Kentucky Geological Survey Annual Report 2014-15

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

Brandon Nuttall

KGS Energy and Minerals Section

Anglin Falls is located in the John B. Stephenson Memorial Forest State Nature Preserve in Rockcastle County. The approximately 75-foot-high falls on a tributary to Anglin Fork of Clear Creek exposes the Pennsylvanian Lee-type deltaic sands of the Grundy Formation at the top through the mixed carbonates and shales of the Upper Mississippian Renfro Member of the Borden Formation at the bottom. Anglin Falls is a short hike and a wonderful location for spring wildflowers including several varieties of trillium and wild ginger.

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Letter from the Director

Since the last KGS annual report was published, I have been serving as interim director while the search for the director and state geologist of the 13th Survey has been under way. That process has taken a full year, including two periods of open searches and interviews with the top candidates late this summer. At this writing, the search process continues and we will inform the public as soon as it is successfully concluded.

As I reflect on the accomplishments and events of the past year, one thing that stands out is Kentucky's stake in the energy revolution that has swept the nation in recent years. Exciting new petroleum plays are developing in the state. The unconventional Berea development in northeastern Kentucky is maturing at the same time the new Rogersville Shale play is in early testing. Updates on these and other energy-related research projects will follow in these pages. I'm especially proud that research conducted at KGS has been an important contributing factor in stimulating interest in these prospects. This is just one example of how KGS benefits the commonwealth by facilitating economic development.

Another central theme to the year's activities has been scientific monitoring. KGS is developing new monitoring networks for a variety of purposes. The Kentucky Seismic and Strong-Motion Network is being significantly expanded to include an induced-seismic array in the vicinity of expanding petroleum development in eastern Kentucky. The possibility of increased use of horizontal drilling, coupled with hydraulic fracturing, has led to concerns about induced earthquakes. Our new network is being installed before this activity ramps up in order to better understand existing low-level seismicity in the region. We're not expecting significant increases in earthquake activity related to oil and gas development, but should it happen, we're

prepared to assess it. At the same time, a new water observation network is under development. Existing and new wells are being instrumented to monitor fluctuations in groundwater levels and to conduct periodic water-quality testing. Finally, sites are being selected to monitor movement and groundwater conditions at active landslides to better understand the processes involved in these common natural hazards.

KGS is also expanding its research activities in the field of public health. We have been working with the UK College of Nursing to develop a better understanding of radon gas production across the state in the context of geologic units. Geology is so often an important factor in the production and pathways for environmental hazards, and health researchers are beginning to recognize the value of our input for their analysis.

KGS staff are also mastering new technologies for geologic research, including LiDAR data and handheld device applications, to speed and enhance field work in sinkhole identification, surficial mapping, landslide detection, and other research areas.

This report highlights people, activities, and projects that exemplify our year-in and year-out contributions to the commonwealth. From data collection and stewardship, to monitoring, assessment, and discovery, these stories document the continuing legacy of the Kentucky Geological Survey.

Gerald A. Weisenfluh
Interim Director

Water Resources

...the commonwealth's principal source of unbiased water data and analysis

The Water Resources Section's mission is to collect and disseminate information vital to the proper use, management, and protection of the commonwealth's groundwater and surface-water resources. As a nonregulatory water-monitoring and research unit, the Water Resources Section is the commonwealth's principal source of unbiased water data and analysis. The section is charged by legislative mandates to manage the state's official repository for groundwater information (KRS 151.035) and to oversee establishment of a long-term groundwater monitoring network (KRS 151.625). In 2014-15, the section was active in conducting research needed to better characterize Kentucky's groundwater and surface-water resources, documenting and assessing sinkhole and karst-related hazards, and providing scientific information and technical assistance on a variety of water and related environmental issues to State, federal, and local agencies, other UK and university researchers, geoscientists and engineers working in the public and private sectors, and the general public.

Groundwater Availability and Water Quality

Hydrogeologist **Glynn Beck,** in collaboration with **Ed Woolery** and student **Marie Cooper** of the University of Kentucky Department of Earth and Environmental Sciences, began a project to collect data needed to better delineate aquifer zones and confining units in parts of the Jackson Purchase Region. Groundwater withdrawals are increasing in this part of Kentucky, largely because of increased agricultural irrigation. Beck has inventoried numerous water-supply and irrigation wells in the area, obtained gamma-ray logs of selected wells, and has also collaborated with Woolery and Water Resources hydrogeologist **Junfeng Zhu** to use seismic-reflection and electrical-resistivity surveying methods to map the Middle Claiborne confining unit. Data collected by this collaborative effort are being used to create more accurate and detailed hydrostratigraphic cross sections of the Jackson Purchase aquifer system, help identify water wells completed in the Upper Claiborne and Middle Claiborne aquifers, and guide plans for additional groundwater monitoring and research needed in the Jackson Purchase.

The section also began a project in collaboration with the Kentucky Department of Military Affairs/Kentucky Army National Guard to conduct a surface-water-quality assessment for Training Areas 7 and 8 at the Wendell H. Ford Regional Training Center in Muhlenberg County. Hydrogeologists **Steve Webb, Glynn Beck,** and **Bart Davidson** are collecting wet- and dry-season water-quality samples from

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Junfeng Zhu collects GPS location coordinates during an inspection of a water-supply well in Elizabethtown.

approximately 98 sites at streams and ponds at the training center. The project will provide resource managers with baseline data needed to assess the existing quality of the surface-water resources at the training center, and help identify areas where management practices or remedial actions can be implemented or improved to minimize degradation and ensure good environmental stewardship of the center's land and water resources.

Hydrogeologist **Junfeng Zhu** continued work on a project that provides technical assistance to the Kentucky Research Consortium for Energy and the Environment, using groundwater-flow and contaminant-transport modeling to simulate and test the potential outcomes of different groundwater remedial actions being used at the Paducah Gaseous Diffusion Plant. The outcomes of Zhu's modeling will allow the U.S. Department of Energy and other federal and State resource managers, as well as private environmental contractors, to evaluate and improve actions being considered and implemented to remediate a variety of radioactive and nonradioactive groundwater contaminants present at the site.

Section Head **Chuck Taylor** and hydrogeologist **Glynn Beck** co-authored the groundwater monitoring section included in the Kentucky Agricultural Science Monitoring Committee's 2014 draft work plan, a document that provides an overview of present and planned water-quality and -quantity monitoring activities and a strategy for improved interagency collaboration to address scientific and environmental data needs for the state's various agricultural entities and interests. In addition, Taylor gave a presentation to and has participated in meetings hosted by the Kentucky Farm Bureau's Water Management Working Group, a 20-member task force assembled by Kentucky Farm Bureau to develop recommendations that will enhance the quality and quantity of water resources accessible for agricultural production in the state. The task force's mission is to research the emerging critical issue of inadequate water supplies available for agricultural production, examine potential actions to solve this deficiency, and make recommendations for bringing new and reliable water sources to key areas of farm production in Kentucky.

Initiation of a New Statewide Groundwater Observation Network

This year the Water Resources Section began work to create a new long-term observation well network needed to better fulfill KGS's legislative mandate to collect data to assess the quantity and availability of the state's groundwater resources. Data collected by the planned network will help predict the occurrence and severity of droughts, and evaluate the potential impacts of drought conditions on groundwater and surface-water resources throughout Kentucky.

Groundwater samples will also

Steve Webb and Chuck Taylor check the operation of telemetry equipment they installed in a groundwater observation well at the Kentucky Horse Park. It was the first of 14 wells planned for the new groundwater network.

be routinely collected from the network wells to help provide baseline data needed to better characterize natural variations in groundwater quality and help identify, assess, and track possible effects of nearby human activities related to energy production, agricultural activities, or urban development.

Plans call for continuous observation stations at a minimum of 14 existing or newly drilled well sites over the 2015-16 fiscal year. Each of the wells will be selected to monitor naturally occurring changes in groundwater levels and groundwater quality that are representative of the major aquifer present in particular areas of the state.

All network wells will be equipped with pressure transducers and data loggers capable of continuously recording changes in groundwater levels at 15- to 30-minute increments. Approximately seven of the wells will also be equipped with telemetry that will automatically transmit recorded groundwater-level data to the Survey each day, enabling more rapid tracking and evaluation of current groundwater conditions. All groundwater data collected from the network's wells will eventually be posted to the Kentucky Groundwater Data Repository website and available for the public's use.

Chuck Taylor, Glynn Beck, Steve Webb, and **Bart Davidson** have begun making field visits to inspect and test a number of currently unused water wells in various parts of the state for inclusion in the network. At the time of this report's publication, one observation station with telemetry has been established in the Inner Bluegrass karst aquifer system at an existing KGS-owned well at the Kentucky Horse Park, and another observation station has been established in the central Kentucky karst at an existing well located at Mammoth Cave National Park.

Chuck Taylor uses borehole video-logging equipment to inspect a well at Mammoth Cave National Park prior to adding it to the new statewide groundwater observation network.

Glynn Beck prepares to remove a turbine pump collar prior to conducting a borehole video inspection of an irrigation well at the Murray State University Agricultural Farm in Murray.

In some parts of the state, suitable existing wells are not available for monitoring, so KSG has planned to drill up to five new monitoring wells in 2015-16 in areas of critical need. For example, KGS has signed a memorandum of agreement with Murray State University to enable drilling of up to three observation wells at the university's West Farm Complex, each monitoring a different aquifer zone. When completed in early fall of 2015, this observation well cluster will provide important information on groundwater levels in the major aquifer zones in the Mississippi Embayment aquifer system, which is heavily used for agricultural and public water withdrawals in this part of the state.

Public interest in and concerns about the potential hazards associated with karst and sinkholes remained high in 2014-15. Because of the increased awareness by the public of what karst is and how it can affect buildings and infrastructure, Water Resources staff members **Jim Currens, Chuck Taylor**, and **Junfeng Zhu** have responded to many requests for information from concerned homeowners and others who reported sinkholes and requested help assessing the potential hazards and remedies. KGS received more than 100 cover-collapse reports or inquiries during the year. About 50 percent of these sites were visited by section staff. In many cases, a report was

first submitted by the property owner through the KGS online sinkhole reporting form (www.uky.edu/KGS/water/general/karst/cover_collapse.htm). Since 1997, the section has systematically collected information about the occurrence of cover-collapse sinkholes in Kentucky. **Jim Currens** conducts the majority of sinkhole field inspections, and manages and updates the sinkhole inventory database, which includes information about their locations, topographic and geologic settings, and physical characteristics. Some of the sinkhole occurrence data compiled in the inventory predates 1997. In 2012, the inventory contained 257 individual sinkhole records, and between 2012 and 2015, the number of cover-collapse reports increased by 41 percent with the addition of data from 107 sinkholes. A preliminary analysis of these data is presently under way and should provide useful information about sinkholes in Kentucky. For example, the sinkhole inventory data indicate that the frequency of cover-collapse sinkhole occurrence is greatest from April to June, and is triggered by spring storms. Further analysis of the most current inventory data is under way, and a KGS Report of Investigations is anticipated to be published in early 2016 to present the findings. In 2015 Currens also assisted UK Department of Earth and Environmental Sciences

KGS karst hydrogeologist Jim Currens and Earth and Environmental Sciences students Bill Pierskalla and Adam Nolte inspect a cover-collapse sinkhole near Midway.

student **Matthew Cecil** on a project to conduct a preliminary GIS analysis of sinkhole occurrence in Kentucky. By combining data obtained from the sinkhole inventory database, the state's karst potential area map, and population data from state census tracts, they determined that approximately 9,343,494 acres. (36 percent) of the total area of Kentucky is underlain by well-developed karst, characterized by an abundance of sinkholes, and that 67 percent of Kentucky's population lives in sinkhole-prone karst areas. The population density for the karst areas is 0.31 persons per acre, whereas the density in the nonkarst areas is 0.09 persons per acre.

Karst and Sinkhole Research

Water Resources hydrogeologist **Junfeng Zhu** continued his research into using LiDAR data and new terrain-processing methods he developed during the previous year to improve sinkhole identification and mapping in Kentucky, particularly in urbanized and suburbanized areas. Zhu and UK Department of Earth and Environmental Sciences students **Bill Pierskalla** and **Adam Nolte** applied the new data-processing methods to map sinkholes in surface watersheds in Bullitt, Jefferson, and Oldham Counties. Results obtained thus far demonstrate that the number of probable sinkholes identified from LiDAR mapping is approximately four times greater than the number identifiable using contoured depressions visible on topographic maps.

The work for Bullitt County is almost done. In that county, 822 sinkholes have been identified from LiDAR. Random field checks of 25 LiDAR-identified features found that 24 of them were true karst sinkholes. This research is ongoing, and the objectives are to refine the method and extend the mapping area to other sinkhole areas of the Bluegrass Region.

Other karst research being conducted by KGS is focused on characterizing karst hydrogeologic flow systems and water quality. **Jim Currens** continued his research funded by the UK College of Agriculture, Food

and Environment on the Royal Spring–Cane Run karst basin hydrology project.

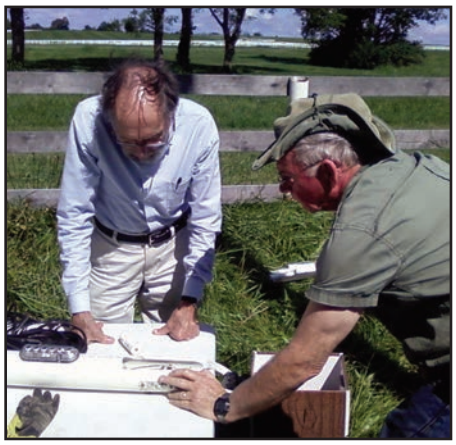
This year's effort included collaborative field studies conducted by Currens and other Water Resources staff members, **Dr. James Fox** and Ph.D. student **Admin Husic** of the UK College of Civil Engineering, and **Dr. Alan Fryar** and student **Ashley Bandy** of the UK Department of Earth and Environmental Sciences. Various field, computer modeling, and statistical methods were applied to evaluate the complex hydrologic mechanisms involved in nutrient transport and fate in both the groundwater and surface-water components of the basin.

Currens leads the efforts directed at gathering data needed to measure the discharge of groundwater and potential contaminants such as nitrate, phosphorus, fecal bacteria, and suspended sediments in the karst aquifer beneath the Cane Run surface drainage basin in Fayette and Scott Counties. He has collected and analyzed data obtained using quantitative dye-tracing tests, Doppler sonar, borehole flowmeter, and continuous water-quality monitoring at a field monitoring station at the Kentucky Horse Park.

Continuous high-resolution data have been collected from wells drilled directly into the Royal Spring karst conduit—the major cave stream passage that underlies and drains part of the approximately 15,000 acres of the Cane Run Basin—in order to quantify and track changes in the discharge of subsurface water and contaminant concentrations through the conduit.

The data and findings obtained by this project are helping the UK College of Agriculture, Food and Environment and the Lexington-Fayette Urban County government design and implement best management practices to improve stormwater disposal and water quality in the Cane Run Basin, a tributary of North Elkhorn Creek. Data from 2011 to 2014, including periodic and event-related data, are presently under evaluation, and will be discussed in a KGS Report of Investigations in mid to late 2015.

Anticipated future KGS studies will focus on the relationships between various water-quality parameters (for example, total suspended sediments and nutrients) and the dynamics of groundwater and surface water mixing in the Cane Run–Royal Spring basin.



Retired Eastern Kentucky University professor Ralph Ewers and Jim Currens attach lasers to a downhole camera turret at the Kentucky Horse Park to delineate the width of an underground conduit that conducts groundwater to Royal Spring in Georgetown.

Additional karst-related activities were: (1) publication of the Hopkinsville 30 X 60 minute quadrangle karst groundwater basin map (scale 1:100,000), (2) data compilation and drafting of dye-traced karst flow paths for the yet-unpublished Louisville, Elizabethtown, and Morehead karst groundwater basin maps, and (3) acting in a technical advisory capacity for a volunteer project sponsored by Friends of Wolf Run, which is being conducted by **Ben Currens**, a student in the UK Department of Earth and Environmental Sciences, to map the groundwater basin of Gardenside Spring, located in a suburban area in west-central Lexington; to date, three groundwater traces have been attempted, but none have been successful. The karst groundwater basin of the Gardenside area may be hydrologically more complex than first thought, and additional investigations could result in a major improvement in our understanding of karst hydrogeology in western Fayette County.

Kentucky Groundwater Data Repository

The Kentucky Groundwater Data Repository, hosted at the KGS website, contains data for more than 101,000 wells, including domestic, public, industrial, monitoring, and agricultural wells. In addition, data for more than 5,000 springs and 44,000 sample suites

(representing millions of individual analytical results) are available. The data in the repository were compiled from more than 15 agencies, but the largest contributor continues to be the Kentucky Division of Water. Groundwater data uploads from the division are added quarterly—wells, springs, and groundwater-quality data (including pesticide sampling from approximately 20 sites being investigated by the Division of Water and the Department of Agriculture). Well and sample data collected through their certified well driller program and the Kentucky Interagency Groundwater Monitoring Network are uploaded to the repository, providing users with 24/7 access to the most recent groundwater data available. Scanned water-well-drillers' logs and associated documents are uploaded approximately every six months. The repository can be accessed at kgs.uky.edu/kgsweb/DataSearching/watersearch.asp.

Collaboration With Kentucky Division of Water Sampling Efforts

The Kentucky Division of Water is responsible for sampling wells and springs at about 60 sites across Kentucky. These sites comprise the Kentucky Interagency Groundwater Monitoring Network. Most water samples are collected on a quarterly or biannual basis by Division of Water personnel on about 11 different sampling runs. KGS hydrogeologists were invited

Bart Davidson and Jim Calhoun of the Kentucky Division of Water collect water samples from Royal Spring near Georgetown.

by Division of Water personnel to assist in collecting some of these samples. To date, KGS personnel have accompanied Division of Water personnel in the midwest, north-central, and south-central parts of the state. KGS has been invited to take over the quarterly sampling of three sites in the north-central area: McConnell Springs and Russell Cave Spring in Fayette County and Royal Spring in Scott County. The Environmental Services Branch Laboratory in Frankfort will continue to analyze these samples. KGS wishes to express its appreciation for the collaborative spirit of the Division of Water in allowing our participation in this endeavor. Public access to the data collected for the Division of Water sampling program and the Kentucky Interagency Groundwater Monitoring Network is through the network's website at www.uky.edu/KGS/water/gnet.

Groundwater Atlas of Kentucky

KGS is currently developing a series of web pages designed to disseminate information about the availability, quantity, and quality of Kentucky's groundwater resources. Designed to work in conjunction with the Kentucky Groundwater Data Repository and Kentucky groundwater resource reports, these pages will contain aquifer location maps, groundwater-quality maps based on data from the repository, and information from aquifer tests

Jim Calhoun of the Kentucky Division of Water and Bart Davidson collect water samples from the Blue Hole at McConnell Springs near Lexington.

conducted by KGS across the state in recent years. In the near future, near-real-time groundwater-level observation data from wells and springs in the newly developed Kentucky Groundwater Observation Network may be available through the Groundwater Atlas website. The Groundwater Atlas, when completed, will be accessed via the Kentucky Groundwater Data Repository's website: kgs.uky.edu/kgsweb/DataSearching/watersearch.asp.

KGS Rock and Water Analytical Laboratory

In the fall of 2013, the KGS laboratory was restructured and administratively placed in the Water Resources Section. This move improved the research and data-collection needs of the Water Resources Section while continuing to provide important laboratory analytical services on rock, oil, gas, and water samples collected throughout the state by other KGS geologists. Laboratory manager **Jason Backus** and analyst **Andrea Conner** also collaborated with researchers from other UK academic departments and state universities, various State and federal agencies, the Kentucky Water Watch program, and private citizens to provide laboratory services that met their individual needs and also contributed useful analytical data to the water, rock, oil, and gas databases maintained by KGS. Highlights of this year's laboratory activities, and the analytical data they produced, are:

- Water samples collected from 98 sites were analyzed for major ions, trace metals, nutrients, and other water-quality constituents for the Wendell H. Ford Regional Training Center project.
- Approximately 200 shale samples were analyzed for total organic carbon and inorganic carbon as part of the Energy and Minerals Section's characterization of the regional geology and hydrocarbon production of the Berea Sandstone oil play in eastern Kentucky (www.uky.edu/KGS/emsweb/berea_ss/Upper_Devonian_Berea_SS.htm).
- As part of a large project with the UK Mining Engineering Department, concentrations of rare earth elements in coal ash and byproducts were measured in approximately 1,000 samples.
- Samples from **Dr. Ming Gong** from the UK Medical Center were analyzed for sodium and potassium by inductively coupled plasma-optical emission spectroscopy to determine the uptake and transport of these elements in certain organs in mice.
- Spring and fall water-quality samples collected by the Kentucky River and Four Rivers groups of the Kentucky Watershed Watch program were analyzed for nutrients, metals, and atrazine concentrations.
- Water monitoring samples from several sites were submitted by **Dr. Alan Fryar** of the UK Department of Earth and Environmental Sciences for analysis every two weeks over the spring 2015 semester. This project brought high school and middle school science teachers into the University research community for hands-on experience.
- Nine groups, including professionals, high school students, graduate geology students, and candidates for a professor in the UK Department of Earth and Environmental Sciences, toured the lab.
- Eighteen University of Kentucky students were taught analysis techniques and assisted in their research by the lab. Six students were taught TOC/shale analysis; seven students were taught X-ray diffraction and fluorescence analytical principles and techniques; and five graduate students were taught X-ray fluorescence principles and techniques, which they used for their research. These students came from all over the University, including the departments of Mining Engineering, Chemistry, Plant and Soil Science, Materials Science, Chemical Engineering, and Earth and Environmental Sciences. ●

Energy and Minerals

...research on energy sources, carbon storage, rare earth elements, and brine disposal

Conventional and unconventional energy resources, carbon storage, as well as wastewater disposal and rare earth elements continue to be subjects of research in the Energy and Minerals Section.

Carbon Storage

Carbon-Storage Demonstrations as Part of the Kentucky Energy Independence and Incentives Act

Section researchers continued data interpretation and documentation for two projects funded by the Kentucky General Assembly in 2007.

Eastern Kentucky Coal Field Deep Saline Injection Well

Steve Greb and **Rick Bowersox** completed analysis of data collected from the 4,835-foot-deep KGS No. 1 Hanson Aggregates stratigraphic research well drilled in 2013 in northern Carter County, in the Eastern Kentucky Coal Field. Research in the past year focused on laboratory analysis of core and samples from the Ordovician High Bridge Group, Wells Creek Formation, Beekmantown Dolomite, and Rose Run Sandstone, and the Cambrian Copper Ridge Dolomite, Nolichucky Shale, Maryville Limestone, Maryville sands, and basal sandstone. A final report on the project was nearing completion at the end of the fiscal year.

Devonian Shale Enhanced Gas Recovery Demonstration Using CO_2

Brandon Nuttall led a project in Johnson County to test the hypothesis that black organic-rich shales may serve for long-term CO_2 storage and play a role in enhanced natural gas recovery. The final report for this project is in progress.

Regional Carbon Storage Partnerships

KGS continued its participation in the Midwest Regional Carbon Sequestration Partnership, funded by the U.S. Department of Energy and managed by the Battelle Memorial Institute. The project covers Indiana, Kentucky, Maryland, Michigan, New Jersey, New York, Ohio, Pennsylvania, and West Virginia. **Brandon Nuttall, Tom Sparks,** and **Steve Greb** were involved in phase III research, the regional characterization of reservoirs and confining intervals, and injection testing (in other states) to help prepare for future possible commercialization of carbon storage. KGS is heading up a regional assessment of the potential for carbon storage and enhanced gas recovery in organic-rich Devonian shales. Total organic carbon content, density, and maturity data are being used to refine models for estimating carbon storage capacity in shales across the region, especially those that have the potential to use CO_2 for enhanced oil or gas recovery.

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KGS also continues collaborative research to investigate subsurface geology and refine models for estimating carbon storage capacity in deep Cambrian and Ordovician reservoirs. Information and publications about the regional partnership can be found at www.mrcsp.org.

Deep Co_2 Storage in the Illinois and Michigan Basins

This project, funded by the U.S. Department of Energy, was 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 was evaluated. The project was completed in November 2014.

Dave Harris completed a report that includes regional cross sections and core descriptions for the Knox and related units in the Illinois Basin. Stratigraphic correlations refined the interpretation of an important sandstone reservoir in southern Indiana and western Kentucky. This sandstone is more than 350 feet thick in parts of southern Indiana. It has excellent porosity and permeability at sufficient depths for supercritical CO_2 storage, and serves as an additional sequestration target in the Knox.

Cores from five wells in western Kentucky were described to allow interpretation of the control of depositional facies on reservoir properties. These lithofacies represent deposition in shallow subtidal to restricted intertidal/supratidal environments, and are remarkably similar across western Kentucky. Three cores were classified by lithofacies to determine if primary depositional facies correlates to reservoir quality. Quartz sandstones in the KGS No. 1 Blan well have the best reservoir properties (average of 8.8 percent porosity and 194 millidarcies permeability). Dolomite lithofacies vary in average porosity and permeability, and there is significant variability within a given lithofacies.

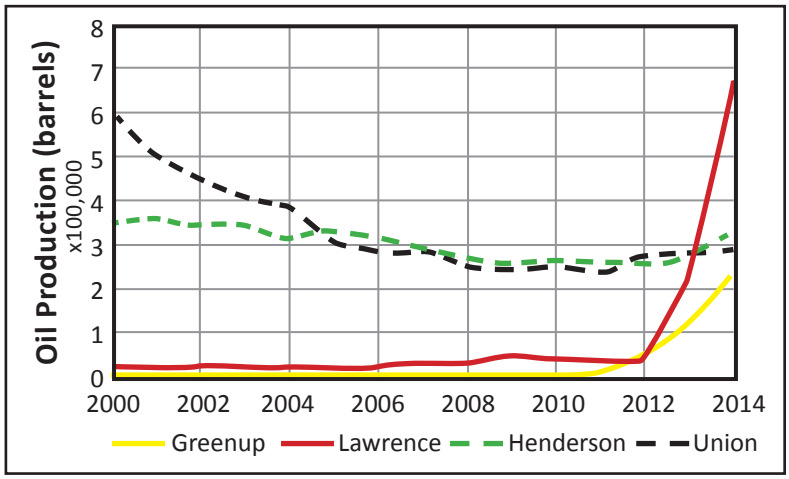
John Hickman completed an analysis of the sealing capacity of faults cutting through the Knox Formation. Two cross sections were made across different regional fault systems (Rough Creek Fault Zone in Kentucky and the LaSalle Anticlinorium in Illinois) to calculate subsurface stratigraphic juxtapositions across each fault zone. Using these stratigraphic and lithologic data, three different algorithms were used to calculate the sealing potential of a theoretical Knox reservoir at each section location. Results indicate a high probability for sealing in the Rough Creek Fault Zone, but a much lower probability for a continuous seal in the LaSalle Anticlinorium.

Marty Parris and a consultant continued to revise a paper on reactive transport modeling to predict reactions between CO_2-saturated brines and confining zones (shale or nonporous carbonates).

Oil and Natural Gas Resources

Petroleum System Consortium

Despite the downturn in oil prices and attendant decrease in completions, investigation into the Berea Sandstone petroleum system has made considerable progress since August 2014. The project is funded by an eight-company industry consortium along with in-kind technical partners at the U.S. Geological Survey, Ohio Division of Natural Resources, R.J. Lee



Recent oil production from the Berea Sandstone in Greenup and Lawrence Counties spurred the creation of the Berea consortium.

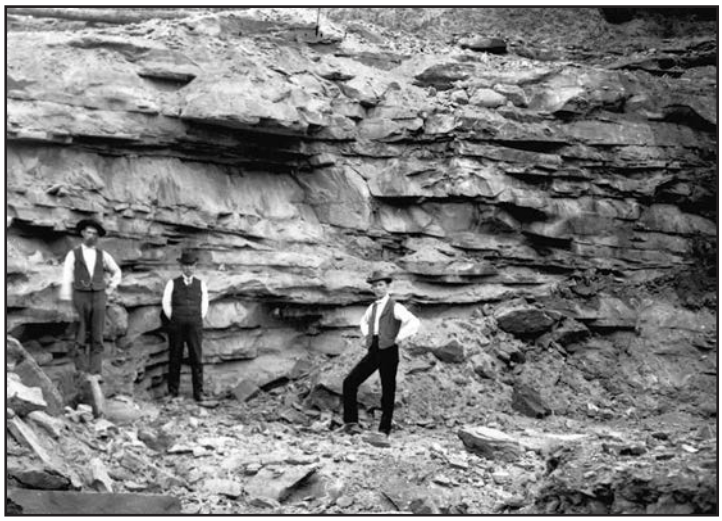
Group, and Universal Well Services. At KGS the project is headed by **Marty Parris, Steve Greb,** and **Cortland Eble.**

Historically, the Berea Sandstone was targeted as a gas reservoir. About four years ago, however, operators began producing oil—which was somewhat of an enigma—from the Berea in an area in which the likely source rocks, the Mississippian Sunbury and the Devonian Ohio Shales, are immature or in the lower oil window. To better understand the source rocks and their thermal maturity history, 132 core and cuttings samples from 11 wells have been sampled along a northwest-southeast transect extending from Scioto County in southern Ohio to Pike County in southeastern Kentucky. The organic and inorganic carbon content of the samples has been measured and the maturity level of the organic matter has been assessed with vitrinite reflectance and pyrolysis measurements.

The distribution of hydrocarbons in the Berea Sandstone reservoir is being investigated through core and log analysis. Macroscopically, three to four depositional facies have been recognized. Mapping of the facies and characterization of their mineralogic and porosity and permeability properties is ongoing. In addition to identifying better reservoirs in the Berea Sandstone, we anticipate that the facies characterization work will help with decisions about geosteering (a new technology for steering horizontal wellbores) horizontal wells.

Evaluation of Heavy Oil and Tar Sand Resources, Western Kentucky

The evaluation of the western Kentucky tar sands resources by **Rick Bowersox** is near completion. The tar sands belt extends from Logan County to Breckinridge County, an area of about 975 square miles; resources are in the Late Mississippian Big Clifty and Hardinsburg Sandstones and Early Pennsylvanian Caseyville Formation. An extended abstract was published and a presentation of the preliminary results of this study was made at the Eastern Unconventional Oil and Gas Symposium in Lexington in November 2014. A review article was published in *Sustain* magazine, a journal of environmental and sustainability issues from the University of Louisville. In the course of this evaluation, the records of 1,500 wells and coreholes, and analyses of about 4,000 core samples, were reviewed to calculate the heavy oil and bitumen resources in place in western Kentucky. This preliminary review estimated that the total heavy oil and bitumen (a natural tar-like substance) resources in the surface and shallow subsurface of the tar sands belt is about 3.87 billion barrels, of which 2.46 billion barrels is in the Big Clifty and the balance in the Hardinsburg and Caseyville. A companion short history of western Kentucky's rock asphalt industry was completed early in 2015 and is in review for a KGS Special Publication. This project estimated that the total tar sands mined for road topping from 1889 to the collapse of the industry in 1957 was about 6 million tons containing 2.3 million barrels of heavy oil and bitumen. A poster outlining the history of Kentucky's rock asphalt industry was presented at the KGS annual seminar in May 2015. Also in



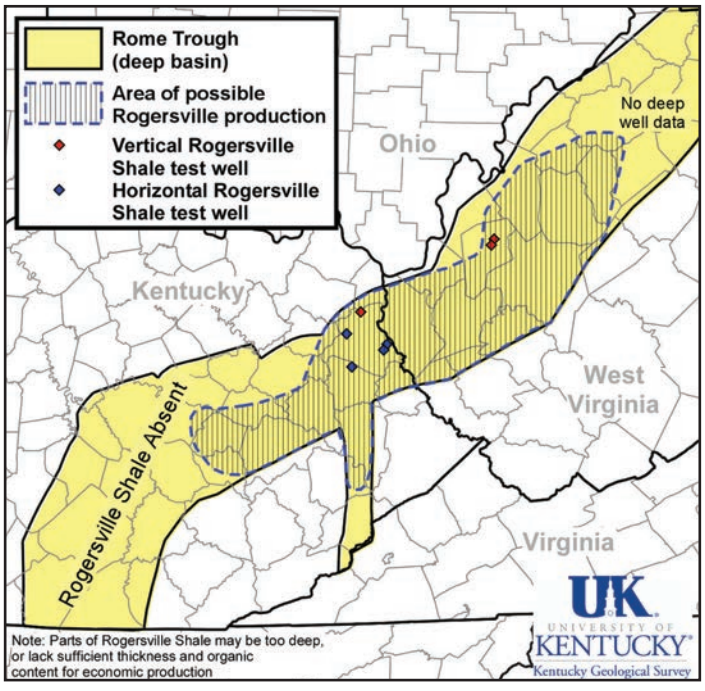
The abandoned American Standard Rock Asphalt Co. pit in Logan County. This pit is in the tar sand area evaluated by Rick Bowersox. (Photo by S.D. Averitt, *in* Miller, A.M., 1919, The geology of Kentucky: Kentucky Geological Survey, ser. 5, Bulletin 2, p. 304.)

progress is a review of the Devonian-Mississippian petroleum system in western Kentucky and its relationship to the tar sands deposits. This article will be published in an international journal focused on unconventional resources.

Unconventional Resource Potential of the Cambrian Rogersville Shale, Eastern Kentucky

One of the oldest formations in Kentucky is the focus of new exploration to determine its potential for unconventional oil and gas production in the Rome Trough, eastern Kentucky. Previous work by the Rome Trough Consortium at KGS in 2002 identified the Cambrian Rogersville Shale (Conasauga Group) as a mature hydrocarbon source rock, with total organic carbon content of up to 4 percent. The Rogersville was identified as the source of gas and condensate produced in the Homer Field in Elliott County. This source rock is now being evaluated as a possible unconventional gas or oil reservoir, similar to Kentucky's Devonian black shales. By July 2015, three deep wells had been drilled to test the Rogersville Shale in Lawrence and Johnson Counties, and a fourth well was completed in Putnam County, W.Va. Data from the new wells remain confidential; however, initial reports are encouraging, and significant deep leasing activity has resulted.

KGS is continuing to conduct research on the Rogersville Shale to support significant interest in the play from across the country. **John Hickman** and **Dave Harris** have been interviewed by the media and fielded numerous public requests for geologic data. They have also made regional play maps to show the extent and likely productive area of the Rogersville. Hickman also gave a paper at the American Association of Petroleum Geologists' annual meeting in Denver, which included new structure and isopach maps for the Rogersville. He is also writing a paper on the Rome Trough and related Rough Creek Graben for a journal. High-resolution core photographs were made of all the older Cambrian cores from the West Virginia part of the play prior to releasing these cores to the West Virginia Geological and Economic Survey for permanent storage. These images will be made available on the KGS website later in 2015. Geochemical data from industry and previous research were compiled. **Cortland Eble** continued to analyze organic matter from the Rogersville to improve our understanding of its hydrocarbon potential and maturity.

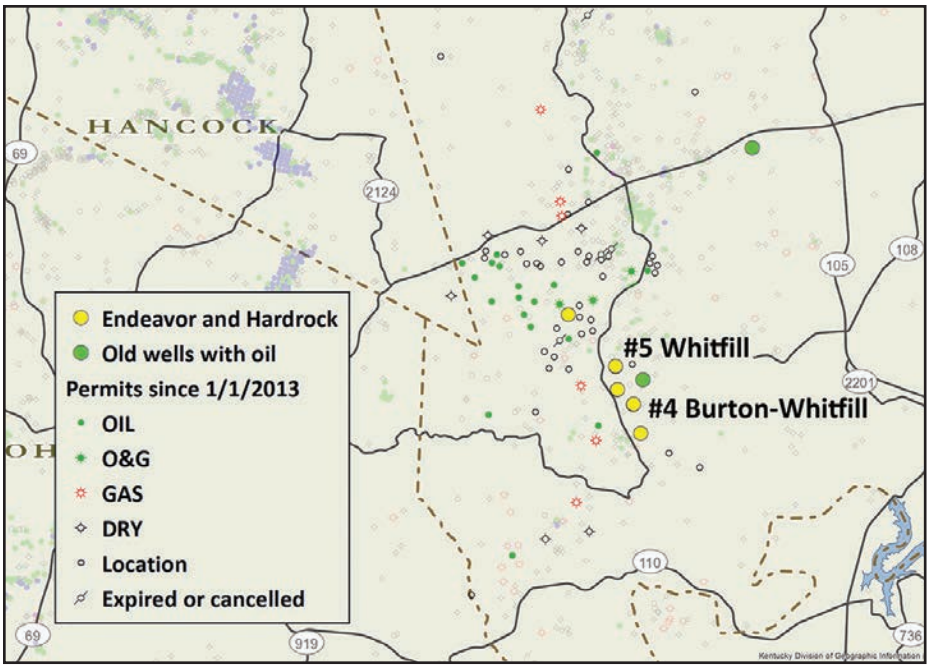


Extent of the Rogersville Shale and test wells drilled in the region.

Hydraulic fracturing will be required to produce the low-permeability Rogersville Shale, and KGS has been proactive in starting a new microseismic monitoring program *(see* Geologic Hazards Section). As new well data are released, our understanding of the Rogersville Shale and its resource potential will improve.

Oil Production from the New Albany Shale, Breckinridge County, Western Kentucky

Brandon Nuttall, Marty Parris, and **Glynn Beck** visited two Devonian New Albany wells in Breckinridge County that are producing oil from the shale. Geochemical characterizations of the shale and produced oil and gas were determined. These data suggest the shale in this loca-



Status of development of the New Albany Shale in Breckinridge County. The Endeavor and Hardrock are recent wells with significant oil production.

tion is not sufficiently mature to account for the observed volumes of oil, which includes an anomalously high light gasoline fraction. Additional oil samples have been acquired for analysis. A partnership was formed with the Illinois State Geological Survey and the Indiana Geological Survey to respond to a solicitation for proposals from the Energy Division of the Advanced Research Projects Agency. The proposed research is aimed at developing a better understanding of the liquids potential of the New Albany Shale in the Illinois Basin and investigating the possible role of low-temperature catalytic generation of hydrocarbons in organic-rich shale.

Utica Shale Appalachian Basin Exploration Consortium

KGS completed a collaborative five-state study of the geology, stratigraphy, and hydrocarbon potential of the Ordovician Utica Shale in June 2014. Research was conducted by **John Hickman, Cortland Eble,** and **Jason Backus,** as well as researchers in other states.

Results of the study remained confidential to industry sponsors for 12 months. The final report and data were released to the public in July 2015. Hickman and Eble presented their research at a project workshop in Canonsburg, Pa. The report and data files are available at www.wvgs.wvnet.edu/utica.

Coal Resources

Rare Earth Elements From Coal and Coal Combustion Byproducts

Recently, coal and byproducts of coal combustion have received attention as potential sources of rare earth elements, which include the lanthanide series elements and yttrium. Rare earth elements are essential for hundreds of applications. Although the United States once was largely self-sufficient in these critical materials, it has become largely, if not entirely, dependent upon imports during the past 25 years.

With funding from the U.S. Department of Energy, **Jerry Weisenfluh, Cortland Eble, Jim Hower** of the UK Center for Applied Energy Research, and members of the UK Mining

An outcrop of the Economy Member of the Kope Formation, a Utica Shale equivalent in Bracken County.

Engineering Department collected more than 1,000 coal and coal preparation plant gravity fraction samples. **Jason Backus** and **Andrea Conner** analyzed these in the KGS laboratory for lanthanide series and yttrium content. Existing data from the Kentucky coal resources information database and some more recently collected samples were also used for the study. Testing for rare earths is labor-intensive and requires reducing samples to a very fine powder, ashing (burning) the sample at controlled temperatures, and dissolving the ash in very pure acids before element concentrations can be detected using inductively coupled plasma mass spectrometry.

Results revealed a wide range in lanthanide and yttrium contents. Some coal beds, notably the Fire Clay in the Eastern Kentucky Coal Field, have a relatively uniform enrichment (greater than or equal to 1,000 parts per million total rare earth elements). Most of the other coal beds have much more complex distribution patterns, however. Similarly, ash byproducts from coal-fired electric power generation facilities also indicate enrichment. Collectively, the results indicate that coal and coal combustion byproducts may represent a potential source of lanthanide and yttrium for the country's increasing needs.

Pennsylvanian Geology of the Eastern and Western Kentucky Coal Fields

Cortland Eble and **Steve Greb** continued research on coal-bearing strata in both the Eastern and Western Kentucky Coal Fields. Sampling data from beds in both coal fields are routinely included in KGS stratigraphic, coal-quality, and palynologic databases. KGS also has a cooperative agreement with the U.S. Geological Survey's National Coal Resources Data System to provide data on Kentucky coal and coal-bearing rocks. Although our own state's coal mining has been declining, data from past mining and exceptional outcrops continue to attract both national and international geologic interest. For example, KGS geologists are working with researchers from several universities throughout the world to study the lateral and temporal variation in coal characteristics and coastal/estuarine depositional facies models, to test and better understand sequence-stratigraphic applications, and for use in subsurface reservoir models in other areas.

Mineral Resources

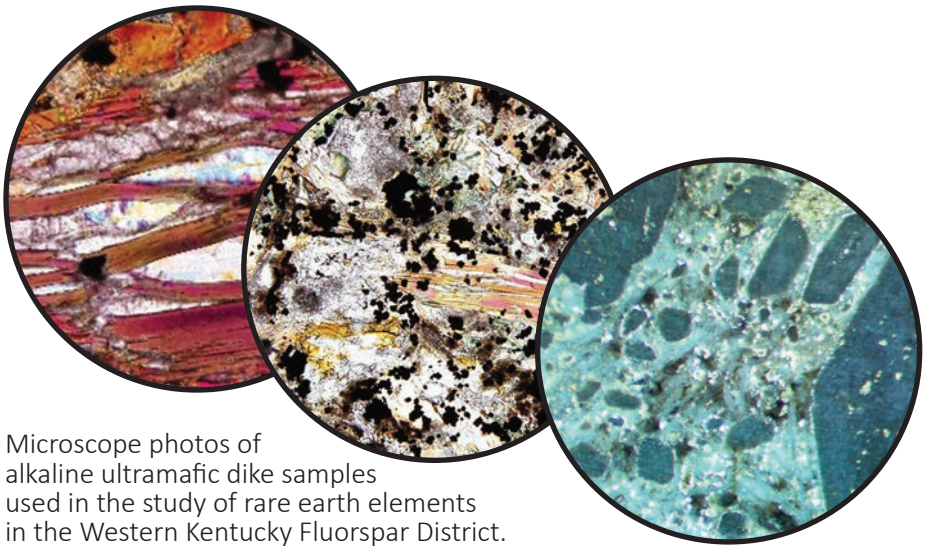
KGS Minerals Database

Mining industry response has been positive to the Kentucky minerals database, which was made available as a map service in 2014 at kgs.uky.edu/kgsmap/KGSMineral. **Warren Anderson** and **Tom Sparks** developed the database, and **Richard Smath** of the Geologic Information Management Section and numerous student workers scanned thousands of documents, including core logs, cross sections, mine and property maps, geochemical and geophysical maps, chemical analyses, and unpublished reports. Geologic Information Management Section Head **Doug Curl** was instrumental in building the spatial database and developing the online map service.

Updates to the map service have been completed as new data are made available. Since the release of the map database, more than 400 additional records (petrographic photographs, X-ray diffraction analyses, core logs, and scanned maps) have been added to the inventory. The most significant contribution was the addition of more than 200 legacy core logs from a mining company.

Rare Earth Element Research

Warren Anderson and **Jason Backus** are concluding their investigation of rare earth elements in igneous rocks in the Western Kentucky Fluorspar District. Rare earth elements occur in alkaline ultramafic igneous rocks in the district. Previous research in the district has been related to the geology of fluorite mineralization, and only limited work has been conducted on the rare earth potential of these igneous rocks. The Western Kentucky Fluorspar District contains numerous alkaline ultramafic rocks,



Microscope photos of alkaline ultramafic dike samples used in the study of rare earth elements in the Western Kentucky Fluorspar District.

such as lamprophyre, alnoite, and peridotite, in a series of complex igneous intrusions of dikes, sills, diatremes, and igneous breccias, suggesting a heterogeneous petrologic suite of igneous rocks. More than 60 igneous intrusions have been identified, examined, analyzed, and photographed during this investigation. The similarity of the Kentucky rocks to other rare earth deposits suggests a complex petrologic history, which raises the level of interest in these rocks for rare earth potential. Both X-ray diffraction mineralogical analysis and induced coupled plasma elemental analysis were performed on samples from selected dikes to help us understand the potential for rare earth elements in these igneous rocks. These analyses detected both enriched rare earth elements and several minerals bearing rare earth elements, in addition to numerous sulfide minerals in many of the dikes.

Fluorite was also examined for potential rare earth elements, since many fluorites throughout the world contain them. Although rare earth elements do occur in the ore-stage fluorites in the Western Kentucky Fluorspar District, Anderson and Backus found only slight enrichment.

A report documenting the mineralogy, petrology, and analytics of these igneous rocks, containing abundant photographs, diffraction images, and analytical tables, has been written and is in review.

Brines and Underground Waste Disposal

Mapping Underground Brine-Disposal and Enhanced Recovery Wells

Environmental concerns (i.e., water safety, pollution, and induced seismicity) about wastewater disposal wells have received attention from the news media and the public. Brines brought to the surface with oil and gas production are reinjected into the same or similar porous underground formations from which they were initially produced. This practice ensures the protection of underground drinking-water sources. The U.S. Environmental Protection Agency maintains primacy by permitting and regulating all Class II wells in Kentucky under its Underground Injection Control program.

After a new database of all Class II wells in Kentucky was compiled, a new map service developed by **Tom Sparks** was linked to the KGS petroleum map service. The database was developed following the release of multiple Freedom of Information Act documents by the EPA and includes data from all of the original 100 brine-disposal wells presented in "Class I Waste-Disposal Wells and Class II Brine-Injection Wells in Kentucky" (Map and Chart 204, 2013), as well as an additional 2,900 enhanced oil recovery injection wells. As new brine-injection disposal wells continue to be permitted and existing Class II wells are reclassified by the EPA, the map service has been periodically updated.

Plans are under way to initiate a new request to the EPA for brine injection volumes of all currently active disposal wells in Kentucky. The current database was created in 2013 from a request for operational data (injection volumes and pressures) from 2008 through 2012. This will help with the microseismicity monitoring work that is being initiated by

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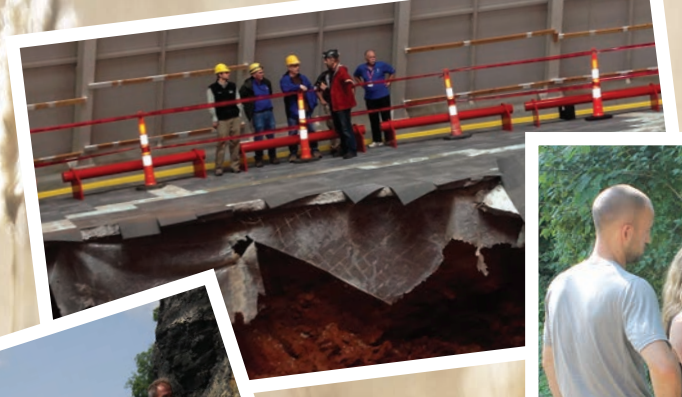


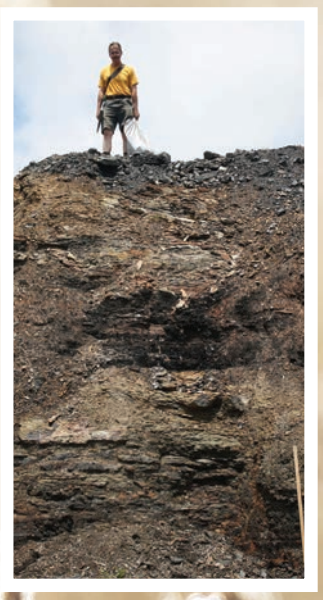
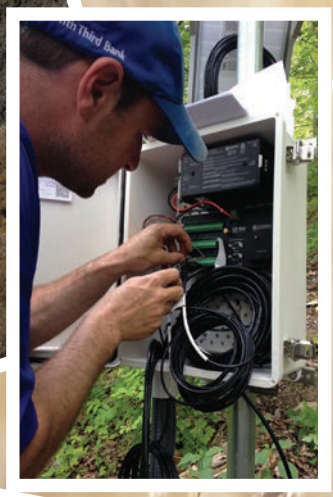






In the field...

Field Work Remains Key to Research

Technology has become a pervasive presence in virtually all facets of modern life, including geologic research. As with researchers in many scientific fields, KGS staff use a wide variety of modern technologies to do their work, from ubiquitous desktop computers to state-of-the-art instruments for analysis, seismic-event detection, water monitoring, and sampling. Geologic research has been immeasurably improved by such technological advances.

But thorough study of the earth sciences still requires that scientists leave their offices and laboratories and go into the field to conduct basic activities such as gathering samples and data and observing and recording geologic conditions and processes firsthand. And so KGS researchers still wade into streams across Kentucky, peer into sinkholes and fissures, drill shallow holes to sample soil and deep wells to inject CO_2, stand below landslides to assess underlying causes and triggers, and set out seismic instruments in collaboration with Chinese colleagues in earthquake-prone Gansu Province, among many other activities.

In addition, purely for the sake of learning more or refreshing their education, groups of Survey staff occasionally take field trips to view the diversity of landscapes and formations Kentucky's geology offers, both on the surface and in caves and deep mines.

Technology is indispensable to modern scientific research. But no less important is the regular, direct contact in the field with the subjects of our inquiry. The blend of the two has made KGS a comprehensive research and public service organization. ●

Continued from page 17

the Geologic Hazards Section. An annual update to the database of brine injection activity and operational data is anticipated and will be maintained by the Survey.

Development of a Brine Disposal Framework for the Northern Appalachian Basin

Tom Sparks and **Marty Parris** completed their participation in a project studying brine disposal in the Appalachian Basin. The project was led by Battelle Memorial Institute, and participants were from the state surveys of Kentucky, West Virginia, Pennsylvania, and Ohio. In order to develop a regional geologic framework for brine injection zones, reservoir properties such as injectivity and fracture strength, storage capacity, operations requirements, and potential costs were assessed. Each state survey supplied appropriate reservoir parameter data from its active and potential injection zones.

Battelle studied rock mechanics (compressive, acoustic, and tensile strength testing) of three whole-core samples from the recently drilled KGS No. 1 Hansen Aggregates well in Carter County. Zones investigated were from the Rose Run Sandstone, porous Copper Ridge Dolomite, and Mount Simon Sandstone.

Each state was assigned a target injection reservoir for detailed geologic analysis. KGS interpreted the Mississippian Weir Sandstone geology, stratigraphy, and injection characteristics (depth, injection rates and volumes, lab analysis, porosity and permeability data), along with an overall risk profile assessment. Because of the Weir's shallow depth and numerous penetrations, KGS personnel do not view it as a large-scale target injection zone. The KGS characterization simply reflects the abundance of geologic and reservoir data in Kentucky, where the Weir Sandstone is an important oil and gas producer.

Battelle released a 16-page pamphlet, "Injection Horizons, Geology, and Operational Data," that summarizes operational and geologic information for brine disposal reservoirs in the northern Appalachian Basin. It covers 10 injection zones from the shallow Mississippian Big Injun sandstone to the deep Cambrian basal sandstones in the northern Appalachian Basin. The pamphlet is presented as a general guide for field operators, engineers, and other interested stakeholders. In addition, Battelle is writing a final report, "Development of Subsurface Brine Disposal Framework in the Northern Appalachian Basin—Final Technical Report," that will be available later this year through the KGS website. The report will include KGS contributions for the Kentucky portion of the analysis. ●

Geologic Hazards

...investigating earthquakes and induced seismicity

The Kentucky Seismic and Strong-Motion Network

In cooperation with the UK Department of Earth and Environmental Sciences, the Geologic Hazards Section continued to operate and upgrade the Kentucky Seismic and Strong-Motion Network from analog to digital. KGS maintained a real-time data share with the neighboring seismic network operated by the University of Memphis and also with IRIS Data Management Center for archiving. Data from networks operating in Kentucky and surrounding states, including EarthScope USArray stations (www.earthscope.org/science/observatories//usarray) were acquired in tandem with real-time data from the network and used to detect seismic events in Kentucky with unprecedented sensitivity. A joint research project was developed with Indiana University and Purdue University and funded by the USGS through the National Earthquake Hazards Reduction Program. The project will use temporary seismic stations in the OIINK (Ozark, Illinois, Indiana, and Kentucky) project (www.indiana.edu/~oiink) to detect and analyze earthquakes too small for permanent stations to detect. The project will develop automatic methods to discriminate between the signals of infrequent microearthquakes and those from the numerous blasts that occur daily.

Fifteen minor earthquakes were located in the state during the fiscal year, with magnitudes from 1.2 to 2.8. Five of these events happened in the Mississippi Embayment, and 10 in eastern Kentucky. One of the earthquakes was felt by local residents: a magnitude-2.8 earthquake approximately 5 miles south-southeast of Williamsburg, on March 3. And one of the eastern Kentucky earthquakes, a magnitude-1.2 event

Zhenming Wang and Seth Carpenter install a new seismometer as part of the temporary monitoring network in eastern Kentucky.

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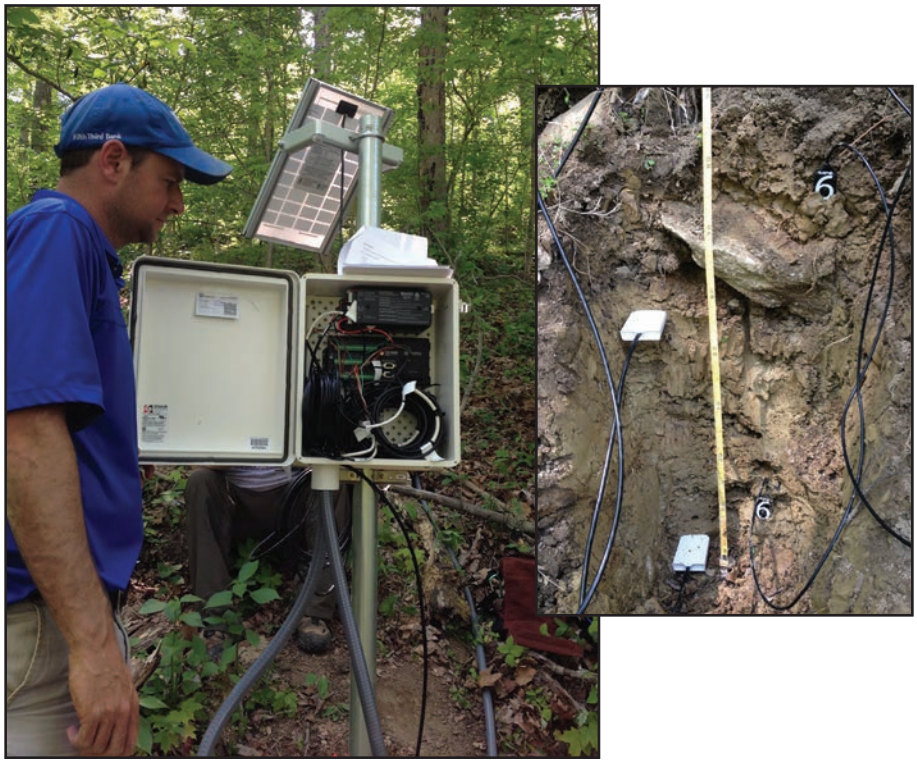
on June 27 in northern Greenup County, was only detected by seismic stations operated by the University of Kentucky and was not reported by other agencies. This earthquake was only detected and located because of the temporary seismic stations in the Rome Trough of eastern Kentucky, a project coordinated by **Seth Carpenter**.

This temporary network is being established with State support and in partnership with the Department of Earth and Environmental Sciences at UK and private companies. The network monitors very small earthquakes (microseismicity), both natural events and those that could have been induced by fluid injection and hydraulic fracturing (fracking). It is a proactive measure to establish background levels of microseismicity and to monitor any induced events in response to increasing interest in producing the unconventional Rogersville Shale oil and gas play. By the end of the 2015 fiscal year, all station locations for this temporary network were selected, and four of the stations were installed. The data arrive at KGS in real-time using wireless communication for processing and archiving.

Using data from the Central U.S. Seismic Observatory, UK geology student **Clayton Brengman** wrote a master's thesis, "Instrument Correction and Dynamic Site Profile Validation at the Central United States Seismic Observatory, New Madrid Seismic Zone." **Ed Woolery, Zhenming Wang, Seth Carpenter, Ron Street,** and **Clayton Brengman** co-authored a paper, "The Central United States Seismic Observatory—Site 1 Characterization, Instrumentation, and Recordings," and submitted it to the *Bulletin of the Seismological Society of America*.



Matt Crawford sets up a monitoring station at a Kenton County landslide. Sensors buried at the top and bottom of the slide, monitor hydrologic conditions such as water content, electrical conductivity, and temperature.

Landslide Hazards

Matt Crawford added many new entries to the landslide inventory database, bringing the total number of entries up to 2,443 by the end of the fiscal year. The information came from State agencies, published maps, field investigations, LiDAR mapping, and reports from the public. A KGS Information Circular documenting the creation of the landslide inventory database and its application was published in early 2014 (kgs.uky.edu/kgsweb/olops/pub/kgs/IC31_12.pdf). This database serves as a foundation for improving our understanding of landslides and provides information to assist mitigation efforts by land-use planners, transportation officials, emergency managers, and the public.

The database was also used to create an online, interactive landslide information map (kgs.uky.edu/kgsmap/kgsgeoserver/viewer.asp?layoutid=25). The map service helps with investigations of landslide hazard areas by showing known landslide locations in a spatial geologic and geomorphic con-

Crawford talks with a Floyd County homeowner whose house was severely damaged by a debris flow after heavy rains in February.

text. The landslide inventory and related map service allow government agencies and local communities to assess landslide locations, evaluate areas of high landslide occurrence, correlate landslides with geologic formations and slope morphology, see the distribution of landslides by slope angle, and correlate landslides with rainfall (if the slope failure date is known). Even though predicting landslides on a regional scale is difficult, knowing the locations of preexisting landslides and their associated rock and soil properties allows for better determination of where future landslides may occur. Government agencies and local communities need access to this information, and efforts to communicate these resources, which support risk analysis and damage reduction, are vital.

The first half of 2015 was a particularly wet period across Kentucky, and many landslides were triggered, including several very damaging debris flows. Crawford and others visited several of these slides with community officials and emergency managers, to assist with post-disaster landslide hazard evaluation. They inspected landslide features, geologic conditions, slope morphology, soil types, and other contributing factors to the slides. This information was used in FEMA Hazard Mitigation Grant Program applications for several communities and homeowners, ultimately helping with the cost-benefit analysis for mitigation decisions about the landslides. Thanks to the information that KGS provided, communities were able to make decisions about landslide stabilization, drainage infrastructure, and possible home demolition, all of which have long-term safety and economic implications. Crawford also monitored and characterized three landslides in Kenton, Lewis, and Pulaski Counties.

Slope hydrogeology, precipitation, landslide material and strength properties, landslide movement, and surface electrical resistivity data were collected from the Kenton and Lewis County sites. Data collection for Pulaski County will start in fall 2015. Electrical-resistivity measurements have shown contrasts that correlate to lithologic changes, failure surface depth, and groundwater conditions. These site-specific projects will provide a better understanding of shallow landslides and demonstrate that repeated electrical resistivity surveys can be correlated to the hydrologic conditions in the slope, which are needed to make effective slope stability assessments.

Seismic Hazard and Mitigation Policy

The Geologic Hazards Section focused on improved communication of seismic-hazard and mitigation policies through publications, presentations, and seminars, and helped develop seismic-hazard and design ground-motion maps. The peak ground acceleration for western Kentucky, the Paducah area in particular, was significantly reduced in the 2014 update of the national seismic hazard map.

Section Head **Zhenming Wang** had an opinion paper, "Predicting or Forecasting of Earthquake and the Resulting Ground Motion Hazards: A Dilemma for Earth Scientists," published in *Seismological Research Letters*. He also made a presentation, "Seismic Hazard Assessment: A Difficult but Necessary Task for Seismologists," at the 2015 Seismological Society of America annual meeting in Pasadena, Calif. Section staff participated in the 2017 National Earthquake Hazards Reduction Program update, and **Zhenming Wang** presented three lectures on seismic hazards and design maps to the Kentucky Society of Professional Engineers in Somerset, Prestonsburg, and Paducah.

China Scholarly Exchange and Cooperative Research

This was the 11th year for the exchange program between KGS and the Lanzhou Institute of Seismology and other organizations in the China Earthquake Administration. Two KGS staff—**Zhenming Wang** and Director Emeritus **Jim Cobb**—visited China to give lectures and conduct research in August 2014. They also visited the Earthquake Administration of Jilin Province in northeastern China and took a field trip to the Changbai Mountain Range on the border between China and North Korea, where they studied the Changbaishan volcano and its summit caldera, Tianchi (Heavenly Lake). Four researchers from the China Earthquake Administration of Fujian Province visited KGS in October 2014. Four additional visiting scholars from China came to UK to participate in research projects and exchanges, resulting in several publications in the *Journal of Earthquake Engineering and Engineering Dynamics* and the *Journal of Earthquake Sciences*, and a KGS Report of Investigations, "Comparison of the Ground-Motion Attenuation Relationship Between the Wenchuan, China, Area and the Central and Eastern United States." ●

During a 2014 trip to China, Zhenming Wang, Jim Cobb, and Jilin Province Earthquake Administration Director Yaqiang Sun visited Heavenly Lake, a volcano crater along the China–North Korea border.

Geologic Mapping

...helping Kentucky's communities with surficial maps

The work done by the Geologic Mapping Section makes a difference for Kentucky communities in a variety of ways, providing valuable information for community planning, environmental management, and healthcare.

Funded by the U.S. Geological Survey's cooperative mapping programs, section staff continued mapping the surficial geology of Kentucky, focusing their 2014-15 efforts on the southern and southeastern areas of the Louisville Metro area. To develop new surficial 7.5-minute quadrangle maps, staff members conduct landform analysis, record soil descriptions, collect new cores, and examine geotechnical reports. New draft geologic maps were created for the Kosmosdale, Valley Station, Shepherdsville, Jeffersontown, and Mount Washington quadrangles. Depicting a wide variety of features, these maps will be useful for activities including geotechnical planning and assessments of earthquake and landslide risks.

Geologic Mapping Section staff on a field-checking trip in the Shepherdsville quadrangle, Bullitt County.

The Louisville/Jefferson County Information Consortium has provided crucial GIS data for the metro area mapping work, including recently collected LiDAR and aerial imagery. KGS plans to file a copy of the new digital surficial geologic maps with the consortium when the maps are complete.

Steve Martin worked on revisions of the surficial geologic maps along the Ohio River Valley in western Kentucky to prepare them for publication.

With the help of **Doug Curl** and **Mike Ellis** of the Geologic Information Management Section, two geologic mappers began working with tablet computers to collect mapping notes in the field and streamline data collection. Using the ESRI Collector for ArcGIS app, **Antonia Hansen** and **Max Hammond** uploaded field notes, location data, and geo-tagged

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Antonia Hansen uses the ESRI Collector app to gather field data for her mapping work.

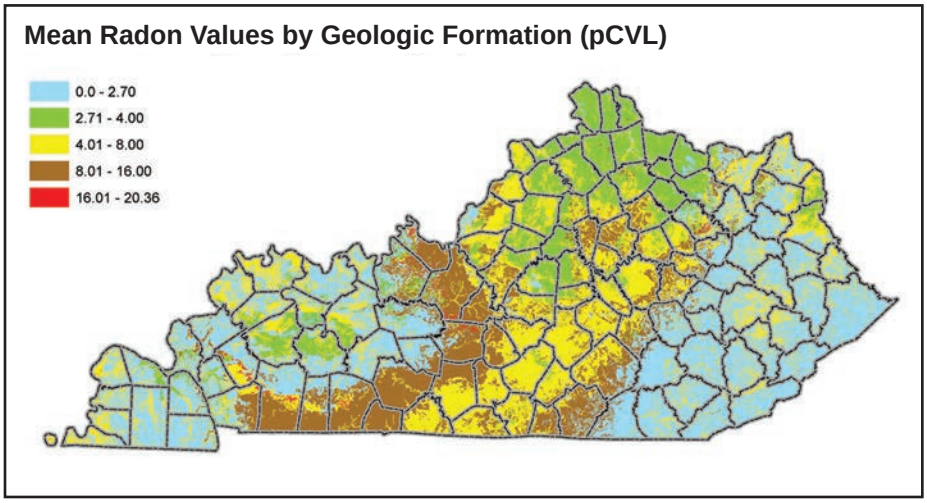
photos from mapping-project sites in near real-time to KGS databases. The app helps save time and preserve field-mapping accuracy.

Bethany Overfield continued working on a productive collaboration with the Clean Indoor Air Partnership at the UK College of Nursing to provide better information on the geologic context of radon occurrence in Kentucky. During the fiscal year, she completed a statistical study of the association between in-home radon measurements and the associated underlying geologic map units, and began work on county-level maps of geologic radon potential. Overfield, Section Head **William Andrews,** and staff at the Clean Indoor Air Partnership published a paper in *Preventive Medicine Reports,* "Radon Potential, Geologic Formations, and Lung Cancer Risk." They have a pending publication about the collaborative project for a GSA Special Volume, *Geoscience for the Public Good and Global Development: Toward a Sustainable Future.*

The UK Department of Earth and Environmental Sciences donated a Beckman-Coulter laser particle-size analyzer to the mapping section, to replace an older instrument. It is an invaluable tool for rapid grain-size characterization on field samples. **Amy Bleichroth-King,** who works out of the Henderson office, is the main technician on the instrument.

Amy Bleichroth-King uses the particle-size analyzer in the Henderson office on field samples.

UK student employees at the Survey gain valuable experience working with professional geologists. Student **Michael Priddy** worked this year with the mapping section, reviewing western Kentucky field mapping data and helping organize section databases. ●



Preliminary statewide map displaying mean radon values by geologic formation. It was derived from more than 60,000 residential radon measurements provided by the UK College of Nursing, as part of Bethany Overfield's collaborative work with the college.

Geologic Information Management

...managing KGS data and providing it to users online

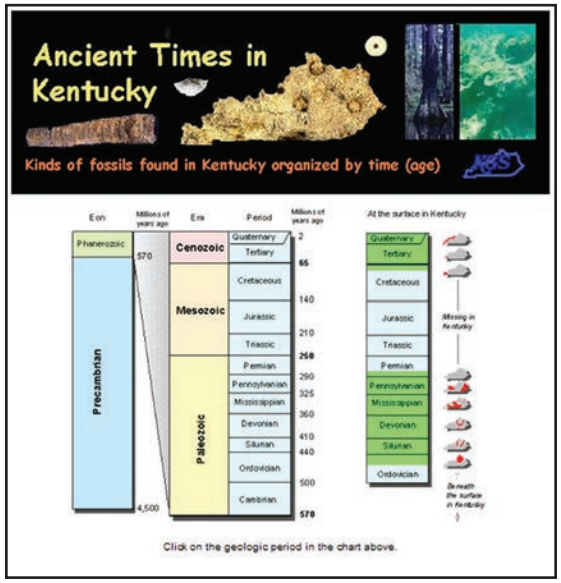
The Geologic Information Management Section works with KGS researchers to manage, store, and disseminate the geologic data collected at KGS. This includes database and file management, IT support, web development for dissemination of both tabular and map-based data, and GIS development and support.

A primary activity of the section is to develop and maintain the main KGS website (www.uky.edu/KGS), which continued serving a diverse audience in the United States and around the world during the fiscal year. More than 285,000 users from 224 countries accessed information about KGS, Kentucky's resources, and geoscience education from the website. About 75 percent of users were from the United States; others were from the United Kingdom, Canada, India, and Australia. About a third of domestic users are from Kentucky; the next most common group of users is from Texas, California, Ohio, Pennsylvania, and New York.

KGS online services had close to 1.3 million hits during the fiscal year. About 30 percent of the visits came from mobile and tablet users, which was a jump of 10 percent from the previous year. After the home page, the most popular pages on the KGS website were the fossil identification pages, followed by the seismic station recordings, educational resources pages, rock and mineral identification, and the methods of mining web pages.

Almost a million visits from 174 coun-

The KGS website had visits from 285,000 users in 224 countries around the world during the fiscal year.



The KGS fossil identification page is one of the most popular of our web pages.

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tries were made during the fiscal year to the KGS database, maps, and publications search website (kgs.uky.edu/kgsweb). The great majority of visitors were from the United States (89 percent). Users from all 50 states and the District of Columbia visited the site; a little more than half were from Kentucky, followed by users from Texas, Indiana, Pennsylvania, and Tennessee. The most common international users were from India, Canada, Germany, and the United Kingdom, in that order. Nearly 357,000 database searches were conducted by 127,000 users, representing about a 2.5 percent decrease in users from the previous year. There was also a decrease (13 percent) in database searches from last year, primarily the result of a 13 percent decrease in searches for oil and gas data. There is continued growth with mobile and tablet users, with an 18 percent increase in usage over the 2013-14 fiscal year.

KGS online map services were accessed nearly 95,000 times, about an 8 percent decrease from the previous fiscal year, much of it caused by a decrease in access of oil and gas map data. There were almost 20,000 tabular data downloads, which was about a 10 percent decrease from the 2013-14 fiscal year, consistent with the decrease in oil and gas database searches. The total number of files downloaded exceeded 2.5 million, consistent with the last fiscal year. Oil and gas records, online publications, coordinate conversion services, and data from the online geologic map server continue to be the most frequently downloaded data.

Several additions and updates to the web services were completed throughout the year. These and other KGS web services can all be accessed through the KGS website at www.uky.edu/KGS:

- A map-based web page was developed by **Elizabeth Adams** for querying and viewing oil and gas wells drilled over a specific period. Along with a map displaying the queried well locations, the page includes a histogram that indicates the number of oil and gas permits issued each month. Passing a cursor over each month's bar shows the total number of permits issued that month.
- Adams also developed a map-based web page for displaying natural arch locations in Kentucky; the data were gathered and compiled by **Steve Martin**. At the end of the fiscal year, 40 arches were shown on the website. Clicking on an arch location on the map will bring up information for the feature, including its name and type, the county where it is located, and size. Several photos of each arch or bridge are also available, linked from the KGS photo database. The arches are all on public lands, such as state parks, national forests, and national recreation areas, and each location has an established trail leading to the arch.

Richard Smath and **Doug Curl** started a project to develop web-based "Story Maps" of geologic areas of interest throughout Kentucky. Users can access the story maps on their mobile devices to direct them through a geologic

Geologic Information Management section staff spent a day in the Red River Gorge testing the Collector mobile application and examining arch locations found on the KGS arch and bridge website.

tour of these areas. The first is a walking geologic tour of Cove Springs Park in Frankfort. This web application will be released to the public in fall 2015.

Geoscience Information Management Section staff took part in a variety of activities during the fiscal year:

- **Elizabeth Adams** reviewed oil and gas well permit locations for the Kentucky Division of Oil and Gas (about 60 wells a month) and maintained the database of permits and well-location data. She also continued supervising several students, including **Bailee Hodelka** and **David Seckinger**, from the UK Department of Earth and Environmental Sciences. The students added new data to our oil and gas databases, scanned and organized oil and gas well documents for archiving and web dissemination, and contributed to several grant-funded projects such as the Kentucky Department of Transportation project to organize reports from 2007 to 2014 and upload them to the department's database.
- Two University of Southern Indiana students, **Kristen Schmeisser** and **Holly Keimig,** scanned legacy oil and gas well documents from the KGS Henderson office for the 2014-15 USGS National Data Preservation project. Through June 2015, documents from about 8,250 oil and gas records were scanned, resulting in the addition of 3,082 records to the KGS oil and gas database.
- **Doug Curl** and **Mike Ellis** assisted both the Geologic Mapping Section and the Water Resources Section with deploying Collector for ArcGIS, a new electronic field data collection tool from the GIS software company ESRI. (More information on how the app is being used by KGS geologic mappers can be found on page 25.

Mike Ellis helps KGS mapper Antonia Hansen with the use of the Collector for ArcGIS app for gathering field data.

- Section personnel maintained and updated a KGS YouTube channel, which includes both instructional videos about KGS website usage and presentations about the work of KGS. About 30 videos have been created for the channel.
- The section maintained the Kentucky hub for the Association of American State Geologists' National Geothermal Data System. The system provides GIS services for 13 state geological surveys in the Southeast. To support this activity, a new map server dedicated to providing the geothermal data was set up by **Mark Thompson**. ●

A walking tour of Cove Springs Park in Frankfort is the first web-based "Story Map" of geologic areas being developed by the Geologic Information Management staff.

Henderson Office

...research and public assistance in western Kentucky

For 65 years, KGS has operated an office in Henderson to conduct research and provide outreach in the western part of Kentucky. The office is staffed with an office manager and members of the KGS Water Resources and Geologic Mapping Sections. Soil sampling equipment and a sediment laboratory are available for staff use. Staff also provides technical assistance to local government agencies, industries, and agricultural interests.

The Henderson office participates in a variety of KGS research projects involving geologic mapping, carbon storage, enhanced oil and gas recovery, and water-quality sampling. This year Office Manager **Dave Williams** has focused his attention on paleochannel deposits in the upper part of the Carbondale Formation and the Shelburn Formation. **Scott Waninger** mapped unconsolidated sediments in the Louisville area, and **Amy Bleichroth-King** conducted laser diffraction particle size analysis on the Beckman-Coulter instrument in the sediment lab.

Waninger has also been assisting **Seth Carpenter** of the Geologic Hazards Section with installing seismic instruments for the microseismicity project in eastern Kentucky. **Glynn Beck** has been running gamma-ray neutron logs and a downhole camera in water wells in western Kentucky. He is also involved with the establishment of a groundwater monitoring network for Kentucky. He has assisted other KGS researchers with analysis of surface water in the Wendell H. Ford Regional Training Center for the National Guard in Muhlenberg County.

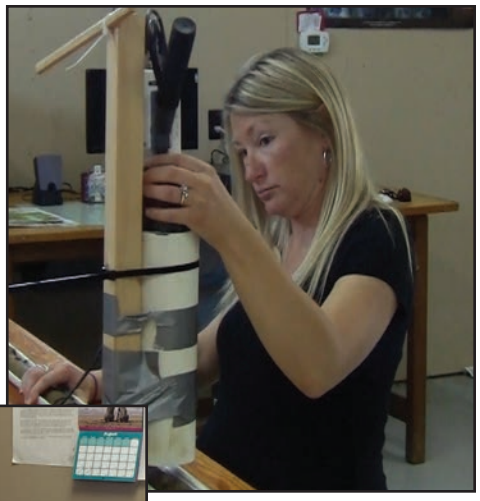
Holly Keimig, who joined the office during the year, is archiving oil and gas drilling files. A new scanner and computer has improved the production and quality of the images, which are placed into the KGS database.

Manager:
Dave Williams
williams@uky.edu

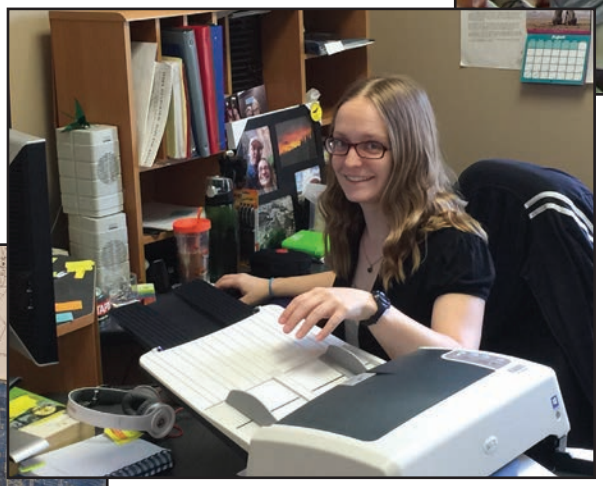
Western Kentucky office and seismic lab.

Dave Williams and **Scott Waninger** conducted field investigations into geologic hazards and resources, and collected samples.

In addition, researchers from the University of Memphis and the USGS visited the sediment lab to use the magnetic susceptibility meter to examine cores from Mississippi Embayment sediments for seismic research. ●



Amy Bleichroth-King uses a magnetic susceptibility meter to run magnetic profiles on soil cores.



Holly Keimig scans oil- and gas-drilling records at the Henderson office, to make them available on the KGS website.

Scott Waninger prepares samples for the particle size analyzer in the sediment laboratory.

Dave Williams investigates a rockfall in the Hardinsburg Sandstone at a roadcut of the Western Kentucky Parkway between Leitchfield and Elizabethtown.

Well Sample and Core Library

...thousands of samples available for research

Manager:
Patrick Gooding
gooding@uky.edu

The Well Sample and Core Library has readily available cores and well cuttings for examination and geochemical analysis. Devonian Berea Sandstone and black shales, Cambrian Rogersville and Nolichucky mudstones, Ordovician Utica shales, and Mississippian tar sands continued to be the subject of scientific investigations conducted at the Well Sample and Core Library. Kentucky followed a renewed national trend of exploring unconventional oil and gas formations. Existing collections will be studied in the Energy and Mineral Section's two industry consortium investigations that will further our understanding of unconventional petroleum systems in Kentucky. Several exploration companies, including ExxonMobil, Chesapeake Energy, Cabot Oil and Gas, Cimarex Energy, Southwestern Energy, and SM Energy, examined and sampled our vast collection.

Researchers and exploration geologists from throughout the United States and the world, including Wales, England, France, Italy, the Netherlands, and Switzerland, examined samples at the library. All are taking advantage of the tremendous

European petroleum geologists examined Pennsylvanian rocks at the core library before visiting similar-age outcrops in eastern Kentucky. The rocks are comparable to formations the geologists encounter beneath the North Sea.

availability of roadcut exposures in eastern Kentucky, the KGS online database of core descriptions and geophysical logs, and cores from the library to conduct three-dimensional assessments of reservoir analogs for Carboniferous deposits. Cores available at the library are an outstanding teaching tool and lead to a better understanding of the producing reservoir rocks, where these companies are currently exploring. Understanding the subsurface geology is a high priority, and our exceptional collection provides significant glimpses of what lies beneath the surface.

The facility is filled beyond capacity, making access inefficient and time-consuming. An expansion is long overdue. In spite of these limitations, cores and well cuttings remain of great importance in research and development of Kentucky's oil and gas and mineral industry. With additional acquisitions of rock materials of stratigraphic significance and State law mandating the collection of well cuttings, the library will continue to be overcrowded.

Researchers excited by several hydrocarbon discoveries investigated and explored ever deeper prospects in the Appalachian and Illinois Basins. A total of 182 petroleum exploration scientists, professors, research geologists, and students representing eight universities, four state surveys, and 17 companies used the facility this past year. Younger, shallower deposits were evaluated and previously explored areas were reexamined. More than 236,254 feet of well cuttings and cores were examined during these investigations. In addition, more than 738 samples were provided for geochemical and physical properties testing. ●

Among recent additions to the core library is this Knox Group dolomite from the KGS No. 1 Hanson Aggregates research well in Carter County. Intervals like this were found to have properties that would qualify them as CO_2 storage reservoirs. ▶

The many cores stored at the Well Sample and Core Library provide an understanding of the deep geology and resources of Kentucky. The current storage facility is filled beyond capacity with important cores and cuttings that must be provided to KGS by state law. ▼

Outreach and Education

...geologic information for the public

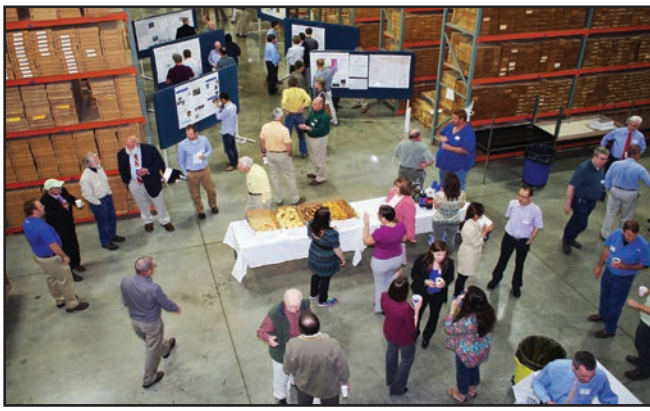
Opportunities for public education and professional development are offered each year by KGS.

KGS and the UK Center for Applied Energy Research organized the first Eastern Unconventional Oil and Gas Symposium, held in Lexington November 5–7, 2014. The event, which drew 120 participants, dealt with energy production from unconventional resources in the Appalachian, Illinois, and Michigan Basins.

The Survey was a sponsor and co-host with several private geotechnical companies of a geohazards workshop, on February 17, 2015. It focused on landslide mitigation design and construction.

KGS hosted the 14th Geohazards Impacting Transportation in Appalachia Forum, August 5–7, 2014. About 100 people attended the annual gathering sponsored by Marshall University and took field trips to the Cumberland Gap Tunnel in southeastern Kentucky (below).

KGS editor **Meg Smath** hosted the 48th meeting of the Association of Earth Science Editors, October 8–10, 2014, at KGS.



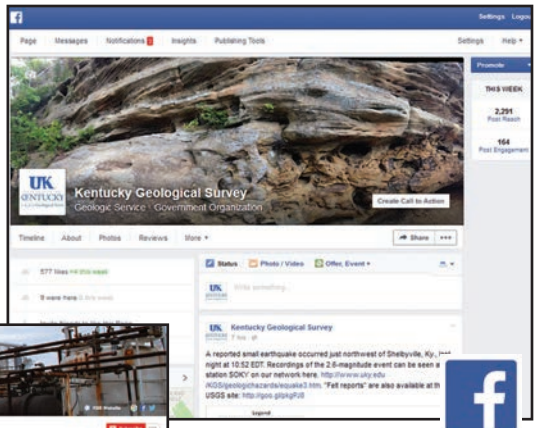
The 55th KGS annual seminar (above) drew 111 people to the Well Sample and Core Library on May 15, 2015. The theme of the seminar was "KGS Research in the Public Interest." The seminar is considered the largest annual gathering of geologists in Kentucky.

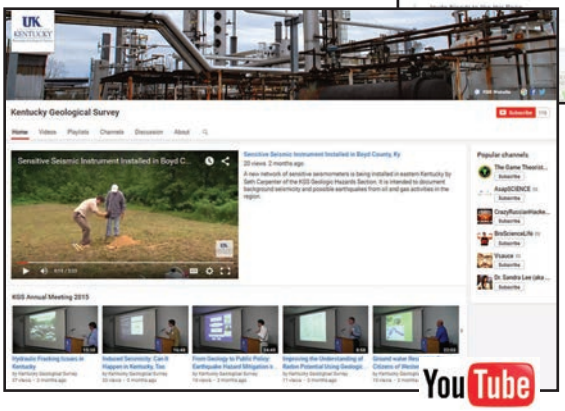
Steve Greb and **Richard Smath** conducted carbon dioxide experiments and demonstrations for students who attended the Center for Applied Energy Research Energy Fair at the UK Student Center, December 9, 2014.

Retired University of Cincinnati professor **Dave Meyer** spoke at the annual Darwin Lecture on "A Sea Without Fish: Life in the Ordovician Sea of the Cincinnati Region." Professional geologist groups, universities, societies, and KGS sponsord this event.

Steve Greb talks to students at the CAER Energy Fair.

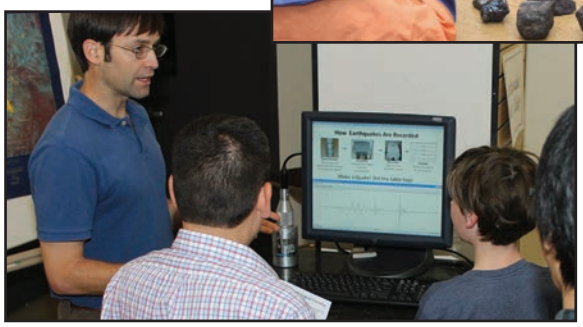
The Well Sample and Core Library helps disseminate scientific and educational information to the geologic community. During the fiscal year, 23 meetings, workshops, short courses, and seminars were hosted, attracting 551 participants. Library staff responded to 244 inquiries on rock identification and other geologic topics. Assistance was provided to 1,049 people, including students and scientists.





KGS also uses news releases, a Facebook page, and a YouTube channel to provide the public with information about Survey activities. ●

KGS and several other organizations held the annual Earth Science Week open house on October 15, 2014. About 200 students, teachers, and parents toured displays on the first two floors of the Mining and Mineral Resources Building to learn about a variety of earth science topics. KGS scientists set up displays on water, energy, fossils, meteorites, rocks, and minerals. Geology students and professors in the UK Department of Earth and Environmental Sciences helped prepare the building for the evening and staffed several displays and experiments. Other educational exhibits came from the Kentucky Paleontological Society, the Bluegrass Gem and Mineral Club, the Kentucky Water Resources Research Institute, and the UK Mining Engineering Department.



Publications

...research and activities available to the public

Twenty new titles were added to the list of KGS publications during the fiscal year. The database of all publications available through KGS can be accessed through a link on the Survey's home page, www.uky.edu/kgs.

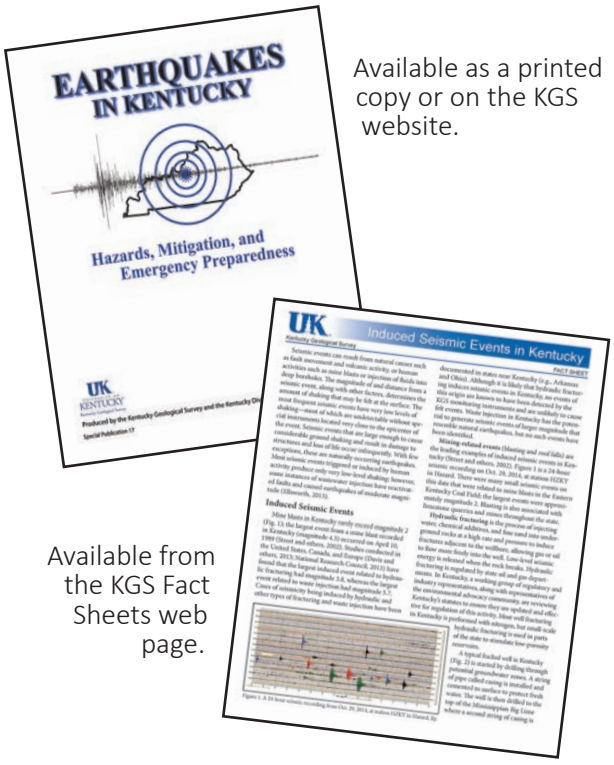
Among the new titles:

Ten Quaternary and surficial geologic maps of 7.5-minute quadrangles were completed by Geologic Mapping Section staff. These maps were produced with funding from the U.S. Geological Survey's STATEMAP program.

Matt Crawford of the Geologic Hazards Section completed "Kentucky Geological Survey Landslide Inventory: From Design to Application" (Information Circular 31, 2014). This technical publication describes the design and compilation of the online KGS landslide database that Crawford maintains and its value and use.

Detail from the Quaternary geologic map of the Paducah East 7.5-minute quadrangle, western Kentucky.

"Earthquakes in Kentucky: Hazards, Mitigation, and Emergency Preparedness" (Special Publication 17, 2014), was written by **Seth Carpenter, Zhenming Wang,** and **Mike Lynch.** This 11-page nontechnical booklet was produced to help the Kentucky Division of Emergency Management explain the earthquake hazard in Kentucky, potential effects from earthquakes, and how to prepare for damaging earthquakes.

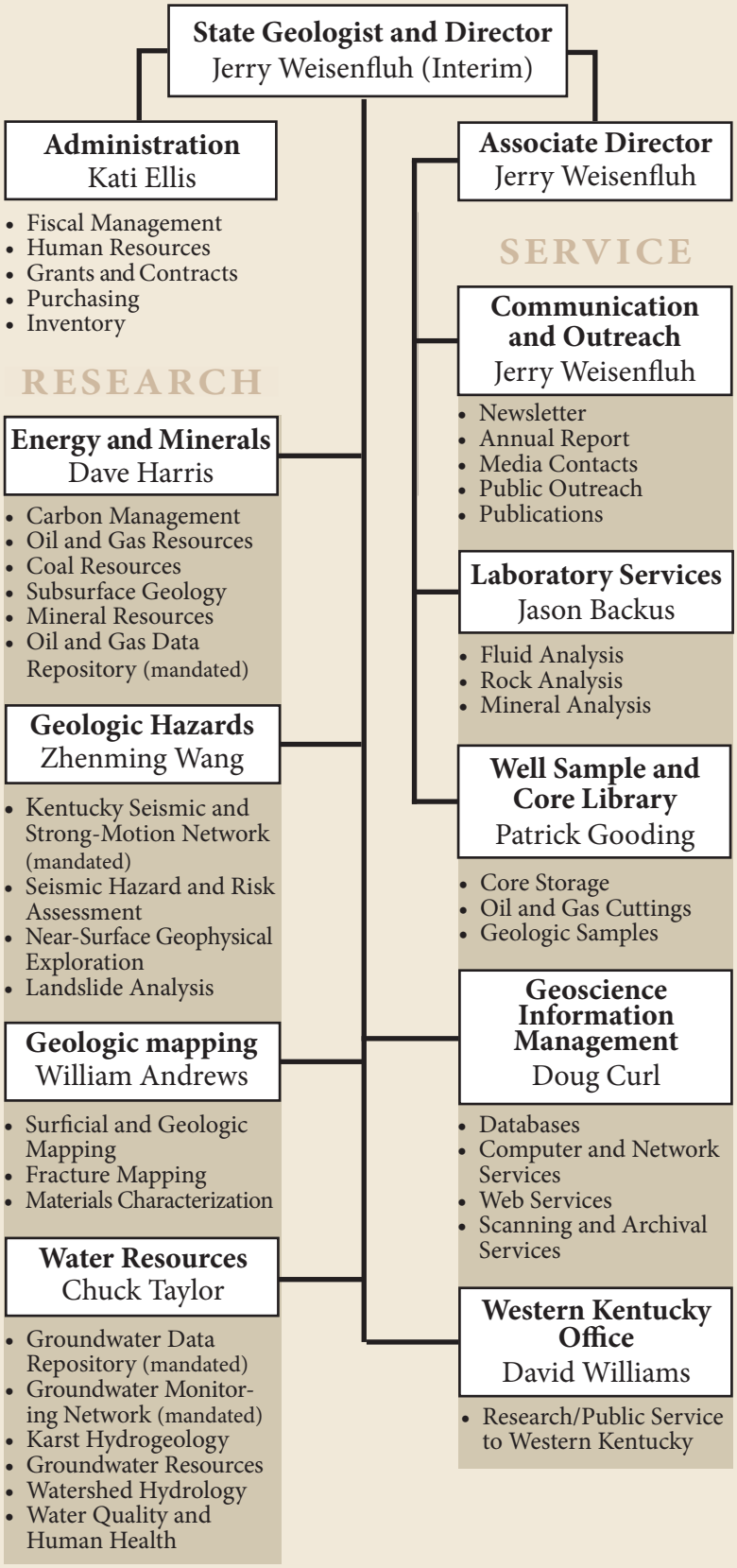


Available as a printed copy or on the KGS website.

Available from the KGS Fact Sheets web page.

Several KGS staff wrote and illustrated a new fact sheet, "Induced Seismic Events in Kentucky" (Fact Sheet 2, 2014). Human-caused earthquakes resulting from deep injection of waste fluids produced by oil and gas operations have been getting attention from the news media, environmental groups, and property owners. This publication addresses the possibilities of such events in Kentucky. ●

KGS Organizational Chart



Research Projects

Fiscal Year 2014-15

ENERGY

Carbon Management

CO_2 Sequestration and Enhanced Oil and Gas Recovery Using CO_2
End date 6/30/2016
Funding source: Governor's Office of Energy Policy

Midwest Regional Carbon Sequestration Partnership (Appalachian Basin)
Fiscal year funding: $99,969
End date: 12/31/2019
Funding source: U.S. Department of Energy through Battelle Memorial Institute

Coal Resources

Resource Assessment for the Extraction of Rare Earth Elements from Coal
Fiscal year funding: $115,071
End date: 12/1/2014
Funding source: National Energy Technology Laboratory

Oil and Gas Resources

Berea Consortium Project
Fiscal year funding: $82,500
End date: 1/31/2016
Funding source: industry consortium

GEOLOGIC INFORMATION

Coal Information

Computerized Coal Resources for the National Coal Resources Data System
Fiscal year funding: $15,000
End date: 6/30/2015
Funding source: U.S. Geological Survey

Data Dissemination

National Geologic and Geophysical Data Preservation Program
Fiscal year funding: $31,789
End date: 8/31/2015
Funding source: U.S. Geological Survey

National Geothermal Data System Program
End date: 12/31/2014
Funding source: U.S. Department of Energy through Arizona Geological Survey

Watershed Watch of Kentucky Web-Based System for Data Preservation
Fiscal year funding: $50,000
End date: 12/31/2014
Funding source: Watershed Watch of Kentucky Inc.

GEOLOGY

Geologic Mapping

Quaternary and Surficial Geologic Mapping for Multiple Applications in Kentucky
Fiscal year funding: $162,774
End date: 7/31/2016
Funding source: U.S. Geological Survey

Geology and Human Health

Fiscal year funding: $3,163
End date: 6/30/2015
Funding source: Kentucky Department for Public Health

Subsurface Investigations

Development of Subsurface Brine Disposal Framework in the Northern Appalachian Basin
Fiscal year funding: $51,792
End date: 9/30/2015
Funding source: U.S. Department of Energy through Battelle Memorial Institute

HAZARDS

Karst Risk Assessment

Sinkhole Probability Mapping: Integrating Human Impacts and Natural Processes in Conjunction with LiDAR to Predict Karst Subsidence
Fiscal year funding: $5,000
End date: 2/29/2016
Funding source: Kentucky Water Resources Research Institute through U.S. Geological Survey

Seismic Risk Assessment

Microseismicity in the Ste. Genevieve, Wabash Valley, and Rough Creek Seismic Zones Using Earthscope Flex Array Data: Implications for Earthquake Hazards
Fiscal year funding: $31,347
End date: 12/31/2015
Funding source: U.S. Geological Survey

WATER RESOURCES

Surface-Water Characterization

Surface Water Quality Assessment for Training Areas 7 and 8, Wendell H. Ford Training Site
Fiscal year funding: $94,953
End date: 6/30/2016
Funding source: Kentucky Department of Military Affairs

Water Information

Sinkhole Recognition from LiDAR
Fiscal year funding: $9,803
End date: 2/28/2015
Funding source: Kentucky Transportation Cabinet

Staff Awards and Appointments

Bethany Overfield serves on the board of the Kentucky River Watershed Watch and as treasurer for the organization, which works to protect water quality in the Kentucky River Basin.

William Andrews is an invited technical advisor for the Kentucky Geographic Information Advisory Council. He also serves as an adjunct graduate faculty member for the UK Department of Geography and a staff sponsor for UK's men's volleyball club.

Doug Curl is the KGS designee to the Kentucky Geographic Information Advisory Council.

Jerry Weisenfluh continues his role of ex-officio member of the Kentucky Board of Registration for Professional Geologists.

Glynn Beck is a member of the Kentucky Agriculture Science and Monitoring Committee. He is also on the Environmental and Natural Resource Issues Task Force, formed in 1994 to develop environmental education programs for the University of Kentucky College of Agriculture, Food and Environment's Cooperative Extension Service.

Chuck Taylor is also on the Agriculture Science and Monitoring Committee and serves as an appointed member of the Kentucky Agriculture Water Quality Authority.

Bart Davidson serves on the Kentucky Water Well Drillers' Certification Board.

Ray Daniel received a Geological Society of Kentucky Service Award and was re-elected to serve as a councilor at large for the GSK.

Retired Water Resources Section Head **Jim Dinger** received the Distinguished Service Award from the Geological Society of Kentucky.

Patrick Gooding continues to serve as secretary/treasurer of the Geological Society of Kentucky and received a service award from GSK. He serves on the House of Delegates to the American Association of Petroleum Geologists and on four AAPG committees.

Richard Smath received a Presidential Certificate of Merit from the Kentucky Section of the American Institute of Professional Geologists.

Zhenming Wang was promoted to adjunct associate professor in the UK Department of Earth and Environmental Sciences and is also an adjunct research fellow for the Institute of Crustal Dynamics of China's Earthquake Administration.

Matt Crawford is vice-chair of the Geological Society of America's Environmental and Engineering Geology Division and also serves on the organizing committee for the Geohazards Impacting Transportation in Appalachia annual technical forum.

John Hickman was elected treasurer of the Eastern Section of the American Association of Petroleum Geologists for 2014-15.

Dave Williams was reappointed to the Henderson City/County Planning Commission and was elected vice moderator for the commission.

KGS Staff

Fiscal Year 2014-15

STATE GEOLOGIST'S OFFICE

Cobb, Jim
State Geologist Emeritus

Weisenfluh, Jerry
Interim Director

ADMINISTRATIVE

Ellis, Kati
Administrative Staff Officer II

Long, Mandy
Administrative Support Associate I

Phillips, Gwen
Staff Support Associate II

ENERGY AND MINERALS

Harris, Dave
Section Head

Anderson, Warren
Geologist V

Bowersox, Rick
Geologist IV

Davis, Ethan
Student Worker

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

Wang, Zhenming
Section Head

Carpenter, Seth
Geologist IV

Chen, Jifeng
Temporary Technician

Crawford, Matt
Geologist III

Kang, Jianhong
Temporary Technician

Potter, Grondall
Student Worker

Rodriguez Asihama, Paul
Student Worker

Rong, Mianshui
Temporary Technician

Woolery, Ed
Geophysics Faculty Associate

Zhu, Gengqing
Temporary Technician

GEOSCIENCE INFORMATION MANAGEMENT

Curl, Doug
Section Head

Adams, Elizabeth
Geologist I

Carden, Darion
Student Worker

Cecil, Matthew
Student Worker

Ellis, Mike
Computer Support Specialist II

Hodelka, Bailee
Temporary Technician

Pulliam, Carrie
Geologist II

Seckinger, Clay
Student Worker

Smath, Richard
Geologist III

Thompson, Mark
Information Technology Manager I

Wang, Rebecca
Database Analyst

COMMUNICATIONS AND OUTREACH

Weisenfluh, Jerry
Section Head

Banks, Roger
Stores Supervisor

Hounshell, Terry
Chief Cartographic Illustrator

Lynch, Mike
Technology Transfer Officer

Rulo, Collie
Senior Graphic Design Technician

Smath, Meg
Geologic Editor

GEOLOGIC MAPPING

Andrews, William
Section Head

Hammond, Max
Geologist I

Hansen, Antonia
Geologist I

Martin, Steve
Geologist III

Overfield, Bethany
Geologist III

Priddy, Michael
Student Worker

WATER RESOURCES

Taylor, Chuck
Section Head

Caudill, Robin
Student Worker

Cooper, Marie
Student Worker

Currens, Jim
Geologist V

Davidson, Bart
Geologist IV

Nolte, Adam
Student Worker

Pierskalla, Bill
Student Worker

Webb, Steve
Geologist II

Zhu, Junfeng
Geologist V

LABORATORY

Backus, Jason
Scientist II/Laboratory Manager

Conner, Andrea
Scientist I

WELL SAMPLE AND CORE LIBRARY

Gooding, Patrick
Geologist IV/Manager

Daniel, Ray
Principal Research Analyst

Pinkston, Ryan
Research Analyst

Young, Denzel
Student Worker

HENDERSON OFFICE

Williams, Dave
Section Head

Beck, Glynn
Geologist IV (Water Resources Section)

Bleichroth-King, Amy
Temporary Technician

Waninger, Scott
Geologist II (Geologic Mapping Section)

Schmeisser-King, Kristen
Temporary Technician

Keimig, Holly
Temporary Technician

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

Retired KGS mapper
Martin Noger
dies in March

Martin Charles Noger, who worked at KGS for 27 years, died on March 3 at the Thomson-Hood Veterans Center in Wilmore, Ky. Noger was born in Hazard, Ky., on November 30, 1923. He was a graduate of the University of Kentucky and also served in Europe during World War II.

Before he was hired by KGS, he spent 13 years as an exploration geologist at Shell Oil. Known as "M.C." at the Survey, he coordinated the geologic mapping of Kentucky with the U.S. Geological Survey, making Kentucky the first state of significant size to be completely mapped at a detailed scale. Noger retired from the Survey in 1993, but he continued to work part-time at KGS through 2005.

He authored or co-authored 40 KGS publications on a broad range of topics, including tar sands, subsurface stratigraphy, roadside geology, and geologic land use. He compiled the "Geologic Map of Kentucky: Sesquicentennial Edition of the Kentucky Geological Survey" (1988).

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Lexington, KY 40506-0107

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