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science for a changing world

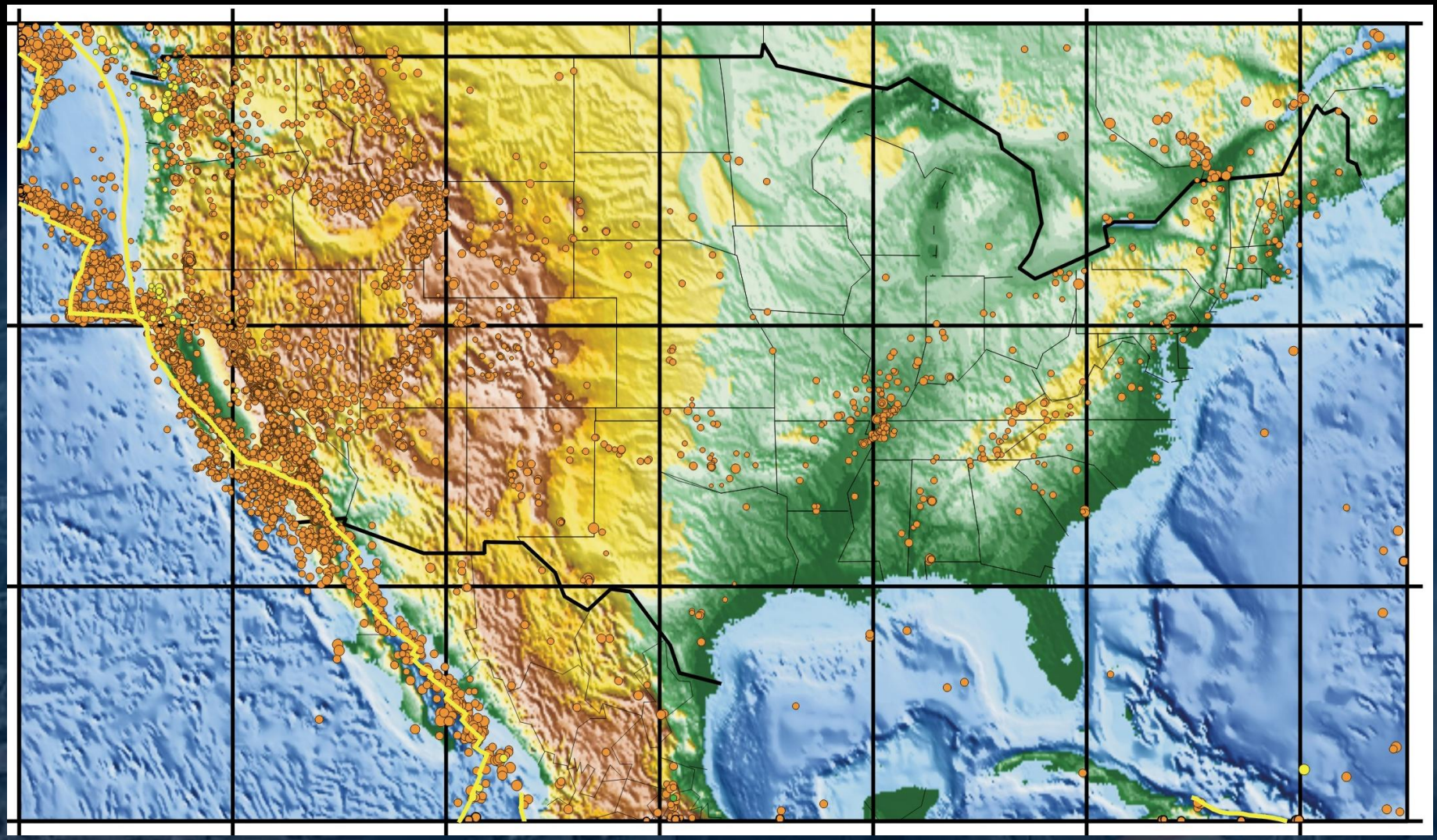
Earthquakes ★ Floods ★ Hurricanes ★ Landslides ★ Tsunamis ★ Volcanoes ★ Wildfires

What We Know About Earthquakes in the New Madrid Fault Zone in Mid-America

Arthur Frankel
Coordinator for Earthquake Effects Research
U.S. Geological Survey

U.S. Department of the Interior
U.S. Geological Survey

New Madrid Area has the highest rate of earthquakes in the U.S. east of the Rocky Mountains. Map shows earthquake epicenters from 1990-2000



USGS

Source: USGS National Earthquake Information Center

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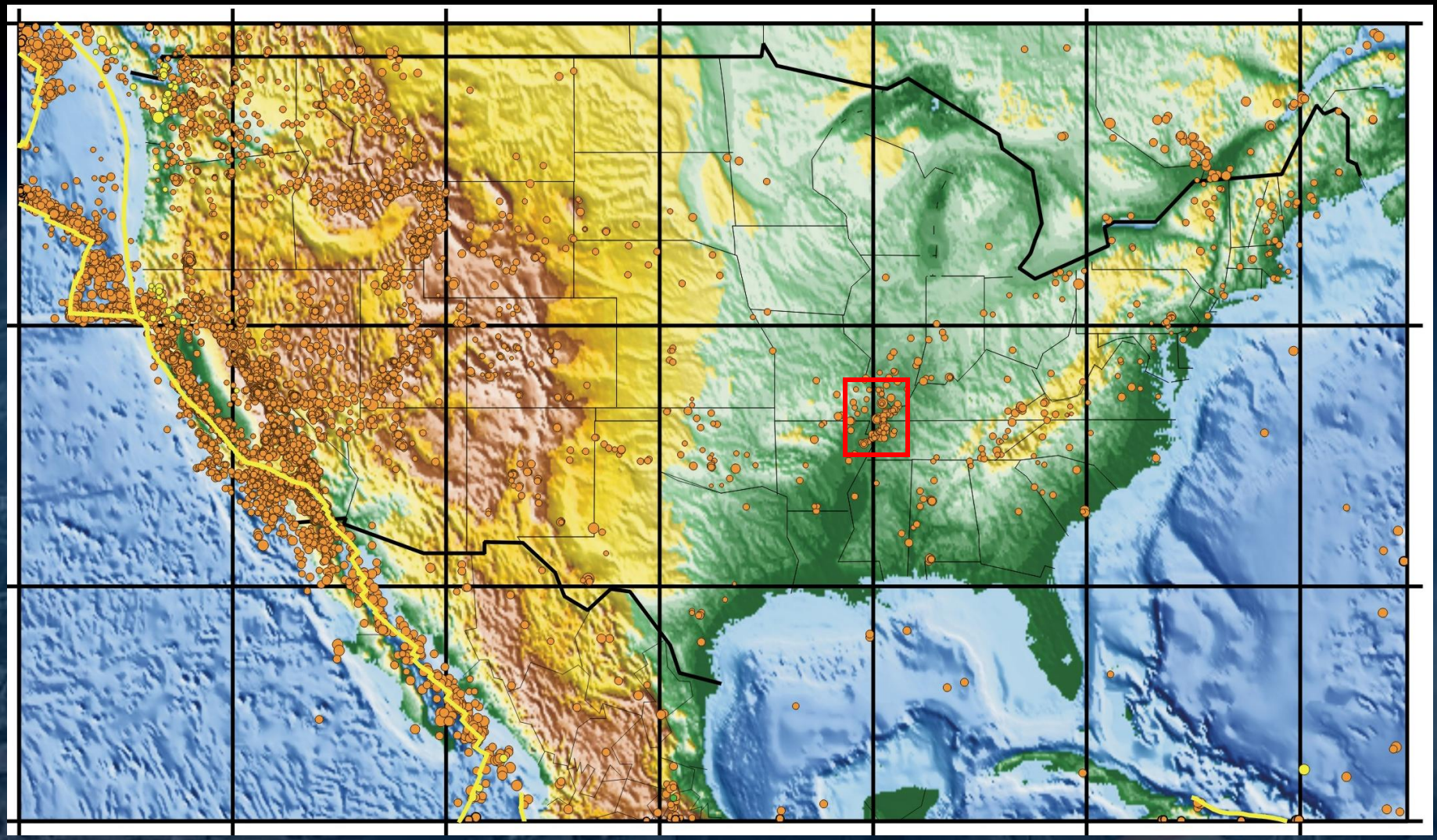
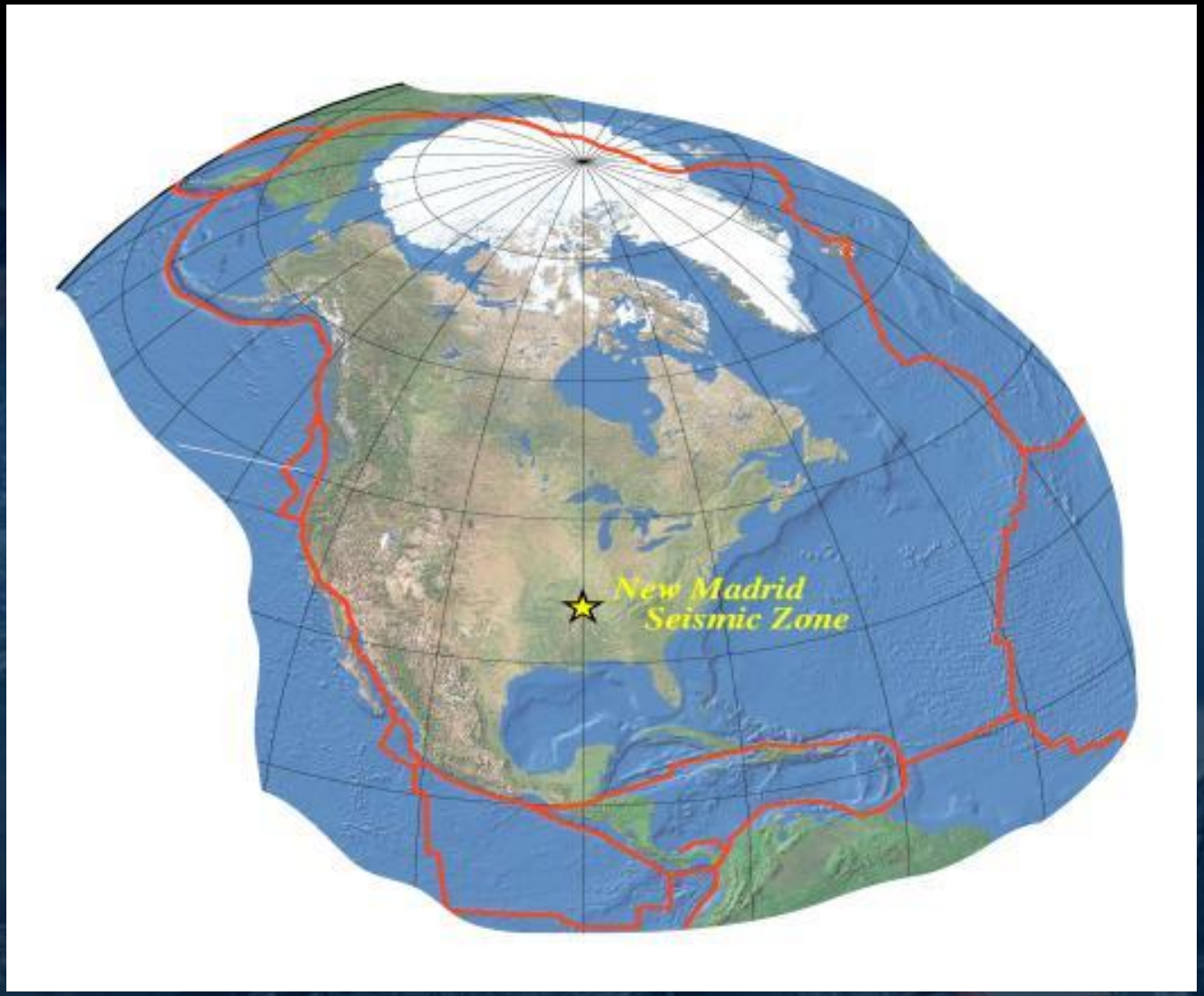


USGS

Source: USGS National Earthquake Information Center

Why Are There Earthquakes in the New Madrid Region?
This Region is Far From Boundaries of North American Tectonic Plate



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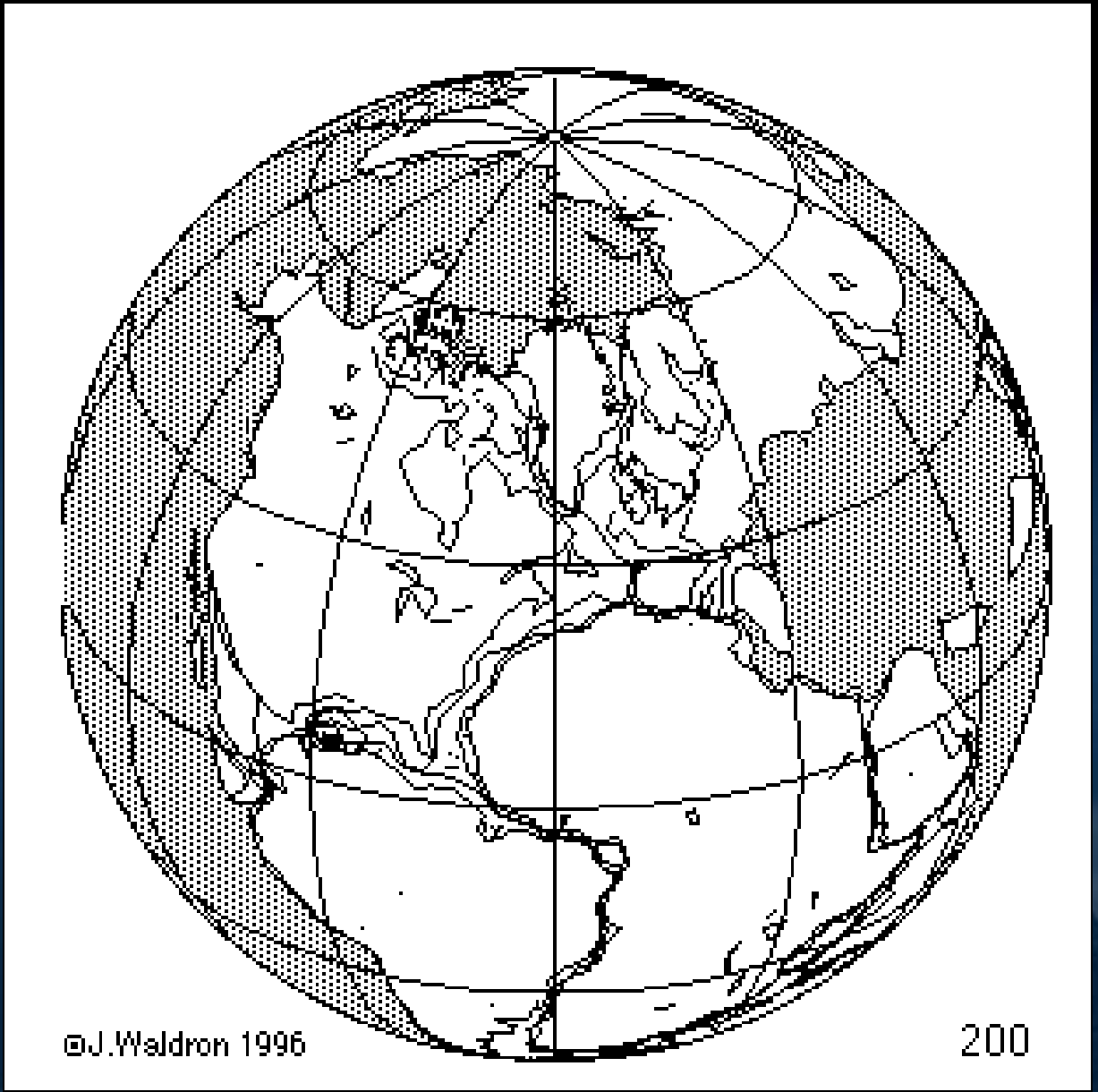
Animation of plates showing opening of Atlantic Ocean basin starting 200 million years ago

Faulting in the New Madrid region was produced during the previous cycle when the continent was torn apart by the opening of the ocean basin prior to the Atlantic



USGS

Animation Produced By Nova Scotia Museum

The New Madrid area was near a plate boundary about 500 million years ago: green lines

Slide from William Thomas GSA Today Feb. 2006

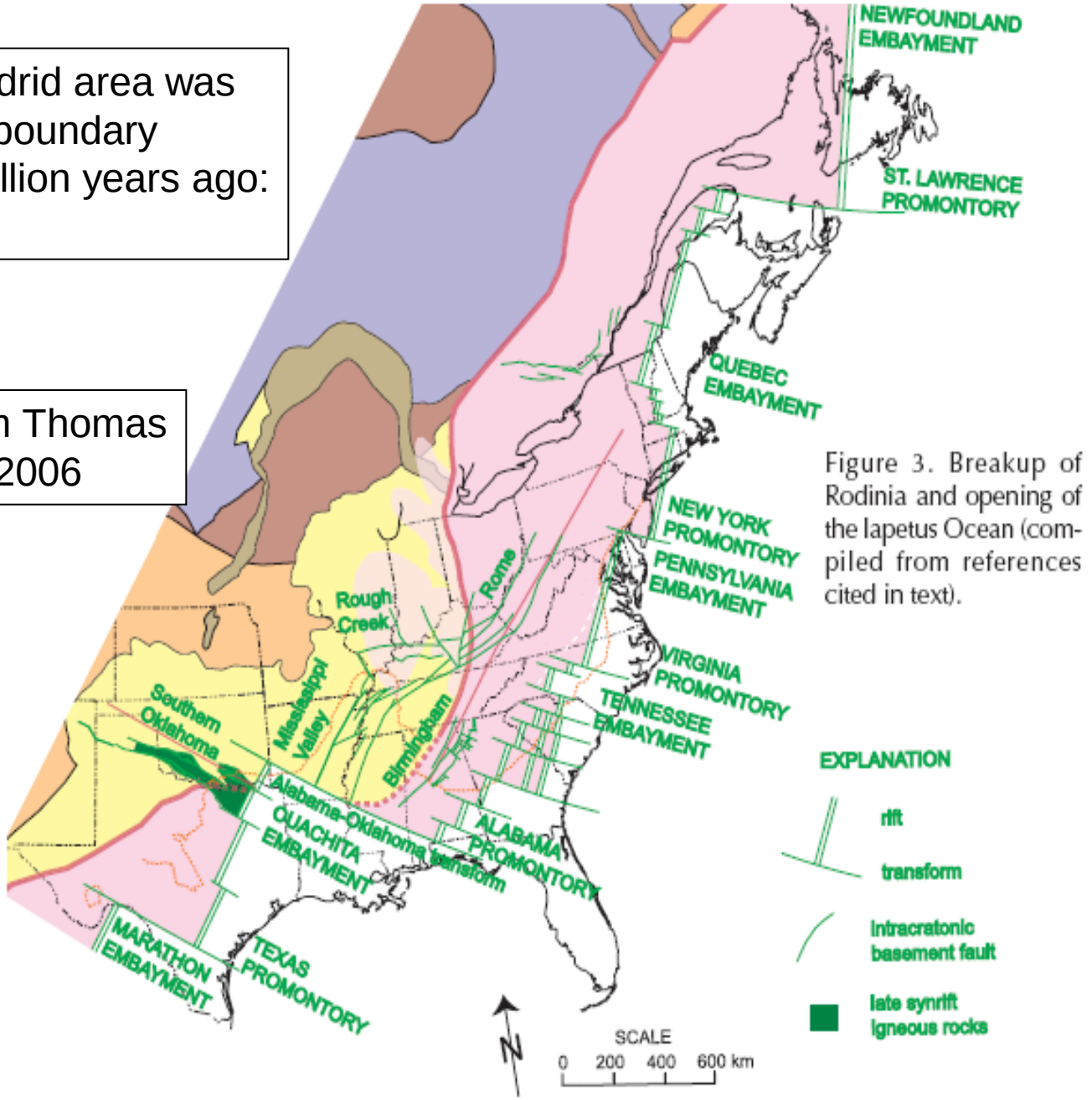
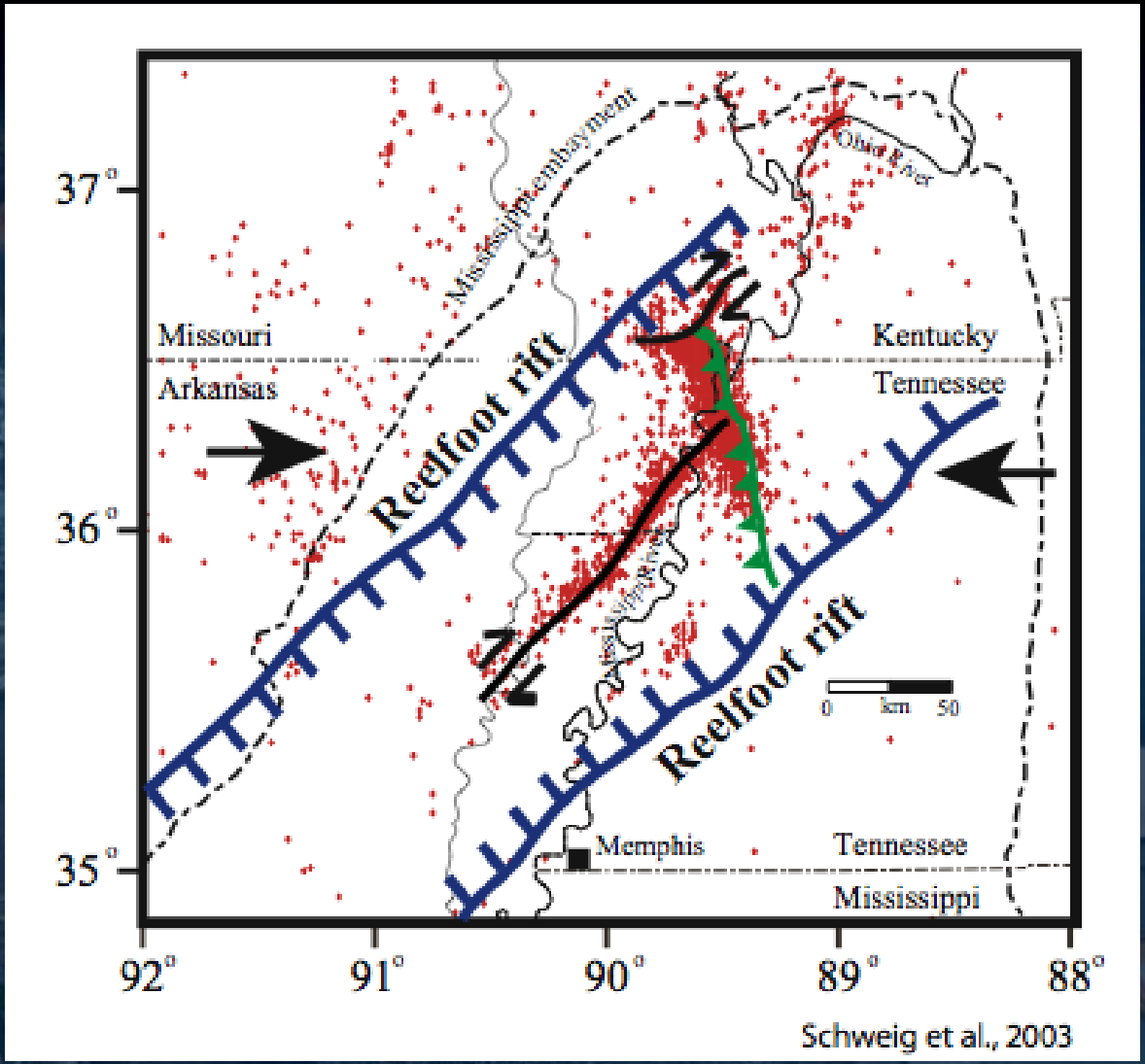


Figure 3. Breakup of Rodinia and opening of the Iapetus Ocean (compiled from references cited in text).

USGS

New Madrid faults:
within failed rift from opening of ocean basin prior to Atlantic Ocean about 500 million years ago; this was near a plate boundary at that time



Now these ancient faults have been reactivated by compression within the plate

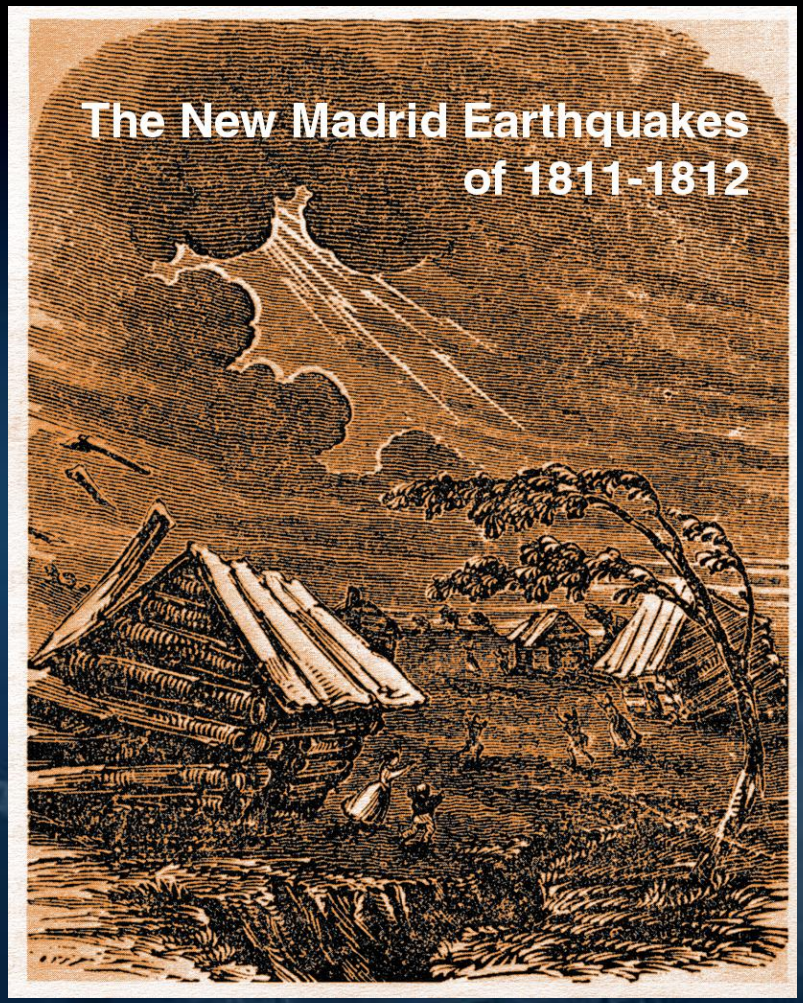
USGS

USGS employs four-part strategy to reduce risk in the region

1. Monitor and report on the seismicity; rapid reporting of magnitude, location, and shaking of earthquakes
2. Develop and distribute products to reduce earthquake losses
3. Educate people in the use of these products
4. Continue the long-term research that will lead to improvements in these products and reduced levels of uncertainty

USGS

1811-1812 three earthquakes, magnitude 7.5-8.0 struck the New Madrid region within 2 months; thousands of aftershocks followed.



Examples of damage:
Houses were destroyed in New Madrid, houses damaged in Cape Girardeau, chimneys toppled in St. Louis, Vincennes, Nashville, and other locations.

Tops of trees sheared off in area of epicenters

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USGS funds studies of historical earthquakes

Riverbanks caved.

Riverbanks Falling In—Missouri River
Courtesy of the State Historical Society of Missouri,
Columbia, Mo.

USGS

Vast tracts of land sank and were uplifted …

Reelfoot Lake

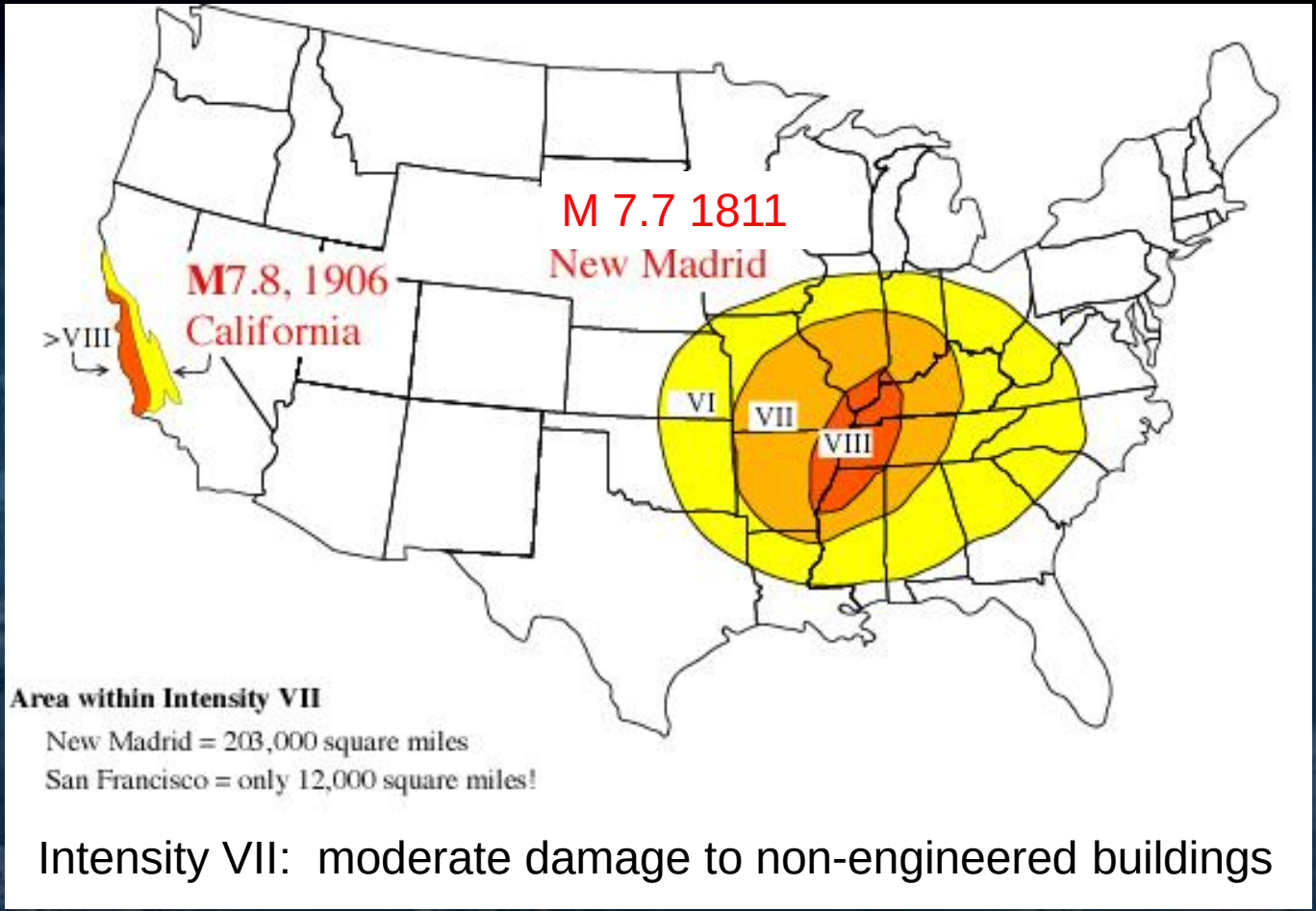
USGS

Movement of the Reelfoot fault in the Feb. 1812 earthquake also produced waterfalls on the Mississippi River

Landslides occurred all along the bluffs

USGS

In the central & eastern U.S., earthquakes affect much larger areas than in the west



Intensity VII: moderate damage to non-engineered buildings

USGS

1811-12 earthquakes felt as far as New England

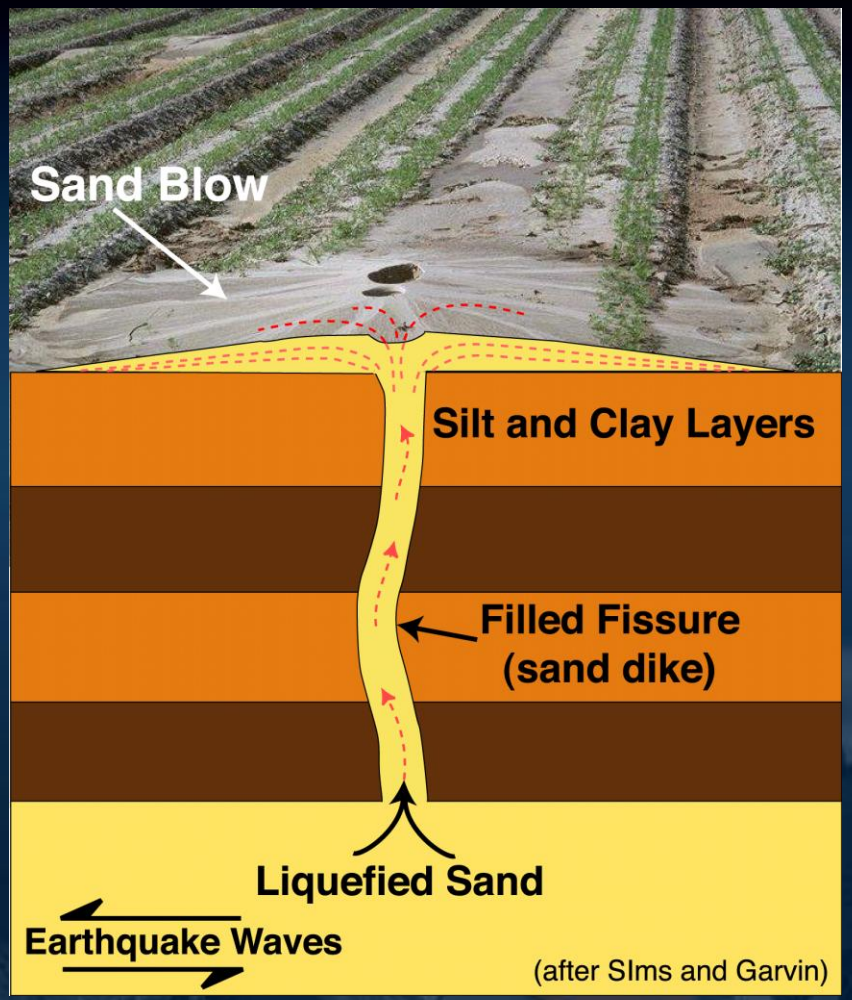
USGS funds studies on how seismic waves travel through the Earth's crust

What remains today…
(Blytheville, Arkansas)

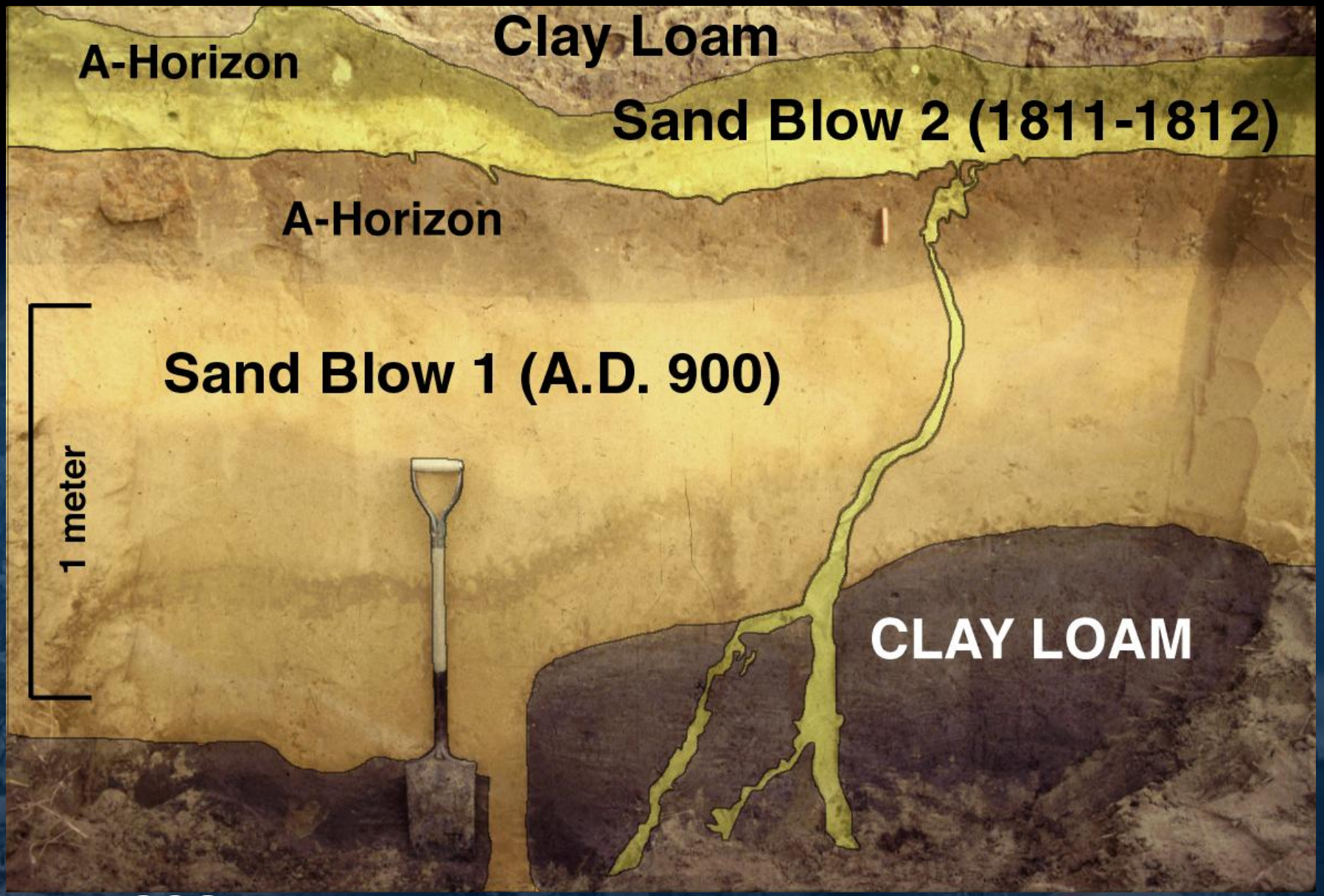
USGS

Liquefaction and Sand Blow Formation

During strong shaking, pore water pressure in saturated, loose sand increases until the sand loses its strength and acts like a liquid, finally erupting to the surface through fissures, forming sand blows.



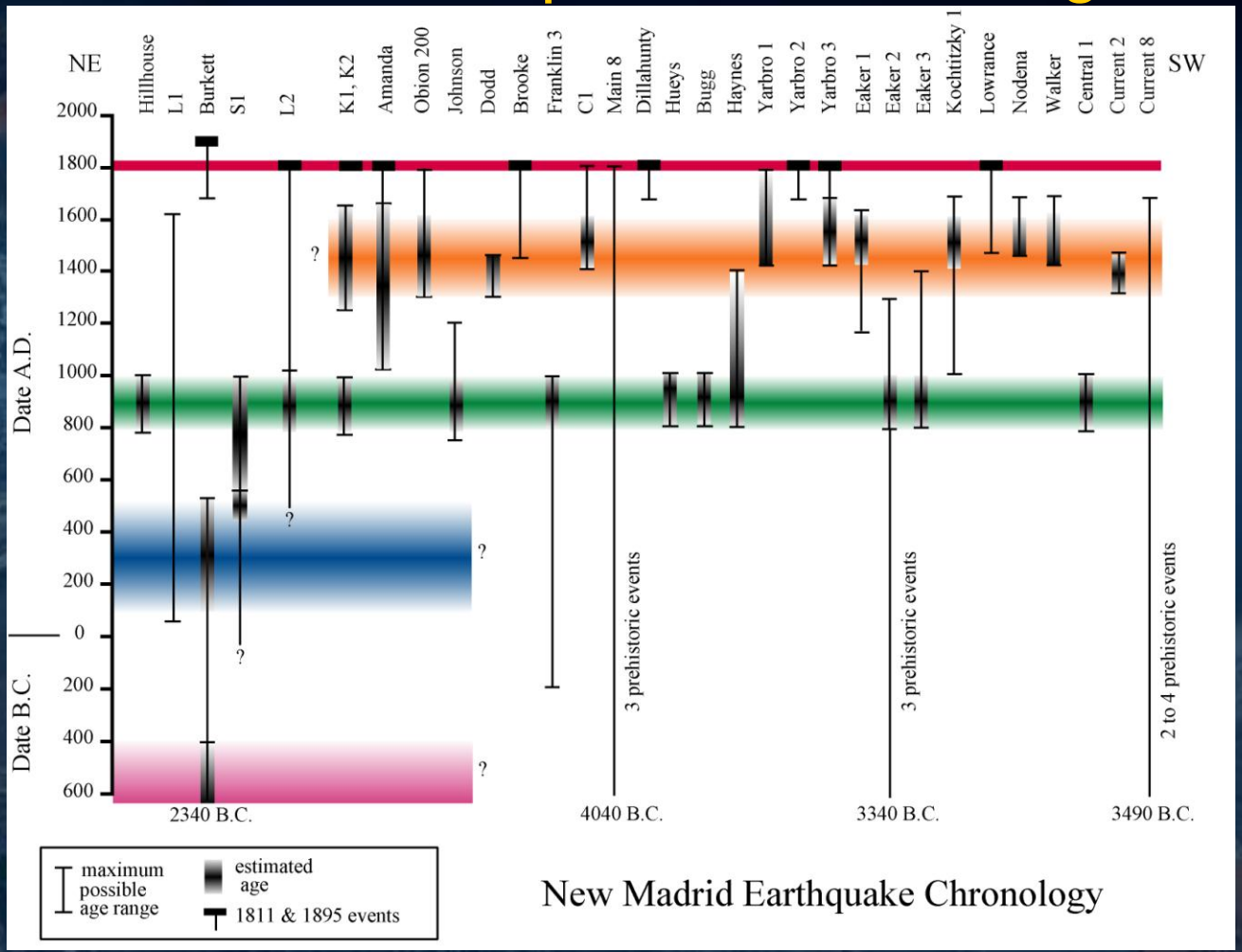
USGS



USGS

Sand blows are the smoking guns that prove the occurrence of past large earthquakes

How often do 1811-12 type earthquakes occur? Sand blows show that previous large earthquakes occurred around 1450 and 900 A.D.; about 500 years between M7.5-8.0 earthquakes, on average



USGS

Probabilities of large earthquakes in the next 50 years in the New Madrid Zone

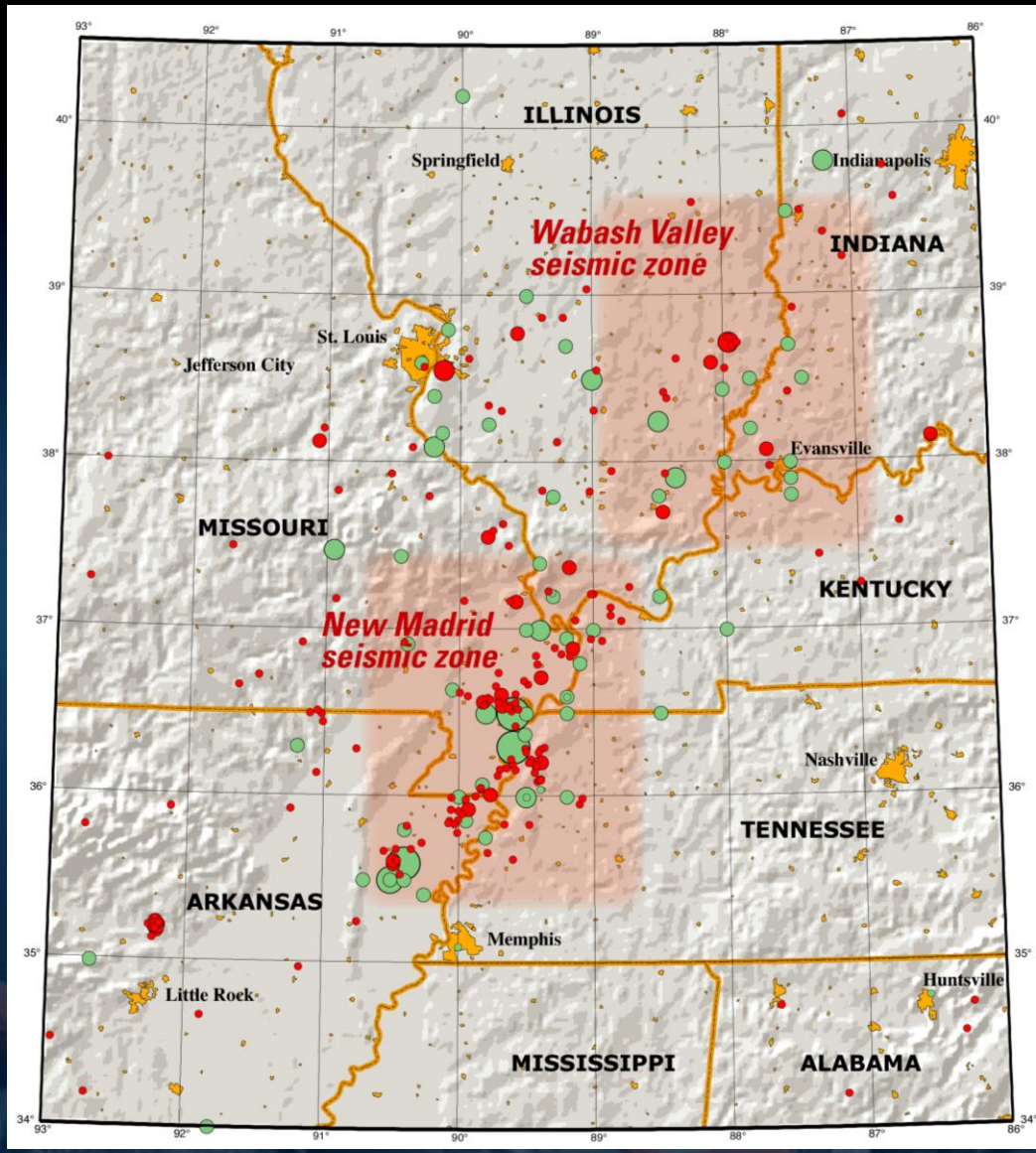
- Repeat of 1811-1812 (magnitude 7.5-8.0)
  - Approximately 7-10%

- Magnitude 6.0 or greater (such as the 1843 Marked Tree, AR and 1895 Charleston, MO earthquakes)
  - Approximately 25-40%

From studies of instrumental, historical, and prehistoric earthquakes

USGS

Earthquakes continue today in New Madrid and Wabash Valley seismic zones and scattered over Illinois, Indiana, Missouri, Arkansas, Tennessee, Kentucky, Alabama, and Mississippi

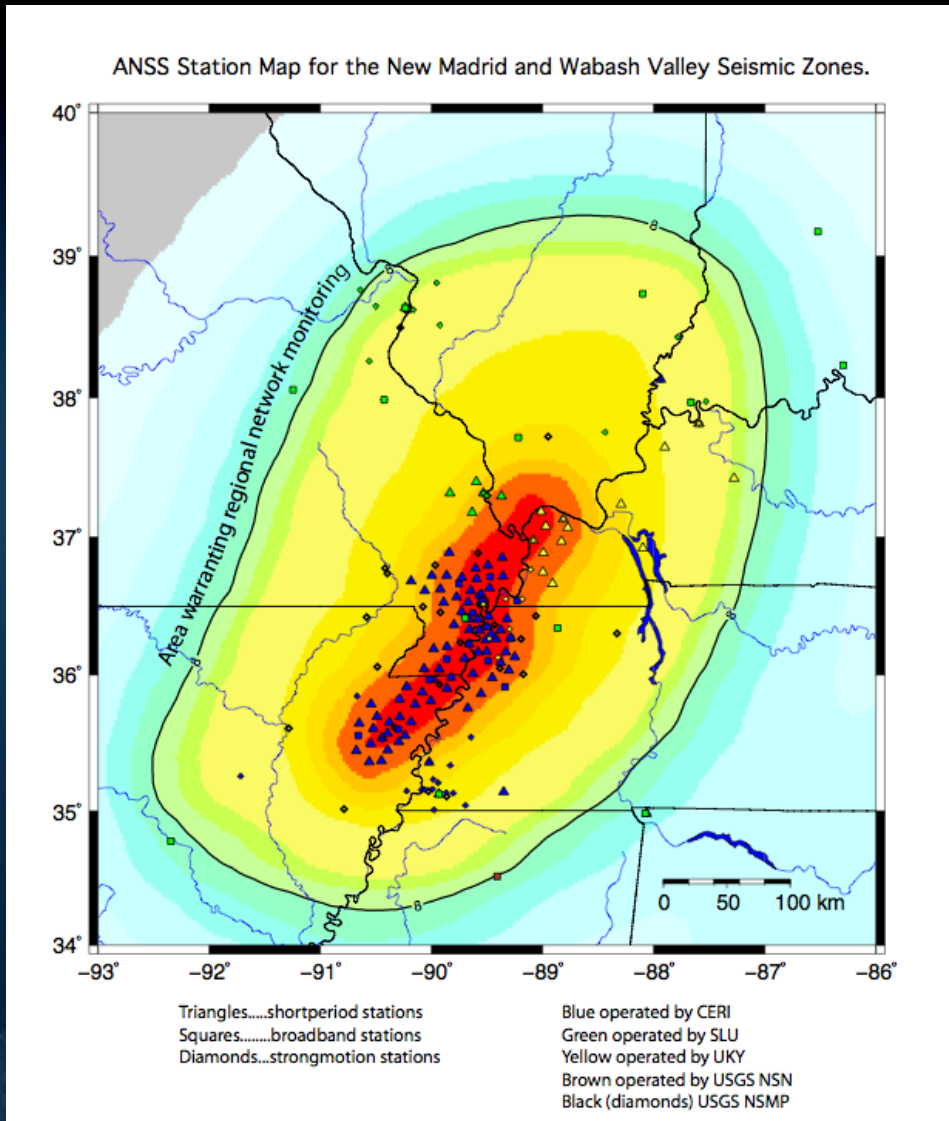


USGS

USGS funds earthquake monitoring the central U.S.

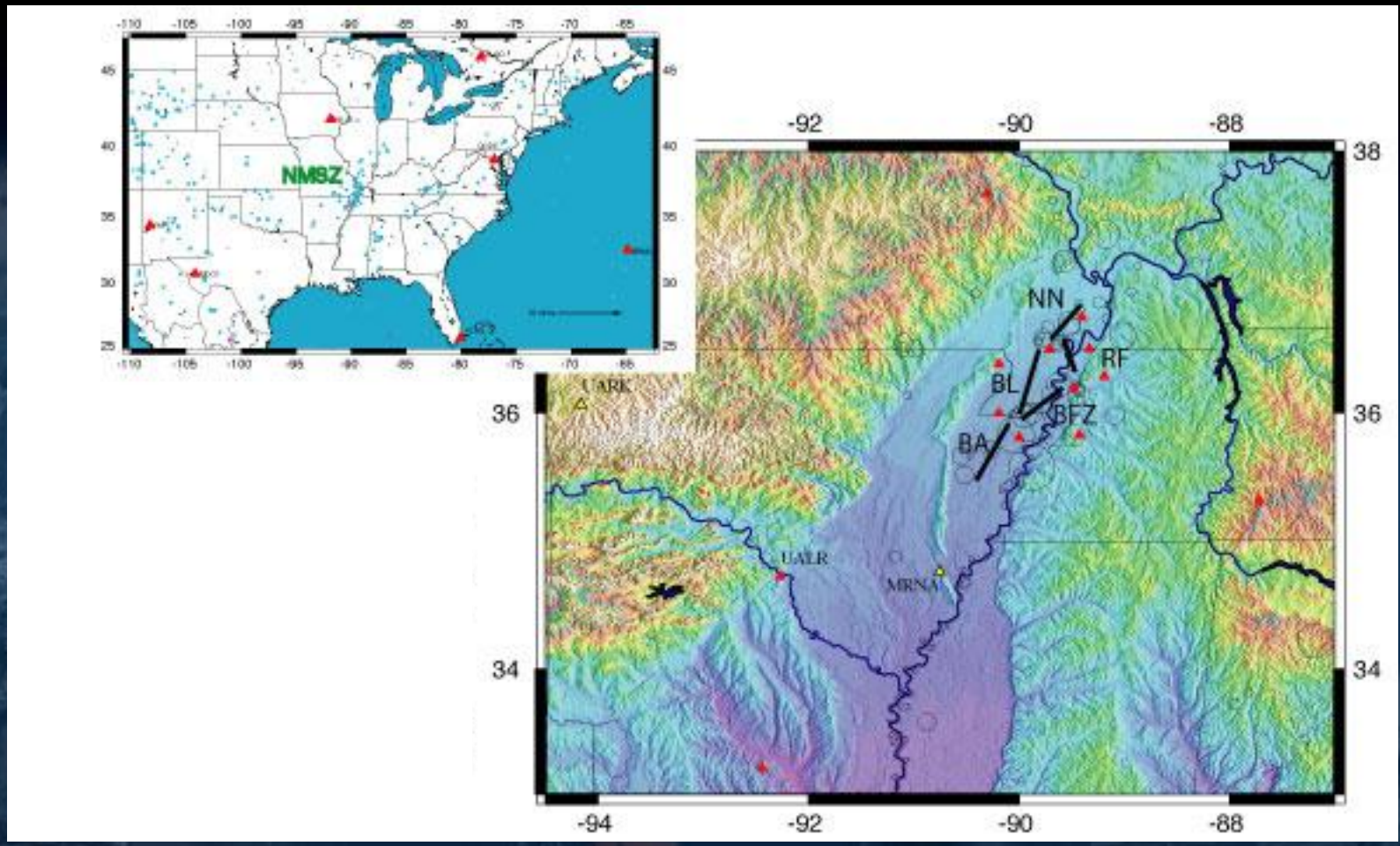
Monitoring Earthquakes

- Network upgraded as part of Advanced National Seismic System (ANSS)
- In addition to National Backbone, over 120 stations operated by local universities and USGS
  - 20 new strong-motion stations monitoring urban areas and region: St. Louis, Memphis, Evansville
- National Earthquake Information Center (NEIC) now 24/7



USGS

Monitoring Ground Deformation



- 10 continuously operated Global Positioning System (GPS) stations operated by the University of Memphis and the University of Arkansas

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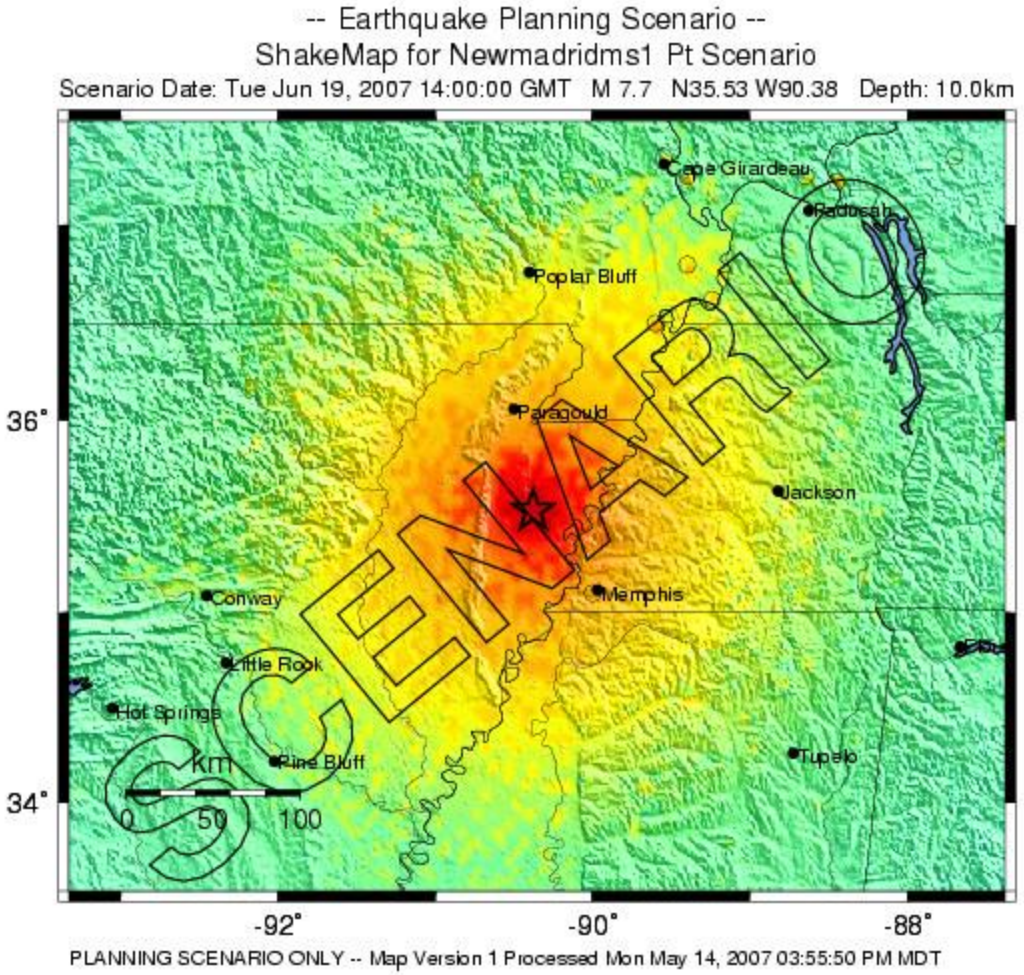
ShakeMaps

about 5 minutes after the earthquake, the USGS and CERI (Univ. of Memphis) notify local, state, and federal emergency management officials and others with the epicenter and preliminary magnitude of the earthquake.

15 minutes after the earthquake, an initial set of Shakemaps of the earthquake is released by the USGS showing areas of expected higher ground shaking for emergency response, utilities, business recovery, public awareness

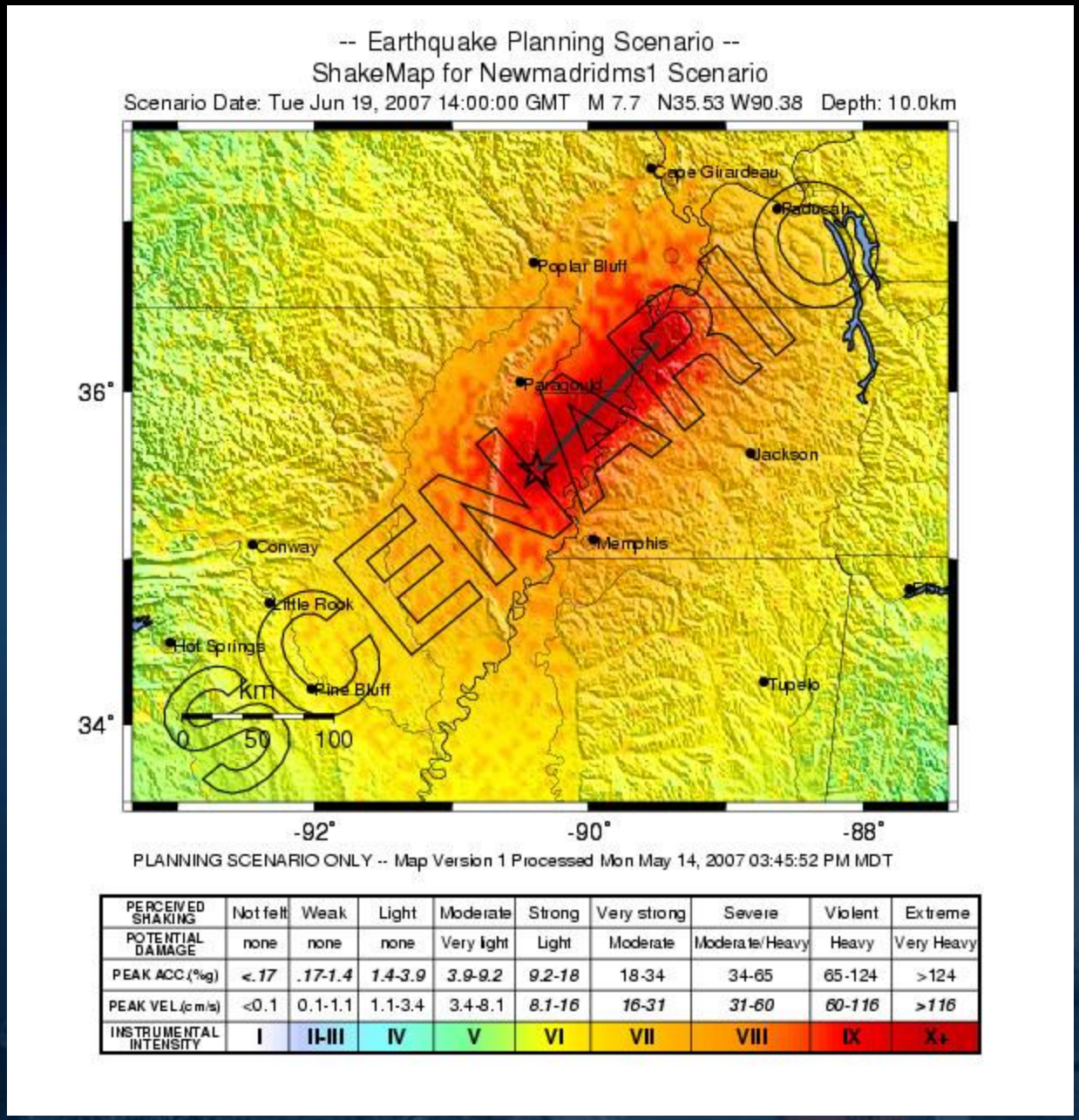
USGS



PERCEIVED SHAKING	Not felt	Weak	Light	Moderate	Strong	Very strong	Severe	Violent	Extreme
POTENTIAL DAMAGE	none	none	none	Very light	Light	Moderate	Moderate/Heavy	Heavy	Very Heavy
PEAK ACC.(%g)	<.17	.17-1.4	1.4-3.9	3.9-9.2	9.2-18	18-34	34-65	65-124	>124
PEAK VEL.(cm/s)	<0.1	0.1-1.1	1.1-3.4	3.4-8.1	8.1-16	16-31	31-60	60-116	>116
INSTRUMENTAL INTENSITY	I	II-III	IV	V	VI	VII	VIII	IX	X+

ShakeMaps

60 minutes after the earthquake, seismograms have been analyzed to determine the geometry of the fault and an improved ShakeMap is released.



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PAGER

Prompt Assessment
Of Global Earthquakes
For Response

Available about 15 minutes after earthquake; Improved version released about 60 min. after earthquake

Currently prototype; Publicly operational in September

USGS

USGS USAID

M 7.7 New Madrid Scenario - First Main Shock (Finite Fault) PAGER

Origin Time: Tue 2007-06-19 14:00:00 UTC
Location: 35.53°N 90.38°W Depth: 10 km

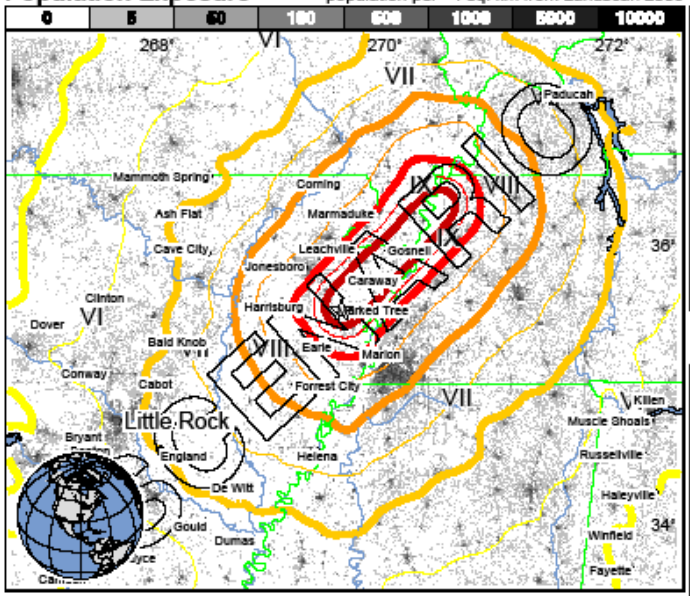
Version 1
Created: 5 hrs, 35 mins after earthquake

Estimated Population Exposed to Earthquake Shaking

ESTIMATED POPULATION EXPOSURE (k = x1000)		-.-*	-.-*	-.-*	-.-*	-.-*	-.-*	1,584k	89k	79k
ESTIMATED MODIFIED MERCALLI INTENSITY		I	II-III	IV	V	VI	VII	VIII	IX	X+
PERCEIVED SHAKING		Not felt	Weak	Light	Moderate	Strong	Very strong	Severe	Violent	Extreme
POTENTIAL DAMAGE	Resistant Structures	none	none	none	V. Light	Light	Moderate	Moderate/Heavy	Heavy	V. Heavy
	Vulnerable Structures	none	none	none	Light	Moderate	Moderate/Heavy	Heavy	V. Heavy	V. Heavy

*Estimated exposure only includes population within the map area.

Population Exposure population per ~1 sq. km from Landscan 2005

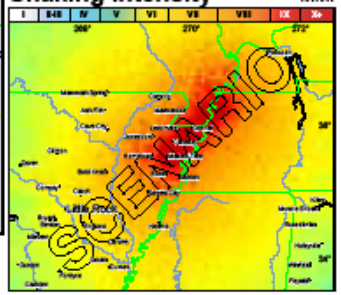


Selected City Exposure

MMI	City	Population
X	Caraway	1k
X	Blytheville	16k
X	Lepanto	2k
X	Marked Tree	2k
X	Gosnell	3k
X	Luxora	1k
VIII	Jonesboro	58k
VI	Conway	51k
VI	Little Rock	184k
VI	Florence	36k
VI	Hot Springs	37k

bold cities appear on map (k = x1000)

Shaking Intensity MMI



The population exposure estimates are NOT a direct estimate of earthquake damage. Comparable shaking intensities will result in significantly lower losses in regions with well built and engineered structures than in regions with vulnerable structures. Users should consider the preliminary nature of this information when making decisions relating to public safety.

This information was automatically generated and has not been reviewed by a seismologist.

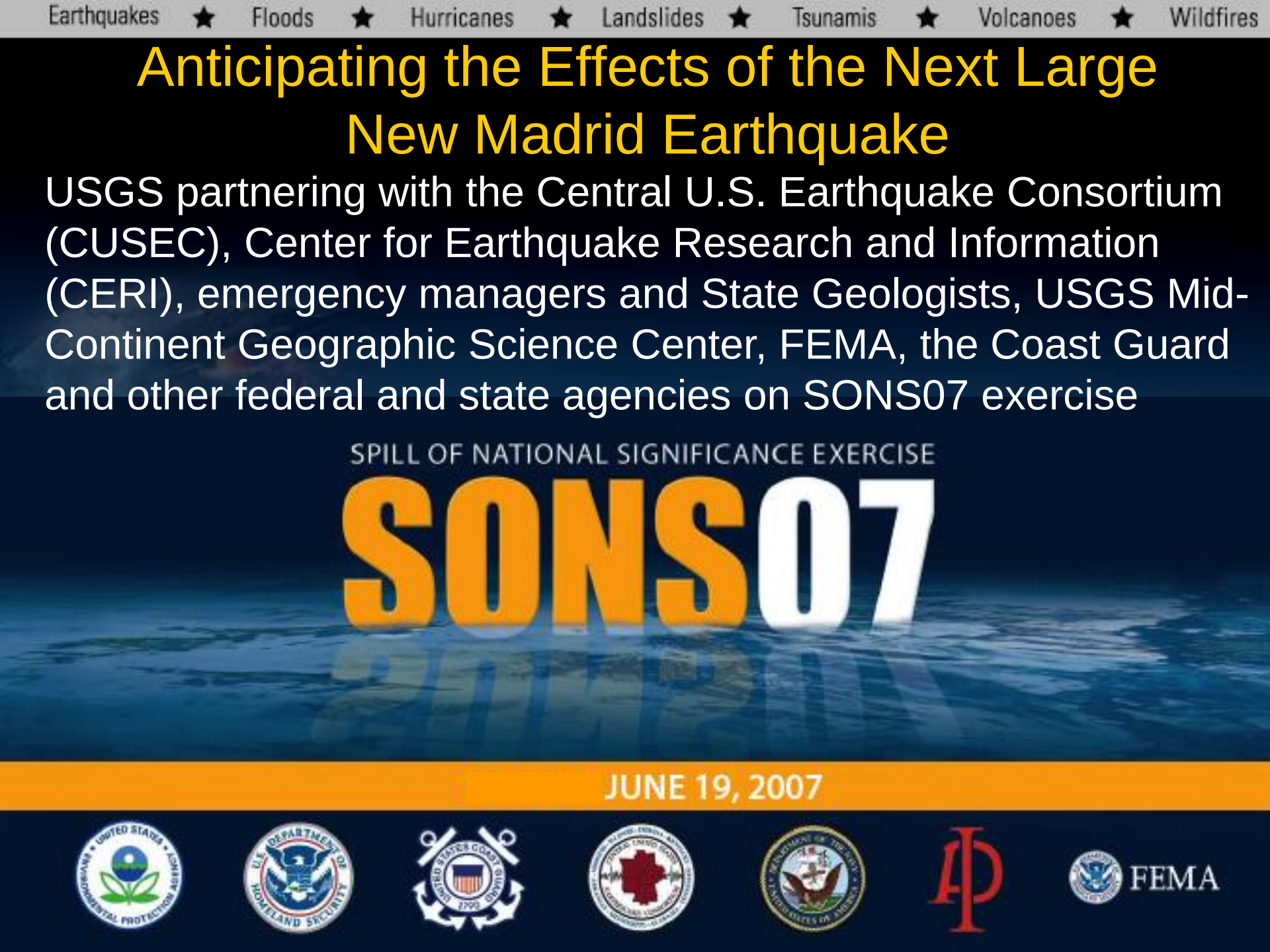
http://earthquake.usgs.gov/pager

Event ID: usNewMadridMS1_se

Earthquakes ★ Floods ★ Hurricanes ★ Landslides ★ Tsunamis ★ Volcanoes ★ Wildfires

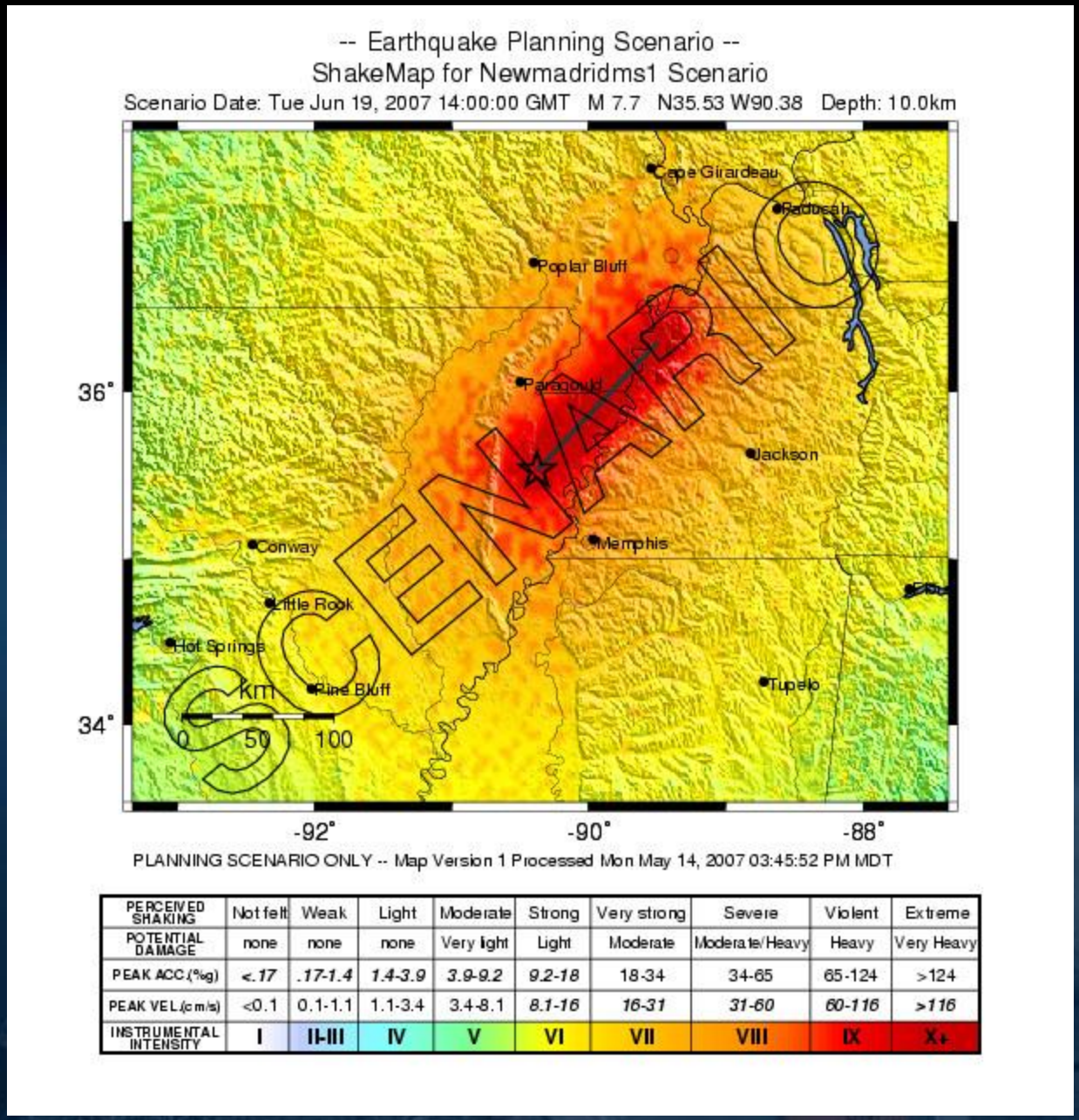
Anticipating the Effects of the Next Large New Madrid Earthquake

USGS partnering with the Central U.S. Earthquake Consortium (CUSEC), Center for Earthquake Research and Information (CERI), emergency managers and State Geologists, USGS Mid-Continent Geographic Science Center, FEMA, the Coast Guard and other federal and state agencies on SONS07 exercise



Scenario ShakeMaps

We make and distribute maps of expected ground shaking for possible earthquakes on specific faults. These are used for emergency planning and loss estimation. We are working with the MAE Center, FEMA, CUSEC, and Earthquake Engineering Research Institute by providing maps of expected shaking for a M7.7 New Madrid earthquake scenario.



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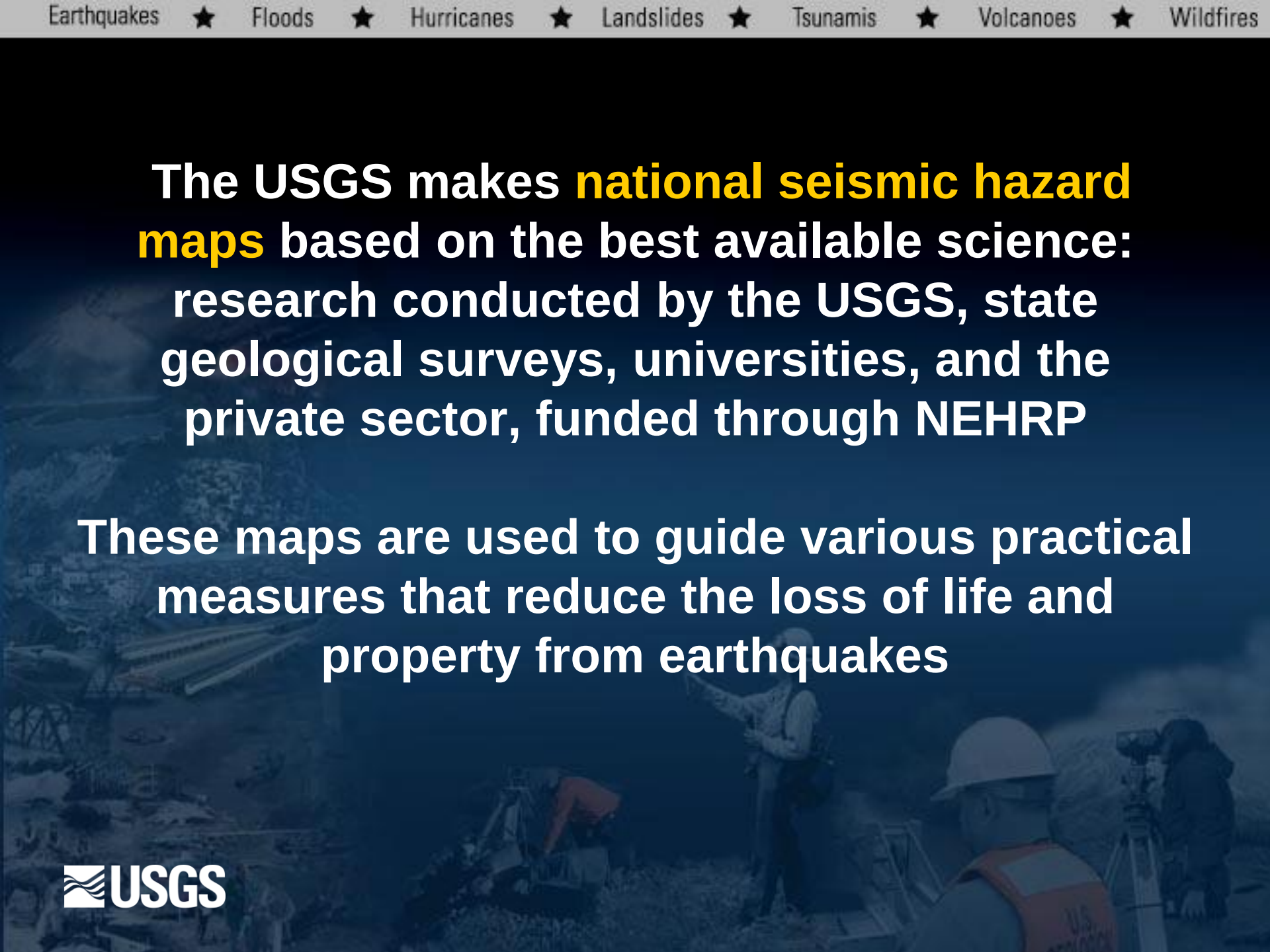
USGS



The USGS makes national seismic hazard maps based on the best available science: research conducted by the USGS, state geological surveys, universities, and the private sector, funded through NEHRP

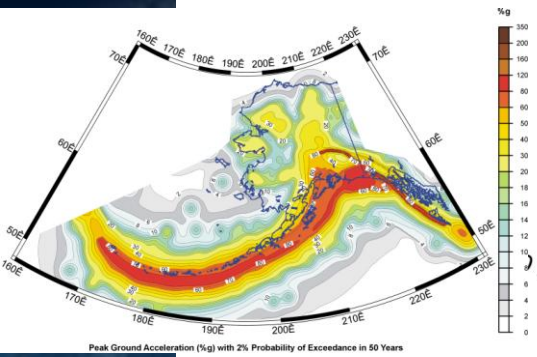
These maps are used to guide various practical measures that reduce the loss of life and property from earthquakes

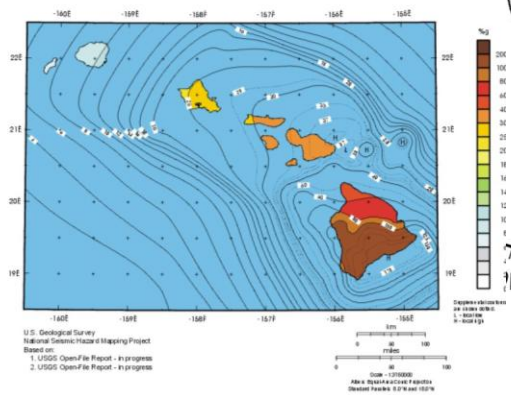
USGS

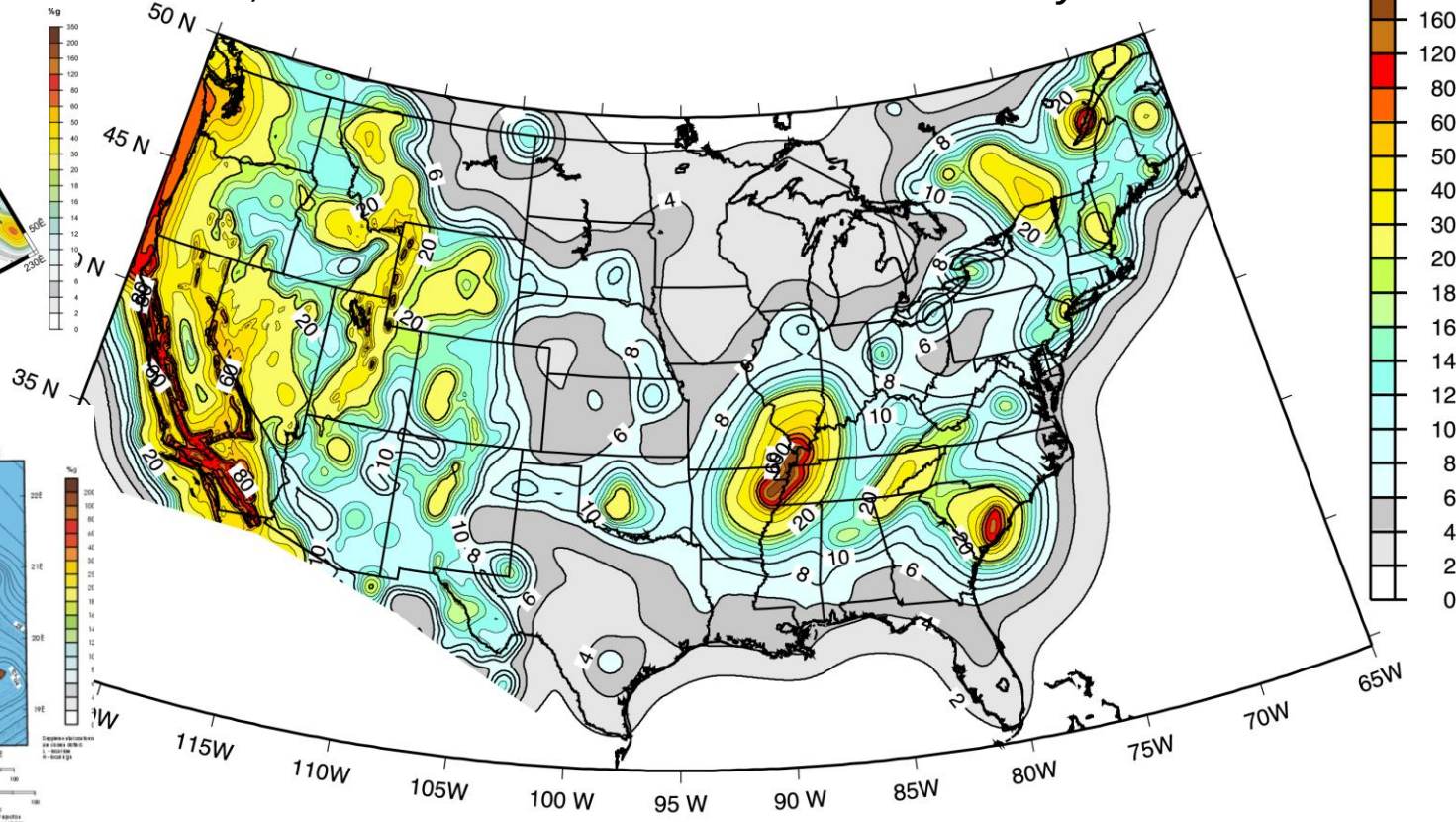
The USGS works in cooperation with FEMA to incorporate the national seismic hazard maps into model building codes

The national seismic hazard maps are the basis for seismic design maps in the International Building Code and the International Residential Code

This map is used in building codes in
47 states and DC; will be enacted in 3 more states next year







USGS

One set of the USGS National Seismic Hazard Maps shaking with a 2% chance of being exceeded in 50 years

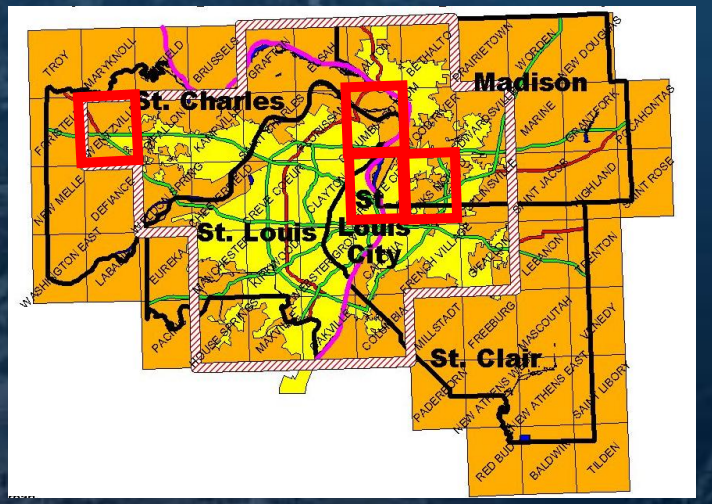
From Earthquake Monitoring and Research To Improving Public Safety

- **Seismic hazard maps** have improved building codes and the design of bridges and other structures; they help to save lives and reduce property losses (for example, Northridge, Loma Prieta, and Nisqually earthquakes)
- They are also used in the design of critical facilities (DOE), dams (Army COE), landfills (EPA) and in the evaluation of nuclear power plants (NRC)
- They are used in loss estimation studies
- They are used to set premiums for earthquake insurance

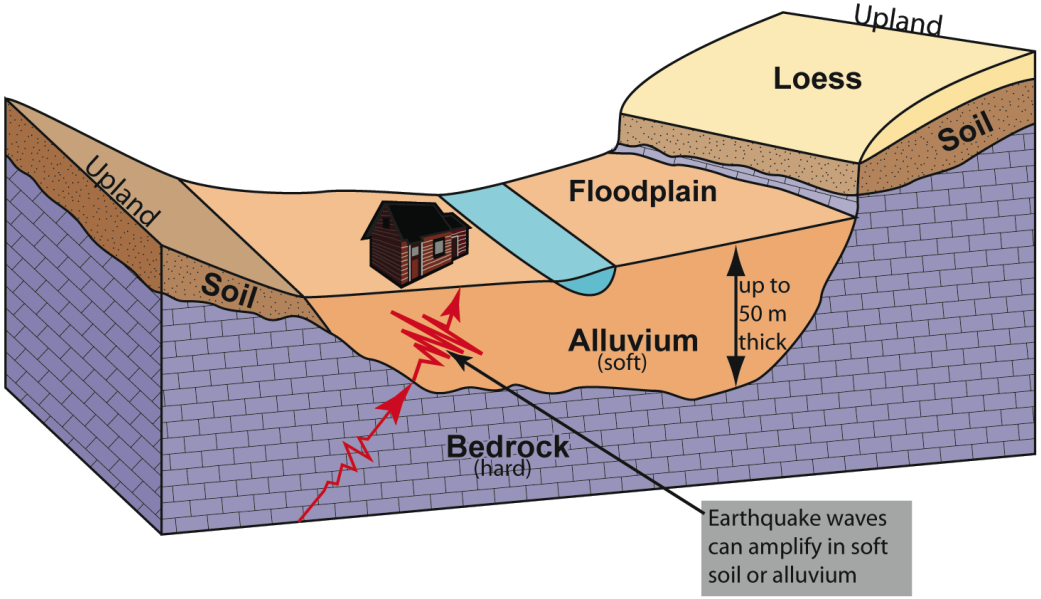
USGS

Urban Seismic Hazard Maps

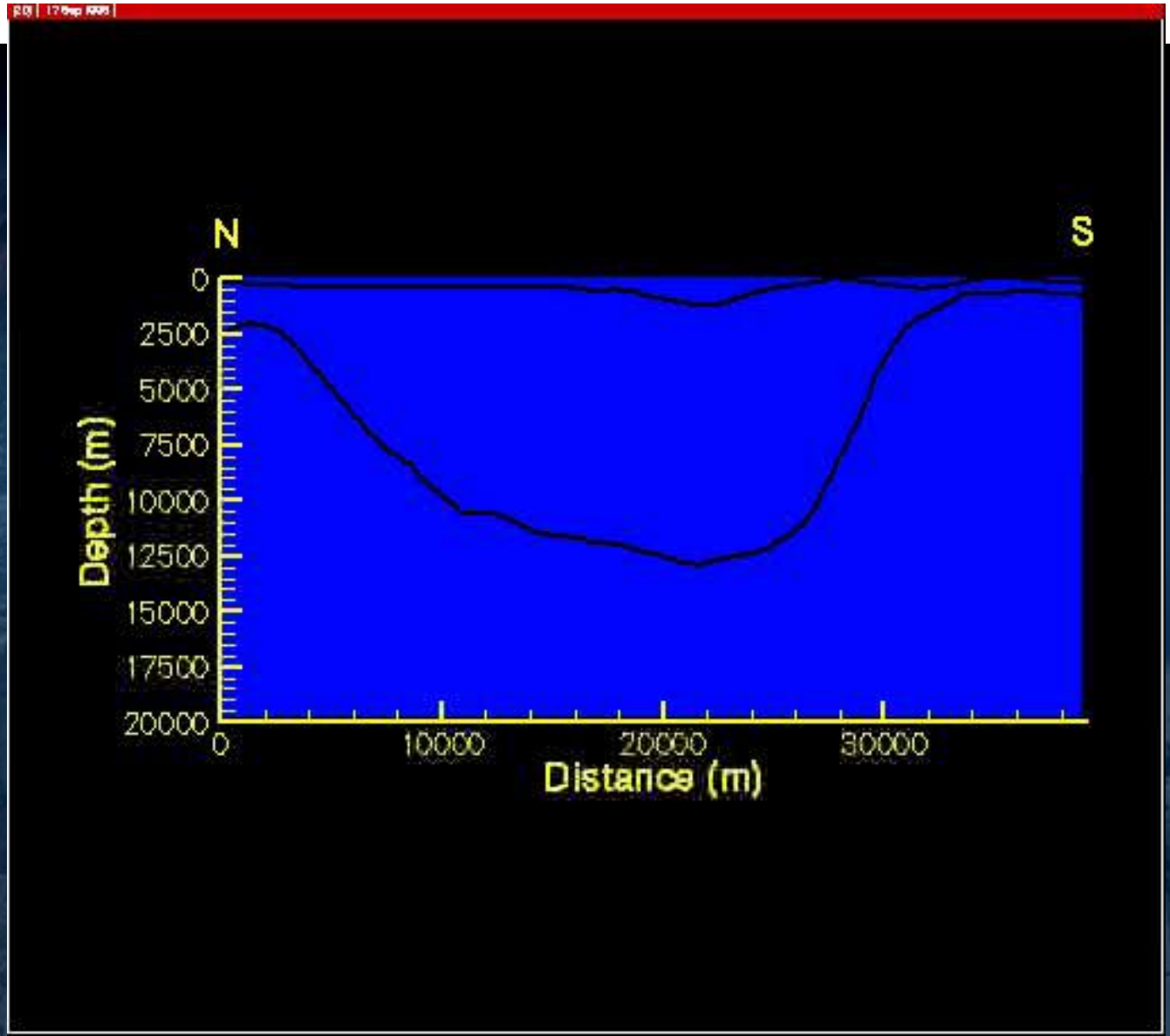
- Include the effects of the local geology
- Need detailed maps of surficial geology and knowledge of sub-surface geology
- Useful for: prioritizing retrofitting of unreinforced masonry buildings, initial seismic design of structures, screening studies, urban planning



USGS

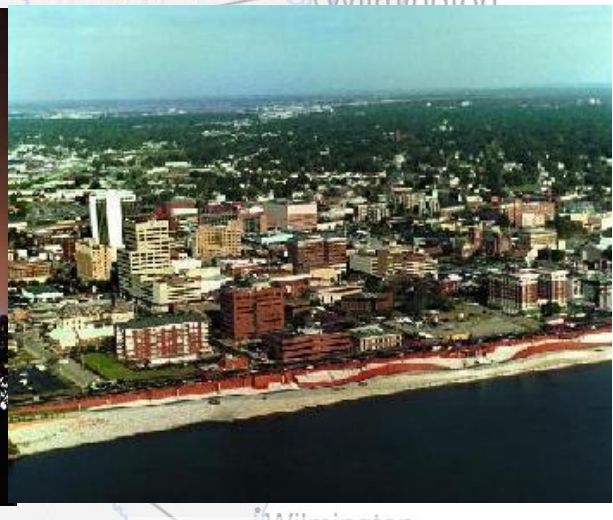


Computer Simulation of M6.5 Earthquake near Seattle Showing How Shallow Soils Amplify and Trap Seismic Waves



USGS

Urban hazard mapping in the Central U.S. involves local and state partners



St. Louis

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USGS science for a changing world

Saint Louis University Earthquake Center

ISGS Illinois State Geological Survey

Missouri Dept Of Natural Resources

University of Missouri-Rolla

The University of Memphis

Kentucky Geological Survey University of Kentucky

ERI

Research Questions on Mid-America Earthquakes To Reduce Uncertainties and Improve Risk Mitigation

- What is the full extent of the New Madrid seismic zone? Search for more geologic evidence. Use seismic and geophysical exploration methods to identify active fault systems.
- Are there other areas in mid-America besides the New Madrid zone that can produce large earthquakes? How often do they occur? We know that Wabash Valley zone has M≥6.5 with about 4000 yr recurrence. Search for geological and geophysical evidence of prehistoric earthquakes and active fault systems.
- Can we identify areas of high hazard using GPS measurements of ground deformation?
- What level of ground shaking can we expect from future large earthquakes? Use data from the Advanced National Seismic System; map the properties of soils that amplify ground shaking; need more instruments to improve Shakemap and urban hazard maps

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Earthquakes ★ Floods ★ Hurricanes ★ Landslides ★ Tsunamis ★ Volcanoes ★ Wildfires

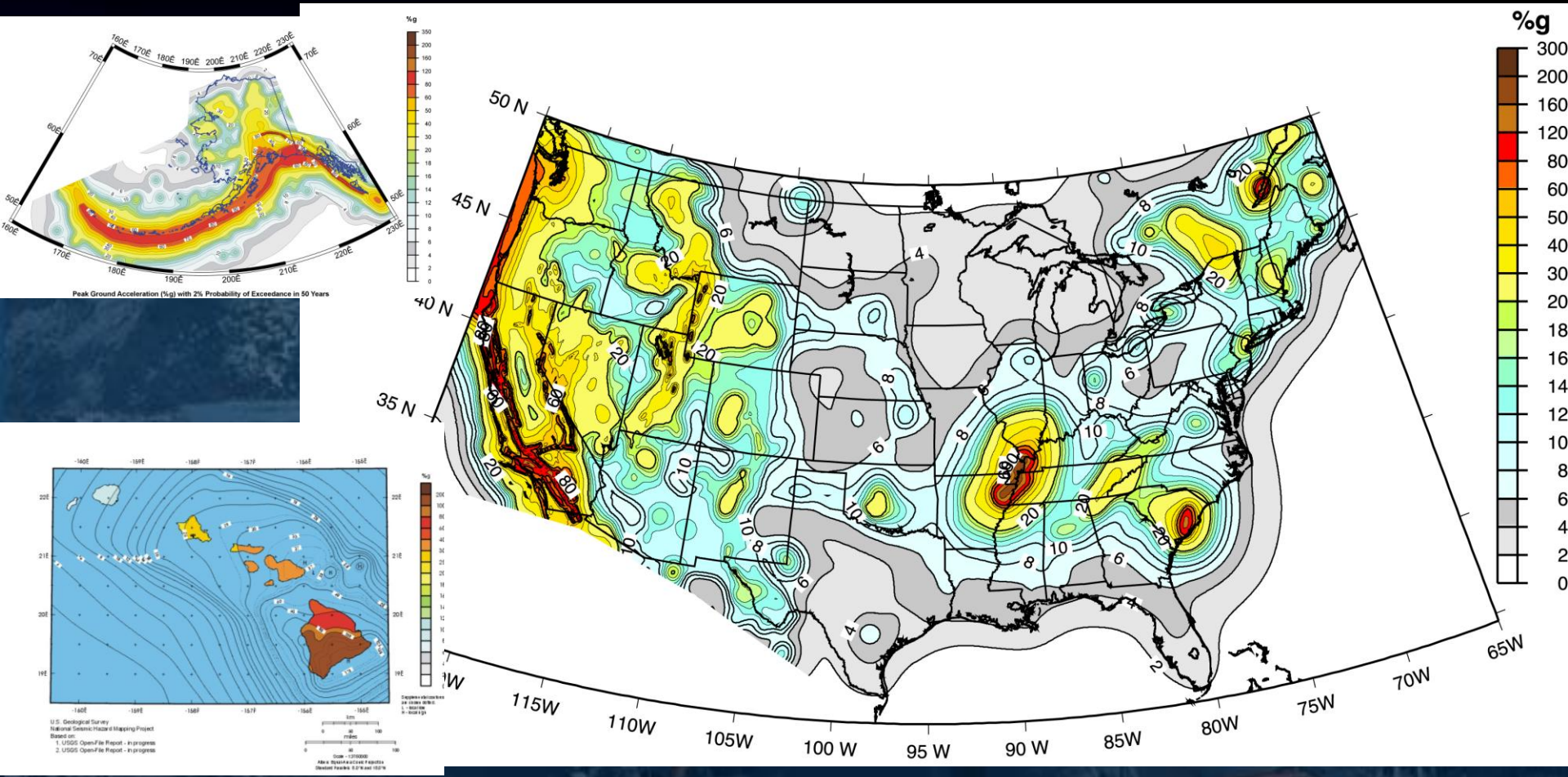
USGS

From Earthquake Monitoring and Research To Improving Public Safety

- Scenario ground-shaking maps provide information on expected shaking for future large earthquakes to emergency managers, engineers, government officials, businesses, and the public, so that they can plan for these earthquakes and ensure community resilience
- ShakeMaps provide rapid information on observed and expected ground shaking when an earthquake occurs; key to situational awareness and emergency response to reduce loss of life and property and speed business recovery
- Seismograms from ANSS are used in the design of buildings and critical facilities; they tell us how strong the ground will shake in future large earthquakes

USGS

What we can do before the earthquake to reduce its effects on communities: the USGS makes national seismic hazard maps based on geoscience research conducted by the USGS, state geological surveys, universities, and the private sector, funded through NEHRP

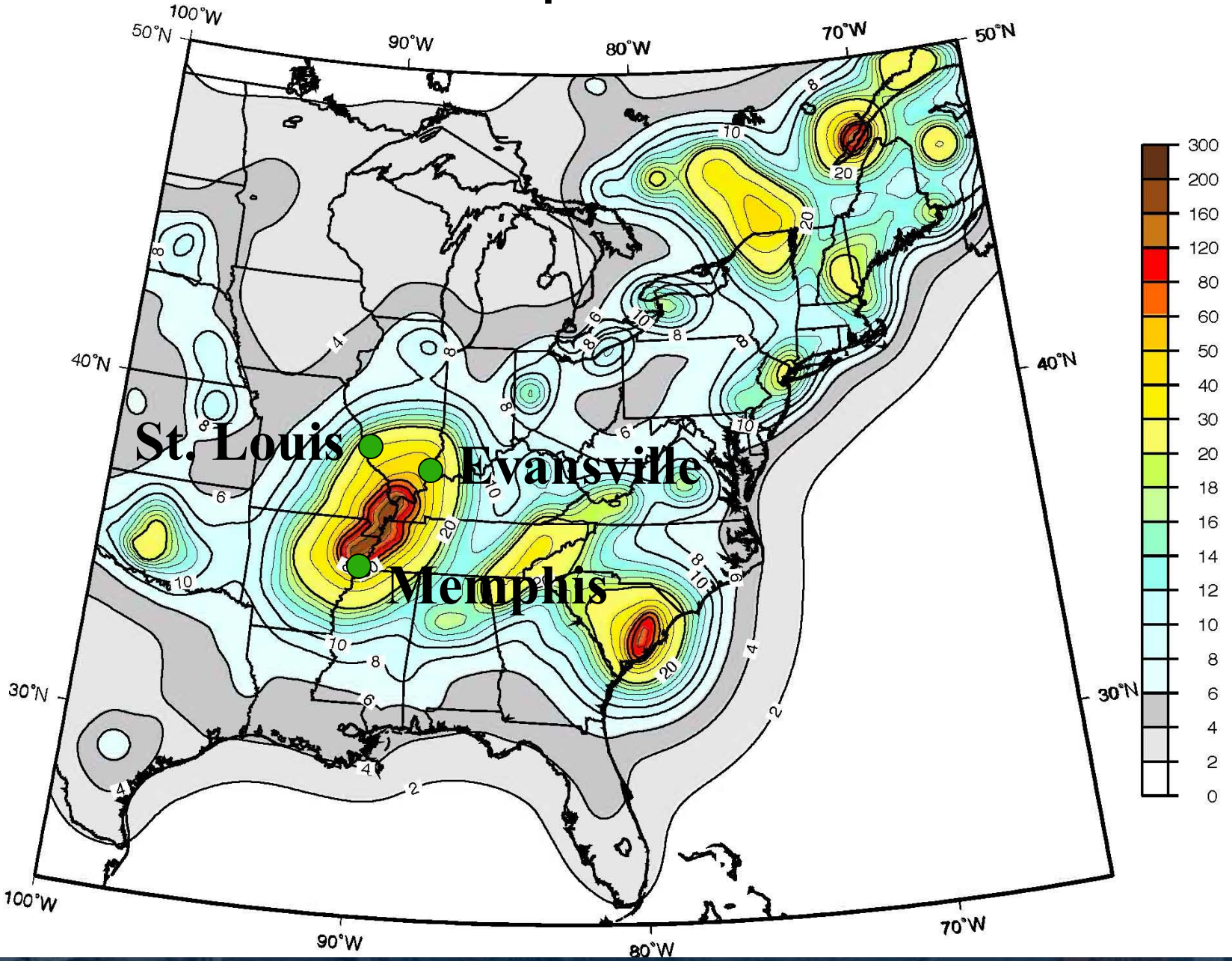


One of the USGS National Seismic Hazard Maps: shows the ground shaking with a 2% chance of being exceeded in 50 years

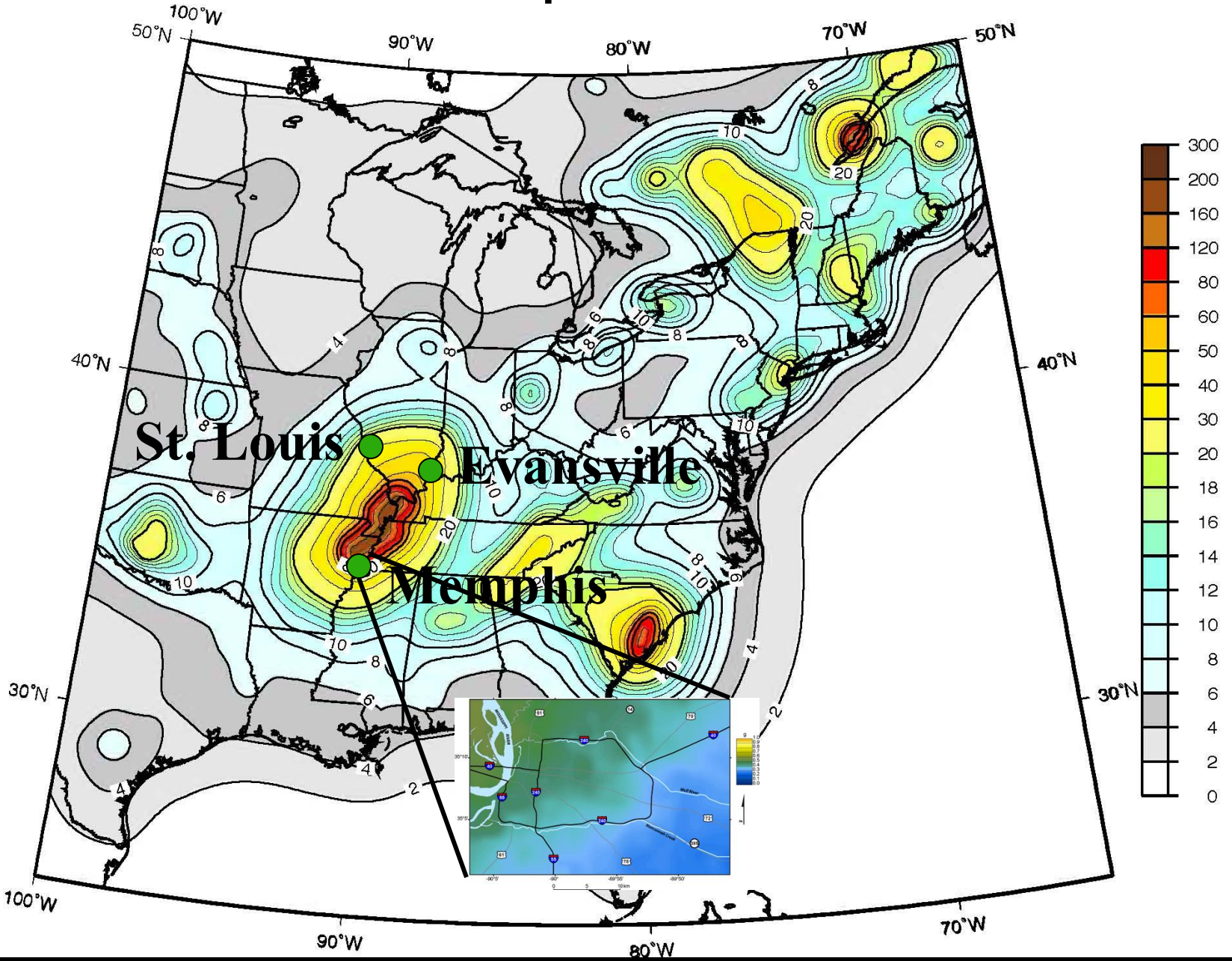
Earthquakes ★ Floods ★ Hurricanes ★ Landslides ★ Tsunamis ★ Volcanoes ★ Wildfires

USGS

Urban Hazard Maps in the Central U.S.



Urban Hazard Maps in the Central U.S.



Urban hazard maps involve state and local partners

University of Missouri-Rolla

Saint Louis University Earthquake Center

USGS science for a changing world

Missouri Dept Of Natural Resources

ISGS Illinois State Geological Survey

Making Seismic Hazard Maps

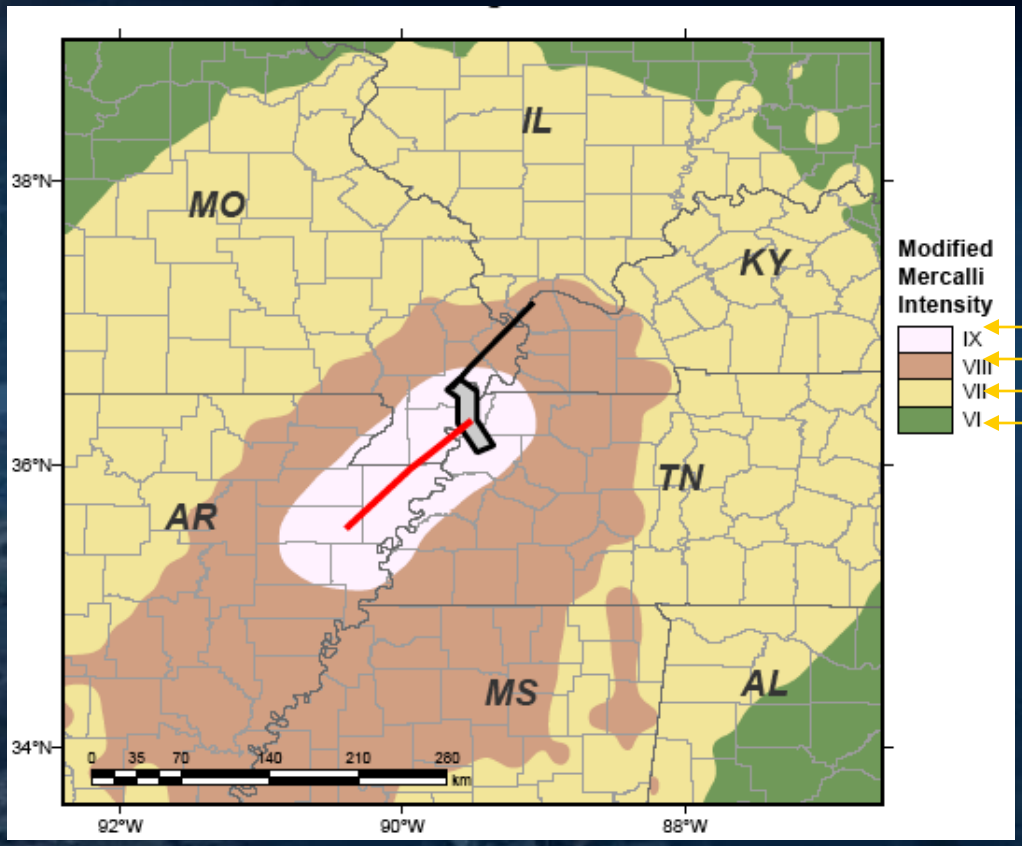
- **Use fault information, evidence of prehistoric earthquakes, instrumental and historical earthquake catalog (ANSS), and ground deformation measurements to estimate probabilities of large earthquakes**
- **Estimate the level of ground shaking if these earthquakes occur (ANSS data)**
- **Hazard maps show the ground shaking to be expected with a certain probability**

USGS

USGS makes ground-motion maps for earthquake scenarios:

M 7.7 Southwest Segment

New Madrid Seismic Zone



USGS

Here we have converted ground motion values to intensities

These types of maps are used to estimate losses given inventory of buildings

From Science to Mitigation of Risk

Earth Science Information

Seismological: earthquake monitoring , ground-motion studies (ANSS)

Geological: studies of prehistoric earthquakes, fault studies, geologic mapping

Geophysical: crustal deformation GPS, studies to determine subsurface properties

Quantitative Assessment Of Hazard

USGS national seismic hazard maps

Urban seismic hazard maps

Scenario ground motion maps

Mitigation of Earthquake Risk

Seismic provisions in building codes

Design standards for bridges

Land-use planning

Loss estimation

Earthquake insurance

Emergency management

USGS

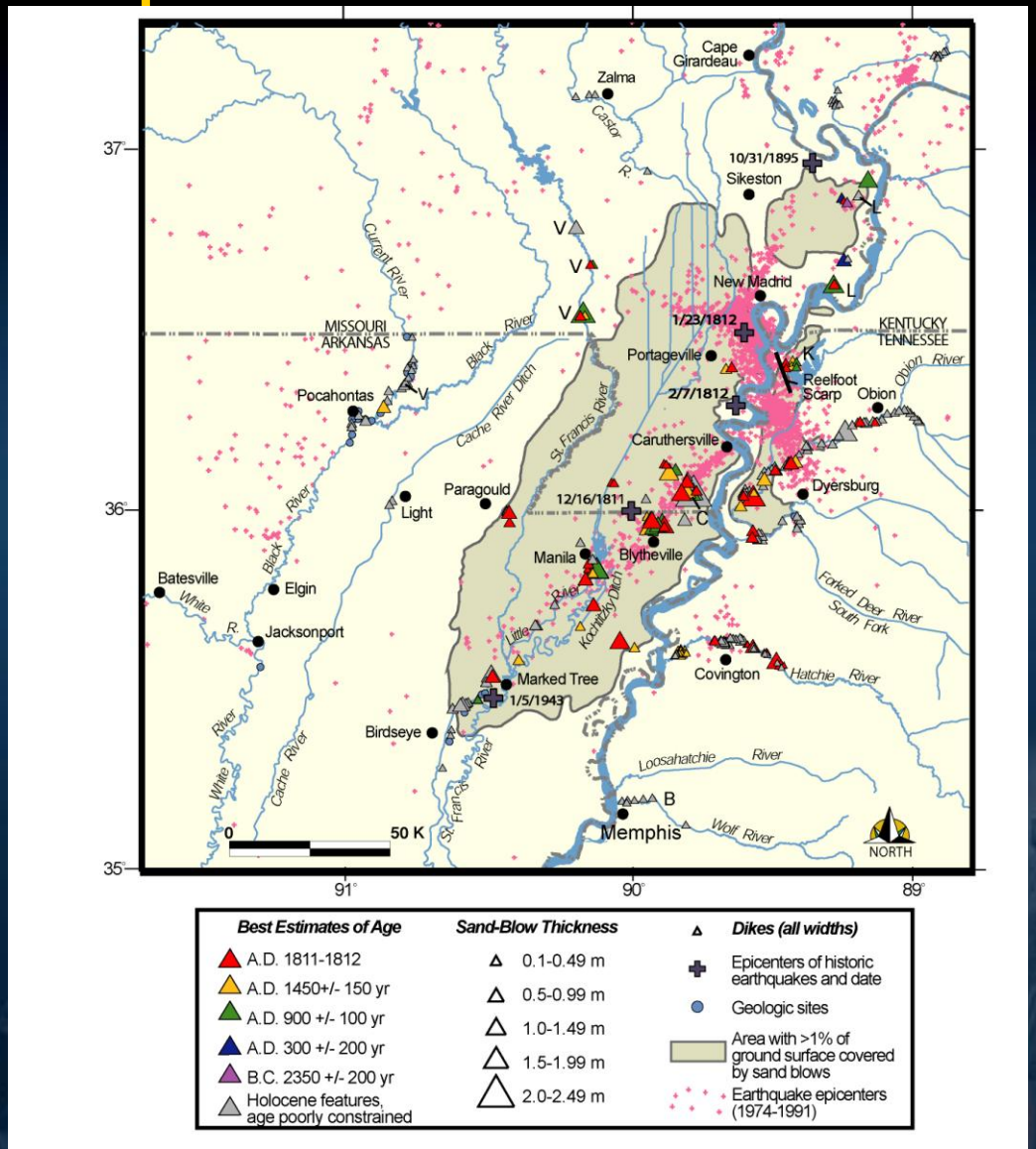
Educate people in earthquake hazard

- **Building shaking scenarios for state and local exercises**
- **Hosting field trips**
- **Local earthquake town hall meetings**
- **Fact sheets**
- **Public Earthquake Resource Center**
- **Preparing educational and informational materials**
- **Working with state emergency management agencies, departments of transportation, and geological surveys through Central U.S. Earthquake Consortium**

USGS

How Often Do 1811-12 Type Earthquakes Occur?

USGS funds studies to identify and date sand blows from prehistoric earthquakes



USGS

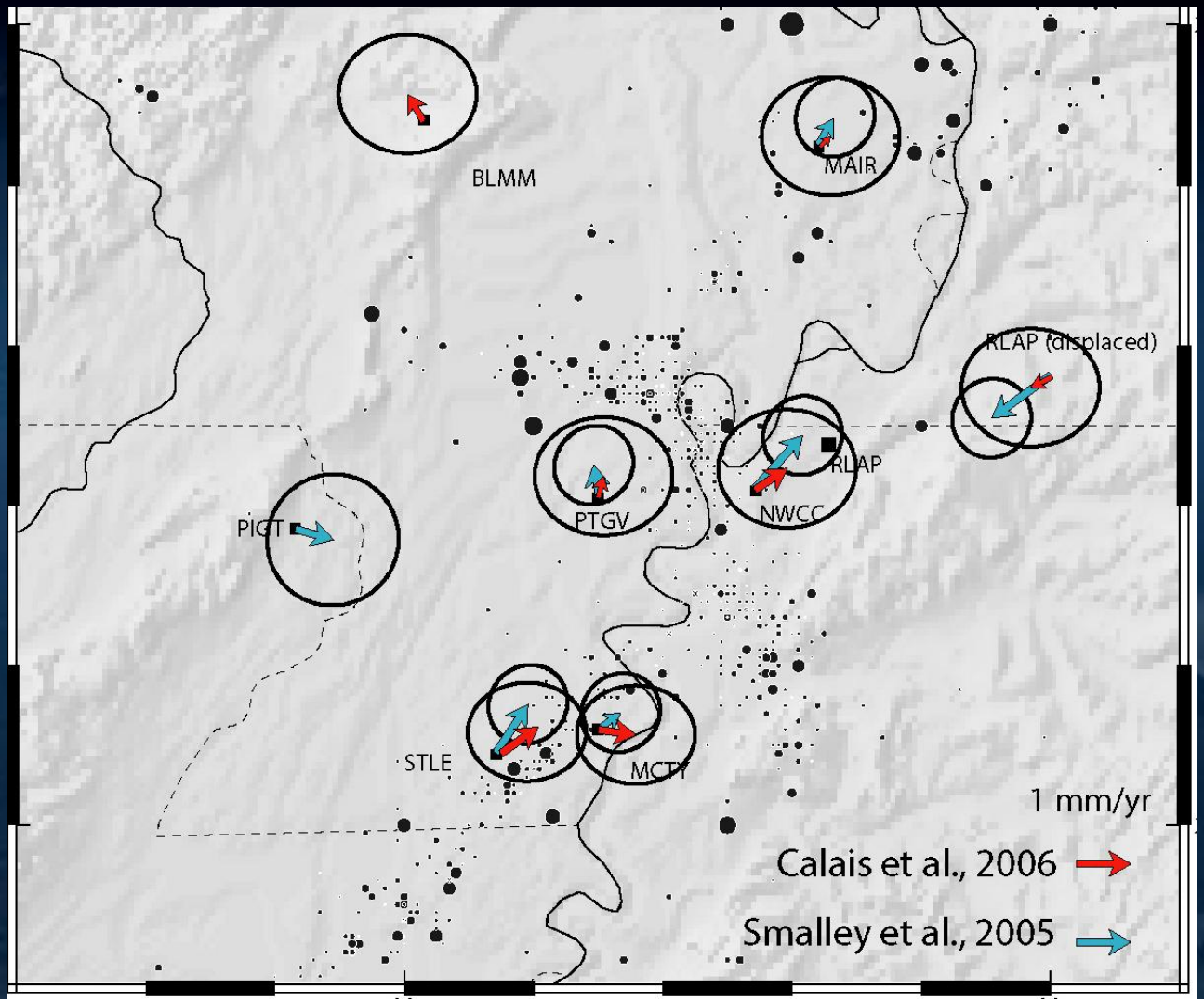
In some states, building codes are adopted on a local level:

Shelby County (Memphis) has recently amended its building code to allow non-essential buildings to be designed to lower ground-shaking levels than used previously. They reduced the force levels for 10 story buildings by 45%, compared to the Standard Building Code that was used prior to 2006.

USGS

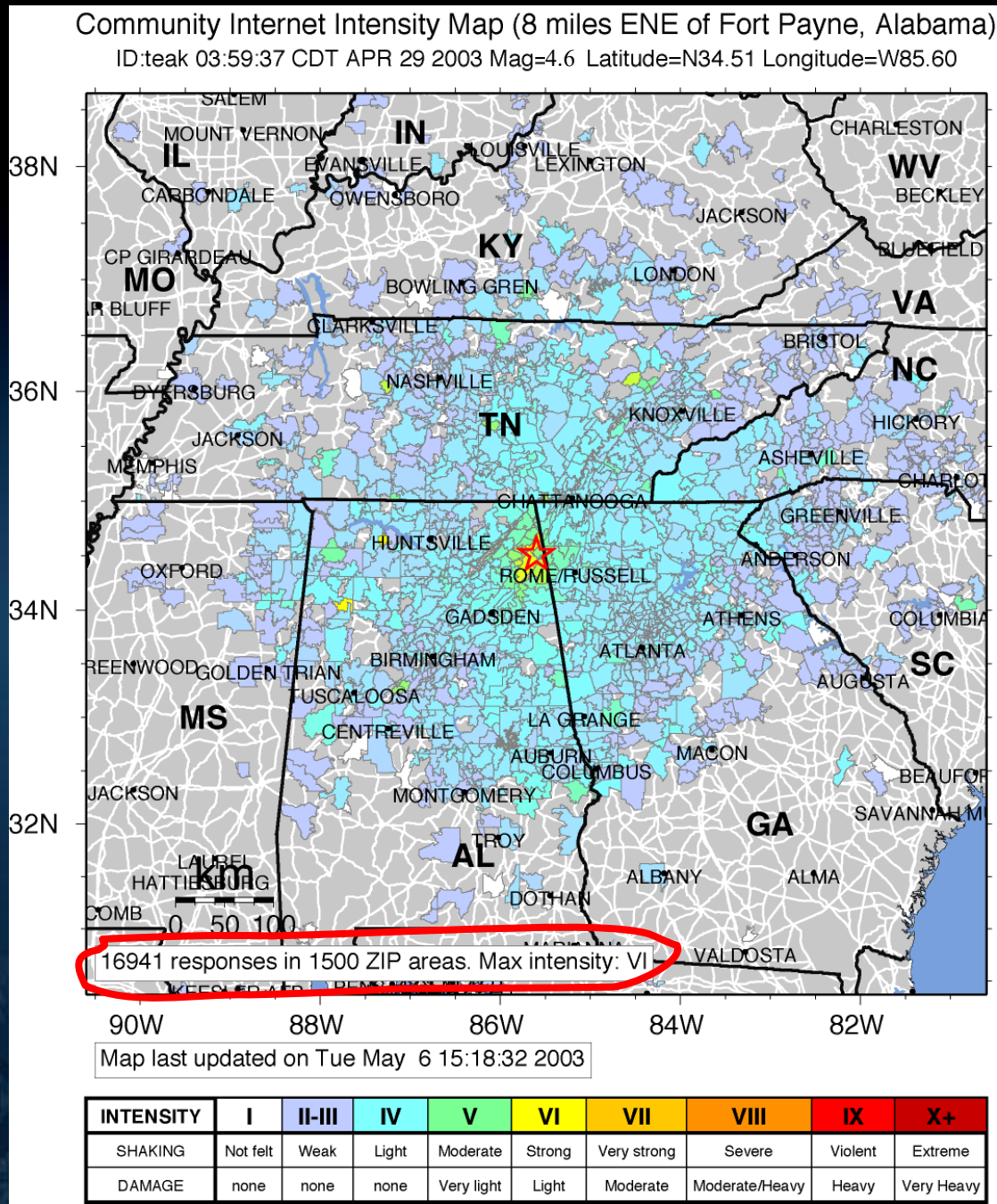
Two GPS studies: one finds significant deformation across New Madrid zone, the other doesn't.
We need a longer observation time; also some models of intra-plate processes predict little deformation in the time between earthquakes.

In any case, there is clear geologic evidence of repeated large earthquakes and high seismic hazard



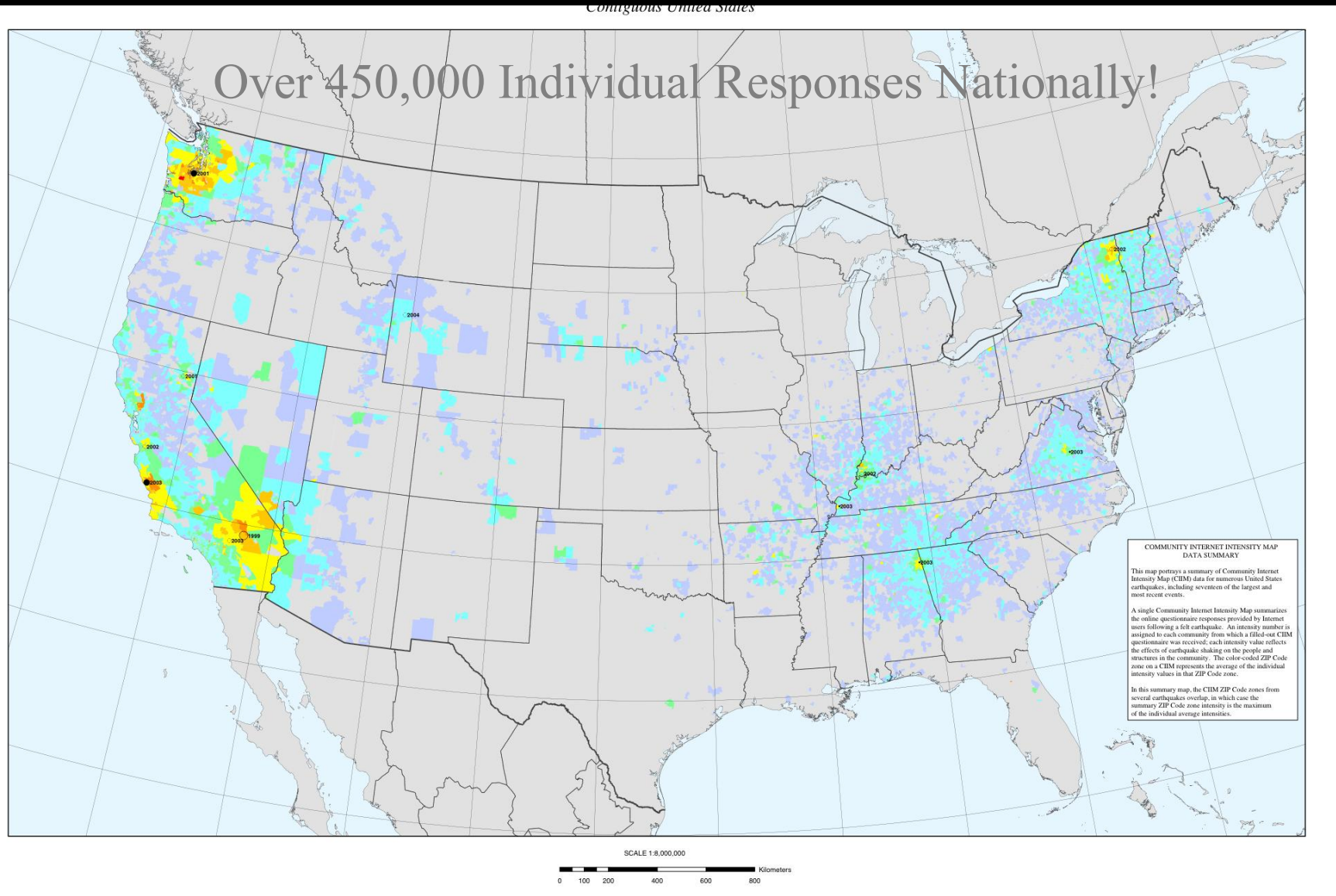
USGS

Did You Feel It?



INTENSITY	I	II-III	IV	V	VI	VII	VIII	IX	X+
SHAKING	Not felt	Weak	Light	Moderate	Strong	Very strong	Severe	Violent	Extreme
DAMAGE	none	none	none	Very light	Light	Moderate	Moderate/Heavy	Heavy	Very Heavy

USGS

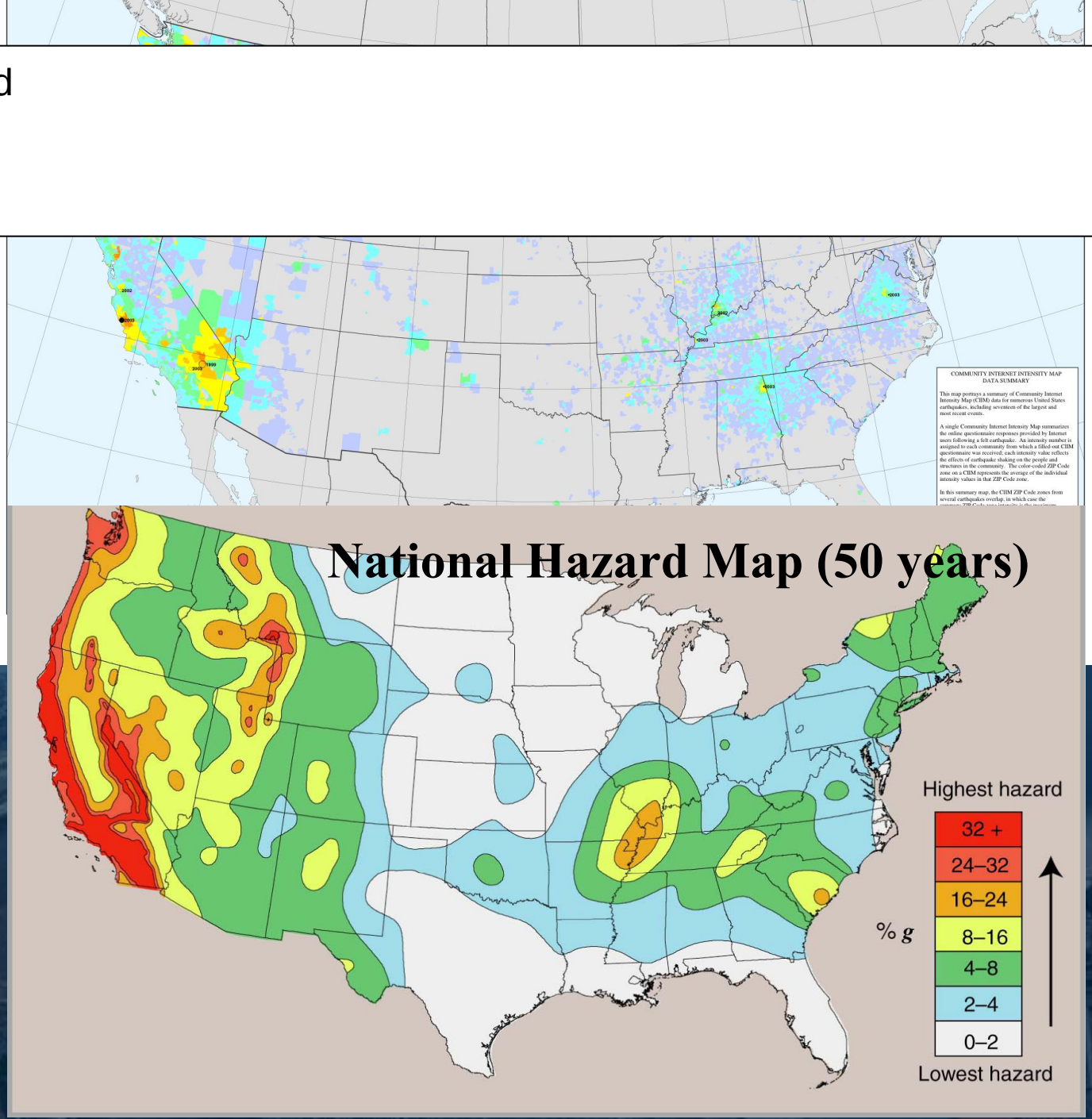


Yellow ≈ MMI 6 Slide provided by D. Wald, USGS

Earthquakes

Wildfires

Slide composed
by D. Wald



USGS

USGS
science for a changing world