The Earthquake Hazard in Kentucky:

the Problems, Research, Current Assessment, and On-line Seismic Readings from the KSSMN

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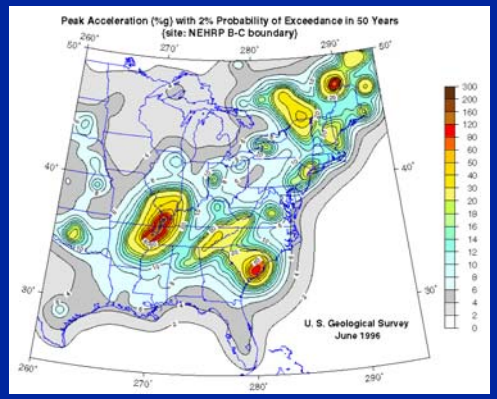
KGS

Geologic Hazards Section
Kentucky Geological Survey

***Geohazards in Transportation* Symposium, August 3, 2005**

Problems

- Is the seismic hazard assessment for KY controversial?



- The NEHRP seismic hazard and design maps
  - The NEHRP seismic hazard maps (USGS)
    - The 1996 national seismic hazard maps
    - The 2002 national seismic hazard maps
  - The NEHRP seismic design (mitigation) maps (FEMA)
    - The Building Seismic Safety Council (BSSC) – a group of engineers, seismologists, and others
    - Become base maps for seismic safety regulations and designs for
      - The Federal agencies: FEMA, DOE, USACE, EPA, FHWA, and others
      - The State agencies: KY-EPA, Dept. of Housing, Economic Development
      - Other private organizations
    - The International Building Code (IBC) and Residential Code (IRC)
      - KBC-2002 (INC-2000)
      - KRC-2002 (IRC-2000)

Problems

- Question: does it make sense if
  - You have to pay more for mitigating seismic hazards in Paducah than in San Francisco or Los Angeles?

Development Issues

- Mr. David Mast (a staff member from KY congressman Ed Whitfield's office): Why can't I build a two-story house in Paducah?
- SEAOK protests that it is impossible to construct residential structures in westernmost Kentucky without enlisting a seismic design professional (IRC 2000).
- DOE cannot get a permit from EPA to build a landfill at PGDP for clean-up.
- One of the main reasons that Kentucky lost the centrifuge facility ($2B).

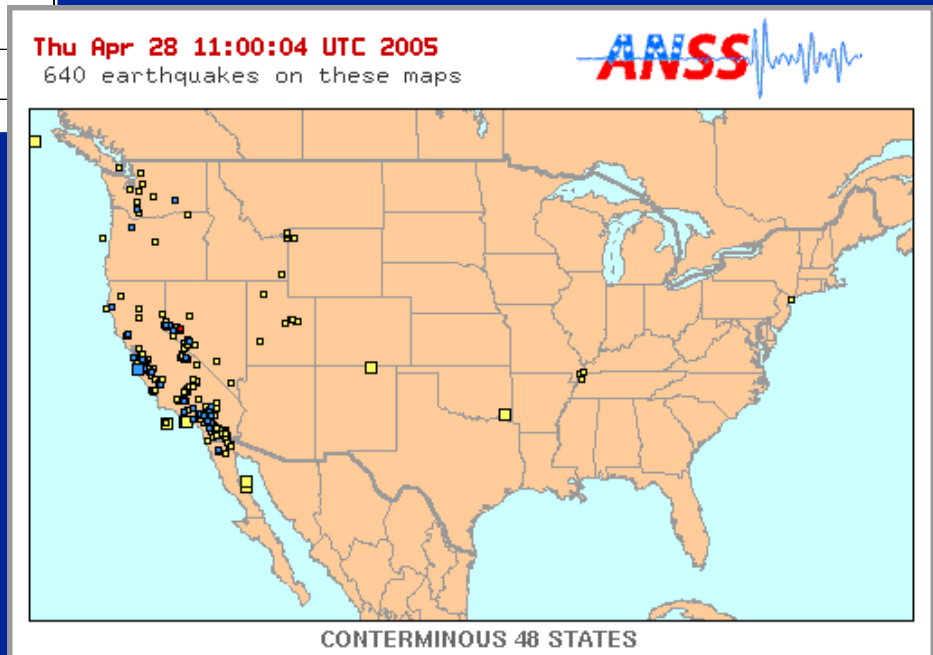
Summary on Seismic Hazard

- There is no question: there are seismic hazards in Ky., WK in particular.
- The question is: what level of the seismic hazard.
- Current assessment (USGS) is too high in WK
  - It does not reflect the state-of-knowledge
- Seismic hazard assessment is a difficult job. Our focus are:
  - How to characterize it
    - Methodologies
    - Input parameters (source, frequency, and attenuation)
  - How to communicate it??

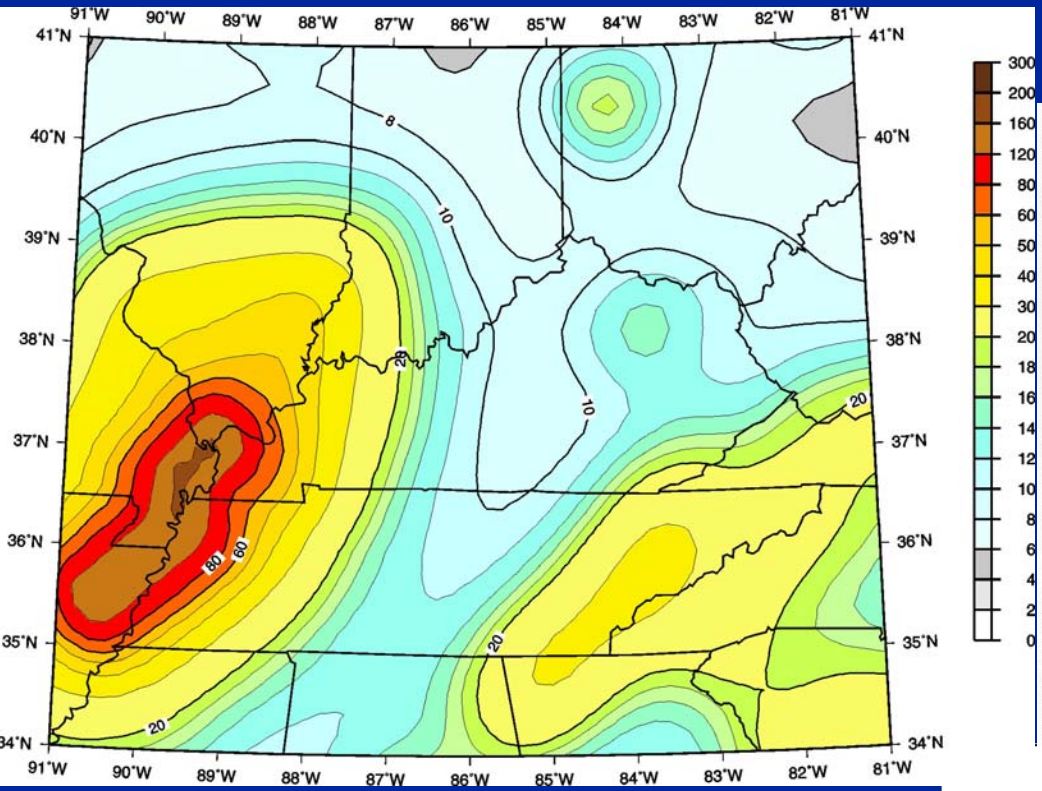
Problems

- **Answer: NO! (geology and seismology)**

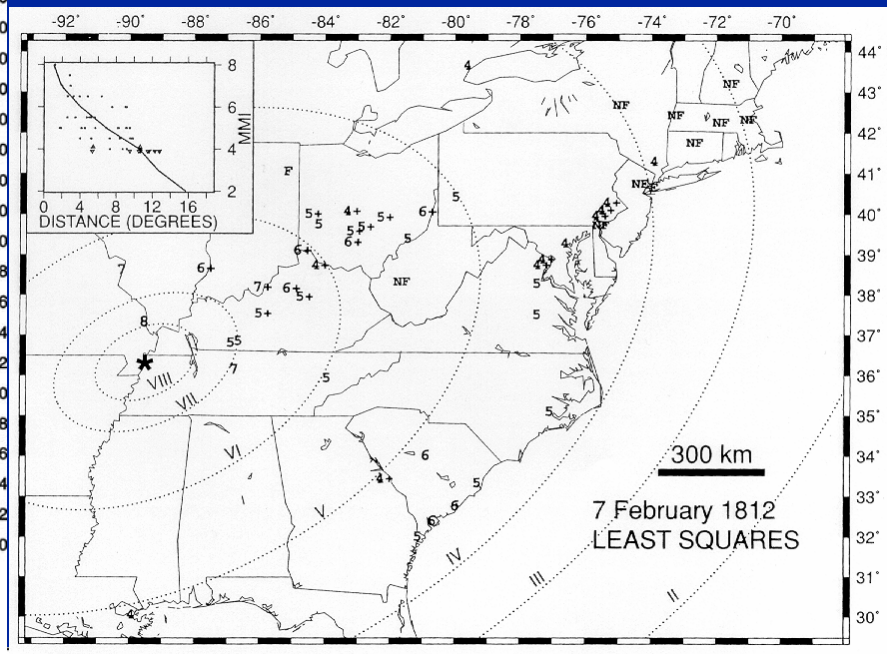
	California		West Kentucky	
Probability	(Deterministic)		2 % ~ 5% in 50 years	
Design (0.2 s)	<=1.0g (UBC-97)	<=0.7g PGA (CALTRAN)	>1.0g (IBC-2000)	>1.0g PGA (Bridge)
Geology	San Andreas fault >20 mm/y well defined		New Madrid faults <2 mm/y poorly defined	
Seismology	High M7.0-8.0: ~100 y M6.0-7.0: ~20-50 y		Low M7.0-8.0: ~500 y M6.0-7.0: ?	
Performance	Very well		?	



Problems



(Hough et al., 2000)



Very limited data points!

Modified Mercalli Intensity Scale

INTENSITY	EFFECTS	AVE. PEAK ACCELERATION
VI	Strong 0.06–0.07g	Felt by all. Damage slight.
VII	Very Strong 0.10–0.15g	Everybody runs outdoors. Considerable damage to poorly designed buildings.
VIII	Destructive 0.25–0.30g	Considerable damage to ordinary buildings.
IX	Ruinous 0.50–0.55g	Great damage to ordinary buildings
X	Disastrous >0.60g	Many buildings destroyed.
XI	Disastrous	Few, if any, structures remain standing

(Simplified from Bolt, 1993)


图例

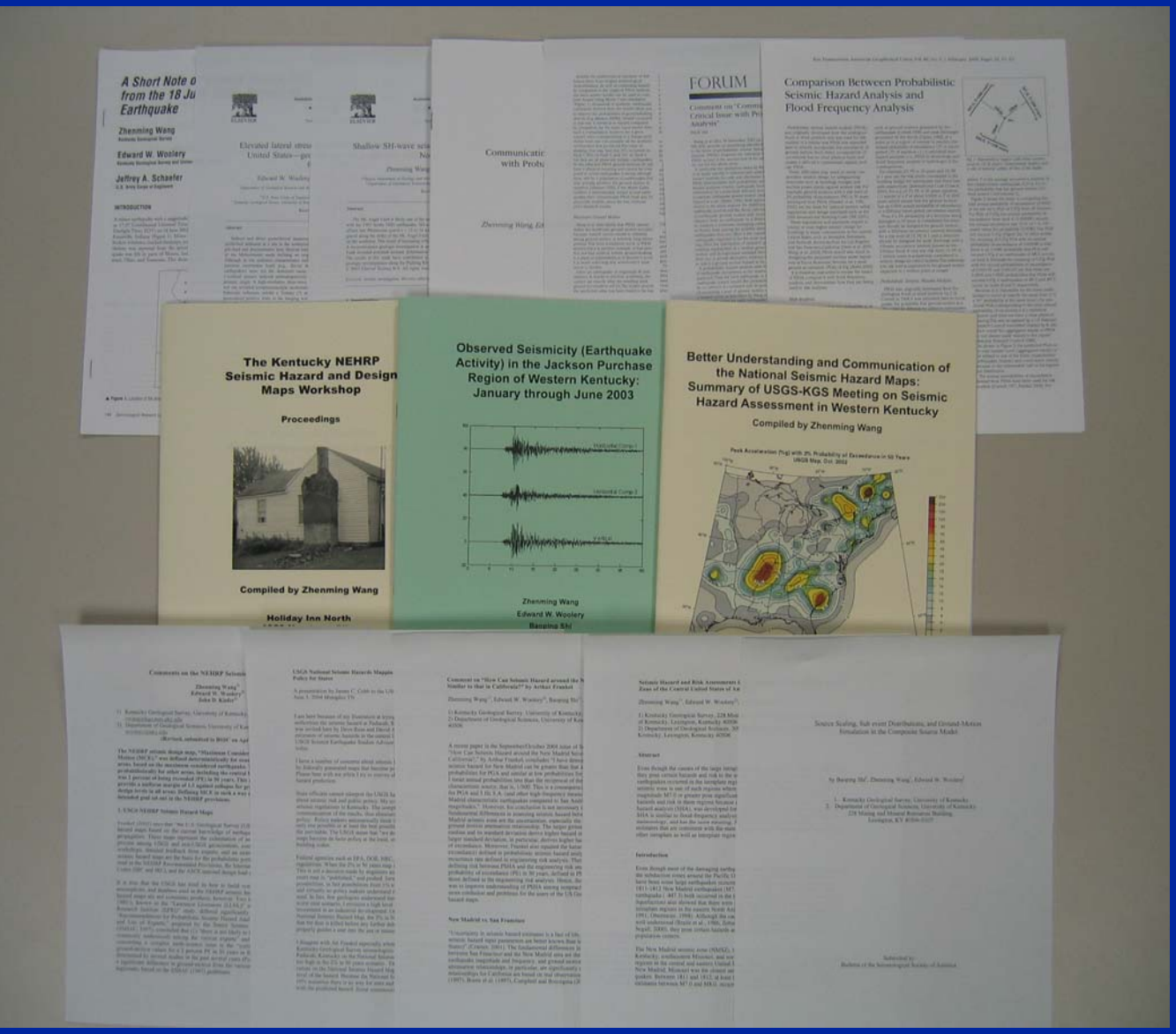
KGS-DGS Research

- Seismic hazard mitigation policies, such as building codes, are complicated
  - Sciences (seismology and geology)
  - Engineering
  - Economic
  - Political
  - Societal
- Our focus: Sciences (geology and seismology) – bases
  - What do we know (data at UK – Ron Street)?
  - What information can we provide (how large uncertainty)?
  - How should we communicate with decision makers (understandable)?
- Projects (~$300K/year combined)
  - USGS NEHRP
  - DOE
  - NSF: US - China Collaborative Research ($2.5M proposal)

KGS-DGS Research

- Scientific Research
  - Detailed analyses on the USGS seismic hazard maps
    - Methodology (PSHA)
    - Input database used in the national hazard mapping
    - Products (what they are)
  - Enhancing the Kentucky Seismic and Strong Motion Network
  - Neo-tectonics – geophysical investigations
  - Earthquake ground motion and its attenuation
- Communication
  - Elected officials (Governor, US and State Representatives)
  - Governmental agencies:
    - USGS, FEMA, DOE, NRC, USACE, EPA
    - KY-EPA, Dept. of Housing, Economic Development
  - Professional communities: SSA, EERI, AGU, AEG, GSA
  - Non-governmental organization: BSSC, SEAOK, CUSEC

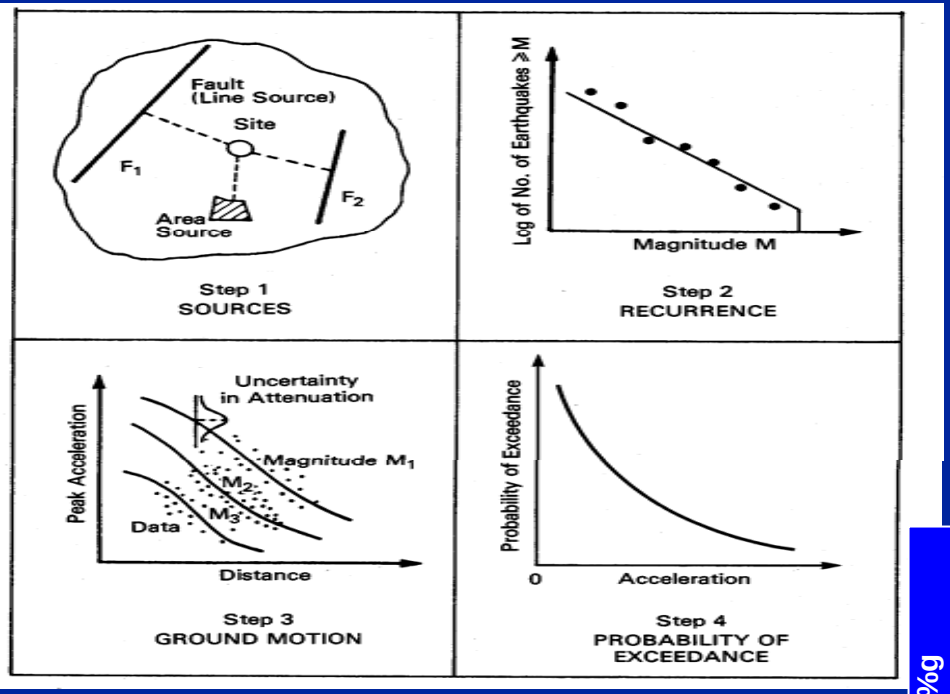
KGS-DGS Research



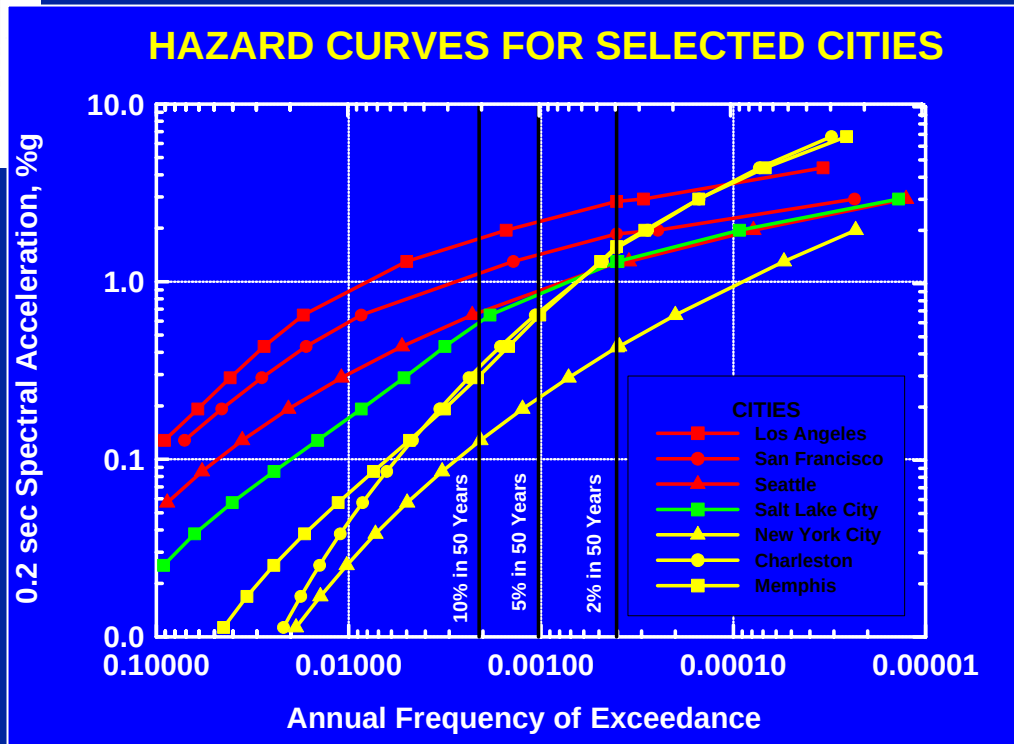
1. Journal papers
2. KGS special publications
3. Comments
4. Abstracts
5. Presentations

(Some seismic hazards related publications in last three years)

KGS-DGS Research



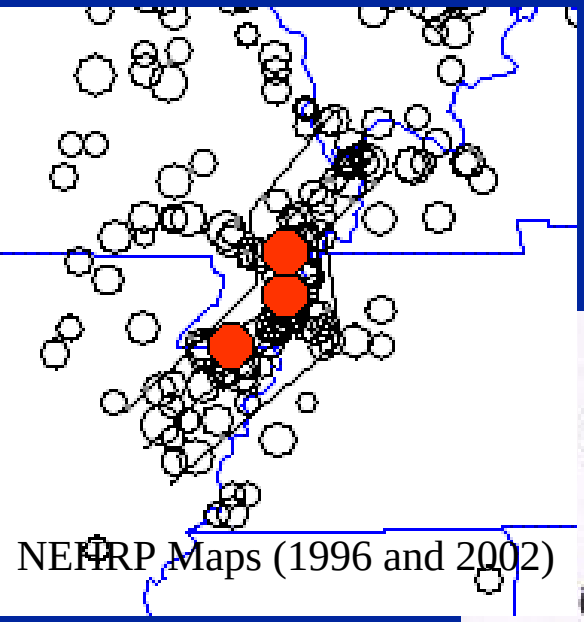
Probabilistic Seismic Hazard Analysis (PSHA)



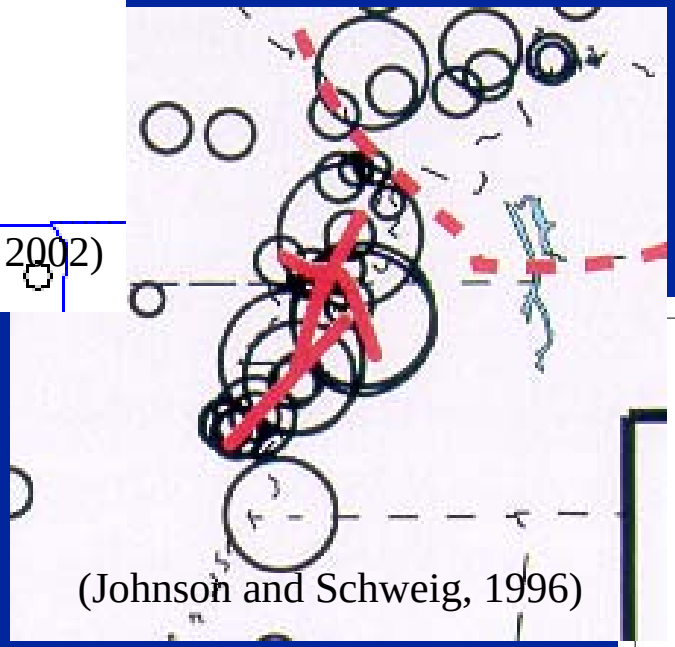
Problems:

1. many choices
2. why one point is better than the others
3. what is the physical meaning of the point chosen

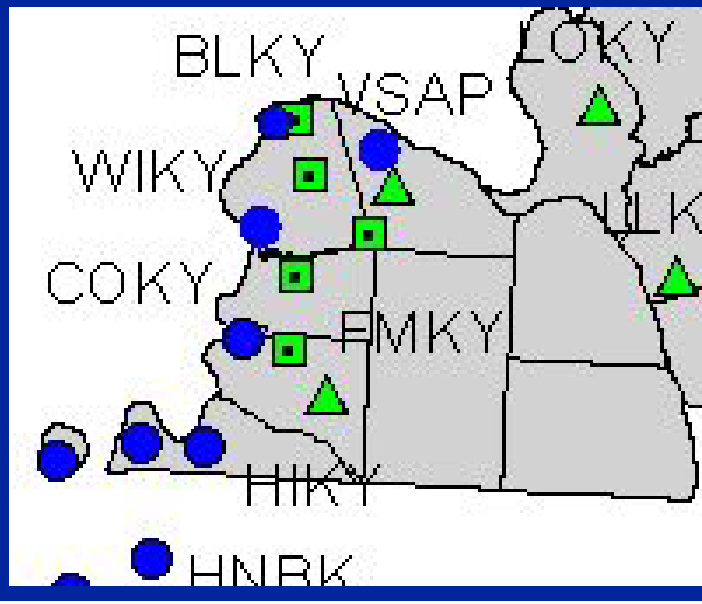
KGS-DGS Research

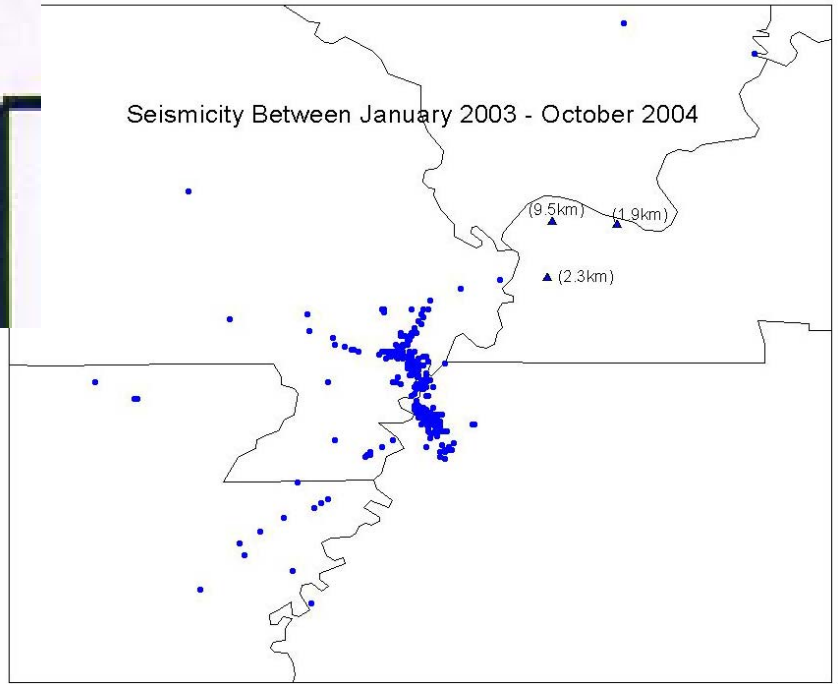


NEHRP Maps (1996 and 2002)

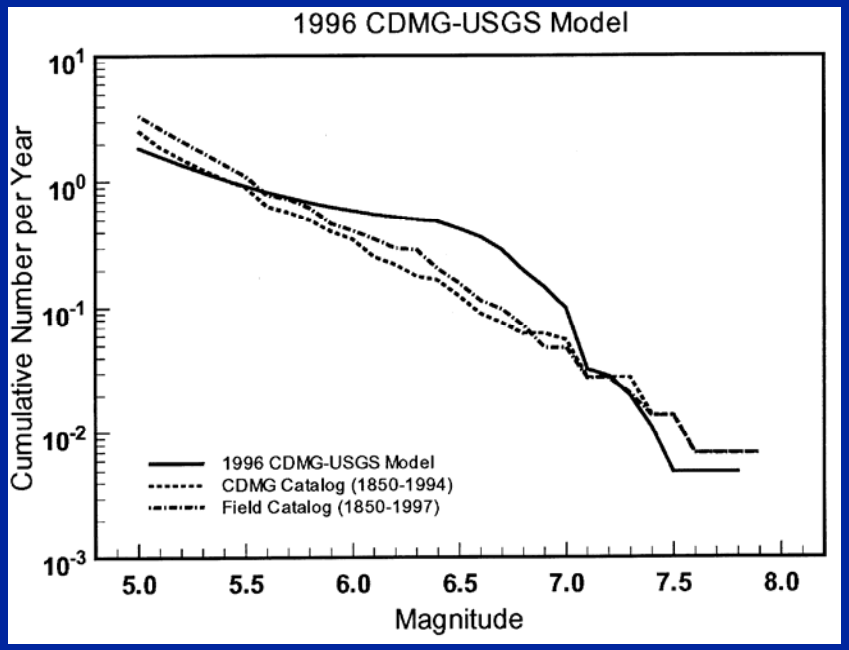


(Johnson and Schweig, 1996)

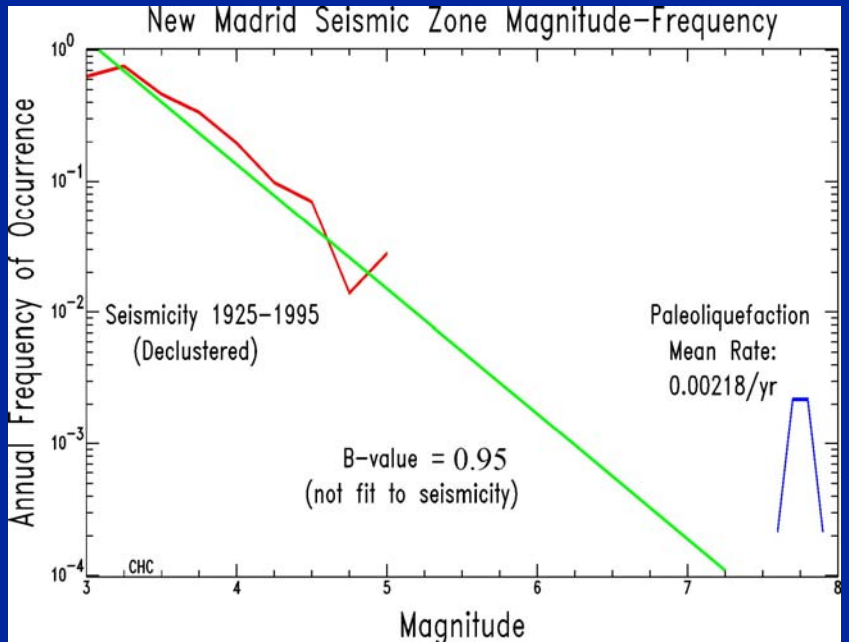




KGS-DGS Research

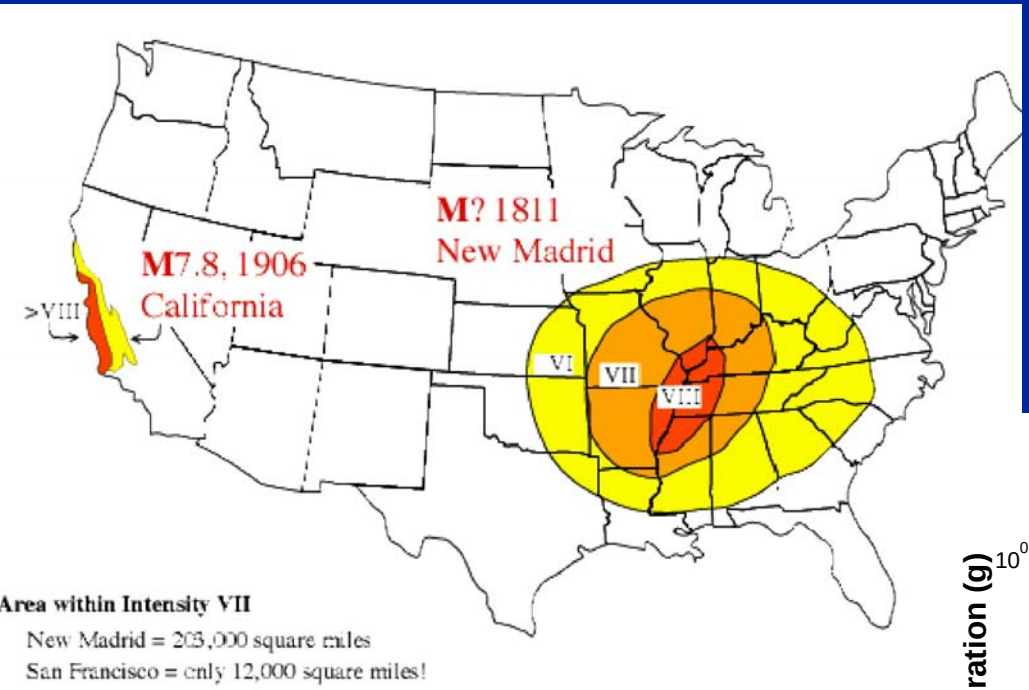


Seismicity in Southern California

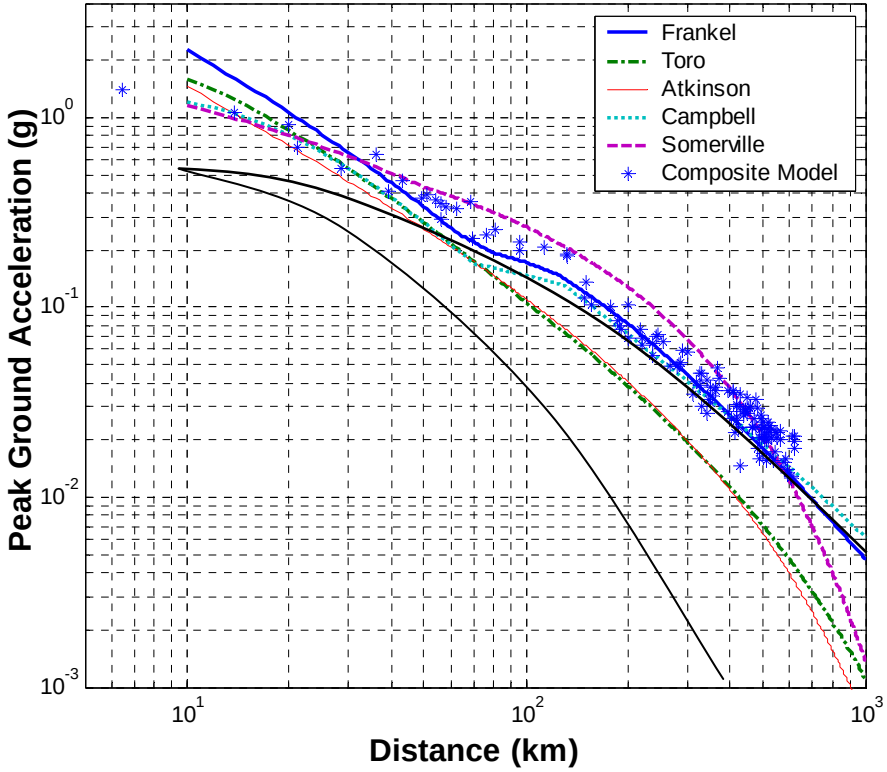


Seismicity in New Madrid Seismic Zone (Characteristic Earthquake)

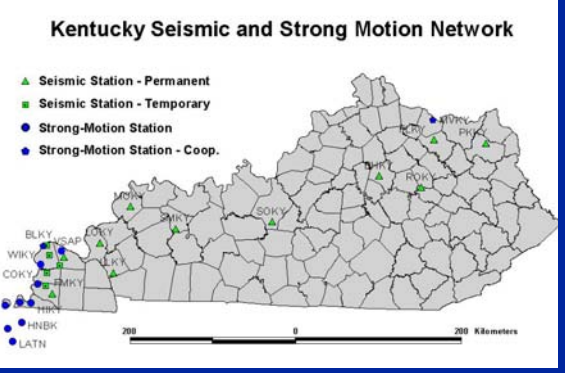
KGS-DGS Research

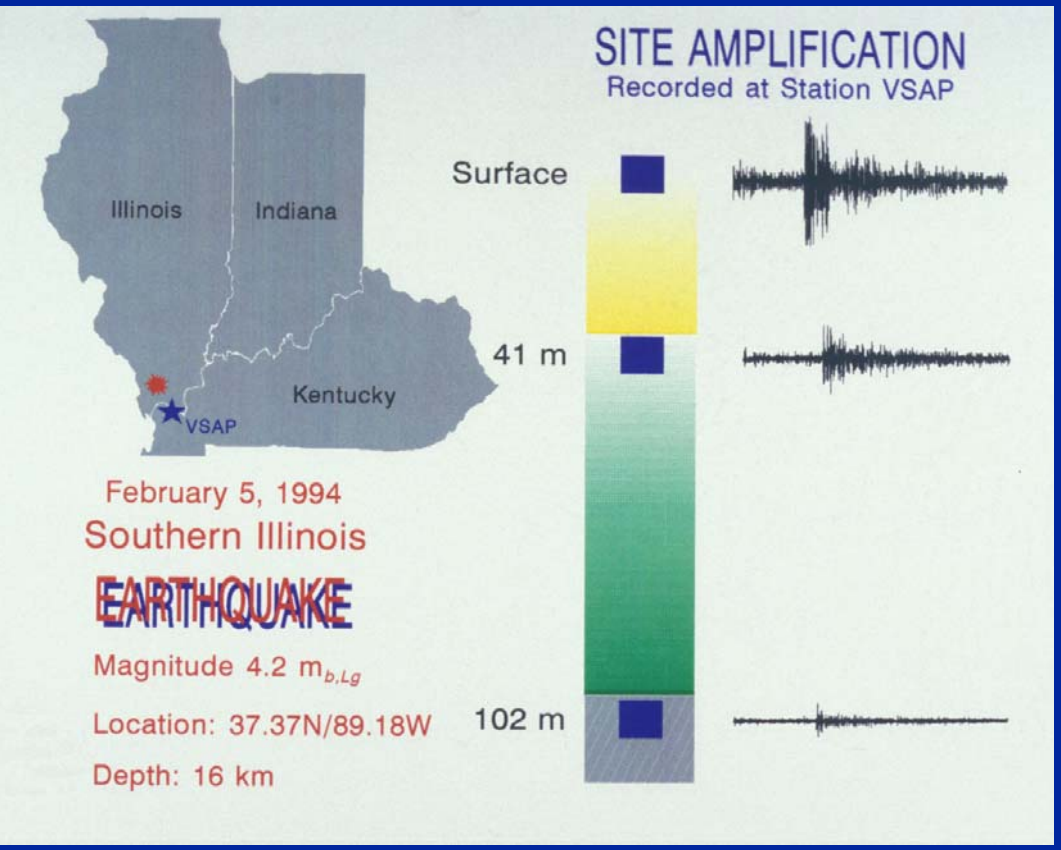


Ground motion attenuation comparison



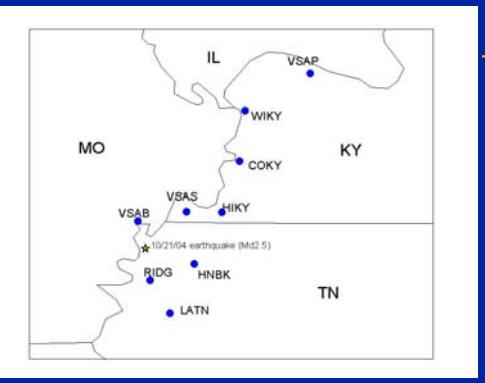
KGS-DGS Research

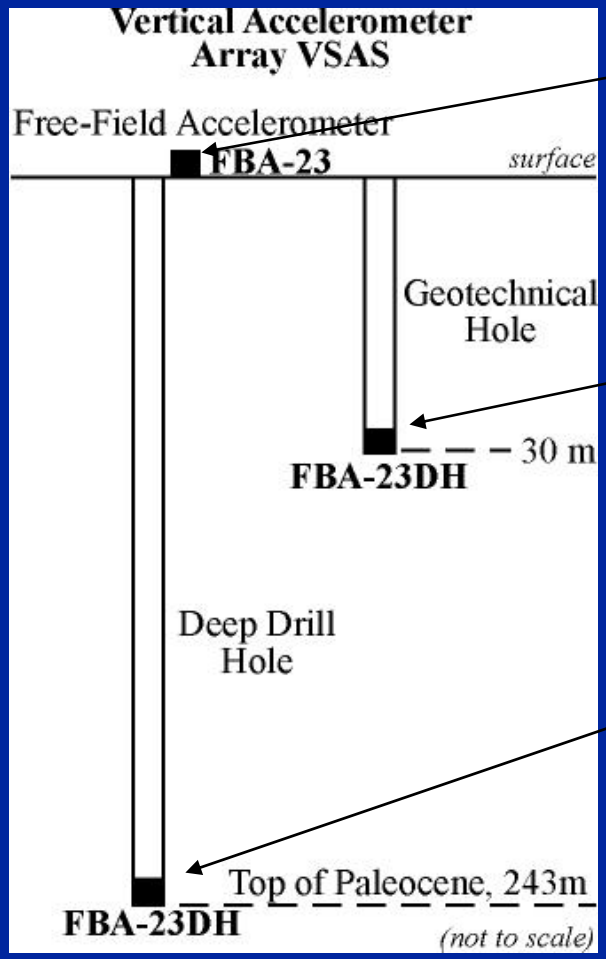




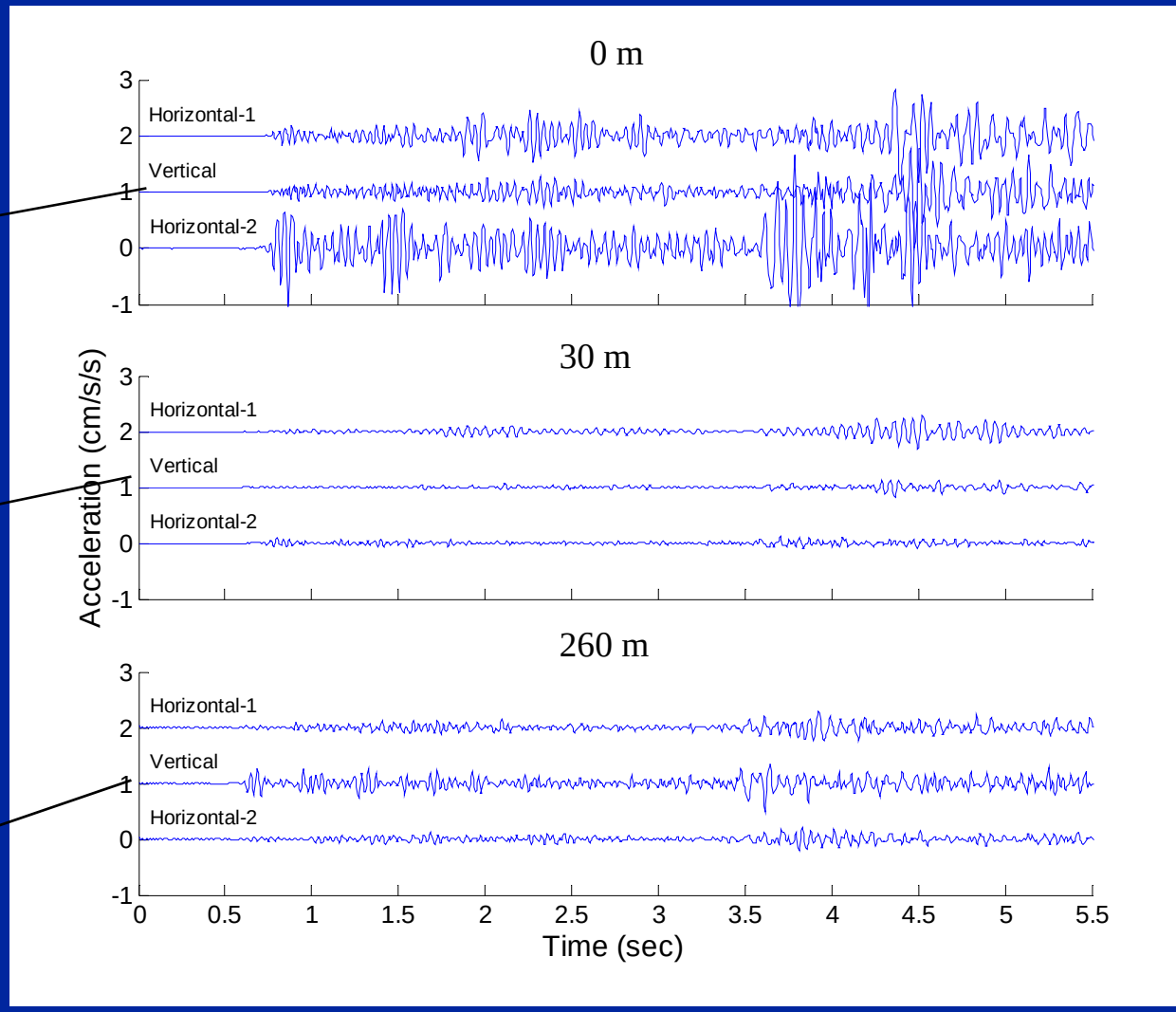
The first recordings from a vertical strong motion array in the central and eastern US (-Ron Street)

KGS-DGS Research



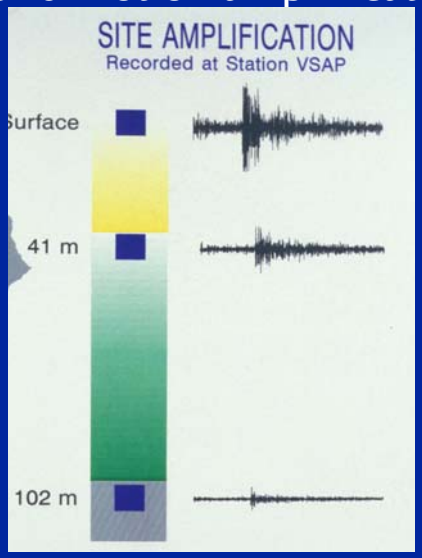


October 21, 2004, earthquake (Md2.5)

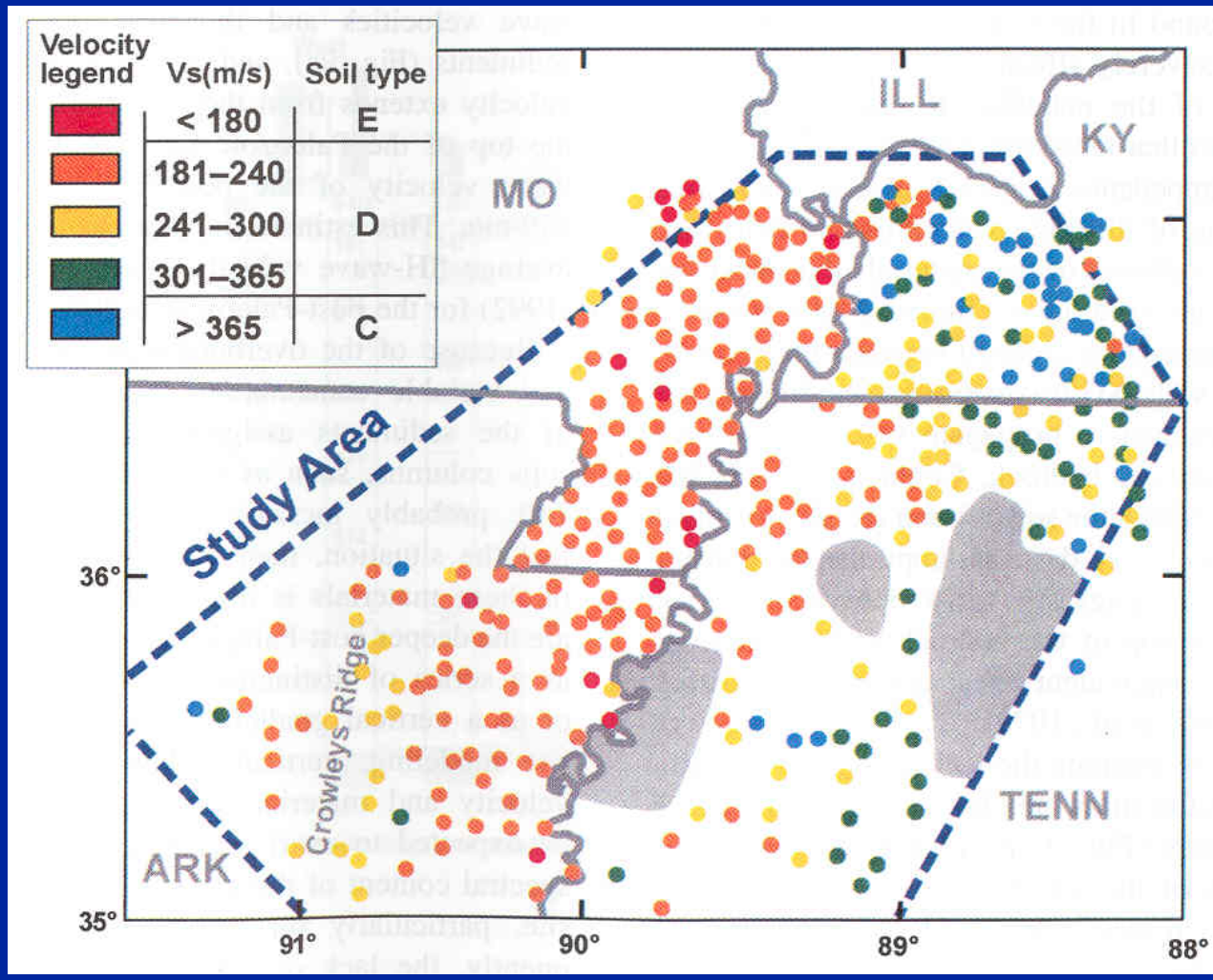


KGS-DGS Research

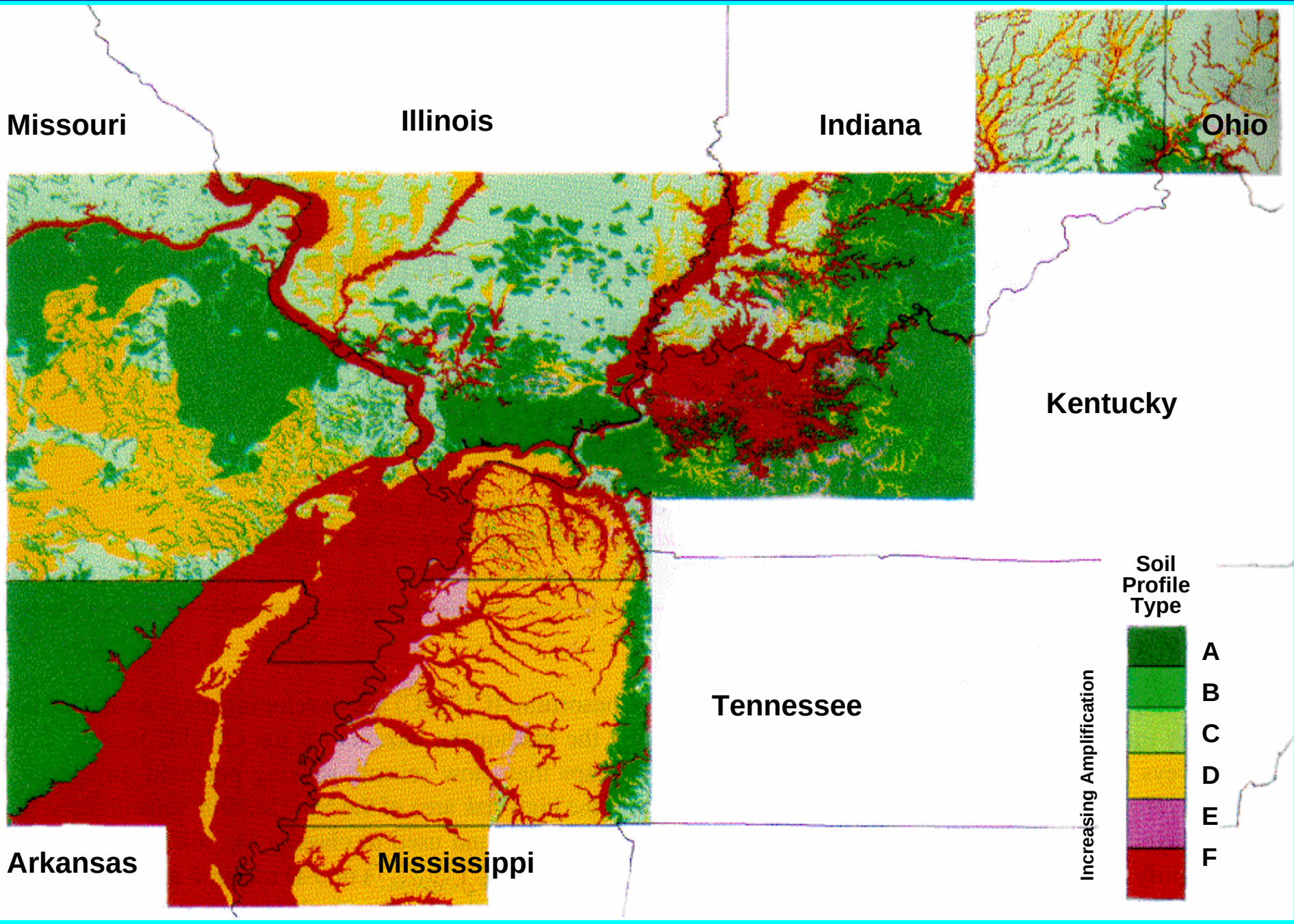
Ground motion amplification



NEHRP Soil Classification



(Street et al., 2001, Engineering Geology, 62:123-135)


Missouri
Illinois
Indiana
Ohio
Kentucky
Tennessee
Arkansas
Mississippi
Soil Profile Type
Increasing Amplification
A
B
C
D
E
F

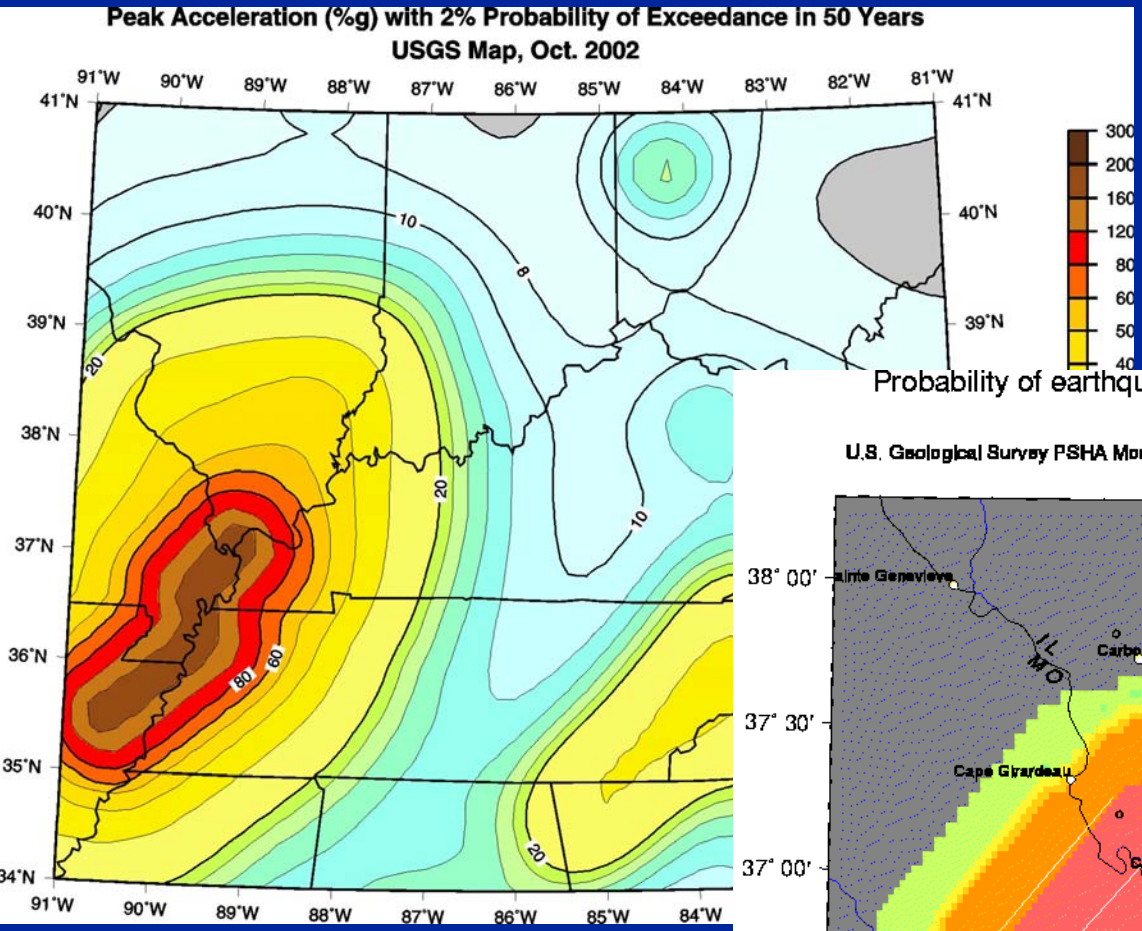
Site Class Definitions

TABLE 1615.1.1
SITE CLASS DEFINITIONS

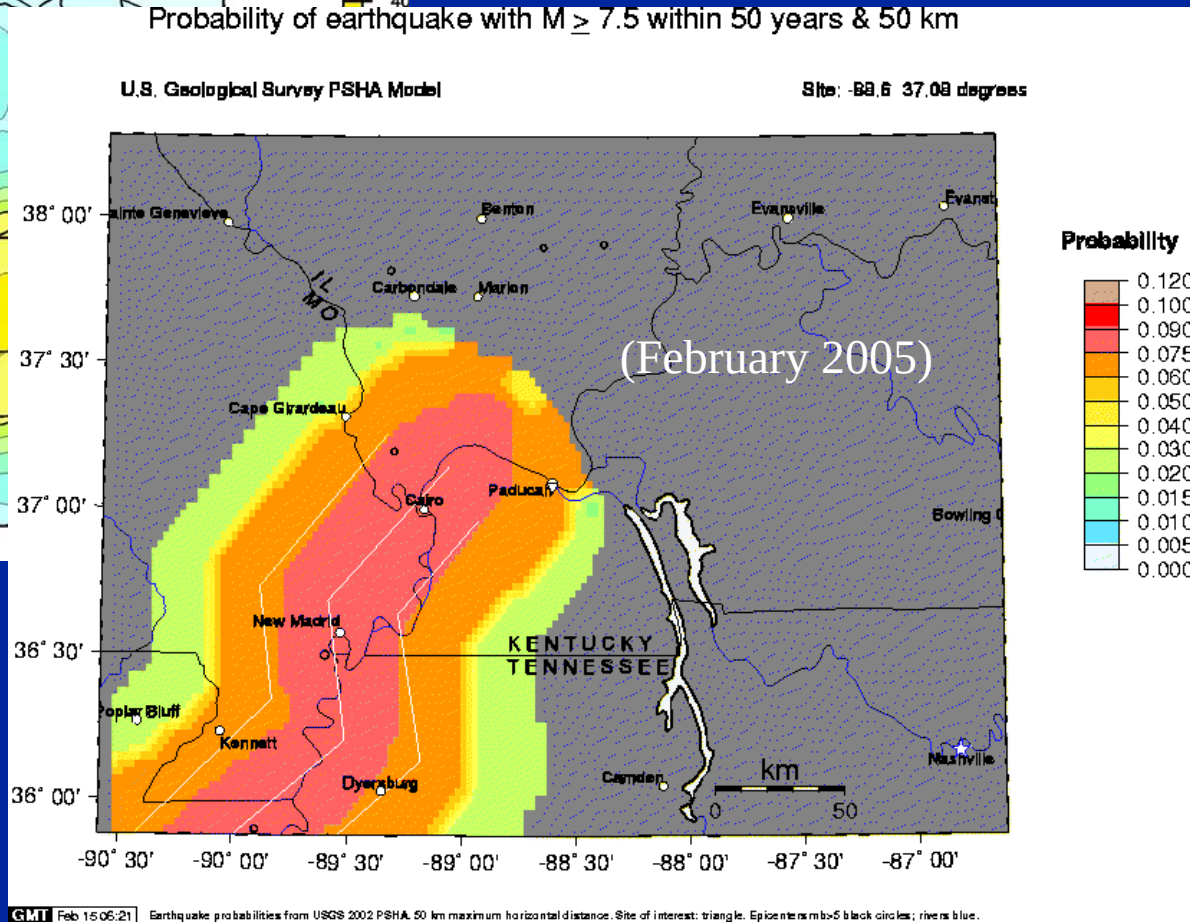
SITE CLASS	SOIL PROFILE NAME	AVERAGE PROPERTIES IN TOP 100 feet, AS PER SECTION 1615.1.5		
		Soil shear wave velocity, $\bar{v}_s$, (ft/s)	Standard penetration resistance, $\bar{N}$	Soil undrained shear strength, $\bar{s}_u$, (psf)
A	Hard rock	$\bar{v}_s > 5{,}000$	Not applicable	Not applicable
B	Rock	$2{,}500 < \bar{v}_s \leq 5{,}000$	Not applicable	Not applicable
C	Very dense soil and soft rock	$1{,}200 < \bar{v}_s \leq 2{,}500$	$\bar{N} > 50$	$\bar{s}_u \geq 2{,}000$
D	Stiff soil profile	$600 \leq \bar{v}_s \leq 1{,}200$	$15 \leq \bar{N} \leq 50$	$1{,}000 \leq \bar{s}_u \leq 2{,}000$
E	Soft soil profile	$\bar{v}_s < 600$	$\bar{N} < 15$	$\bar{s}_u < 1{,}000$
E	—	Any profile with more than 10 feet of soil having the following characteristics: 1. Plasticity index $PI > 20$; 2. Moisture content $w \geq 40\%$, and 3. Undrained shear strength $\bar{s}_u < 500$ psf		
F	—	Any profile containing soils having one or more of the following characteristics: 1. Soils vulnerable to potential failure or collapse under seismic loading such as liquefiable soils, quick and highly sensitive clays, collapsible weakly cemented soils. 2. Peats and/or highly organic clays ($H > 10$ feet of peat and/or highly organic clay where H = thickness of soil) 3. Very high plasticity clays ($H > 25$ feet with plasticity index $PI > 75$) 4. Very thick soft/medium stiff clays ($H > 120$ ft)		

For SI: 1 foot = 304.8 mm, 1 square foot = 0.0929 m^2, 1 pound per square foot = 0.0479 kPa.

Current Assessment



http://eqhazmaps.usgs.gov/



2% PE in 50 years =
2,500 years recurrence period
10% PE in 50 years =
500 years recurrence period

On-line seismic readings

Seismic Recordings - Microsoft Internet Explorer

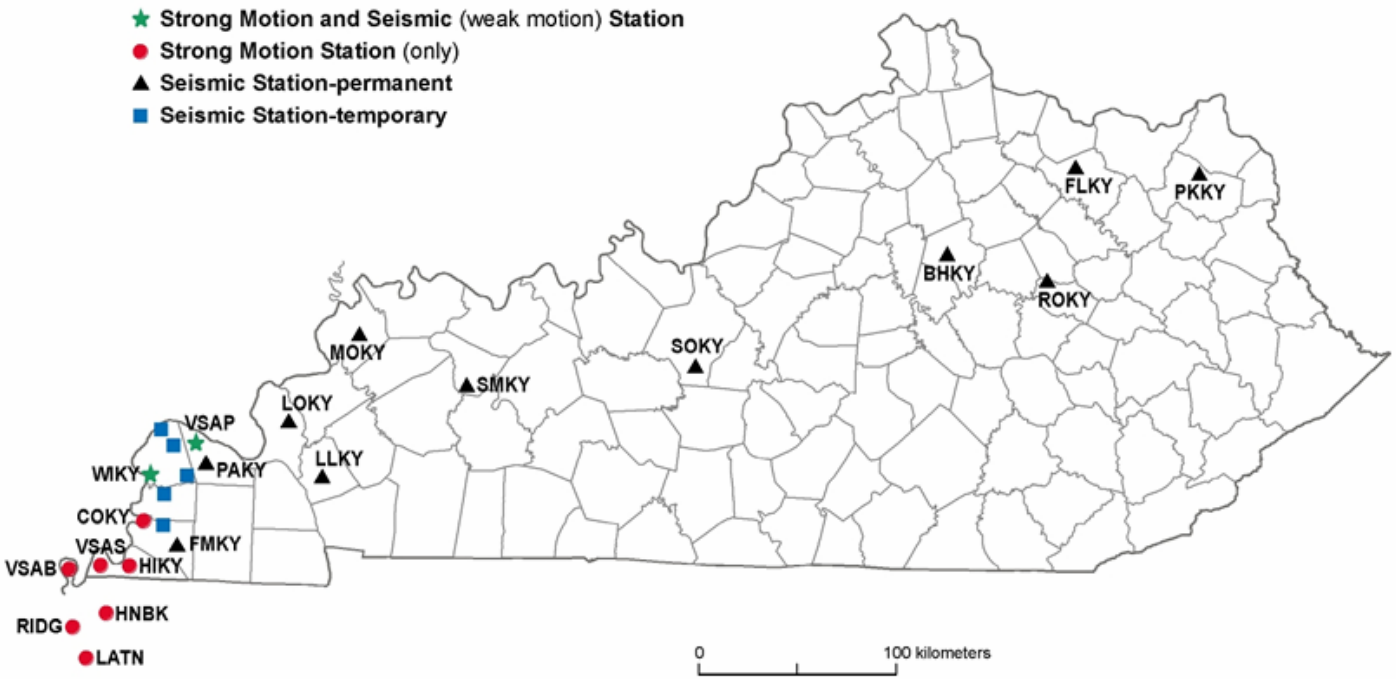
File Edit View Favorites Tools Help

Back Search Favorites

Address http://www.uky.edu/KGS/geologichazards/equake3.htm Go Links

Click on Station to see current Seismic Recordings

Kentucky Seismic and Strong-Motion Network

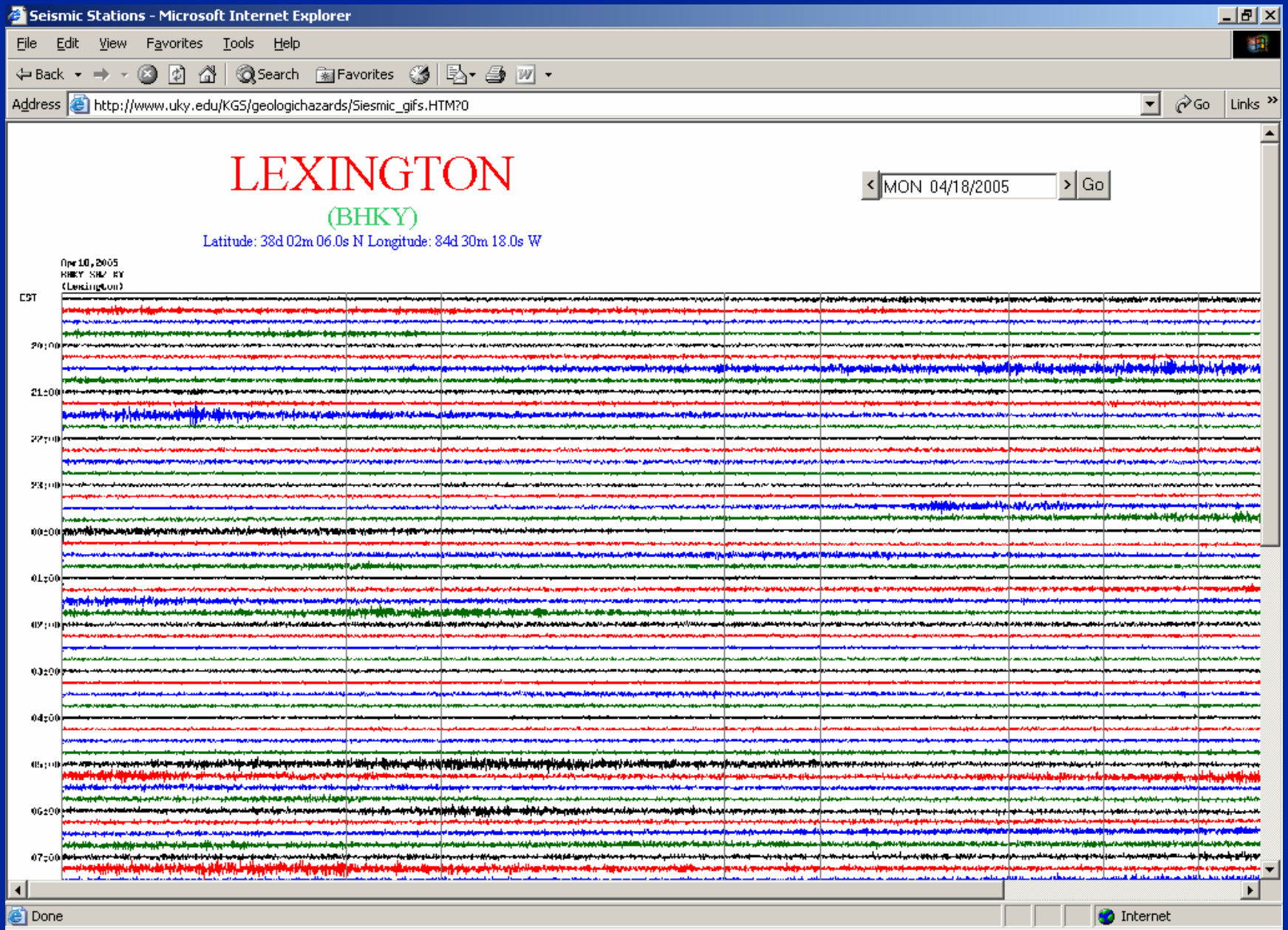


Next: Kentucky Seismic and Strong-Motion Network

http://www.uky.edu/KGS/geologichazards/equake3.htm

Done Internet

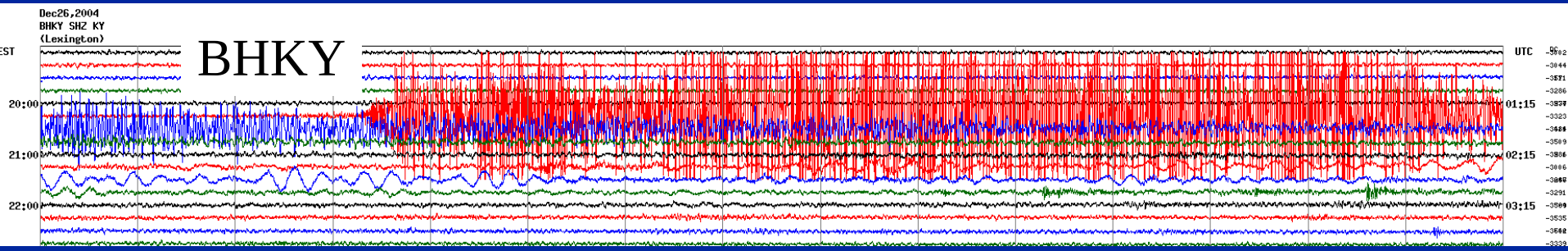
On-line seismic readings



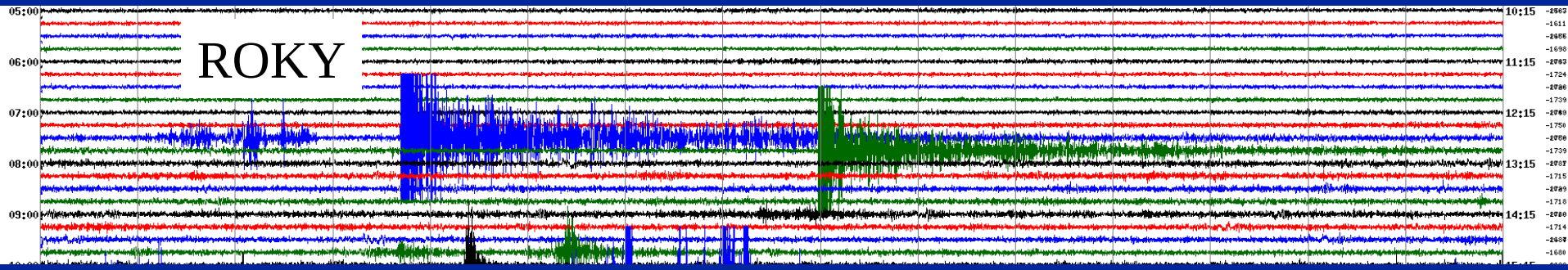
On-line seismic readings

- Kentucky Seismic Network Serves
  - Monitoring/locating earthquakes occurring in and around Kentucky
  - Differentiating earthquake from mine blasts
  - Providing information on earthquakes

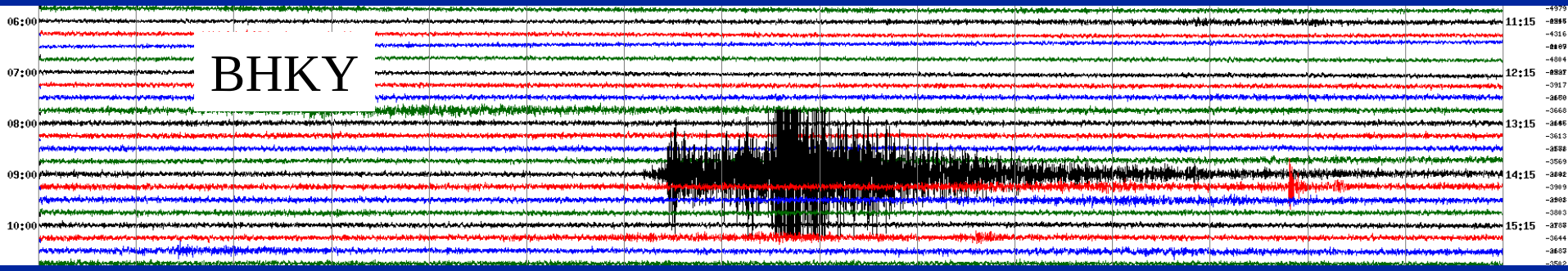
On-line Seismic Readings



December 26, 2004, Sumatra Earthquake (M9+)

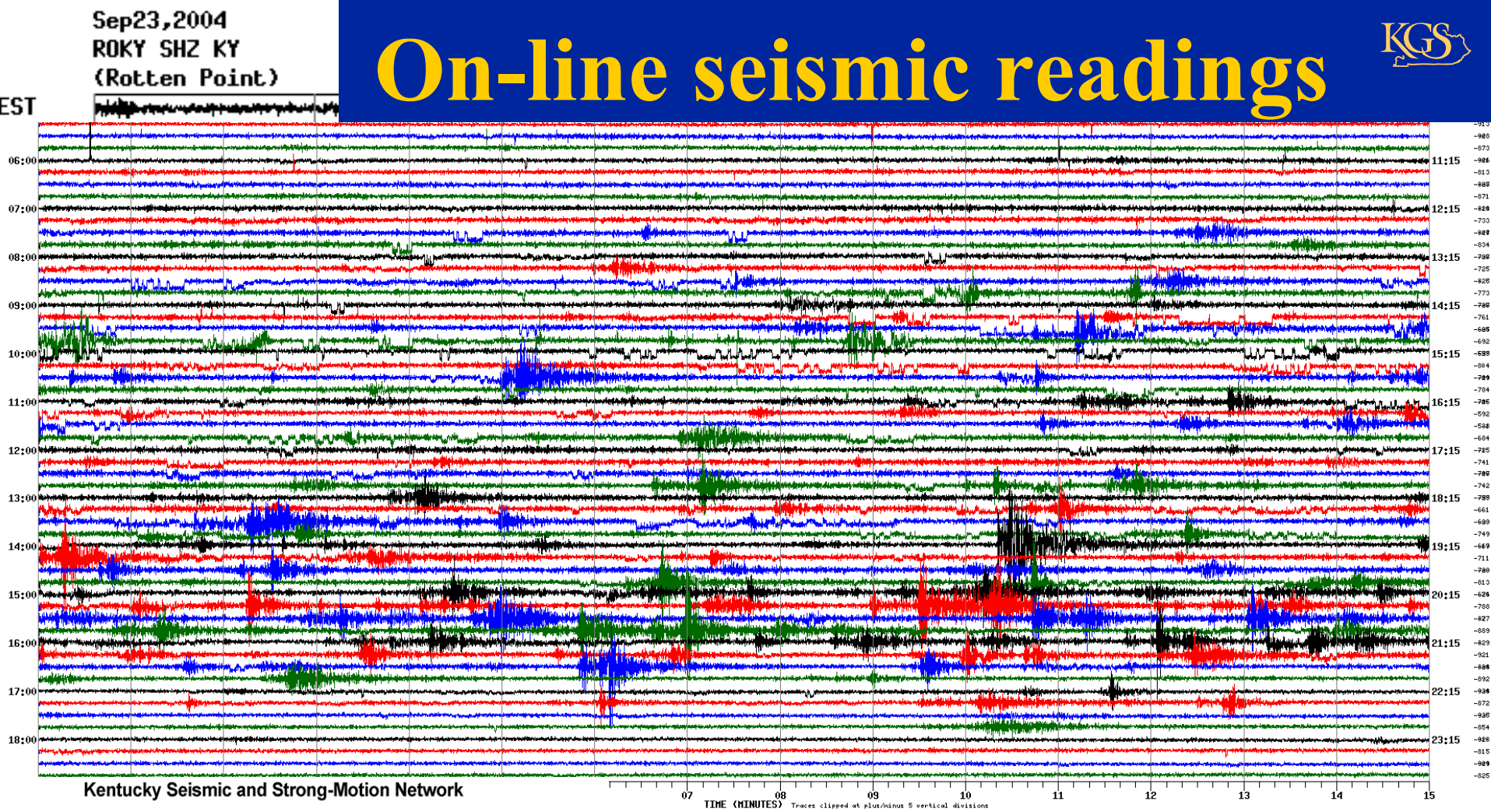


March 21, 2005, Salta, Argentina, Earthquakes (M6.9, 6.0)

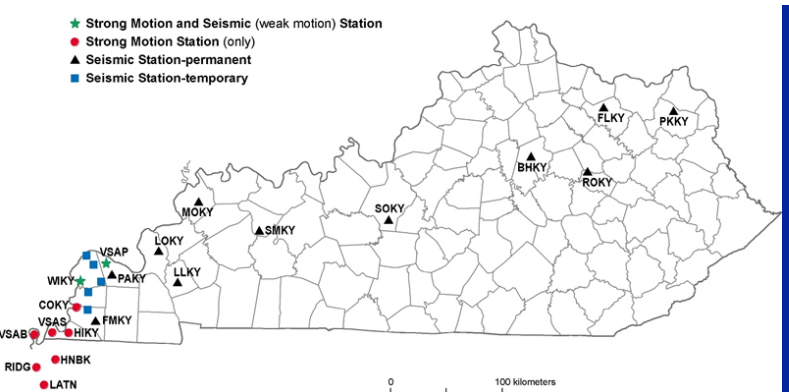


February 10, 2005, Arkansas Earthquakes (M4.1)

On-line seismic readings

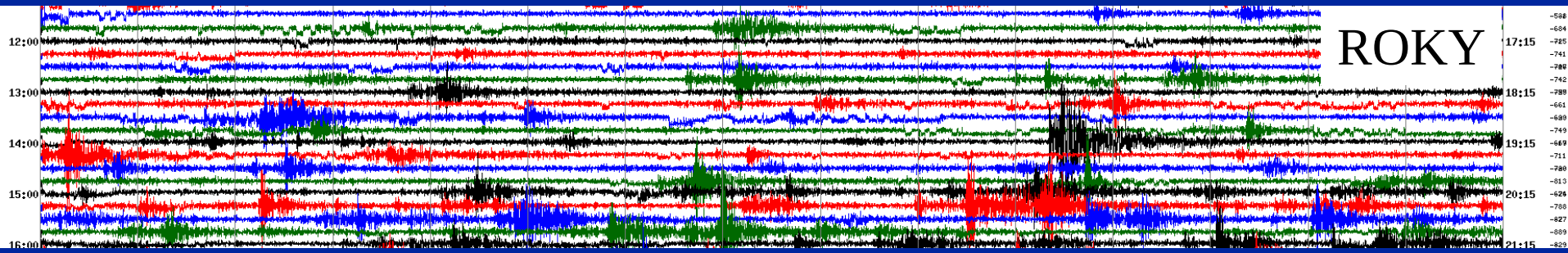


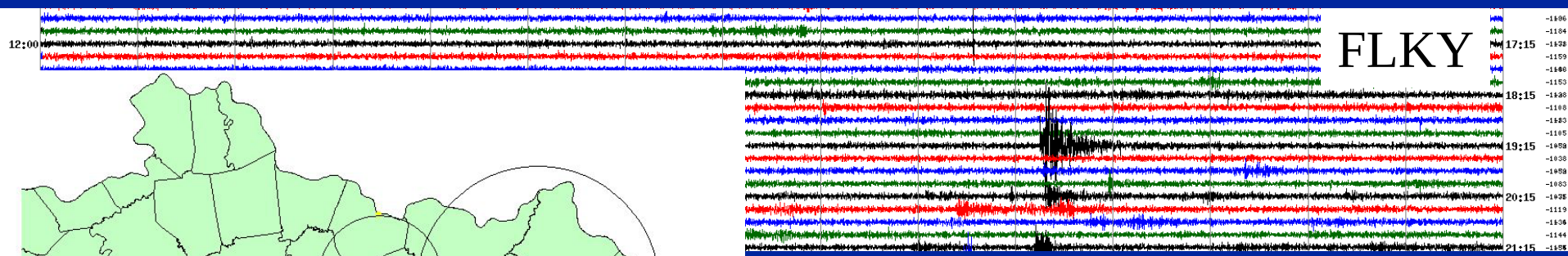
Kentucky Seismic and Strong-Motion Network

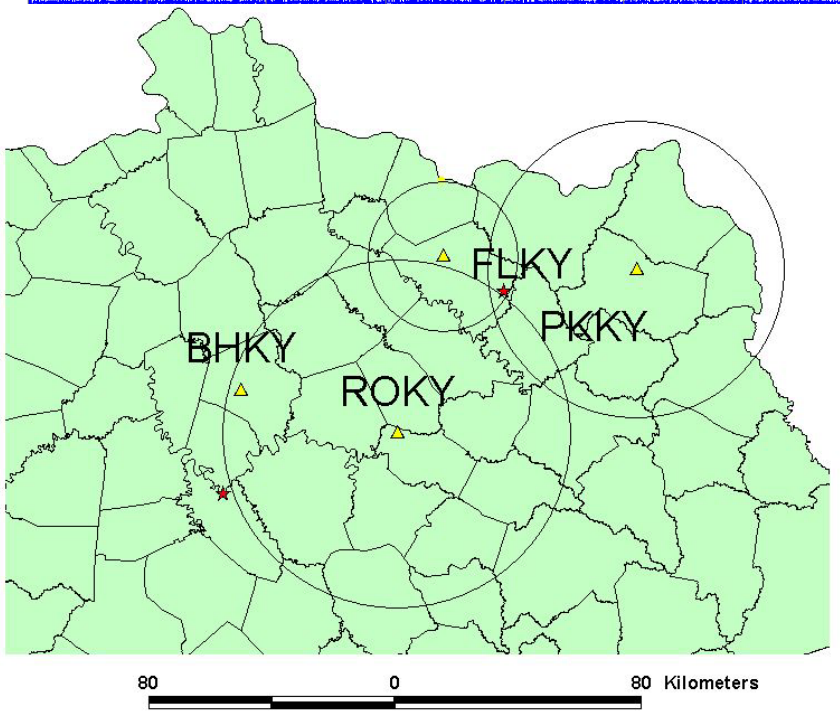


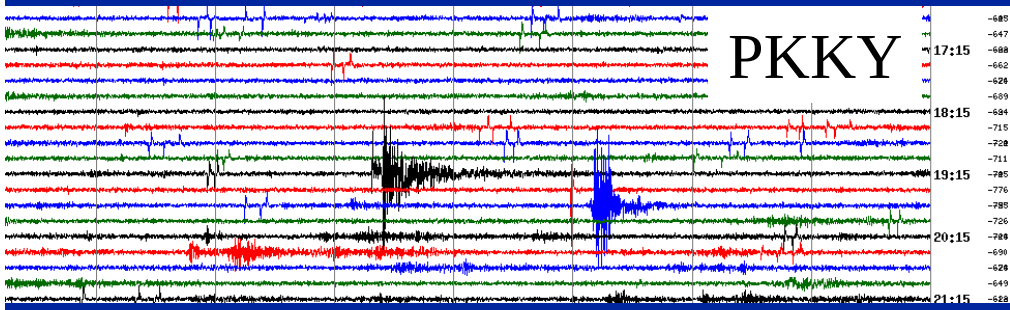
On-line seismic readings

September 23, 2005, earthquake (mb,Lg2.0)









$$X=(Ts-Tp)/(1/Vs-1/Vp) \approx (Ts-Tp)\cdot 8.0$$