Deep seismic observatory now operational in western Kentucky

A new array of seismic instruments installed in a deep borehole in rural western Kentucky is now operational and providing valuable data on earthquake activity in the central United States. The instruments have been installed in a 4-inch-diameter, steel-cased hole that was drilled 1,950 feet deep to bedrock at Sassafras Ridge in western Fulton County. The new vertical array is dubbed the Central U.S. Seismic Observatory (CUSSO) and joins 25 other seismic monitoring stations in the Kentucky Seismic and Strong-Motion Network. CUSSO is the deepest seismic observatory in the eastern half of the United States.

Drilling of the borehole was completed late in 2006. When additional funding was secured, seismic instruments were built by EENTEC of St. Louis and VLF Designs of Jackson, Mo., for the observatory. Three-component accelerometers, which detect strong ground motions, are situated 1,680 and 1,948 feet deep in the borehole; a seismometer measuring medium-period motions is at 1,949 feet, and an inclinometer was placed at the bottom. At the surface, an additional seismometer and accelerometer are housed in a vault. A digital recording system and wireless Internet connection at the site gather and send data to KGS. Two other shallower holes containing seismic instruments were already located nearby.

“This observatory will gather information from earthquake waves in the New Madrid Seismic Zone and other active zones in the Midwest as they propagate to the surface,” says KGS Director Jim Cobb. “In some cases the ground shaking intensifies as the waves move upward through unconsolidated sedimentary layers typical of western Kentucky geology.”

The location of the observatory is near the center of the New Madrid Seismic Zone, the source of several powerful earthquakes in 1811 and 1812. This location, only a few miles from New Madrid, Mo., is a good one to collect the maximum amount of data from the zone. “Data collected will help geologists and engineers better define the earthquake hazard in the region,” according to Geologic Hazards Section Head Zhenming Wang.

Hancock County deep storage project completed; site reclaimed

KGS and its partners have completed research at the deep carbon-storage test well drilled in Hancock County, after two phases in which carbon dioxide and brine were injected to confirm the capacity of the deep geologic formations in the Western Kentucky Coal Field to permanently store the greenhouse gas. After an interval between 4,824 and 5,038 feet deep was isolated, an additional 357 tons of CO$_2$ was injected there in September 2010. During the first phase in 2009, 323 tons of CO$_2$ had been injected.

“In addition, we gathered three-dimensional vertical seismic profile data on the immediate area around the well, both before and after the injection of the carbon dioxide,” says Rick Bowersox, co-principal investigator for the project. “Seismic trucks provided the vibrations at more than 900 locations around the well-pad site, and a set of geophones lowered 3,600 feet into the well recorded the reflections from the geology. We hope to be able to image the CO$_2$ plume as far as the area in which it changes the seismic velocity in the rock. That would give us an idea of just how far from the injection zone the carbon dioxide can be expected to travel.”

Bowersox says he doubts the small amount of deeply injected gas traveled much far-
The American Institute of Professional Geologists recently released a white paper, “Importance and Future Roles of State Geological Surveys,” in light of many state geological surveys experiencing budget cuts because of the recession. AIPG, whose members are predominantly geologists in private practice, felt compelled to write this defense because they are users of the information and services that state surveys provide. An AIPG committee conducted a survey to gather information for their white paper. I know personally how in-depth the fact-finding was because I spent a considerable amount of time responding to questions from the committee. The white paper concluded that “state geological surveys provide critical functions in a cost effective manner that greatly enhances each state’s economy and environment. The surveys provide the public and private sectors considerable support on all types of important environmental and natural resources issues. Continued support of our state geological surveys is critical since the services they provide are invaluable.” I could not agree more with their findings.

State geological surveys have a difficult time calculating the cost-benefit ratio for their activities and putting a value on their programs. Since most survey data, publications, and maps are free or at low cost, the income for a survey is not an indication of its value to society. In the jargon of economic theory, state geological surveys are considered public goods, in contrast to commercial goods and services. Public goods can benefit all and are available to all at no or low cost. Therefore, it is a challenge to fix a value. In 2000, an economic analysis of geologic maps was done based on the theory of public goods and willingness to pay. It found that the value of a geologic map was 25 to 39 times the cost to create the map, a great bargain for society. The geological survey as a whole, much like the geologic map, should also be judged as public goods benefitting all either directly or indirectly.

The Kentucky Geological Survey is a fine example of a public good, providing data to thousands of users each year. These people use our maps, databases, publications, and Web services to produce minerals and fuels needed by society, produce and protect groundwater and surface water, avoid hazards such as faults, sinkholes, and landslides, and remediate damaged land and streams. Based on KGS’s budget and the 2010 census for Kentucky, KGS costs the citizens of this state 95 cents per person per year. Although the value of KGS’s contribution to society and Kentucky’s economy is difficult to quantify in economics terms, there is no question that the millions of bits of data disseminated by the survey to thousands of users contribute tremendously to society. In times of economic recession, the state geological survey is one of the vital components of the engine that can move the state’s economy forward. Therefore, I wholly agree with the findings of the AIPG white paper that so thoroughly endorses state geological surveys and thank AIPG for their great insight.

Weisenfluh receives Gordon Wood Award

KGS Associate Director Jerry Weisenfluh received the Gordon H. Wood Jr. Memorial Award from the Eastern Section of the American Association of Petroleum Geologists at the section’s September 2010 annual meeting in Kalamazoo, Mich. The award, begun in 1989, recognizes outstanding contributions to the geology of coal and other energy minerals and the goals of the Energy Minerals Division of the Eastern Section. With Weisenfluh is Ed Rothman of Mountaineer Gas in Charleston, W.Va. Rothman was president of the Eastern Section at the time of the meeting.

Seismic observatory—continued from p. 1

Section Head Zhenming Wang, who coordinated the development of CUSSO with Ed Woolery of the UK Department of Earth and Environmental Sciences.

“Finding out more about the nature of the earthquake hazard will have an important effect on economic development in the region, because data collected by the observatory will be used to ensure that building codes and construction practices are appropriate for mitigating potential earthquake damages in the region.”

The five partners involved in the project have committed a total of $295,652, with a substantial amount of the funding coming from the U.S. Department of Energy through the Kentucky Research Consortium for Energy and the Environment.
Retired laboratory manager helps with Italian archaeological project

An archaeological investigation into an ancient fortification built in the early fifth century B.C. by the Greek city of Locri Epizephyrii in the Calabria region of southern Italy has received some valuable assistance from the retired manager of the KGS laboratory, Henry Francis. The principal investigator, Associate Adjunct Professor Paolo Visonà, who teaches in the University of Kentucky’s Art Department, has been excavating the remains of this fort since 2005.

“We think it was a small fortified emplacement, with an area of about 1,200 to 1,400 square meters (between 4,000 and 4,600 square feet),” says Visonà. “It was built on a mountaintop near a major communication route to keep an eye on the movement of Greeks from other cities who may have attacked from the north. There was much conflict between Greek city-states in this area of southern Italy at the time.”

Though most of the perimeter wall was constructed with granite, Visonà says that he began noticing isolated fragments and building blocks made from a different variety of stone first shown to him by locals. He was able to tentatively trace the stone to an outcrop found about 500 meters from the excavation site. He theorized that the outcrop was used as a quarry for at least some of the stone used to build the ancient Locrian outpost.

He brought samples back to UK in 2008 and contacted Francis as well as the Department of Earth and Environmental Sciences to help identify them and confirm that they were from the nearby outcrop. “We did X-ray diffraction and X-ray fluorescence analysis here in the lab,” says Francis, who still works part-time at KGS. “In addition, Mössbauer spectroscopy analysis was done by Frank Huggins at the UK office of the Consortium for Fossil Fuel Science. We were able to identify the samples as garnet chlorite schist. We also obtained some research papers with data that corresponds with what we found, confirming the presence of this rock in the region.”

Determining that local material was used for such a building project may not seem remarkable to people of the 21st century, but Visonà says it was significant for the Greeks who lived in southern Italy some 2,500 years ago. “What makes this discovery particularly interesting is that it shows that the Greeks had an ability to identify a quarry of building material. Considering how remote the site is from the coast, where the city of Locri was located, makes that remarkable. They were able to search the area successfully for what they needed. They also found strategic minerals for their needs, including iron and silver.”

The Italian-born archaeologist credits Francis for identifying the material and helping to link it to a local source; he hopes further tests will strengthen the connection and help determine if the Locrians used the material for other purposes. Although the remains of the fortification stand no more than waist high now in some places, he says that the perimeter walls are 2.5 meters thick (8.25 feet) and may have stood over 4 meters high (13.2 feet) when first completed. Their upper courses were probably made of mud brick. In 2010, a cut block of schist was found in the facing of the southern defensive wall, thus proving that the Locrians used this stone for building.

Visonà points out that progress on his research required a multidisciplinary approach, involving geography, archaeology, geology, anthropology, and other sciences. He plans to publish his findings and will set up an exhibit at Lexington’s Central Library at the end of March to present the results of the UK excavations at the southern Italy site.

Unregulated drinking-water initiative project begins

The Centers for Disease Control in Atlanta is working to develop a national repository of water-quality data to promote public health research and has turned to the states for help to develop the system. In fact, according to Bart Davidson of the KGS Water Resources Section, the CDC saw the Survey’s groundwater data repository online and approached KGS to use its system as part of a model for the national repository.

KGS is representing Kentucky on a national workgroup of at least 15 states and other agencies cooperating with the CDC on the project. It is focused on gathering data that would help health-care professionals who want to investigate possible connections between unregulated drinking-water sources and illnesses among people who drink that water. KGS has received $41,000 from the CDC for the first phase of the work in Kentucky.

“Our tasks during this first year of the project are to look for groundwater-quality data among State agencies that have never been scanned or digitized and to estimate how much digitizing would cost,” Davidson says. “Some State agencies, in fact, have such data in paper form only, so they can’t be easily added to a digital database.”

Davidson and Water Resources Section Head Jim Dinger are the principal investigators for the project. Davidson says they have already found one major source of nondigital data at the Kentucky Division of Mine Permits. The information comes from drinking-water wells that are monitored for possible contami-
John Hickman working on new Knox porosity project

John Hickman of the Energy and Minerals Section is working on a new project to determine if a method can be created for predicting porosity in the Knox Supergroup specifically for the purpose of geologic carbon storage.

“I’m doing what’s known as an ‘inversion’ of seismic data. At locations near where we have deep wells with known properties, we can model the seismic response that we’d expect to get,” says Hickman. “By comparing actual recorded seismic data to our model, we can ‘reverse engineer’ the difference to estimate additional properties of the geology. We’re hoping that with these revised models, we can image rock properties that would normally be below the resolution of the existing seismic data.

“Of course, we can currently drill into the deep geologic formations to see if they’re porous. If we can find a way to determine the locations and extent of the porosity from the surface, however, we can save extra time, drilling, and cost.”

He is examining seismic data from several wells drilled in Kentucky and southern Illinois to determine if they can be used to differentiate the known porosity of each well. One of the wells is the deep carbon storage borehole drilled in 2009 by KGS and private partners in Hancock County.

The 3-year project is funded by the U.S. Department of Energy through the Midwest Geological Sequestration Consortium and matching money provided by the nonprofit foundation created by private partners involved in the first phase.

“As successful as this project was, the scientific community in partnership with the energy industry needs further tests to determine the extent of the Knox reservoir and how much CO₂ can be put into it,” says Dave Williams, the other co-principal investigator. “Although we’re more confident we can inject into the deep formations of this region, that needs to be demonstrated in other areas before full-scale geologic carbon storage can start.”

KGS staff, including Brandon Nuttall of the Energy and Minerals Section and Associate Director Jerry Weisenfluh, talk to local officials and news media after the final public meeting on the deep carbon-storage project in Hancock County.

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Western Kentucky enhanced oil recovery projects show mixed results

Two KGS enhanced oil recovery and carbon sequestration projects in western Kentucky have had mixed results. Both projects were initiated to evaluate the effects of carbon dioxide injection on oil production. In the Sugar Creek oil field of Hopkins County, operated by Gallagher Drilling, 7,268 tons of carbon dioxide were injected for one year starting in May 2009. About 1,000 barrels of additional oil was produced as a result of the injection and well maintenance. The Sugar Creek project used a flood-pattern method, in which CO2 was injected into a central well to stimulate additional production in surrounding wells.

“Since CO2 injection was completed and the field returned to a water-flood mode, production has returned to preinjection levels, so it looks like any benefit has already been realized,” says principal investigator Marty Parris of the Energy and Minerals Section. “The recovery of 1,000 barrels of oil means that we injected 7 tons or 119,000 cubic feet of CO2 for each barrel of oil recovered, which is not a good efficiency.” He adds that most Kentucky operators don’t have the resources to take on a complex flood-pattern project such as the one at Sugar Creek, because of the amount of reservoir engineering needed before CO2 injection. In addition, the infrastructure of many of Kentucky’s oil fields is not sufficient for multiple wells. KGS, the Illinois State Geological Survey, and Gallagher Drilling are jointly administering the project, which is funded by the State of Kentucky and the U.S. Department of Energy through the Midwest Geological Sequestration Consortium.

A second project, in Basin Petroleum’s Euterpe Field of Henderson County, injected 20 tons of CO2 into a single well in late October. Originally, the operations plan called for 80 to 100 tons of CO2 to be injected in the single-well cyclic project. A tubing leak, however, halted injection operations after the first day of injection.

After injection, the well was shut-in (taken off production) for a week and then the pressure was bled off over an additional week so that the pump could be placed back on the well safely. The well went back into production in mid-November, and initially the produced fluid formed an emulsion akin to chocolate mousse, which is a problem for production because the oil and water cannot be readily separated. The emulsion did suggest, however, that CO2 was interacting with oil and water in the reservoir. The problem was solved with the addition of a demulsifying agent. Since late November, the well has been producing intermittently, and during those times production rates have increased significantly from a preinjection value of 0.6 barrels of oil a day to about 4 barrels of oil a day. The initial results are promising enough that an additional round of CO2 injection was planned for late January.

Parris notes that “the likely large number of leaky wells in Kentucky represents a significant challenge for broad implementation of CO2 enhanced oil recovery. The infrastructure is suspect in many cases, and I think there needs to be serious evaluation of wellbore integrity before doing such a project. In fact, I’m interested in starting a possible project this year to conduct field studies on some representative fields to get a better assessment of the magnitude of leaky wells.”

Earth Science Week open house brings large crowd to KGS

KGS had one of its most successful Earth Science Week open house events as a crowd of over 250 students, parents, and teachers visited the Mining and Mineral Resources Building on the evening of Oct. 13. Survey staff set up exhibits and demonstrations related to energy topics, dinosaurs, caves, karst, minerals, and polished rocks. Several other organizations brought displays as well. The UK Department of Earth and Environmental Sciences brought a stream table; the UK Mining Engineering Department demonstrated coal separation techniques. Displays also came from the Kentucky Archaeological Survey, the National Energy Education Development program, the Kentucky Water Resources Research Institute, and the Kentucky Paleontological Society.

Above, Rachel Hatch, president of the UK geology club, tells open house visitors about samples of thin rock sections as they inspect them under microscopes.

The event is promoted each year among public and private schools in Fayette and surrounding counties, and a number of teachers ask for lists of the exhibits so they can urge students to attend and find answers to specific questions about earth science topics.
KGS, Energy and Environment Cabinet hold collaboration session

Staff members of Kentucky’s Energy and Environment Cabinet traveled to the KGS Well Sample and Core Library October 26 to spend a day sharing information about their work and learning more about the research done by Survey staff.

After introductions by Director Jim Cobb and Energy and Environment Secretary Len Peters, KGS section heads spent the morning talking about the Survey’s research and how it affects Kentucky and State government agencies. The topics included geologic carbon storage, enhanced recovery of Kentucky’s oil and gas resources, the search for drinking water in rural communities, earthquake studies, surficial mapping, and dissemination of KGS data and mapping.

During the afternoon, commissioners from the Environmental Protection, Natural Resources, and Energy Development and Independence Departments spoke about the activities and responsibilities of their agencies. The wide-ranging cabinet oversees and regulates issues including coal mining, water quality, oil and gas drilling, dam safety, and energy policy planning.

KGS and the cabinet are working together on several collaborative projects, the largest of which are carbon storage and enhanced oil recovery projects mandated by the State legislature in 2007.

During the day-long exchange, participants determined that there are several areas in which KGS can offer additional help to the State agencies. Secretary Peters asked KGS for assistance with determining the locations of geologic anomalies, which he called the one issue preventing the state from reaching the goal of zero fatalities in underground coal mining. The cabinet is also interested in technical assistance on coal-combustion waste products, geologic hazard assessment, and the relationship between stream-water conductivity and possible chemicals that may affect water quality and health.

Environmental Protection Commissioner Bruce Scott speaks at the October 26 meeting between staff members of KGS and the Kentucky Energy and Environment Cabinet.

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