Kentucky Geological Survey

2019-2020 Annual Report

KGS - University of Kentucky
December 14, 2020

Introduction

Bill Haneberg, State Geologist

A Message from the State Geologist:

Long before most of us had ever heard of a coronavirus—or, at least, used the word in everyday conversation—we at KGS decided to change the look and delivery of our annual report. Printing and mailing a 50-ish-page full-color report cost us thousands of dollars each year and tied us to a static and timeworn format. We mailed hundreds of copies of our annual report to people on our mailing list each year but rarely knew if they were read or not. So we decided to do things differently.

This year, like so many other things in our lives, the KGS annual report is online in a format that allows links to supporting files, interactive graphics, and videos. Everyone on our annual report mailing list will receive a postcard with a scannable QR code that will bring up the annual report on desktop and mobile devices. In fact, there's a good chance that is how you arrived here today.

Read more

Kentucky's Geologic Heritage: The History of KGS and the Geology of Kentucky

COVID-19 concerns forced us to cancel a series of face-to-face stakeholder engagement workshops in eastern Kentucky earlier this year. The workshops were to have been part of a science communication collaboration funded by the National Academies of Science, Engineering, and Medicine. When it became clear that we would not be able to meet in person, KGS created an introductory video to help tell our story as we made a transition to virtual meetings with non-traditional stakeholders. The video shares the story of our organizational history, summarizes our research, and highlights some interesting aspects of Kentucky's geology. The video also introduces stakeholders to the purpose of a geological survey and illustrates how KGS geologists work with our stakeholders to solve practical problems affecting the commonwealth.

Kentucky's Geologic Heritage: The History of KGS and the Geology of Kentucky.

Energy and Minerals

Staff Update

The Energy and Minerals Section welcomed **Gina Lukoczki**, carbonate geologist, to the section in October 2019. Lukoczki earned a master of science in geology and geography at the University of Szeged in Hungary and a Ph.D. from Oklahoma State University. Lukoczki interned with the MOL Hungarian Oil and Gas Company, where she learned several techniques to characterize organic matter, including vitrinite reflectance measurements and Rock-Eval analysis. She continued her interest in carbonates as a research fellow with the Hungarian Academy of Sciences at Eötvös Loránd University in Budapest. While there she studied and conducted research on the genesis of Late Triassic peritidal dolomites in the Transdanubian Range, Hungary.

As a student in the Ph.D. program at Oklahoma State University, as part of her doctoral research, she conducted research on Triassic dolomites in the Mecsek Mountains and expanded it to include a crystallographic approach to

dolomite recrystallization using advanced diffraction techniques. Lukoczki's goal for her new role at KGS is to develop a robust research program integrating basic and applied sciences to help us better understand the genesis and alteration of carbonate rocks. She looks forward to developing projects in which she can combine her expertise in carbonate rocks with her experience in the energy industry. [Link: https://www.uky.edu/KGS/news/gina-research.php]

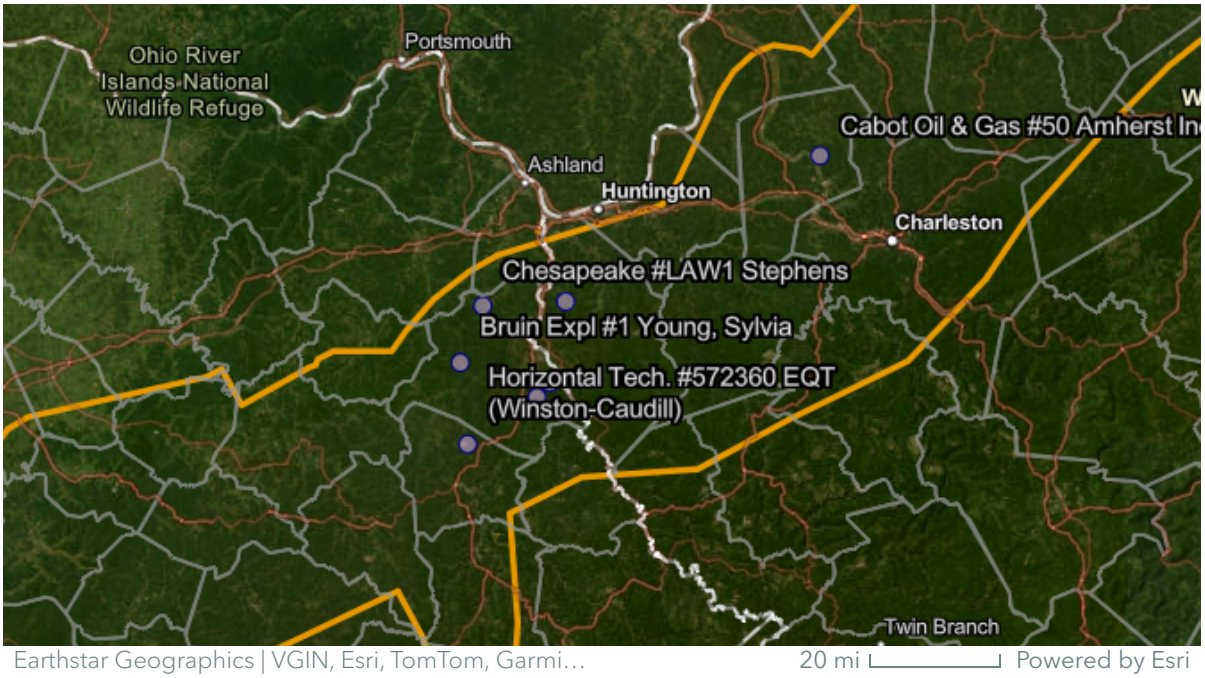
Patrick Gooding, KGS researcher and registered professional geologist, retired in February 2020 after being employed with KGS since 1977. He served as the manager of the KGS Well Sample and Core Library, now referred to as EARL, for many years. Shortly before his retirement, Gooding co-authored with Frank Ettensohn, professor in the Department of Earth and Environmental Sciences at the University of Kentucky, "Mississippian-Devonian Black Shales of Kentucky: East-West Transect in Five Cores from the Appalachian Basin to the Illinois Basin."

Gooding is a member of several professional and scientific organizations, including the American Association of Petroleum Geologists, the Geological Society of Kentucky, and the Kentucky Academy of Science. Gooding was involved with K–12 outreach, serving as a judge for earth science fairs, teaching 4-H members about geology, and assisting with fish and wildlife summer camps. Read more.

Conasauga Shale Research Consortium

Data acquired from recent wells and new data from a field laboratory well will be integrated to develop a plan to improve production and economics and accelerate development of the Rogersville Shale unconventional resource.

From 2014–2017, a new unconventional gas and oil play concept was tested in the deep Rome Trough of eastern Kentucky. Six new Rogersville Shale wells were drilled, and although hydrocarbons were produced from several wells, rates did not meet economic thresholds. Low oil and gas prices have put additional constraints on the play's economics, and the play is currently inactive. This research will attempt to improve future well performance through better understanding of the resource and improved well completion techniques.



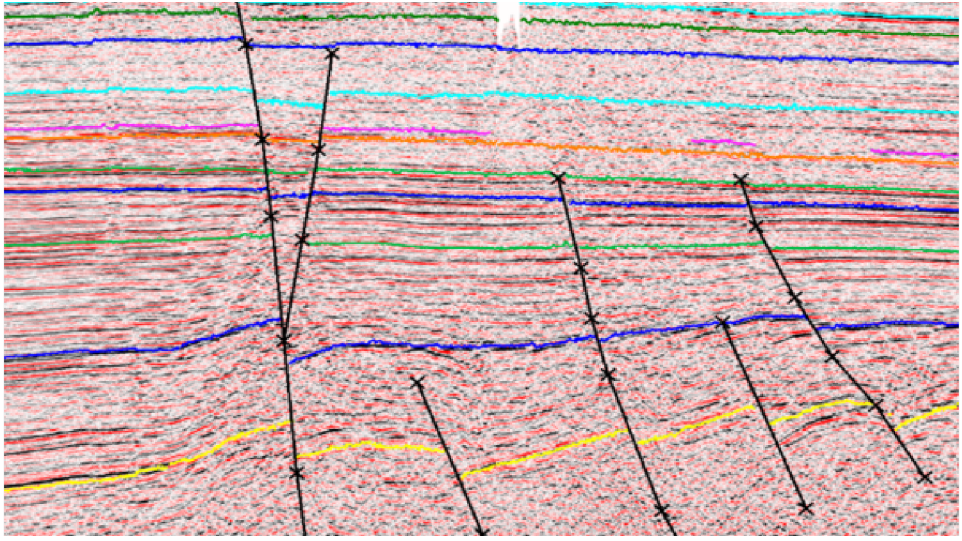
Rogersville Shale wells in eastern Kentucky and western West Virginia. Outline of the Rome Trough, or deep rift basin, outlined in orange.

The current research project was funded in 2019 by the U.S. Department of Energy's National Energy Technology Laboratory. Principal investigator **John Hickman** and co-principal investigator **Dave Harris** are leading a multidisciplinary team of researchers from the Energy and Minerals, Water Resources, and Geologic Hazards Sections at KGS; the West Virginia Geologic and Economic Survey; and West Virginia University's departments of Geology and Geography and Petroleum and Natural Gas Engineering.

Several energy companies have provided data for the project, and our industry partner, Hay Exploration, plans to provide a field laboratory well to allow new well data to be acquired.

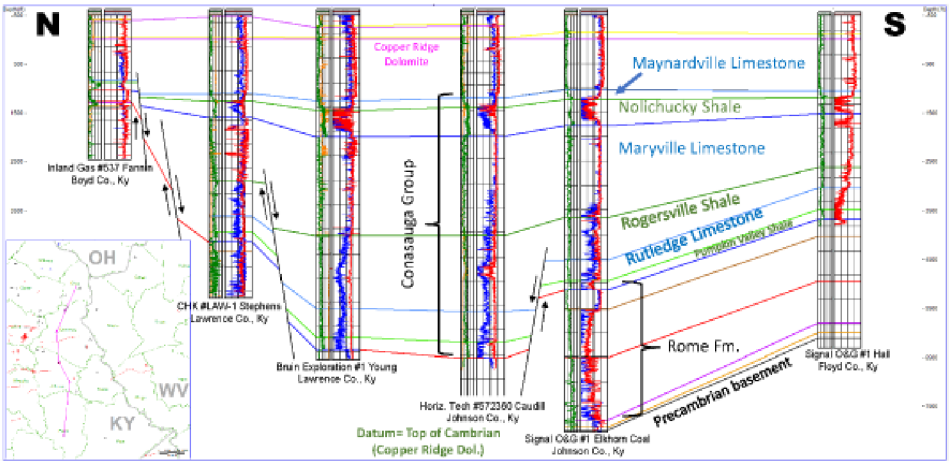
Research began in November 2019 and has focused on

- Compiling and inventorying donated cores, well samples, and several gigabytes of digital data
- Interpreting new seismic reflection data to update subsurface maps
- Compiling a project database with new digital logs and seismic and geochemical data
- Using machine learning to analyze a large proprietary database of information on unconventional well completions to improve Rogersville Shale completion design
- Analyzing recent wells to better understand controls on productivity
- Monitoring regional background seismicity to provide baseline data to help with recognition of future induced seismic events.



Recent seismic reflection data from a part of the Rome Trough study area (interpretation by John Hickman).

Typical Rogersville Shale core: Chesapeake Northup Law 1 well, Lawrence County, Kentucky.



Geophysical well-log cross section through the active play area of Lawrence and Johnson Counties, Kentucky. The section is adjusted to a datum corresponding to the top of Cambrian strata to illustrate the increases in sediment and reservoir thickness within the rift graben.

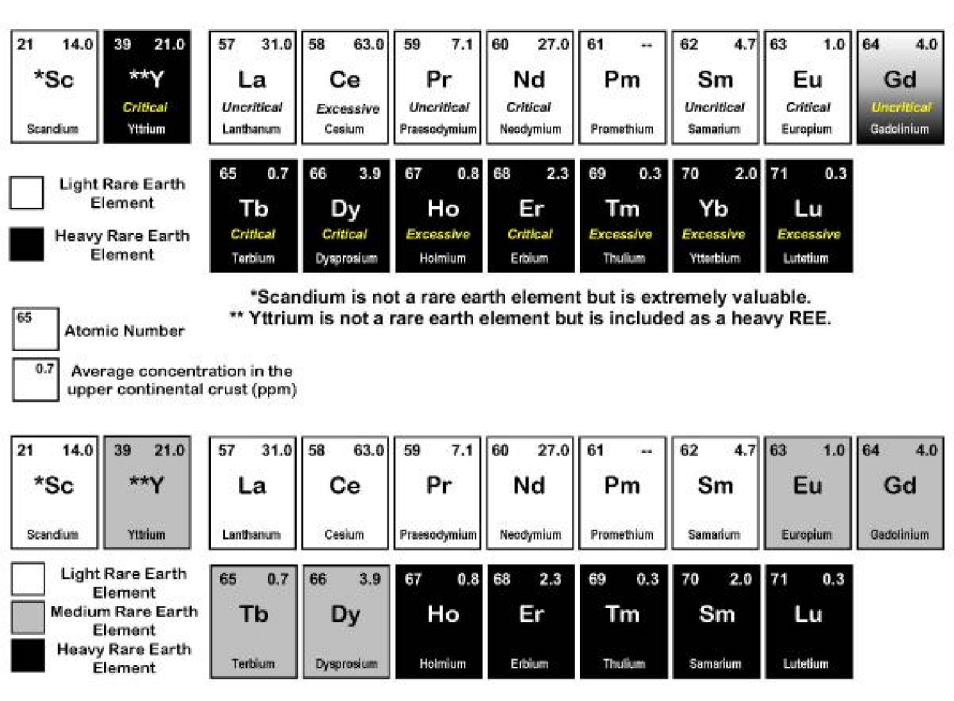
Initial research is underway and funded through early 2021 while we wait for our industry partner to drill the required field laboratory well. In the meantime, we plan to obtain as much data from the rich set of well logs, whole cores and well samples that have been contributed to the project. All results and interpretations will be integrated into a development strategy plan provided on a public website. These results will help guide the next phase of development in the deep Rome Trough.

Rare Earth Elements in Western Kentucky Coal and Coal Byproducts

Coal production in Kentucky has declined over the past decade, with 36 million tons being mined in 2019 compared with 108.2 million tons in 2009, according to the U.S. Energy Information Agency. During the same period there has been a concerted effort to locate and evaluate domestic sources of rare earth elements, which are economically and strategically important, to decrease our reliance on foreign sources. Since 2014, KGS has participated in several U.S. Department of Energy–funded research projects designed to investigate the

potential of coal and coal-mining byproducts as economically viable sources of rare earth elements.

Because of their unique magnetic, luminescent, and chemical properties, rare earth elements play a key role in the manufacturing of materials and products. Yttrium is commonly included with rare earth elements because it is closely associated with them and has a similar ionic radius and an ionic charge equal to that of holmium. Two common classifications of rare earth elements + yttrium (REY) are shown in the figure below: (A) heavy and light and (B) medium, light, and heavy. The terms *light, medium,* and *heavy* refer to the atomic weights of the elements and, in part, relative occurrence value. In general, light REY are more abundant and command a lower market price than medium and heavy REY, which are less abundant and more costly to purchase.

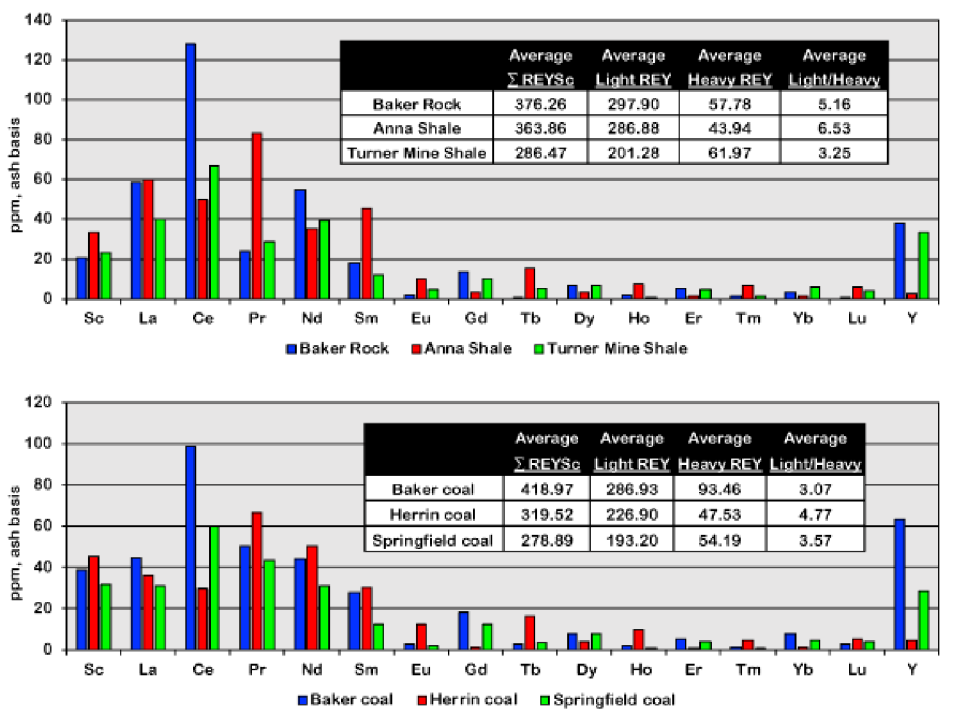


Classifications of rare earth elements + yttrium shown on the periodic table of the elements.

Rare earth elements have been separated into critical (yttrium, neodymium, europium, terbium, and dysprosium),

uncritical (lanthanum, promethium, samarium, and gadolinium), and excessive (cerium, holmium, thulium, and ytterbium) groups, based on their occurrence and requirement in manufactured materials. A parameter called the outlook coefficient is commonly used to determine the relative value of REY-bearing materials. Materials with high coefficients have higher potential industrial value. Although scandium is not a rare earth element, it is included in many assessments because of its high monetary value.

KGS researchers **Cortland Eble, Jason Backus,** and **Ethan Davis** in collaboration with **James Hower** (UK Center for Applied Energy Research), **Rick Honaker** and **Jack Groppo** with UK's Department of Mining Engineering, **Ernie Thacker** and **Justin Biliter** with Alliance Coal, and **Craig Daniels** (Kentucky River Properties) are evaluating coals from the Western Kentucky Coal Field for REY content. Three western Kentucky coals—the Baker (W. Ky. No. 13), Herrin (W. Ky. No. 11), and Springfield (W. Ky. No. 9)—have been evaluated for their REY content as shown in the following figure.



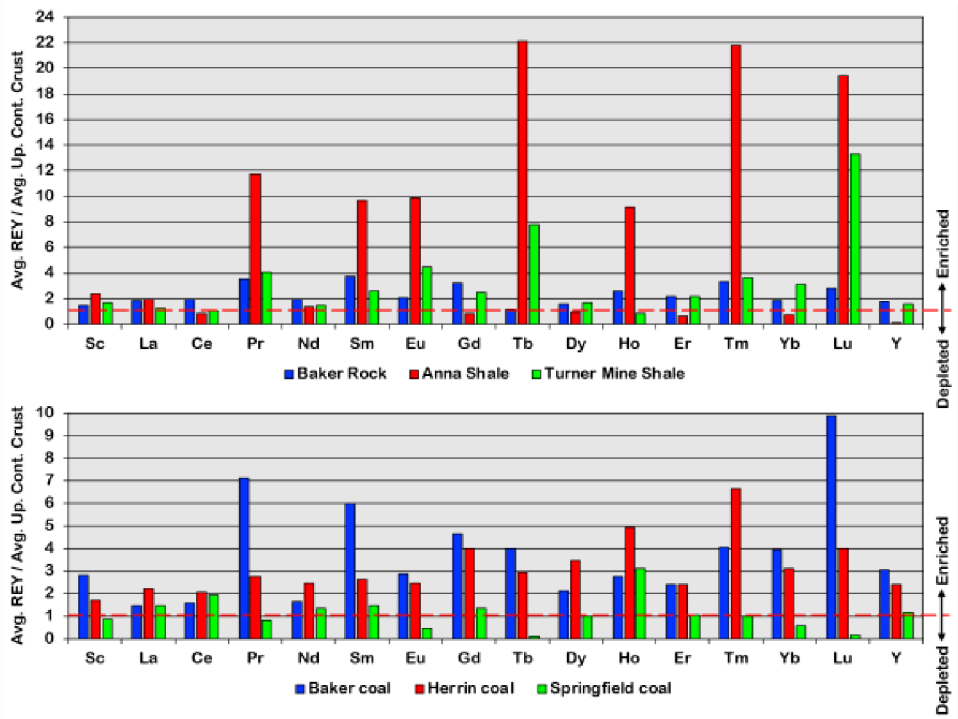
	Average ΣREYSc	Average Light REY	Average Heavy REY	Average Light/Heavy
Baker Rock	376.26	297.90	57.78	5.16
Anna Shale	363.86	286.88	43.94	6.53
Turner Mine Shale	286.47	201.28	61.97	3.25

	Average ΣREYSc	Average Light REY	Average Heavy REY	Average Light/Heavy
Baker coal	418.97	286.93	93.46	3.07
Herrin coal	319.52	226.90	47.53	4.77
Springfield coal	278.89	193.20	54.19	3.57

REY data for the Baker, Herrin, and Springfield coals.

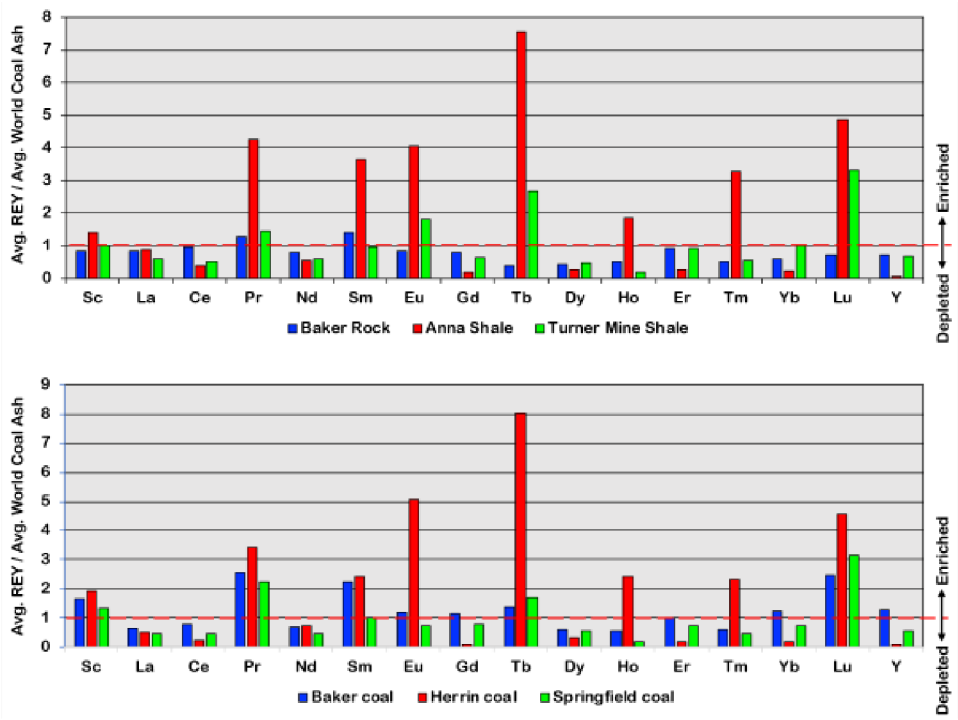
Most of the coal currently produced in western Kentucky comes from these three beds, all of which have significant remaining resources. Average REY abundances are highest in the Baker coal and lowest in the Springfield coal, with light REY being between three to almost five times as abundant than heavy REY. Abundances in rock partings, common in the Baker coal but less common in the Herrin and uncommon in the Springfield coal, and organic-rich roof shale strata above the Herrin (Anna Shale) and Springfield (Turner Mine Shale) coals are similarly distributed, with highest values occurring in the Baker rock partings and lowest in the Turner Mine Shale.

When total rare earth element concentrations from western Kentucky coals and shales are compared with average values from the upper continental crust, several elements show enrichment in the western Kentucky units. The Baker coal is significantly enriched—greater than four times the upper continental crust average—in praeseodymium, samarium, gadolinium, thulium, and lutetium, and the Herrin coal is significantly enriched in gadolinium, holmium, and thulium. The Springfield coal shows no significant enrichment, and several elements, including scandium, praseodymium, europium, terbium, dysprosium, thulium, and lutetium, occur in lower concentrations than upper continental crust averages.



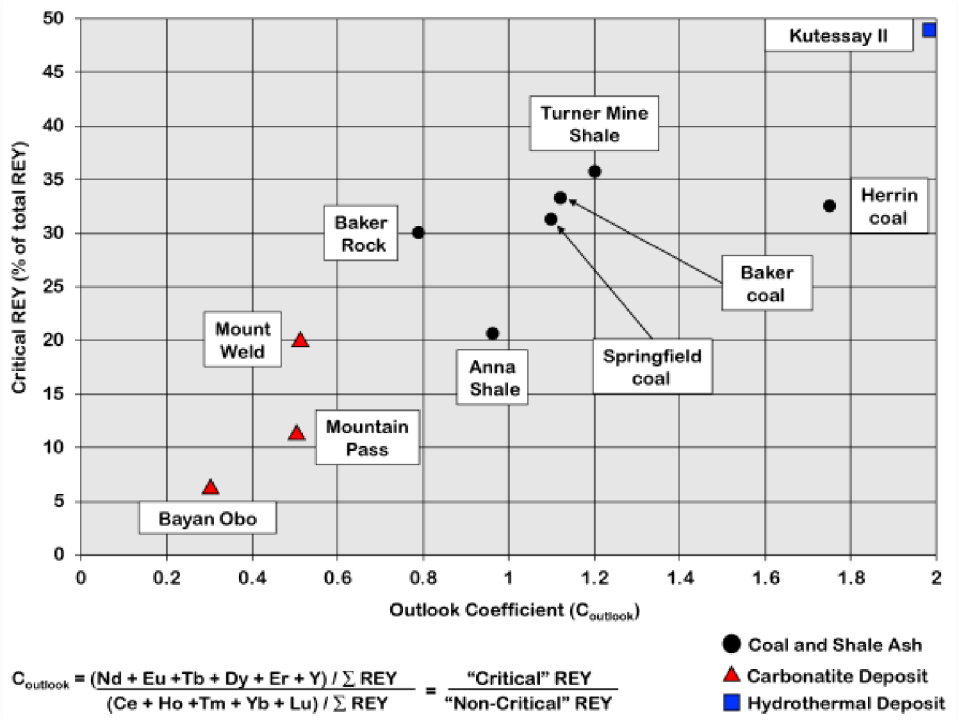
Element enrichment in the coal and shale evaluated in this study.

The Anna Shale shows significant enrichment in praeseodymium, samarium, europium, terbium, holmium, thulium, and lutetium, and the Turner Mine Shale is enriched in europium, terbium, and lutetium. Rock-parting samples from the Baker coal show no significant enrichment, and they are depleted in cesium and holmium compared to the upper continental crust averages. When total rare earth element concentrations from western Kentucky coals and shales are compared with world coal ash averages, only europium, terbium, and lutetium from the Herrin coal and overlying Anna Shale show significant enrichment, and several elements (lanthanum, cesium, neodymium, gadolinium, dysprosium, europium, ytterbium, and yttrium) are noticeably depleted compared to world coal ash averages.



Rare earth element concentrations in the Baker, Herrin, and Springfield coals compared to world coal ash averages.

The figure below shows the percentage of critical elements in western Kentucky coal and shale relative to their respective outlook coefficients, indicating that all the studied lithologies show some potential for economic extraction of REYs, though processing costs and fluctuations in market-driven economic factors must be considered.



Percentage of critical elements in western Kentucky coal and shale relative to their respective outlook coefficients.

Water Resources

Staff Update

Amy Wolfe joined the Water Resources team in July 2019 to conduct research in the fields of geohealth and environmental geochemistry. She plans to develop new techniques for analyzing diverse materials and assessing environmental exposure to chemical compounds in order to better understand contaminant transfer into animal and human populations. She earned a bachelor's degree in marine science at the University of South Carolina, and a Ph.D. in geology at the University of Pittsburgh.

After completing her doctorate, Wolfe was employed with the U.S. Environmental Protection Agency. While there, she studied the relationship between hydraulic fracturing and drinking-water resources. Prior to working for KGS, she managed the operation of six laboratory facilities, including

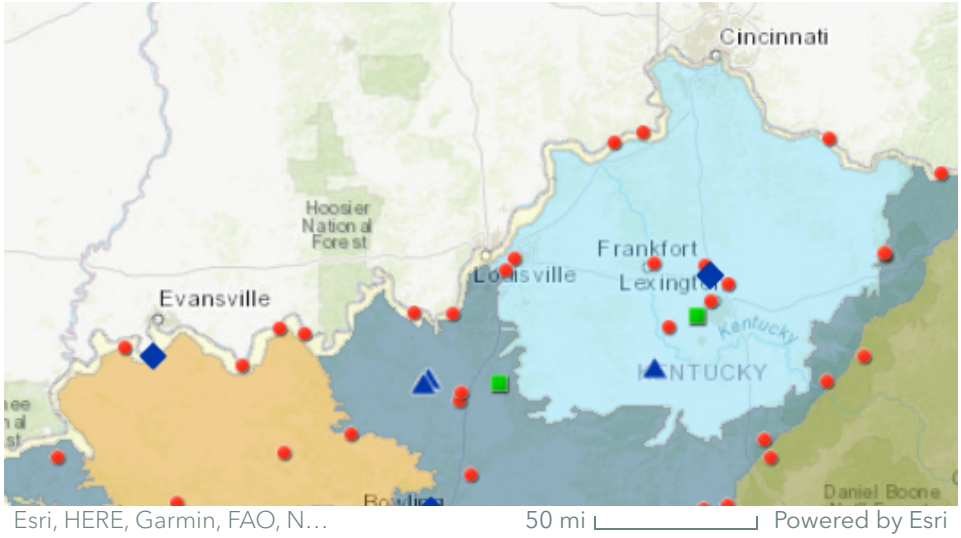
two trace-metal geochemistry labs and four labs housing analytical equipment at Miami University's Department of Geology and Environmental Earth Science. [Link: https://www.uky.edu/KGS/news/amy-wolfe-joins-kgs.php]

Improved Access to Kentucky Groundwater Data

Groundwater is a vital natural resource used extensively throughout Kentucky for public and private water supplies. Because of its connection to rivers, lakes, and wetlands, groundwater is also essential to the health and sustainability of the state's surface waters. Improving access to groundwater data is therefore critical to Kentucky's environmental and economic well-being.

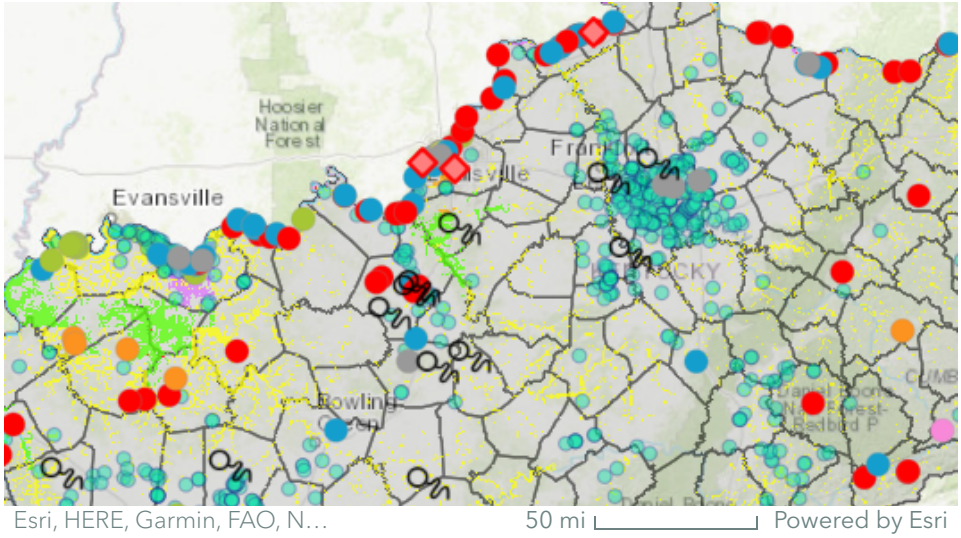
In early 2020, KGS released two new webpages that use interactive digital maps to display and provide access to groundwater data. The pages are accessible under the "Water" dropdown menu from the KGS homepage.

The interactive map on the Groundwater Monitoring page depicts the locations of all active groundwater-monitoring sites and networks in the state. Monitoring sites are identified by the agency responsible for site selection and operations maintenance. They include 10 wells and three springs in the Kentucky Groundwater Observation Network administered by KGS, four wells in the U.S. Geological Survey Climate Response Network, and the Kentucky Division of Water Groundwater-Quality Monitoring Network. Collectively these sites provide a statewide set of water wells and springs used to track and assess short-term and longer-term changes in groundwater conditions in Kentucky's principal aquifers—in particular, changes in groundwater levels or quality (or both).



Interactive Map of Groundwater Monitoring Sites in Kentucky. Access to information about the monitoring sites and to groundwater data collected from the sites is provided in a pop-up window that appears when any monitoring site's symbol is selected or clicked on. Scrolling down farther in the pop-up window gives access to other information about the observation well, including the name of the aquifer being monitored, the date monitoring was started, and a water-level hydrograph. Similar data are provided in pop-up windows for the USGS National Climate Network wells and the Kentucky Division of Water Groundwater-Quality Network sites.

Another interactive map, "Kentucky Permitted Water-Supply Wells and Springs," depicts the locations of wells and springs used for public and private water supplies that withdraw at least 10,000 gallons per day and are regulated under the state's water-withdrawal permit program. It also shows the locations of more than 1,000 agriculture irrigation wells, which are presently exempted from regulation by permit. Pop-up windows provide a summary of the site information, such as a water well's location, total depth, yield, and designated aquifer source, and links are provided to search and retrieve available data stored electronically in the Kentucky Groundwater Data Repository.



Interactive Map of Kentucky Permitted Water-Supply Wells and Springs

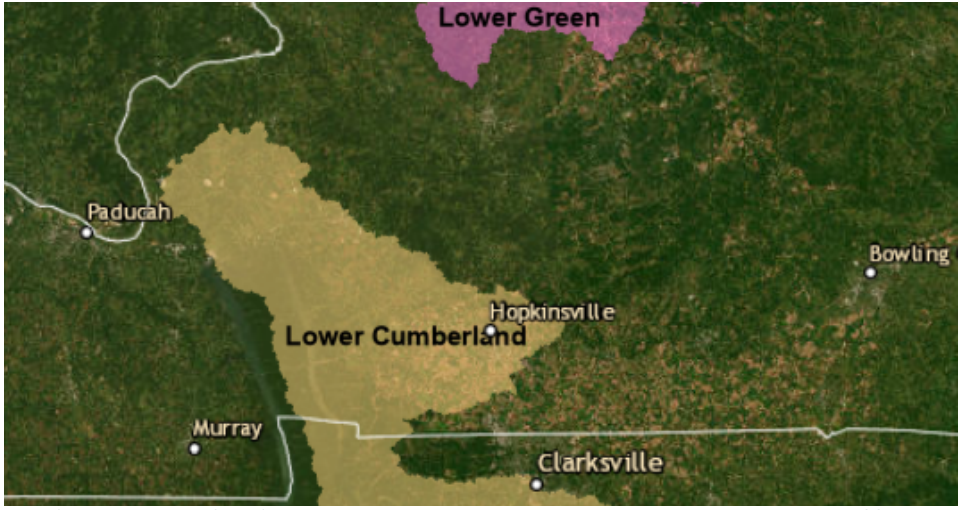
Blue Water Farms: Edge-of-Field Monitoring Network in Western Kentucky

Glynn Beck is conducting edge-of-field monitoring of nutrient and sediment loss from active row-crop fields in the watersheds of the lower Green River and lower Cumberland River in western Kentucky (see figure below) as part of a multiyear collaboration with **Brad Lee, Jason Unrine,** and **Erin Haramoto** of the UK College of Agriculture, Food and Environment. Phase 1 of the project was initiated in early 2018 and should run through 2028. During Phase 1, Beck and his collaborators identified six suitable watersheds, ranging in size from 3.5 to 11.5 acres, and installed a flume, automated sampler, and ultrasonic flow meter in each watershed outlet (see figure below). Phase 1 nutrient and sediment sampling began in July 2018. Phase 2 sampling began in 2019 when a flume, automated sampler, and ultrasonic flow meter were installed in four watersheds, ranging in size from 3 to 7 acres, in the lower Green River watershed. Nutrient and sediment sampling began in July 2019 and should run through 2029. Phase 3 began during the 2019-20 fiscal year. Twelve watersheds ranging in size from 3 to 10 acres were identified in the lower Cumberland River watershed and are currently being instrumented with flumes, automated samplers, and

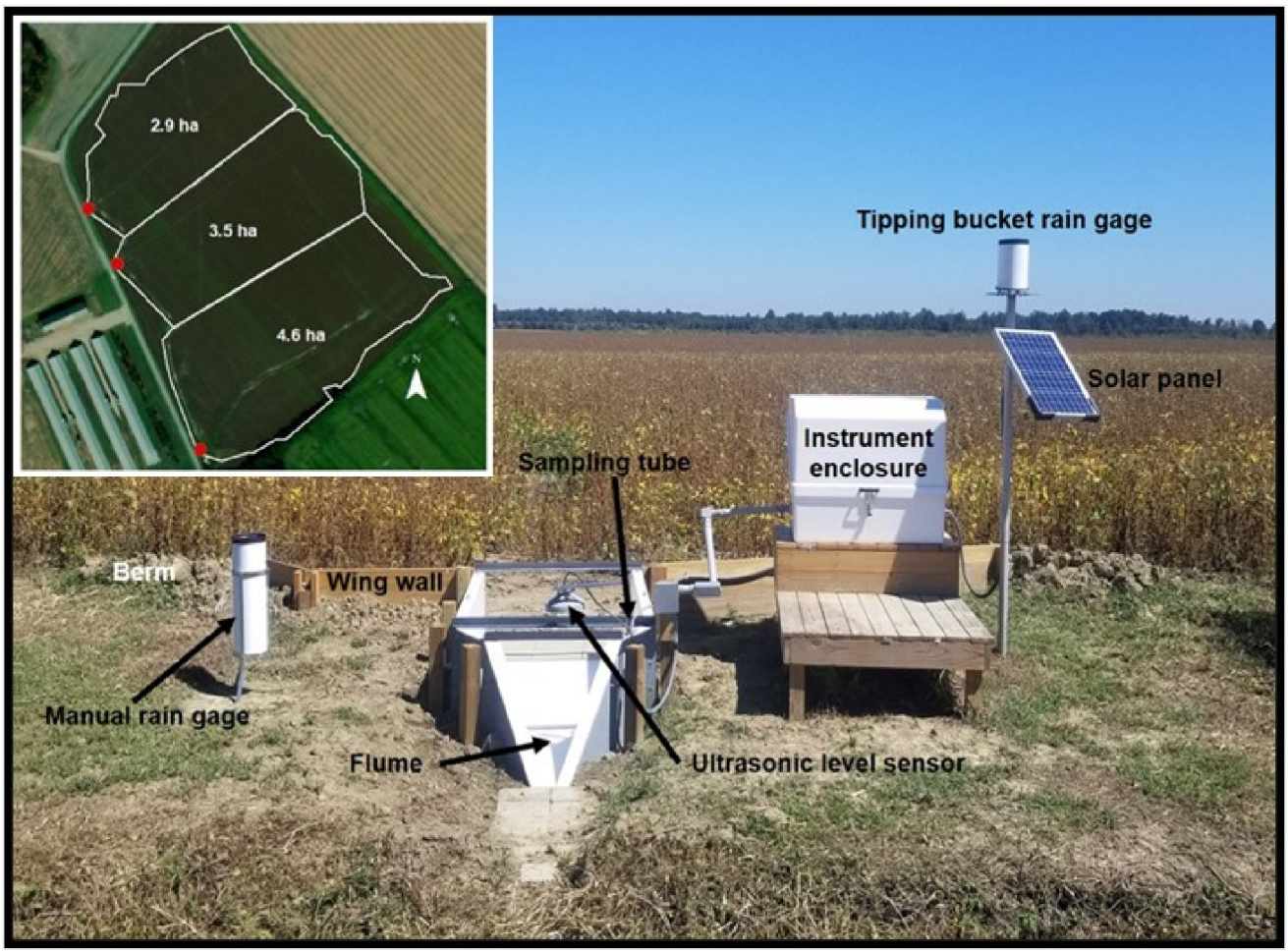
ultrasonic flow meters. Nutrient and sediment sampling is scheduled to begin in January 2021 and should run through 2030.

The project will determine the nutrient (nitrogen and phosphorus) and sediment loss from active row-crop fields under different nitrogen-application methods and cover crops. Two years of baseline data will be collected from paired watersheds prior to implementing a control (current agricultural practice) and treatment (conservation practice). Examples of discharge, total solids, and nitrate plus nitrite concentration data from Phase 1 watersheds are shown in the following figures.

Results of this project have local to national implications. Locally, results are expected to help agricultural producers better manage their nutrient applications and soil loss, which are both directly related to a farm's economy and sustainability. Nationally, nutrient loss from row-crop fields is directly linked to hypoxia in the Gulf of Mexico. Collaborator **Mark Akland** of the UK Department of Plant and Soil Sciences, stationed in the KGS Western Kentucky Office, is conducting field work for the project. The project is funded in part by the Kentucky Soybean Board, through an Environmental Quality Incentives Program contract from the Natural Resources Conservation Service, and the Kentucky Agricultural Development Fund.

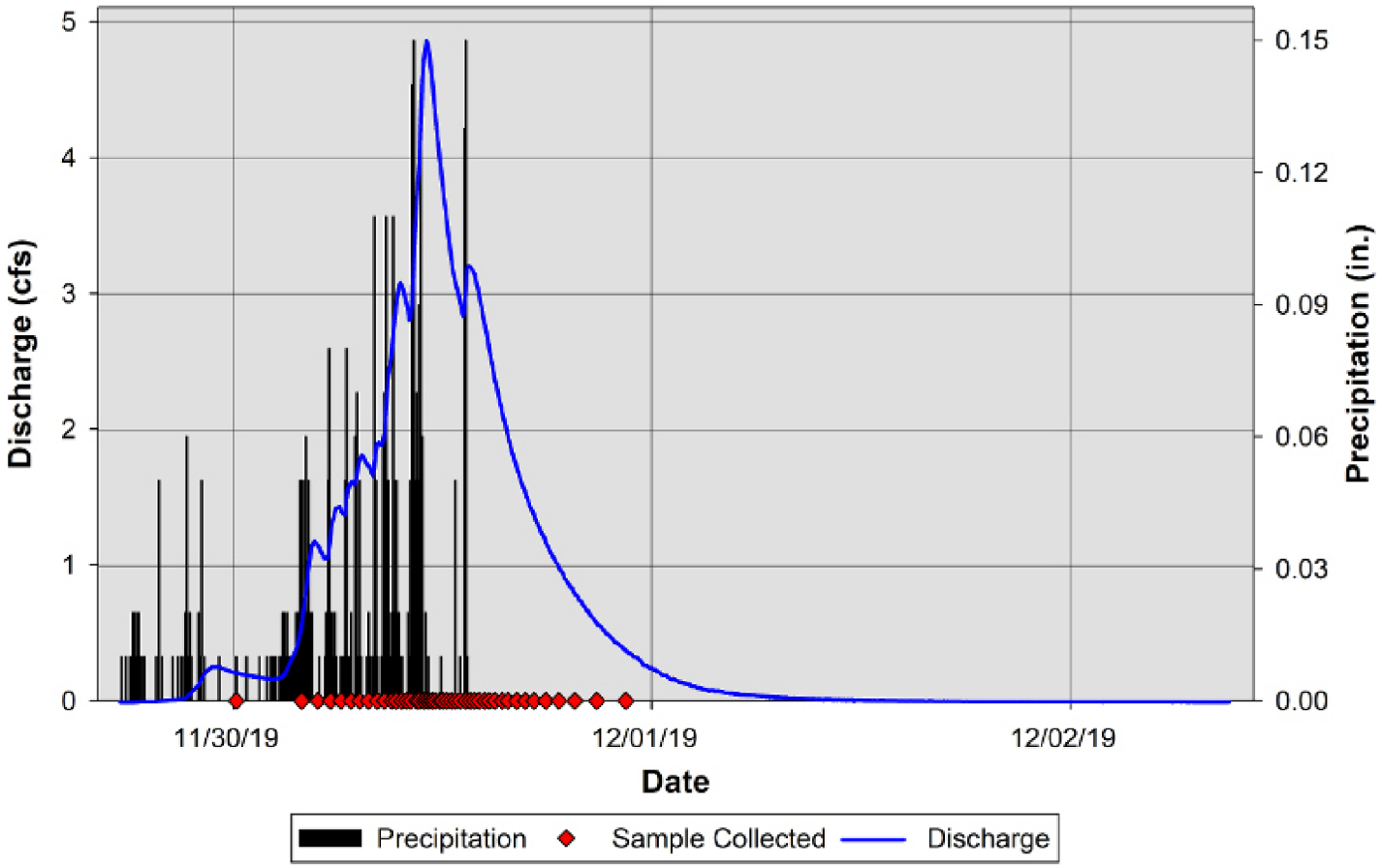


Lower Green and Lower Cumberland watersheds. The project involves parts of the watershed located in Kentucky.



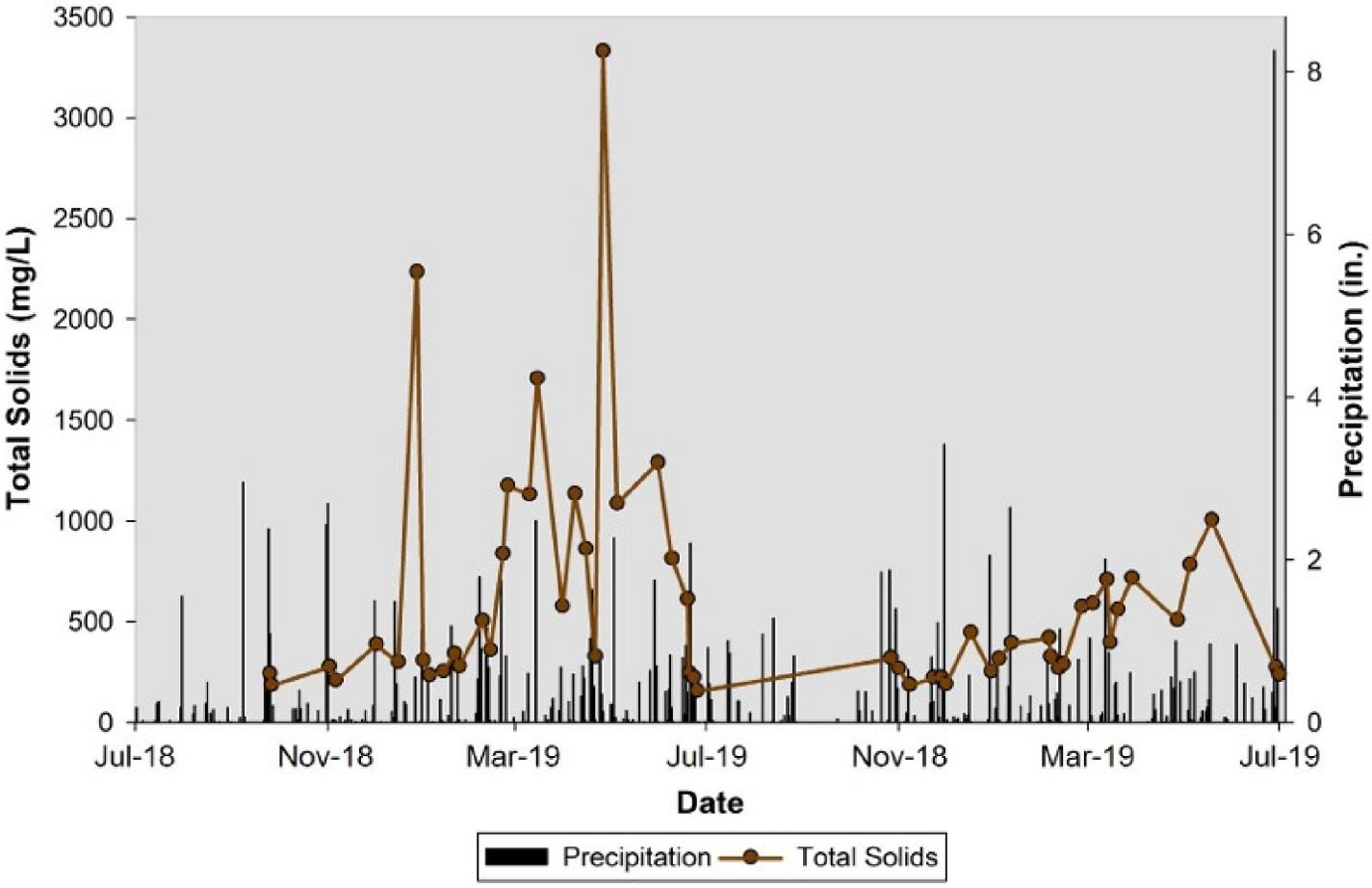
A typical edge-of-field monitoring station

The inset map shows the boundary of three watersheds (white polygons) in a row-crop field and the location of the monitoring stations (red dots).

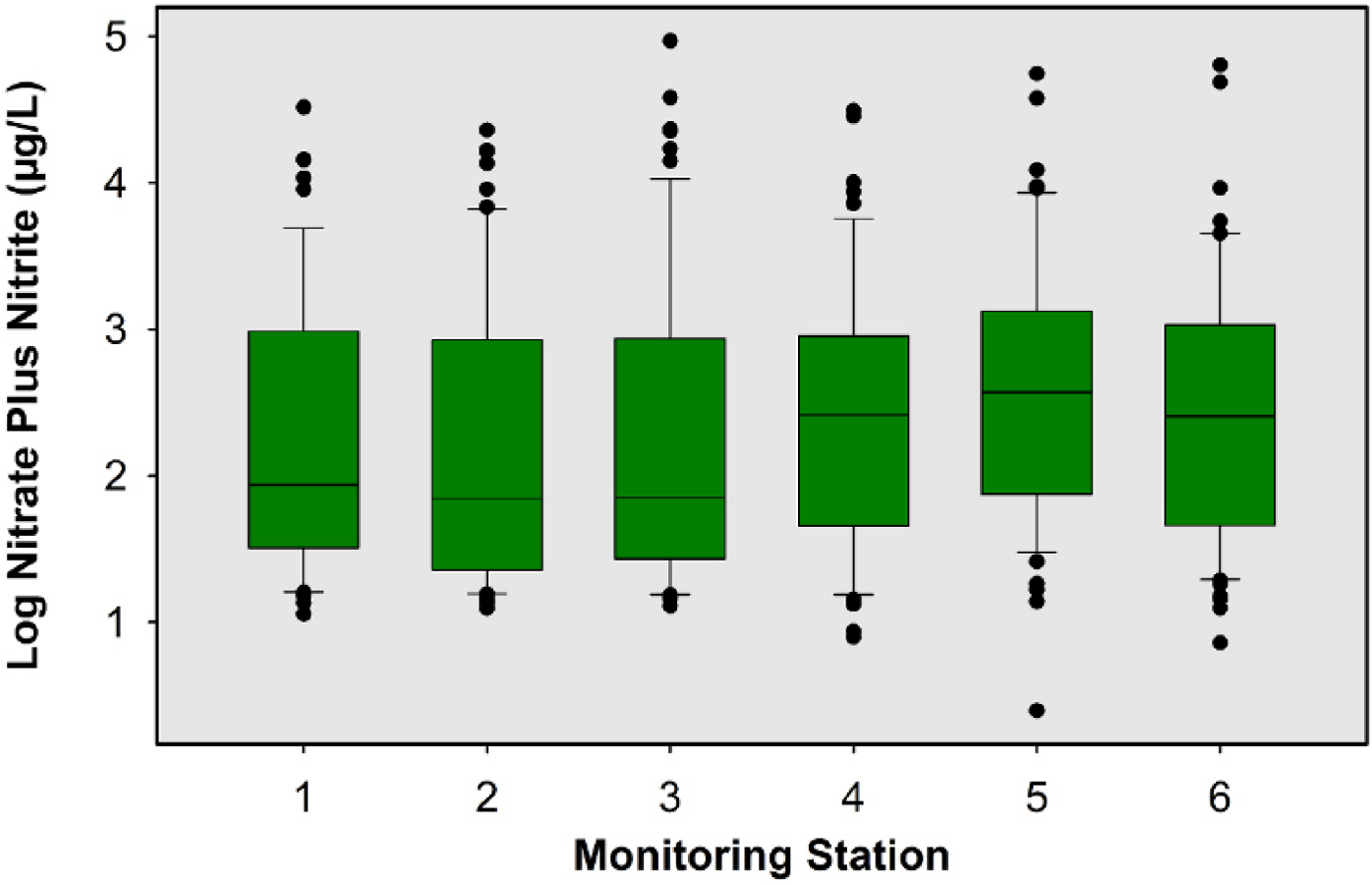


A typical discharge event with precipitation

A red diamond indicates when a water-quality sample was collected during a discharge event. This event occurred at one of the lower Green River watershed monitoring stations.



Total solids data collected from July 1, 2018, to June 30, 2019, from one of the lower Green River watershed monitoring stations.



Log nitrate plus nitrite data for the six monitoring stations in the lower Green River watershed during Phase 1. Data collected between July 1, 2018, and June 30, 2019.

Karst Hydrogeology Projects

KGS scientists participated in varied karst hydrogeology projects to develop innovative methods of characterizing groundwater movement in karst aquifer systems, improve high-resolution mapping of karst sinkholes, and apply geophysical survey methods to identify and better delineate subsurface karst conduits and other hydrogeologic features. Read more.

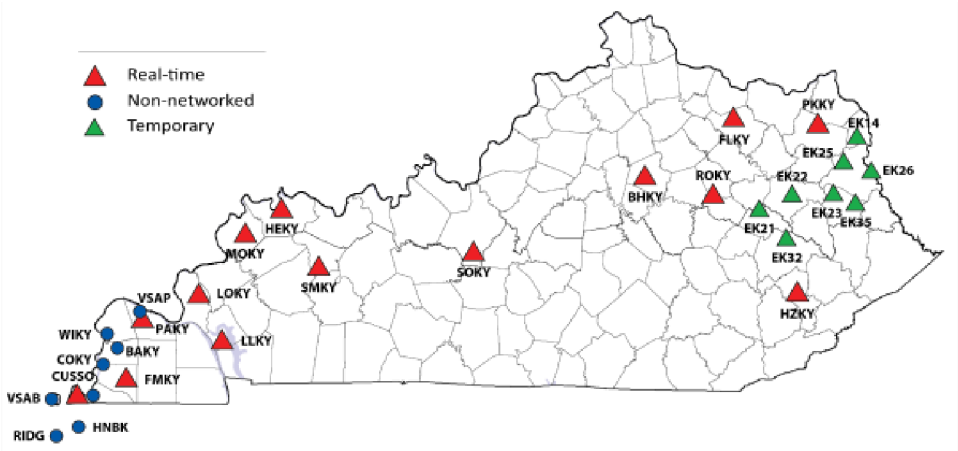
Geologic Hazards

Staff Update

The Geologic Hazards Section welcomed new team member **Jon Schmidt** in March of 2020. Schmidt earned his bachelor of science in geology with a minor in engineering from BYU-Idaho. He is preparing to defend his thesis in completion of his master of science degree in geophysics from New Mexico Tech. Schmidt gained experience in network seismology and instrumentation and earthquake source analysis from his professional experience in both the public and private sectors. In his role at KGS, Schmidt will work on the Kentucky Seismic and Strong Motion Network and the Rogersville Shale project. [Link: https://www.uky.edu/KGS/news/jonathan-schmidt.php]

Kentucky Seismic and Strong Motion Network

The Geologic Hazards Section operates and maintains the Kentucky Seismic and Strong-Motion Network, which monitors earthquakes in and around the commonwealth. The network consists of 22 permanent seismic and strong- motion stations and eight temporary seismic stations (see figure below). Fourteen earthquakes, with magnitudes ranging from 1.1 to 2.9, were located within the state between July 1, 2019, and June 30, 2020. KGS maintained a data share of real-time network recordings from 14 seismic stations with the neighboring seismic network operated by the University of Memphis and with the Data Management Center at Incorporated Research Institutions for Seismology for archiving and global usage. More than 350 gigabytes of our network data was downloaded from IRIS this fiscal year for use around the globe.



Kentucky Seismic and Strong-Motion Network.

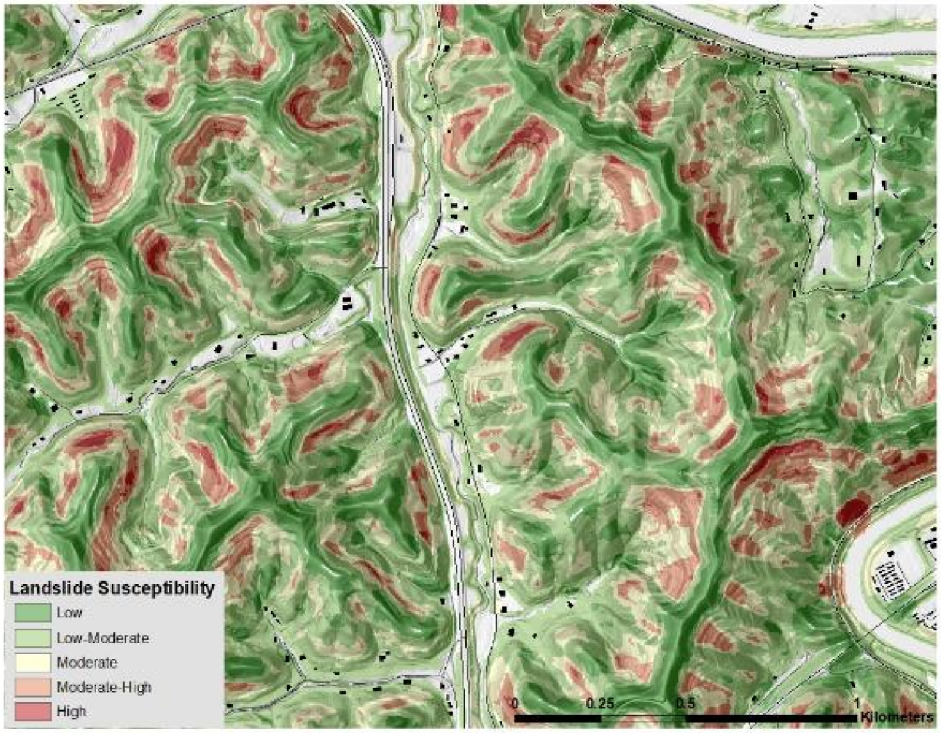
Jon Schmidt works on seismic station EK32 in Breathitt County, Kentucky.

FEMA—Pre-Disaster Mitigation Grant for Landslide Hazard and Mitigation in the Big Sandy Area Development District

Matt Crawford, Hudson Koch, and **Jason Dortch** are working on the FEMA- funded Pre-Disaster Mitigation Grant for landslide hazard and mitigation in the Big Sandy Area Development District. The project assesses landslide hazard and risk, with a goal of mapping and identifying vulnerable areas and the potential impact that landslides have on the built environment. The most important part of the project is to communicate the maps and related information to stakeholders. An approach of combined Machine Learning

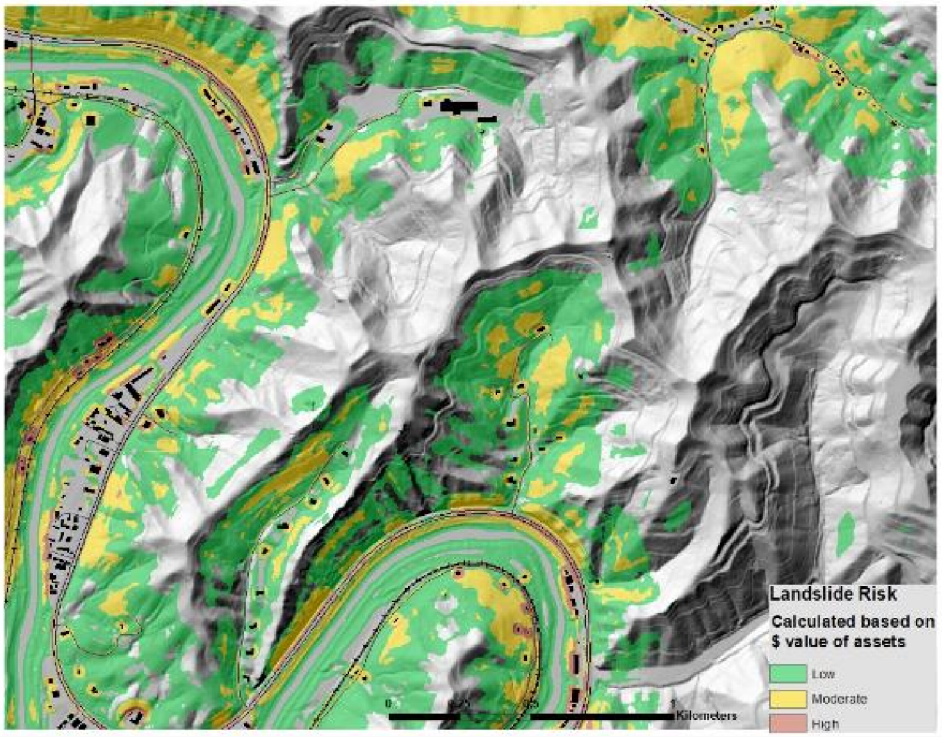
and statistics was developed and applied to produce geomorphic-based landslide susceptibility maps. The maps are divide landslide susceptibility into five classes: low, low–moderate, moderate, moderate–high, and high. **Crawford, Dortch, and Koch,** along with **Ashton Killen, Junfeng Zhu, Lindsey Bryson,** and **Bill Haneberg** co-authored a paper, "Using Landslide Inventory Mapping for a Combined Machine Learning and Statistical Approach to Geomorphic-Based Landslide Susceptibility, Eastern Kentucky," to summarize the mapping methods and submitted it to the *Journal of Landslides* for publication.

Matt Crawford discusses landslide hazard and risk with stakeholders from the Big Sandy Area Development District.



Landslide susceptibility for a part of Floyd County, Kentucky.

The risk assessment includes a semiquantitative and more comprehensive analyses of landslide effects on population, roads, railroads, and buildings. Physical, monetary, and safety vulnerability components of risk will be evaluated. We compiled several datasets related to exposure and vulnerability of assets in the Big Sandy Area Development District (population, roads, buildings, railroads, and land type), which have supported the calculation of landslide risk. The vulnerability data is all based on static monetary value—essentially the direct costs of these assets—represented as GIS datasets. The figure below shows an example of landslide risk map for part of Pike County, Kentucky.



Part of a landslide risk map of Pike County, Kentucky. The solid black lines are roads, the hachured black lines are railroads, and the black polygons are buildings.

Other work related to landslide hazards includes compilation of the landslide inventory database; mentoring a summer intern, **Ashton Killen,** an undergraduate student from Morehead State University; and collaborating with U.S. Geological Survey staff and other researchers to compile publicly available landslide inventories. A paper, "Landslides Across the USA: Occurrence, Susceptibility, and Data Limitations," was published in the *Journal of Landslides*.

U.S. Department of Energy Rogersville Shale Project

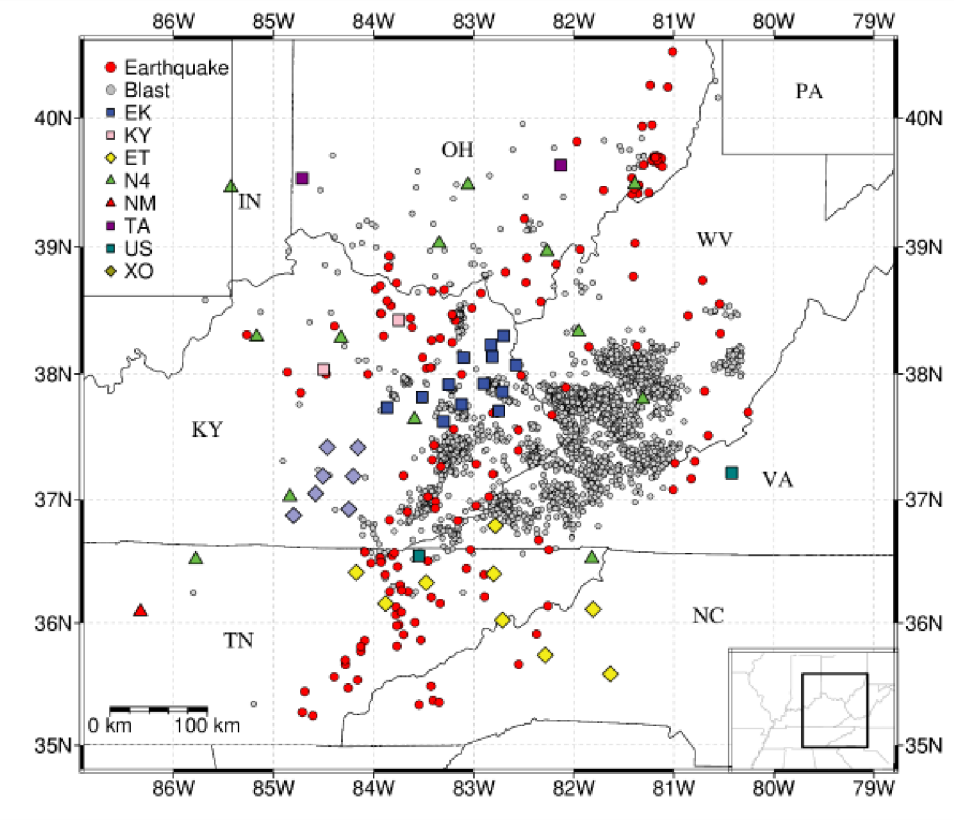
As part of the DOE-sponsored Conasauga Shale Research Consortium, led by **John Hickman** (Energy and Minerals section), **Seth Carpenter, Zhenming Wang,** and **Jon Schmidt,** operated seven sensitive seismic stations in the Rome Trough of eastern Kentucky beginning in October 2019. These stations were installed in 2015 as part of a pilot study to characterize microseismicity where the possibility of inducing earthquakes

from producing hydrocarbons from the Rogersville Shale is greatest and where clusters of wastewater injection wells are in operation. For this project, a new seismic station was installed near Paintsville in February 2020. Recordings from the network of stations are acquired in real-time and analyzed at KGS as part of an effort to continue and improve the investigation that began in 2015.

Results from the initial microseismicity study undertaken by the Geologic Hazards Section from 2015 to 2018, were published in the *Seismological Research Letters* in May 2020, in a paper titled "Natural Seismicity in and Around the Rome Trough, Eastern Kentucky, From a Temporary Seismic Network" by **Seth Carpenter, Andrew Holcomb** (now with KBRWyle Technology Solutions Inc.), **Zhenming Wang, Ed Woolery, John Hickman,** and **Steven Roche** (University of Tulsa). The authors found that the Rome Trough of eastern Kentucky appears to be seismically quiet: Only three earthquakes were observed during the study period in the crust bounded by the trough's boundary faults, where the temporary network was most sensitive. This contrasts with areas of much greater activity to the north and south of the trough, which include the source regions of the 1980 magnitude-5.0 Sharpsburg and 2012 magnitude-4.2 Perry County earthquakes, and suggests that the earthquake potential in the Rome Trough is low.

Machine Learning techniques were applied to analyze seismograms from the initial microseismicity study to accurately and automatically distinguish between earthquake recordings and those of mine blasts. As shown below, more mine blasts than earthquakes were recorded by the seismic network in eastern Kentucky and Tennessee, southeastern Ohio, southwestern Virginia, West Virginia, and western North Carolina between 2015 and 2018. The results were published in May 2020 in *Seismological Research Letters* in a paper titled "High-Accuracy Discrimination of Blasts and

Earthquakes Using Neural Networks With Multiwindow Spectral Data," by visiting scholar **Fajun Miao, Seth Carpenter, Zhenming Wang, Andrew Holcomb,** and **Ed Woolery.** The study demonstrated that machine-learning techniques can greatly improve the efficiency of data analysis and reduce an analyst's effort for event classification by as much as 97 percent.



Earthquakes and mine blasts recorded by the Kentucky Seismic and Strong-Motion Network in eastern Kentucky, Tennessee, southeastern Ohio, southwestern Virginia, West Virginia, and western North Carolina between 2015 and 2018.

Geologic Mapping

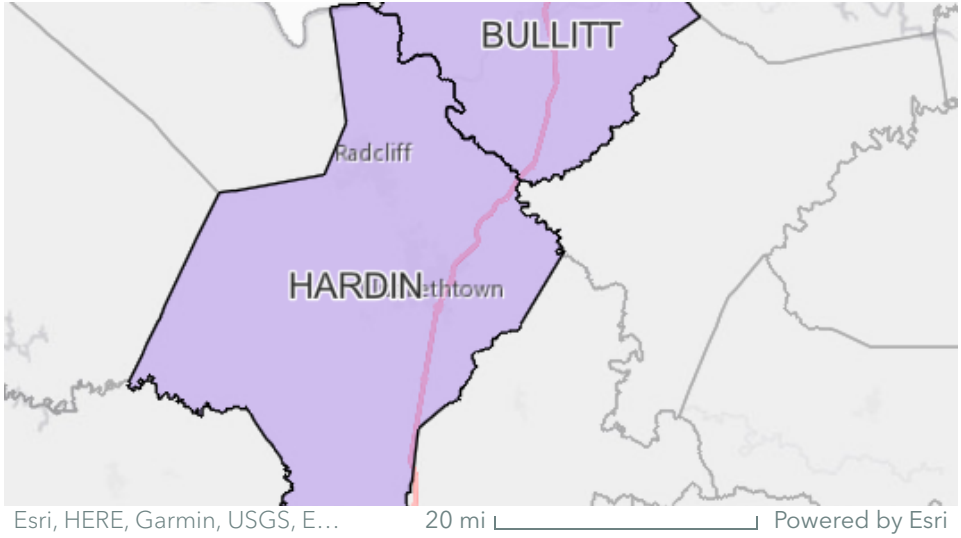
STATEMAP 2020

The KGS mapping program received another U.S. Geological Survey STATEMAP grant for fiscal year 2019 to continue mapping along the Interstate 65 corridor. This mapping builds

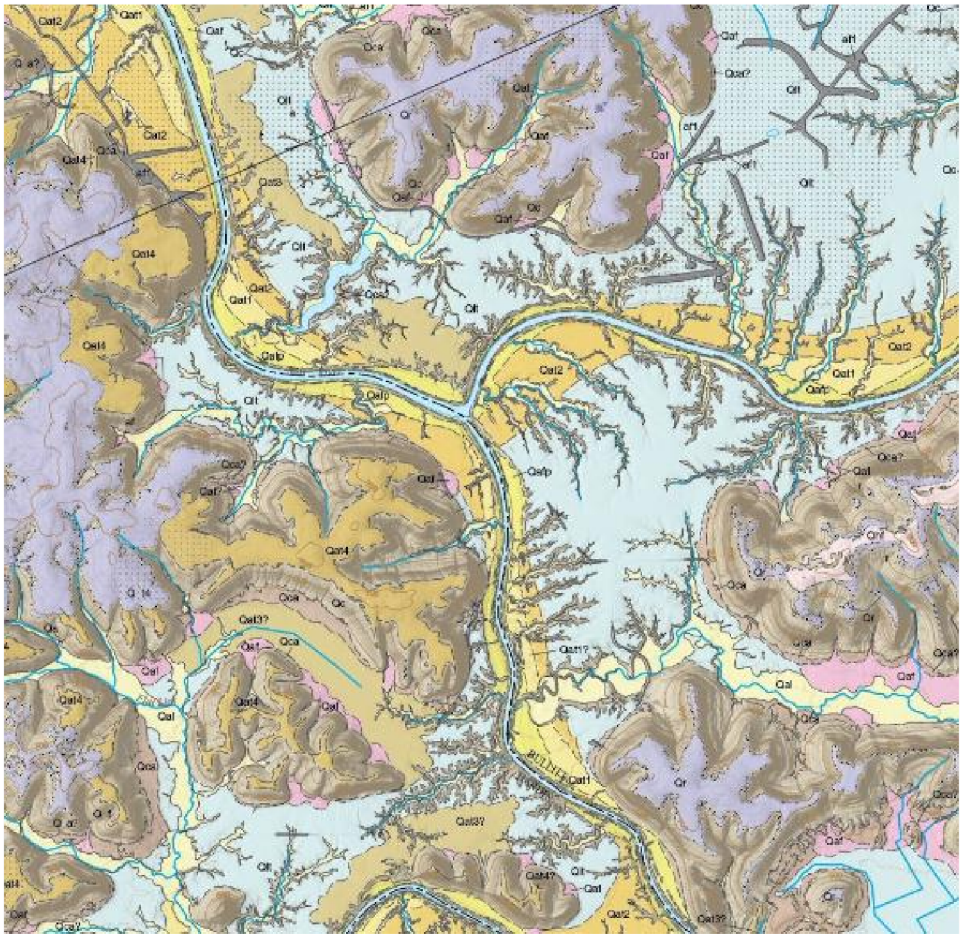
on the previous year's project in Fort Knox, completing Bullitt County and adding to existing mapping in Hardin County. The geologic mapping team is using both LiDAR- and field-based geomorphic analysis, outcrop examination, soil and sediment description, grain size analysis, and X-ray diffraction–and X-ray fluorescence–based mineralogy and chemistry to characterize and differentiate unconsolidated map units.

The grant deliverables and ensuing published quadrangle maps have been delayed because of COVID-19. Despite this, the KGS mapping program received another STATEMAP grant for fiscal year 2020, which is expected to allow us to complete surficial geologic mapping in Hardin County in 2021. Both fiscal year 2019 and fiscal year 2020 mapping projects, as well as all future mapping, will be collected into a new GIS data structure that allows nationwide compatibility of geologic map data, formally known as geologic mapping schema, or GeMS; previous mapping will be converted into GeMS.

Mappers **Antonia Bottoms, Max Hammond, Steve Martin,** and **Matt Massey** have continued working throughout the pandemic, completing GIS work remotely, and performing lab and field work using proper safety measures such as social distancing, N95 mask compliance, and frequent sanitizing of hands and equipment.



Geographic footprint for mapping: Bullitt and Hardin Counties.



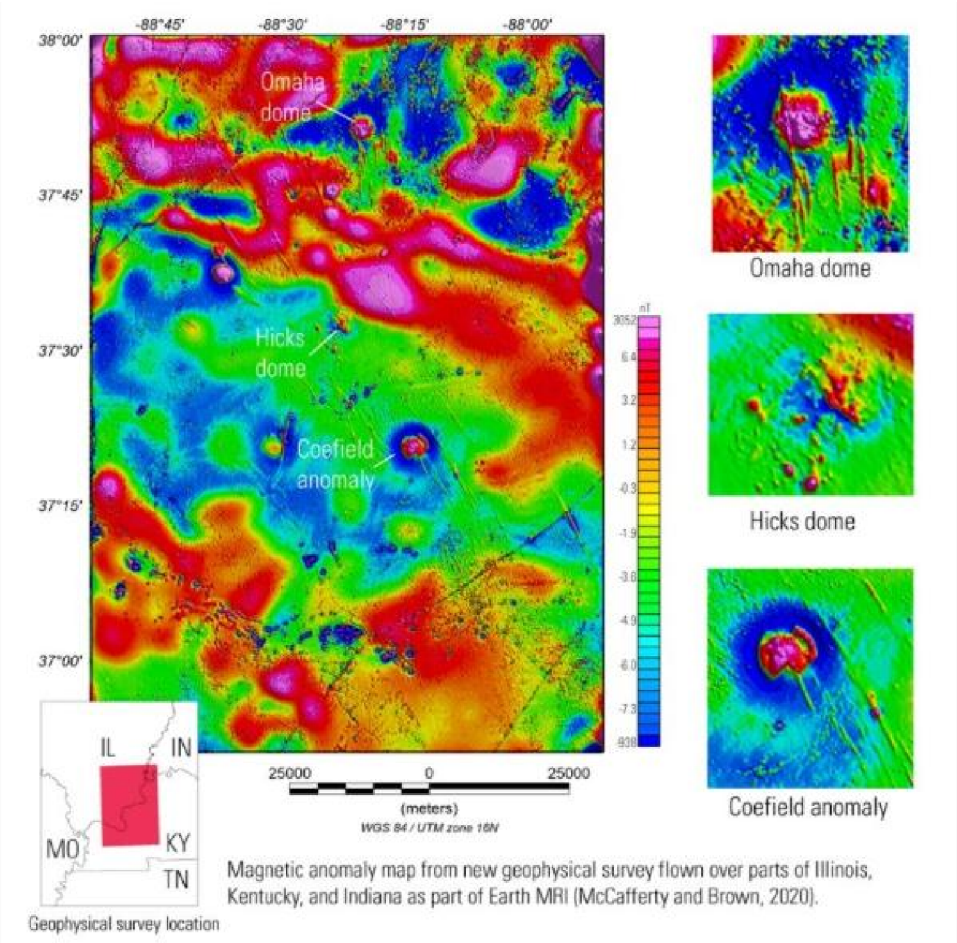
Part of the Pitts Point 7.5 minute quadrangle map.

Kentucky Geologic Data for the Hicks Dome Regional EarthMRI Priority Project

The Kentucky Geological Survey received a two-year grant from the U.S. Geological Survey's Earth Mapping Resources

Initiative, commonly known as Earth MRI, to examine the potential distribution of rare earth elements in the Western Kentucky Fluorspar District. The grant was routed through the USGS National Cooperative Geologic Mapping Program and includes support for developing a regional geologic map in partnership with the Illinois State Geological Survey as well as support for new geochemical sampling in the mineral district.

The first year of the project, managed by principal investigator **William Andrews,** focused primarily on organizing rock cores from the district and assembling the available documents for the cores. In fiscal year 2020-21, **Gina Lukoczki** will serve as principal investigator, and research will focus on interpreting the geochemical data on the submitted samples, supplied by the USGS, to help us better understand the relationship between igneous intrusions, fluorite mineralization, and the distribution of rare earth elements and other critical minerals. The results of the recently completed geophysical survey by Anne McCafferty and Philip Brown, “Airborne Magnetic and Radiometric Survey, Southeastern Illinois, Western Kentucky, and Southern Indiana," will enhance our understanding of the location and role of igneous intrusions and potential igneous centers in the mineralization processes of the district. **Craig Dietsch,** associate professor at the University of Cincinnati, is collaborating on the project by providing expertise in petrology.



High-resolution airborne magnetic anomaly data acquired by the U.S. Geological Survey as part of the Earth MRI project.

Geoscience Information Management

Staff Update

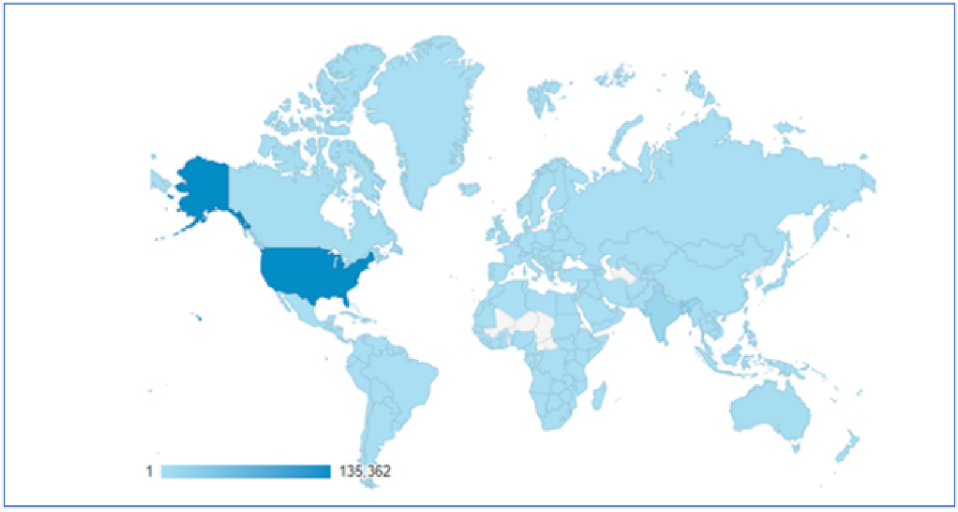
The Geologic Information Management Section welcomed two new staff members in October of 2019. **Sarah Mardon** is our new geoscience communications professional. She oversees communications and public outreach and is working with colleagues to further develop KGS's relationships with state agencies and stakeholders. Mardon will also lead the development of an economic evaluation of geological surveys and expansion of KGS's role in the field of geoscience communications. As an undergraduate student, Mardon studied both geology and economics at the University of

Kentucky. After working for a couple of years, she returned to the University of Kentucky and completed a master's degree in geology. For her thesis, she evaluated the Western Kentucky Coal Field's potential for coalbed methane production and carbon sequestration.
[link: https://www.uky.edu/KGS/news/sarah-mardon-kgs.php]

Monte Rivers returned to KGS as a Geologist I after close to 10 years working in the oil and gas industry. Rivers graduated from Morehead State University with a bachelor's degree in geography with an emphasis in geology. Rivers has earned his Geologist-in-Training certification and holds a GIS certificate. Rivers' more than nine years of hands-on oil and gas experience will be useful in his new role of analyzing, archiving, and managing electric logs and well documents.
[link: https://www.uky.edu/KGS/news/monte-rivers.php]

KGS Website Updates

KGS makes research data, maps and publications, databases, and other information available on our website to researchers and the general public. The main KGS website, which primarily hosts content about KGS research, educational pages, and general geology, had close to 300,000 visits from 234,000 unique visitors originating from 196 countries during the past fiscal year. Along with the main KGS webpage, users mostly visited the informational pages about rocks and minerals, coal, fossils, earthquakes, the Kentucky Seismic and Strong-Motion Network, and maps and GIS.



Location of website visitors by country.

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 81,000 visits originating from 137 countries were made during the past fiscal year to KY Geode, the Survey's page from which to access this information. More than 36,000 users conducted approximately 114,000 database searches.

Close to 1.5 million files were downloaded from the website, including KGS publications and presentations, which was an increase from the previous year. Oil and gas records, water-well and springs data, online publications, coordinate conversion services, and data from the geologic map server continue to be the most frequently downloaded data.

KGS online map services were accessed more than 81,000 times, a slight increase from the previous fiscal year. The most popular map service continues to be the Kentucky Geologic Map Information Service, accessed more than 43,000 times. The next-most popular map services were the water-wells and springs map, a new map application showcasing EARL holdings, and pages about Kentucky Watershed Watch and Kentucky minerals.

KGS web statistics for fiscal year 2019 - 20.

A report on the past 10 years of KGS website statistics shows that overall hits to our website have gone down over time. This trend may be partly because of our recent updates that have improved website efficiency and reduced our overall number of pages. The number of visitors to the main KGS website has stayed relatively constant over time. Also listed and plotted for comparison are the visits for each map and data service. The trends that we see every year with the Geologic Map Information Service and the Oil and Gas Well Data Search as the top map and data search service has held up year after year. Oil and gas searches have fallen over the years, and this correlates with a drop in oil and gas prices and drilling in Kentucky. Because oil and gas users are the largest data users of the KGS website, the decline in usage has likely driven the decrease in use of the geologic map service. Mobile usage has increased over the past 10 years, seen in both the overall mobile and tablet use trends and the use of the mobile version of the geologic map service. Our recent developments and updates of our website have considered mobile users and now the new version of the geologic map service is responsive to work on both large and small screens.

KGS web statistics for the last 10 years.

Development of services available on KY Geode continues; a new map service dedicated to showcasing the EARL holdings was released during the fiscal year. This map service has layers displaying the locations of KGS core holdings, oil and gas samples, and limestone sample sites. Links to a detailed report for each location are made available through a pop-up window.

The most significant development from the past year was releasing a new version of the KGS Geologic Map Information Service, a complete redesign of this custom web application using Esri software. The new version has a streamlined user interface, and several of the tools on the previous version were consolidated. A major upgrade is that this version is now responsive to mobile devices, thus eliminating the need for separate mobile and desktop applications. The service now uses cached layers for a faster, more reliable user experience, and users have more fine-grained control of the layers. Some new tools were developed for this new version, including a custom bookmark tool, which can be used to save a custom layout, and the ability to highlight individual geologic units from the legend.

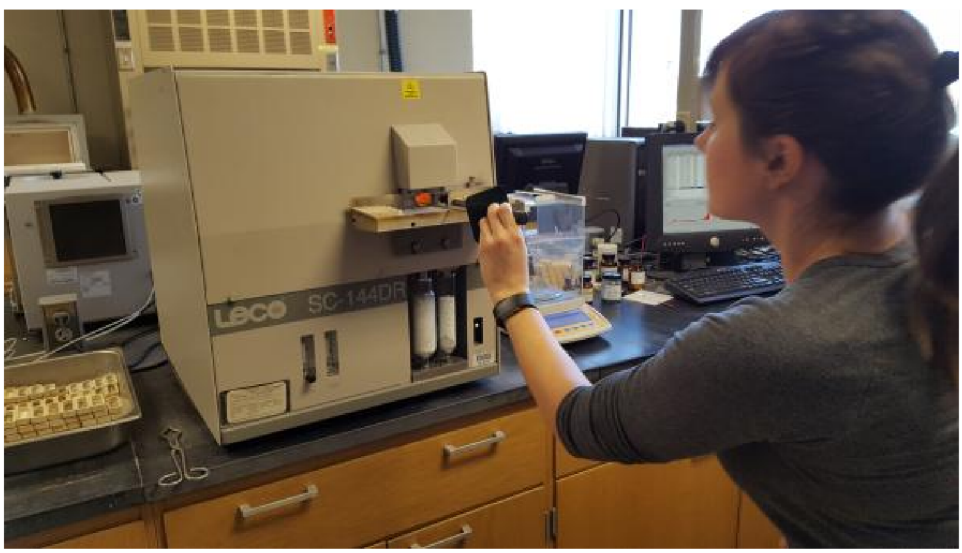
KGS Geologic Map Information Service

New version of the Geologic Map Information Service. https://kgs.uky.edu/geomap

https://kgs.uky.edu/kygeode/geomap/

Analytical Laboratory

The KGS analytical geochemistry laboratory specializes in chemical and physical analysis of water, coal, minerals, and rocks. Trained scientists, using automated instruments and equipment and the latest techniques, efficiently and accurately analyze geologic, environmental, and other samples for research in mineralogical and energy assessments. Learn More about KGS's analytical services.



A student from UK's Department of Earth and Environmental Sciences uses the coulometer.

Radon and the RAD7

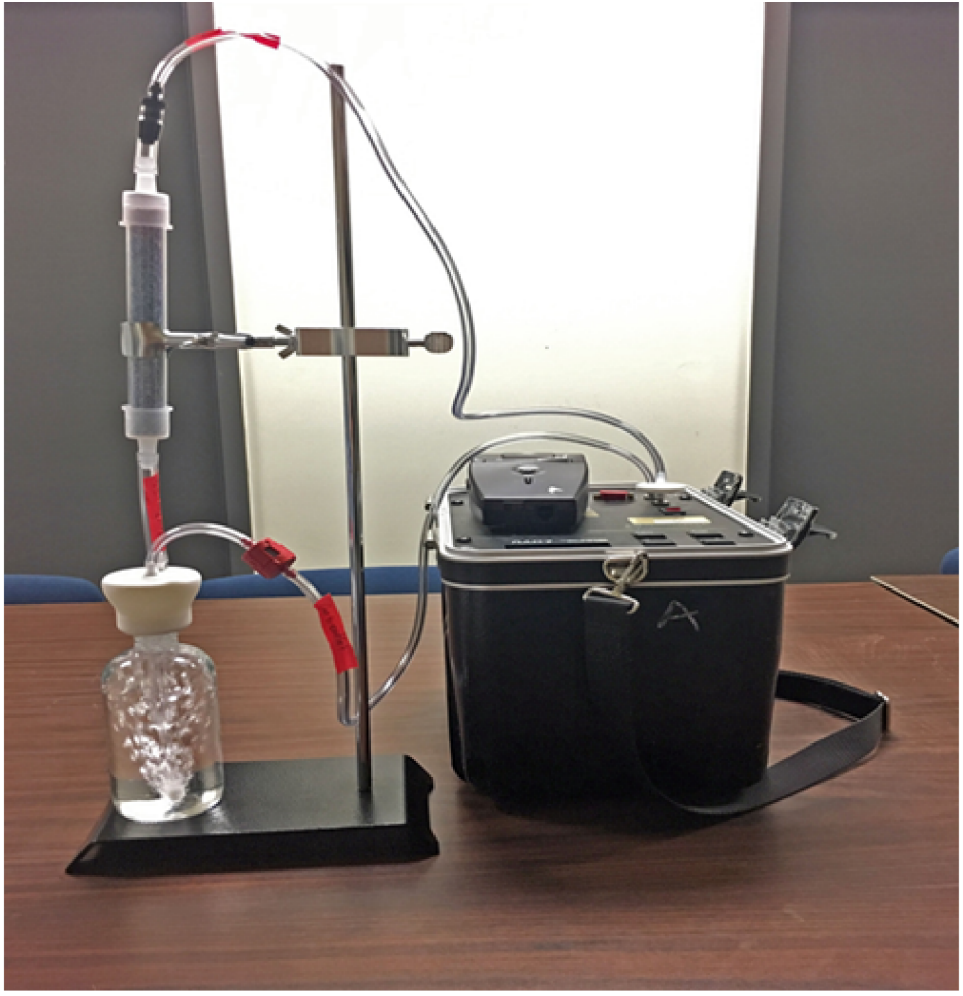
KGS researchers are participating in several projects focused on radon. KGS is collaborating with the UK College of Nursing's BREATHE program, or Bridging Research Efforts and

Advocacy Toward Healthy Environments, to promote home radon testing in Appalachia. In collaboration with the UK College of Public Health, KGS researchers assisted faculty and students in the College in sampling indoor air for radon on UK's main campus. Another collaboration with the BREATHE program and the Kentucky Department for Public Health is creating maps showing indoor radon potential. Radon on the RADAR, in collaboration with the BREATHE program and College of Public Health, funded by a $2.6 million grant from the National Institute of Environmental Health Sciences, engages "citizen scientists" to reduce radon exposure in rural areas. In addition, KGS researchers integrated local bedrock geology (limestone), soil characteristics, and radon concentrations in various media (such as soil, water, or indoors) to better understand the temporal and spatial variability of radon and intrusion into indoor environments at the KGS EARL facility.

As part of an ongoing effort to reduce environmental risks for lung cancer and improve health outcomes in Kentucky, KGS collaborated with the BREATHE program on a citizen science project to validate the results of short-term charcoal radon tool kits, using radon gas measurements in soils. High school students in eastern Kentucky deployed the test kits in their homes to determine the indoor concentration. KGS researchers **Emily Morris** and **Andrea Conner** visited the students' homes and measured radon levels in soil samples using the RAD7, a specialized instrument used to monitor radon.

KGS researchers use a RAD7 electronic radon detector to test for radon in soil samples in eastern Kentucky.

Amy Wolfe and **William Andrews** of KGS, along with **Chris Shepard** of UK's College of Agriculture, Food, and Environment are developing projects at the KGS Earth Analysis Research Library that integrate local bedrock geology (limestone), soil characteristics, and radon concentrations in various media (for example, soil, water, indoors) to better understand the temporal and spatial variability of radon and its intrusion into indoor environments. **Emily Morris** and **Andrea Conner** are assisting with field measurements and analytical support.

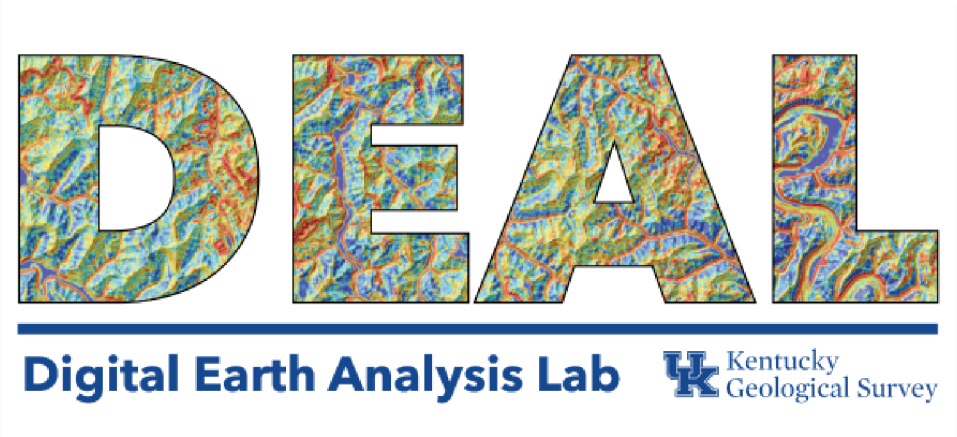


To prepare for measuring radon in water samples collected in the field, **Andrea Conner** and **Emily Morris** conducted a trial run with the RAD7 (pictured above) in the lab to make sure the instrument was functioning properly.

Andrea Conner measures radon levels in a spring behind EARL.

Faculty in the UK College of Public Health's Department of Preventive Medicine and Environmental Health are working with their students to look at indoor air radon levels in the Public Health Building. KGS is assisting with this effort by providing access to the RAD7 and providing training, ultimately enriching the classroom learning experience by enabling hands-on training in data collection and exposure assessments. College of Public Health students will assist the UK Environmental Health and Safety Division with indoor air sampling of radon throughout buildings on UK's main campus in the future.

Digital Earth Analysis Laboratory



The Digital Earth Analysis Laboratory, or DEAL, was established in 2017 to support research on innovative use of LiDAR to benefit the commonwealth. DEAL contains high-end computer workstations capable of working with large LiDAR files, a high-capacity server containing 14 terabytes of Kentucky LiDAR data, an 80-inch touchscreen display to facilitate collaboration, and a variety of specialized mapping and analysis software.

Staff Update

In October 2019, KGS welcomed post-doctoral research fellow **Yichuan Zhu**. He will use his engineering background to solve large-scale problems in a variety of disciplines and his work at KGS will provide him with opportunities to integrate data science with geology. Zhu completed the requirements for a Ph.D. in civil engineering from Texas A&M University and has a master's degree in civil engineering and a bachelor's degree in electrical engineering, both from China University of the Geosciences.

Prior to completing his graduate degrees, he conducted research at the Research Center of Geo-hazard Prevention at the China University of the Geosciences. During his time at Texas A&M, Zhu's research project involved Bayesian inversion, 3-D digital image correlation, and finite-element modeling to quantify uncertainties and calibrate the results of triaxial strength tests on sand. He also worked with **Julie**

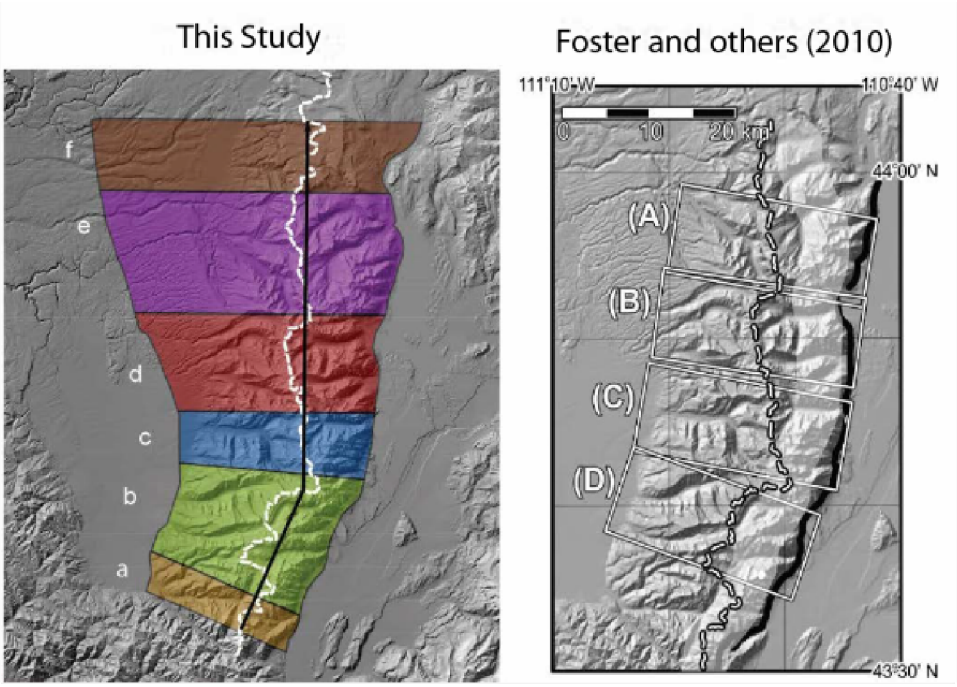
Loisel, a geographer whose research is focused on long-term terrestrial ecosystem response to global change. Zhu has also published research on power-grid reliability, soil erodibility, and probabilistic simulation of gas leaks from pipelines. [Link: https://www.uky.edu/KGS/news/yichuan-research.php]

New Topographic Insights from Advanced Swath Analysis

Jason Dortch, Yichuan Zhu, and **Matt Massey** are developing and using topographic swath analysis tools to assess the Earth's surface. A digital swath is an area from which data are collected and isolated based on specific criteria or reduced to summary statistics. To conduct swath analysis on topographic data, an area or region is selected and the average, minimum, and maximum elevation, along with the interquartile range are calculated. The goal of swath analysis is data reduction. Data reduction via swath analysis helps us understand how geologic processes and land use by humans, such as farming and mining, have altered the landscape.

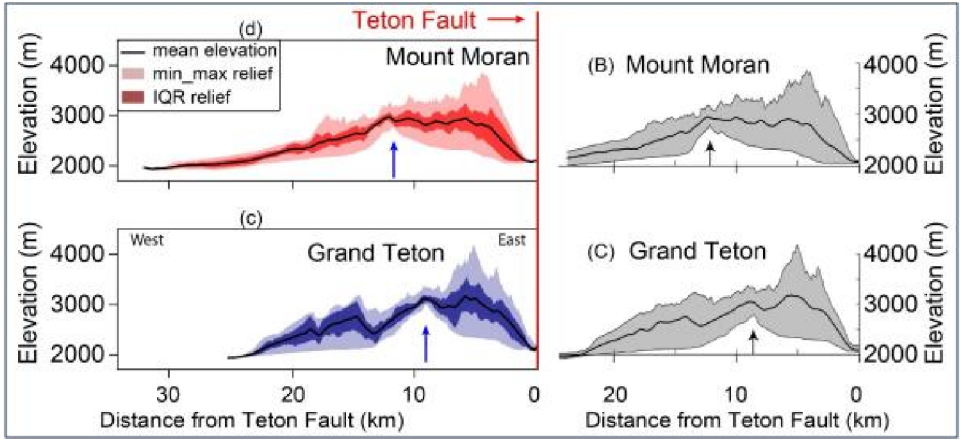
Swath analysis takes a complex three-dimensional digital landscape representation and reduces the information to a two-dimensional profile. Unfortunately, swath analysis has one major limitation: the need for rectangular blocks of data and the inability to analyze areas with irregular boundaries. For example, mountain ranges have complex irregular boundaries. Previous swath analyses included areas, such as basins or plains, outside of the intended topographic target, such as a mountain range, resulting in inaccurate summary statistics in the two-dimensional profile.

Our new approach enables swath analysis to be used on areas with irregularly shaped boundaries, reducing noise, and leaving clearer patterns to be investigated. For our test case, we examined the Teton Range in Wyoming, because it was previously investigated by Foster and others (2010).



Hillshade digital elevation model representing the 3-D terrain of the Teton Range. Left: Six color-coded irregular boundaries identify where our new swath
analysis tool was used. Right: Previously published study undertaken by Foster and
others (2010) used four identically sized swath areas for analysis. Their swath
boxes (C) and (D) overextend into the basin to the west and swaths (A) and (B)
fail to capture the full width of the range. Note the difference between studies in both swath-area orientation and length.

This complex terrain provided an opportunity to evaluate the performance of our new swath-analysis tool and contrast it with the results of Foster and others (2010). Swath areas labeled (D) and (C) in the figure above contain the highest mountains in the Teton Range, so we used them as examples in the figure below to show the reduction from three-dimensional to two-dimensional.



Left: Two example swath profiles from new swath analysis. Black lines represent the average elevation across the range in the corresponding swath area. Lighter colors show the minimum and maximum range of elevations, and darker colors show the middle 50 percent (interquartile range; IQR) where most of the landscape's elevation measurements cluster. Blue arrows indicate the drainage divide, which separates rivers that flow west from those that flow east. Although the general trends are similar, note the significant difference in detail between our profiles compared to the previous swaths from Foster and others (2010). Three obvious examples of swath inaccuracies from Foster and others (2010) are the truncated western side of the Mount Moran swath, steepness of the eastern Mount Moran range front, and the overestimated range height of the western side of the Grand Teton swath.

The simplified patterns indicate that the east side of the range has significantly higher mountains, shown in the larger, lighter-colored area, and a much steeper range front. Future work will focus on applying our swath-analysis tool to the mountainous landscape of eastern Kentucky to gain insight into how the landscape has developed over thousands to millions of years. Understanding the development of mountainous areas will help with KGS's geologic hazards work by identifying patterns associated with the occurrence of landslides. These data will help Kentucky's leaders and citizens make informed decisions about their communities.

[1]Foster, D., Brocklehurst, S.H., and Gawthorpe, R.L., 2010, Glacial-topographic interactions in the Teton Range, Wyoming: Journal of Geophysical Research Earth Surface, v. 115, issue F1, https://doi.org/10.1029/2008JF001135.

Earth Analysis Research Library

EARL Restructuring and Activities

Starting in 2018, we have been reorganizing our well sample and core library for better use of the space and to allocate resources to better serve our patrons. Over the course of this process the building was renamed the Earth Analysis Research Library, or EARL. A new temporary employee and several full-time staff were assigned to EARL for better alignment with the KGS strategic plan.

During the 2019-20 fiscal year, 253 researchers visited EARL; they studied 33 cores, totaling 15,585 feet, and EARL staff provided 923 geophysical samples for analytical purposes. Six classes and core workshops were held at EARL, attended by 141 visitors from universities, industry, and high schools.

People view core during a core workshop at EARL.

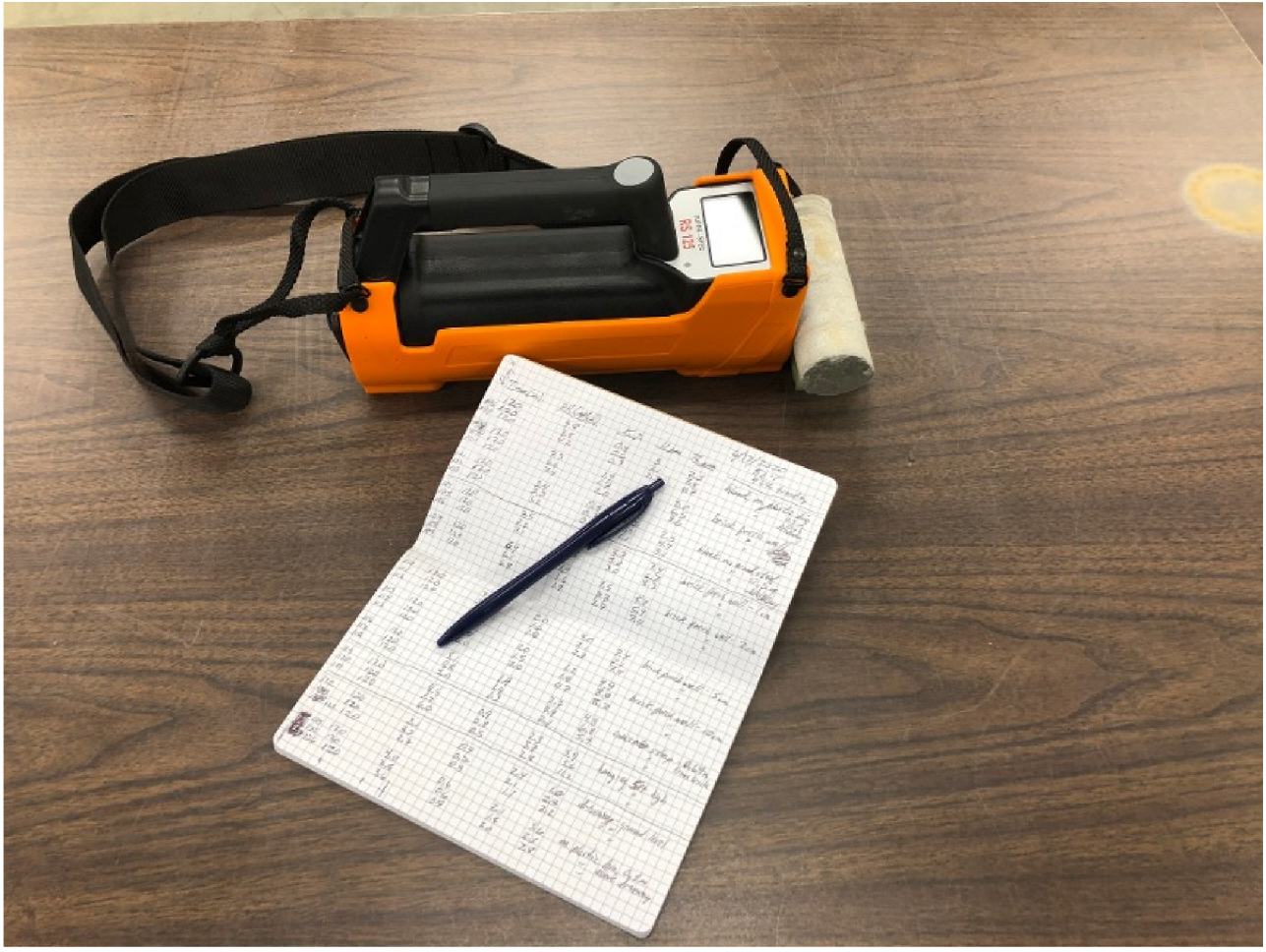
Projects funded by the Institute of Museum and Library Services and the U.S. Geological Survey helped our reorganization; we improved our cataloging and storage of

some of the core collection and the auger collection from the Jackson Purchase Region. We also added new equipment, including a document camera, a portable X-ray fluorescence spectrometer, and a handheld gamma spectrometer, and upgraded the well-cutting washing station by adding a downdraft table.

New Equipment for the EARL

The Lumens DC 170 document camera is used for projecting documents, cores, well cuttings, or other specific samples onto an overhead projector for workshops or can be used for viewing examples for online remote classes and workshops.

The Bruker Tracer IV-SD is used to detect the elements and amount of an element present in a sample. This instrument can be used as a handheld unit in the field or stationary in a lab setting. The unit is on indefinite loan from the UK Department of Earth and Environmental Sciences.



The Terraplus RS-125 Handheld Gamma-Ray Spectrometer is a portable device that detects naturally occurring gamma radiation. It is used specifically for the characterization of the composition of rocks.

The Diversitech Downdraft Table is used to collect silica dust from the air when preparing well cuttings collected from the field to be washed.

Photos of EARL reorganization

Through the hard work of the EARL staff and other KGS employees, the reorganization was completed this fiscal year. The photos below showcase the transformation. Use the slider to see the difference between the before (left photo) and the after (right photo).


North Wall: We cleared the north and south aisles and built new shelving to maximize the space for storing core. This is the north aisle.


Core Stored in Cardboard Boxes: We sorted, cataloged, and relocated more than 10,000 boxes of core stored in cardboard boxes from the aisles to newly built 16-foot shelves.

Outdoor Core: Funding was provided through the U.S. Geological Survey's National Geological and Geophysical Data Preservation Program and the Earth MRI program to properly identify, assess, and rehouse 173 pallets of mineral cores from western Kentucky, most of which had been stored outdoors, subjecting them to degradation from the elements. EARL staff worked diligently over a period of three days in concert with grant-funded staff to establish space indoors for this part of the core collection.

View more photos showcasing EARL's transformation.

Outreach, Communications, and Professional Engagement

Earth Science Week Open House Had Record Number of Participants in 2019

In the 20th year of Earth Science Week, KGS hosted approximately **350 participants**—families, students from local schools, and people interested in geology—on Oct. 16, 2019.

The streamflow table showed how floods can have an impact on our daily lives. Rock, fossil, and mineral collections included examples from Kentucky, and children took rock specimens home with them. UK's Department of Earth and Environmental Sciences continued their tradition of demonstrating a volcano for the open house attendees. **Seth**

Carpenter taught participants about how seismic data are collected and how they are used for earthquake monitoring.

Partner organizations also brought science to the community. UK's departments of Earth and Environmental Sciences and Mining Engineering, the Kentucky Water Resources Research Institute, the Bluegrass Grotto of the National Speleological Society, the Bluegrass Rock and Mineral Club, and the Kentucky Paleontological Society all made presentations or exhibited at the event.

KGS researchers **Jason Dortch** and **Sarah Arpin** demonstrate stream flow.

KGS Annual Seminar

The 59th annual KGS seminar was held May 14, 2020. The theme was "Elements of Change: Innovative Applications of Geochemistry." This year's seminar was held virtually to keep our attendees safe and healthy during the COVID-19 pandemic. In addition to professionals working in Kentucky, several people from out of state and outside of the field of geology attended. A total of **221 participants** registered for the event.

Marc Caffee, a professor of physics and director of the Purdue Rare Isotope Measurement Lab at Purdue University, was the keynote speaker. Caffee, a leader in cosmogenic isotope geochemistry, presented "Cosmic-Ray-Produced Nuclides: Tracers for Terrestrial and Extraterrestrial Geologic Processes." His presentation doubled as the 2020 Donald C. Haney Distinguished Lecture.

Four other researchers gave presentations about their work. **Tom Darrah,** associate professor in the School of Earth Sciences at Ohio State University, presented “Noble Gases of the Appalachian Basin and Midcontinent: Implications for Crustal Fluid Sources, Migration, and Economics Potential.” **Cristopher Alvarez,** a graduate student in the University of Kentucky’s Department of Earth and Environmental Sciences, presented “Geochemical Analysis of Groundwater Methane Occurrence in Areas of Fossil-Fuel Development, Eastern Kentucky.” Two KGS researchers, **Gina Lukoczki** and **Doug Curl,** also presented at the seminar. Lukoczki talked about the geochemical tools and applications she is using for her research on carbonates and Curl demonstrated updates to the online Geologic Map Information Service.

Recording of the Kentucky Geological Survey annual seminar.

Field Trips, Tours, and Workshops

Field Guide to Pennsylvanian Coal

Cortland Eble and **Steve Greb** attended the 36th annual meeting of The Society of Organic Petrology, held in Bloomington, Indiana, in September 2019. They led the post-conference field trip, "Coal Geology of Lower and Lower Middle Pennsylvanian Strata in the Eastern Interior (Illinois) Basin, USA," and compiled the guidebook for the field trip along with **Agnieszka Drobniak,** research geologist with the Indiana Geological and Water Survey.

Cumberland Falls

In October 2019, the Geoscience Information Management Section organized a field trip to Cumberland Falls State Park, and several KGS staff members participated. They reviewed the geology of the area prior to the visit and took field guides with them as they hiked along the falls. They also visited the areas around the visitor center. **Natalie Fields,** who was taking a class on photographing samples for her role at KGS, photographed the area for a class assignment.

KGS staff hike one of the trails along Cumberland Falls.

KGS staff outside the Cumberland Falls State Park lodge.

Geological Society of Kentucky Fall Field Trip and Core Viewing at EARL

Several Kentucky Geological Survey geologists participated in the Geological Society of Kentucky's fall field trip in November 2019. The field trip was organized and led by **Charles Mason** (Morehead State University), **Steve Greb, Richard Lewis** (WPX Energy), **Frank Fugitt** (Ohio Geological Survey), **William Gilliam** (SLG Resources), **Matt Boudreaux** (SLG Resources), **Justin Spears** (Ph.D. candidate, Oklahoma State University), **Ron Martino** (Marshall University), and **Cortland Eble. Richard Smath** oversaw the logistics, made announcements, and worked with **Ray Daniel** to plan lunch for the participants during the field trip.

On Nov. 15, **William Andrews** and **Liz Adams** hosted a core viewing at the Earth Analysis Research Library. Many of the cores were Carboniferous cores from northeastern Kentucky, and focus was on cores from the field trip area. Eighteen people representing KGS, Morehead State University, the Ohio Geological Survey, Western Kentucky University, and private consultants participated in the core viewing, and also

reviewed field trip guides and asked questions about the cores.

From left, **Greg Cornett, Gordon Dowell,** and **Antonia Bottoms** view core at KGS's EARL.

Later in the evening on Nov. 15, field trip leaders **Steve Greb** and **Charles Mason** joined several field trip participants for supper at Carter Caves State Resort Park. As the meal ended, Greb gave a presentation, "Geology of the KGS No. 1 Hanson Aggregates Stratigraphic Test Well, Carter County," summarizing results from the well, which penetrated basement; a variety of Cambrian and Ordovician horizons were sampled and tested to research carbon storage potential in the broader Ohio River industrial corridor.

Steve Greb presents a talk as part of the 2019 Geological Society of Kentucky field trip.

More than 40 people attended the all-day field trip on Nov. 16. They viewed outcrops of the Mississippian Borden Formation and Slade Formation, the Mississippian-Pennsylvanian unconformity, and the Pennsylvanian Grundy and Pikeville Formations.

Geological Society of Kentucky field trip attendees study an outcrop.

Tour of KGS: Society of Petroleum Engineers–East Kentucky Section

The Society of Petroleum Engineers' East Kentucky Section held its January meeting on the University of Kentucky campus. Prior to the meeting, Kentucky Geological Survey staff gave a tour of KGS's on-campus research facilities. During the meeting, **Rick Bowersox** gave an update on current research at KGS, focusing on topics of interest to Kentucky's petroleum industry.

Tour of KGS: Fayette County 4-H Nature Club

The University of Kentucky's Fayette County 4-H Nature Club learned about geologic processes in Kentucky and checked out the large collection of minerals, rocks, and fossils on display in the Mining and Mineral Resources Building in December 2019. **Richard Smath** talked about geologic processes and showed examples of rocks to club members. Then **Smath** and **Sarah Mardon** talked with club members and their parents about the rocks displayed in the lobby of the building. Club members were given small rock samples to take home with them and add to their collections.

Richard Smath, members of the 4-H Nature Club, and **Morgan Murphy** of the 4-H Youth Development Program pose in front of the large gypsum crystal on display in the lobby of the Mining and Mineral Resources Building.

Review of Practical Geology Workshops

In August 2019 and January 2020, **William Andrews** facilitated and taught the “Review of Practical Geology” course for geologists preparing to take the professional geologist licensing exams. In addition to classroom instruction, participants were given a brief tour of the Earth Analysis Research Library, where the class was held.

William Andrews speaks to “Review of Practical Geology” class participants while giving a tour of EARL.

Clastic and Coal Logging Workshop

The Kentucky Geological Survey hosted the “Clastic and Coal Logging Workshop” at EARL in September 2019. It was organized and facilitated by the Kentucky Section of the American Institute of Professional Geologists and the Geological Society of Kentucky.

Funded Research Project List

Listed below are all of KGS's funded research projects for the 2019-20 fiscal year. Some of the projects are described in detail under other sections of the annual report. Projects not highlighted in the report are linked to additional information indicated by "Read More."

Energy and Minerals

Conasauga Shale Research Consortium

- End date: 12/31/2023?; FY funding: $464,528; 4-year project total: $5,876,897
- Funding source: U.S. Department of Energy

Regional Initiative to Accelerate CCUS Development

- End date: 9/30/2022; FY funding: $7,900; 3-year project total: $150,000
- Funding source: U.S. Department of Energy through Battelle Memorial Institute

Midwest Regional Carbon Sequestration Partnership (Appalachian Basin)

- End date: 12/31/2019; FY funding: $7,360; 6-year project total: $482,190
- Funding source: U.S. Department of Energy through Battelle Memorial Institute
- Read More

Assessing the Potential for Compressed Air Energy Storage (CAES) in Kentucky to Augment Energy Production by Renewable Resources

- End date: 2/28/21; project total: $50,131
- Funding source: UK Energy Research Prioritization Program, UK Vice President for Research
- Read More

Geochemistry

Rare-Earth Elements (REES) in U.S. Coal-Based Resources: Sampling, Characterization, and Resource Assessment

- End date: 9/30/2019; KGS FY funding: $27,581; UK 2-year project total: $150,000
- Funding source: University of North Dakota through UK Center for Applied Energy Research

Pilot-Scale Testing of an Integrated Circuit for the Extraction of Rare Earth Minerals

- End date: 6/30/2020; KGS FY funding: $8,912; UK 4-year project total: $6,999,797
- Funding source: U.S. Department of Energy through UK Department of Mining Engineering

Water Quality Analyses for the Kentucky River Watershed Watch Program

- End date: 6/30/2020; KGS FY funding: $3,493; UK project total: $123,878
- Funding source: Kentucky River Authority through UK Kentucky Water Resources Research Institute

Geologic Information

Engaging Nontraditional Geoscience Information Stakeholders in Appalachian Kentucky

- End date: 12/1/2020; FY funding: $27,242; project total: $83,357
- Funding source: National Academy of Sciences
- Read more

Kentucky Geologic Core Digital Image Archive

- End date: 9/30/2021; FY funding: $82,061; 3-year project total: $487,396
- Funding source: Institute of Museum and Library Services
- Read more

National Geological and Geophysical Data Preservation Program

- End date: 12/31/20; FY funding and project total: $172,022
- Funding source: U.S. Geological Survey

- Read more

Geologic Mapping

New Surficial Geological Mapping Along the I-65 Corridor in Bullitt, Hardin, and Nelson Counties Kentucky

- End date: 10/9/2020; FY funding and project total: $325,708
- Funding source: U.S. Geological Survey

Kentucky Geologic Data for the Hicks Dome Regional EarthMRI Priority Project

- End date: 7/31/2021; FY funding: $12,325; 2-year project total: $75,000
- Funding source: U.S. Geological Survey
- Read More

Soil Maps for Seismic Hazard Planning in the Green River Area Development District Project

- End date: 5/20/2021; FY funding and project total: $29,139
- Funding source: Webster County, Kentucky, through Federal Emergency Management Agency

Geology and Human Health

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

- End date: 6/30/2020; KGS FY funding: $3,962; UK project total: $75,000
- Funding source: Kentucky Department for Public Health through UK College of Nursing

Radon on the Radar

- End date: 11/30/2024; KGS FY funding: $11,916; UK 4-year project total: $585,908

- Funding source: National Institute of Environmental Health Services through UK College of Nursing

Linking Environmental Exposure and Health Outcomes: The Importance of Data Coordination

- End date: 3/31/2020; FY funding and project total: $15,050
- Funding source: National Institute of Environmental Health Sciences through UK Center for Appalachian Research in Environmental Sciences

Hazards

Multi-Jurisdictional Hazard Mitigation Plan for Landslides for the Big Sandy ADD

- End date: 3/22/2021; FY funding: $137,211; project total: $400,292
- Funding source: Federal Emergency Management Agency through Kentucky Department of Military Affairs

Improving Estimates of Ground-Motion Site Response in the New Madrid and Wabash Valley Seismic Zones

- End date: 12/31/2020; FY funding: $18,544; project total: $64,462
- Funding source: U.S. Geological Survey

Seismic Monitoring and Site Response Study at the Paducah Gaseous Diffusion Plant

- End date: 3/15/2020; KGS FY funding: $9,000; UK 4-year project total: $1,095,000
- Funding source: U.S. Department of Energy through Center for Applied Energy Research

Water Resources

Collaborative Research: Data Fusion for Characterizing and Understanding Water Flow Systems in Karst Aquifers

- End date: 2/28/2023; FY funding: $37,401; 3-year project total: $421,448
- Funding source: National Science Foundation

In-situ 3-D Electrical Resistivity Method for Understanding Water Dynamics in Shallow Karst Features

- End date: 2/28/2021; project total: $21,380
- Funding source: U.S. Geological Survey through UK Kentucky Water Resources Research Institute

Groundwater Modeling at the Paducah Gaseous Diffusion Plant

- End date: 2/15/2020; FY funding: $43,620; KGS Project Total: $48,710; UK 4- year project total: $1,095,000
- Funding source: U.S. Department of Energy through Center for Applied Energy Research
- Read More

Develop a Groundwater Management Tool for Grand Canyon National Park

- End date: 7/31/2021; FY funding: $38,981; 3-year project total: $115,871
- Funding source: National Park Service

Kentucky Geological Survey Groundwater Observation Wells—Support for Inclusion in the USGS National Groundwater Monitoring Network

- End date: 11/30/2021; FY funding: $12,746; 2-year project total: $80,000
- Funding source: U.S. Geological Survey

Examining Hydrologic Connections at Fern Cave, Alabama, and Implications of Stream Connectivity on Biological Diversity and Isolation

- End date: 12/31/2020; FY funding: $2,759; project total: $14,999
- Funding source: U.S. Fish and Wildlife Service

Blue Water Farms: Edge-of-Field Water Monitoring in Kentucky Soils

- End date: 6/30/2020; KGS FY funding: $29,772; UK project total: $206,003
- Funding source: Kentucky Soybean Promotion Board through UK College of Agriculture

Nutrient and Sediment Runoff Assessment in the Upper Mississippi River Embayment

- End date: 9/15/2022; KGS FY funding: $29,772; UK 5-year project total: $2,074,131
- Funding source: U.S. Department of Agriculture through Natural Resources Conservation Service through UK College of Agriculture

Staff Awards and Honors

William Andrews

- Kentucky Association of Mapping Professionals: Board of Directors (January 2019–December 2020)
- National Cooperative Geologic Mapping Program (USGS) Phase III Planning Workshop (February 2020)
- National Geologic Map Database (USGS) Technical Working Group

- Association of American State Geologists: associate member, and winter/spring liaison participant (February 2020)

Sarah Arpin

- Association for Women Geoscientists, Southeastern Bluegrass Chapter: vice president, Steering Committee (October 2019–present)
- Kentucky Academy of Science: secretary of Geology Section (November 2019–present)
- Kentucky Speleological Survey: Board of Directors (March 2019–present); chair, Data Committee (April 2017–present)
- National Cave and Karst Research Institute: Board of Directors; chair, Research Committee (May 2020–present)

Glynn Beck

- Kentucky Agricultural Science and Monitoring Committee: member

Rick Bowersox

- Kentucky Board of Registration for Professional Geologists: board member

Seth Carpenter

- Awarded doctorate in geology in December 2019 from the University of Kentucky Department of Earth and Environmental Sciences

Doug Curl

- Kentucky River Watershed Watch: board member (2014–present)
- KYFromAbove Kentucky Aerial Photography & Elevation Data Program: Technical Advisory Committee

- National Geologic Map Database Working Group

Ray Daniel

- Geological Society of Kentucky: councilor at large

Bill Haneberg

- National Geospatial Advisory Committee (2020–present)
- International Advisory Panel for Geological Uncertainty and Societal Risk: The Perspectives of Engineering, Environment, and Geohazards at National Central University in Taoyuan City, Taiwan

Dave Harris

- Potential Gas Committee: Atlantic Work Group

Gina Lukoczki

- Association for Women Geoscientists, Southeastern Bluegrass Chapter: Steering Committee secretary (October 2019–present)

Sarah Mardon

- Kentucky Academy of Science: newsletter editor (through May 2020)

Meg Smath

- Association of Earth Science Editors: co-editor of newsletter *(Blueline)*

Richard Smath

- Geological Society of Kentucky: councilor at large

- American Institute of Professional Geologists, Kentucky Section: communication coordinator and website manager (2005–present)

Chuck Taylor

- Kentucky Agriculture Water Quality Authority: member
- Kentucky Agricultural Science and Monitoring Committee: member

Ben Tobin

- Geological Society of America: treasurer (term ends October 2020)
- *Carbonates and Evaporites:* guest editor for special issue
- National Speleological Society: director (2020–2023)
- Kentucky Speleological Survey: member at large (term ends January 2021)

Rebecca Wang

- Geological Society of Kentucky: webmaster

Amy Wolfe

- American Geophysical Union, Geohealth Section: co-chair, Communications and Outreach Sub-committee

Junfeng Zhu

- *Groundwater:* associate editor (December 2017–present)

Presentations

- Brandon Nuttall (recently retired from KGS), Tom Sparks, and Steve Greb received the Best Poster Award from the American Association of Petroleum Geologists' Division of

Environmental Geosciences for their poster presented at the 2019 AAPG Annual Convention and Exhibition
- Rick Bowersox, Steve Greb, and Dave Harris received the 2019 Excellent Paper Award at the 1st International Conference on Exploration and Utilization of Underground Space

Publications

KGS Contract Reports

CNR 18. Surficial Geologic Map of the Colesburg 7.5-Minute Quadrangle, North-Central Kentucky, by Antonia Bottoms, Steve Martin, Matt Massey, and Max Hammond. Released 11/26/2019.

CNR 19. Surficial Geologic Map of the Fort Knox 7.5-Minute Quadrangle, North-Central Kentucky, by Max Hammond, Matt Massey, Steve Martin, and Antonia Bottoms. Released 11/26/2019.

CNR 20. Surficial Geologic Map of the Pitts Point 7.5-Minute Quadrangle, North-Central Kentucky, by Matt Massey, Max Hammond, Antonia Bottoms, and Steve Martin. Released 11/26/2019.

CNR 21. Surficial Geologic Map of the Vine Grove 7.5-Minute Quadrangle, North-Central Kentucky, by Steve Martin, Antonia Bottoms, Max Hammond, and Matt Massey. Released 11/26/2019.

CNR 22. Quaternary Geologic Map of the Salt Lick 7.5-Minute Quadrangle, Eastern Kentucky, by J.D. Spears and C.E. Mason. Released 11/26/2019.

CNR 23. New Quaternary Geologic Mapping in North-Central Kentucky, by Matt Massey. Released 11/26/2019.

CNR 24. The Geologic Context of Landslide/Sinkhole and Rockfall Maintenance Costs for Kentucky Transportation District 1—2002 to 2009, by Bethany Overfield, Dan Carey, Jerry Weisenfluh, and Rebecca Wang. Released 06/30/2020.

CNR 25. The Geologic Context of Landslide/Sinkhole and Rockfall Maintenance Costs for Kentucky Transportation District 2—2002 to 2009, by Bethany Overfield, Dan Carey, Jerry Weisenfluh, and Rebecca Wang. Released 06/30/2020.

CNR 26. The Geologic Context of Landslide/Sinkhole and Rockfall Maintenance Costs for Kentucky Transportation District 3—2002 to 2009, by Bethany Overfield, Dan Carey, Jerry Weisenfluh, and Rebecca Wang. Released 06/30/2020.

CNR 27. The Geologic Context of Landslide/Sinkhole and Rockfall Maintenance Costs for Kentucky Transportation District 4—2002 to 2009, by Bethany Overfield, Dan Carey, Jerry Weisenfluh, and Rebecca Wang. Released 06/30/2020.

CNR 28. The Geologic Context of Landslide/Sinkhole and Rockfall Maintenance Costs for Kentucky Transportation District 5—2002 to 2009, by Bethany Overfield, Dan Carey, Jerry Weisenfluh, and Rebecca Wang. Released 06/30/2020.

CNR 29. The Geologic Context of Landslide/Sinkhole and Rockfall Maintenance Costs for Kentucky Transportation District 6—2002 to 2009, by Bethany Overfield, Dan Carey, Jerry Weisenfluh, and Rebecca Wang. Released 06/30/2020.

CNR 30. The Geologic Context of Landslide/Sinkhole and Rockfall Maintenance Costs for Kentucky Transportation District 7—2002 to 2009, by Bethany Overfield, Dan Carey, Jerry Weisenfluh, and Rebecca Wang. Released 06/30/2020.

CNR 31. The Geologic Context of Landslide/Sinkhole and Rockfall Maintenance Costs for Kentucky Transportation District 8—2002 to 2009, by Bethany Overfield, Dan Carey, Jerry Weisenfluh, and Rebecca Wang. Released 06/30/2020.

CNR 32. The Geologic Context of Landslide/Sinkhole and Rockfall Maintenance Costs for Kentucky Transportation District 9—2002 to 2009, by Bethany Overfield, Dan Carey, Jerry Weisenfluh, and Rebecca Wang. Released 06/30/2020.

CNR 33. The Geologic Context of Landslide/Sinkhole and Rockfall Maintenance Costs for Kentucky Transportation District 10—2002 to 2009, by Bethany Overfield, Dan Carey, Jerry Weisenfluh, and Rebecca Wang. Released 06/30/2020.

CNR 34. The Geologic Context of Landslide/Sinkhole and Rockfall Maintenance Costs for Kentucky Transportation District 11—2002 to 2009, by Bethany Overfield, Dan Carey, Jerry Weisenfluh, and Rebecca Wang. Released 06/30/2020.

CNR 35. The Geologic Context of Landslide/Sinkhole and Rockfall Maintenance Costs for Kentucky Transportation District 12—2002 to 2009, by Bethany Overfield, Dan Carey, Jerry Weisenfluh, and Rebecca Wang. Released 06/30/2020.

KGS Reports of Investigations

RI 9. CO2-Enhanced Gas Recovery in Shale: Lessons Learned in the Devonian Ohio Shale of Eastern Kentucky, by Brandon Nuttall. Released 7/16/2019.

RI 10. Major Lower Paleozoic Horizons of the Southern Illinois Basin, by John Hickman. Released 12/11/2019.

RI 11. Geologic Characterization, Hydrologic Monitoring, and Soil-Water Relationships for Landslides in Kentucky, by Matt Crawford, Sebastian Bryson, Zhenming Wang, and Ed Woolery. Released 1/31/2020.

KGS External Publications

Crawford, M.M., Dortch, J.M., Koch, H.J., Killen, A.A., Zhu, J., Zhu, Y., Bryson, L.S., and **Haneberg, W.C.,** in revision, Using landslide-inventory for a combined bagged-trees and logistic regression approach to landslide susceptibility in eastern Kentucky: Landslides.

Guo, X., Tang, Y., **Eble, C.F.,** and Li, P., 2020, Study on petrographic characteristics of devolatilization char/coke related to coal rank and coal macerals: International Journal of Coal Geology, v. 227, doi.org/10.1016/j.coal.2020.103504.

Greb, S.F., Harris, D.C., and **Bowersox, J.R.,** accepted, Reservoir geology of the Berea Sandstone (uppermost Devonian), eastern Kentucky, *in* Parris, T.M., ed., Upper Devonian Berea Sandstone Petroleum System: American Association of Petroleum Geologists Special Publication.

Greb, S.F., Nelson, W.J., and Elrick, S.D., accepted, Mining geology of the principal resource coals of the Illinois Basin: International Journal of Coal Geology.

Hackley, P.C., Araujob, C.V., Borrego, A.G., Bouzinos, A., Cardott, B.J., Carvajal-Ortiz, H., López Cely, M.R., Chabalalah, V., Crosdale, P.J., Demchuk, T.D., **Eble, C.F.,** Flores, D., Furmann, A., Gentzis, T., Gonçalves, P.A., Guvad, C., Hámor-Vidó, M., Jelonek, I., Esteban, J., and Zapataag, J., 2020, Testing reproducibility of vitrinite and solid bitumen reflectance measurements in North American unconventional source-rock reservoir petroleum systems: Marine and Petroleum Geology, v. 114, doi.org/10.1016/j.marpetgeo.2019.104172.

Haneberg, W.C., Wiggins, A., Curl, D.C., Greb, S.F., Andrews, W.M., Jr., Rademacher, K., Rayens, M.K., and Hahn, E.J., in revision, A geologically based indoor-radon potential map of Kentucky: GeoHealth.

Haneberg, W.C., Johnson, S.J., and Gurung, N., submitted, Response of the Laprak landslide to the 2015 M7.8 Gorkha, Nepal earthquake: Bulletin of Engineering Geology and the Environment.

Hower, J.C., **Eble, C.F.,** and O'Keefe, J.M.K., 2020, History of applied coal petrology in the United States. IV. Reflections on the centennial of the introduction of coal petrology to North America: International Journal of Coal Geology, v. 229, doi.org/10.1016/j.coal.2020.103576.

Hower, J.C., **Eble, C.F., Backus, J.S.,** Xie, P., Liu, J., Fu, B., and Hood, M.M., 2020, Aspects of rare earth element enrichment in central Appalachian coals: Applied Geochemistry, v. 120, doi.org/10.1016/j.apgeochem.2020.104676.

Mirus, B.B., Jones, E., Baum, R.L., Godt, J.W., Slaughter, S., **Crawford, M.M.,** Lancaster, J., Stanley, T., Kirschbaum, D., Burns, W.J., Schmitt, R., Lindsey, K.O., and McCoy, K., 2020, Landslides across the United States: Occurrence, susceptibility, and data limitations: Landslides, doi.org/10.1007/s10346-020-01424-4.

Saksa, P.C., Bales, R.C., Tague, C.L., Battles, J.J., **Tobin, B.W.,** and Conklin, M.H., 2020, Fuels treatment and wildfire effects on runoff from Sierra Nevada mixed-conifer forests: Ecohydrology, doi:10.1002/eco.2151.

Tobin, B.W., and Schwartz, B.F., 2020, Quantifying the role of karstic groundwater in a snowmelt-dominated hydrologic system: Hydrological Processes, v. 34, no. 16, p. 3439–3447, doi.org/10.1002/hyp.13833.

Wang, Z., Carpenter, N.S., and **Woolery, E.W.,** submitted, Scenario seismic hazard analysis and its applications in Kentucky, central United States: Earthquake Sustainable Infrastructure.

Wang, Z., Carpenter, N.S., Woolery, E.W., and Kalinski, M.E., in revision, Ground-motion site response and new site correction factors: Examples in the central United States: Soil Dynamics and Earthquake Engineering.

Wolfe, A.L., 2020, Exposure: Poisoned water, corporate greed, and one lawyer's twenty-year battle against DuPont [book review]: Groundwater, doi:10.1111/gwat.13028.

Wood, A.J., Springer, A.E., and **Tobin, B.W.,** 2020, Geochemical variability in karst-siliciclastic aquifer spring discharge, Kaibab Plateau, Grand Canyon: Environmental and Engineering Geoscience, doi:10.2113/EEG-2345.

Zhu, J., Nolte, A.M., Jacobs, N., and Ye, M., 2020, Using machine learning to identify karst sinkholes from LiDAR-derived topographic depressions in the Bluegrass Region of Kentucky: Journal of Hydrology, v. 588, 125049, doi.org/10.1016/j.jhydrol.2020.125049.

Contact Information

Staff List

FY 2019-20 State Geologist's Office

- Haneberg, Bill. State Geologist and Director
- Cobb, Jim. State Geologist Emeritus

Administration

- Ellis, Kati. Administrative Business Officer
- Banks, Roger. Stores Supervisor
- Long, Mandy. Administrative Support Associate I
- Phillips, Gwen. Staff Support Associate

Communications and Outreach

- Banks, Roger. Stores Supervisor
- Mardon, Sarah. Geoscience Communications Professional
- Smath, Meg. Geologic Publication Manager

Digital Earth Analysis Lab

- Haneberg, Bill. State Geologist and Director
- Crawford, Matt. Geologist III
- Dortch, Jason. Geologist IV
- Johnson, Sarah. Research Assistant
- Zhu, Yichuan. Post-Doctoral Fellow

Energy and Minerals

- Harris, Dave. Section Head
- Bowersox, Rick. Geologist IV
- Eble, Cortland. Geologist V
- Gooding, Patrick. Geologist IV, retired Feb. 4, 2020
- Greb, Stephen. Geologist V
- Hickman, John. Geologist IV
- Lukoczki, Gina. Geologist III
- Parris, Marty. Geologist V
- Sparks, Tom. Geologist III

Geologic Hazards

- Wang, Zhenming. Section Head
- Ahmed, Faisal. Research Assistant
- Carpenter, Seth. Geologist IV
- Crawford, Matt. Geologist III
- Killen, Ashton. Landslide Hazards Intern
- Koch, Hudson. Geologist I
- Rogers, Russel. Seismic Network Intern
- Schmidt, Jon. Geologist II
- Woolery, Ed. Geophysics Faculty Associate

Geoscience Information Management

- Curl, Doug. Section Head
- Adams, Liz. Research Administrative Coordinator
- Dalrymple, Emma. Student Worker
- Ellis, Mike. Computer Support Specialist II
- Mardon, Sarah. Geoscience Communications Professional
- Mullins, Seth. Student Worker
- Pulliam, Carrie. Geologist II
- Rivers, Monte. Geologist I
- Smath, Richard. Geologist III
- Thompson, Mark. Information Technology Manager I
- Wang, Rebecca. Database Analyst

Geologic Mapping

- Andrews, William. Section Head
- Bottoms, Antonia. Geologist
- Dortch, Jason. Geologist IV
- Hammond, Max. Geologist I
- Martin, Steve. Geologist III
- Massey, Matt. Geologist IV
- Morris, Emily. Cartographic Data Manager

Water Resources

- Taylor, Chuck. Section Head
- Anderson, Scott. Student Worker
- Arpin, Sarah. Geologist II
- Beck, Glynn. Geologist IV/Manager
- Clark, Gillian. Student Worker
- Evers, Beth. Student Worker
- Nolte, Adam. Geological Technician Senior
- Susko, Amy. Student Worker
- Tobin, Ben. Geologist IV
- Webb, Steve. Geologist II
- Wilson, Jonathan. Research Assistant

- Wolfe, Amy. Geologist IV
- Zhu, Junfeng. Geologist V

Laboratory

- Backus, Jason. Geologist III/Laboratory Manager
- Conner, Andrea. Geologist II
- Davis, Ethan. Laboratory Technician

Earth Analysis Research Library

- Andrews, William. Geologic Manager, July 2019–May 2020
- Curl, Doug. Geologic Manager, May 2020–June 2020
- Pinkston, Ryan. Principal Research Analyst and Facility Manager
- Adams, Liz. Archive Manager
- Daniel, Ray. Principal Research Analyst
- Clay, Mitchell. Geologic Technician
- Dowell, Gordon. Geologic Technician
- Fields, Natalie. Photographic Technician
- Gullett, Clayton. Geologic Technician
- Hislop, Ann. Geologic Technician
- Thomas, Alex. Student Worker
- Vicroy, Stephanie. Student Worker

Western Kentucky Office

- Beck, Glynn. Geologist IV/Manager
- Bleichroth-King, Amy. Laboratory Technician

Cover Photo: Cumberland Falls State Park, Kentucky. Courtesy of Doug Curl.

KGS Director and State Geologist	Bill Haneberg
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