

# Kentucky Seismic and Strong Motion Network - Including the Central United States Seismic Observatory (CUSSO)

**Jonathan McIntyre**  
Kentucky Geological Survey  
University of Kentucky

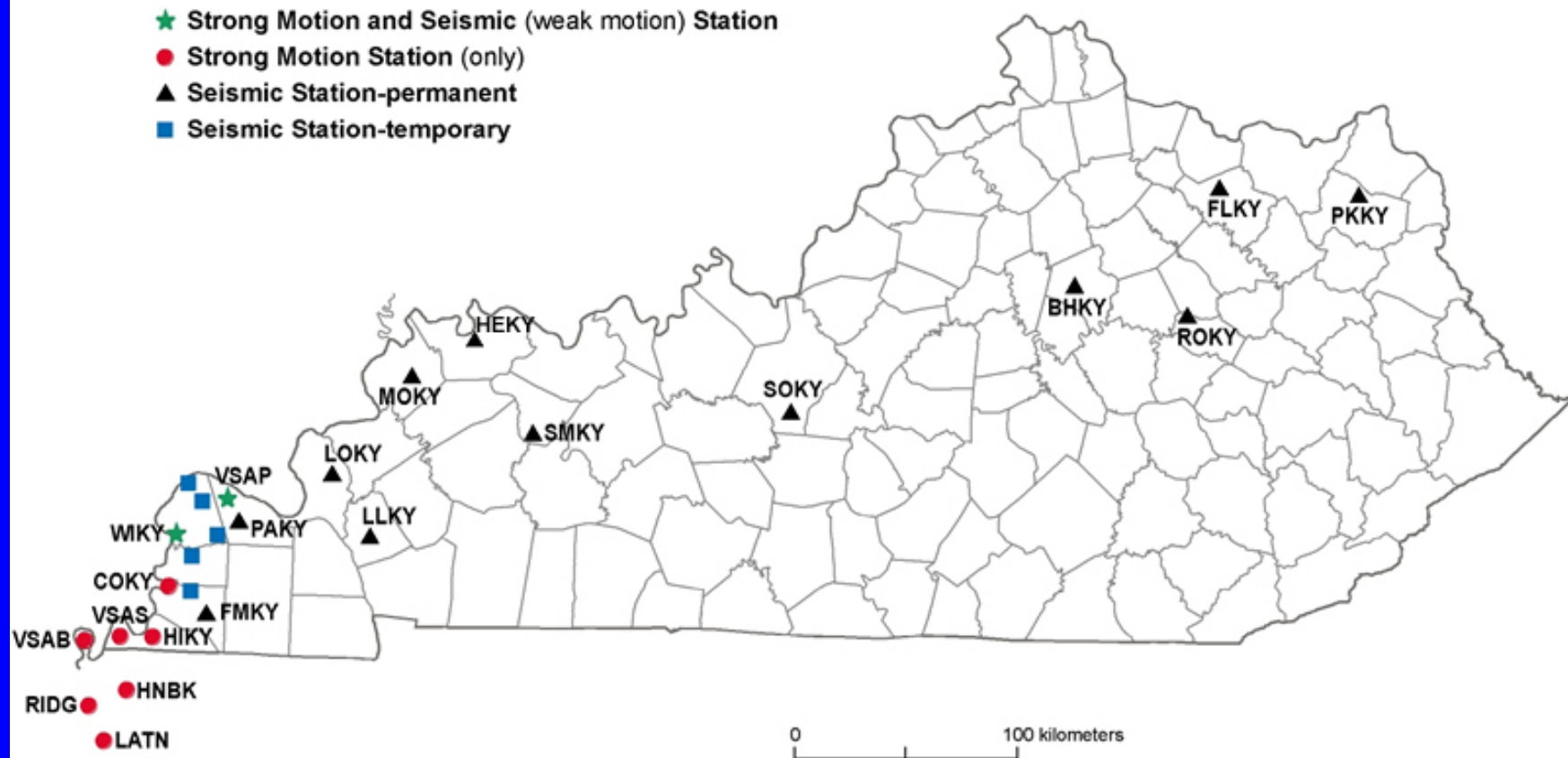
**Zhenming Wang**  
Kentucky Geological Survey  
University of Kentucky

**Edward W. Woolery**  
Department of Earth and Environmental Sciences  
University of Kentucky



2007 KRCEE-PGDP Technical Symposium  
30 October 2007

# Kentucky Seismic and Strong-Motion Network

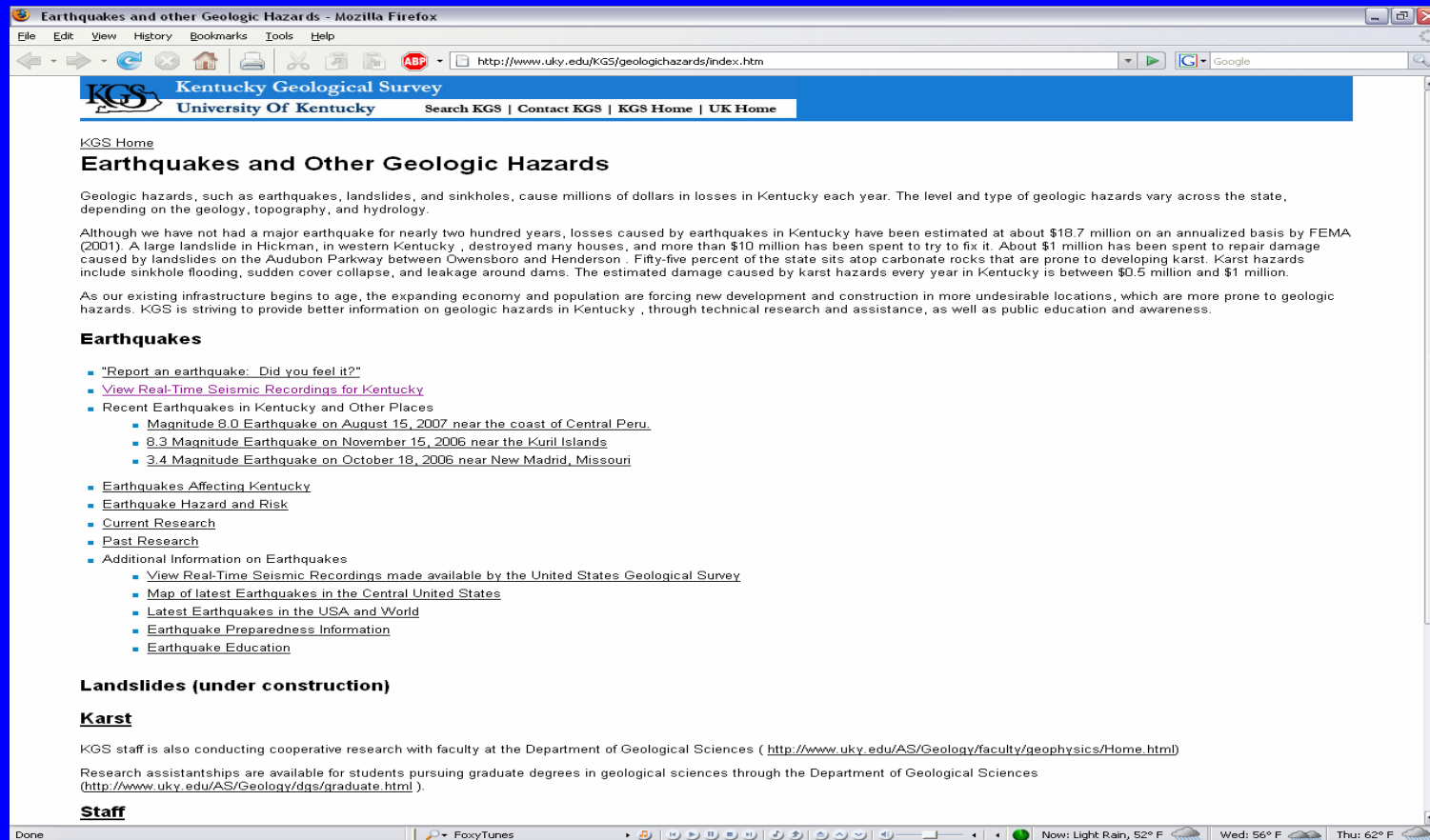


- 26 monitoring stations
- 19 short-period seismometers
- 12 strong-motion accelerometers
  - 2 vertical arrays (3 other boreholes w/o instruments)
  - CUSSO (595-m borehole awaiting instrumentation)

- KSSMN capable of monitoring any earthquake with a magnitude 2.0 or larger within Kentucky.
- Significant blasts, mine collapses, and explosions are also monitored and catalogued.
- Data from 12 seismic stations are continuously recorded as part of the “near” real-time monitoring system. System “triggers” to record events of note to be reviewed (noise, mine blasts, earthquakes). Real-time network utilizes the Kentucky Early Warning System (KEWS) for data transmission.
- Data from remaining stations are downloaded via modem (weekly) or are downloaded manually (quarterly).
- Recorded 30+ earthquakes since January 1, 2006. Magnitudes ranged from 1.5 to 3.4. Instruments available to rapidly begin aftershock studies for large events.
- Communicate with CERI if discrepancies occur from what is recorded by KSSMN and what is reported by CERI.

# Website

- Near real-time viewing of digital webicorders for 12 stations.
- Refreshes every 3 minutes.
- Images are archived.



The screenshot shows a Mozilla Firefox browser window displaying the website "Earthquakes and other Geologic Hazards - Mozilla Firefox". The address bar shows the URL "http://www.uky.edu/KGS/geologic\_hazards/index.htm". The website header includes the KGS logo and navigation links: "Search KGS | Contact KGS | KGS Home | UK Home". The main content area is titled "Earthquakes and Other Geologic Hazards" and contains introductory text about geologic hazards in Kentucky. Below this, there is a section for "Earthquakes" with several bullet points linking to reports, real-time recordings, and recent earthquakes. Further down, there are sections for "Landslides (under construction)", "Karst", and "Staff". The browser's status bar at the bottom shows weather information: "Now: Light Rain, 52° F", "Wed: 56° F", and "Thu: 62° F".

**Earthquakes and Other Geologic Hazards**

Geologic hazards, such as earthquakes, landslides, and sinkholes, cause millions of dollars in losses in Kentucky each year. The level and type of geologic hazards vary across the state, depending on the geology, topography, and hydrology.

Although we have not had a major earthquake for nearly two hundred years, losses caused by earthquakes in Kentucky have been estimated at about \$18.7 million on an annualized basis by FEMA (2001). A large landslide in Hickman, in western Kentucky, destroyed many houses, and more than \$10 million has been spent to try to fix it. About \$1 million has been spent to repair damage caused by landslides on the Audubon Parkway between Owensboro and Henderson. Fifty-five percent of the state sits atop carbonate rocks that are prone to developing karst. Karst hazards include sinkhole flooding, sudden cover collapse, and leakage around dams. The estimated damage caused by karst hazards every year in Kentucky is between \$0.5 million and \$1 million.

As our existing infrastructure begins to age, the expanding economy and population are forcing new development and construction in more undesirable locations, which are more prone to geologic hazards. KGS is striving to provide better information on geologic hazards in Kentucky, through technical research and assistance, as well as public education and awareness.

**Earthquakes**

- ["Report an earthquake: Did you feel it?"](#)
- [View Real-Time Seismic Recordings for Kentucky](#)
- [Recent Earthquakes in Kentucky and Other Places](#)
  - [Magnitude 8.0 Earthquake on August 15, 2007 near the coast of Central Peru.](#)
  - [8.3 Magnitude Earthquake on November 15, 2006 near the Kuril Islands](#)
  - [3.4 Magnitude Earthquake on October 18, 2006 near New Madrid, Missouri](#)
- [Earthquakes Affecting Kentucky](#)
- [Earthquake Hazard and Risk](#)
- [Current Research](#)
- [Past Research](#)
- [Additional Information on Earthquakes](#)
  - [View Real-Time Seismic Recordings made available by the United States Geological Survey](#)
  - [Map of latest Earthquakes in the Central United States](#)
  - [Latest Earthquakes in the USA and World](#)
  - [Earthquake Preparedness Information](#)
  - [Earthquake Education](#)

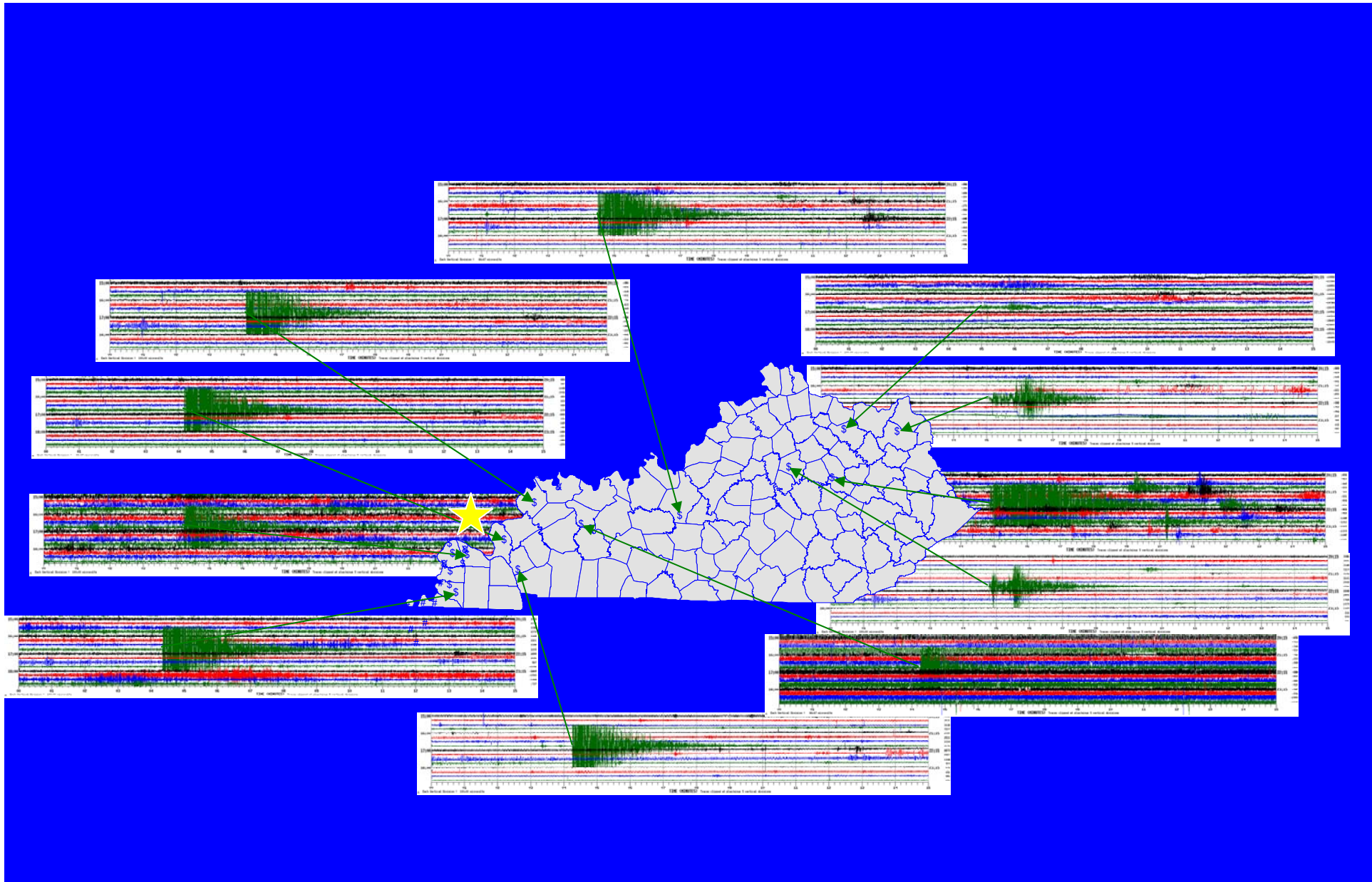
**Landslides (under construction)**

**Karst**

KGS staff is also conducting cooperative research with faculty at the Department of Geological Sciences ( <http://www.uky.edu/AS/Geology/faculty/geophysics/Home.html>)

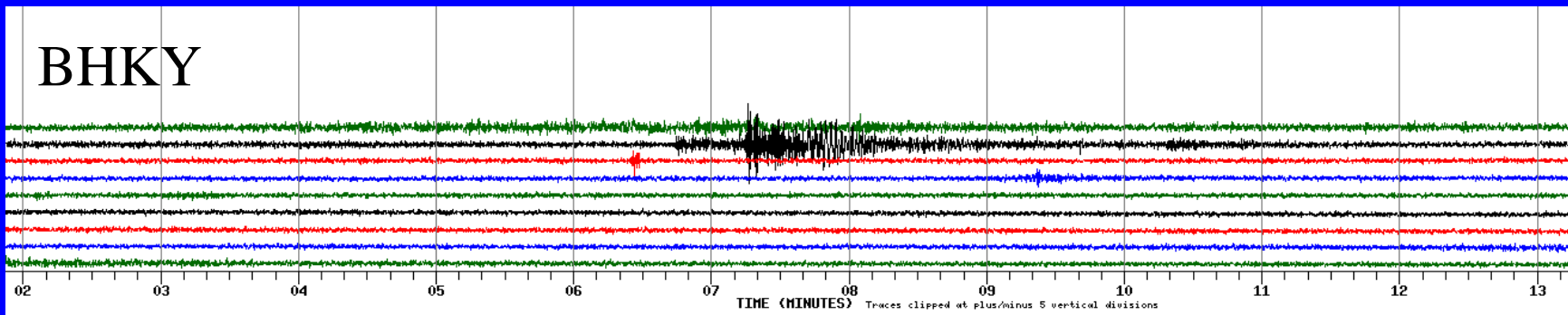
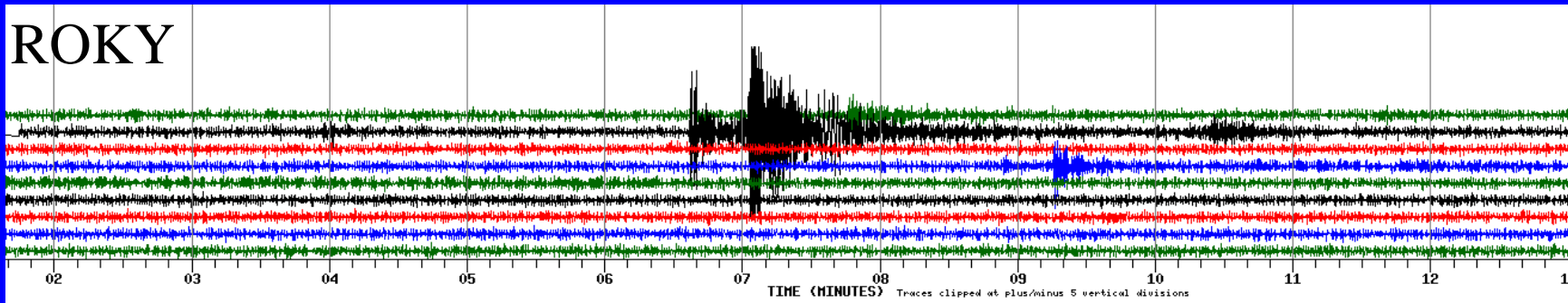
Research assistantships are available for students pursuing graduate degrees in geological sciences through the Department of Geological Sciences (<http://www.uky.edu/AS/Geology/dgs/graduate.html>).

**Staff**



Magnitude 3.6 - Illinois  
January 2, 2006 21:48:57 UTC

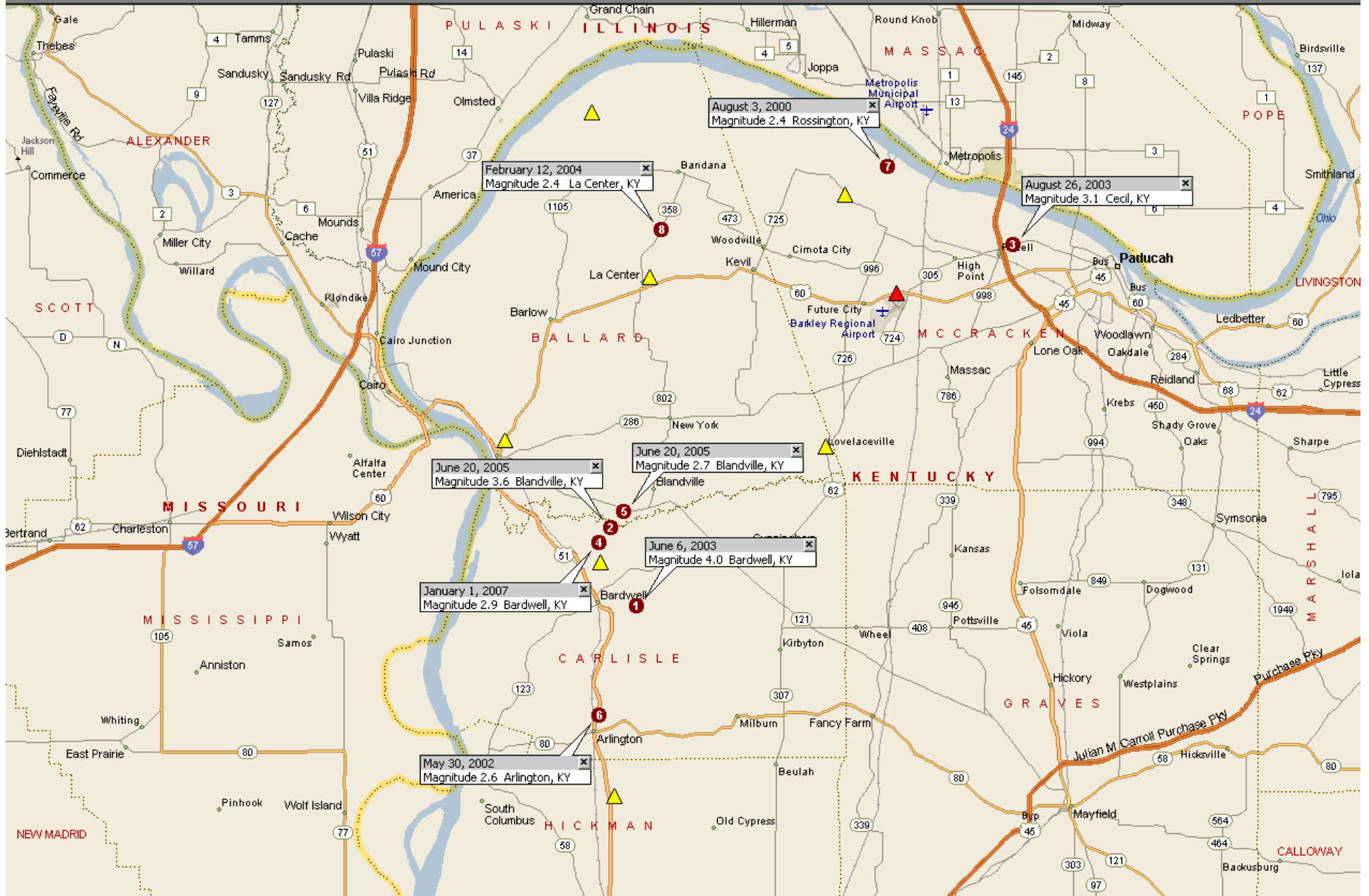
# Mine blast



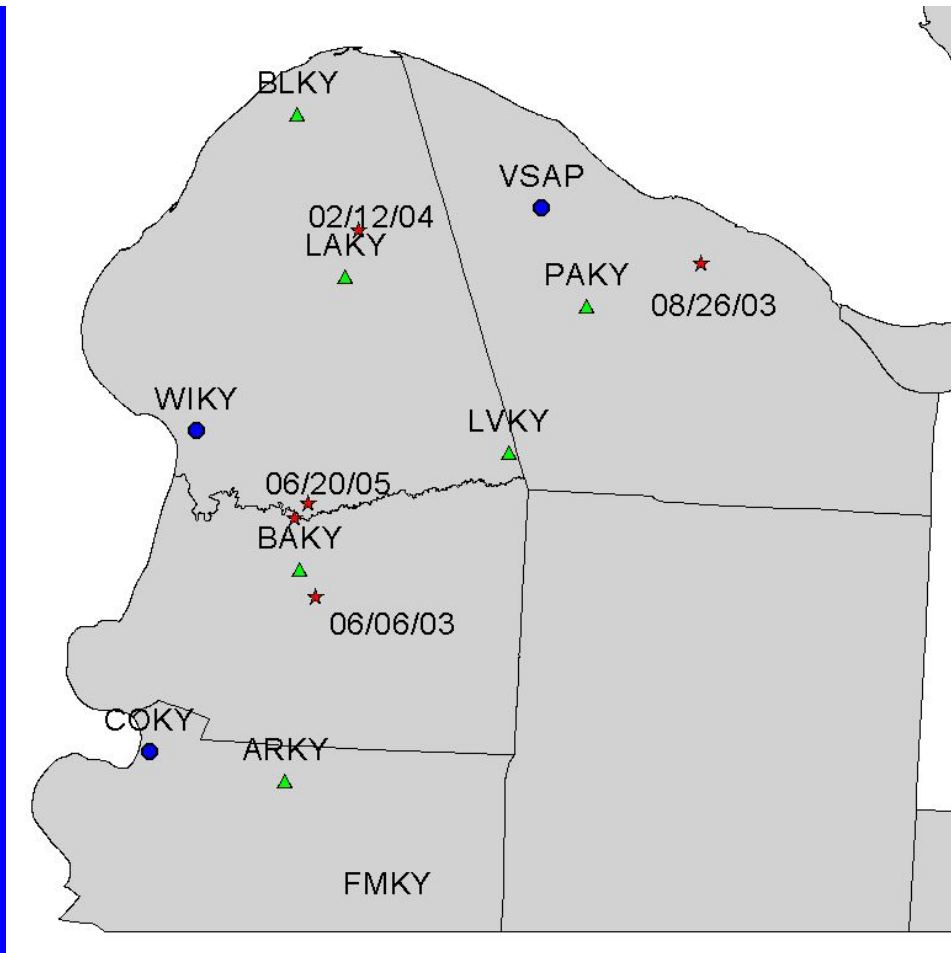
October 17<sup>th</sup>, 2007 10:06:40 UTC

# Temporary Seismic Network (PGDP area)

- 7 seismometers near PGDP, Wickliffe, Arlington, La Center, Lovelaceville, Ballard WMA, and Bardwell.
- Manually downloaded every 2-3 months and archived.
- Data compared to CERI and NEIC reported information.







Date	Time (UTC)	Lat.	Long.	Depth (km)	Magnitude	Depth (UK)
06/06/03	12:29:34	36.870	-88.980	2.6	4	1.5
08/26/03	2:26:58	37.100	-88.680	1.9	3.1	2.0
02/12/04	6:49:49	37.110	-88.960	27.2	2.4	9.8
06/20/05	2:00:32	36.930	-88.990	9.8	2.7	8.7
06/20/05	12:21:42	36.920	-89.000	18.7	3.6	8.9
01/31/07	23:47:43	36.910	-89.010	16.0	2.9	Unprocessed

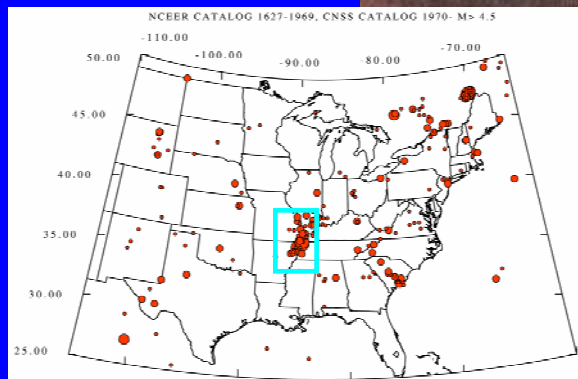
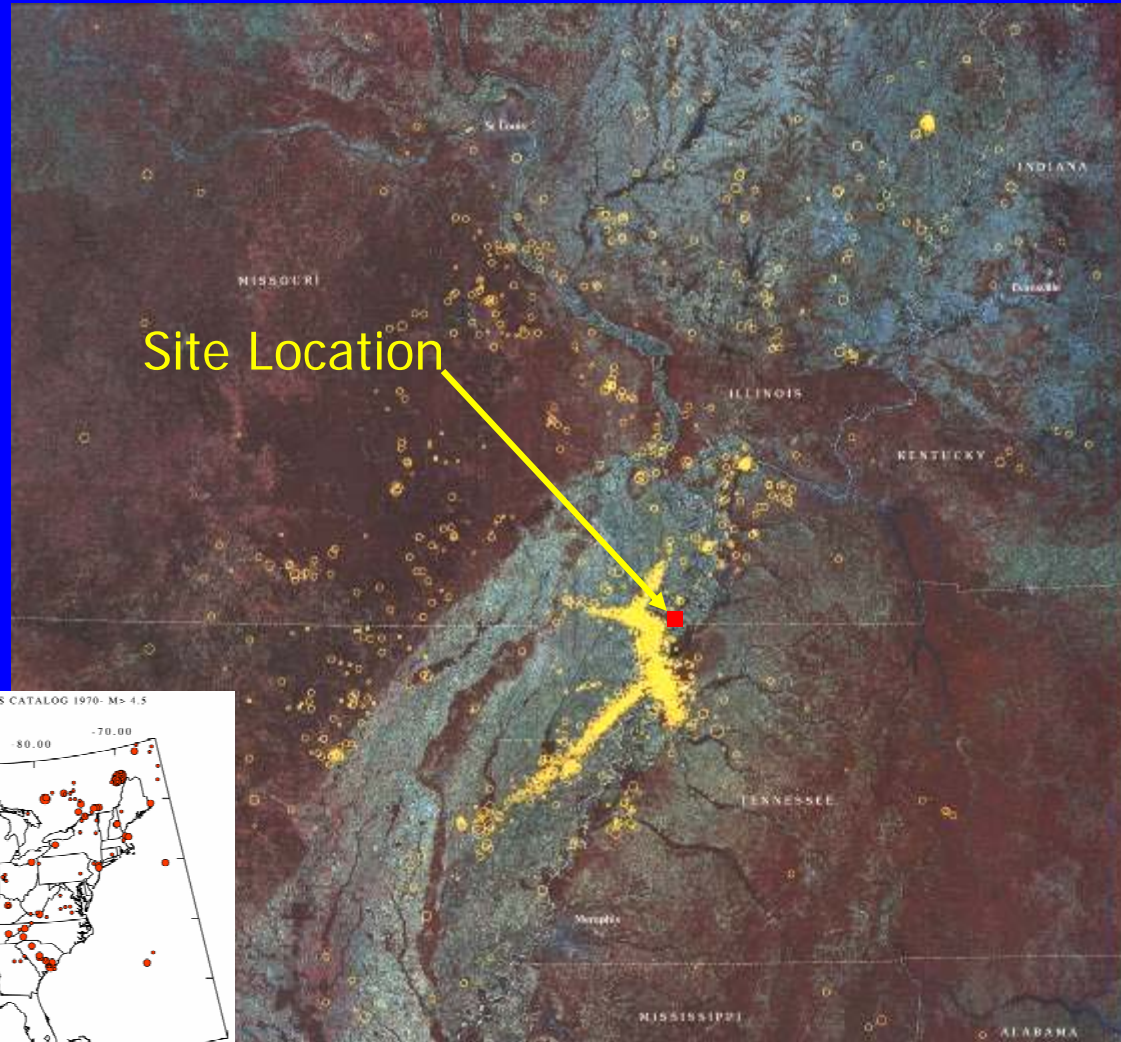
# Strong-motion Network

- Nine active stations. Two vertical arrays (VSAS, VSAP).
- Data recorded and stored locally temporarily. Events are recorded based on ground-motion thresholds specific to each site.
- Stored events are reviewed weekly via dial-up connection. Noise events are deleted. Seismic events are downloaded and archived. Usually average +/- 500-600 event triggers/week.
- Boreholes available to expand vertical array network.

# Central US Seismic Observatory (CUSSO) Project

- Phase 1 complete:
  - Drilled, logged, and cased a 595 m hole near the central segment of the NMSZ
- A cooperative effort between federal agencies and various elements at the University of Kentucky:
  - the United States Department of Energy
  - the U.S. Geological Survey
  - the Kentucky Geological Survey
  - the Kentucky Research Consortium for Energy and Environment
  - the Department of Earth and Environmental Sciences

# Location

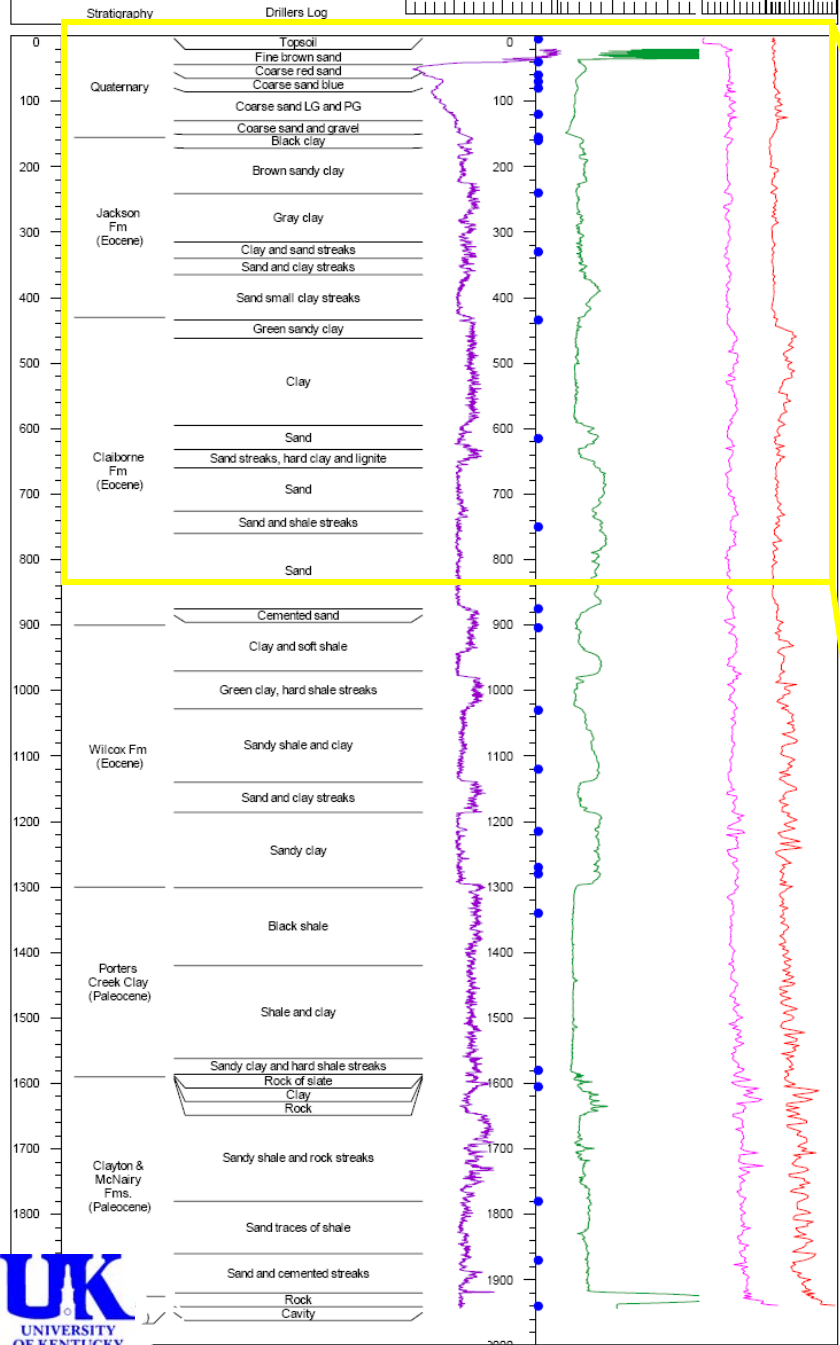
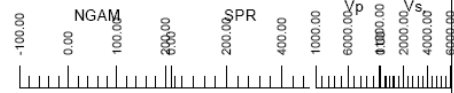


(modified from USGS)

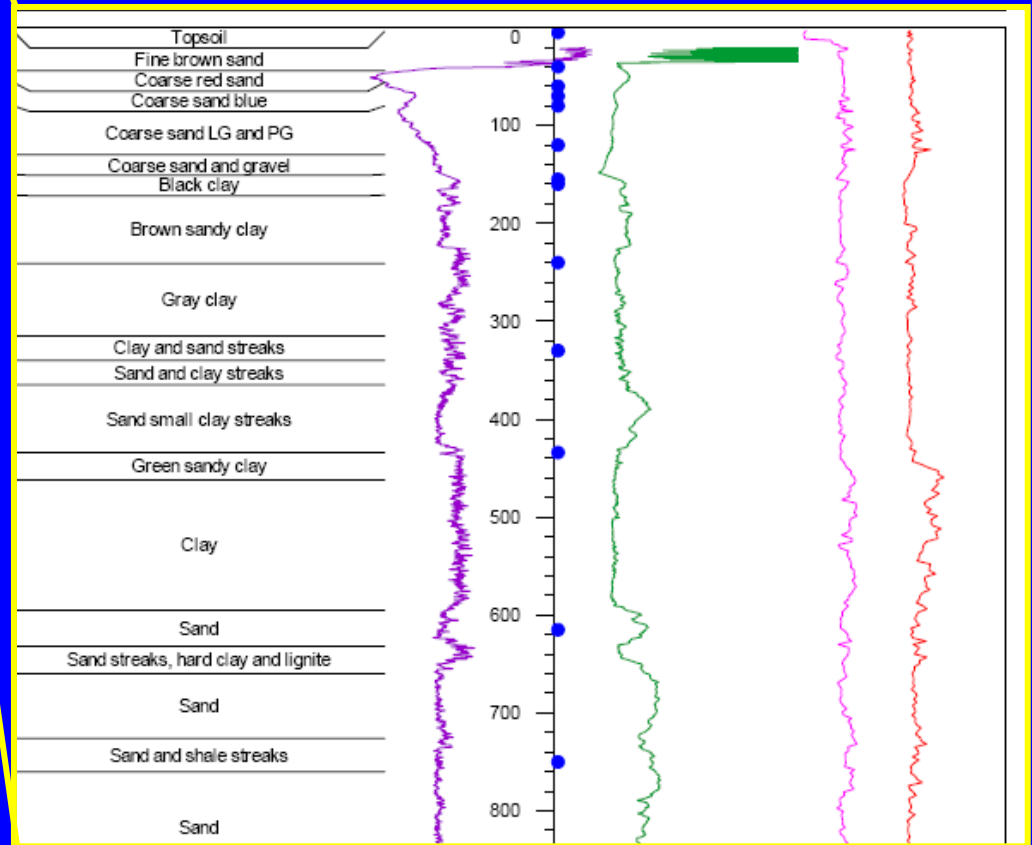
# Borehole Specifics



- Mud-rotary operation
- 585 m (1,920') soil/sediment
- 9.5 m (30') into rock
- 4" steel casing (0 – 1,930')
- 4" stainless steel (1,930' – 1,950')

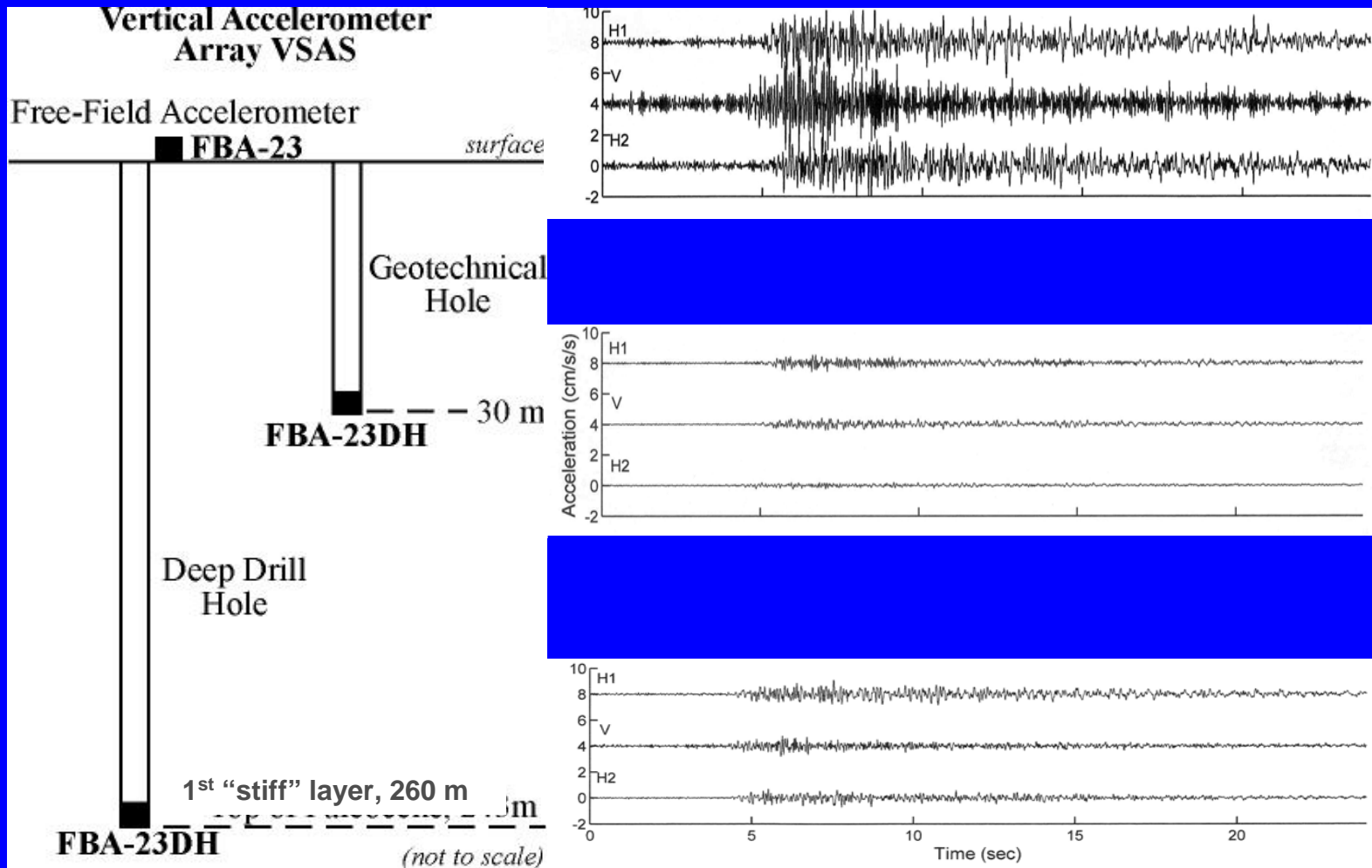


# Logging



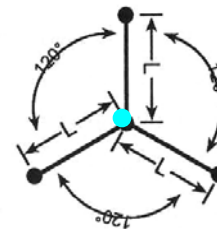
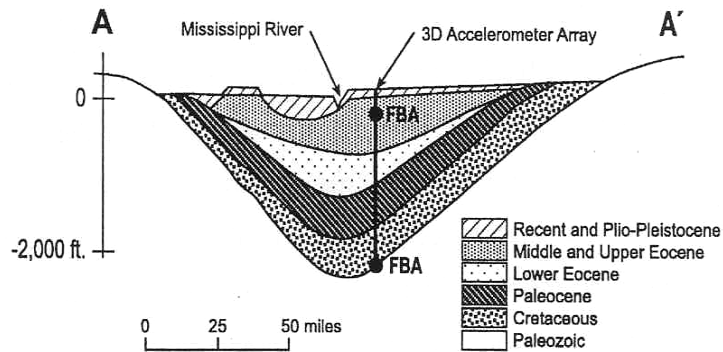
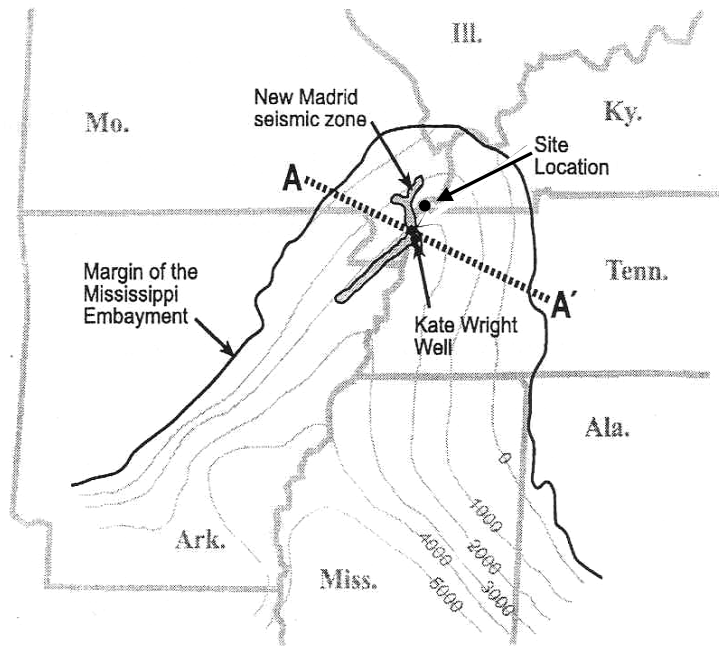
\*log courtesy Drew Andrews and Steve Martin (KGS)

# Site Amplification



Existing vertical array @ CUSSO site

# Instrumentation Plan

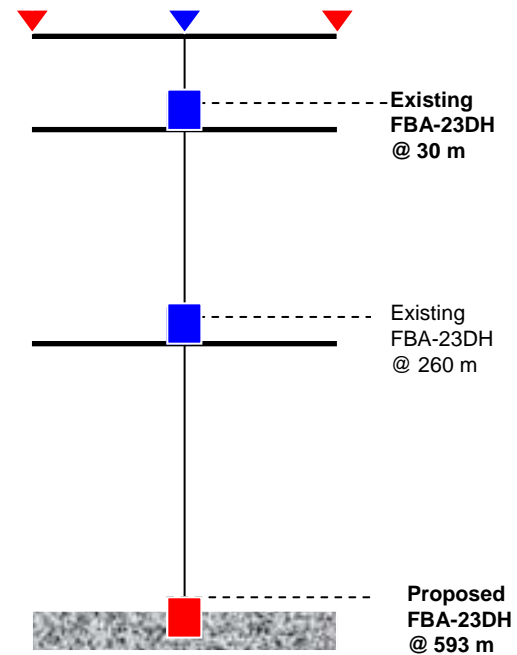


Plan View

Free-field  
FBA-23

$L=4\lambda$   
for 10Hz  
est.  $L@ 35-45m$

- FBA-23 Surface accelerometer (plan)
- ▼ FBA-23 Surface accelerometer (section)
- FBA-23DH Downhole accelerometer (section)





# Immediate Tasks

- Instrumentation acquisition
- Perform refraction and reflection seismic imaging to obtain a comprehensive understanding of subsurface structural and stratigraphic geologic features in three dimensions in order to provide information regarding vertical and lateral variations in geometry and  $G_{max}$  at the site.
- Measure deep borehole ground motion while shaking at the ground surface to obtain synthetic site response data.

# Phase II: Instrumentation of the Deep Borehole

- Phase I of the Central United States Seismic Observatory (CUSSO) is completed
- Phase II will consist of installing and operating a three-dimensional array of borehole and surface accelerometers at the site
- A proposal has been submitted to NEHRP for funding of a workshop to be hosted at the University of Kentucky. The focus of the workshop will be to determine how to best instrument the observatory to compliment/enhance the existing instrumentation on site
- Phase II will begin upon completion of this workshop and after acquiring necessary funds to purchase the instrumentation

# Project Significance

Five significant technical contributions to earthquake engineering are ultimately expected from the final 3-D seismic observatory (CUSSO) in the New Madrid Seismic Zone:

1. Evaluation of the effect of deep soil conditions on earthquake ground motions.
2. Characterization of the dynamic soil properties of sediments in the New Madrid Seismic Zone.
3. Evaluation of current analytical models for deep soil sites. Several analytical models are currently being used to predict the seismic response of deep soil sites; however, these analytical procedures have not been validated for sites deeper than 100 m (i.e., design engineers cannot be confident in their predictions).
4. Evaluation the recommended provisions of NEHRP, as they pertain to the New Madrid Seismic Zone.
5. Study of lateral propagation effects and spatial variation in ground motions.

In addition to the scientific and engineering significance, the ability to reduce the large uncertainty in the existing seismic hazard definitions for western Kentucky will have positive societal impacts, particularly in the area of economic development.

# Acknowledgements

- The Department of Energy
- The United States Geological Survey
- The Kentucky Research Consortium for Energy and Environment
- Mr. Austin Voorhees for providing the land for CUSSO
- Special acknowledgement: Dr. Ron Street. Who originally proposed the project in the early 1990's during his tenure as Professor at the University of Kentucky Department of Geological Sciences

