiDAR (light detecting and ranging) to identify and map sinkholes in karst areas. He and student worker **Patrick Taylor** developed data-processing methods and used them to delineate sinkholes in the drainage area of Floyds Fork, a surface stream draining parts of Jefferson, Oldham, Shelby, and Bullitt Counties in north-central Kentucky. Using the new LiDAR



UK student Patrick Taylor photographs a depression in a neighborhood in Bullitt County while searching for sinkholes in a project overseen by Junfeng Zhu.

mapping method, they identified four times more probable sinkholes than could be identified using contoured depressions visible on topographic maps. A field inspection of 80 probable sinkholes located using the LiDAR mapping method indicated that interpretation of LiDAR data was 89 percent successful in identifying and delineating sinkhole depressions actually created by karst hydrogeologic processes.

#### ***Groundwater contaminant modeling at the Paducah Gaseous Diffusion Plant***

**Junfeng Zhu**, working with the Kentucky Research Consortium for Energy and the Environment, developed a computer model of groundwater flow in the aquifer system at the Paducah Gaseous Diffusion Plant, where a variety of radioactive and nonradioactive hazardous wastes were released in the past. The model will be used to assist Department of Energy and other State and federal resource managers and contractors in remediating groundwater at the site by simulating the movement of contaminants. Zhu will use the model to test the potential outcomes of different groundwater remedial actions that are being considered and used in cleanup of the Paducah site.

#### ***Cumberland Gap tunnel roadway subsidence***

The Water Resources Section staff collaborated with the Kentucky Transportation Center at UK to investigate the causes of roadbed aggregate dissolution and subsidence in the Cumberland Gap tunnel near Middlesboro, Ky. In a previous project completed in 2012, groundwater and roadbed drainage samples were collected and analyzed to characterize water chemistry. In addition, the dissolution of samples of limestone aggregate

suspended in 2-inch-diameter stainless-steel baskets in four test borings in the northbound tunnel was monitored to improve understanding and quantification of the processes involved in the roadbed subsidence.

Using geochemical modeling, **Junfeng Zhu** analyzed the water chemistry and dissolution data and found that water draining through the tunnels is corrosive to limestone, and that in parts of the tunnel the aggregate may be totally dissolved by groundwater in 15 years. These findings have prompted the Transportation Center and federal highway engineers to initiate remedial measures to replace the existing limestone roadway aggregate with insoluble granite aggregate. Future monitoring of changes in the chemistry of water in the roadbed aggregate during and after the remedial highway construction is planned. Water-level recorders in the tunnel are being maintained by **Steve Webb** to help monitor groundwater inflow and quantify drainage through the existing roadbed aggregate.

### *Emerging contaminants*

According to the U.S Geological Survey, recent water resources research is “documenting with increasing frequency that many chemical and microbial constituents that have not historically been considered as contaminants are present in the environment on a global scale. These emerging contaminants are commonly derived from municipal, agricultural, and industrial wastewater sources and pathways” ([toxics.usgs.gov/regional/emc](http://toxics.usgs.gov/regional/emc)). The Environmental Protection Agency has also defined these contaminants as “a chemical or material that is characterized by a perceived, potential or real threat to human health or the environment or lack of published health standards. A contaminant may also be ‘emerging’ because of the discovery of a new source or a new pathway to humans, or a new detection method or treatment technology has been developed” ([epa.gov/fedfac/pdf/emerging\\_contaminants\\_nanomaterials.pdf](http://epa.gov/fedfac/pdf/emerging_contaminants_nanomaterials.pdf)).

These potential contaminants include anti-microbial and endocrine disruptor chemicals contained in various pharmaceuticals and personal care products.

In 2011-12, hydrogeologist **Glynn Beck** at the KGS Western Field Office in Henderson sampled 56 surface stream sites in six watersheds in Kentucky for two emerging contaminant compounds of interest: 17- $\beta$  estradiol (one of three naturally produced estrogens) and fluoroquinolones (a subset of the synthetic broad-spectrum antibacterial drugs known as quinolone antibiotics). Two of the watersheds are in the Jackson Purchase Region, two are in central Kentucky, and one each is in northern and eastern Kentucky. These watersheds were chosen because they are distributed in different physiographic regions and contain a wide variety of land-cover types (developed, cultivated, forest, and pasture). In addition, five of the six watersheds have municipal wastewater treatment plant outfalls, and five of the six watersheds are classified as priority watersheds selected for restoration and protection efforts by the Kentucky Division of Water.

In 2012-13, four of the six watersheds were resampled to obtain more statistically significant data. Twenty sites in the four watersheds were sampled four times each. In addition to water-quality samples, field measurements (pH, specific conductance, dissolved oxygen, temperature, and total dissolved solids) were recorded, and stream discharge was measured at some of the sites.

Results from the study will be described in a KGS report under preparation. Among the findings:

- (1) Estradiol was detected in all six watersheds.
- (2) Fluoroquinolones were detected in four of the six watersheds.
- (3) Watersheds with the most developed land cover (South Elkhorn Creek, 24 percent; Banklick Creek, 36 percent; and Floyds Fork, 18 percent) had the highest detected

estradiol concentrations (14.3, 11.1, and 8.2 parts per trillion, respectively).

Sampling and analysis was funded in part by the U.S. Department of Agriculture’s National Institute of Food and Agriculture Southern Regional Water Program and the USGS’s State Water Resources Research Institute Program. The project was also conducted in collaboration with the UK Department of Biosystems and Agricultural Engineering, UK Department of Plant and Soil Sciences, and Kentucky State University College of Agriculture, Food Science and Sustainable Systems.

## ENERGY-RELATED PROJECTS

**Junfeng Zhu** worked with Energy and Minerals Section staff to complete geochemical models of interactions among supercritical carbon dioxide, brines, and the minerals in the Knox carbonate reservoir and seal rocks. He and others in the Water Resources Section have worked with the Energy and Minerals Section on several recent projects on the water components of carbon dioxide. (See Energy and Minerals, page 6.) □



Glynn Beck samples the waters of Banklick Creek in Kenton County for the emerging contaminant project.

# Geologic Hazards

## *Geologic hazards remain a concern for KGS researchers.*

### HAZARD ASSESSMENT

The seismic hazard assessment for the central United States remains a major concern for the Geologic Hazards Section because western Kentucky's economic development has been hindered by overstated ground-motion hazard estimates from the U.S. Geological Survey. Section Head **Zhenming Wang** and KGS Director **Jim Cobb** co-authored "A Critique of Probabilistic Versus Deterministic Seismic Hazard Analysis with Special Reference to the New Madrid Seismic Zone," published as a Geological Society of America Special Paper, describing the scientific defects of the national seismic hazard maps. A video highlighting the hazard map issues was made by the UK Research Communications Office and posted on the KGS YouTube channel, [www.youtube.com/user/KGSUK](http://www.youtube.com/user/KGSUK).

Presentations on the hazard maps and their resulting design maps were made to the USGS National Seismic Hazard Map Workshop on Ground Motion Prediction Equations for the 2014 Update and to the Kentucky Society of Professional Engineers Paducah Spring Seminar.

### COOPERATIVE RESEARCH AT UK

The Geologic Hazards Section continued cooperative work with the academic units on the UK campus, particularly the Department of Earth and Environmental Sciences, on the operation and maintenance of the Kentucky Seismic and Strong-Motion Network. Three strong-motion sensors were purchased with funds from the department.

Another activity was site reconnaissance for a large array of seismic instruments in the Ozarks,

Illinois, Indiana, and Kentucky. The project was conducted by Indiana University, the University of Illinois, and Purdue University with funding from the National Science Foundation.

A survey on seismic hazard assessment and mitigation policy in western Kentucky was also conducted.

The above projects were carried out by graduate students and visiting scholars and partially funded by KGS.

### CHINA SCHOLARLY EXCHANGE AND COOPERATIVE RESEARCH

This was the ninth year for the exchange of scholars and cooperative research between KGS and several institutes under the China Earthquake Administration. Geologic Hazards Section Head **Zhenming Wang** visited the Lanzhou Institute of Seismology in August 2012 to give a lecture and conduct research. One postdoctoral student and four visiting scholars from China came to UK to participate in research projects and exchanges. One of the scholars, **Qian Li**, authored a KGS publication. A thesis, "A Comparison of Ground Motion Prediction Equations Between China, Wenchuan Area, and the Central and Eastern United States," was developed and successfully defended by visiting scholar **Jiwei Feng**. Three related papers were submitted to or published by scientific journals.

### THE KENTUCKY SEISMIC AND STRONG-MOTION NETWORK

A magnitude-4.2 earthquake on November 10, 2012, in Perry County caught the attention of the

public and the news media, generating interest in earthquakes and the Geologic Hazards Section's work. The 20-kilometer-deep event was felt more than 1,000 kilometers away, with reports from Ashford, Conn., to the northeast and Magnolia, Ala., southwest of the epicenter. Moderate to strong shaking was reported within 40 kilometers of the epicenter in northern Leslie County. Minor cracks appeared in a basement wall in the Letcher County courthouse, in Whitesburg, 21 kilometers away. All of these effects drew public and news media attention for several days.

Geologic Hazards staff detected 15 aftershocks from November 10–14, most of which occurred on November 10, and were able to determine locations for seven of them. The section has ongoing research to determine if the event is evidence of a continuation of the seismically active Eastern Tennessee Seismic Zone farther north than



Zhenming Wang and Seth Carpenter install the new seismic station behind the Perry County Public Library.

previously recognized, into south-eastern Kentucky.

About a month after this earthquake, a new seismic station was added to the Kentucky Seismic and Strong-Motion Network at the Perry County Public Library in Hazard. With upgrades at other network sites during the fiscal year, this station became one of four that now record both weak-motion and strong-motion data in real time. Operation and maintenance of the 24-station network is one of the Geologic Hazards Section's main tasks. The network monitors earthquakes, mine blasts, and other seismic activities in Kentucky and the central United States. It also records the largest earthquakes from around the world. Near-real-time recordings from 14 of the network seismic stations can be monitored on the KGS website at [www.uky.edu/KGS/geologichazards/equake3.htm](http://www.uky.edu/KGS/geologichazards/equake3.htm). Work continues to expand and upgrade the network, to improve our understanding of earthquake sources and ground motions in Kentucky.

Seventeen earthquakes were located in the state during the fiscal year, with magnitudes from 0.2 to 4.2. Five of these events occurred in the Mississippi Embayment (west of



Seth Carpenter installs a computer to record data from the Hazard seismic station and transmit to KGS.



Meadowview landslide research site. The main scarp is outlined with a dashed line and the arrow shows direction of movement. The rain gage station is visible at left.

Hickman, Ky.), and the remaining events occurred in the eastern Kentucky counties of Perry, Clay, and Breathitt. Many of the real-time stations were upgraded from analog to digital in order to use the upgraded Kentucky Emergency Warning System. These stations have improved sensitivity to seismic signals and can record a larger range of ground motions than previously possible.

Data from networks operating around and in Kentucky, including EarthScope USArray stations ([www.earthscope.org/science/observatories/usarray](http://www.earthscope.org/science/observatories/usarray)), are now being acquired in tandem with real-time Kentucky Seismic and Strong-Motion Network data and used to detect seismic events in Kentucky with unprecedented sensitivity.

## LANDSLIDE HAZARDS

### *Landslide monitoring and characterization*

**Matt Crawford** is monitoring a landslide in Boyd County, in the northeastern part of the Eastern Kentucky Coal Field. The slide has caused a home to be abandoned and is typical of many slides in eastern Kentucky.

The purpose of this study is to determine the depth, shape, and velocity of the sliding mass, using various tools for a full site character-



Monitoring instrumentation used for data collection at the landslide site. Inclinometer and data logger shown in the foreground and rain gage and water level transducer box shown in background.

ization. Tools include soil test borings, two open standpipe piezometers to measure long-term groundwater levels, and two inclinometer casings to monitor slope movement and development of the probable failure surface. Slotted PVC pipe was also installed to conduct downhole electrical resistivity testing. Soil samples were tested in the laboratory to determine shear strength, density, soil plasticity, and moisture content,

continued on page 18



# KGS: Research, Collaboration, and Education

*Serving as both a State-mandated agency and a research center of the University of Kentucky, KGS provides scientific information on Kentucky's geology and resources and participates in collaborative research with other University departments.*

## Students learn while working

KGS employed 19 students from UK and other Kentucky universities during the fiscal year. The students learned how to gather field data, prepare maps, take samples, and perform other scientific tasks, with KGS geologists serving as mentors. □



UK student Julie Floyd interacts with KGS mapping staff during a field trip.



Student Brittany Shelton helps Jim Currens calibrate instruments at the Cane Run watershed project.



Student Patrick Taylor identifies sinkhole locations for a water resources project.



Geology student Bailee Hodelka listens as Rick Bowersox explains the research at the Carter County deep well.

Morehead State University student Justin Spears (right) takes soil samples as MSU professor Charlie Mason watches.



## Cooperation with UK pharmaceutical research

Rock samples from the Carter County carbon storage research well were taken at 100-foot intervals for analysis by the Center for Pharmaceutical Research and Innovation at

UK's College of Pharmacy. Center Director **Jon Thorson** says that in similar projects a number of novel molecules have been found in unusual environments and developed into useful drugs. The biodiversity of the Appalachian region and the conditions surrounding coal mines and deep wells provide such environments.

The process can involve months of work propagating bacteria found in the samples and identifying those that appear to be producing novel molecules. When those molecules can be produced and isolated, their potential value for pharmaceutical research can be investigated.



Contract mud logger Jeff Balsa arranges rock samples gathered for pharmaceutical research.

Since novel molecules that do not have pharmaceutical usefulness are also found, Thorson and his colleagues are creating a repository of such discoveries to allow other UK researchers to study them for potential uses. □



Madan Kharel of the Center for Pharmaceutical Research and Innovation examines samples in a laboratory.

## Earth Modeling and Visualization Lab

KGS has developed a new visualization laboratory during the fiscal year for earth modeling, in collaboration with two other University of Kentucky departments. The Center for Visualization and Virtual Environments custom-built a 4 × 7 foot, high-resolution touch screen that is the center of the facility. It uses six interlaced LCD projectors to achieve a screen resolution comparable to a desktop monitor and laser technology to simulate the touch capabilities of a tablet. The system was designed to show large amounts of mapping or subsurface data with fidelity comparable to desktop monitors, thus



Staff from the UK Center for Visualization and Virtual Environments assemble the display screen.

increasing the efficiency of data analysis. Scientific progress is sometimes limited by how much data can be visualized and interpreted in a single work session.

Associate Director **Jerry Weisenfluh** had been hoping for a way to computerize the creation of cross sections now done in a time-consuming process using paper strip logs. Computer monitor size had been a limiting factor until he saw a prototype of the large touch screen. UK computer science student **Ashkan Hosseini** is developing a computer application to simulate Weisenfluh's paper cross sections on the screen, so that the logs can be moved vertically for bed correlation, cross sections can be aligned for later retrieval, synthetic cores of the logs can be viewed, and coal-bed correlations can be edited in the computer database. **Caleb Essex**, an undergraduate student in the Department of Earth and Environmental Sciences, is using the new program to do a regional assessment of the Upper Elkhorn No. 1 coal bed in eastern Kentucky. The new application significantly shortens the data-analysis phase, which could have taken a year using the old method, and realizing Weisenfluh's dream of a computer-based cross-section tool.

The lab was also developed to encourage scientific collaboration and provide a unique teaching environment for small groups. **Ed Woolery** of the Department of Earth and Environmental Sciences intends to use seismic processing and analysis software for joint projects with the KGS Geologic Hazards Section. □



UK student Caleb Essex points out details on striplogs from the Upper Elkhorn No. 1 coal bed.

Continued from page 15

properties important for analyzing slope stability. In addition, work will be done to correlate the measured electrical resistivity with variations in material properties. Slope stability will be analyzed, and the results will be compared to failure planes predicted by electrical resistivity testing. Detailed landslide investigations that compare these data sets will increase our knowledge of slides in the study area and bring together valuable information for geologists, engineers, emergency managers, and others to make better decisions about landslides.

This study was funded internally by KGS, and Terracon Inc. provided geotechnical assistance.

**Landslide inventory**

To better document the distribution and context of Kentucky’s landslides, **Matt Crawford** is compiling a landslide inventory database. A comprehensive inventory serves as a foundation for understanding landslide basics; assisting land-use planners, trans-

portation officials, emergency managers, and the public; and creating hazard maps. The database design is based on common attributes collected by other states that have active inventories and landslide hazard programs, as well as attributes necessary to collect what is already known about landslides in Kentucky and future goals for research.

Sources of landslide locations include State government agencies, published maps, KGS field work, LiDAR mapping, and reports from the public. In addition, the database has been used to create a landslide information map that is part of the KGS Geologic Map Information Service.

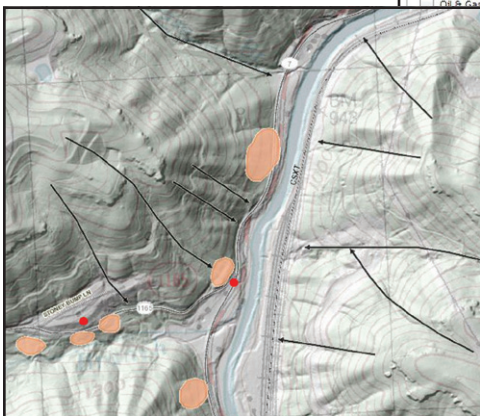
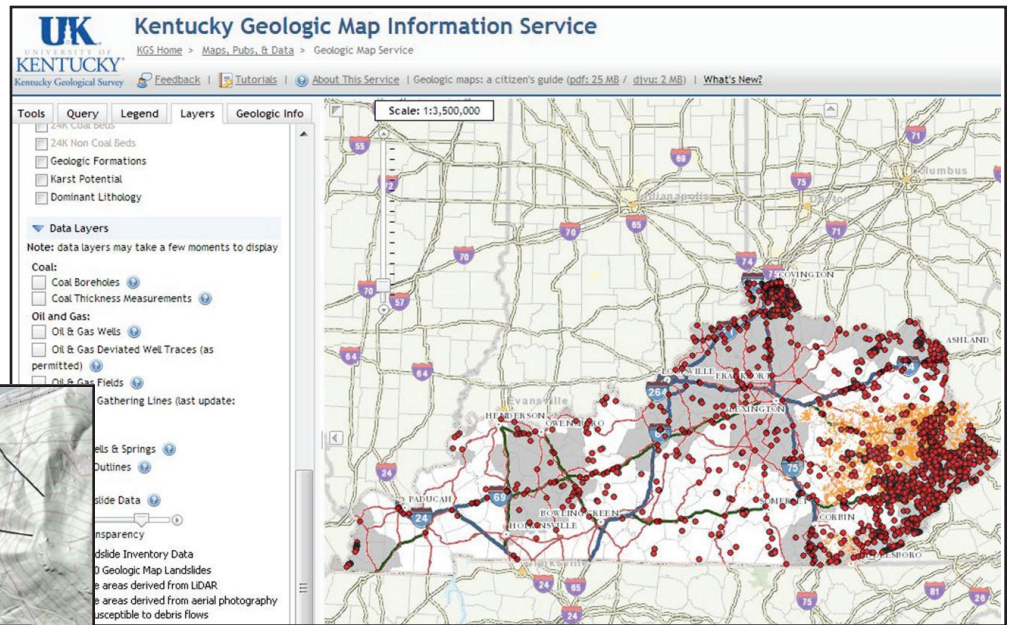
The landslide map shows the locations of known landslides and areas susceptible to landslides in a geologic and geomorphic context. It provides an overall view of landslide hazards across the state. There are several landslide data layers, represented as points, lines, and polygons.

**New pamphlet**

A citizen’s field guide for landslide hazards in Kentucky, Ohio, and Indiana was developed through a joint effort between KGS, the Indiana Geological Survey, and University of Cincinnati geology professors **Paul Potter** and **Barry Maynard**.

To make it readable for the average person, the pamphlet uses understandable language, supplemented with a glossary explaining geologic and engineering terms. Graphics depict and explain the types of landslides, and photos show examples of landslide effects. A list of private organizations and government agencies with more information on the issue and geologic maps or soil data for the region is also provided in the publication, which folds to a pocket-size 4 × 8 inches. When unfolded to full size, it is 28 inches long by 16 inches tall. It was released in the second half of 2013. □

Kentucky Geological Survey landslide information map.



Zoomed-in view of the landslide information map showing a LiDAR hillshade and topography basemap, along with several landslide locations.

# Geologic Mapping

*Mappers continue producing new surficial maps.*



William Andrews conducts a review course for professional geologist exams.

The Geologic Mapping Section continued production of new surficial geology 7.5-minute quadrangle maps for the state with funding from the USGS STATEMAP program. **Scott Wanninger** completed mapping of the Central City East and Central City West quadrangles, **Antonia Hansen** mapped the Burlington quadrangle in northern Kentucky, and **Max Hammond** completed the Ashland and Catlettsburg quadrangle maps.

**Bethany Overfield** continued research on the geologic context of highway maintenance costs. She also collaborated with the UK

College of Nursing's Clean Indoor Air Group on the geologic controls on the occurrence of radon in Kentucky.

**Steve Martin** continued field work to inventory classifications of natural arches in Kentucky and to develop a fracture database. He completed a manuscript on fracture trends adjacent to the Glencairn Fault near the Red River Gorge, now available as a KGS publication.

**Ron Counts**, who worked for the Geologic Mapping Section in the Henderson office, left the Survey during the fiscal year. He had worked with the section's

surficial mapping since the 2003 resumption of field mapping, and he helped develop the Survey's soil-drilling and sampling capabilities.

Section Head **William Andrews** conducted three well-attended review courses to prepare geologists for the Association of State Boards of Geology tests.

The section also received a grant from Jefferson County Emergency Management and the University of Louisville to provide updated geologic maps for a hazard assessment of the Louisville metropolitan area.

Section staff mentored geology students from the University of Kentucky and Morehead State University to help them develop their field mapping techniques. □



Mapping section employee Max Hammond studies a map on a teaching field trip in the Red River Gorge.

**Dan Carey** retired from the Geologic Mapping Section and KGS in 2012 after spending 23 years working in several of the Survey's sections. He became one of the most prolific authors of publications in KGS history. A search of the online publications database turned up 276 publications for which he was the principal author or a co-author. Among them were generalized geologic maps for each of Kentucky's counties, county groundwater publications, and public-interest maps such as the highway geology series. Dan's last assignment in the Geologic Mapping Section was working with **Bethany Overfield** to correlate State highway expenditures with the geologic conditions at maintenance sites.



# Well Sample and Core Library

## *Collection of cores and samples continues to grow.*

The KGS Well Sample and Core Library added to its large collection of materials from exploratory and research drillings throughout Kentucky. The collection is used by students and academic researchers, as well as industries for a variety of investigations into Kentucky's energy resources, groundwater, and environment. More than 100 sets of cores and samples were added to the collection, and 3,300 boxes were examined by visitors to the facility. The visitors included students and professors from the University of Geneva in Switzerland.

Staff at the core library maintain a searchable online database of the collection, and a system was

installed during the fiscal year to photograph cores and well cuttings and add the photographs to the database. More efficient lighting was added to the warehouse area of the library, and larger ceiling fans were installed to provide a more comfortable working environment.

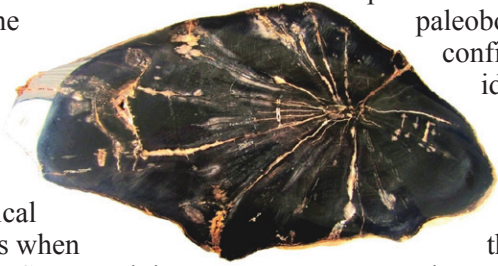
The facility is known for its outstanding collection of rock cores and oil and gas cuttings, but it also contains a number of other special collections that are less well known. One of these collections contains materials sampled for the analysis of limestone aggregate resources in the state. KGS staff have been inventorying the holdings to document the locations of

the samples and to digitize descriptions and analyses related to the quarries, mines, outcrops, and cores. More than 16,000 foot-by-foot chemical analyses from 230 localities have been computerized, and residual materials ranging from powder to whole-rock samples are available for many of the samples. The chemical data provide basic vertical chemical profiles for most aggregate-producing units across Kentucky. The residual samples, once properly cataloged, can be made available to industry and academic researchers for other kinds of analysis. □



# A Devonian *Archaeopteris* Tree in Marion County

When a rare or unique fossil is discovered in Kentucky, it gives geologists and paleontologists an opportunity to learn more about the natural history and origin of the rocks and fossils in the state. The fossilized remains of ancient organisms give information about conditions on earth at the time the organisms, either plant or animal, lived. When discoveries are made, the Kentucky Geological Survey appreciates when citizens contact the Survey, giving our scientists an opportunity to add to our knowledge of the state. While digging on his property in Marion County, **Danny Mudd** encountered what looked to him like a tree in the black shale he was excavating. Mudd contacted KGS for help to identify the find. The digital images from Mudd showed what looked like a petrified tree.



KGS geologists **Patrick Gooding** and **Richard Smath** and **Frank Etensohn**, of the UK Department of Earth and Environmental Sciences investigated the fossil where it was found. It was lying horizontally in the Devonian shale. It measured 20 inches in diameter; about 13 feet of it had been excavated from the bedrock, but more of it remained in place. Initial identification indicated that it was *Archaeopteris* (*Callixylon*), a Middle to late Devonian progymnosperm with fern-like leaves and gymnosperous wood. *Callixylon* is the formal genus name given to the petrified wood of *Archaeopteris*. Pieces of the tree were taken and cut into slabs at the KGS Well Sample and Core Library for closer examination. The polished slabs

revealed internal cell structures of wood, growth rings, quartz crystals, and fragments of woody material. The cell structures are similar to those of modern conifers. The organic black color and minerals, mainly quartz, were absorbed into the cell structure from the sediments as the log underwent petrification. **Cortland Eble**, a paleobotanist at KGS, confirmed the initial identification. Analytical testing on petrified wood samples and surrounding material confirmed that the three most prominent elements, in descending order, were silicon dioxide, aluminum oxide, and iron oxide.

The *Archaeopteris* tree is Middle to Late Devonian age, or about 370 to 390 million years old. The origin of such trees at this location may be explained by a couple of hypotheses. They may have been transported by ocean currents from a forest located to the northeast and came to rest in shallow water on the Cincinnati Arch. The trees eventually became waterlogged, sank, and were embedded in accumulating organic-rich black sediments. Another hypothesis is that they grew near where this specimen was found, but no confirming root casts have been found to date. Follow-up field work in the vicinity and adjacent counties located other occurrences of petrified trees in the Devonian black shales.

The Devonian Period was a time of significant evolutionary development for land plants. Abundant *Archaeopteris*-dominated forests were widespread across the continents. The Smithsonian Museum in Washington, D.C., has a number of outstanding specimens of Devonian petrified logs from Kentucky in its Hall of Evolution Exhibit.



# Western Kentucky Office

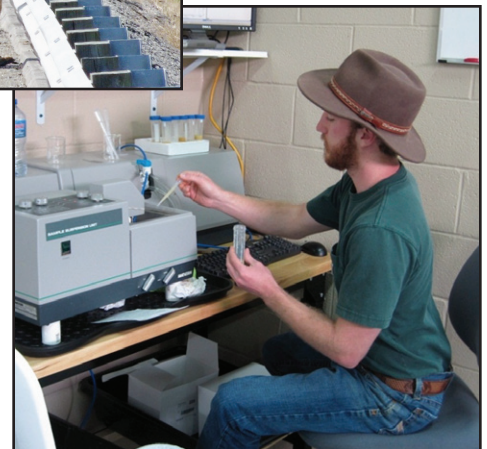
## *Service and Research Across the State*

**K**GS maintains a facility in Henderson with staff from the Geologic Mapping and Water Resources Sections, as well as an office manager. They provide public service for local governments, industries, agricultural interests, and schools while also conducting research in the western part of the state. The office has soil sampling equipment and a sediment laboratory.

Office Manager **Dave Williams** is often asked to speak to community service organizations and schools and to investigate geologic issues and incidents that affect property and buildings, such as soil erosion and sinkholes. Williams's other projects include mapping paleochannels in the Western Kentucky Coal Field and adding information from petroleum tests in western Kentucky to the KGS database. □



Scott Waninger gathered information on a road-fill failure along the Natcher Parkway in Ohio County.



Morehead State University student Justin Spears uses the Malvern particle size analyzer in the Sediment Lab at the Henderson office.



Henderson Office Manager Dave Williams organized a field trip on tar sands for the Energy and Minerals Section along with faculty and students of the Western Kentucky University Department of Geography and Geology. Here he discusses a Big Clifty asphalt seep on the Western Kentucky Parkway.

# KGS Laboratory

*More than 3,000 samples analyzed in the fiscal year*

Research projects at KGS as well as from other departments at the University of Kentucky and State government agencies depend on the KGS laboratory for rock, water, mineral, and other analyses. The laboratory also oversees the scheduling of its X-ray diffraction instrument for students and research staff throughout the University community, used for a variety of projects.

During the fiscal year, the laboratory analyzed 3,056 unique samples: 1,072 water, 1,629 mineral and rock, and 355 coal.

Samples from several KGS water-related projects were analyzed by the laboratory. **Glynn Beck** of the KGS Water Resources Section sent samples from a surface-water monitoring project to determine the levels of the hormone estradiol and the pharmaceutical marker fluoroquinolone. Samples were also analyzed for a water-monitoring project at the Kentucky Horse Park conducted by **Jim**

**Currens** of the Water Resources Section. Samples from the Cumberland Gap Tunnel project and the Kentucky Transportation Department were analyzed by the lab as well. (More information on KGS water research can be found on page 11.)

Samples were analyzed for a KGS Energy and Minerals Section project investigating the total organic carbon content of the Utica Shale. Ongoing projects include water analysis for several deep wells, including the Carter County deep storage research well and brine water from the Knox Formation. (KGS energy research information begins on page 6.)

The laboratory staff continues to conduct analyses on surface-water samples for the KentuckyWater-



Manager Jason Backus explains the work of the KGS laboratory to a group of visiting college students.

shed Watch program, which monitors the quality of the state's waters and wetlands. Samples taken by civil engineering researchers at UK were analyzed to help determine the water quality of the South Elkhorn watershed.

The lab helped the UK Department of Plant and Soil Sciences complete a project investigating the migration of bromine in soils. The lab's X-ray fluorescence spectrometer was used to analyze 700 soil samples for bromine and silica. A participating researcher from Vienna, Austria, spent time at the laboratory analyzing the samples. □

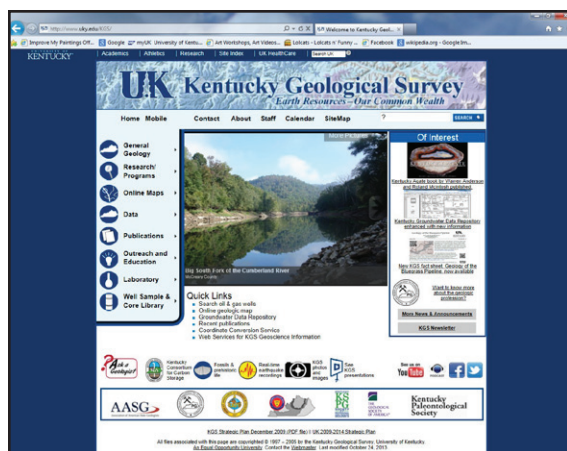


Andreas Schwen, a researcher at the University of Natural Resources and Life Science in Vienna, uses the KGS laboratory to analyze 700 soil samples in a project to map the network of pores in soils and analyze the leaching behavior of tracers injected in soils with different land uses. Schwen worked with UK plant and soil sciences researchers for 3 months in 2013.

# Geologic Information Management

*A large collection of free data is available online.*

The KGS website continues to serve a diverse audience, receiving a very large number of visits during the fiscal year. Nearly 415,000 database searches were conducted by 124,000 users. That was an increase of 7 percent from the previous year—mostly from searches for oil and gas data, which were up about 10 percent over the previous year. There was a significant increase in mobile and tablet users over the last year—up about 165 percent.



KGS online map services were accessed more than 100,000 times, with more than 13,000 tabular data downloads. The total number of files downloaded exceeded 2 million. As in the past, users most frequently downloaded oil and gas records, online publications, coordinate conversion services, and data from the online geologic map server.

Updates to the web services mostly were service improvements and layer additions to the existing Geologic Map Information Service. Printing capabilities for the map services were improved. The ability to map database search results to the Geologic Map

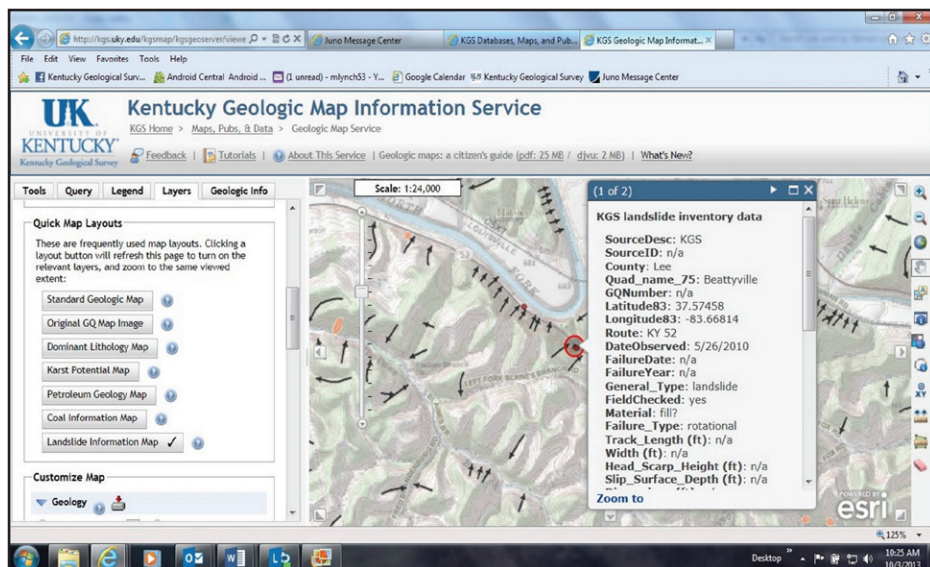
Information Service was added. Searching parameters were added to the oil and gas and water well database search applications, and metadata for GIS services were improved. Layers added to the Geologic Map Information Service include KGS landslide inventory data, LiDAR, and improved information on horizontally drilled oil and gas wells.

Staff in the Geoscience Information Management Section also:

- Reviewed the locations for oil and gas well permits (about 85 wells a month) and maintained the database of permits and well location data.
- Maintained the Kentucky hub for the grant-supported Association of American State Geologists National Geothermal Data System, which includes providing GIS services for 13 state geological surveys in the southeastern United States.
- Prepared KGS geothermal data and sent it to the National Geo-

thermal Data System. Most Kentucky data consists of various types of well location information, oil and gas top-of-formation data, borehole temperatures, and geologic map data. The data will be made available through public web-accessible services in the AASG National Geothermal Data System.

- Prepared and scanned more than 60 years of legacy geologic field notes from the limestone exploration program for the National Data Preservation project. This project catalogs, scans, and makes accessible notes collected since 1949 from 234 field sites, including measured sections, diagrams, photographs, unit descriptions, and physical rock samples and their analyses.
- Started maintaining and updating a KGS YouTube channel, which includes instructional videos about KGS website usage and various videos from KGS field work. □



The Kentucky Geologic Map Information Service page as viewed on the KGS website.



# KGS Publications 2012-13



Most of the 59 new publications from KGS that became available during the fiscal year were contract reports. The Survey emphasized the release of these publications because of their usefulness to the public. The Contract Report series includes final reports from projects supported by contracts and grants and the geologic maps produced with funding from the USGS STATEMAP program. The topics of the contract reports reflect the diversity of KGS research. They include metallurgical coal in the Eastern Kentucky Coal Field, protection of domestic well water from contamination, and evaluation of carbon dioxide injection in the Hancock County deep saline test well.

Four new Information Circulars, three new Map and Chart publications, and one Special Publication were also issued.

Among the new Map and Chart publications were several with beneficial information on geologic resources and waste-disposal wells. One of them, "Limestone and Dolomite Resources of Kentucky," by **Garland Dever** and **Jerry Weisenfluh** (Map and Chart 203, series 12, 2013), depicts the geologic formations containing commercial limestone and dolomite deposits, as well as locations of active and abandoned quarry operations. The 33 x 55 inch map shows the distribution of the 13 rock units from which limestone and dolomite have been commercially produced in Kentucky.

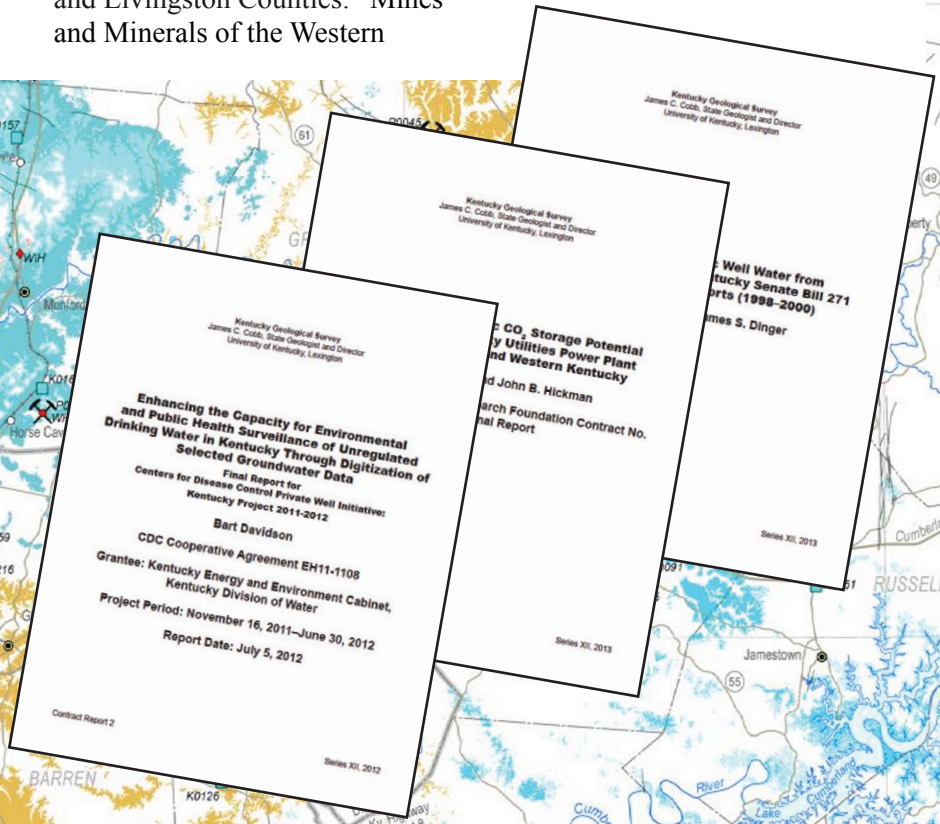
A new fluorspar resource map of western Kentucky shows locations of the known mines, mineral prospects, and igneous intrusions in Caldwell, Crittenden, and Livingston Counties. "Mines and Minerals of the Western

Kentucky Fluorspar District," by **Warren Anderson** and **Tom Sparks** (Map and Chart 201, series 12, 2012), was compiled from multiple maps and files to create an up-to-date, comprehensive catalog for the district. It is available for free download from the KGS website or for purchase in paper form.

Another map available for downloading provides locations and information on disposal wells for industrial wastewater, hazardous chemicals, and brines. "Class I Waste-Disposal Wells and Class II Brine-Injection Wells in Kentucky," by **Tom Sparks**, **Dave Harris**, and **Rick Bowersox** (Map and Chart 204, series 12, 2013), may be helpful to oil and gas producers and others interested in the safe underground injection of wastes in the state. □



The Contract Report publication series helps make useful research publicly available.



# Public Outreach

## *Seminars, training sessions, and earth science education*

*Seminars for professional and student geologists, combined with events tailored for the general public, help KGS reach hundreds of people each year, supplemented by a wealth of information on our web services used by thousands of others.*

### **KGS ANNUAL SEMINAR**

The 2013 KGS annual seminar was held on May 17 with the theme “Emerging Geoscience Issues Impacting the KGS Mission.” Speakers told the 120 participants about current issues in energy and water resources, geologic mapping, environmental science, industrial minerals, and geologic hazards. This event is the largest gathering of geologists in Kentucky each year.

### **PALYNOLOGICAL SOCIETY MEETING**

Sixty-five people from 10 countries attended the 45th Palynological Society meeting, held on the UK

campus in July 2012. **Cortland Eble** of the KGS Energy and Minerals Section and Jennifer O’Keefe of Morehead State University hosted the event. The palynologists, who study pollen, spores, and other microscopic organic particles in rocks, held their general sessions at the W.T. Young Library and took field trips to visit outcrops in the region.

### **GEOLOGIST CERTIFICATION**

Geologic Mapping Section Head **William Andrews** led three day-long review courses offered free of charge for geologists interested in taking exams for professional geologist certification. The course content was developed by KGS and professional geologist societies to provide information of interest to geologists.

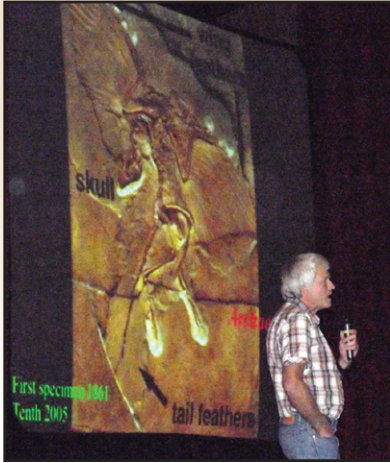
### **AAPG DISTINGUISHED LECTURE**

In March 2013, AAPG Distinguished Lecturer **Marek Kacwicz**, of Chevron Energy Technology Co. in Houston, lectured at KGS. His topic was “Carbonates: A Challenge for Basin Modelers.”



KGS Annual Seminar





### DARWIN LECTURE SERIES

A free educational talk, “Feathered Dinosaurs and the Origin of Birds,” was offered to the public in February on the UK campus as part of the Darwin Lecture Series, sponsored by KGS and other organizations and departments. The talk was given by Dr. **Philip Currie** of the Department of Biological Sciences at the University of Alberta, Canada.



### OTHER MEETINGS

The Well Sample and Core Library has meeting space available for professional and academic gatherings. It hosted 22 meetings, short courses, and workshops during the fiscal year, attracting 552 participants.

### OPEN HOUSE

In October 2012, more than 220 students, teachers, and parents from the Lexington area attended the Earth Science Week open house. A variety of earth science displays and demonstrations were set up by KGS geologists, as well as faculty and students at UK’s Department of Earth and Environmental Sciences and the Department of Mining Engineering. Other groups, including the Kentucky Paleontological Society and the Kentucky Water Resources Research Institute, had exhibits at the event. Individuals displayed collections of fossils, agate, and amber and answered questions about their collections. □



*Learning and fun at the open house*

# Research Projects, Fiscal Year 2012-13

## COMMUNICATIONS OUTREACH

### Communications Specialist Liaison for the Kentucky Board of Registration for Professional Geologists

FY funding: \$7,700  
End date: 6/30/2013  
Funding source: Kentucky Board of Registration for Professional Geologists

## ENERGY

### Carbon Management

#### An Evaluation of the Carbon Sequestration Potential of Cambro-Ordovician Knox Strata

End date: 9/30/2013  
Funding source: U.S. Department of Energy through Illinois State Geological Survey

#### CO<sub>2</sub> Sequestration and Enhanced Oil and Gas Recovery Using CO<sub>2</sub>

End date: 6/30/2014  
Funding source: Governor's Office of Energy Policy

#### Stimulation Framework for Regional Carbon Storage Infrastructure Along the Arches Province of the Midwest United States

FY funding: \$50,000  
End date: 9/30/2012  
Funding source: U.S. Department of Energy through Battelle Memorial Institute

### Oil and Gas Resources

#### Development of Subsurface Brine Disposal Framework in the Northern Appalachian Basin

FY funding: \$25,138  
End date: 3/31/2015  
Funding source: U.S. Department of Energy through Battelle Memorial Institute

#### Utica Shale Appalachian Basin Exploration Consortium

FY funding: \$87,803  
End date: 3/31/2014  
Funding source: West Virginia University

## GEOLOGIC INFORMATION

### Coal Information

#### An Internet Map Application for Kentucky Coal Resource Information

FY funding: \$39,300  
End date: 6/30/2013  
Funding source: Kentucky Department for Energy Development and Independence

#### Computerized Coal Resources for the National Coal Resources Data System

FY funding: \$15,000  
End date: 6/30/2015  
Funding source: U.S. Geological Survey

### Data Dissemination

#### Data and Web Support for Kentucky Water Watch

FY funding: \$15,000  
End date: 6/30/2013  
Funding source: Kentucky Natural Resources and Environmental Protection Cabinet through Kentucky Water Resources Research Institute

#### National Geologic and Geophysical Data Preservation Program

FY funding: \$25,000  
End date: 8/31/2013  
Funding source: U.S. Geological Survey

#### National Geothermal Data System Program

End date: 8/28/2013  
Funding source: U.S. Department of Energy through Arizona Geological Survey

## GEOLOGY

### Geologic Mapping

#### Engineering Geologic Maps for Jefferson County Emergency Planning

FY funding: \$11,328  
End date: 12/31/2013  
Funding source: Federal Emergency Management Agency through University of Louisville

### Quaternary and Surficial Geologic Mapping for Multiple Applications in Kentucky

FY funding: \$203,069  
End date: 6/30/2013  
Funding source: U.S. Geological Survey

## HAZARDS

### Seismic Monitoring

#### Installation of the Central U.S. Seismic Observatory

End date: 9/30/2013  
Funding source: U.S. Department of Energy through Center for Applied Energy Research, University of Kentucky

## WATER RESOURCES

### Groundwater Information

#### Feasibility Study for Compiling a National Groundwater Quality Database

FY funding: \$50,250  
End date: 9/29/2013  
Funding source: Centers for Disease Control through Kentucky Division of Water

#### Groundwater Velocity and Discharge at the Kentucky Horse Park Groundwater Station

End date: 2/28/2013  
Funding source: U.S. Geological Survey through Kentucky Water Resources Research Institute

### Groundwater Monitoring

#### Groundwater Modeling at the Paducah Gaseous Diffusion Plant

FY funding: \$6,000  
End date: 9/30/2013  
Funding source: U.S. Department of Energy through Center for Applied Energy Research, University of Kentucky

### Water Quality and Human Health

#### Sampling for Pharmaceuticals in Kentucky Surface Waters

End date: 2/28/2013  
Funding Source: U.S. Geological Survey through Kentucky Water Resources Research Institute

# Staff Awards, Recognitions, Committee Assignments



**William Andrews** received the Kentucky American Institute of Professional Geologist's Geologist of the Year Award, as well as a UK Faculty Partner Award. He also served on the Kentucky Geographic Information Advisory Committee.



**Steve Greb and Rebecca Wang** are co-webmasters for the Coal Division of the Geological Society of America. Greb also serves on the Professional Development Committee for GSA.



**Matt Crawford** is a board member of the Appalachian Coalition for Geologic Hazards in Transportation, as well as a board member at-large for the Geological Society of America Environmental and Engineering Geology Division.



**Bethany Overfield** is a member of the board of directors of Kentucky River Watershed Watch.



**Steve Mock**, a member of the UK Staff Senate, served on the Institutional Finances and Resource Allocation Committee.



**Ray Daniel** is an elected councilor at Large for the Kentucky Society of Professional Geologists.



**Jim Drahovzal**, retired head of the Energy and Minerals Section, received the Eastern Section of AAPG's John T. Galey Memorial Award. The award recognizes outstanding accomplishments and contributions to the geologic profession.



**Patrick Gooding** was secretary/treasurer of KSPG and a KSPG delegate to the AAPG. He served on four AAPG committees, including the Preservation of Geoscience Data and the Public Outreach Committees.



**Bart Davidson** completed the term of retired Water Resources Section Head Jim Dinger on the Kentucky Water Well Drillers Certification Board and was appointed to a full four-year term.



**Rick Bowersox** was recognized by the American Association of Petroleum Geologists in March for 40 years of membership in the society.



**Meg Smath** served as past-president of the Association of Earth Science Editors for 2013.



**Dave Harris** was a member of the American Association of Petroleum Geologists Advisory Council, and also the Eastern Section AAPG Honors and Awards Committee.



**Jerry Weisenfluh** is the associate member's representative to the Association of American State Geologists' Executive Committee.



**Chuck Taylor** serves as a member on the Kentucky Agriculture Water Quality Authority, which promotes soil and water conservation to protect waters from adverse agricultural impacts.

# KGS Staff 2012-13

## State Geologist's Office

### Cobb, Jim

State Geologist/Director

Weisenfluh, Jerry

Associate Director

Haney, Don

State Geologist Emeritus

## Administrative Section

### Ellis, Kati

Administration Staff  
Officer II

Long, Mandy

Administration Support  
Associate I

Phillips, Gwen

Staff Support Associate II

## Energy and Minerals Section

### Harris, Dave

Section Head

Anderson, Warren

Geologist V

Bandy, Ralph

Student Worker

Bowersox, Rick

Geologist IV

Eble, Cortland

Geologist V

Greb, Steve

Geologist V

Grider, Jerrad

Student Worker

Hickman, John

Geologist IV

Nuttall, Brandon

Geologist V

Parris, Marty

Geologist V

Sparks, Tom

Geologist III

## Geologic Hazards Section

### Wang, Zhenming

Section Head

Brengman, Clayton

Student Worker

Carpenter, Seth

Geologist IV

Crawford, Matt

Geologist III

Holcomb, Andrew

Student Worker

Hu, Caibo

Temporary Technician

Li, Qian

Temporary Technician

Lan, Jingyan

Temporary Technician

Song, Jindong

Temporary Technician

Woolery, Ed

Geophysics Faculty  
Associate

Xie, Zhuojuan

Temporary Technician

Zhang, Lifang

Temporary Technician

## Geoscience Information Management Section

### Curl, Doug

Section Head

Adams, Elizabeth

Senior Geologic Technician

Conover, Suzanne

Student Worker

Ellis, Mike

Computer Support  
Specialist II

Hodelka, Bailee

Student Worker

Hosseini, Ashkan

Student Worker

Pulliam, Carrie

Geologist II

Smath, Richard

Geologist III

Spaulding, Dan

Student Worker

Thompson, Mark

Information Technology  
Manager I

Ulanday, Joe

Temporary Technician

Wang, Rebecca

Information Support  
Specialist

Whalen, Patrick

Student Worker

Wolfe, Phillip

Student Worker

## Communications and Outreach

### Weisenfluh, Jerry

Section Head/  
Associate Director

Banks, Roger

Stores Supervisor

Bratcher, Jordan

Student Worker

Essex, Caleb

Student Worker

Fedorchuk, Nick

Temporary Technician

Hounshell, Terry

Chief Cartographic Illustrator

Lynch, Mike

Technology Transfer Officer

Hower, Judy

Temporary Technician

Rulo, Collie

Senior Graphic Design  
Technician

Rufft, Kelsey

Temporary Technician

Smath, Meg

Geologic Editor

## Geologic Mapping Section

### Andrews, William

Section Head

Carey, Dan

Geologist V

Floyd, Julie

Student Worker

Hammond, Max

Geologist I

Hansen, Antonia

Geologist I

Holcomb, Andrew

Student Worker

Martin, Steve

Geologist III

Overfield, Bethany

Geologist III

Priddy, Michael

Student Worker

## Laboratory Services

### Backus, Jason

Scientist II/Laboratory  
Manager

Conner, Andrea

Scientist I

Francis, Henry

Temporary Technician

Mock, Steve

Scientist I

## Water Resources Section

### Taylor, Chuck

Section Head

### Davidson, Bart

Acting Section Head,  
until January 2013

Currens, Jim

Geologist V

Farwell, Mike

Student Worker

Shelton, Brittany

Student Worker

Taylor, Patrick

Student Worker

Webb, Steve

Geologist II

Zhu, Junfeng

Geologist V

## Well Sample and Core Library

### Gooding, Patrick

Geologist IV/Manager

Daniel, Ray

Principal Research  
Analyst

Pinkston, Ryan

Research Analyst

## Western Kentucky Office at Henderson

### Williams, Dave

Office Manager

Beck, Glynn

Geologist IV (Water  
Resources Section)

Bleichroth, Amy

Temporary Technician

Counts, Ron

Geologist III (Geologic  
Mapping Section)

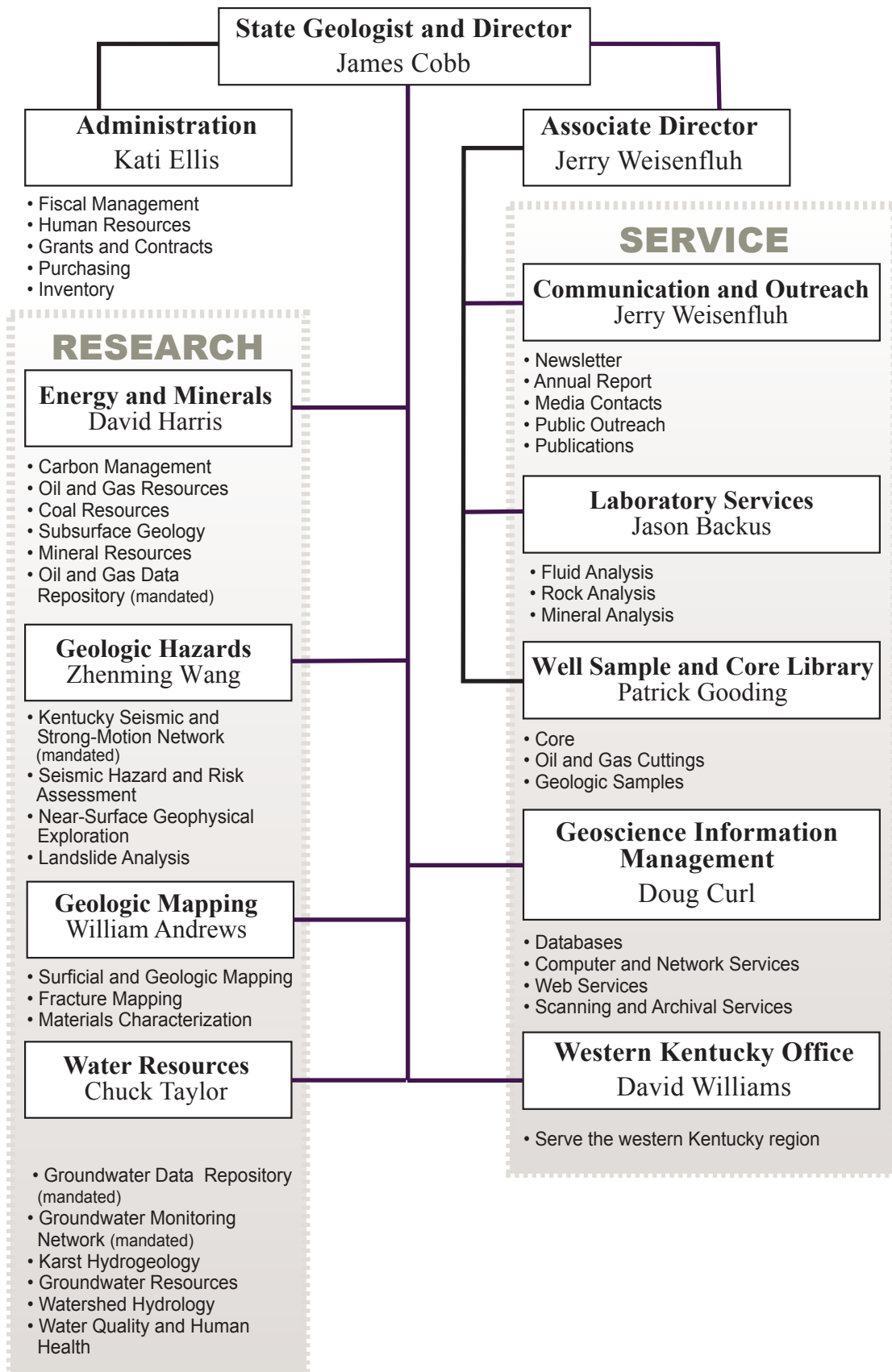
DeJaco, Robert

Student Worker

Waninger, Scott

Geologist I (Geologic  
Mapping Section)

# KGS Organizational Chart



# Feedback

## *What they're saying about us...*




---

Every time I work in another state it just makes me appreciate the KGS even more. Why can't every state geological survey be as proactive as you guys... Thanks for all you do.

Tommy Cate ,  
President Fireborn Energy, Somerset, Ky.  
geologic and energy consultants




---

"... I know I am speaking on behalf of all of us here at Summit Engineering Inc. in thanking you again for the very informative presentation you gave us... The vast and varied amount of data on the Kentucky Geological Survey website helps every one of our divisions during the planning or operational stages of our projects.

"The ability to search and display such a wide variety of critical data on high-quality maps with customization options is absolutely incredible. This technology helps us maximize project efficiency while at the same time providing the accurate, high quality information that is essential to every discipline of the consulting geology/engineering industry ....

"Keep up the great work, we out here in the consulting industry really appreciate your efforts and the quality of products you have made available online to use."

A. Bruce Rogers, P.G., chief geologist for Summit Engineering  
from a letter to Bart Davidson (KGS Water Resources Section)




---

I wanted to send a quick note and say Thank You for the panel discussion at our eastern Kentucky meeting. There is no doubt that it was a huge draw for one of our best meetings in years. I appreciate all of your help and support of KOGA and look forward to continuing to work together going forward.

Thanks so much...  
Andrew V. McNeill  
Kentucky Oil & Gas Association




---

Dear Mike (Mike Lynch, Technology Transfer Officer),

My husband & I volunteer at our Elementary School K-3 to teach beginning science classes. We found your site excellent for our new class this month as we wanted to discuss in detail how coal is formed and the properties of it. Therefore we wish to thank you for the use of your diagrams to make it easier for the students to understand the forming of coal process. Each student voluntarily gives up their play time with classmates to take our classes with only 10 students per class so we can answer questions of each of them.

Again thank you and Stephen Greb (Energy and Minerals Section) for your work to help all students around the USA & other countries.

Best regards,  
Karen & Gary Duggins  
Steilacoom, Washington



## OUR MISSION

is to increase knowledge  
and understanding of the mineral,  
energy, water resources, geologic hazards,  
and geology of Kentucky for the benefit  
of the commonwealth and nation.

## COVER PHOTO

by Steve Greb, KGS

A creek flowing over moss-covered, Upper Ordovician  
limestone ledges at Raven Run Nature Sanctuary, Fayette  
County. Near right-angle ledges in the bedrock are  
controlled by fracture orientations.



228 Mining and Mineral Resources Building  
University of Kentucky  
Lexington, KY 40506-0107  
[www.uky.edu/KGS](http://www.uky.edu/KGS)

Editor: Mike Lynch  
Copy Editing: Meg Smath  
Design and Layout: Collie Rulo