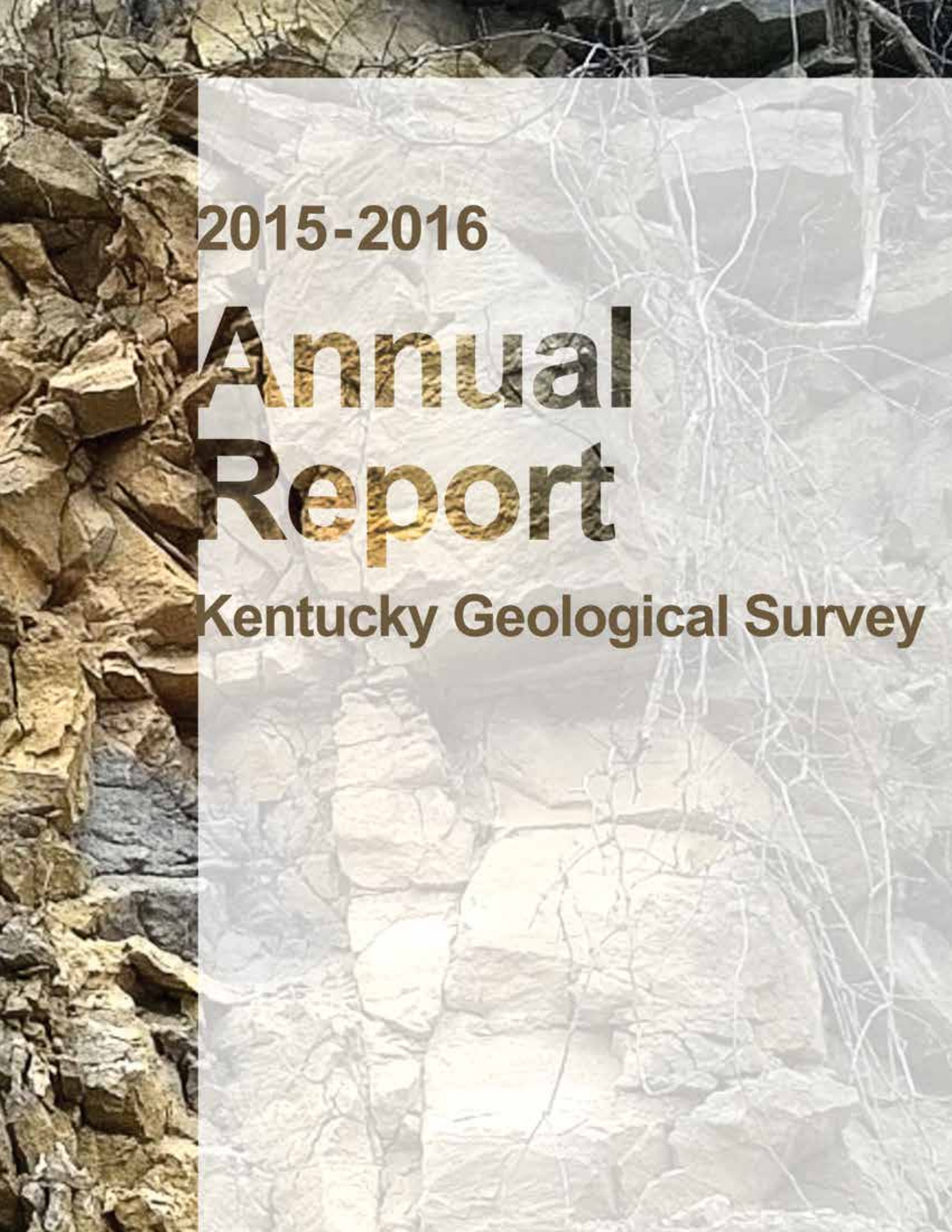




2015-2016

Annual Report

Kentucky Geological Survey



KGS Annual Report

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The Kentucky Geological Survey is a department under the University of Kentucky, Office of the Vice President for Research. Since 1854, KGS has investigated a wide range of geologic and hydrologic topics important to the commonwealth. Its 45 staff members conduct field studies across the state and provide data, reports, and advice to industry, State government, academia, and the public. The director is also the state geologist of Kentucky.

Contents

From the Associate Director	3
-----------------------------	---

Water Resources	4
-----------------	---

Energy and Minerals	10
---------------------	----

Geologic Hazards	16
------------------	----

New State Geologist and KGS Director	20
--------------------------------------	----

Geologic Mapping	22
------------------	----

Geologic Information Management	24
---------------------------------	----

Western Kentucky Office	28
-------------------------	----

Well Sample and Core Library	30
------------------------------	----

Outreach Activities	32
---------------------	----

Research Projects	34
-------------------	----

Publications	36
--------------	----

Staff Awards and Appointments	37
-------------------------------	----

KGS Staff	38
-----------	----

KGS Organizational Chart	39
--------------------------	----

In Memoriam	40
-------------	----

On the Cover

The uppermost Big Clifty Sandstone Member of the Golconda Group underlies the Haney Limestone Member of the Golconda Group on the north side of the Western Kentucky Parkway, 3 miles east of the Millerstown Road exit, near Clarkson, Grayson County. Tidal creeks in the upper Big Clifty are filled with gray, coarse-grained crinoid-columnal biosparite limestone, indicating that deposition was in a shoreline environment. The Haney Limestone, capping the roadcut about 12 feet above road level, is a light yellow-brown, flaggy, packed biomicrite from a bryozoan bioherm, a reef-like limestone buildup found in shallow near-shore deposits. On weathered surfaces, many varieties of fossil bryozoans (colonial organisms) can be seen. Photo by **Rick Bowersox**, KGS Energy and Minerals Section.

From the Associate Director



This past year the Arizona Geological Survey lost all of its base funding when the state's executive branch transferred the Survey from state government to the University of Arizona. With only grants and contracts to support its functions and considerably less space for operations, the AGS staff has been reduced by about half of the previous workforce. And its future is extremely uncertain. When news like this reaches our office, it causes us to reflect about the contributions we make to the citizens of Kentucky, and whether they are valued by our government agencies, academia, private-sector companies, and landowners. When you read this issue of the KGS annual report, you will find that virtually all of our research and service work is focused on the state of Kentucky, and our scope of work spans energy, mineral, and water-resource assessment; geologic-hazards characterization and mitigation; geologic mapping; public health issues in the context of geology; and data preservation and dissemination.

Many State agencies, such as the divisions of the Department for Natural Resources and the Transportation Cabinet, depend on KGS maps, data, and expertise to conduct their day-to-day activities. KGS staff participate in many State advisory boards and committees to make sure our expertise is available when needed. Likewise, we provide geologic and technical assistance to private, nonprofit groups such as Kentucky River Watershed Watch in areas where our missions overlap. And despite our small size, we routinely give assistance to private citizens when they experience geologic issues on their land, such as cover-collapse sinkholes or landslides. Our strategic decision to provide

all of our data free of charge over the Internet has resulted in a decade and a half of advantages to all the sectors in Kentucky and around the globe that depend on our information. The benefit of instant access to the information goes far beyond the savings in costs accrued to our users.

KGS is also an important asset for economic development in Kentucky. Research projects related to energy resources have stimulated interest in new developments related to the Berea Sandstone and Rogersville Shale unconventional reservoirs. Our geologic mapping information is an essential beginning point for developing land wisely and avoiding natural hazards. And samples and cores made available by the KGS Well Sample and Core Library can be just what is needed to stimulate interest in an exploration program.

This issue of the KGS annual report contains many stories that highlight activities like these that benefit the commonwealth. I hope you enjoy reading it.

A handwritten signature in dark ink, reading "G.A. Weisenfluh". The signature is fluid and cursive, with the first letters of the first and last names being capitalized and prominent.

G. A. "Jerry" Weisenfluh

Water Resources

The Water Resources Section conducts groundwater and surface-water investigations and helps meet the water-related data and scientific-technical needs of State and federal agencies, local municipalities, other UK and state university researchers and students, environmental and geotechnical consultants, and the general public. By legislative mandate, the section is also responsible for maintaining the State's official groundwater data repository and for oversight of a statewide groundwater-monitoring network.

During fiscal year 2015-16, Water Resources staff conducted research and collected data that spanned from one end of the state to the other. Two major water-quality sampling projects, one focused on surface water and the other on groundwater, were conducted in the Western and Eastern Kentucky Coal Fields, respectively. Other efforts included establishing well sites for a new statewide groundwater-level observation network, conducting aquifer tests to better characterize aquifers and groundwater availability, and researching the occurrence of and factors contributing to cover-collapse sinkholes.

Water-Quality Sampling and Assessment at the Wendell H. Ford Regional Training Center

The section completed field water-quality sampling for a project conducted in collaboration with the Kentucky Department of Military Affairs and the Kentucky Army National Guard at the Wendell H. Ford Regional Training Center in Muhlenberg County. Hydrogeologists **Steve Webb, Glynn Beck, and Bart Davidson** worked under often-difficult field conditions collecting dry-season samples during September and October 2015 at approximately 98 streams and ponds in Training Areas 7 and 8 at the training center.

The results obtained from this round of sampling will be compiled and evaluated along with sampling results collected previously under wet-weather conditions from the same sites during March and April 2015. Much of the training center is located on previously mined land.

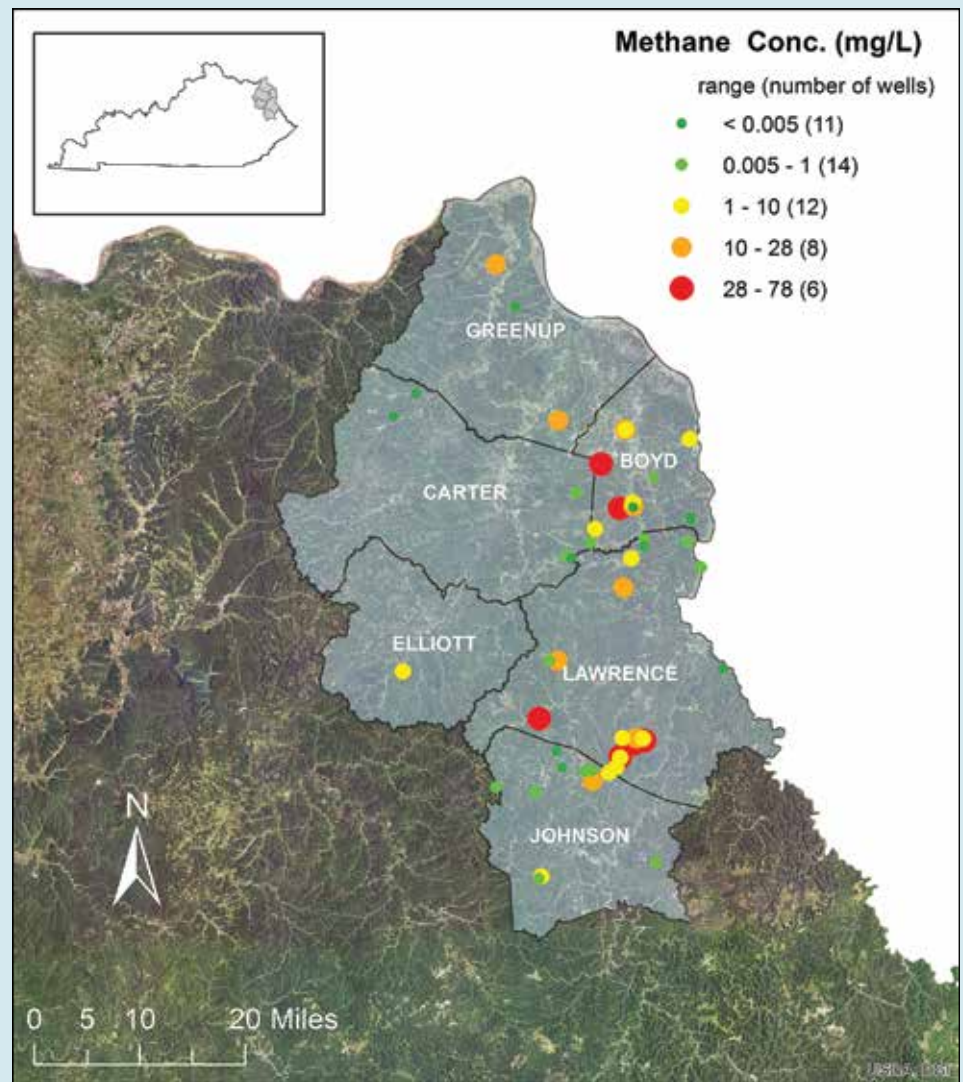
The results obtained by this project will provide Army National Guard resource managers with baseline data needed to evaluate the existing quality of the surface water at the training center, and help identify and set priorities for areas in which best land-use practices or remedial actions can be implemented to improve environmental conditions.

Field Sampling of Water Wells in the Berea Sandstone Oil and Gas Play, Northeastern Kentucky

Recent interest and increases in the use of horizontal drilling and hydraulic fracturing technology to extract oil and gas from low-permeability reservoir rocks has increased public concerns about possible impacts to the environment, especially shallow freshwater aquifers. In parts of eastern Kentucky, horizontal drilling and fracturing are being used to extract gas and oil associated with the Upper Devonian Berea Sandstone, and exploratory efforts are also under way in limited areas underlain by the Rogersville Shale, a deep, thick, organic-rich shale projected to also become a major oil and gas play in eastern Kentucky.

Given the likely increase in energy-extraction activities, background information about existing groundwater quality in shallow aquifers in the Berea and Rogersville play areas is critical to help address the public's environmental concerns and protect groundwater resources.

During March and April 2016, hydrogeologists **Steve Webb** and **Bart Davidson**, assisted by geologist **Richard Smath** of the Geoscience Information Section, collected and analyzed samples from 51 domestic and public water-supply wells in Greenup, Carter, Boyd, Lawrence, Johnson, and Elliott Counties. Samples were analyzed for major cations and anions, trace metals, and dissolved gases including methane. Wells with elevated methane



methane typically associated with oil and gas production was present or detectable in the area's freshwater aquifers. Results obtained from this research indicate that methane is a relatively common chemical constituent in groundwater in the Berea

wells drilled in many lower-permeability rocks in eastern Kentucky. The isotopic and water-chemistry data also indicate that the methane detected in groundwater in the study area is mostly generated from microbial activity under anaerobic (chemically reducing) conditions. The sampling results obtained during this project, which will be made publicly available in a forthcoming report, serve as a valuable reference data set that will be critical to assessing any potential impacts of horizontal drilling and hydraulic fracturing on groundwater resources in the area.

The successful completion of this important project required the involvement and collaboration of many partners: University of Kentucky agricultural county Extension Service agents and personnel from the Kentucky Rural Water Association assisted in contacting domestic well owners and identifying wells suitable for sampling. KGS conducted the

Given the likely increase in energy-extraction activities, background information about existing groundwater quality in shallow aquifers in the Berea and Rogersville play areas is critical to help address the public's environmental concerns and protect groundwater resources.

concentration were also analyzed for carbon and hydrogen in order to identify or chemically "fingerprint" sources of methane, and to determine if thermogenic

and Rogersville play areas. Its occurrence in the study area was typically associated with sodium-bicarbonate-dominated groundwater, which is encountered in

project in collaboration with researchers from GSI Environmental Inc., based in Austin, Texas, who are developing and testing sampling protocols for methane in domestic water-well systems as part of a larger national project funded by the U.S. Department of Energy's Research America program, in collaboration with the Environmentally Friendly Drilling Systems Consortium. GSI Environmental personnel visited the study area with KGS staff during the first two weeks and assisted with some groundwater sampling. Inorganic chemical constituents and metals were analyzed by the KGS water laboratory, dissolved gases and methane were analyzed by Eurofins Laboratory in Pennsylvania, and stable isotopes were analyzed by IsoTech Laboratories in Illinois. Analytical results were evaluated and interpreted by project leader **Junfeng Zhu** and by **Marty Parris**, with the KGS Energy and Minerals Section. UK Department of Earth and Environmental Sciences students **Ethan Davis** and **Adam Nolte** also contributed to data compilation, and additional project assistance was provided by Water Resources Section hydrogeologist **Glynn Beck** and **Section Head Chuck Taylor**.

Water-Quality Sampling in Collaboration with Kentucky Division of Water

The Kentucky Division of Water is responsible for sampling about 60 groundwater sites (both wells and springs) across Kentucky that comprise the Kentucky Interagency Groundwater Monitoring Network (www.uky.edu/KGS/water/gnet). These samples are intended to provide data needed to characterize and track changes in the groundwater quality of aquifers used for potable water throughout the state. Most samples are collected once a quarter or twice a year by Division of Water personnel on 12 different sampling runs across the state.

Beginning in February 2016, KGS personnel began sampling three sites in the Inner Bluegrass on behalf of the Division: McConnell Springs and Russell Cave Spring in Fayette County, and Royal Spring in Scott County. The Environmental Services Branch Laboratory in Frankfort continues to analyze these samples.

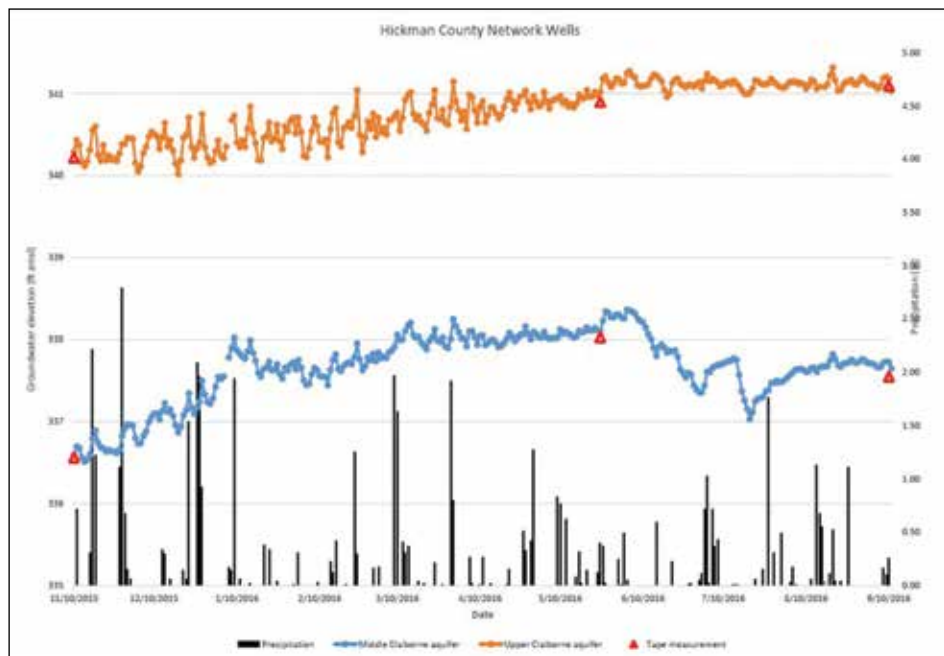
Kentucky Groundwater Data Repository

The Kentucky Groundwater Data Repository contains data for more than 102,000 wells, including domestic, public, industrial, monitoring, and agricultural wells. In addition, data for more than 5,200 springs and 45,000 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. Well and sample data collected through the Division's Certified Well Driller Program and the Kentucky Interagency Groundwater Monitoring Network are uploaded to the repository approximately once every quarter, providing users with 24/7 access to the most recent groundwater data available. Scanned water-well drillers' logs and associated documents are uploaded to the repository approximately every six months.

Results from these sampling sites, and all others in the Interagency Groundwater Monitoring Network, are stored in and publicly accessible from the KGS Groundwater Data Repository website.

Kentucky Groundwater Observation Network

Progress continues on reestablishing a statewide network of groundwater-level observation wells. **Glynn Beck** oversaw the installation of four new network observation wells in the Jackson Purchase.



Preliminary hydrographic data from the shallow (top) and deep (bottom) well cluster near Clinton in Hickman County show water-level fluctuations relative to precipitation in wells that are part of the new Kentucky Groundwater Observation Network.

KGS contracted with Gus Well Drilling Inc. to install the four monitoring wells. Two wells were installed in Calloway County and two in Hickman County. The Calloway County wells are located at the Murray State University Hutson School of Agriculture West Research Farm. One well is completed in the Lower Wilcox aquifer and the other is completed in the McNairy aquifer. The Hickman County wells are on private property in Clinton owned by the Naranjo family. One well is completed in the Upper Claiborne aquifer and the other in the Middle Claiborne aquifer. Continuous groundwater-elevation data have been collected at each site since early November 2015.

At present, 10 wells are being monitored as part of the observation network, including the four Jackson Purchase wells listed above. The other wells are one observation well completed in the McNairy aquifer near Benton in Marshall County, one observation well at the KGS Western Kentucky Office completed in a shallow confined alluvial aquifer, one well completed in fractured-karstic limestone in Mammoth Cave National Park, one well completed in fractured-karstic limestone in Hardin County, and two wells completed in fractured-karstic limestone in Scott County. Several additional wells are undergoing preliminary evaluations, including video

and gamma-ray borehole logging, hydraulic tests (slug or drawdown-recovery tests), and water-level monitoring. One well was completed in karstic limestone in Logan County, two wells were completed in fractured sandstone in Breathitt County, and one well was completed in fractured sandstone in Lawrence County. Other unused wells are being sought in certain parts of the state, in order to establish 15 observation wells for the network by early 2017.

A website is being created to display hydrographs of water-level measurements obtained from each network observation well. The wells in the network will help fulfill KGS's legislative mandate to collect data needed to assess the quantity and availability of the state's groundwater resources. Samples will also be periodically collected and analyzed from the network wells to help provide baseline information about groundwater quality in the aquifers being monitored.

Aquifer Test of Municipal Supply Wells in Elizabethtown, Kentucky

An aquifer test of public water-supply wells in Elizabethtown was conducted by **Junfeng Zhu, Chuck Taylor, and Steve Webb** in October 2015. The test

was conducted on behalf of Hardin County Water District No. 2 to obtain data needed by managers to evaluate the practicality and economical effects of increasing withdrawals from well PW-1, the primary water-supply well, completed in a fractured-karstic limestone aquifer at the Elizabethtown water treatment plant.

The test was conducted using PW-1 as the sole pumping well, and monitoring the rate of withdrawal from PW-1 and water-level changes in four nearby wells over a 24-hour period. Both well drawdown and recovery (after pumping ceased) were recorded and used in the analysis. Large values of hydraulic conductivity and transmissivity calculated from pumping-test data are typical of highly productive karstic limestone aquifers. The data obtained from the test results were also used to predict changes in the cone of depression (or zone of contribution) caused by pumping groundwater at other withdrawal rates under alternative management scenarios.

Other Aquifer Tests and Short-Term Groundwater Monitoring

The University of Kentucky Research and Education Center at Princeton, which is part of the College of Agriculture, Food and Environment, currently has three irrigation wells on site. One of the wells is used for drip irrigation of tobacco, one for lateral irrigation of corn, and the other is unused. The wells are completed in karstic fracture-flow limestone bedrock. **Glynn Beck and Steve Webb** conducted an aquifer test on two of the wells in order to better characterize the hydraulic properties of the local fractured-karstic limestone aquifer. The unused well has been instrumented with a pressure transducer to record changes in groundwater elevation. Data from the transducer will help the center's researchers determine how extended pumping of the irrigation wells during the growing season will affect local groundwater levels. Water Resources personnel plan to continue working with center personnel over the next year to conduct karst dye tracing and electrical-resistivity profiles on newly acquired property. Results from this work will help the center locate a site at which to install a high-yield well for a pivot-irrigation system.



Junfeng Zhu records the rate of groundwater discharge from a municipal supply well during an aquifer test at the Elizabethtown Water Treatment Plant.



Steve Webb uses a tethered boat with acoustic-Doppler stream-monitoring equipment to measure discharge in a stream at the Kentucky National Guard's Wendell H. Ford Regional Training Center.

Karst Hydrogeology and Sinkholes

Karst hydrogeologic mapping and evaluation of sinkhole hazards continued during 2015-16. Karst hydrogeologist **Jim Currans** worked on data compilation necessary to create additional maps in the KGS Karst Atlas. The Elizabethtown and Louisville 30 x 60 minute quadrangle karst groundwater basin maps were completed in 2016, and maps for the Tompkinsville and Corbin quadrangles are very close to being ready for publication. Currans

also made progress on the Morehead and Paducah-Madisonville quadrangles; these may be completed and published by early 2017.

Currans also continued to investigate and document the occurrence of cover-collapse sinkholes in the state, examining 13 such features in 2015, and 13 to date in 2016. A report on the distribution of these sinkholes and possible factors that contribute to their occurrence is in preparation and is anticipated to be published by early 2017. In addition to

these activities, Currans continues to assist the general public by answering inquiries about sinkhole occurrences and conducting site inspections. In 2015-16, he responded to 64 requests for assistance.

Hydrogeologist **Junfeng Zhu** continued to use a newly available LiDAR terrain elevation data set to map sinkhole occurrences in parts of Kentucky. Last year, LiDAR-delineated sinkholes were mapped in Bullitt, Jefferson, and Oldham Counties, resulting in an additional 4,140 sinkhole features being added to the KGS online map service. This year, 1,821 sinkholes were identified from LiDAR data for Fayette County; these features are still undergoing final processing and review. Zhu authored a paper published in the *Journal of Hydrology* on his innovative application of random forests data-processing techniques to enable computer-automation of the sinkhole identification process.

KGS Water and Rock Laboratory Activities

The KGS laboratory provides analytical services for the Survey's researchers, as well as other University of Kentucky researchers' water, coal, and rock samples. In addition to routine sample analysis, laboratory manager **Jason Backus** and analyst **Andrea Conner** collaborated with and trained students from numerous UK departments in analyses, techniques, and instrumentation that the lab uses on a daily basis.

The KGS laboratory analyzed samples for the Wendell H. Ford Training Center project summarized above. Water-monitoring testing for the KGS Cane Run project continues every other week, as well as water-quality testing for an ongoing KGS Water Resources Section statewide groundwater monitoring project. The laboratory also analyzed groundwater samples for the project in cooperation with GSI Environmental to assess water quality in the Berea play area.

Total organic carbon determination and shale/coal analysis was performed for the KGS Energy and Minerals Section on a routine basis for projects studying the Berea play and rare earth elements. Total carbon and inorganic carbon were tested in order to determine total organic carbon values for approximately 200 samples.

Ethan Davis, an Earth and Environmental Sciences student, was taught how to perform inorganic carbon analysis using the coulometer and total carbon analysis using the combustion analyzer. Total sulfur, proximate, and X-ray fluorescence elemental analysis were also performed during the year.

A large project was conducted with the UK Department of Mining Engineering to study the concentrations of rare earth elements in coal ash and byproducts. Approximately 750 samples were processed, digested, and analyzed in the KGS laboratory.

Samples from **Ming Gong** from the UK Chandler Medical Center continue to be analyzed for sodium and potassium using inductively coupled plasma atomic emission spectroscopy. The study is investigating the uptake and transport of these elements in certain organs in mice.

Work with the Kentucky Watershed Watch program continues. Samples from low flow in the Kentucky River watershed were analyzed by the lab for nutrients and total metals concentrations.

KGS Lab Expanding Its Teaching Responsibilities

Teaching students is increasingly becoming a larger responsibility of the lab. Twenty-two University of Kentucky students were taught analysis techniques and assisted in their research by the lab.

Four of **Mike McGlue's** students in the Department of Earth and Environmental Sciences were taught total organic carbon/shale analysis. Twelve students from all over the University, including the departments of Mining Engineering, Chemistry, Plant and Soil Science, Materials Science, and Chemical Engineering, were taught X-ray diffraction principles and techniques. Five graduate students of Earth and Environmental Sciences' **Mike McGlue** and **Dave Moecher** were taught X-ray fluorescence principles and techniques and used the technique for their research.

In addition, the lab participated in the STEM (science, technology, engineering, and math) project conducted by UK undergraduate students and led by

Student Mentoring and Education

KGS staff actively mentored and assisted educational research of UK students.

Hydrogeologist **Glynn Beck** assisted **Marie Cooper** of the University of Kentucky Department of Earth and Environmental Sciences as she completed work on a geophysical surveying project to collect data to better delineate aquifer zones and confining units in parts of the Jackson Purchase Region. Beck is conducting follow-up research based partly on Cooper's results, which includes collecting gamma-ray logs of existing water wells in the Purchase, and may use additional geophysical survey data gathered with Geologic Hazards Section seismologist **Ed Woolery** and his students in the UK Department of Earth and Environmental Sciences.

Beck is also beginning field work to assist research being conducted by Earth and Environmental Sciences graduate student **Jason Merrick** to develop a coupled groundwater-surface water flow model for the Obion Creek and Bayou de Chien watersheds in Hickman and Fulton Counties. Hydrogeologist **Junfeng Zhu** will also be involved in the study as Merrick begins developing a computer model to simulate groundwater levels and stream discharges in the study area. Zhu also supervised Earth and Environmental Sciences undergraduate student **Adam Nolte**, who assisted with the project using LiDAR to map sinkholes.

Earth and Environmental Sciences graduate student **Ben Currens** also worked with Water Resources Section personnel during the summer of 2016 on various projects, including updating karst hydrogeologic mapping and dye-tracer databases and assisting with field data collection at the Cane Run Basin karst water instrumentation system monitoring station.

Alan Fryar of the Department of Earth and Environmental Sciences. Water monitoring samples from several sites were submitted for analysis every other week during the academic year. This project brought middle and high school science teachers into the University research community to receive hands-on experience.

Finally, tours of the lab were given to six different groups, including professionals,

high school students, and undergraduate and graduate students in geology from UK and Morehead State University.



Energy and Minerals

Energy issues, whether relating to Kentucky's resource supply or the effects of resource recovery, are the subject of KGS research. Activities this year included investigation of emerging oil and gas plays, such as the Berea Sandstone and Rogersville Shale, as well as assessments of known resources, including coal from Kentucky's two coal fields and the heavy oils and tar sands of western Kentucky.

Other energy-related work maps wells used for injection of wastewater from drilling projects and investigates the geologic conditions in regions where horizontal drilling and hydraulic fracturing are occurring. KGS continues to participate in regional research into the possibility of deep geologic storage of carbon dioxide emitted by energy production and other industrial processes. Section staff also looked into the availability of rare earth elements, both in their natural environment and in coal and its byproducts.

Oil and Natural Gas Resources

Berea Sandstone Petroleum System Consortium

Funded by an industry consortium, the analysis of the Berea petroleum system in eastern Kentucky concluded in May 2016. The project was headed by KGS and included the U.S. Geological Survey, Ohio Division of Natural Resources, and R.J. Lee Group as in-kind technical partners. Industry partners were Fireborn Land and Energy, Nytis Exploration, EQT, Hay Exploration, Cimarex Energy, Vinland Energy, Abarta Oil and Gas, and Country Mark Energy Resources. Since 2012, the Upper Devonian Berea Sandstone oil play in northeastern Kentucky has become the leading oil producer in the state. The play developed in an area in which the primary source rocks, the Mississippian Sunbury Shale and the Devonian Ohio Shale, are immature or in the lower oil window. Thus, the overall motivation for the study was to understand the origin of the oil and gas, and the stratigraphic controls on reservoir quality.

The project was divided into three focus areas:



Marty Parris was one of the speakers at the final meeting of the Berea Sandstone Petroleum System Consortium.

1. Thermal maturity of the source rock and the organic and inorganic carbon content of source rocks was evaluated by **Cortland Eble**. Petrographic observations and vitrinite reflectance and programmed pyrolysis measurements were made on core and cutting samples from 12 wells extending from Scioto County in southern Ohio to Pike County in southeastern Kentucky.
2. Using oil and gas samples collected by **Marty Parris** from the industry-partner wells, gas chromatography, stable isotope, and biomarker measurements were used to characterize thermal maturity and the source of oils. Our data were compared with similar measurements from bitumen extracts to assess whether oils were generated locally or migrated from deeper in the Appalachian Basin. The thermal maturity and organic geochemical analyses were in collaboration with Paul Hackley of the USGS, with significant assistance from **Ethan Davis**.
3. **Steve Greb** used outcrop, core, and log data to assess the stratigraphic controls on porosity and permeability distribution in order to determine the economic viability of the Berea play. **Brandon Nuttall** analyzed historic and recent production trends in the Berea play.

The project concluded with a wrap-up meeting on April 26 at the KGS Well Sample and Core Library. Researchers from KGS, USGS, and the R.J. Lee Group presented their results. On April 27, **Steve Greb** and **Cortland Eble** led a field trip to eastern Kentucky to examine

outcrops of the Berea Sandstone and other relevant stratigraphic units. Seventeen technical and industry partners attended the wrap-up meeting and field trip. A final digital copy of the Berea analysis was provided to the partners and will remain confidential until May 1, 2017.

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 of 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 weight percent. This source rock is now being evaluated as a possible unconventional gas or oil reservoir, similar to Kentucky's

Devonian black shales. Four recent deep wells have been drilled to test the Rogersville Shale in Lawrence and Johnson Counties, and a fifth well was completed in Putnam County, W.Va. Data from the new wells remain confidential; however, initial reports are encouraging, and significant leasing activity for deep mineral rights 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 given numerous presentations on the hydrocarbon potential of the Rogersville Shale at regional and national technical conferences, and to various industry groups. A recent addition of new seismic data has prompted Hickman to begin revising past seismic interpretations of the structure and internal stratigraphy of the Rome Trough.

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, p. 16). As new well data are released, our understanding of the Rogersville Shale and its resource potential will improve.

Evaluation of Heavy-Oil and Tar-Sand Resources, Western Kentucky

The western Kentucky tar sands are located in a belt extending from Logan County to Breckinridge County, an area of about 975 square miles. Tar-sand resources are found in the Late Mississippian Big Clifty and Hardinsburg Sandstones and Early Pennsylvanian Caseyville Formation.



Partners in the Berea Sandstone Consortium took a field trip to examine outcrops of the Berea Sandstone and other stratigraphic units in eastern Kentucky.

An evaluation of the western Kentucky tar-sand resources by **Rick Bowersox** was completed in the spring of 2016 with the publication of three reports.

Information Circular 33, “Rocks to Roads to Ruin: A Brief History of Western Kentucky’s Rock-Asphalt Industry, 1888–1957” (45 pages), provides background on one of Kentucky’s most important mineral industries from its inception in the late 19th century to its collapse in the middle of the 20th century. Bowersox pored through period newspaper and trade-journal articles and advertising, KGS publications and reports, State and federal documents, legal decisions from various State and federal courts, and biographies of some of the major players in Kentucky’s rock-asphalt industry.

Report of Investigations 35, “Heavy-Oil and Bitumen Resources of the Big Clifty Sandstone, Northeastern Grayson County and Adjacent Hardin County, Kentucky” (21 pages), focuses on the largely

formations, totaling 3,346 million barrels of heavy oil and bitumen in place. This publication also clears up some of the mysteries surrounding the tar sands, including why calculations from core-analysis data do not add up to 100 percent fluid saturations, what the origin of the tar sands is, and what the original distribution of the tar-sand reservoirs is.

A summary of the major results of this research was presented at the KGS annual seminar in May 2016, followed by a core workshop presented by **Dave Williams** and **Rick Bowersox**. The cores, from two recent MegaWest Energy coreholes in Butler County, showed depositional facies and reservoir diagenetic features of the Big Clifty.

An expanded discussion of the annual seminar presentation was scheduled for the Eastern Section of the American Association of Petroleum Geologists annual meeting in Lexington in September 2016.



*Adits (surface entrances) dug by the Kentucky Rock Asphalt Co. at the Indian Creek Quarry in Edmonson County, about 1927. The company and its operations are among the topics discussed in “Rocks to Roads to Ruin: A Brief History of Western Kentucky’s Rock-Asphalt Industry, 1888–1957,” by **Rick Bowersox**.*

overlooked tar-sand resources in the area where the rock-asphalt industry began. It interprets the geology and estimates the volume of the resource, both identified and exploratory, for the Big Clifty in the region from Tar Hill in Grayson County to Summit in Hardin County.

Report of Investigations 36, “Heavy-Oil and Bitumen Resources of the Western Kentucky Tar Sands” (39 pages), interprets the geology and estimates the resources for the Big Clifty, Hardinsburg, and Caseyville

Dave Williams is working on a report of detailed descriptions of two of MegaWest Energy’s Big Clifty tar-sand cores for publication in late 2016 or early 2017.

Oil and Gas Workgroup

House Bill 563, passed during the 2016 Regular Session of the Kentucky General Assembly, reconvened the oil and gas workgroup to examine the regulations and management of technologically enhanced, naturally occurring radioactive waste materials generated by the oil and gas

industry. **Brandon Nuttall** was appointed to the group by Secretary Charles Snavely of the Energy and Environment Cabinet. Nuttall has given the group advice about the surface and subsurface distribution and geology of naturally occurring radioactive material in the state.

Carbon Storage

CO₂-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. The final report for these demonstration projects is nearing completion.

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 now covers 10 states with the addition of Delaware during the past year.

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 and potential for CO₂ enhanced oil or gas recovery.

KGS is heading up a regional assessment of the potential for carbon storage and enhanced gas recovery in organic-rich Devonian shales.

Data compilation for total organic carbon content, density, and maturity is complete for the Marcellus Shale, and the data are being modeled and mapped to update its carbon storage capacity. Data compiled for a report on the Ordovician Utica play will be used to model and update estimates for that shale.

KGS also continues collaborative research to investigate subsurface geology and refine models for estimating carbon storage capacity in deep Cambrian and

Ordovician reservoirs. KGS has presented the status of the project at partnership meetings at Battelle's facilities in Columbus, Ohio, and in team conference calls during the past year. The next phase of the project on the deeper stratigraphic section has begun. KGS will also assist the partnership with construction of a regional cross section beginning in the Michigan Basin across Ohio and Pennsylvania and ending in the offshore area of the East Coast.

Information and publications about the regional partnership can be found at www.mrcsp.org.

Coal Resources

National Coal and Energy Minerals

The National Coal and Energy Minerals Resource Data System is a national cooperative program between the U.S. Geological Survey and state geological surveys.

NCRDS provides funding for the collection and assimilation of coal-quality (proximate analysis, ultimate analysis, etc.), stratigraphic (borehole records, correlation, etc.), and resource data at the state level for inclusion in a series of national databases. The data will be used for a variety of regional and national resource and other energy assessments.

Although NCRDS was historically used to collect only coal data, the project has been expanded to include domestic solid-fuel, conventional, and geothermal energy resources.

Steve Greb manages the Kentucky part of the cooperative, and **Cortland Eble** and UK Department of Earth and Environmental Sciences students **Ethan Davis** and **Julie Floyd** all contributed this year by updating the coal-thickness and coal-quality databases, collecting total organic carbon and thermal maturity data for organic-rich shales, and making stratigraphic correlations and tagging Pennsylvanian and Devonian energy units on subsurface oil and gas well logs.



Pennsylvanian Geology of the Eastern and Western Kentucky Coal Fields

Steve Greb and **Cortland Eble** continued research on coal-bearing strata in both the Eastern and Western Kentucky Coal Fields. Although our state's coal production has continued to decline in recent years, the national and international geologic community remains interested in data from past mining, the general geology, and outstanding outcrops. Roadcuts in eastern Kentucky provide exceptional data on the lateral and temporal variation in coal characteristics as well as changes in overlying and underlying strata, which are being used in a variety of case studies.

Lateral variation in interval and sequence thicknesses is also being used to improve our understanding of basin subsidence during the Pennsylvanian. Depositional facies between coals are of particular interest to oil and gas researchers, because they can provide two- and three-dimensional exposures of a variety of coastal-deltaic reservoirs for comparison with downhole data from other areas.

Rare Earth Elements from Coal and Coal-Combustion Byproducts

KGS and researchers from the UK Department of Mining Engineering and the UK Center for Applied Energy Research are testing for economic concentrations of rare earth elements in Kentucky coal, coal-preparation refuse, and coal-fired power-plant byproducts. Rare earth elements are the lanthanide series elements (lanthanum through lutetium on the periodic table) and yttrium—collectively known as REEY.

This group of important elements has unique magnetic and conductive properties, making them critical in the production of cellphones, tablets, and computers—devices we rely on heavily.

Since the late 1980s, nearly all of the REEY used in the United States have been imported from China. The current project

at UK is part of an aggressive effort to boost domestic production. Funding for the project is through the U.S. Department of Energy. **Cortland Eble** and **Jason Backus** are the principal investigators from KGS.

Coal Information Update

Jerry Weisenfluh, **Cortland Eble**, **Tom Sparks**, and **Steve Greb** finished a coal education project funded by the Kentucky Department for Energy Development and Independence. The project updated coal-production data, resource maps, coal-quality data in the KGS databases, and general coal education information on the KGS website. New resource maps for the Upper Elkhorn No. 1 and Clintwood coal seams were completed. Several hundred coal-quality chemical analyses, coal-thickness data, and stratigraphic measured sections were added to corresponding coal databases. In addition, new content, photographs, and illustrations about coal

formation, classification, and uses were added to the “Coal Information” part of the website. These new pages will be incorporated into the main KGS website after final editorial review has been completed.

Mineral Resources

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, and analysis indicates that these igneous rocks exhibit some unique mineralogy that suggests a mantle intrusion complex in parts of the district.

A preliminary presentation was made at the North-Central Section of the Geological Society of America annual meeting, and several other presentations are planned for the 2016-17 fiscal year.

Although rare earth elements do occur in the ore-stage fluorites in the Western Kentucky Fluorspar District, the investigations have found only slight enrichment.

A report documenting the mineralogy, petrology, and analytics of these igneous rocks, containing abundant photographs, diffraction images, and analytical results,

has been written and is in review and should be published in the coming year.

Brines and Underground Waste Disposal

Mapping Underground Brine-Disposal and Enhanced-Recovery Wells

Environmental concerns—water safety, pollution, and induced seismicity—about wastewater disposal wells have received much attention recently from the news media and the public.

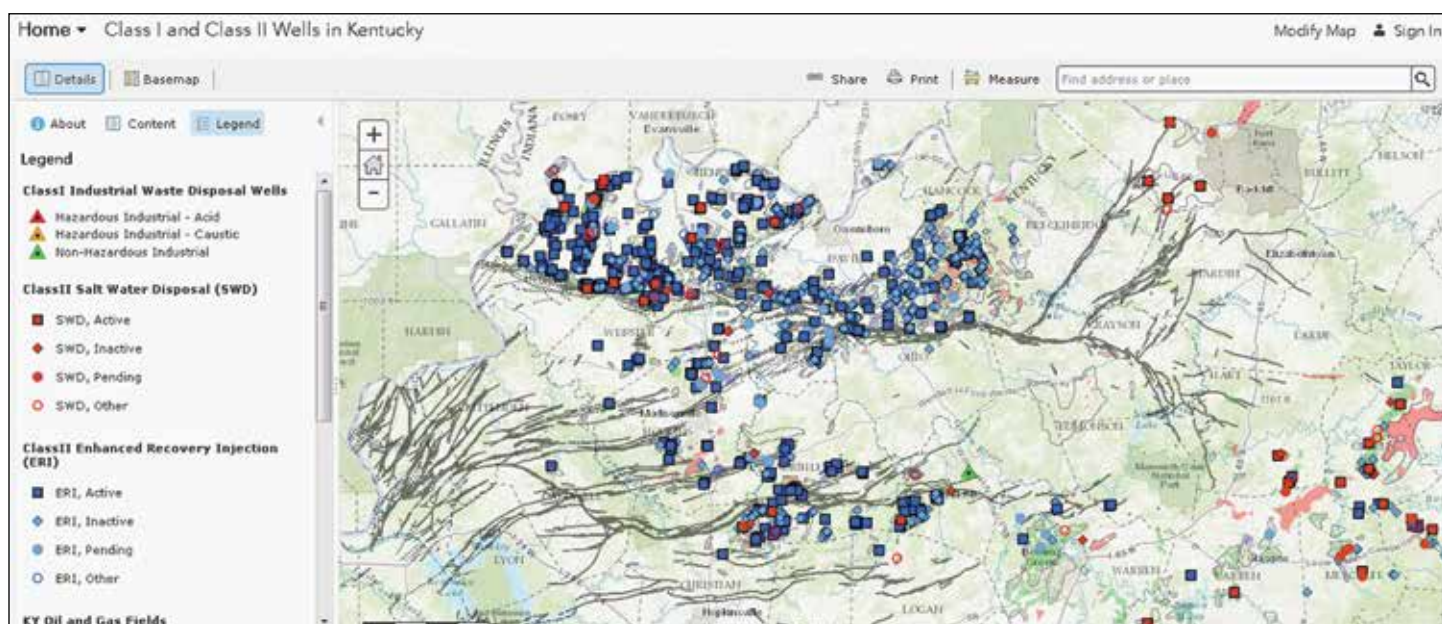
In wastewater disposal, brines brought to the surface with oil and gas production are reinjected into the same or porous underground formations similar to where they were initially produced. This practice helps protect underground drinking-water sources.

The U.S. Environmental Protection Agency maintains primacy by permitting and regulating all Class II wells in Kentucky under its Underground Injection Control Program, but the Commonwealth of Kentucky has formally applied for primacy. A completed application form was submitted by the Kentucky Division of Oil and Gas to the EPA in November 2015, and final approval is anticipated in the near future.

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 on the KGS Oil and Gas Data webpage. 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.

A new request was made to the EPA for brine-injection volumes of all currently active disposal wells in Kentucky, and was received in 2015. The current database was created in 2013 from a request for operational data (injection volumes and pressures) from 2008 through 2012. These new data will help with the microseismicity monitoring that is being conducted by 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.



A map service on the KGS website provides locations and other information about Class I waste-disposal wells and Class II injection-disposal wells in Kentucky.

Reassessing the Fresh-Saline Water Interface in Eastern Kentucky

The Berea unconventional oil and gas play in northeastern Kentucky is being developed using horizontal drilling and hydraulic fracturing (fracking).

Much of the development has occurred at depths of less than 2,000 feet from the surface, which has prompted concerns about protecting groundwater quality. The shallow depths call for diligence regarding well-casing integrity and depth of casing. Information about the distribution of potable groundwater is largely based on the “Fresh-Saline Water Interface Map of Kentucky” by **H.T. Hopkins** (Kentucky Geological Survey, scale 1:500,000, 1966). Examination of Hopkins’s methods shows, however, that the map likely underestimates the depth of the fresh-saline water interface in most places.

To make a more robust and accurate interpretation of the distribution of fresh and saline water in the subsurface, **Ethan Davis**, **Jerrad Grider**, and **Marty Parris** are updating the Hopkins map using new groundwater data and observations of

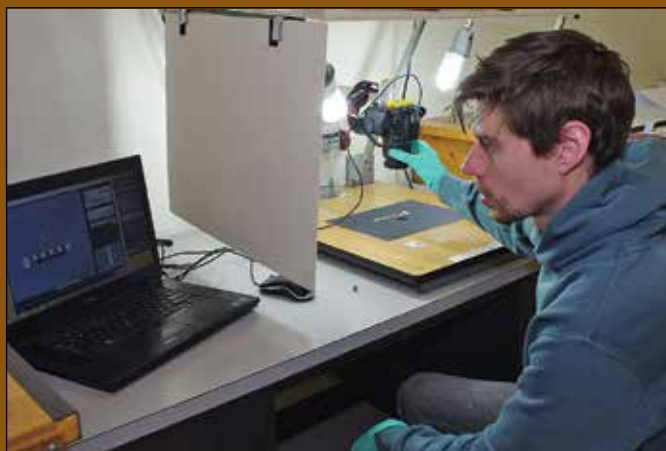
Much of the Berea play development has occurred at depths of less than 2,000 feet from the surface, which has prompted concerns about protecting groundwater quality. The shallow depths call for diligence regarding well-casing integrity and depth of casing.

fresh and salt water in oil and gas wells. Early results have increased the number of data points by a factor of four or more. The depth to the fresh-saline water interface has increased by hundreds of feet in some areas. The updated analysis and map remain an estimate, however, limited by data quality and the geologic complexity of aquifers. Nevertheless, an updated fresh-saline water interface map will provide a more accurate framework for deciding casing depth and analyzing groundwater quality in the context of energy resource development.

This project is being extended to include areas that might be affected by the nascent oil and gas play developing in the Cambrian Rogersville Shale.

Results of this work have been presented at conferences convened by the Kentucky Academy of Sciences, American Association of Petroleum Geologists—Eastern Section, and the Kentucky Water Resources Research Institute.

UK student **Ethan Davis** takes photos of specimens from the KGS meteorite collection for a new page on the KGS website. **Warren Anderson**, who curates the collection, hopes to unveil the photos and information about the collection during the next year. The collection consists of meteorites or thin sections of meteorites donated in 2014 by the late **William Russell**, a meteorite collector and amateur astronomer from Goshen, Ky., and specimens donated earlier by **William Ehman**, a former UK chemistry professor and nationally recognized meteorite and moon-rock researcher. Anderson plans to show the location where each meteorite fell on a map of the world, along with specific information about each meteorite, such as this one that fell in Clark County, Ky.





Geologic Hazards

The natural hazards that threaten Kentucky and its communities include earthquakes and landslides, and KGS staff actively work to increase our understanding of these two hazards and their potential effects on the state. Geologic hazards researchers gather earthquake data through a statewide seismic network, investigate the effects of hazard-mitigation policies, and interact with their counterparts in a continuing exchange with China's Earthquake Administration.

Information on landslides across the state is being gathered, incorporated into maps, and made available online, and landslide-monitoring stations have been set up in several locations where ground movement is occurring or likely to occur.

The Kentucky Seismic and Strong-Motion Network

The Kentucky Seismic and Strong-Motion Network continued to grow this fiscal year with three additional stations installed in eastern Kentucky. KGS maintained a real-time data share with the neighboring seismic network operated by the University of Memphis and also with the Data Management Center at Incorporated Research Institutions for Seismology for archiving. Data from networks operating in Kentucky and surrounding states, including EarthScope USArray stations (www.usarray.org), were acquired in tandem with real-time data from the Kentucky Seismic and Strong-Motion Network and used to detect seismic events in Kentucky with unprecedented sensitivity.

Eighteen earthquakes occurred in the state during the fiscal year, ranging in magnitude from 1.2 to 3.5. Seven of these events, including the largest, happened in the Mississippi Embayment, five occurred in the Bluegrass, five occurred in eastern Kentucky, and one was located south of Henderson. Eleven of the earthquakes were reported as felt by local residents. The May 1, 2016, magnitude-3.5 earthquake in northern Ballard County was the largest

earthquake to occur in Kentucky since the Nov. 10, 2012, Perry County earthquake, magnitude 4.2, and was felt in four states and as far away as St. Louis. Two of the eastern Kentucky earthquakes and one earthquake in the Bluegrass were not reported by other agencies.

Detailed analysis of these earthquakes, including determination of faulting style for two events, was possible because of a temporary network that KGS established with State support and in partnership with the UK Department of Earth and Environmental Sciences and private companies. By the end of the 2015-16 fiscal year, 13 of these temporary stations were operating. The data arrive at KGS in real time using wireless communication for processing and archiving.

Seismic data were analyzed by a student, **Kyle Combs**, of Paul Lawrence Dunbar High School in Lexington, for his Capstone Research Project, a part of the requirements for the Math, Science, and Technology Center of Fayette County Public Schools. Combs is reviewing archived data from the seismic network, along with data from the EarthScope USArray stations, in search of unreported microearthquakes, and will use these results to add to our knowledge about active faults in and near Kentucky.



KGS staff, visiting Chinese scholars, and UK students install seismic station EK-22 at the West Liberty Airfield, one of 13 stations in a temporary network to monitor background seismicity as well as induced quakes possibly caused by wastewater injection activities.

Earth and Environmental Sciences student **Paul Rodriguez Asihama** is using the same data set for his master's thesis to investigate new, robust methodologies to automatically differentiate between natural earthquakes and the ubiquitous seismic signals generated by mine blasts in and around Kentucky.

Another Earth and Environmental Sciences student, **Andrew Holcomb**, is investigating microseismicity recorded by the temporary eastern Kentucky network and characterizing that network's performance for his thesis. Rodriguez Asihama and Holcomb gave presentations on their research at the Eastern Section of the Seismological Society of America annual meeting in Memphis.



*High school student **Kyle Combs** consults with **Seth Carpenter** on seismic data processing and analysis. Combs is participating in the Fayette County Public Schools Math, Science, and Technology Center program.*

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," published in *Seismological Research Letters*. A report, "Site Characteristics, Instrumentation, and Recordings of the Central United States Seismic Observatory," was submitted for KGS publication.

Seismic Hazard and Mitigation Policy

The Geologic Hazards Section continued to address issues related to seismic-hazard assessment and mitigation policy, such as engineering design, through publications, presentations, and seminars.

The issues related to seismic-hazard assessment and engineering design—in particular, the USGS national seismic-hazard maps and their resulting design maps for building codes—have also drawn attention from engineering professionals.

Section Head **Zhenming Wang** made a presentation, “The USGS National Seismic Hazard Mapping Project: Issues and Improvements,” at the Applied Technology Center/USGS Seismic Hazard User-Needs Workshop, Sept. 21–22, 2015, in Menlo Park, Calif. Wang also presented “Seismic Risk Management: From Earthquake Science, Seismic Risk Assessment, and Communication to Decision Making” at the 2016 Seismological Society of America annual meeting in Reno, Nev., in April 2016. A paper, “Seismic Hazard Mapping and Mitigation Policy Development in the Central United States and Western China,” co-authored by **Zhenming Wang, Alice Orton, Lanmin Wang, and Edward Woolery**, was published in *Natural Hazards* in March 2016.

The issues related to seismic-hazard assessment and engineering design—in particular, the USGS national seismic-hazard maps and their resulting design maps for building codes—have also drawn attention from engineering professionals.

In a paper published in the March 2016 edition of *STRUCTURE* magazine, “Seismic Design Value Maps,” **Ronald Hamburger**, who chairs two important committees involved with building-design maps and developing criteria for buildings and other structures, cited a reluctance to adopt the newest national seismic-hazard maps as well as design maps, noting several issues:

1. Structural engineers do not believe the science behind the maps is valid and are dissatisfied with constantly changing building design requirements.
2. The intent of the maps and what they represent has been lost as they have become more complex.
3. The level of precision in seismic design values in the maps is inappropriate, given

the level of uncertainty in the values portrayed.

Landslide Hazards

Matt Crawford added several new entries to the landslide inventory database, bringing the total number of entries up to 2,468 by the end of the fiscal year. The landslide locations came from State agencies, field investigations, published maps, LiDAR mapping, and reports from the public. These records are documented as point data that represent a larger landslide area. In addition to the landslide-inventory point data, landslide features digitized from Landslide and Related Features Maps published by the U.S. Geological Survey were added to the



Matt Crawford downloads data from his landslide monitoring station in Pulaski County in south-central Kentucky.

inventory. From these maps, Crawford and other staff identified more than 13,000 landslide areas derived from aerial photography and more than 60,000 areas susceptible to debris flows derived from aerial photography, topography, and historical records. Both the documented point data and digitized landslide features can be viewed and queried in the KGS online geologic map information service. The resulting large data set serves as a foundation for improving our understanding of landslide occurrence and provides information to assist mitigation efforts by land-use planners, transportation officials, emergency managers, and the public.

Crawford conducted site-specific monitoring of three shallow colluvial landslides in Kenton, Lewis, and Pulaski Counties. He recorded geologic settings, landslide sizes, and slope histories. Slope hydrogeology, precipitation, landslide material and strength properties, landslide movement, and surface electrical-resistivity data are also being collected and analyzed. Hydrologic sensors capture the transient moisture conditions (volumetric water content and water potential) within the slope, which is compared to rainfall. Electrical-resistivity measurements have shown resistivity contrasts that correlate to lithologic differences, failure zone depth, shape of the landslide body, and groundwater conditions.

Crawford worked closely with **Lindsey S. Bryson** of the University of Kentucky Department of Civil Engineering to acquire soils-strength data in the laboratory. The soil properties that primarily govern electrical current flow

also greatly affect slope stability. Work will continue to establish relationships between these parameters that control slope stability.

Crawford and Bryson hypothesized that a comparison of in situ hydrologic data and surface electrical resistivity can provide information on the shear strength of soils, ultimately showing that electrical data can be an indicator of slope stability.

The collaboration with the Department of Civil Engineering is a good example of two UK departments working together, and emphasizes the importance of applied engineering geology.

In addition to research and stakeholder outreach, Crawford participated in several professional development opportunities. He is the current chair of the Geological Society of America's Environmental and Engineering Geology Division. The division is GSA's largest and oldest, with more than 3,000 members, who work to promote applied environmental and engineering disciplines of geology for the benefit of society. Crawford carries out the business of the division and organizes events, awards, and technical sessions at GSA's annual meeting.

Crawford also serves on the organizing committee for the Appalachian Coalition for Geological Hazards in Transportation. The coalition shares information, resources, and best practices among federal, state, local, and private entities that are faced with geologic and geotechnical problems. This past year the committee organized the annual technical forum in Huntington, W.Va.



Students Clay Seckinger, Bailee Hodelka, and Clara Rucker conduct an electrical-resistivity survey for landslide characterization at the Doe Run site in Kenton County.

China Scholarly Exchange and Cooperative Research

This was the 12th year for the exchange program between KGS and the Lanzhou Institute of Seismology and other organizations in the China Earthquake Administration.

Zhenming Wang was invited to visit the Lanzhou Institute in Lanzhou, Gansu Province, in July 2015 and gave lectures and conducted research on earthquake-induced landslides in loess areas. Wang also visited and lectured at the Institute of Crustal Dynamics in Beijing and the Fujian Earthquake Administration in Fuzhou during his visit.

Three visiting scholars, one from the Lanzhou Institute and two from the Institute of Crustal Dynamics, came to UK to participate in research projects and exchanges, resulting in a paper, "Nonlinear Site Response From the Strong Ground-Motion Recordings in Western China," published in the *Journal of Soil Dynamics and Earthquake Engineering*. Another paper, "Evidence of Complex Faulting Near the Huangcheng-Shuangta Fault, Gansu, China, From the 11 May 2012 M_w 4.8 Sunan Earthquake," has been accepted for publication in the *Bulletin of the Seismological Society of America*. The visiting scholars also contributed to two abstracts and posters for the 2016 Seismological Society of America annual meeting in Reno, Nev., in April 2016.

New State Geologist and KGS Director

After a two-year search, engineering geologist **William C. Haneberg** was selected as Kentucky's 13th state geologist and director of KGS on Sept. 1, 2016.

The position had been vacant since the July 2014 retirement of Jim Cobb, who



had been state geologist for 14 years.

Haneberg's previous experience included serving as assistant director and senior engineering

geologist at the New Mexico Bureau of Geology and Mineral Resources, university teaching, research, and private consulting.

Prior to accepting his new position, he had worked as a senior consultant and Quantitative Geohazards Group leader for an American subsidiary of the Dutch geoscience and engineering firm Fugro, N.V.

His expertise includes geologic hazard and risk assessment, structural geology,

hydrogeology, and the use of geologic information to support planning and policy decision-making. Haneberg's career has taken him across North America and to India, Nepal, and New Guinea.

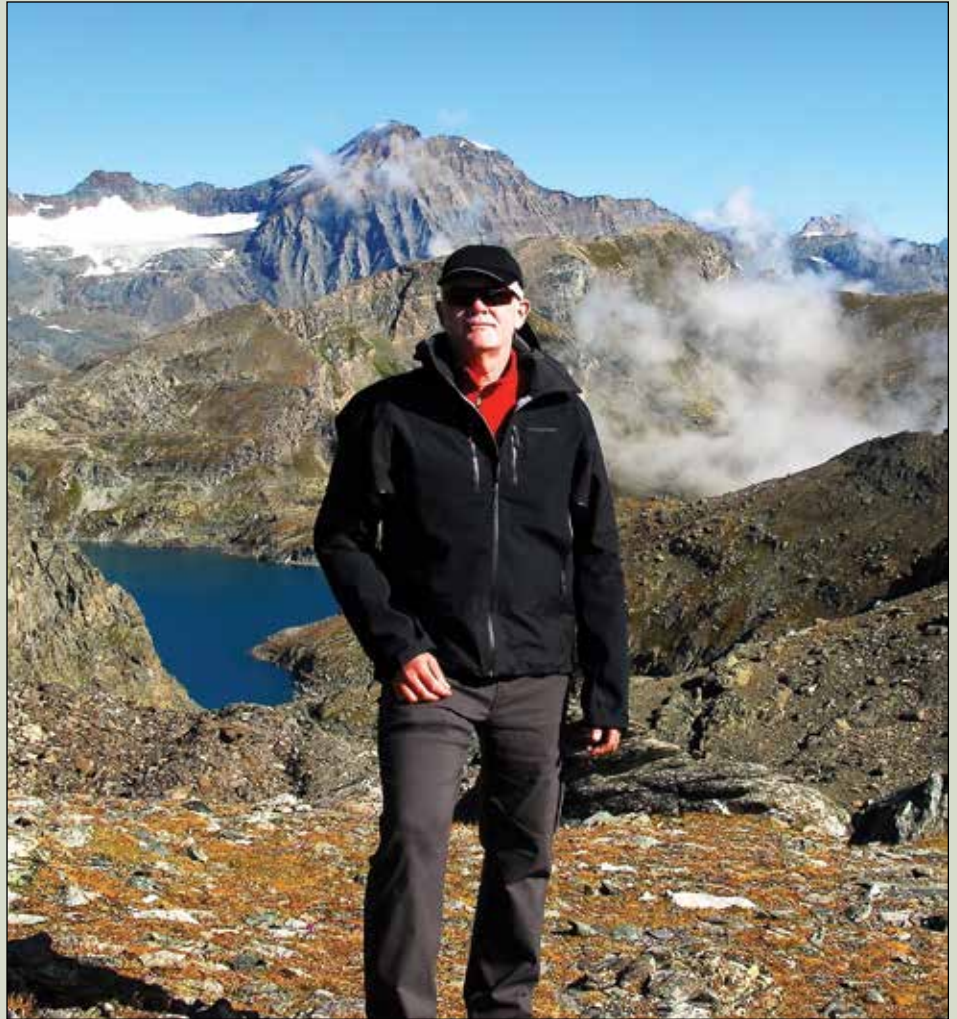
A native of Cleveland, he earned a doctorate in geology from the University of Cincinnati in 1989. He received the 2006 Claire P. Holdredge Award from the Association of Environmental and Engineering Geologists for his 2004 book, "Computational Geosciences With Mathematica." He was the 2011 Richard H. Jahns Distinguished Lecturer in Engineering Geology and is an elected Fellow of the Geological Society of America.

He is also an enthusiastic cyclist, runner, high-altitude mountain trekker, and photographer. His wife, Lisa, is a senior human resources expert with a major health-care organization, speaker, and author of business books and a novel.

In his first few weeks in his new position, Haneberg was busy introducing himself to KGS staff and receiving a ceremonial state geologist's rock hammer from his predecessor, **Jim Cobb**. He attended his first meeting with the KGS Advisory

Board and a reception to meet UK officials, and addressed the opening session of the American Association of Petroleum Geologists–Eastern Section annual meeting, co-hosted by KGS.







The data and maps being developed by the Geologic Mapping Section serve as valuable tools for state and community planning and environmental management, and also assist in the emerging field of geology in public health.

Efforts in the Geologic Mapping Section were supported by a grant of \$150,730 from the U.S. Geological Survey's STATEMAP program. During the fiscal year, the section's mappers completed four new surficial geologic maps:

La Grange, Crestwood, Fisherville, and Waterford quadrangles in the eastern and northeastern Louisville Metro area—and delivered them to the USGS program. With support from the Geologic Information Management Section, the mappers continued using digital technology such as the Esri Collector app and Esri ArcGIS products to more efficiently collect, compile, and analyze their field data. Though Pleistocene glaciers barely reached the part of Kentucky mapped this

year, numerous Pleistocene deposits have significance for land-use and geotechnical planning in the area, and mapping those deposits can be valuable for communities in the region. Thick accumulations of glacial outwash in the Ohio River Valley in a high terrace are used extensively for construction and development, and the underlying sand and gravel provide a valuable aquifer for the Louisville Metro area. The rapidly deposited outwash caused temporary impoundment of tributary streams during the Pleistocene, and remnant lacustrine or slackwater terraces are found in many small valleys in the area. Across much of the intervening uplands, deposits of loess are incorporated with residual soils.

There were some staff changes in the section during the year. **Scott Waninger** left the section for new employment in Indianapolis and **Matt Massey** joined the mapping team. **Steve Martin**, **Max Hammond**, and **Antonia Bottoms** continued with ongoing surficial field mapping.

Amy Bleichroth-King has been working in the KGS Western Kentucky Office to provide grain-size analysis on soil and sediment samples and catalog legacy data from previous mapping, including



Max Hammond investigates an outcrop of Quaternary sediment while mapping the La Grange quadrangle for the STATEMAP program.



Antonia Bottoms, Max Hammond, and Steve Martin examine contacts between hillslope colluvium and floodplain alluvium near Floyds Fork in the Fisherville quadrangle.

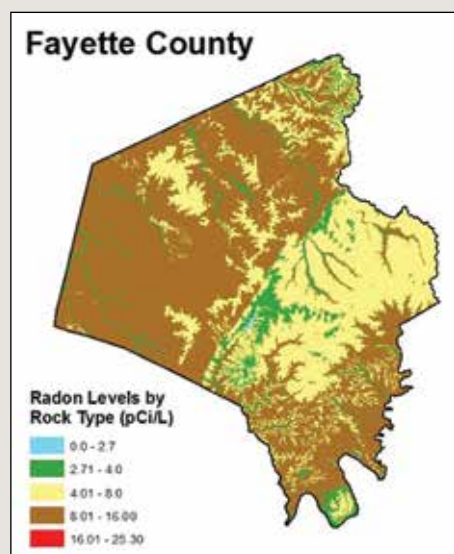
geochronology, gamma logs, grain-size data, and magnetic susceptibility information.

Section Head **William Andrews** assisted with field mapping and completed a seismic soil project for Daviess County in northwestern Kentucky. The resulting map, based on new geologic mapping data as well as KGS shear-wave data, illustrates specific areas of the county that could undergo certain seismic effects such as ground-motion amplification or liquefaction during a large earthquake in the region.

Bethany Overfield continued her cooperative work in applying geologic map information to improve public health

and communication of health issues. She has an ongoing collaboration with the Clean Indoor Air Partnership at the UK College of Nursing, the focus of which is on assessing the influence of geology on radon potential, to help communicate the need for home radon testing. Overfield has completed 15 county maps depicting radon potential for use in public education and awareness campaigns. She will continue with the remaining counties in the state.

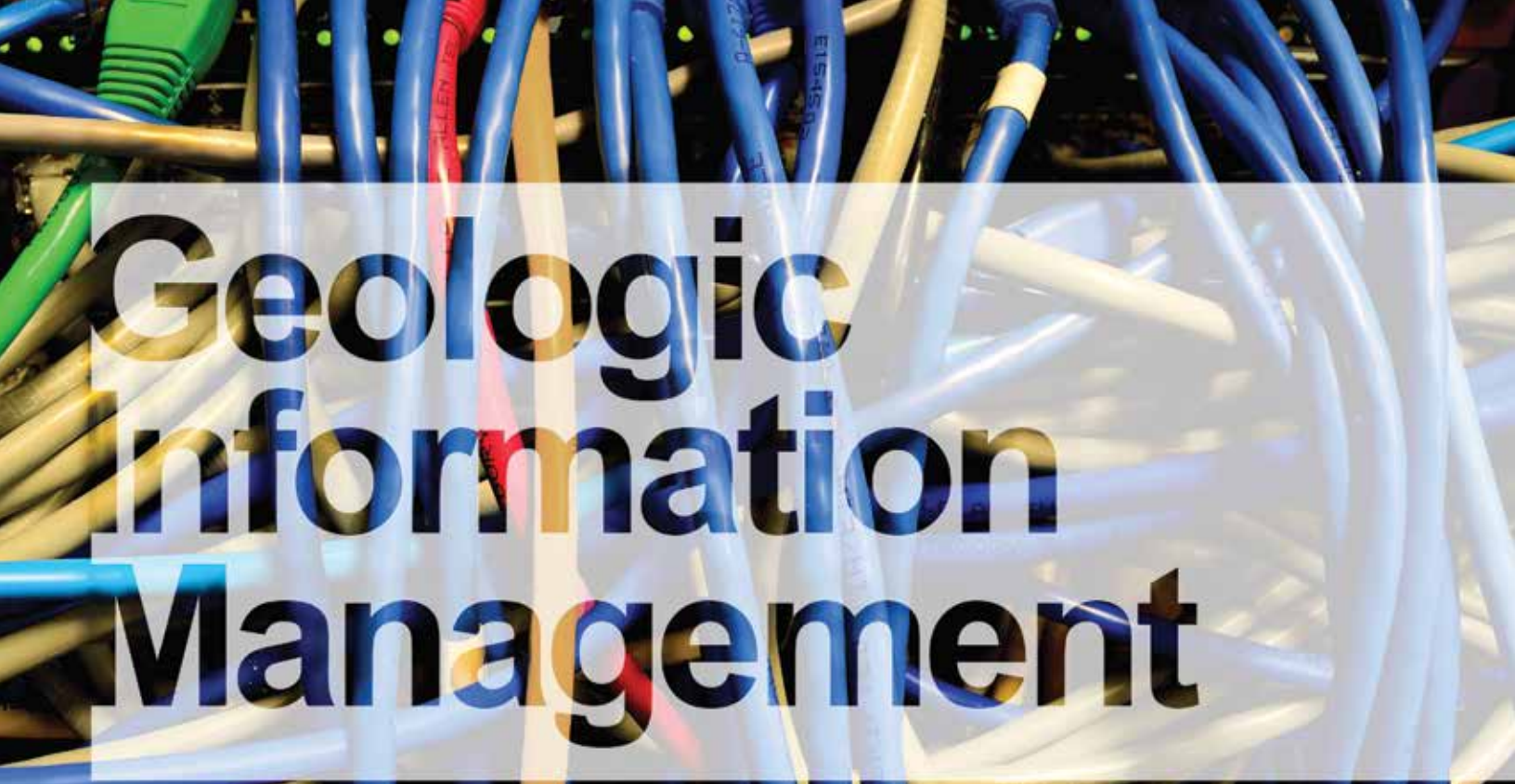
In addition, Overfield is working with a group of scientists led by **Nancy Johnson** at the UK College of Public Health to study biological exposure to trace elements in the Appalachian landscape. Data were collected by the Department of Defense-sponsored Lung Cancer Research Initiative at UK's Markey Cancer Center, with the intent of examining the contribution of environmental exposure and other factors to the high incidence of lung cancer in eastern Kentucky. Overfield is focusing on the spatial components of the study using GIS.



*A map of radon levels in Fayette County developed by **Bethany Overfield**, who created 15 county maps in a cooperative radon project with the UK College of Nursing.*



Matt Massey joined the Geologic Mapping Section in March 2016. He immediately began surficial mapping, supported by the STATEMAP program. He had previous mapping experience in Massachusetts. One project was funded by a STATEMAP post-doctoral grant, and the other through the related EDMAP program for university students. The latter project was the basis of his doctoral dissertation. Massey became interested in geology at a young age, when his father, a coal mining engineer, brought home rocks and geodes from mine sites. Massey worked previously as an instructor and post-doctoral research associate at the UK Department of Earth and Environmental Sciences, as an assistant professor at Marshall University, and as a visiting scientist at the University of Liverpool, England.



Geologic Information Management

KGS staff generate information each year in the form of research data, maps and publications, updates for databases, and other information. The Geologic Information Management Section makes this information available to both researchers and the public.

The online public availability of scanned oil and gas drilling records, water-quality information, and a variety of mapping services depend on the work of this section. Several projects completed during the fiscal year improved and enhanced these services.

A major project by **Elizabeth Adams**, **Carrie Pulliam**, and **Doug Curl** to convert the more than 600,000 web-accessible oil and gas documents from DjVu files into PDF files was completed in December 2015. Having the documents available as PDFs should make them more accessible to users for use on all computer platforms, including mobile devices. E-logs and strip logs from wells were also converted into JPEG-format images for faster viewing on the web and mobile devices.

Richard Smath and **Brandon Nuttall** (KGS Energy Section) developed a web-based “Story Map” walking geologic tour of Cove Spring Park in Frankfort. Users can access the Story Map on their mobile devices (kgs.uky.edu/storymap/covespring) to direct them through a geologic tour of the park.

The Frankfort Parks and Recreation Department and Cove Spring Park administrators were very receptive to this project, and installed numbered plaques to correspond with the stops in the application. Thanks to the success of this project, the section intends to develop more Story Map applications for other areas of geologic interest around the state.



With grant support from the Watershed Watch Kentucky organization, **Doug Curl** developed a web application for viewing results from volunteer water sampling. Through a data portal at kgs.uky.edu/wwky, users can view and download surface-water quality data from sampled sites along creeks and rivers throughout Kentucky.

The KGS website (www.uky.edu/KGS), managed by section staff, continues to serve a diverse audience from this country as well as around the world. More than 288,000 users from 220 countries accessed information about KGS, Kentucky's

resources, and geoscience education from the website.

As with the previous year, approximately 75 percent of users were from the United States; others were from India, the United Kingdom, Canada, and Australia. About a third of domestic users are in Kentucky; the next most common groups of users were from Texas, California, Ohio, Georgia, and Illinois.

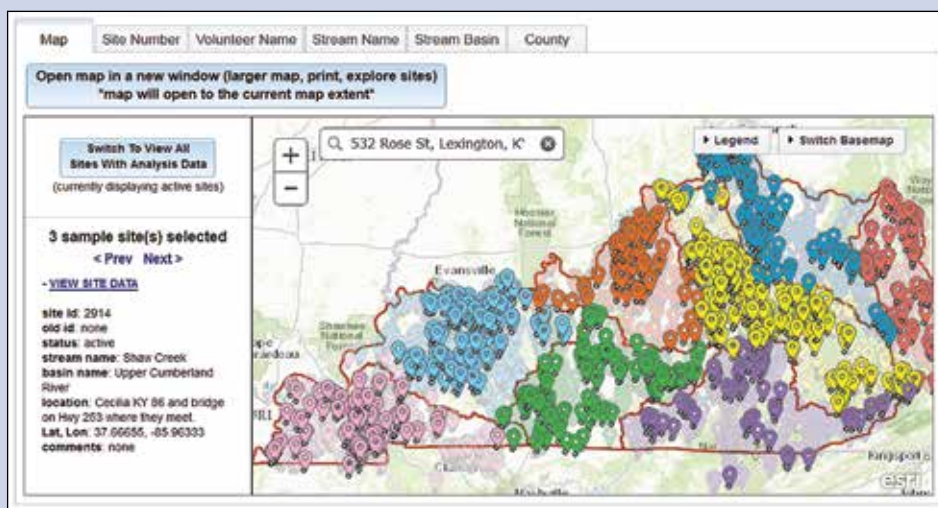
The Survey's online services had more than 1.2 million hits during the fiscal year. More than 30 percent of the visits came from mobile and tablet users, which was a slight

increase (6 percent) over the previous year. The most-visited pages on the KGS website, besides the homepage, were the fossil identification pages, followed by the coal information, rock and mineral identification, and mining methods pages.

Since 2001, KGS has provided free online access to oil and gas records and data, water-well and springs data, coal data, publications, images, and other geologic data, now numbering more than 6.6 million records. More than 670,000 visits originating from 144 countries were made during the past 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 (90 percent), followed by India, Canada, the United Kingdom, and Germany. 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, Pennsylvania, Indiana, and Tennessee.

Nearly 279,000 database searches were conducted by more than 100,000 users and almost 39,000 unique users. There was a 22 percent decrease in database searches from last year, primarily the result of a 20 percent decrease in searches for oil and gas data. Mobile and tablet use of the database and maps site is consistent with the last fiscal year, and represent about 10 percent of users.



A web application developed by Section Head **Doug Curl** allows users to find and download surface-water quality data from sites sampled by the Watershed Watch program in Kentucky.



Elizabeth Adams supervises several students, including **John Piening**, who scan and organize well drilling documents that are made available online through the KGS oil and gas records database.

KGS online map services were accessed more than 77,000 times, about an 18 percent decrease from the previous fiscal year. Much of that reduction and the resulting 33 percent decrease in access of oil and gas map data are related to the slump in oil and gas drilling. There were nearly 15,000 tabular data downloads, which was about a 30 percent decrease from the 2014-15 fiscal year, consistent with the decrease in oil and gas database searches.

The total number of files downloaded from the website, including KGS publications and presentations, was nearly 840,000. 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.

Other Activities During the Fiscal Year

- **Elizabeth Adams** reviewed 350 oil- and gas-well permit locations for the Kentucky Division of Oil and Gas and maintained the database of permits and well-location data. That is a decrease of about half the permitted locations from the previous year, which reflects the sharp downturn in oil and gas exploration caused by lower oil prices. Adams also continued supervising

several students: **Bailee Hodelka**, **Meghan Hackett**, and **John Piening** 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

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.

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, **Holly Keimig** and **Jessica Mayes**, scanned legacy oil- and gas-well documents from the KGS Western Kentucky Office for the 2015-16 USGS National Data Preservation project. Through June 2016, documents from about 2,000 oil and gas records were scanned, resulting in the addition of more than 13,000 pages of records and



Jessica Mayes scans oil and gas drilling records at the Western Kentucky Office as part of the USGS National Data Preservation project.

more than 2,100 e-logs to the KGS oil and gas database.

- **Carrie Pulliam** supervised a student, **Jason Orr**, also from the UK Department of Earth and Environmental Sciences. Orr acquired and entered data from well records into the KGS oil and gas database, and he also entered data according to priority projects from the Energy and Minerals and Geologic Mapping Sections.
- **Doug Curl** continued work with the ArcGIS Collector application, which is used by workers in the field to collect

data. In addition to working with the Geologic Mapping Section to deploy Collector for its field use, Curl has also helped the University of Kentucky Human Development Institute and the UK Forestry Department develop Collector applications for several projects.

- **Mike Ellis** and **Elizabeth Adams** maintained and updated a KGS YouTube channel, which contains both instructional videos about KGS website usage and presentations about the work of KGS. About 40 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**.

Rebecca Wang worked with several KGS staff to develop a new design for the Survey's website, www.uky.edu. The revamped homepage was introduced late in 2016. Visitors to the site found a more contemporary look, including menus that provide direct access to a variety of information pages and services, such as KGS water well, oil, and gas databases, online maps, and educational resources.

A link was also added to current projects to help promote the ongoing work KGS research staff is doing. A news and announcements section is regularly updated with fresh content, providing visitors with a "rolling newsletter" of KGS activities and future events. Links to KGS social media were also made more visible. The new website has been made more responsive, so that it can be viewed in the same format on a variety of devices such as smartphones and tablets, as more users switch to such alternatives to standard computers.

Geologic Information Section staff members are also looking toward future improvements to KGS online services. They worked to streamline data search and geologic map services. In the future, they hope to introduce a new integrated search service to make it easier for users to find data at the KGS website and display it across a variety of devices.





Western Kentucky Office

KGS provides service to the western part of the state through an office located in Henderson, staffed by people who work for several of the Survey's sections. The facility houses equipment for field research in the region as well as a sediment laboratory.

The office has also been beneficial for current and past research activities conducted by KGS in western Kentucky, such as deep carbon storage research and the selection of wells for a new groundwater monitoring network. For more than 65 years, the KGS Western Kentucky Office in Henderson has played a major role in oil, gas, and coal production in the western counties of Kentucky, serving as a source of geologic data for local and regional industry, geologists, and citizens of the western part of the state.

The office is staffed with an office manager and members of the KGS Water Resources, Geoscience Information, and Geologic Mapping Sections. Core-sampling equipment and a sediment laboratory are available for staff use. One of the seismic monitoring stations in the Kentucky Seismic and Strong-Motion Network is located at the office, and equipment used for seismic investigations is also housed there. Staff also provide technical

assistance to local and State government agencies, industry, and agricultural interests. The office in Henderson participates in a variety of KGS projects in geologic mapping, water-quality sampling, hydrostratigraphy, groundwater-elevation data, and geologic data preservation.

Office Manager **Dave Williams** continues to study paleochannel deposits in the

upper part of the Carbondale Formation and the Shelburn Formation. He presented a poster on the topic at the KGS annual seminar this year.

Glynn Beck has continued running gamma-ray logs of water wells throughout western Kentucky and oversaw the installation of four monitoring wells in the Jackson Purchase Region, as part of



*Western Kentucky Office Manager **Dave Williams** examines a geologic cross section as part of his continuing study of paleochannels.*

the statewide Kentucky Groundwater Observation Network being developed and administered by KGS.

Amy Bleichroth-King cataloged legacy mapping data, including grain-size analyses, gamma logs, geochronology data, magnetic susceptibility data, core locations, and descriptions. As part of the Geologic Mapping program, she has also been conducting laser diffraction particle-size analysis, using the Beckman-Coulter instrument in the sediment lab, on sediments from the Louisville area. **Scott Waninger**, who mapped in the Louisville area, left KGS during the year.

Holly Keimig, along with **Jessica Mayes**, who joined the office during the year, scan oil and gas well documents, which are added to the KGS online database. A total of 21,307 page scans have been added to the database this year.



ABOVE: Glynn Beck uses an all-terrain vehicle to access surface-water sampling sites at the Kentucky National Guard's Wendell H. Ford Regional Training Center in Muhlenberg County.



Employees of Murray Well Drilling pull the submersible pump from an unused, 221-foot-deep domestic well in Marshall County. The well is part of the new Kentucky Groundwater Observation Network.



ABOVE: Scott Waninger collects a sediment core at the Murray State University Hutson School of Agriculture West Research Farm. The wells in the picture are part of the Kentucky Groundwater Monitoring Network.

Well Sample and Core Library

The KGS Well Sample and Core Library collections draw academic researchers and exploration geologists from the United States and around the world, while also serving as a learning facility for geology professors and students. The 48,000-square-foot facility houses cuttings from about 18,000 oil and gas wells and core samples from more than 3,000 sites in Kentucky. Cores are also accepted from environmental studies, highway construction, limestone quarries, water and engineering projects, and from State and federal agencies. Twenty sets of well cuttings from oil and gas exploration were donated and added to the collection this year.

Ongoing KGS energy-related research, such as the study of the Berea petroleum system and the Rogersville Shale in eastern Kentucky, depend on the Core Library's collections. During the fiscal year, 73 academic and 19 industry representatives examined cores or samples, and close to 2,000 boxes of core and 21 boxes of well cuttings were available for examination. Sampling is also permitted if enough samples are available. During the fiscal year, 683 samples were provided for analytical testing for research.

The collections at the Core Library are also used to provide presentations to youth groups and camps, elementary and high school students, and other groups interested in geology.

A searchable online database of the collection provides well or borehole information for samples in the collection,

as well as data on samples and call numbers for finding them at the facility. Information for potential users, including forms for donating cores and requesting samples for testing, can be found at the Core Library's webpage, linked from the KGS homepage.



Richard Smath directs **Ray Daniel** as they prepare a collection of donated cores to be moved to the Core Library.



ABOVE: A box of core on display during a workshop on the Berea Sandstone.



*LEFT: **Steve Greb**, second from left, uses collections stored at the Well Sample and Core Library as he leads the Berea Sandstone Consortium workshop at the facility.*



***Ryan Pinkston** retrieves boxes of core for examination by researchers.*



As grant funding declines and some state geological surveys have been shrinking, demonstrating the value and relevance of a state survey to society has become more important. During the year, KGS participated in a variety of outreach activities benefiting multiple audiences and promoting the Survey's resources and services.

Annual Seminar

The 2016 KGS annual seminar was titled "Navigating the New Energy Landscape in Kentucky." KGS and State-agency presenters talked about Kentucky's coal,

oil, gas, and renewable energy resources and utilization, as well as KGS research on the environmental effects of energy development. The timely topic drew about 130 people to the Well Sample and Core Library on May 13 for the seminar,

poster sessions, and afternoon workshops. Kentucky Energy and Environment Cabinet Secretary Charles Snaveley gave opening remarks, and some of his staff spoke on energy issues.



Earth Science Week Open House

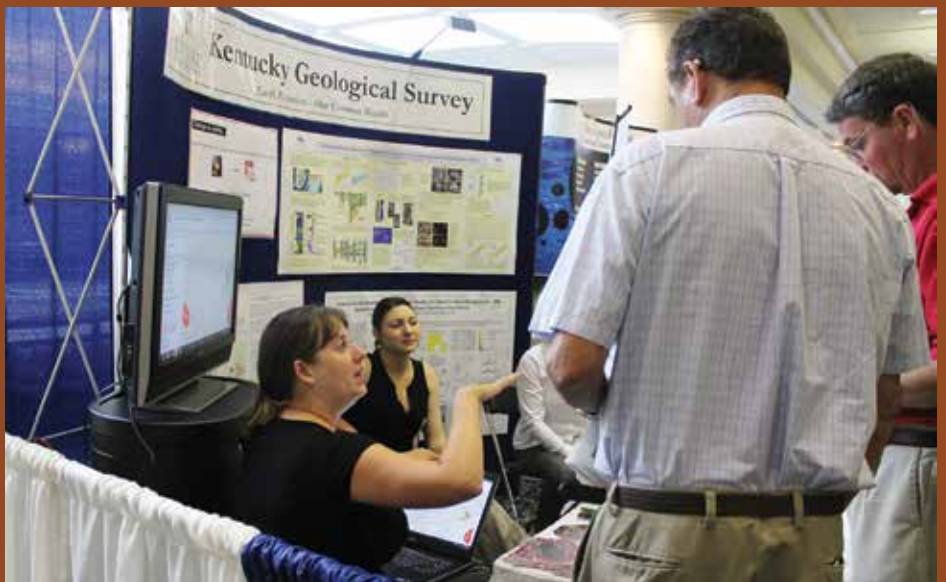
The largest educational event offered by KGS for the general public each year is the Earth Science Week open house, held each October.

Using emails to science teachers, news releases, and social media, KGS invites students and families to browse earth science–related displays and demonstrations at the Mining and Mineral Resources Building. They range from displays of rocks, minerals, fossils, gems, and meteorites to simulations of volcanoes and demonstrations of earthquake recording and geologic carbon storage.

The 2015 open house drew about 190 people, and included the participation of the Kentucky Paleontological Society and the Bluegrass Gem and Mineral Club, as well as the Kentucky Water Resources Research Institute and the UK Department of Mining Engineering.



KGS sets up displays each year at several professional and educational events, including this one at the Kentucky Oil and Gas Association annual meeting. KGS staff attended the July 2015 KOGA convention at the Lexington Center, promoting our online oil and gas database and answering questions about other KGS services and resources.



Research Projects—Fiscal Year 2015-16

Energy

Carbon Management

CO₂ Sequestration and Enhanced Oil and Gas Recovery Using CO₂

End Date: 9/30/2016

Funding Source: Governor's Office of Energy Policy

Midwest Regional Carbon Sequestration Partnership for the Appalachian Basin

Fiscal Year Funding: \$100,009

End Date: 12/31/2019

Funding Source: U.S. Department of Energy through Battelle Memorial Institute

Oil and Gas Resources

Industry Consortium for Unconventional Petroleum Development in the Berea Sandstone

Fiscal Year Funding: \$82,500

End Date: 1/31/2016

Funding Source: Industry consortium

Geochemistry

Geochemistry of Rock

Appalachian Research Initiative for Environmental Sciences

Fiscal Year Funding: \$11,337

End Date: 7/31/2016

Funding Source: Virginia Polytechnic Institute and State University through UK Department of Mining Engineering

Evaluation of Coal Waste Slurry for Rare Earth Mineral Recovery

Fiscal Year Funding: \$3,200

End Date: 2/29/2016

Funding Source: Kentucky Energy and Environment Cabinet through UK Department of Mining Engineering

Pilot-Scale Testing of an Integrated Circuit for the Extraction of Rare Earth Minerals Characterization of Slurry Impoundments for REE Extraction

Fiscal Year Funding: \$16,122

End Date: 8/31/2017

Funding Source: U.S. Department of Energy through UK Department of Mining Engineering

Geochemistry of Water

Kentucky Watershed Management Services: Water Watch

Fiscal Year Funding: \$9,109

End Date: 6/30/2016

Funding Source: Kentucky River Authority through Kentucky Water Resources Research Institute

Geologic Information

Coal Information

Computerized Coal Resources for the National Coal Resources Data System

Fiscal Year Funding: \$15,000

End Date: 8/31/2020

Funding Source: U.S. Geological Survey

Updating Energy Infrastructure, Coal Resource, and Coal Information Websites

Fiscal Year Funding: \$20,000

End Date: 6/30/2016

Funding Source: Kentucky Department for Energy Development and Independence

Data Dissemination

National Geologic and Geophysical Data Preservation Program

Fiscal Year Funding: \$63,320

End Date: 7/7/2016

Funding Source: U.S. Geological Survey

Geology

Geologic Mapping

Quaternary Geologic Mapping in the Northern Louisville Metro Area, Kentucky

Fiscal Year Funding: \$150,739

End Date: 6/30/2016

Funding Source: U.S. Geological Survey

Summary Soil Map for Seismic Hazards, Daviess County

Fiscal Year Funding: \$5,629

End Date: 11/30/2015

Funding Source: Daviess County Fiscal Court

Geology and Human Health

Lung Cancer Research Initiative: Environmental Geology and Human Health Mapping

Fiscal Year Funding: \$16,000

End Date: 6/14/2016

Funding Source: U.S. Army Medical Research through UK Markey Cancer Center

Prescription for Radon: County-Scale Maps of Geologic Radon Potential

Fiscal Year Funding: \$4,057

End Date: 6/30/2016

Funding Source: Kentucky Department for Public Health through UK College of Nursing

Hazards

Geotechnical Assessment

Geophysical Properties of Wolfcamp Shale Cores, Midland Basin

Fiscal Year Funding: \$2,371

Ending Date: 5/16/2017

Funding Source: Pioneer Natural Resources through UK Department of Earth and Environmental Sciences

Seismic Assessment

Microseismicity in the Ste. Genevieve, Wabash Valley, and Rough Creek Seismic Zones Using Earthscope Flex Array Data: Implications for Earthquake Hazards

End Date: 12/31/2016

Funding Source: U.S. Geological Survey

Water Resources

Groundwater Monitoring

Baseline Groundwater Chemistry Assessment for the Berea Play and the Rogersville Shale, Eastern Kentucky

Fiscal Year Funding: \$85,621

End Date: 8/31/2016

Funding Source: U.S. Department of Energy through GSI Environmental Inc.

Groundwater Resources

Aquifer Test of Well No. 1 for Elizabethtown Municipal Supply Well Field

Fiscal Year Funding: \$7,165

End Date: 12/31/2015

Funding Source: Hardin County Water District No. 2

Karst Hydrogeology

Sinkhole Probability Mapping: Integrating Human Impacts and Natural Processes in Conjunction With LiDAR to Predict Karst Subsidence

End Date: 2/29/2016

Funding Source: U.S. Geological Survey through Kentucky Water Resources Research Institute

Surface-Water Resources

Surface-Water Quality Assessment for National Guard Training Areas 7 and 8, Wendell H. Ford Training Site

Fiscal Year Funding: \$95,447

End Date: 12/31/2016

Funding Source: Kentucky Department of Military Affairs

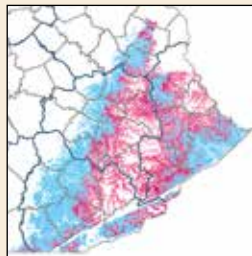
Publications

KGS makes its research findings and mapping products freely available through a link on the Survey's home page. During this fiscal year, 12 new titles were published by KGS researchers or students who worked at KGS.

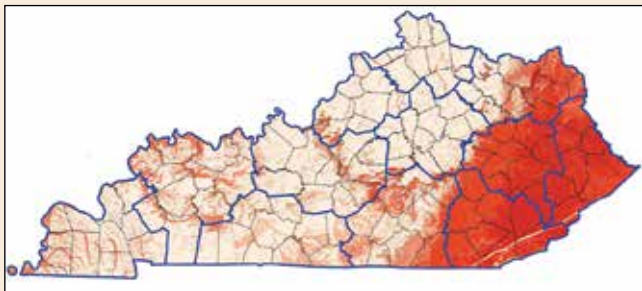
Rick Bowersox completed three new publications about heavy-oil resources in the tar sands of western Kentucky: "Rocks to Roads to Ruin: A Brief History of Western Kentucky's Rock Asphalt Industry, 1888-1957" (Information Circular 33), "Heavy Oil and Bitumen Resources of the Big Clifty Sandstone, Northeastern Grayson County and Adjacent Hardin County, Kentucky" (Report of Investigations 35), and "Heavy Oil and Bitumen Resources of the Western Kentucky Tar Sands" (Report of Investigations 36).

Bethany Overfield was the main author of "The Geologic Context of Landslide and Rockfall Maintenance Costs in Kentucky—2002 to 2009" (Report of Investigations 34), in which Kentucky highway maintenance costs were matched with geologic units to assess the most costly and frequently repaired pavement sections according to geologic formation. Among the conclusions were that eastern and northern Kentucky, with greater slope and relief as well as shale-bearing units, had the highest costs and repair frequencies. **Dan Carey, Jerry Weisenfluh, Rebecca Wang, and Matt Crawford** were co-authors.

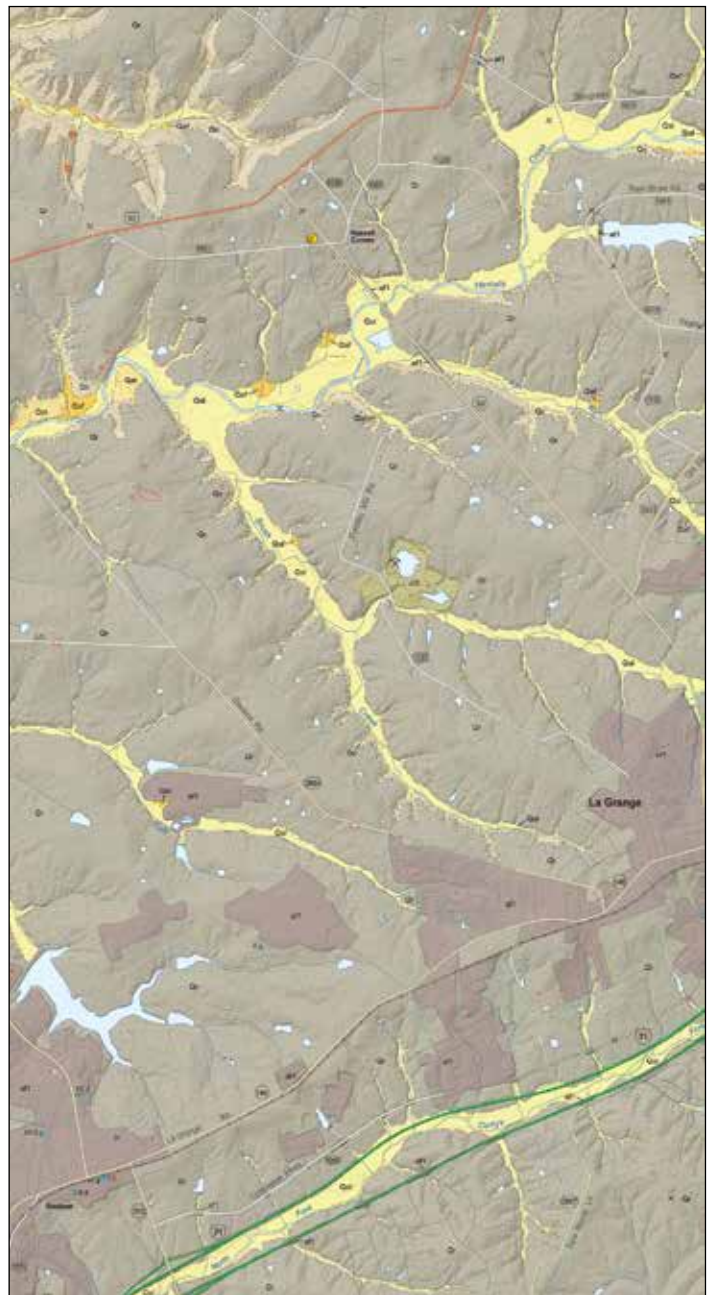
RIGHT: This map, from "The Geologic Context of Landslide and Rockfall Maintenance Costs in Kentucky—2002 to 2009," depicts the distribution of the two most costly geologic formations to maintain in eastern Kentucky: the Pikeville (blue) and Hyden (pink).



BELOW: The same publication depicts average expected rockfall maintenance costs by geologic unit (by cost per mile per year).



All of these publications are available for download from the Publications tab on the KGS website.



Four new surficial geology maps of 7.5-minute quadrangles were completed by Geologic Mapping Section staff with funding from the U.S. Geological Survey's STATEMAP program; one of those is the La Grange quadrangle, part of which is shown above.

Staff Awards and Appointments



Zhenming Wang was promoted to adjunct associate professor in the UK Department of Earth and Environmental Sciences in the fall of 2015.



Brandon Nuttall was appointed to represent KGS in a State government oil and gas workgroup on radioactive wastes, including oilfield waste, after the passage of a bill relating to the disposal of naturally occurring radioactive waste materials.



Matt Crawford was elected chair of the Geological Society of America Environmental and Engineering Geology Division. He also serves on the organizing committee of the Geohazards in Transportation in Appalachia Forum.



Marty Parris received the A.I. Levorsen Memorial Best Paper Award, with co-authors **Jerrad Grider** and **Ethan Davis**, for the 2015 AAPG meeting in Indianapolis, for "Reexamining the Fresh-Saline Water Interface in the Area of the Devonian Berea Oil Play, Northeastern Kentucky."



Patrick Gooding was elected secretary of the Eastern Section of the American Association of Petroleum Geologists, is a member of the AAPG House of Delegates and other AAPG committees, and is secretary/treasurer of the Geological Society of Kentucky.



Bethany Overfield was treasurer and board member in 2015 for Kentucky River Watershed Watch and still serves as a science advisor and outreach coordinator for the group.



William Andrews was an invited technical adviser to the Kentucky Geographic Information Advisory Council, and he teaches a review course for the American Institute of Professional Geologists–Kentucky Section.



Glynn Beck serves on the Kentucky Agricultural Science and Monitoring Committee and the Environmental and Natural Resources Issues Task Force.



John Hickman was vice president of the Eastern Section of the American Association of Petroleum Geologists and was Technical Program co-chair for the section's 2016 meeting in Lexington. He also served as an adjunct faculty member with the UK Department of Earth and Environmental Sciences.



Chuck Taylor serves on the Kentucky Agricultural Science Monitoring Committee and the Kentucky Agricultural Water Quality Authority.



Dave Williams is a member of the Henderson City/County Planning Commission.



Bart Davidson served as a member of the Kentucky Water Well Drillers Certification Board, which oversees water-well drilling issues and regulations of the Kentucky Division of Water.



Doug Curl was the KGS designee to the State's Geographic Information Advisory Council and vice chair of the Kentucky River Watershed Watch board.



Ray Daniel served as a councilor at large for the Geological Society of Kentucky.



The Geological Society of Kentucky recognized **Richard Smath** with an outstanding service award and presented **Jerry Weisenfluh** with its Distinguished Service Award during the 2016 KGS annual seminar. Weisenfluh was also an ex officio member of the Kentucky Board of Registration for Professional Geologists.



KGS Staff—Fiscal Year 2015-16

State Geologist's Office

Weisenfluh, Jerry—Interim Director

Cobb, Jim—State Geologist Emeritus

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

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

Holcomb, Andrew—Student Worker

Kang, Jianhong—Temporary Technician

Rodriguez Asihama, Paul—Student Worker

Woolery, Ed—Geophysics Faculty Associate

Geoscience Information Management

Curl, Doug—Section Head

Adams, Elizabeth—Geologist I

Ellis, Mike—Computer Support Specialist II

Hackett, Megan—Student Worker

Hodelka, Bailee—Temporary Technician

Orr, Jason—Student Worker

Piening, John—Student Worker

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

Banks, Roger—Stores Supervisor

Hounshell, Terry—Chief Cartographic Illustrator

Lynch, Mike—Technology Transfer Officer

Smath, Meg—Geologic Editor

Geologic Mapping

Andrews, William—Section Head

Bottoms, Antonia—Geologist I

Hammond, Max—Geologist I

Martin, Steve—Geologist III

Massey, Matt—Geologist IV

Overfield, Bethany—Geologist III

Waninger, Scott—Geologist II

Water Resources

Taylor, Chuck—Section Head

Cooper, Marie—Student Worker

Currens, Ben—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

KGS 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

Western Kentucky Office

Williams, Dave—Section Head

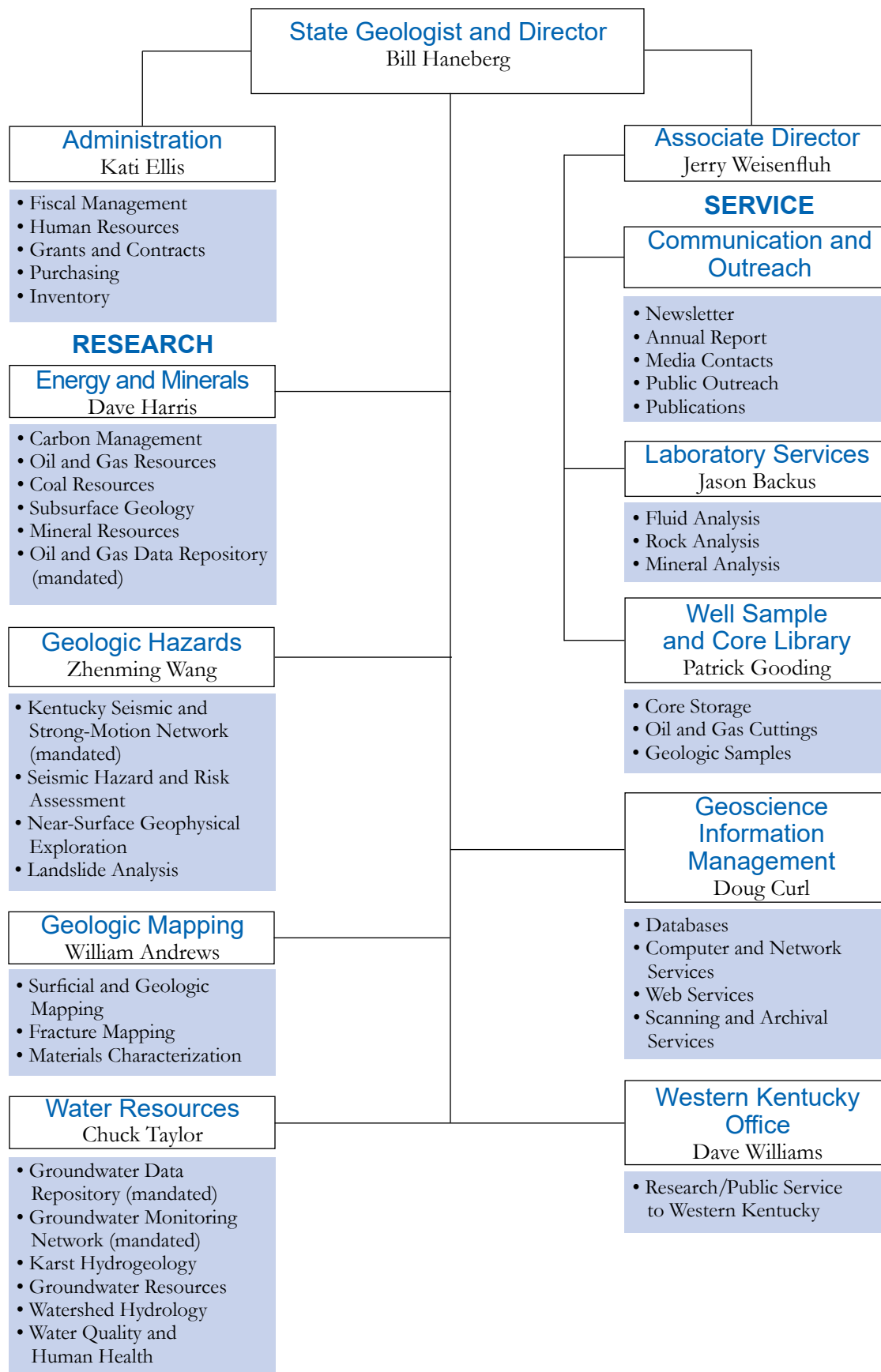
Beck, Glynn—Geologist IV (Water Resources Section)

Bleichroth-King, Amy—Temporary Technician

Keimig, Holly—Temporary Technician

Mayes, Jessica—Temporary Technician

2016 KGS Organizational Chart



In Memoriam



Garland Dever

June 19, 1935–May 17, 2016

Retired KGS researcher **Garland Dever Jr.** died on May 18, 2016, in Lexington. The Lebanon, Ky., native joined KGS on July 1, 1963, and retired from the Survey in June 2001. He returned as a part-time employee a few months later to help with a statewide assessment of limestone resources in Kentucky under the National Geologic Mapping Program.

At least 68 Survey publications bear his name as author or co-author.

The field notes Dever kept and data he compiled on limestone and industrial minerals during his 38 years at the Survey are an invaluable asset to KGS and to Kentucky. His fellow employees appreciated and admired both his geologic knowledge and his warm personality and humor.



Henry Francis

May 28, 1942–August 26, 2016

Retired KGS laboratory manager **Henry Francis** died on August 26, 2016, in hospice care in Lexington. He joined KGS as the lab manager in April 1988, after working in a similar position at the University of Kentucky's Chemical Engineering Department. He had previously taught chemistry at Eastern Kentucky University and worked as a research scientist at the Institute for Mining and Minerals Research at UK, which eventually became the Center for Applied Energy Research.

During his years at the KGS laboratory, Francis, a native of Glasgow, Ky., was involved in water-quality projects across Kentucky, both through partnerships with UK institutes and with the Kentucky Watershed Watch. Francis stayed active in such volunteer efforts after his retirement.



Carl Petersen

December 27, 1945–March 14, 2016

Retired KGS digital mapper **Carl Petersen Jr.** passed away on March 14, 2016. A member of the Digital Mapping Group, Petersen compiled more than 50 individual 7.5-minute digital quadrangles and was considered very thorough in his work. Those who knew him at KGS considered him a good friend. After working about six years at KGS, he was employed by the Kentucky Department of Natural Resources.

Born in Westbrook, Maine, Peterson earned a bachelor of science in engineering from Northeastern University and a master's degree in geology from the University of Kentucky. He enjoyed the outdoors, including hiking in Kentucky, the coast of Maine, the mountains of the western United States, and the Pisgah area of North Carolina.