Kentucky Cross Section
Earth Resources—Our Common Wealth
Fall 2009

CO_2 injected at Hancock County test well; second phase approved

KGS and its industry partners successfully completed the injection of carbon dioxide into an 8,126-foot-deep well at a test site in Hancock County. A total of 323 tons of CO_2 was injected into the well on August 19 and 20.

Originally mandated and funded by the Kentucky legislature, the project was developed to test the technical feasibility of storing carbon dioxide in deep underground rock formations in western Kentucky. The ability of these deep rock formations to accept and permanently store CO_2 is an essential element of carbon capture and storage, a set of new technologies being developed to significantly reduce the emission of CO_2 from coal-burning electricity generation plants into the atmosphere.

Injection testing showed that the Knox Group, a dolomite formation present under much of the Midwest, will readily accept injected carbon dioxide. CO_2 injection came after KGS and industry scientists and engineers used brine injection testing to confirm that the Knox Formation, at depths between 3,800 and 7,400 feet, would store the injected CO_2.

Overlying impermeable rock formations and natural pressure will hold the brine and the CO_2 permanently in place. The CO_2 will pose no threat to the surface or the water table. Monitoring of the injected materials will continue for up to three years.

Dianna Tickner, chair of the Western Kentucky Carbon Storage Foundation, said, "We are pleased that early results from the injection tests suggest good potential for safely storing substantial volumes of CO_2 deep underground in

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Twelfth Survey celebrates its 10th anniversary

KGS staff celebrated the 10th anniversary of the 12th Survey on Friday, October 2. It marked a decade since the appointment of Dr. Jim Cobb as state geologist and KGS director.

Speaking to the Survey staff, Dr. Cobb summarized the major accomplishments and challenges of the period. He noted the 409 new publications issued by KGS in 13 categories, the completion of the scanning of all paper records of oil and gas wells to make them freely available online, and the explosive growth of the use of the KGS Web site by people worldwide.

He also pointed out that KGS hosts and manages the largest state-operated seismic network in the eastern half of the country, the Kentucky Seismic and Strong-Motion Network. KGS staff continues to develop new information that is valuable for a variety of purposes and audiences, from a Kentucky landslide database and surficial mapping of the state to data on deep geologic carbon dioxide storage and enhanced oil recovery.

Despite the challenges of shrinking budgets and the loss of several staff positions in recent years, KGS remains relevant and important to a number of State agencies and local communities that need assistance, Dr. Cobb added. Agencies such as the Kentucky Transportation Cabinet and the Energy and Environment Cabinet regularly turn to KGS for technical assistance, and rural communities seek KGS assistance for topics including water supplies and stormwater management. ❖

A 10th anniversary cake, provided by Rick Sergeant of KGS, included binary code spelling out "KGS."

Kentucky Geological Survey
228 Mining & Mineral Resources Bldg.
University of Kentucky
Lexington, KY 40506-0107
859.257.5500
fax 859.257.1147
www.uky.edu/KGS

Jim Cobb, State Geologist and Director
Jerry Weisenfluh, Associate State Geologist
Mike Lynch, Editor, *Kentucky Cross Section,* mike.lynch@uky.edu
Meg Smath, Copy Editor

Trends in the Kentucky coal industry

By Jerry Weisenfluh, KGS associate director

There is probably no more important economic issue for Kentucky than the future of the coal mining industry in the state. The recent Coal Forum held at the University of Kentucky on November 5 highlighted both the contributions by and challenges for the industry. Participants in this important dialog included those from industry, research groups, regulatory agencies, and environment organizations. Passion about the issues, especially those related to impacts of surface mining, was not in short supply. At the end of the day, though, it was evident to me that a more dispassionate discussion, based on available data, was in order. A review of long-term coal production trends can shed light on the future of the industry.

The graphs below from the Kentucky Office of Mine Safety and Licensing annual reports show important trends for coal production by mining method for both of the state's coal fields. The reasons for the trends are typically complex, but each graph tells a different story. Those stories relate to the state of the coal resource, the regulatory environment, and the marketplace. The simplest case is western Kentucky surface mining. Most people consider the most important distinction between the two coal fields to be coal quality, with western Kentucky having higher sulfur coal. Although this distinction is generally true, the *most* important difference is actually related to topography. Eastern Kentucky's hilly terrain provides greater surface access to the coal resources in that basin, whereas the flat terrain of western Kentucky restricts surface access of the best coal to the southern margin of the basin. The graph showing a steady decline of western Kentucky surface production since 1972 to the current level of about 5 million short tons per year is primarily because of the depletion of accessible coal. Price increases may make some deeper reserves available for surface mining in the future, but this trend will never reverse itself. This also explains the trend for western Kentucky underground mine production. Although western deep mine production shows typical cyclical patterns related to the market, it has been steadily increasing for the entire history of mining in the region. Western Kentucky contains the state's most uniform and persistent coal reserves in the Springfield coal, and almost all of this coal will be mined in large, high-production underground mines. The field has only 10 active underground mines in the Springfield, but seven of them produce more than 2 million short tons per year and several produce 4 to 5 million short tons. Increased demand for medium-sulfur coal because of greater numbers of scrubbed power units has benefitted this region, and mining costs are significantly lower compared to eastern Kentucky underground mines, because the coal is uniform, has negligible in-seam impurities, and is still abundant at depths less than 1,000 feet.

Although eastern Kentucky still produces about 75 percent of the state's total coal production, the trends are not positive. The great attention given to the issue of surface mining in the Appalachian region would lead people to think there has been a significant rise in that activity. The data for eastern Kentucky show just the opposite. Surface production has been consistently declining (although, at a modest pace) since its maximum of about 55 million short tons in 1977 (the year the Surface Mining Control and Reclamation Act was passed). There is no question that regulatory issues are part of this equation. Obtaining and complying with modern permits has become much more expensive and time-consuming. Recent gains in surface production have been influenced by large multi-seam operations that are feasible because of the relatively high coal prices of the period. In the long term, though, I think that resource availability will eventually take its toll as it did in western Kentucky. Much of the extensive surface deposits have been developed, and with increasing mining and reclamation costs, surface mining will be very sensitive to fluctuations in coal prices. The big surprise for me was the marked decline of underground production in eastern Kentucky. I believe the future of eastern production, as in western Kentucky, lies in underground mining. The declining trend we see began in 1990, the year the Clean Air Act was initially passed. Our

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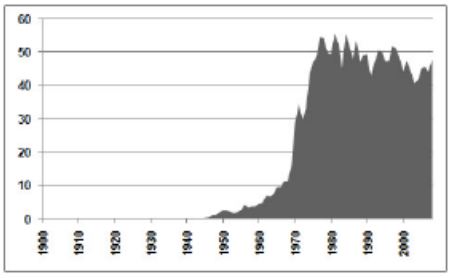
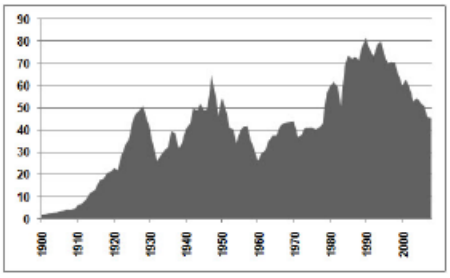
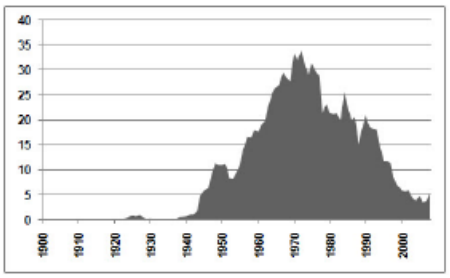


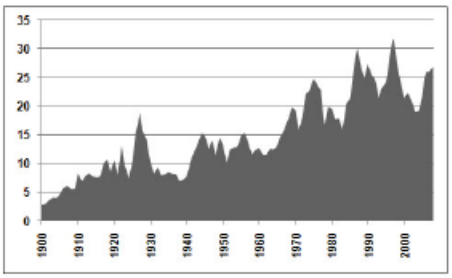
Eastern Kentucky surface production.



Eastern Kentucky underground production.



Western Kentucky surface production.



Western Kentucky underground production.

Carbon dioxide injection tested in the Mount Simon Sandstone in Boone County

The Midwest Regional Carbon Sequestration Partnership, which includes KGS, has successfully injected 1,000 metric tons of carbon dioxide (CO_2) at Duke Energy's East Bend Generating Station, near the town of Rabbit Hash in Boone County. The CO_2 was injected into the Mount Simon Sandstone, a deep saline formation that is widespread across much of the Midwest.

Preliminary results indicate that the formation has good CO_2 storage potential and could serve as a permanent storage zone for CO_2 emissions captured from stationary sources in the region. Carbon capture and storage is considered to be a key technological solution to reducing CO_2 emissions and combat climate change.

In the controlled test, the MRCSP research team injected liquefied CO_2 into the lowest 100 feet of the Mount Simon Sandstone, 3,230 to 3,530 feet below ground at the East Bend site. The formation has properties that are considered conducive to CO_2 storage, such as the appropriate depth, thickness, porosity, and permeability; layers of low-permeability rock that should keep the CO_2 safely and permanently confined also overlie the storage zone.

Before drilling the test well, a seismic survey was conducted at the site. The research team then injected clean brine, as required in the permit issued by the EPA, to determine formation properties such as the maximum safe injection pressure. Following brine injection, the CO_2 was injected in two steps of 500 metric tons each, concluding on September 25. The injection rate, pressure, temperature, and quantity of CO_2 in the formation were measured throughout the test to confirm that the injection proceeded as planned.

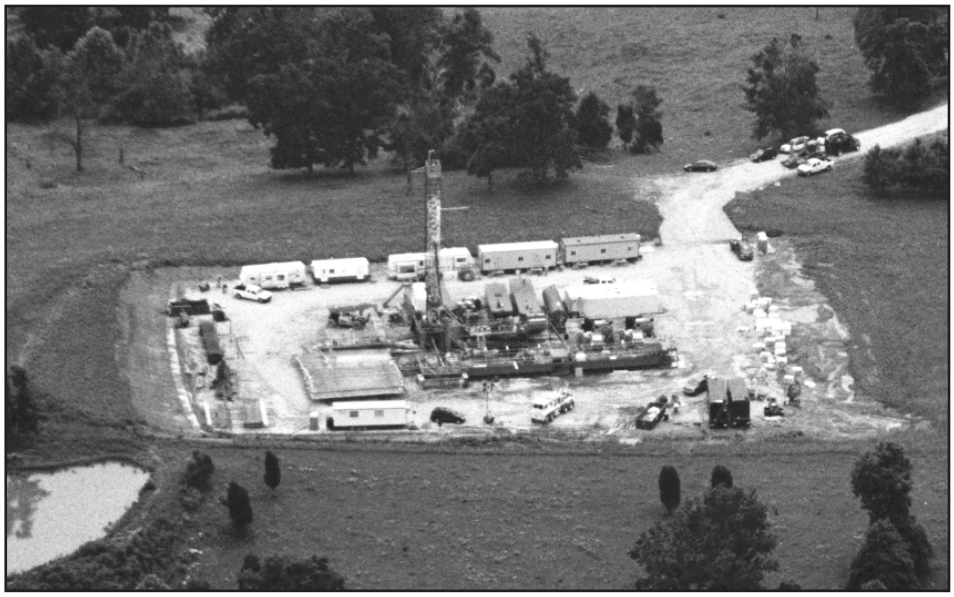
The East Bend test follows in the footsteps of two other MRCSP injection tests in other parts of the region: the Appalachian Basin test at the R.E. Burger Power Plant in Shadyside, Ohio, and the Michigan Basin test near Gaylord, Mich., in which more than 60,000 metric tons of CO_2 were safely injected into a deep saline formation called the Bass Islands Dolomite. In addition to Battelle, Duke Energy, and KGS, key partners and technical contributors involved in the East Bend test include the Indiana and Ohio geological surveys. ❖

"Hancock County"—continued from p. 1

Kentucky's Knox dolomite formations." The nonprofit foundation was created by Peabody Energy, ConocoPhillips, and E.ON U.S. to provide significant funding and technical assistance to the project.

Funding for the project has been provided through a $1.5 million allocation from a grant by the Kentucky General Assembly in 2007, as well as a total of $6.5 million in grants from the Western Kentucky Carbon Storage Foundation, Illinois Office of Coal Development and Marketing, U.S. Department of Energy's National Energy Technology Laboratory, and Tennessee Valley Authority.

Meanwhile, a second phase of testing was planned for the well with the announcement in September of a new grant from the U.S. Department of Energy. The additional research was made possible by a DOE grant of $4.8 million from the American Recovery and Reinvestment Act to the University of Illinois and several partners, including KGS, to further evaluate the CO_2 storage potential of deep geologic formations under the Midwest. The grant to KGS includes funding for CO_2 injection, data collection, and modeling. Several new tasks are important to the research:



An aerial view of the deep carbon storage test site in Hancock County during the drilling phase. Courtesy W.C. Ging and Sandia Technologies, LLC.

- Additional analysis of rock samples taken earlier at both this well and others in the region to learn more about their ability to permanently store CO_2 underground
- Additional injection of CO_2 and brine into the well and monitoring the movement of the material after injection
- Collection of data for modeling the permeability and porosity of the formation where CO_2 has been injected
- Analysis of fractures and faults in the formation and their effect on porosity and permeability.

KGS and its partners plan to complete the field portion of the work in the summer of 2010, and further studies will continue through 2011. ❖

Oil and gas well record scanning project completed

KGS staff have completed a decades-long project to scan all available oil and gas well records and make them accessible on the KGS Web site. The well records have been housed at the Survey since the Kentucky General Assembly in 1960 mandated that oil and gas operators submit their records to KGS, which became the official repository of the records.

A decision was made over 25 years ago to scan the records into computerized images, despite the primitive nature of the available computer systems at that time. "The project to scan the entire archive began in March 1984, at a time when the Internet as we know it today didn't exist," says Steve Cordiviola, head of the KGS Geoscience Information Section. "So the decision for a computerized archive turned out to be a better one than we could imagine at the time."

By the summer of 2002, the first scanned records became available on the KGS Web site. At the time, the paper records occupied 530 file drawers. This summer, 25 years after the project began, the backlog of drilling records has been completely scanned. Today, a database of more than 590,000 records from 170,000 wells drilled in Kentucky can be accessed at www.uky.edu/KGS/emsweb/data/ogdata.html.

"The cooperation between KGS and our agency is invaluable, and the electronic well records library is an important connection in our partnership," said Kim Collings, director of the Kentucky Division of Oil and Gas, which regulates drilling operations. "The database has become a daily tool for the Division's office and field staff. It contains a wealth of information, especially for preregulation wells for which the Division may have no records."

The database has not gone unnoticed by drillers and others interested in oil and gas operations in the state. In calendar year 2008, there were more than 83,560 searches of this database, which has been of great value to operators. "The benefits of this database to the state's oil and gas industry can hardly be measured," says John Gabbard, executive director of the Kentucky Oil and Gas Association. "For operators who are looking into places to recover oil or gas resources, it is an invaluable tool for helping them determine where to drill or where not to, based on previous experiences available through the online database."

"The records are crucial for exploring new oil and gas resources and are used for other geologic purposes, such as determining groundwater and coal resources, environmental issues, and rock properties," says KGS Director Jim Cobb. "The records are used by industry, government agencies, and private landowners. These users are not only from Kentucky, but also from around the United States and the world."

The online records database offers users a variety of criteria for searches, such as geographic area, date of the record, and type of record. A tutorial on how to use the database is available at www.uky.edu/KGS/emsweb/data/tutorial.html. ❖

Three from KGS, UK visit China for earthquake exchange program

KGS Director Jim Cobb led a group from the Survey and the University of Kentucky's Department of Earth and Environmental Sciences on a visit to Tianshui in southeastern Gansu Province of China from July 27 to August 8. The visit was part of the ongoing earthquake science exchange program with the Lanzhou Institute of Seismology in the Gansu Earthquake Administration. Tianshui was a center of early Chinese civilization and the birthplace of Taoist "Ba Gua" or "eight symbols." Many large earthquakes have occurred there in the past several thousand years, including the 2008 Wenchuan 8.0-magnitude earthquake.

"This has been a tremendous success for us and for our Chinese counterparts," said Cobb. "Our work in China has provided us with opportunities to examine active faults and earthquake effects not seen in Kentucky. This has been very important for our studies of the New Madrid Seismic Zone and other earthquake zones that affect Kentucky."

The exchange program has produced scientific papers and studies of earthquakes in both countries. The May 2008 earthquake killed an estimated 85,000 people and brought a renewed sense of purpose to the exchange. The research being done bears directly on improving public safety in the United States and China by assessing earthquake-prone faults and the responses of soils and rock to shaking from earthquakes. Zhenming Wang, head of the KGS Geologic Hazards Section, and Edward Woolery, associate professor in the Department of Earth and Environmental Science, accompanied Cobb on the visit and conducted seismic hazard mapping with their Lanzhou counterparts.

"With a long civilization and rich historical earthquake records, Tianshui provides an ideal place for seismologists to study earthquake science and seismic hazard mitigation policy," said Wang.

Ed Woolery (center, standing) and Zhenming Wang (right, seated) work with researchers from the Lanzhou Institute of Seismology on seismic hazard mapping in Tianshui.

It was the fourth trip by UK scientists to China to collaborate with Chinese colleagues, presenting papers and conducting research on seismic hazards. Seismologists from China have made an equal number of trips to Kentucky, and two Chinese seismologists spent a year at UK as visiting scholars.

"The scholarly exchange is providing our research program an important opportunity to compare their actual

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New river basin maps, "Geologic Map of Kentucky" released

A new series of maps on the seven major river basins of Kentucky was published by KGS between June and November. Each was created by Dan Carey of the KGS Geospatial Analysis Section. A topographic map occupies the center of each large-format publication, depicting the major rivers and streams, lakes, highways, counties, and cities in the basin. Surrounding the central map is a wealth of additional text, tables, and illustrations depicting resources, activities, and terrain features associated with the basin. Information on the communities that draw water supplies from the basin and boat docks on streams and lakes is also included.

"Someone called asking for a map of the Kentucky River Basin," says Carey, "and since we knew of nothing like that already available, we decided to make a map for each major basin in Kentucky. I think they will put each river basin of Kentucky in context and help people visualize the basin for its extent, the communities it affects, and the resources associated with each basin."

Carey drew data from a variety of sources, including River Basin Coordinating Committees, the Kentucky Infrastructure Authority, the State's Department of Fish and Wildlife Resources, the U.S. Geological Survey, and the U.S. Army Corps of Engineers.

"Because these maps combine information from a variety of sources, including our own Division of Water and our river basin coordinators, we believe they provide a valuable integrated overview of the major river basins in Kentucky," says Len Peters, secretary of the Kentucky Energy and Environment Cabinet. "The maps include links to further information on the basins, and should be of interest to planners, environmentalists, educators, boaters, fishermen, and anyone who lives in or has an interest in a particular basin."

Another new KGS publication, the "Geologic Map of Kentucky" (Geologic Map 19), is the result of compilation of over 700 digital maps to make a complete geologic map of the state. It can be downloaded from the KGS Web site or purchased in paper form and laminated. This colorful 1:350,000-scale map includes all major geologic formations of the state, along with major surface faults, counties, county seats, streams, and rivers. The 36 x 80 inch map was created from 707 U.S. Geological Survey 7.5-minute geologic quadrangle maps that were digitized during the 1996–2006 KGS Digital Geologic Mapping Program.

"This publication encapsulates the original mapping done during a cooperative project by the USGS and KGS from 1960 to 1978, when Wally Hagan was state geologist," says Tom Sparks of the KGS Geospatial Analysis Section. "Just about anyone interested in the general geology of Kentucky, as well as educators and students of geology, will find the map useful and interesting." Sparks points out that a long list of people contributed to the program and the map, including KGS project staff, visiting scholars, students, volunteers, and summer interns.

The publication illustrates regional changes in stratigraphic nomenclature (proper geologic names and their associated characteristics within the rock record) that arise from lateral variations in the rocks but may also be caused by evolving nomenclature usage during and after the original mapping program. While compiling the maps, Sparks says, every effort was made to resolve inconsistencies in the formation names, to adopt more recent usage, and edge match adjoining maps. The end result is a map that uniquely combines the fidelity of large-scale maps with the regional perspective of a statewide compilation to illustrate the achievements of the KGS Digital Geologic Mapping Program.

To view and download these publications online, go to the KGS Web site, www.uky.edu/KGS, click on the "Recent Publications" link, and scroll down to the particular publication. Paper copies of the maps are available from the KGS Public Information Center in the Mining and Mineral Resources Building on the UK campus and may be ordered by calling (859) 257-3896 or toll free at (877) 778-7827. ❖

"Earthquake Exchange"—continued from p. 4

large-magnitude earthquake observations with our theoretical or modeled seismic responses for similar sized events in the central United States," says Woolery. "Ultimately, this will allow us to better understand seismic hazards here at home."

Future plans for the exchange program include a hazard assessment of Tianshui City, assessment of data from 2009 field work in China, hosting another visiting scholar from the Lanzhou Institute, and publication of results from previous field investigations. ❖

Retired Assistant State Geologist John Kiefer was honored by the Kentucky Society of Professional Geologists with its "Distinguished Career Award" in November. Kiefer retired in June after 30 years at KGS. KSPG Executive Committee member Ken Kuehn presented Kiefer the award (right) at the 2009 KSPG meeting at Northern Kentucky University.

Endurance horse races cross KGS core library property

Horses and riders from 23 countries competed October 14 in two long-distance endurance races that crossed the grounds of the KGS Well Sample and Core Library (right) and other properties in the area. The second race was scheduled to be a qualifying event for the 2010 Alltech FEI World Equestrian Games, to be held at the Kentucky Horse Park, a short distance from the Core Library on Iron Works Pike in Lexington. That race had to be shortened from its original length of 100 miles to 75, as footing became questionable because of mud and slippery conditions caused by rain. The races began at the Horse Park and crossed local farms and University property, frequently returning to the Horse Park for required veterinary inspections. U.S. participants dominated the second race, garnering gold, silver, and bronze medals for teams and individuals. ❖

A rider is shown passing behind the KGS core library on October 14 as part of the Kentucky Cup Endurance Race.

"Coal Trends"—continued from p. 2

sources in the industry suggest that this initially affected eastern Kentucky mines producing medium-sulfur coal, but ultimately low-sulfur mines have become less competitive because of the trend in the power industry to switch to cheaper and higher-sulfur coals from other regions. The resource issue that is affecting eastern Kentucky underground mining has to do with the character of the remaining reserves. Remaining coals are thinner than those previously mined and contain more rock partings. This has significantly increased mining and cleaning costs compared to other coal-producing regions. Again, sensitivity to price fluctuations will have a significant impact on eastern Kentucky's future underground mining.

At a time when critical energy policies are being formulated and implemented for Kentucky and the nation, it will be prudent to base those policies on the best available data, rather than the passions of the debate. This simple analysis of coal production data should be part of that dialog. At the same time, it demonstrates the difficulty of making long-term projections about future production of coal in the state, because of the uncertainty of two important factors: coal prices and energy-related regulations. ❖

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

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