# Central U.S. Earthquakes: History & What to Expect

Robert A. Bauer
Illinois State Geological Survey

ILLINOIS
UNIVERSITY OF ILLINOIS AT URBANA-CHAMPAIGN

ILLINOIS STATE GEOLOGICAL SURVEY
PRAIRIE RESEARCH INSTITUTE

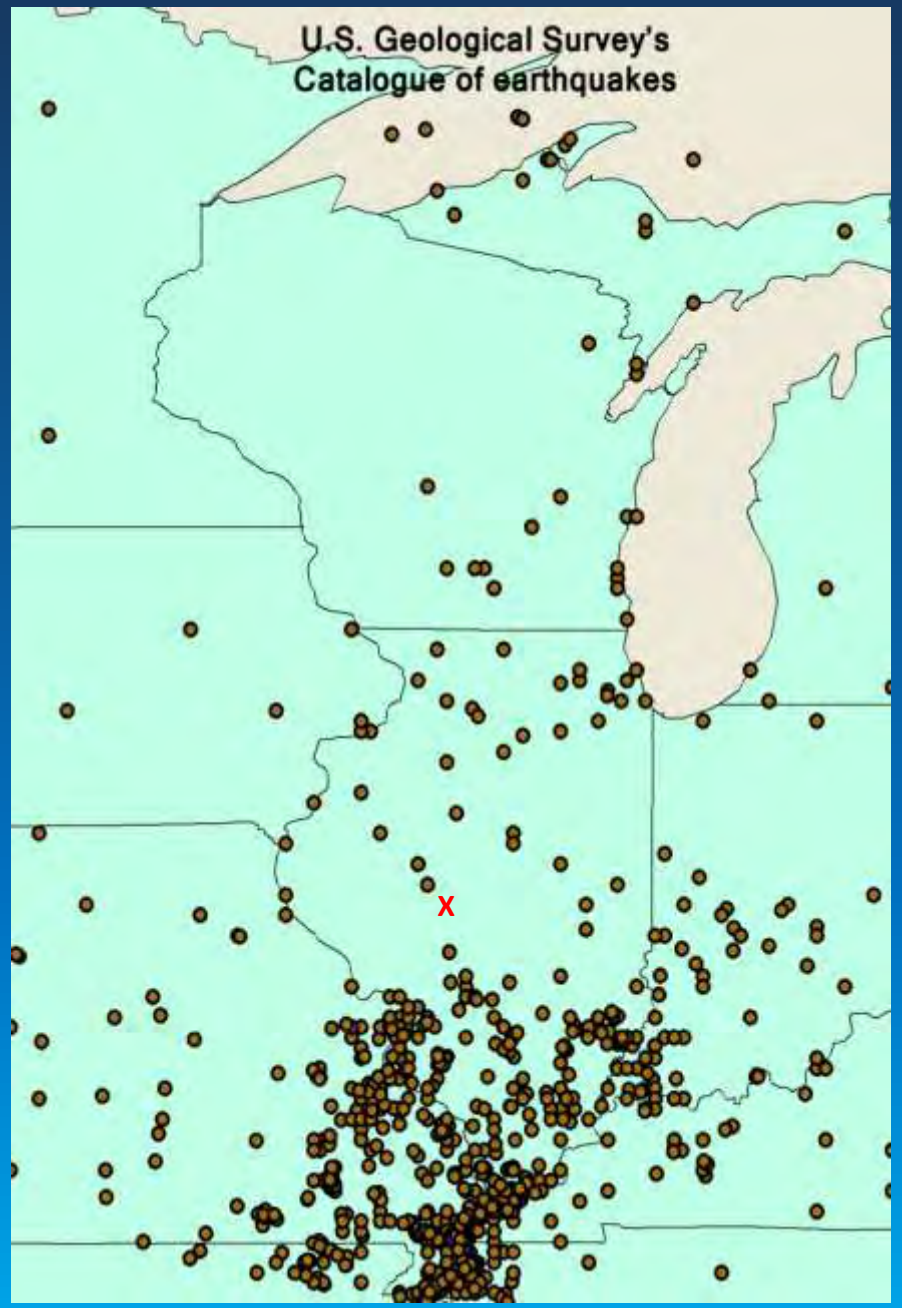
General background on earthquakes

New Madrid 1811-1812 earthquakes & aftershocks

Pre-historic earthquakes in Central U.S.

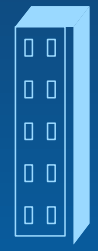
What types of damage might you encounter?

Where is it going to affect Illinois?

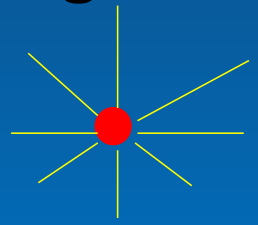

U.S. Geological Survey's
Catalogue of earthquakes
X

# FACTORS AFFECTING GROUND MOTION

Distance



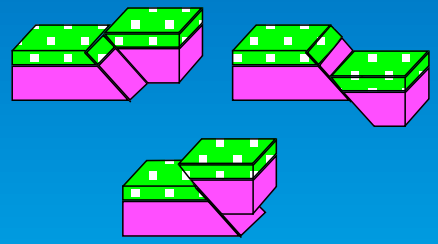
Magnitude



Condition
of rock along
transmission path

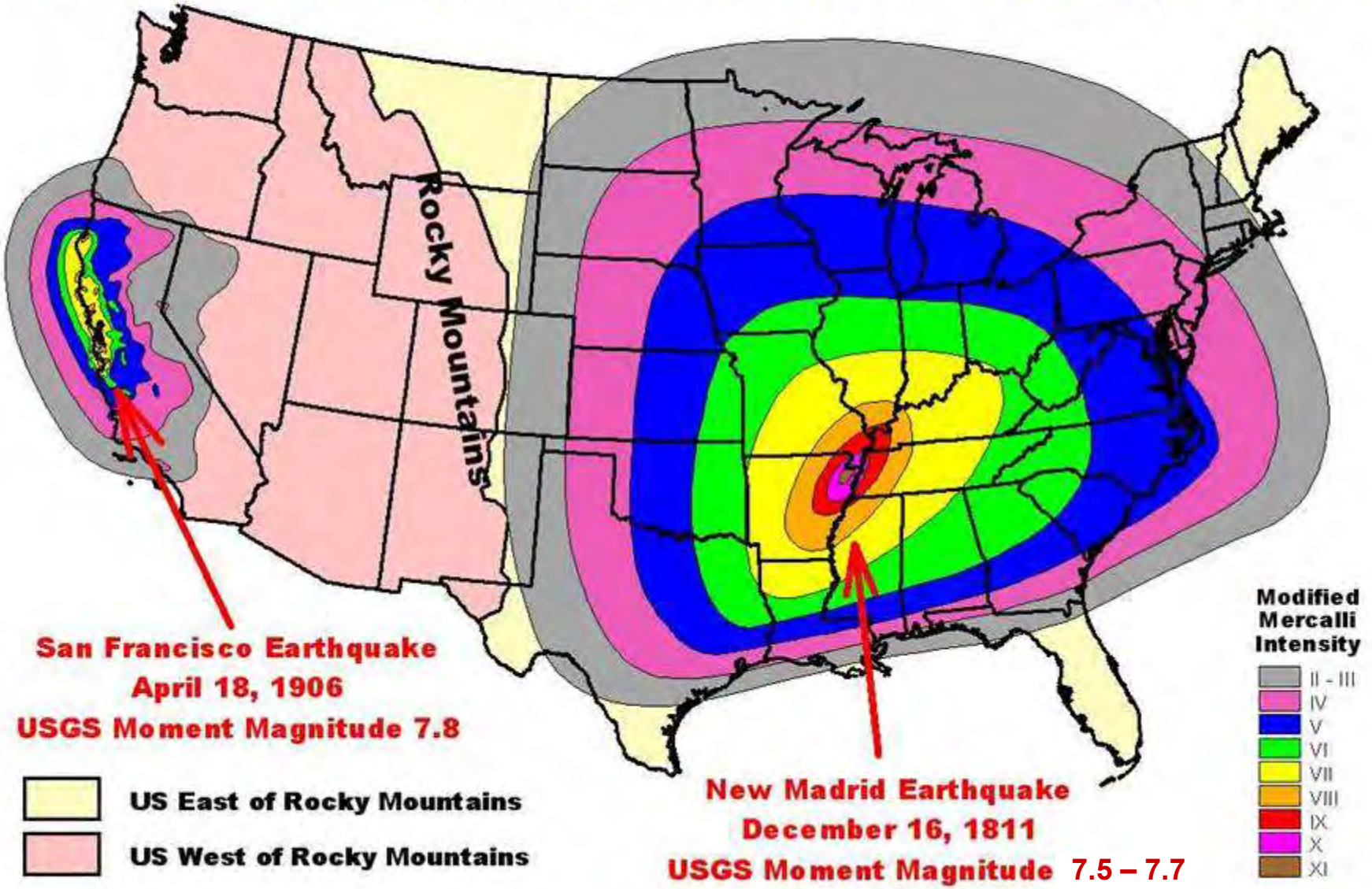
Local Soil
Conditions

Source
mechanism



Duration of Shaking

# Modified Mercalli Intensity Areas for Central & Eastern verses Western US Earthquakes



# INTENSITY

Is an evaluation of the

effects,

observations,

and

experiences

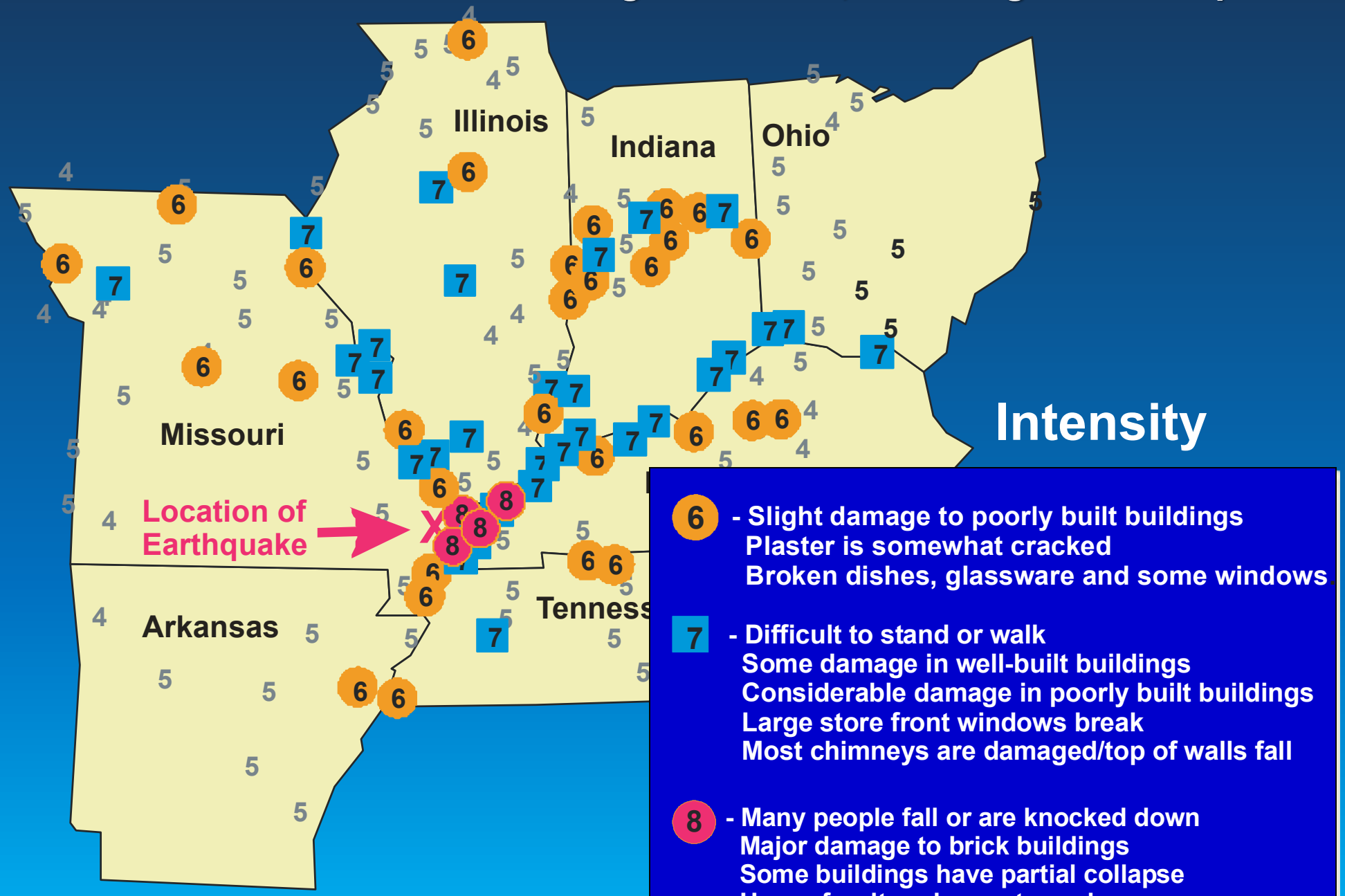
in an area.

# Intensity

| MMI Value | Perceived Shaking | Potential Damage | Full Description |
|---|---|---|---|
| I. | Not Felt | None | Not felt. Marginal and long period effects of large earthquakes. |
| II. | Weak | None | Felt by persons at rest, on upper floors, or favorably placed. |
| III. | Weak | None | Felt indoors. Hanging objects swing. Vibration like passing of light trucks. Duration estimated. May not be recognized as an earthquake. |
| IV. | Light | None | Hanging objects swing. Vibration like passing of heavy trucks; or sensation of a jolt like a heavy ball striking the walls. Standing motor cars rock. Windows, dishes, doors rattle. Glasses clink. Crockery clashes. In the upper range of IV, wooden walls and frame creak. |
| V. | Moderate | Very Light | Felt outdoors; direction estimated. Sleepers wakened. Liquids disturbed, some spilled. Small unstable objects displaced or upset. Doors swing, close, open. Shutters, pictures move. Pendulum clocks stop, start, change rate. |
| VI. | Strong | Light | Felt by all. Many frightened and run outdoors. Persons walk unsteadily. Windows, dishes, glassware broken. Knickknacks, books, etc., off shelves. Pictures off walls. Furniture moved or overturned. Weak plaster and masonry D cracked. Small bells ring (church, school). Trees, bushes shaken (visibly, or heard to rustle). |
| VII. | Very Strong | Moderate | Difficult to stand. Noticed by drivers of motor cars. Hanging objects quiver. Furniture broken. Damage to masonry D, including cracks. Weak chimneys broken at roof line. Fall of plaster, loose bricks, stones, tiles, cornices (also unbraced parapets and architectural ornaments). Some cracks in masonry C. Waves on ponds; water turbid with mud. Small slides and caving in along sand or gravel banks. Large bells ring. Concrete irrigation ditches damaged. |
| VIII. | Severe | Moderate/Heavy | Steering of motor cars affected. Damage to masonry C; partial collapse. |

| | | | |
|---|---|---|---|
| | | | Doors swing, close, open. Shutters, pictures move. Pendulum clocks stop, start, change rate. |
| **VI.** | **Strong** | **Light** | Felt by all. Many frightened and run outdoors. Persons walk unsteadily. Windows, dishes, glassware broken. Knickknacks, books, etc., off shelves. Pictures off walls. Furniture moved or overturned. Weak plaster and masonry D cracked. Small bells ring (church, school). Trees, bushes shaken (visibly, or heard to rustle). |
| **VII.** | **Very Strong** | **Moderate** | Difficult to stand. Noticed by drivers of motor cars. Hanging objects quiver. Furniture broken. Damage to masonry D, including cracks. Weak chimneys broken at roof line. Fall of plaster, loose bricks, stones, tiles, cornices (also unbraced parapets and architectural ornaments). Some cracks in masonry C. Waves on ponds; water turbid with mud. Small slides and caving in along sand or gravel banks. Large bells ring. Concrete irrigation ditches damaged. |
| **VIII.** | **Severe** | **Moderate/Heavy** | Steering of motor cars affected. Damage to masonry C; partial collapse. Some damage to masonry B; none to masonry A. Fall of stucco and some masonry walls. Twisting, fall of chimneys, factory stacks, monuments, towers, elevated tanks. Frame houses moved on foundations if not bolted down; loose panel walls thrown out. Decayed piling broken off. Branches broken from trees. Changes in flow or temperature of springs and wells. Cracks in wet ground and on steep slopes. |
| **IX.** | **Violent** | **Heavy** | Masonry D destroyed; masonry C heavily damaged, sometimes with complete collapse; masonry B seriously damaged. (General damage to foundations.) Frame structures, if not bolted, shifted off foundations. Frames racked. Serious damage to reservoirs. Underground pipes broken. Conspicuous cracks in ground. In alluvial areas sand and mud ejected, earthquake fountains, sand craters. |
| **X.** | **Extreme** | **Very Heavy** | Most masonry and frame structures destroyed with their foundations. Some well-built wooden structures and bridges destroyed. Serious damage to dams, dikes, embankments. Large landslides. Water thrown on banks of canals, rivers, lakes, etc. Sand and mud shifted horizontally on beaches and flat land. Rails bent slightly. |

# What was felt in different cities during the Oct. 31, 1895 Mag. 6.0 Earthquake

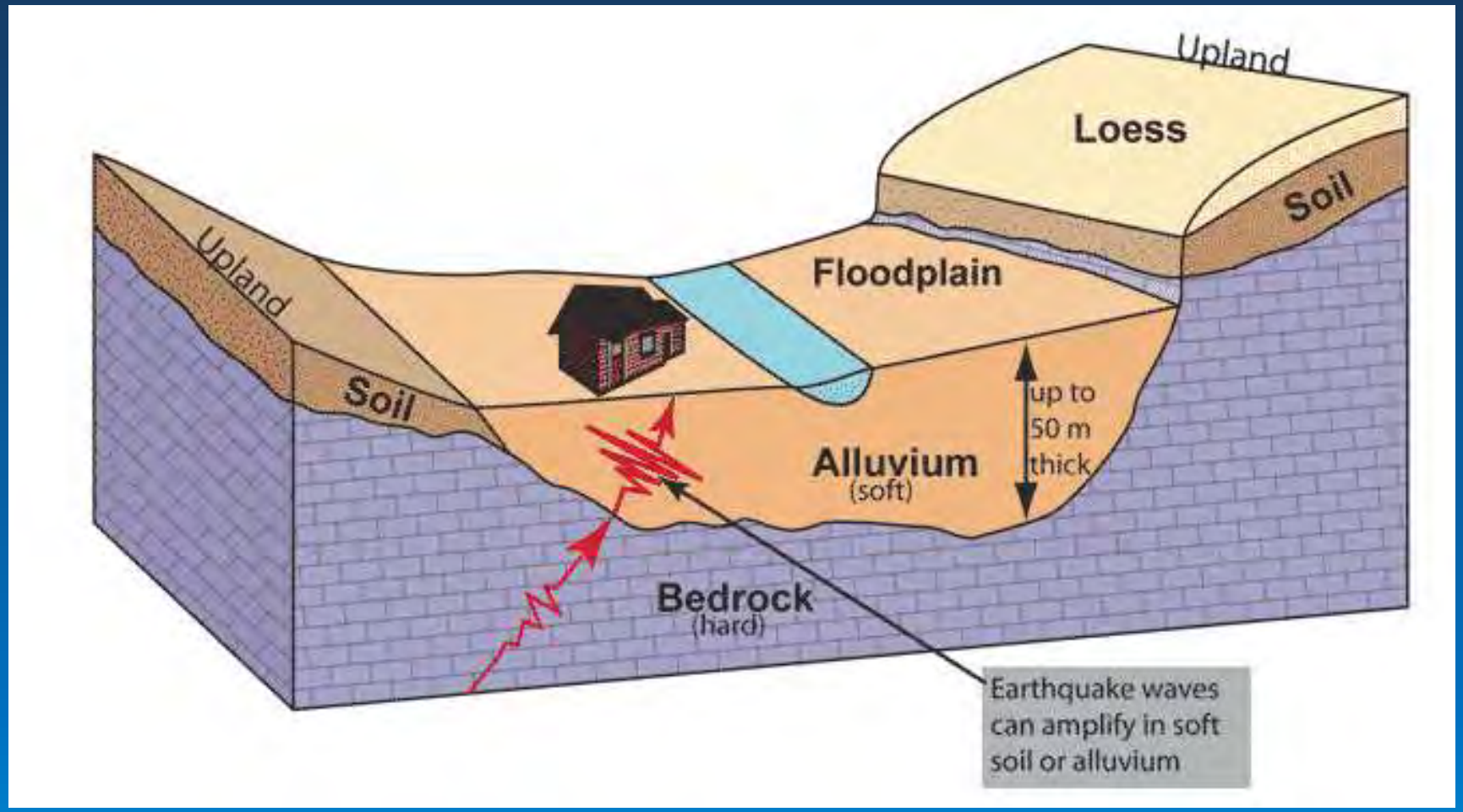


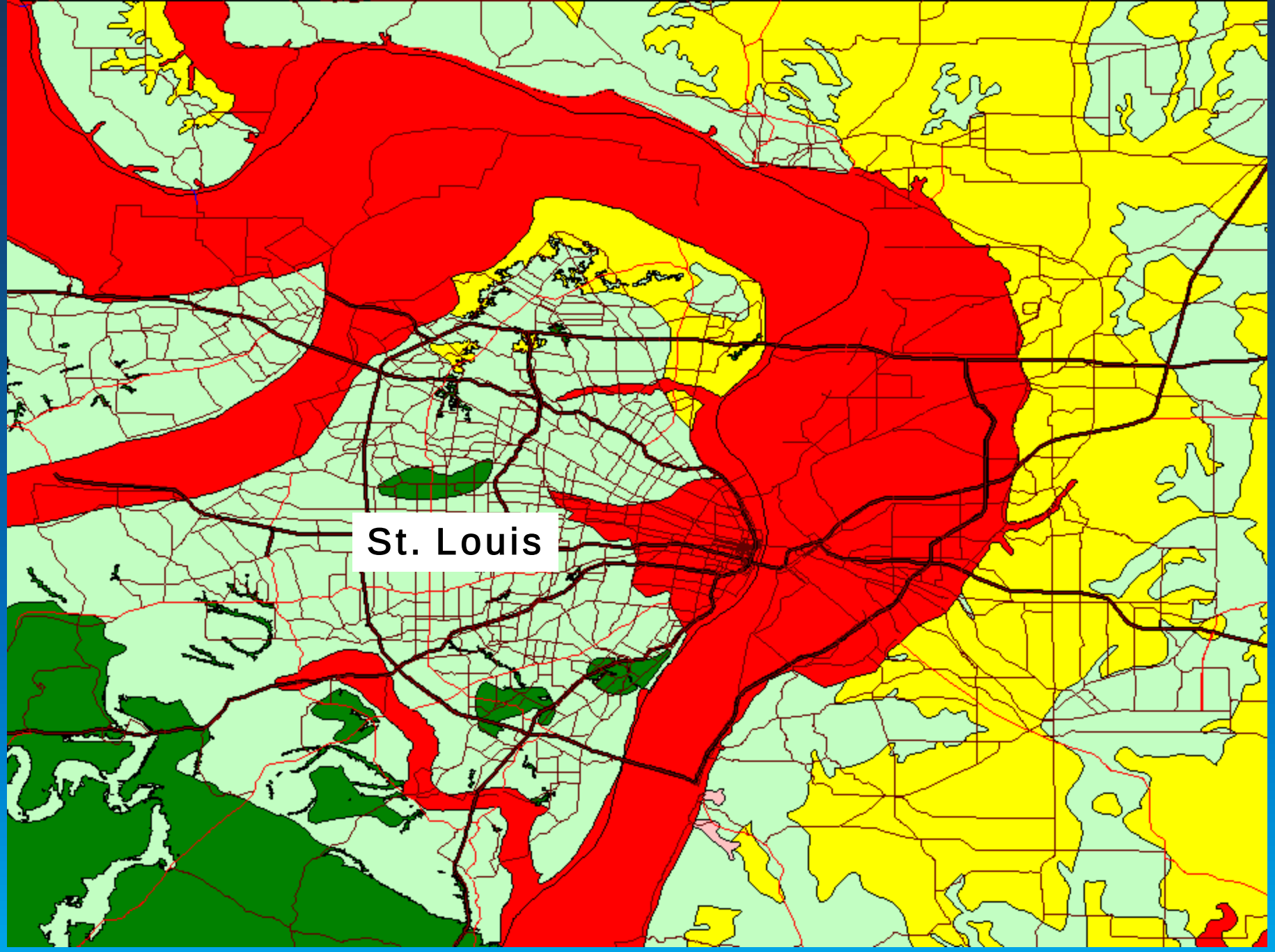

## Intensity

**6** - Slight damage to poorly built buildings
Plaster is somewhat cracked
Broken dishes, glassware and some windows

**7** - Difficult to stand or walk
Some damage in well-built buildings
Considerable damage in poorly built buildings
Large store front windows break
Most chimneys are damaged/top of walls fall

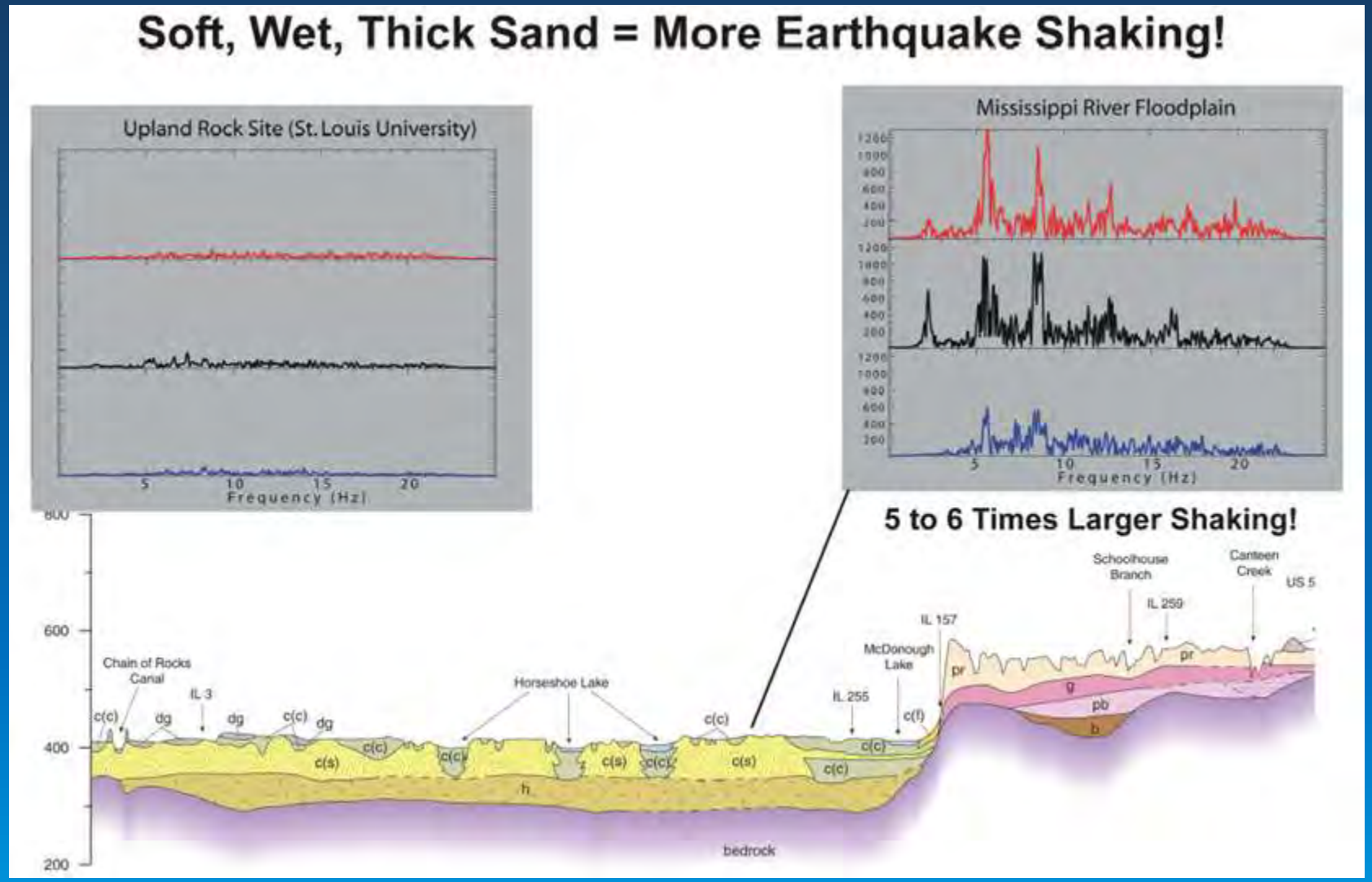
**8** - Many people fall or are knocked down
Major damage to brick buildings
Some buildings have partial collapse
Heavy furniture is overturned


Upland
Loess
Soil
Upland
Floodplain
Soil
up to
50 m
thick
Alluvium
(soft)
Bedrock
(hard)
Earthquake waves
can amplify in soft
soil or alluvium


St. Louis

Bedrock

Floodplain




**Thick, soft, wet river sediments amplify earthquake ground motions compared to bedrock.**

# Loma Prieta – World Series Earthquake  mag = 7.1

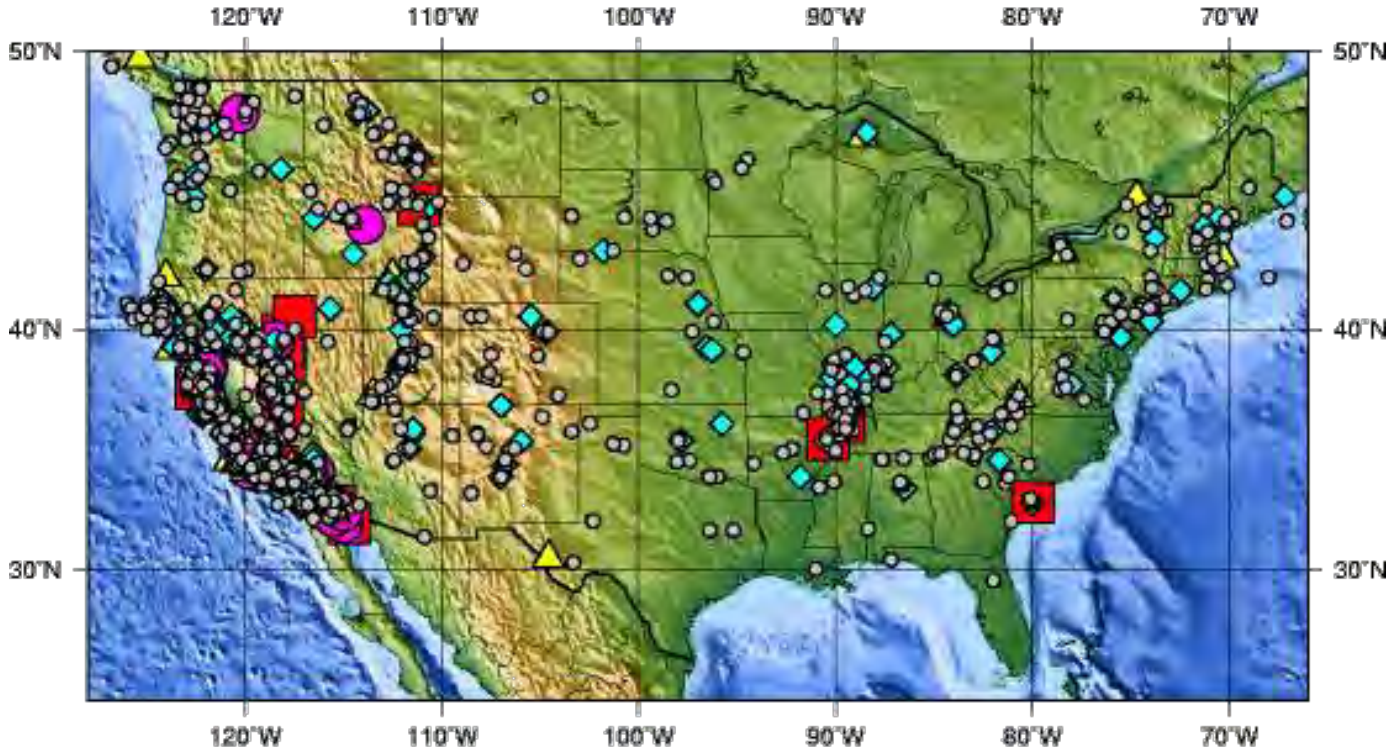
Loma Prieta - Epicenter

60 miles from Epicenter

# US Earthquakes Causing Damage

## 1750 - 1996

## Modified Mercalli Intensity VI - XII




Intensity

- VI
- VII
- VIII
- IX
- X-XII

Prepared by:
USGS National Earthquake Information Center

Data Source:
Seismicity of the United States, 1750 - 1989
Preliminary Determination of Epicenters, 1990 - 1996

# MAGNITUDE

## "Richter Scale"

Is a measure of the

total energy released.

# CHANGES IN MAGNITUDE

## Two Unit Rule

4 → 6 → 8

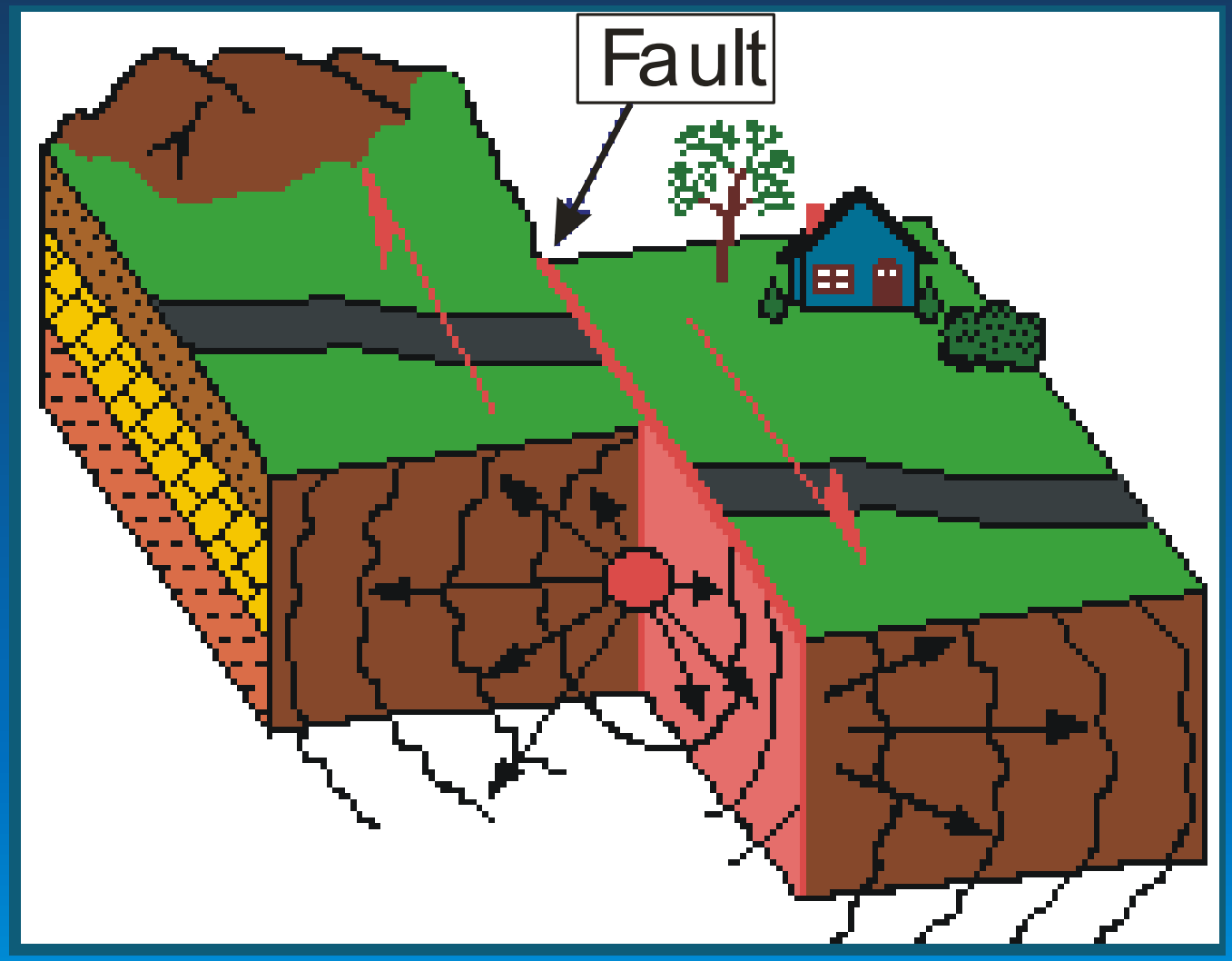
1000 times more energy released

# CHANGES IN MAGNITUDE

## Two-Tenths Rule

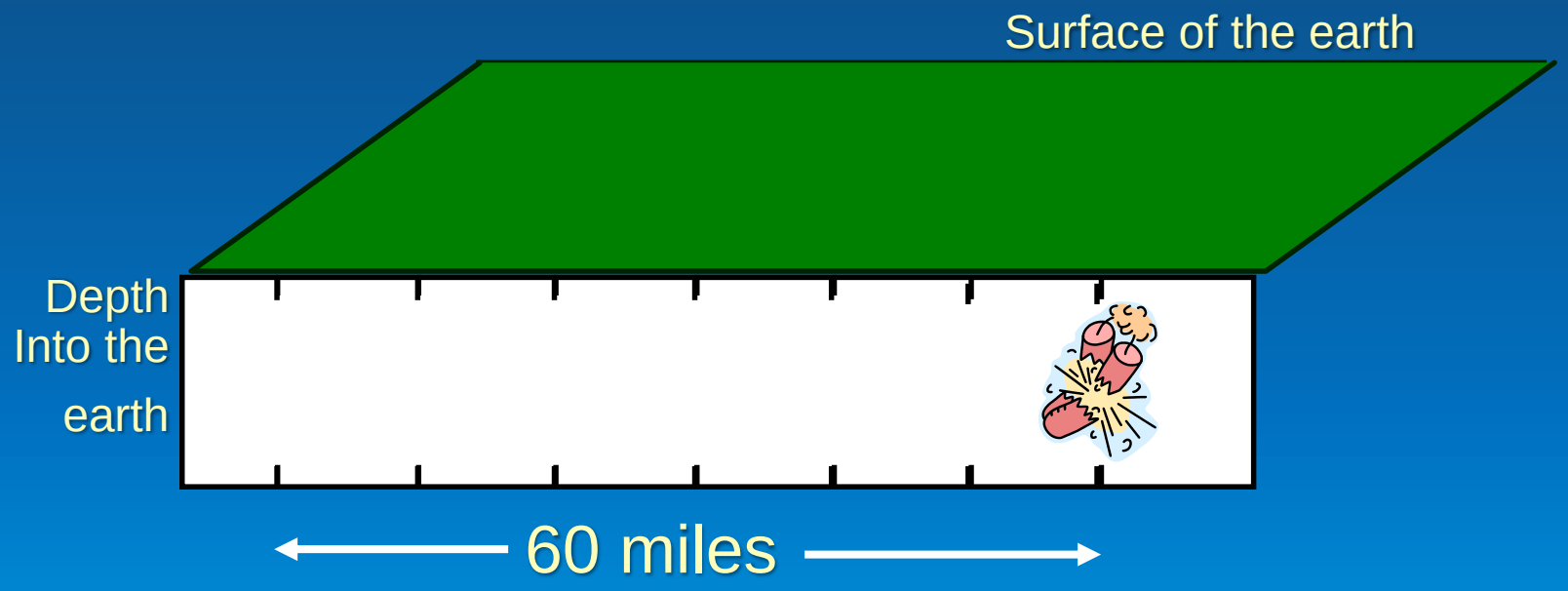
5.2 → 5.4

**Doubles energy released**

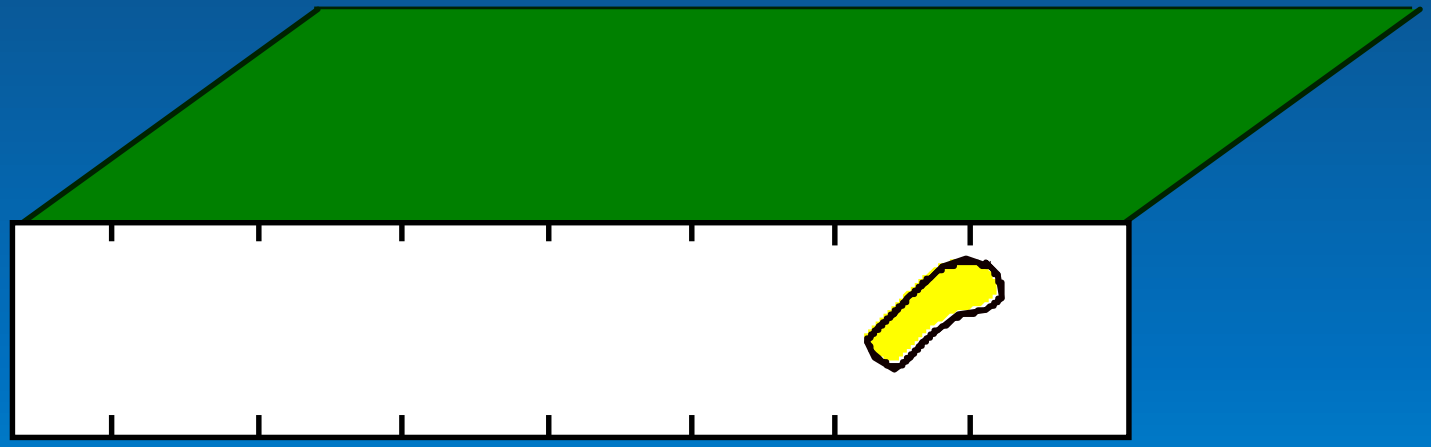



**Strike-Slip Fault**

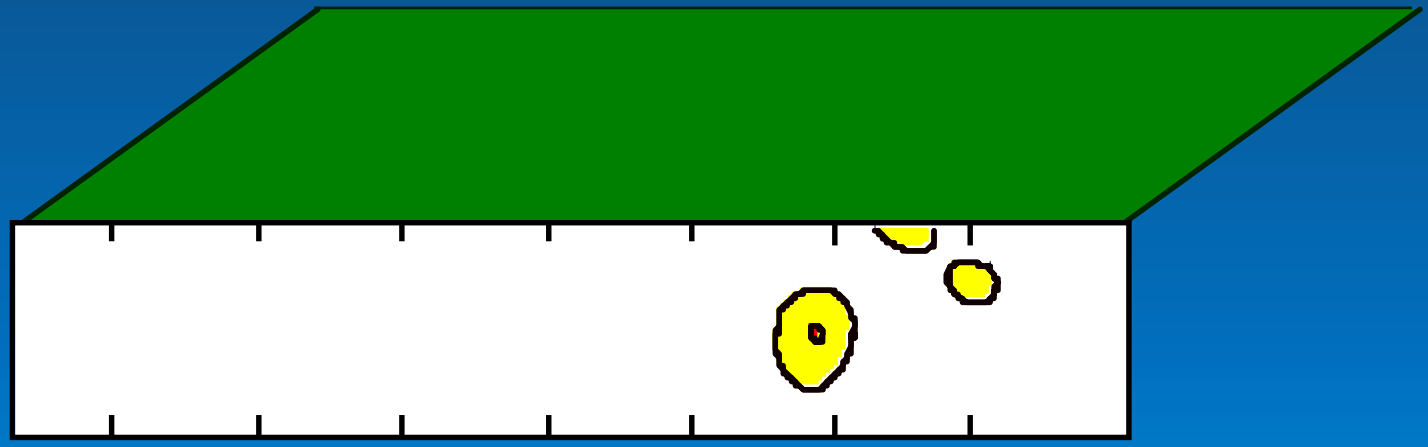
# Slip on fault = earthquake



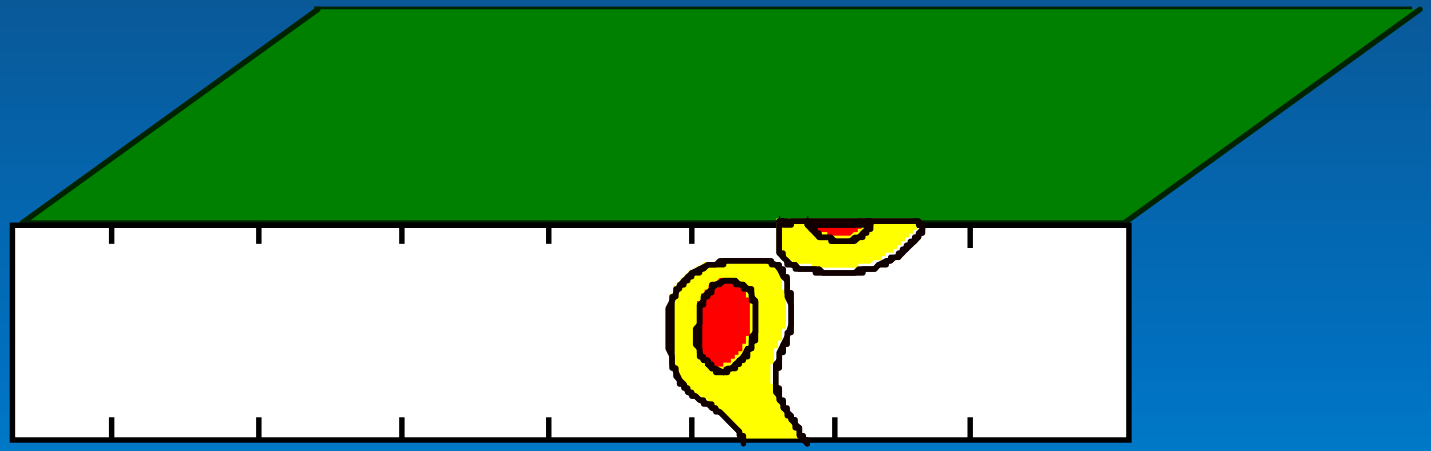
# Second 2.0



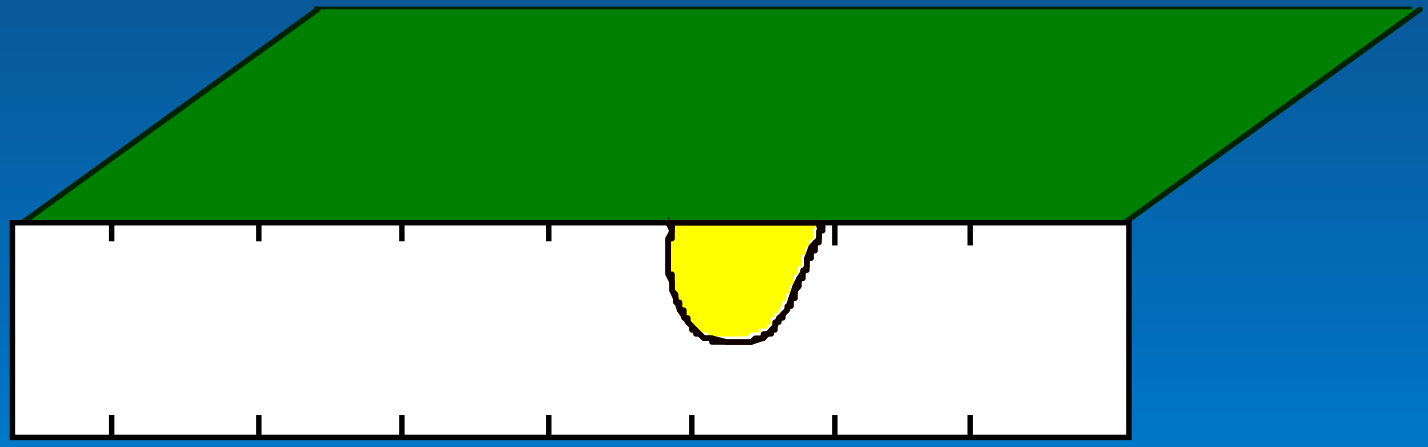
# Second 4.0



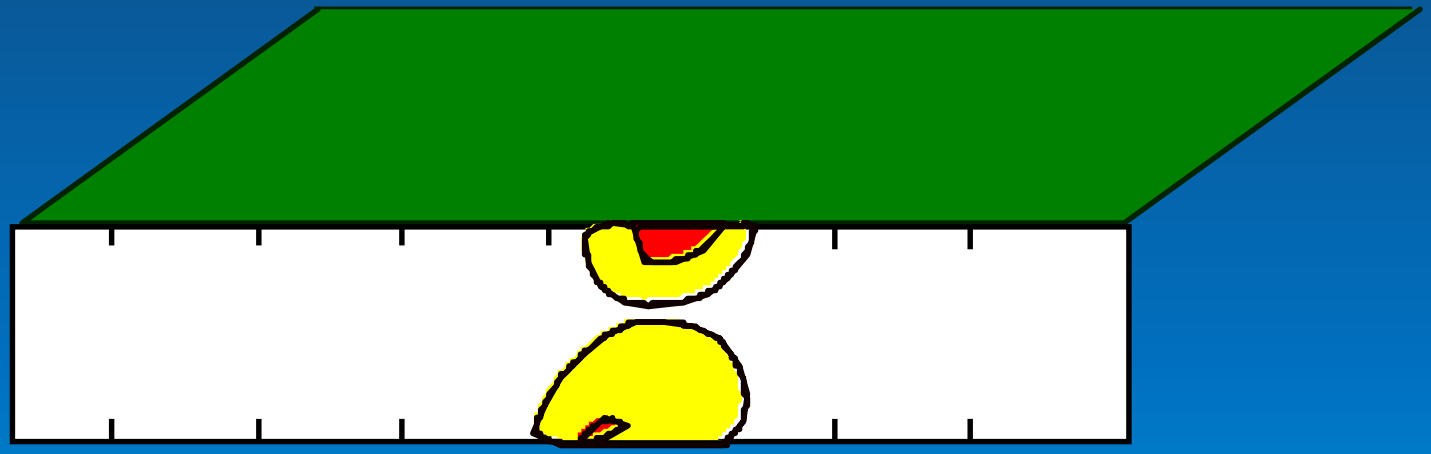
# Second 6.0



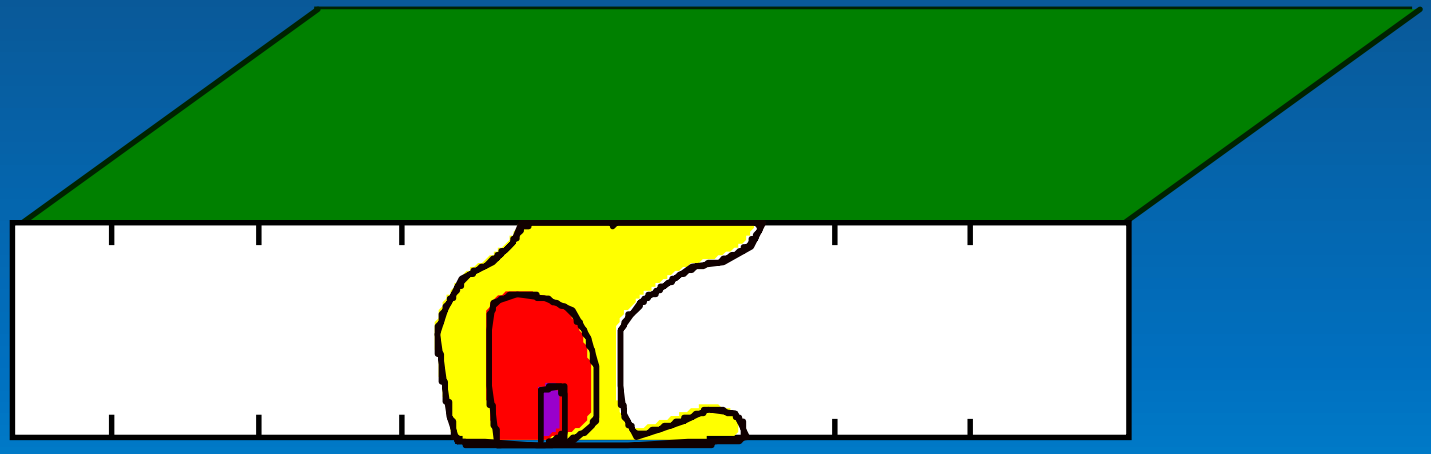
# Second 8.0



# Second 10.0

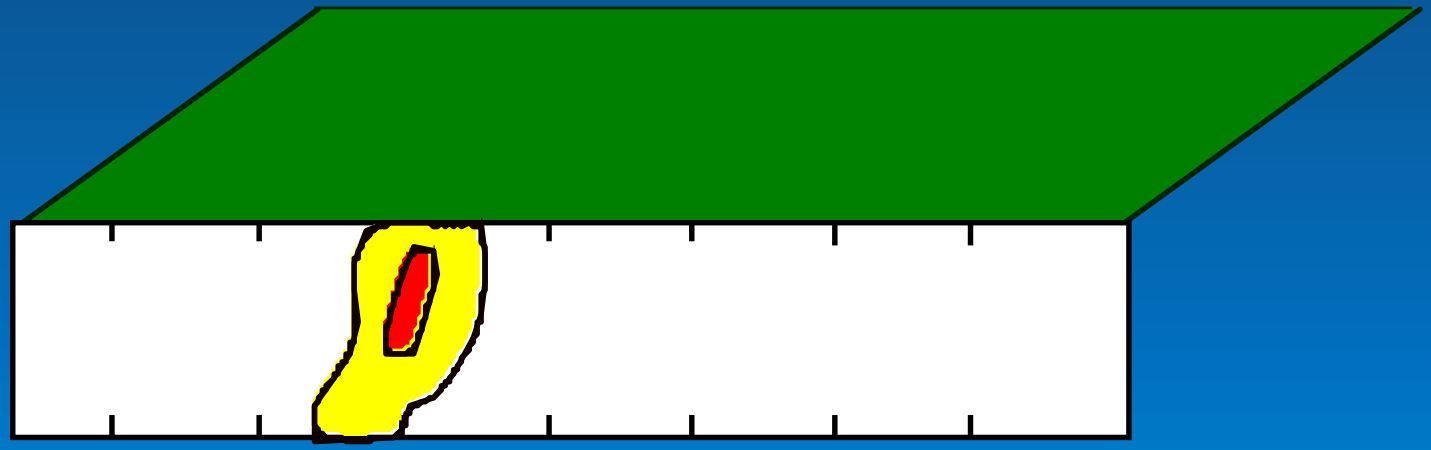


# Second 12.0

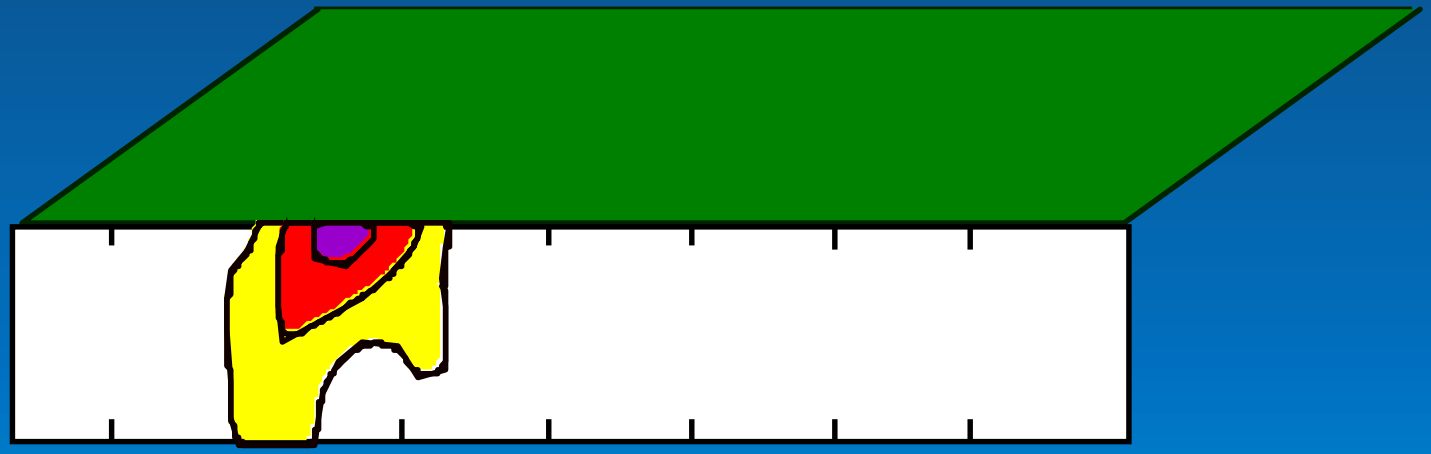


# Second 14.0

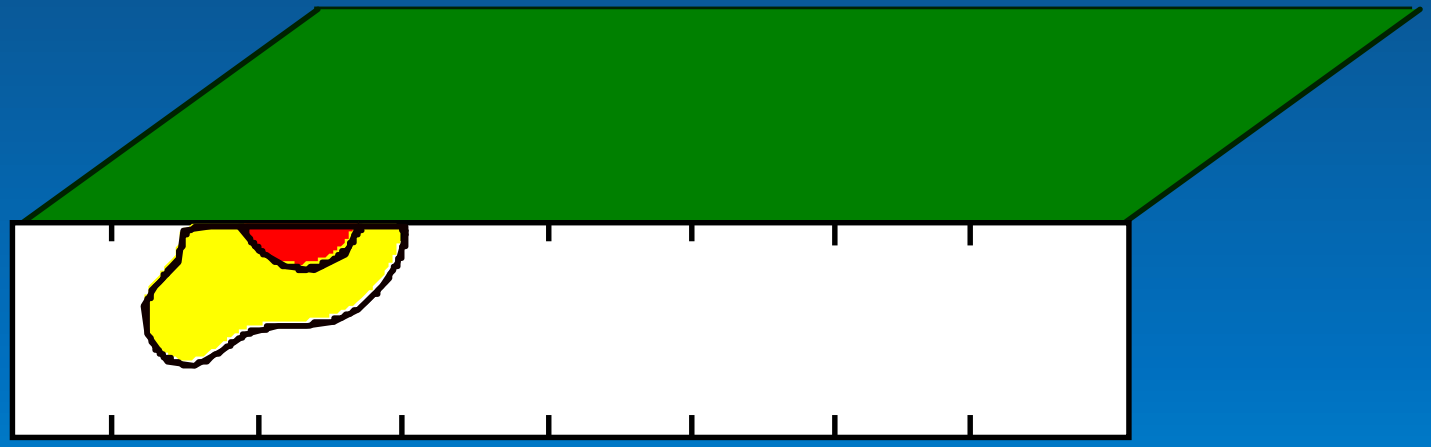
# Second 16.0



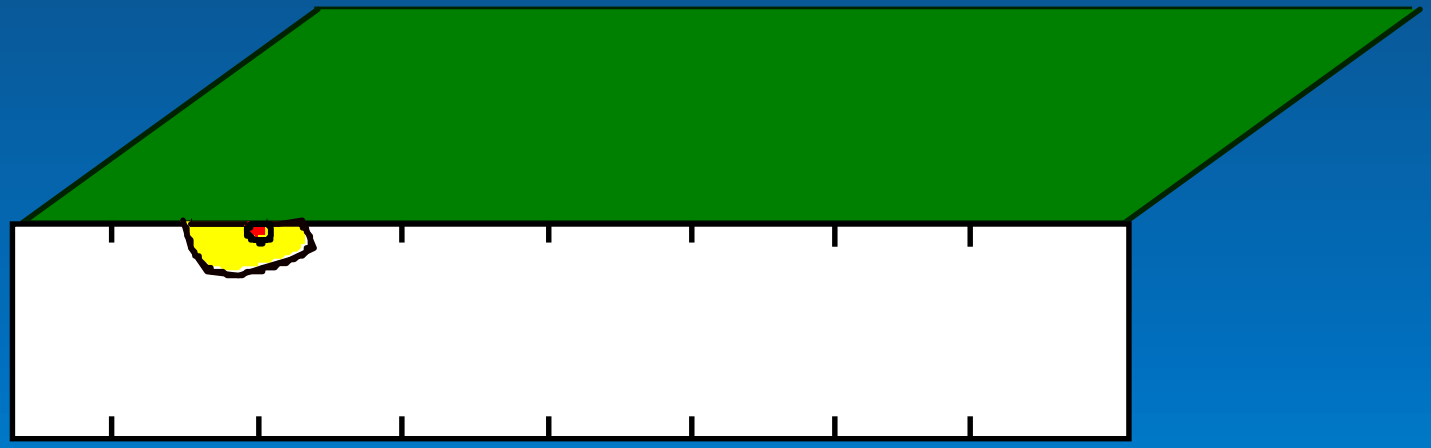
# Second 18.0



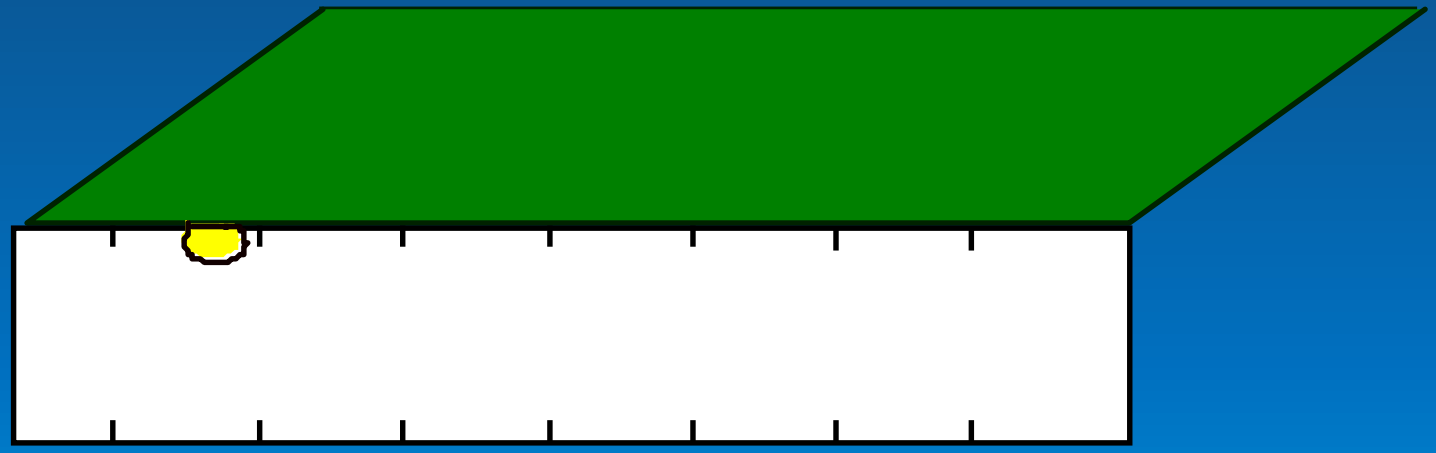
# Second 20.0



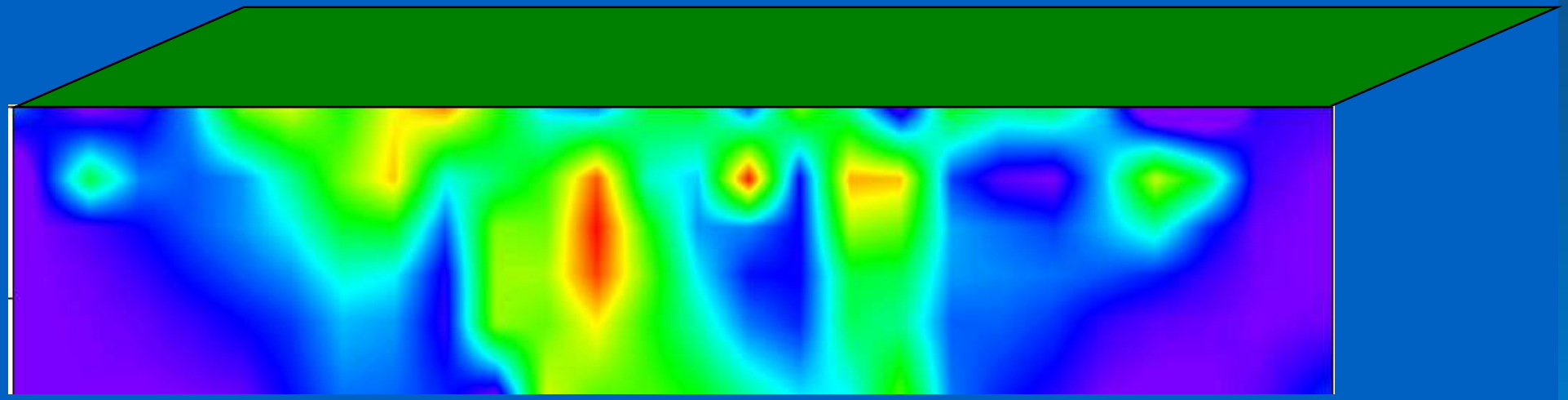
# Second 22.0

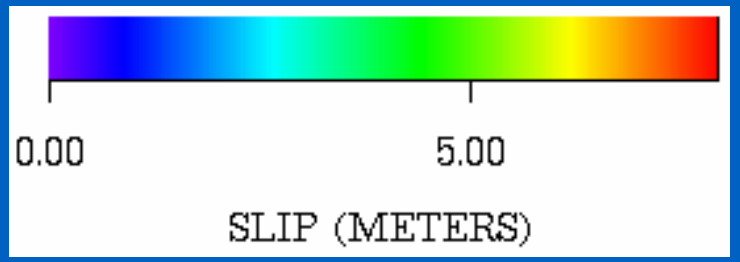


# Second 24.0



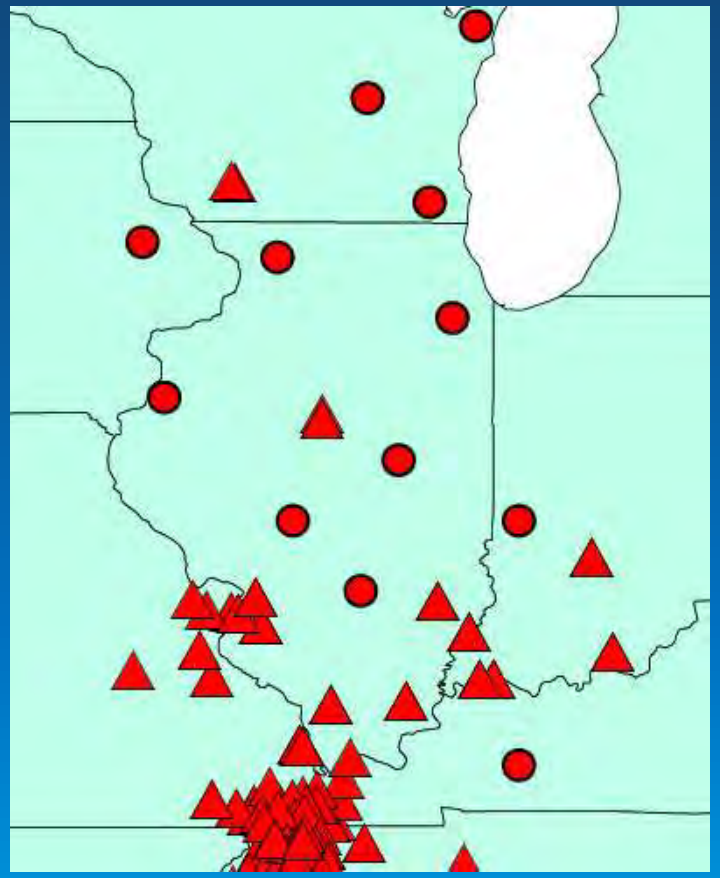
# Rupture on Fault for M7.3 Landers Earthquake

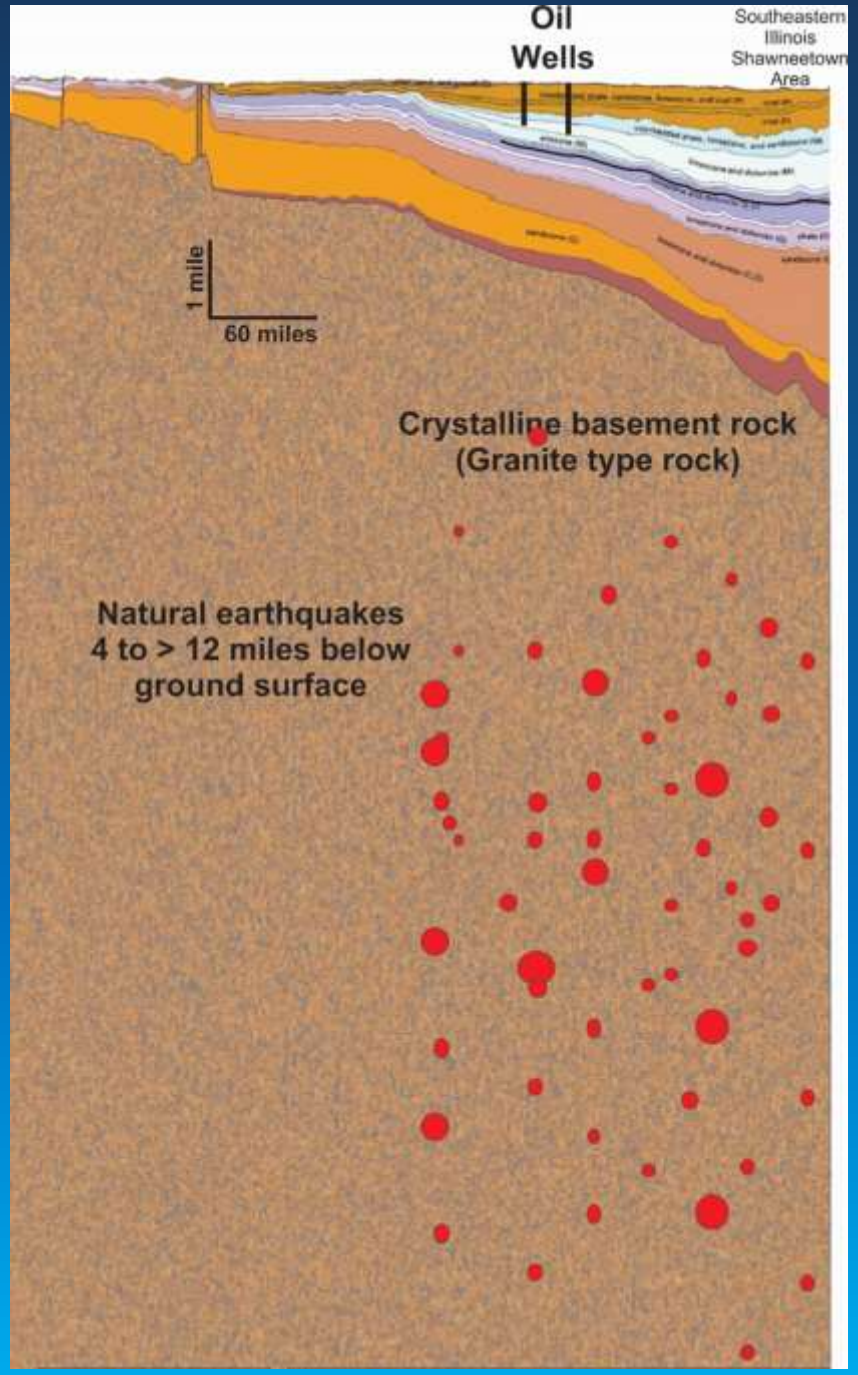





USGS

# National Seismic Monitoring Stations

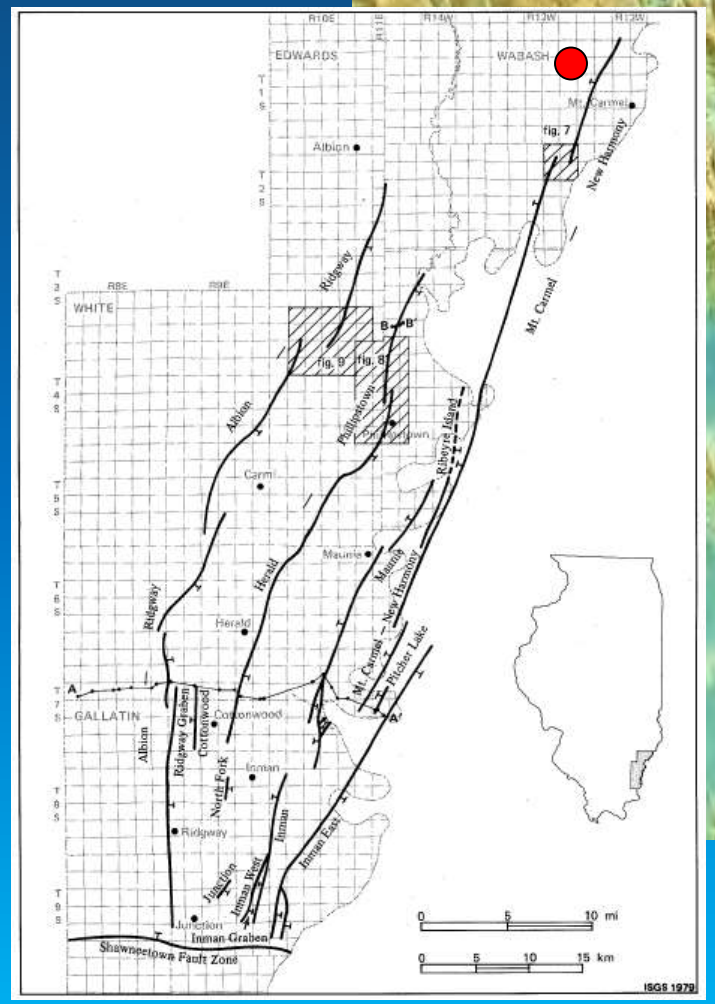


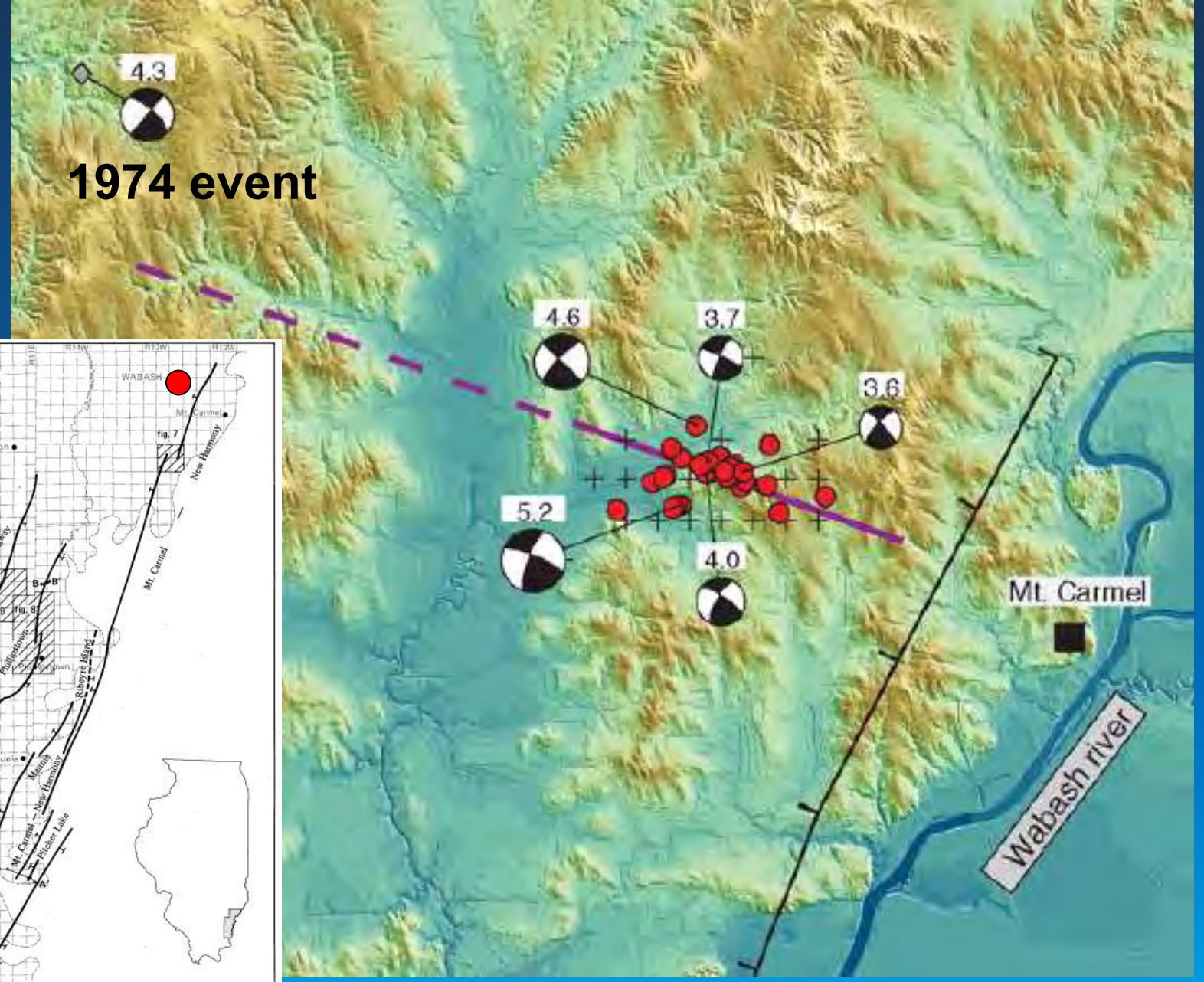



Faults in the Basement are not mapped

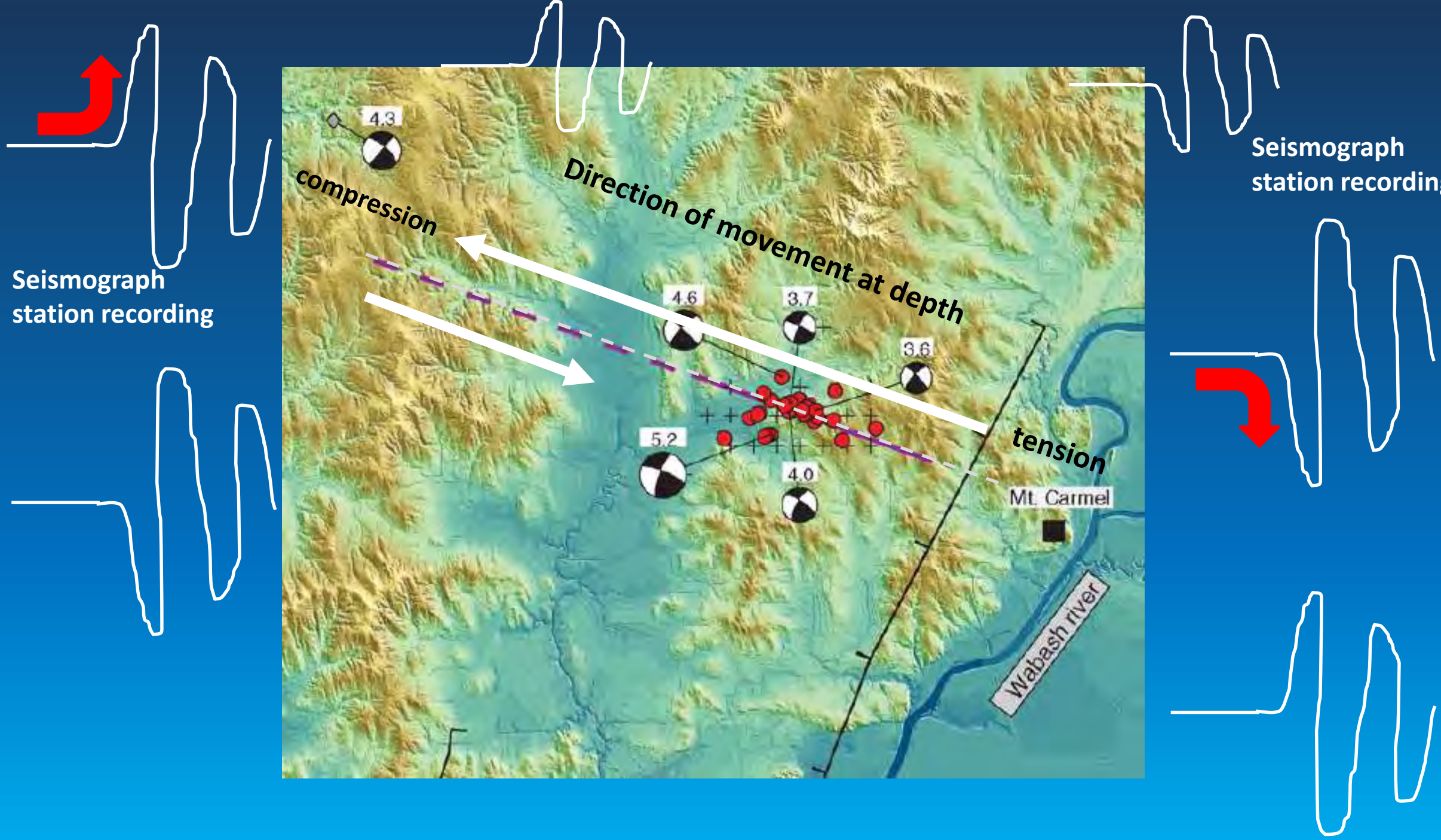
How do we know what is going on since we do NOT see surface ruptures with our deep fault movements?

# April 18, 2008
# Mag = 5.2

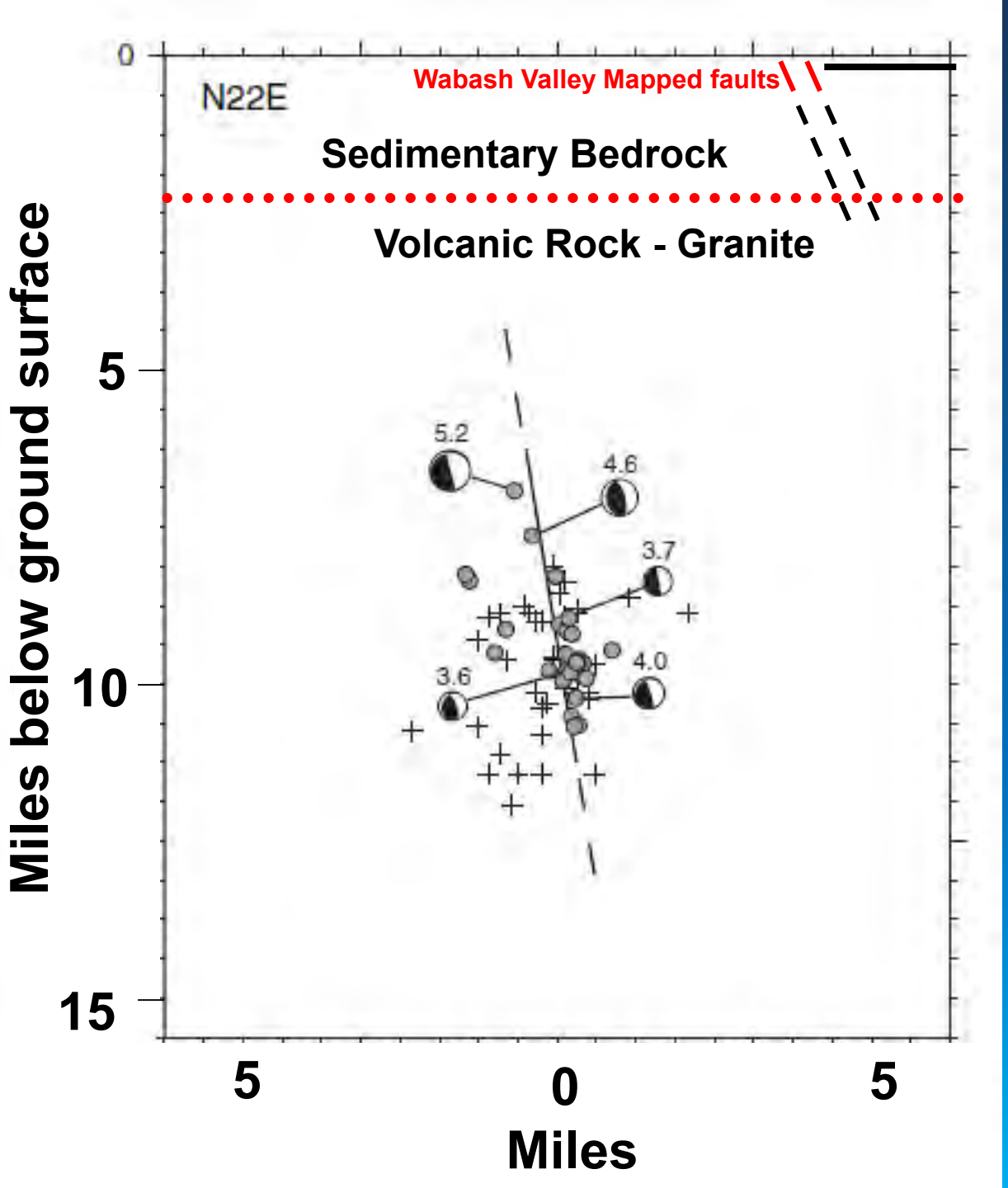


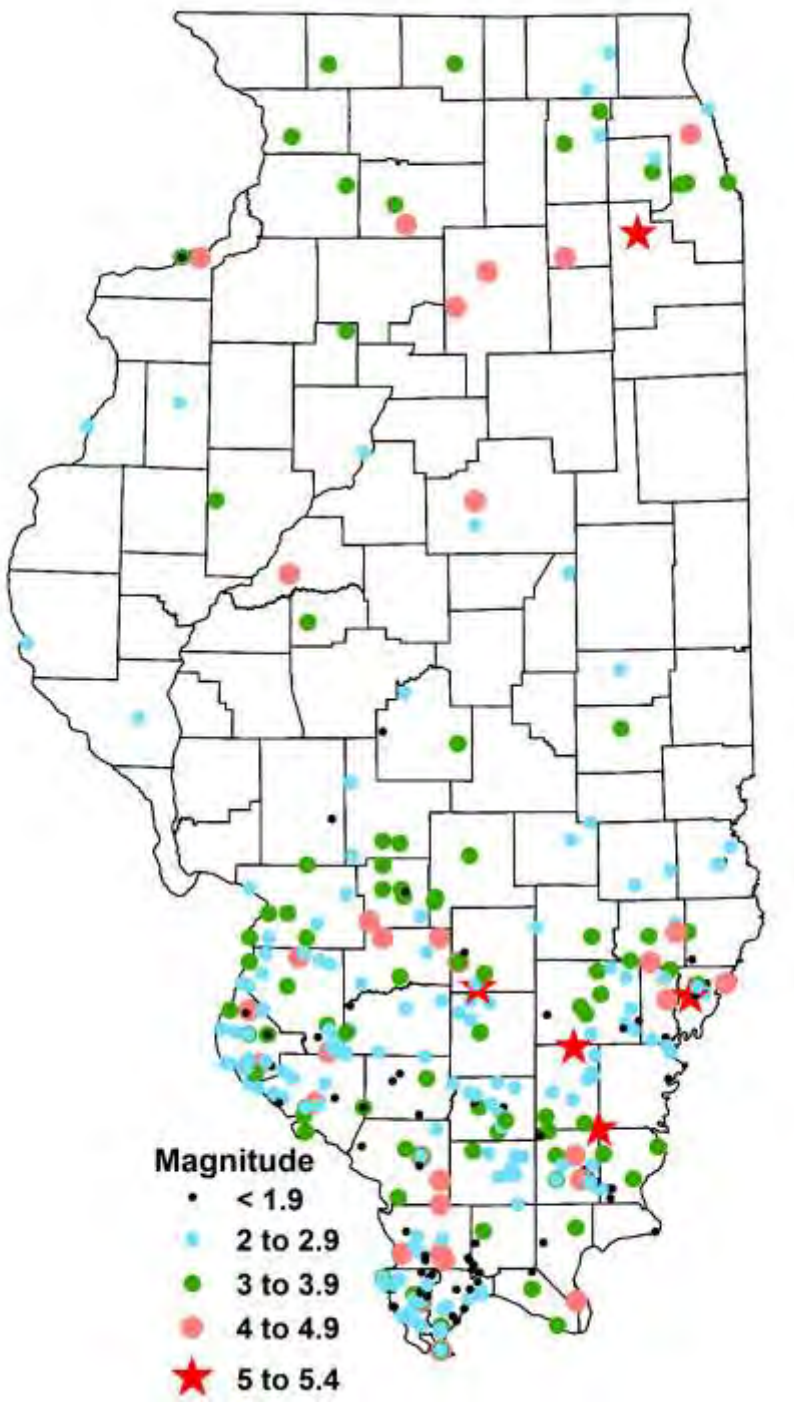

Yang et al., 2009

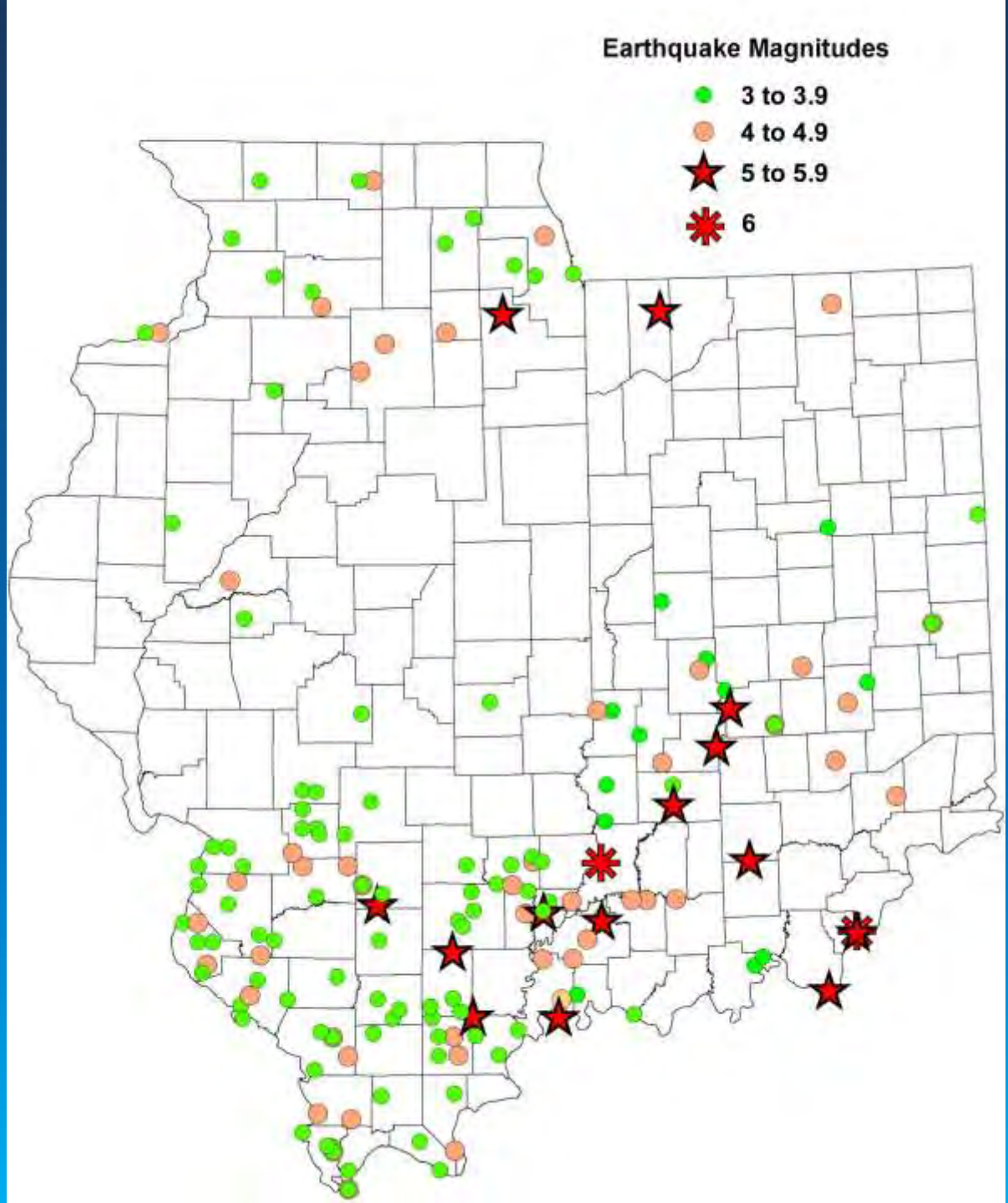



Yang et al., 2009

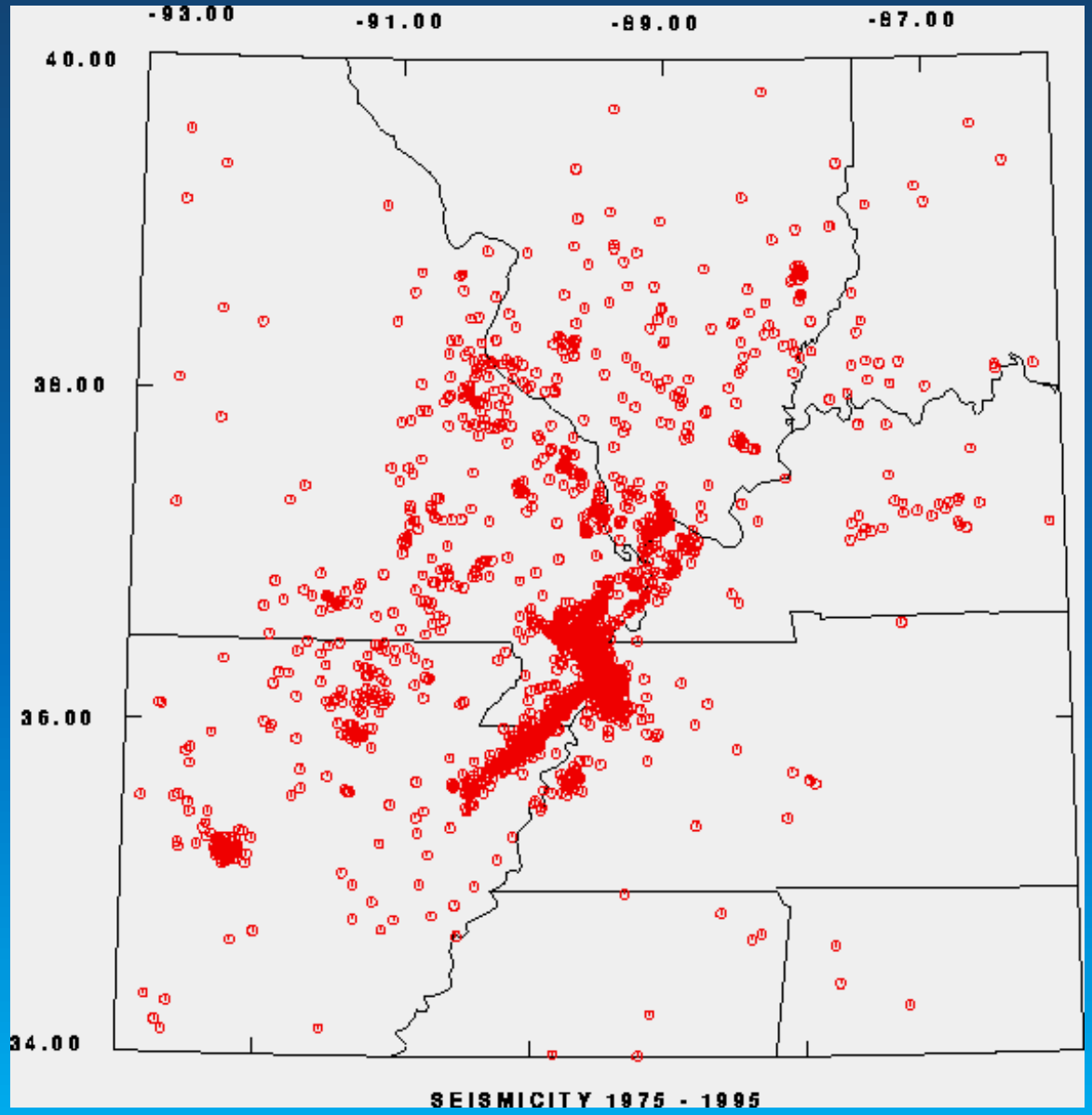

0
N22E
Wabash Valley Mapped faults
Sedimentary Bedrock
Volcanic Rock - Granite
5
10
15
Miles below ground surface
5.2
4.6
3.7
4.0
3.6
5
0
5
Miles

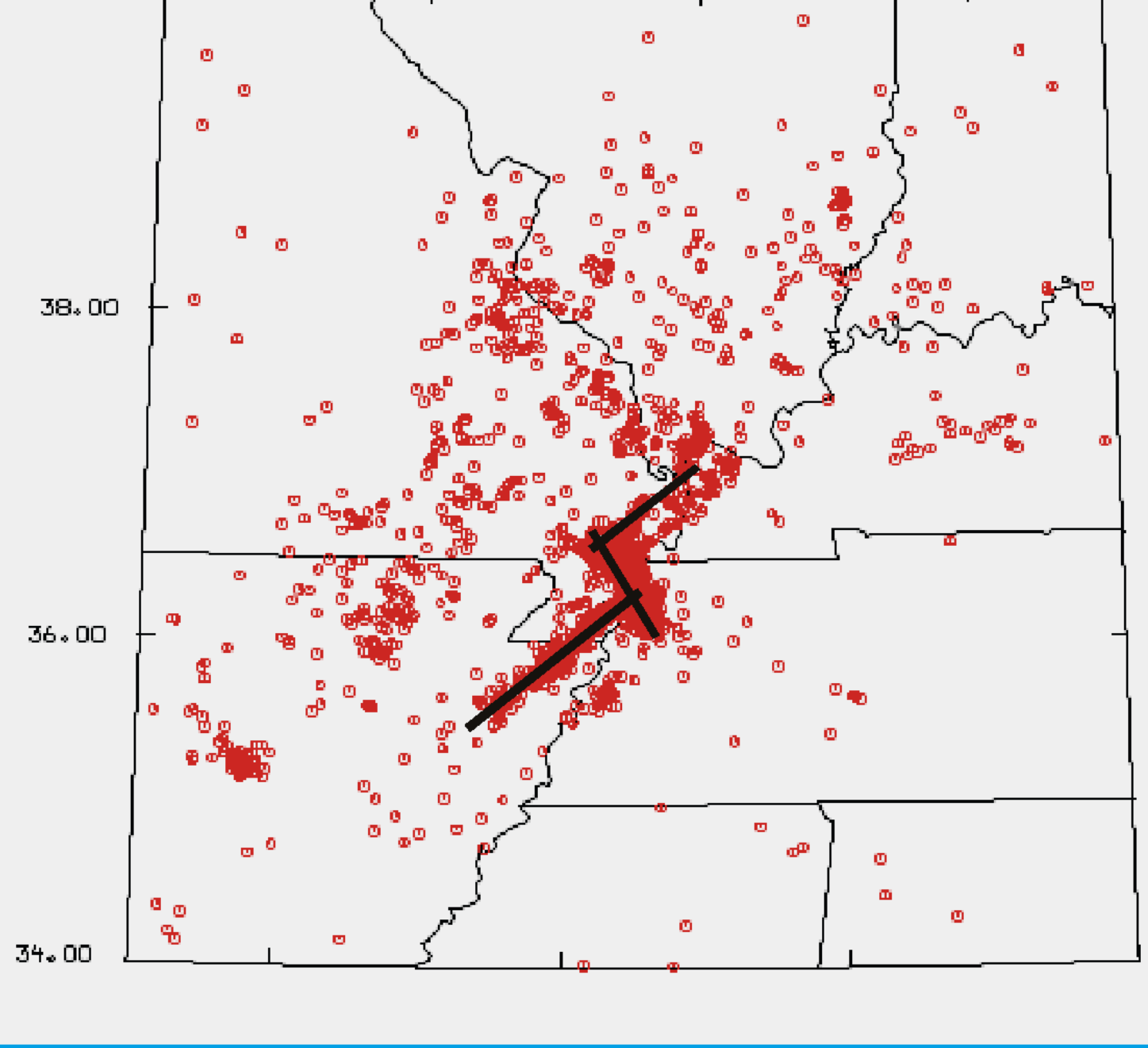
Coal Mine

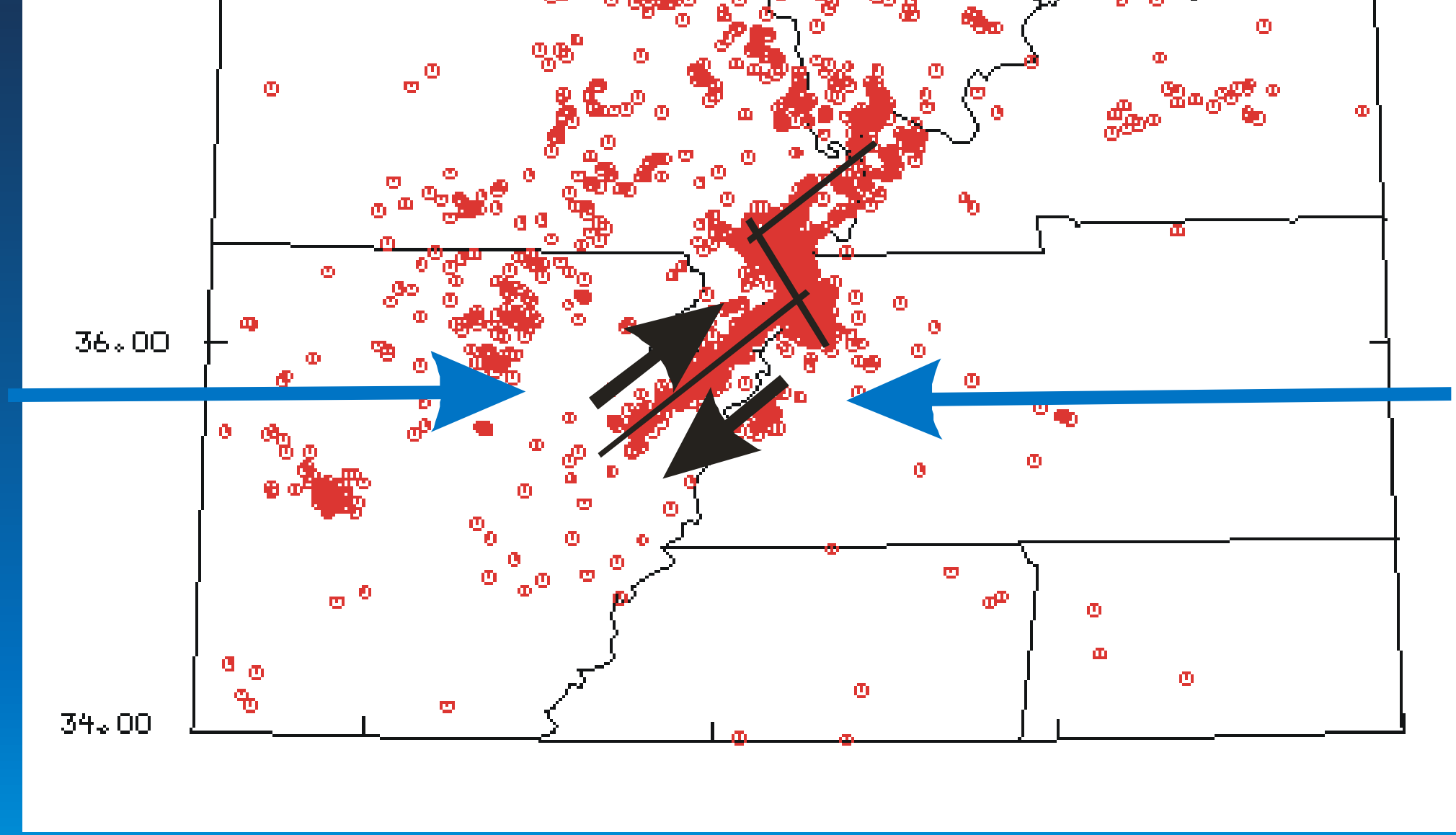

Magnitude
< 1.9
2 to 2.9
3 to 3.9
4 to 4.9
5 to 5.4


Earthquake Magnitudes
3 to 3.9
4 to 4.9
5 to 5.9
6

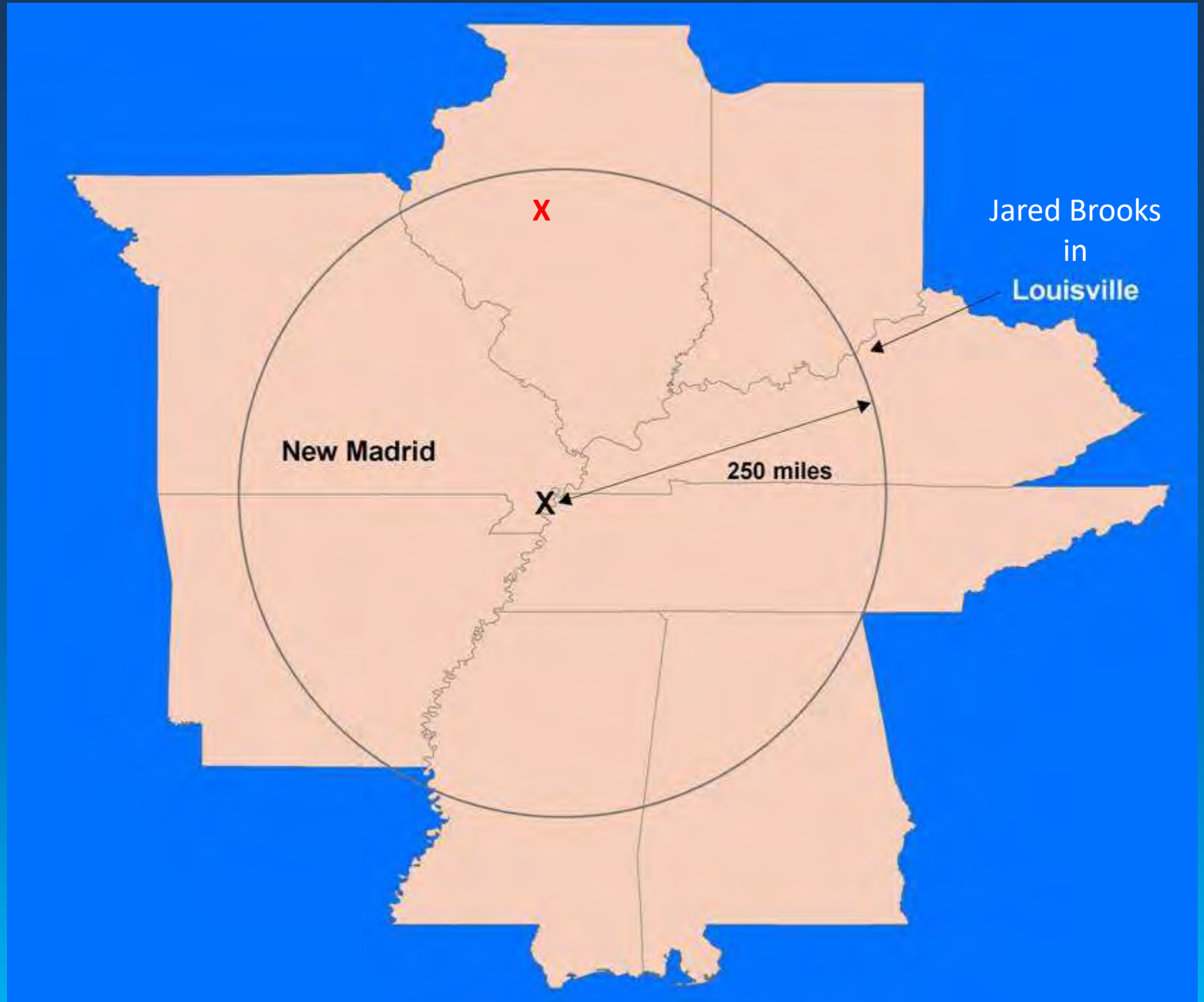
# New Madrid 1811-1812 Earthquakes




38.00
36.00
34.00

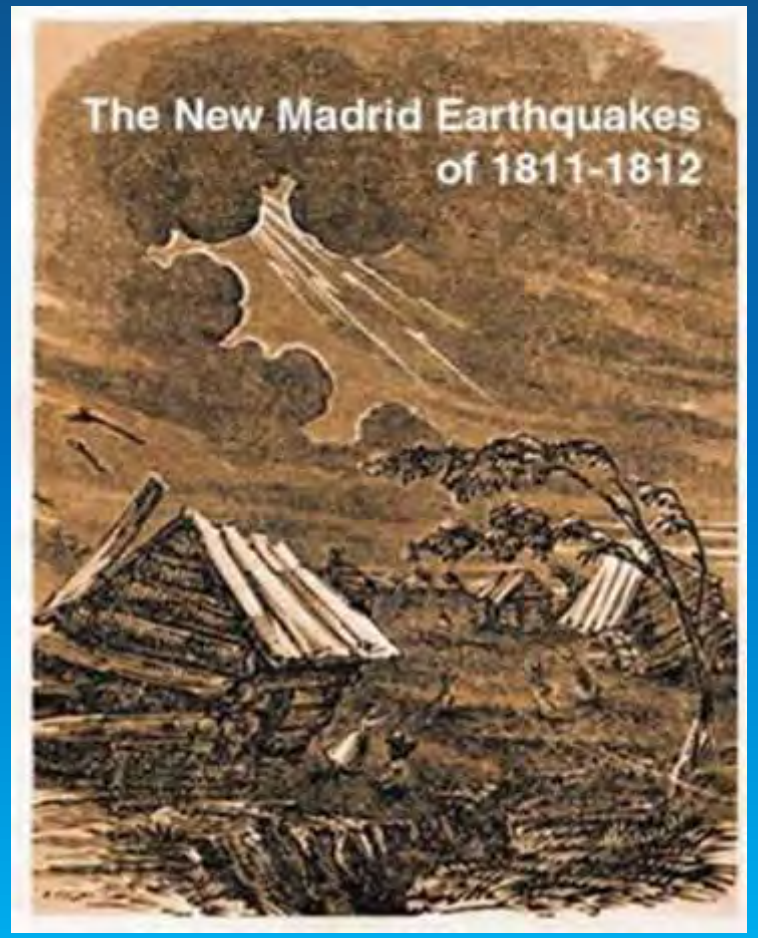



Dec. 16, 1811 Mw ≈ 7.6


X
Jared Brooks
in
Louisville
New Madrid
250 miles
X

# Dec. 16, 1811

**2:15 am.** commencing with about half the strength to which it gradually increased in about one minute; held at tremendous about one minute, then gradually subsided; whole duration, from 3 ½ to 4 minutes; other slight motions follow. 2:35 am - Moderate motion 15 seconds.

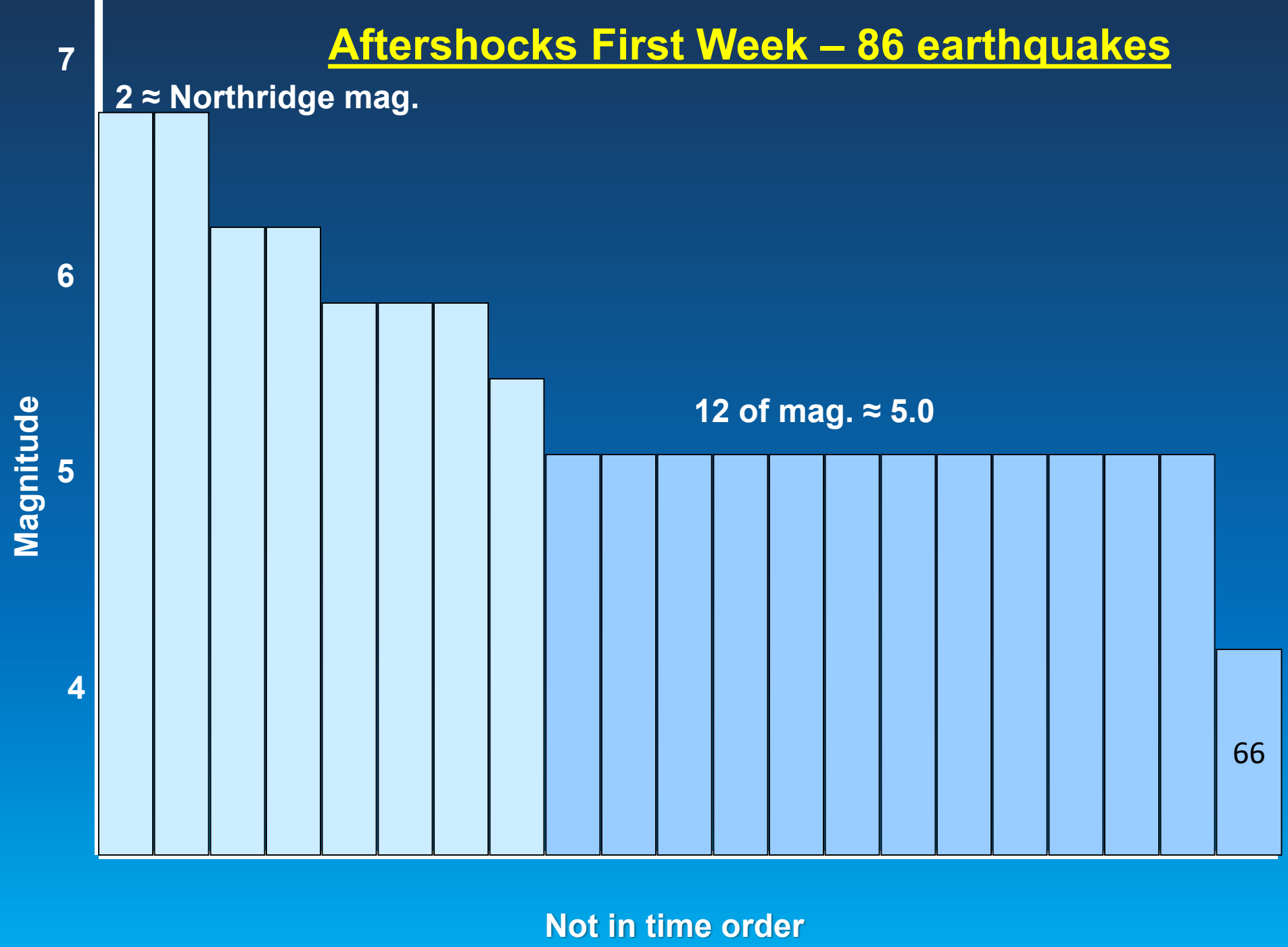



Magnitude ≈ 7.6

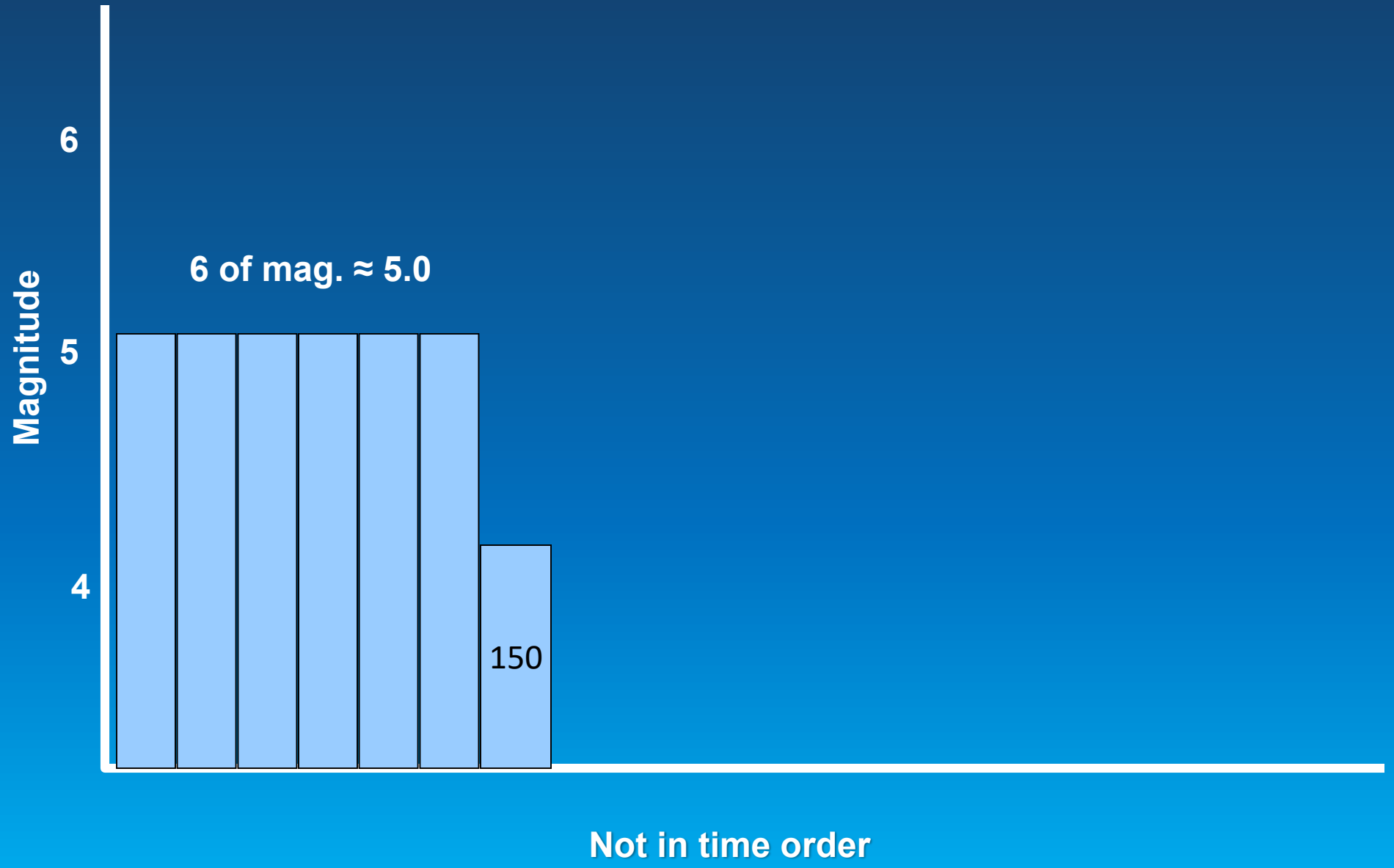
7:20 am – sudden; violent about 1 minute, then moderated through the 2d and 3d minutes to slight tremor; this followed by small and placid motion of about 10 minutes; then severe, stood at that 10 seconds; gradually subsided, but not to perfect rest; six considerable shocks are felt during the succeeding 30 minutes; then became constant, and strengthened at a dreadful rate to tremendous, so as to threaten the town with total destruction; duration of greatest violence 1 ½ minutes; it is doubtful if the earth is at rest from these troubles 10 minutes during the day and succeeding night.

**Magnitude ≈ 7.2**

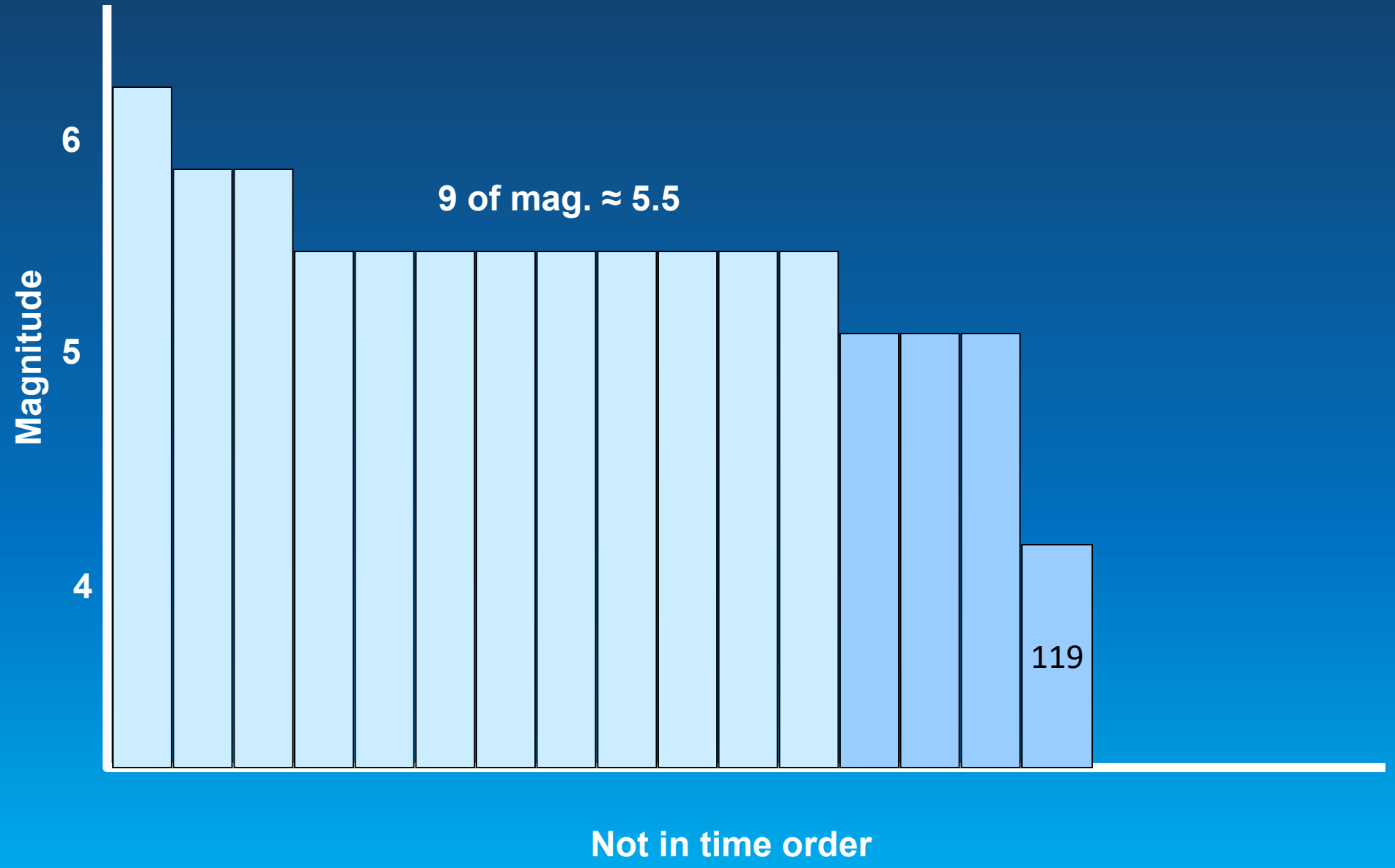
# Aftershocks First Week – 86 earthquakes



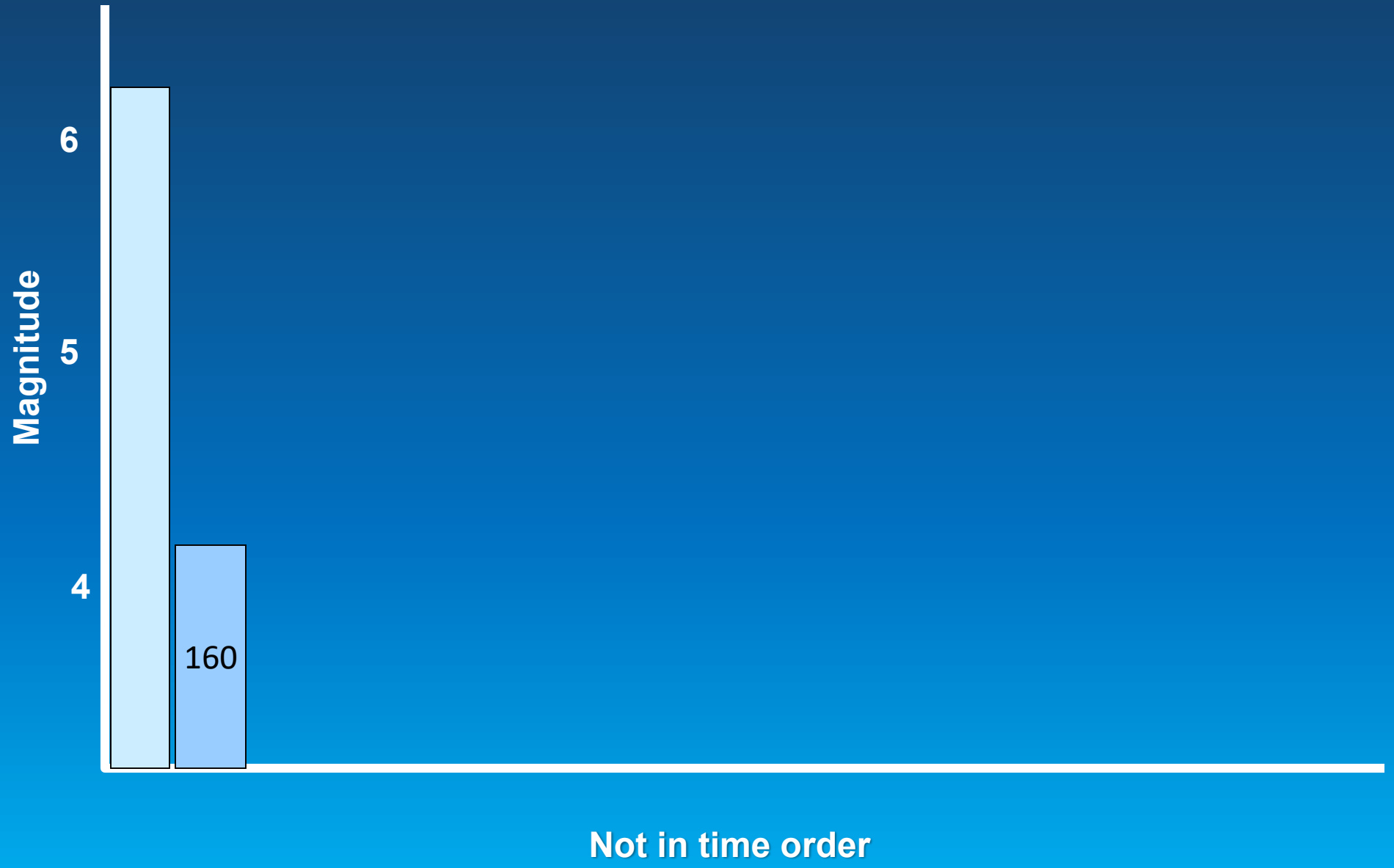
# Aftershocks Second Week – 156 events



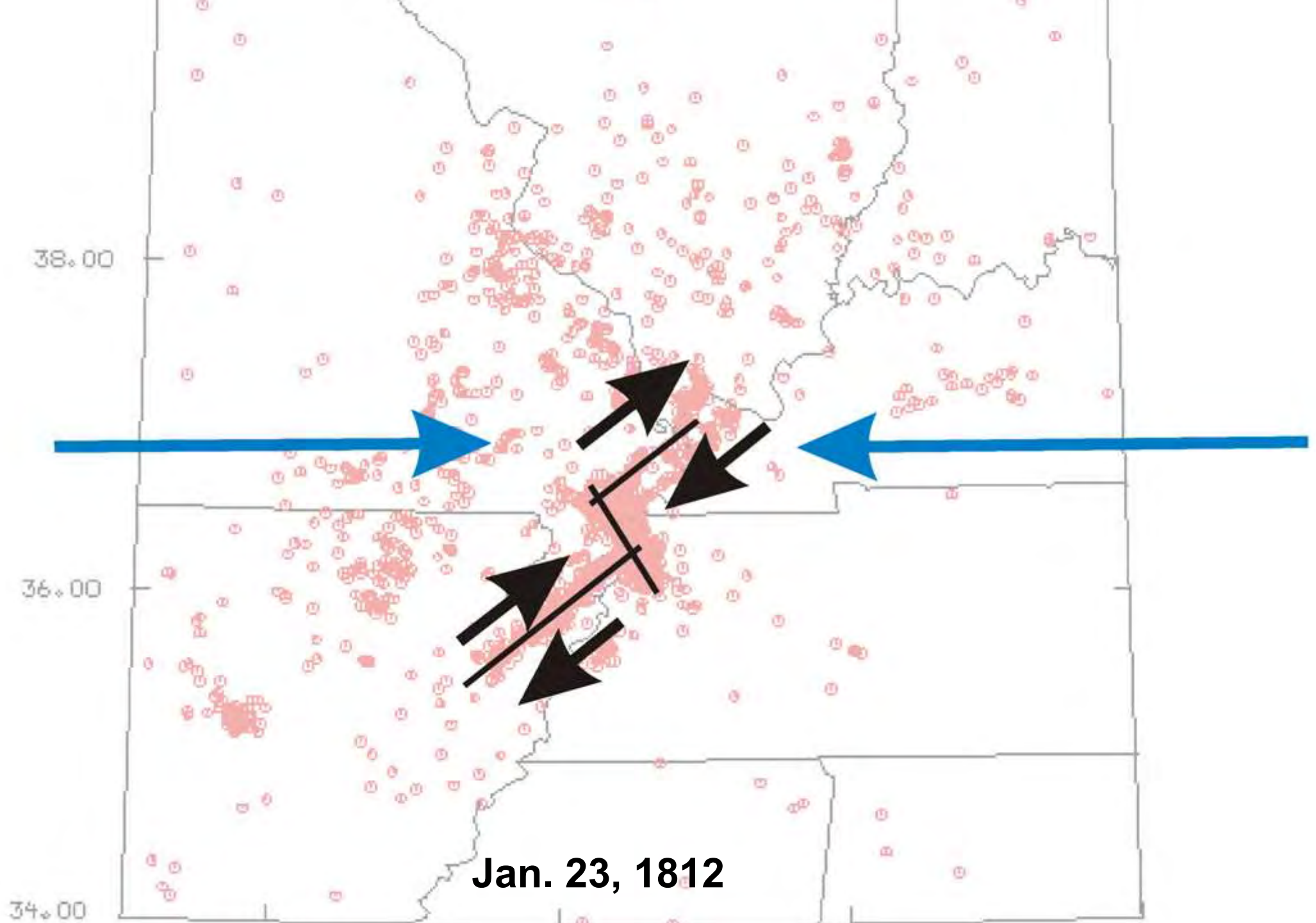
# Aftershocks Third Week – 134 earthquakes



# Aftershocks Fourth Week – 161 earthquakes

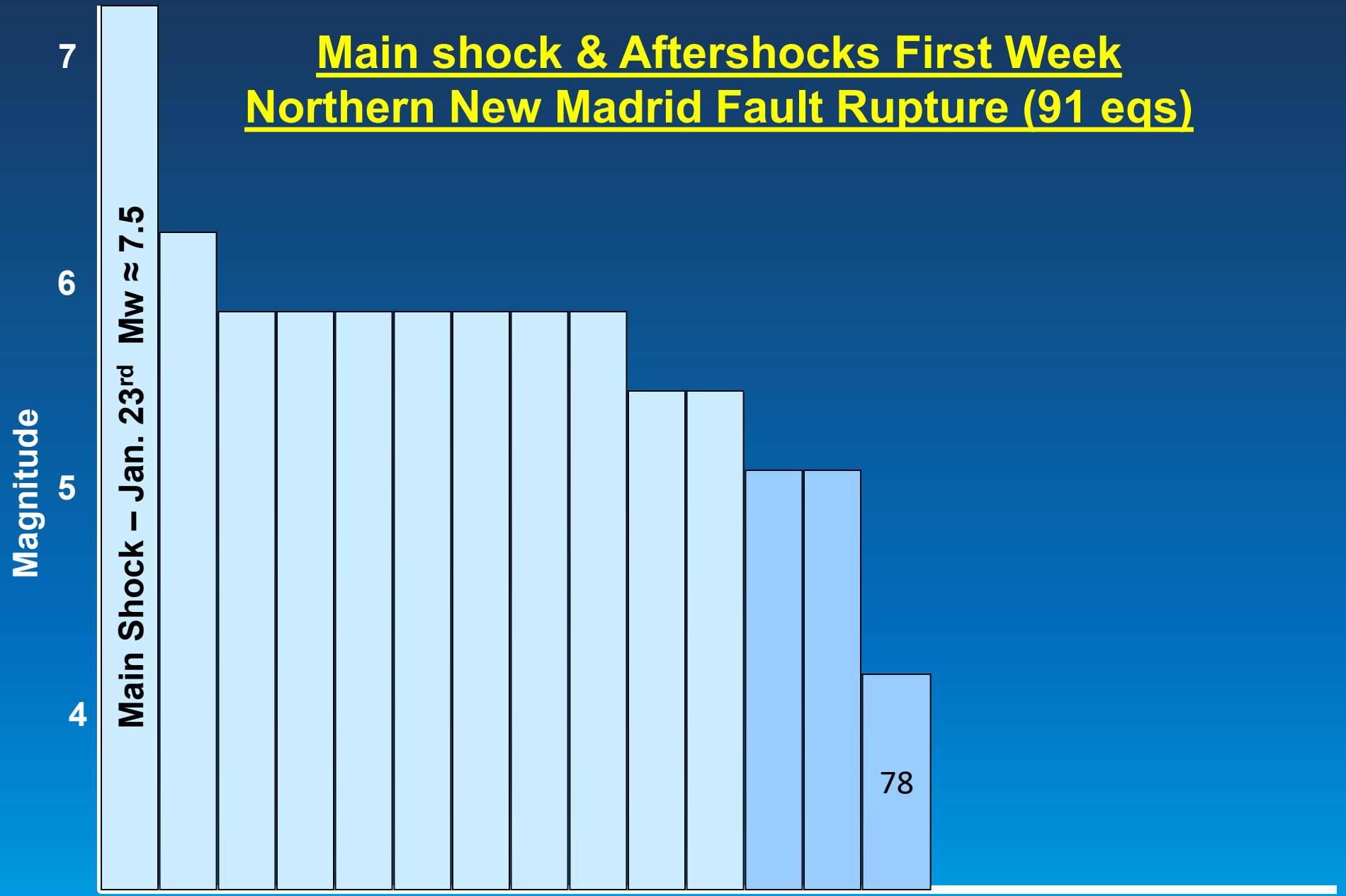


# Aftershocks Fifth Week – 65 earthquakes

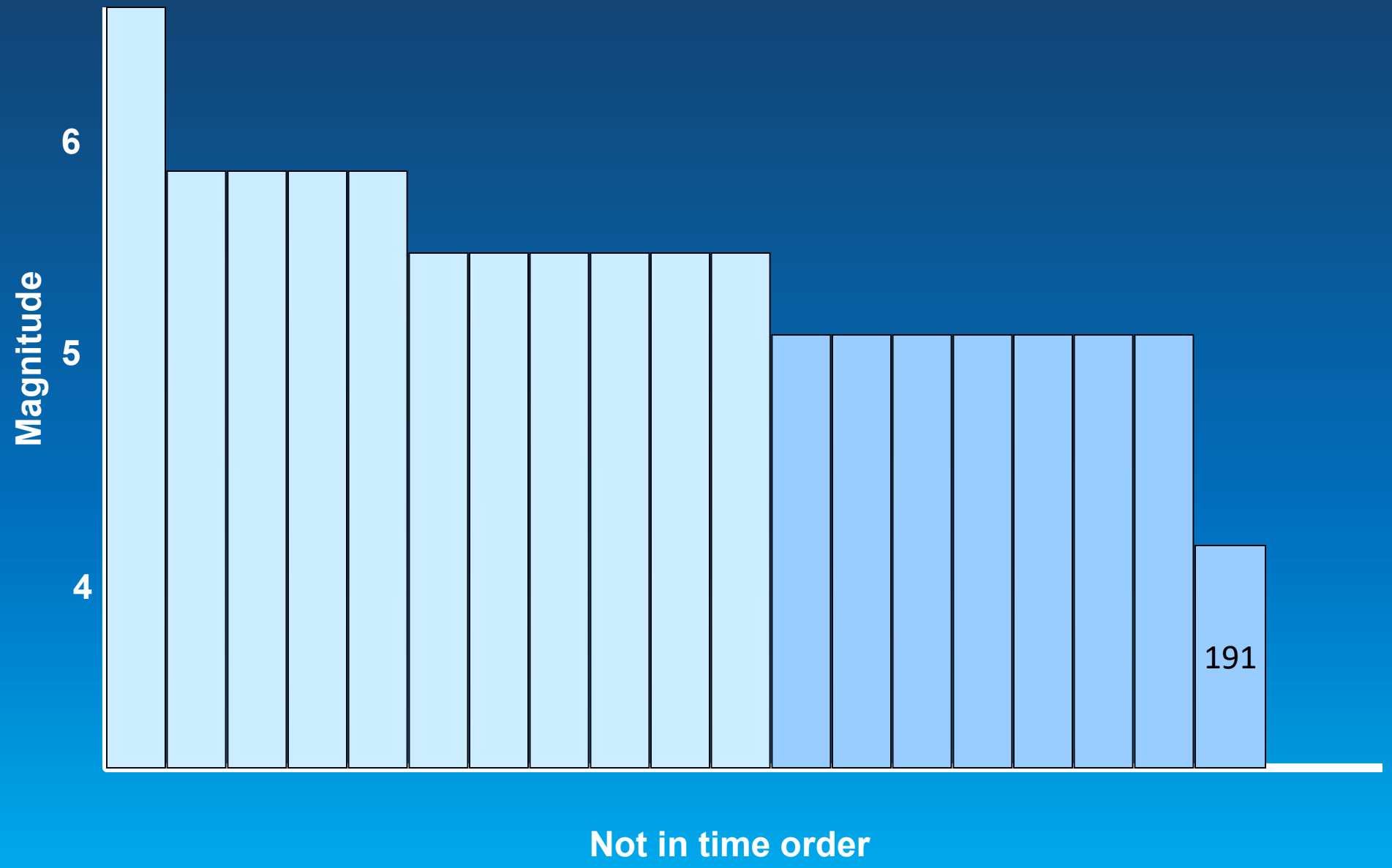


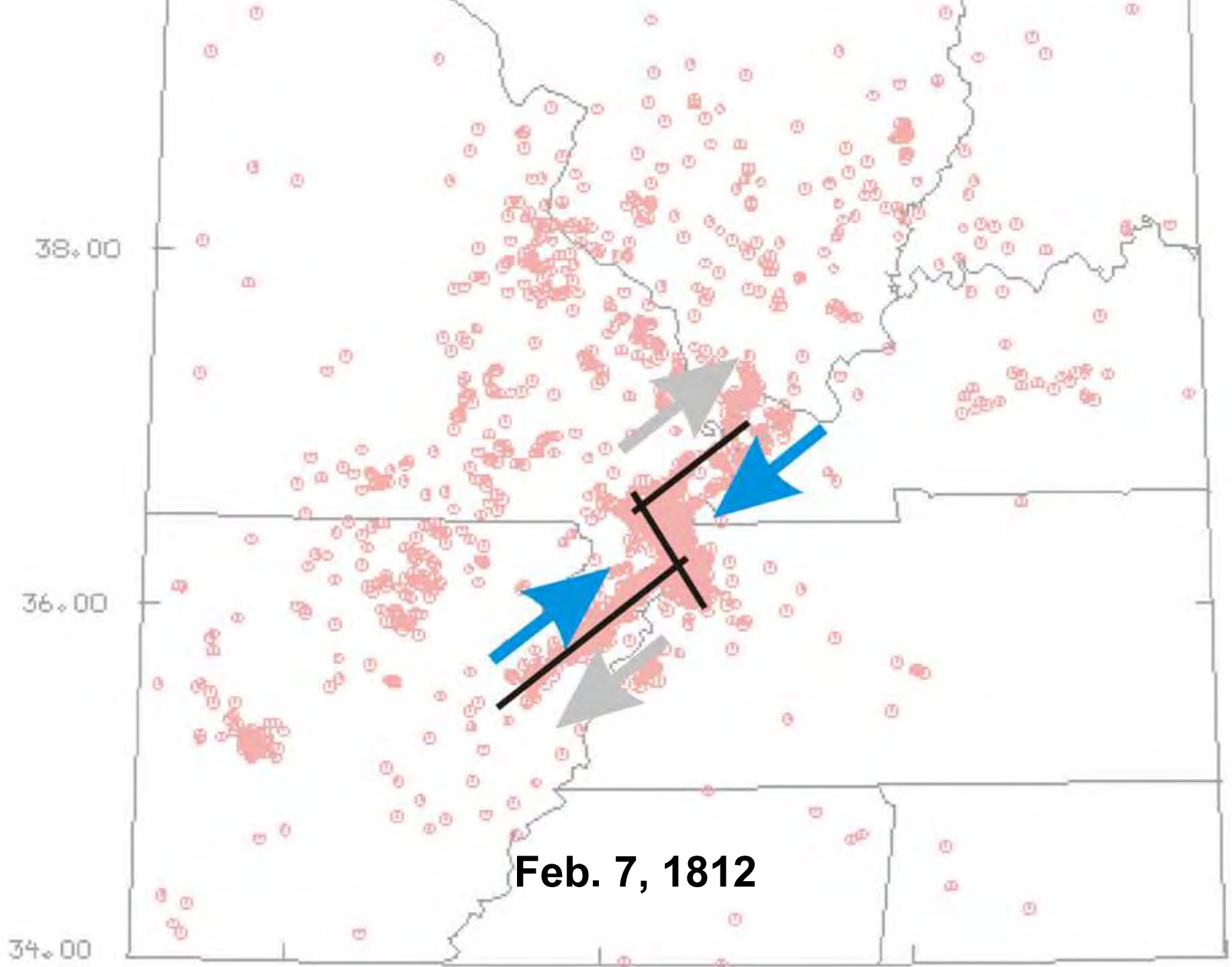

Jan. 23, 1812

# Main shock & Aftershocks First Week
# Northern New Madrid Fault Rupture (91 eqs)

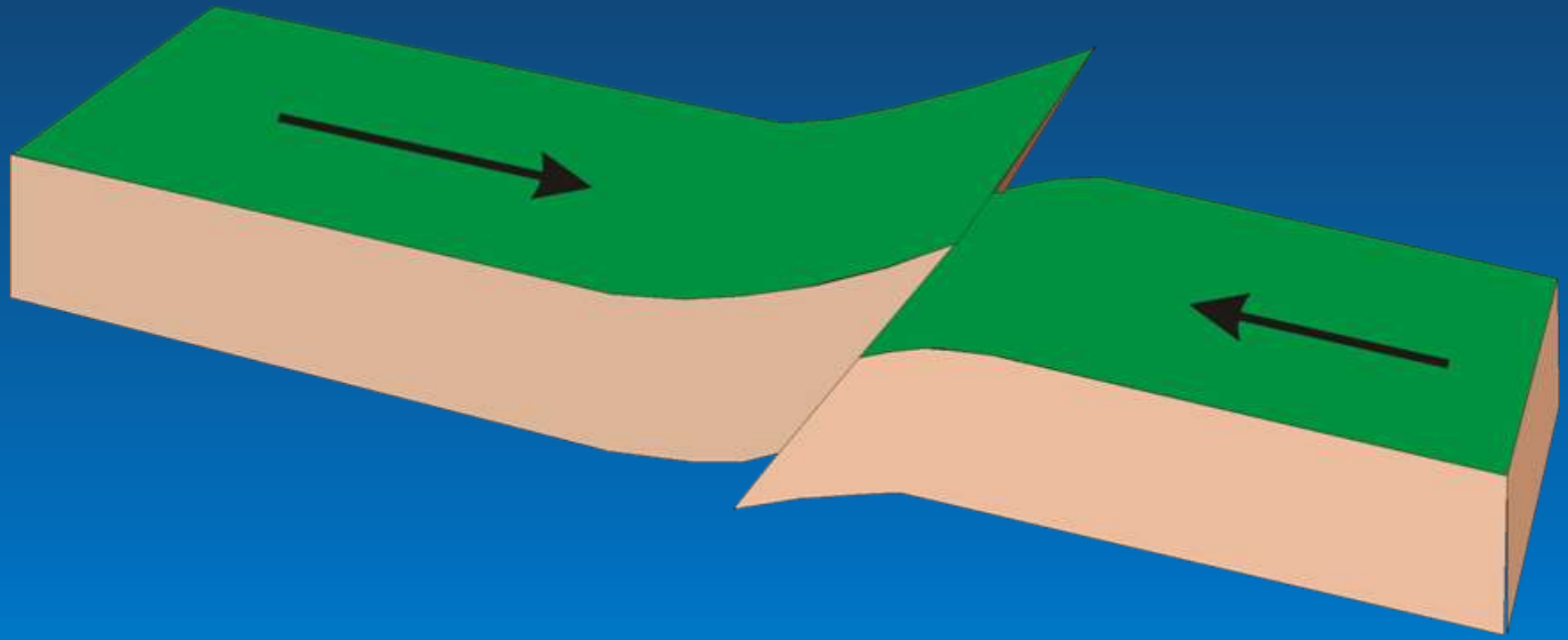


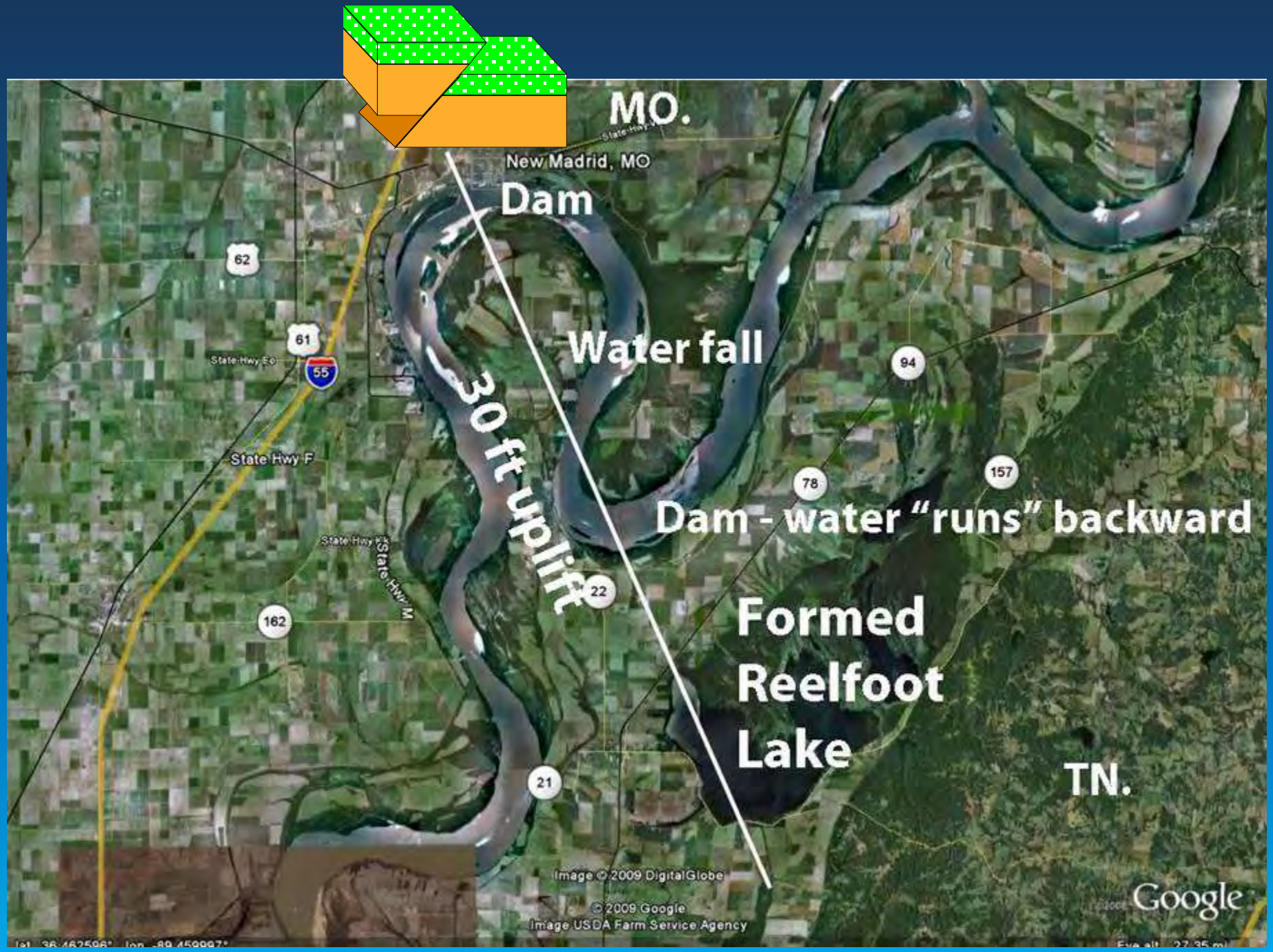
# Aftershocks Second Week after Second New Madrid Fault Rupture (209 eqs)

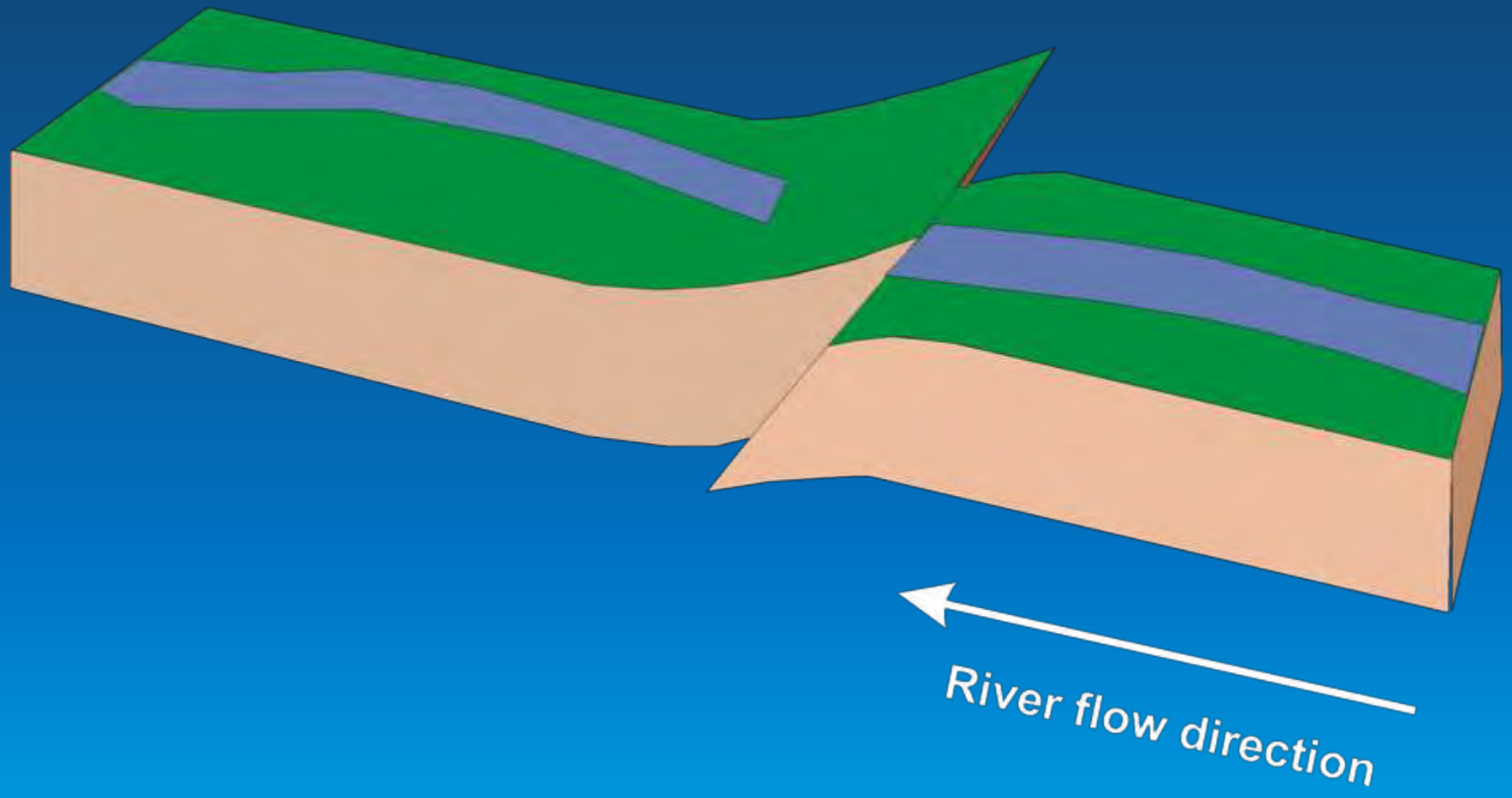


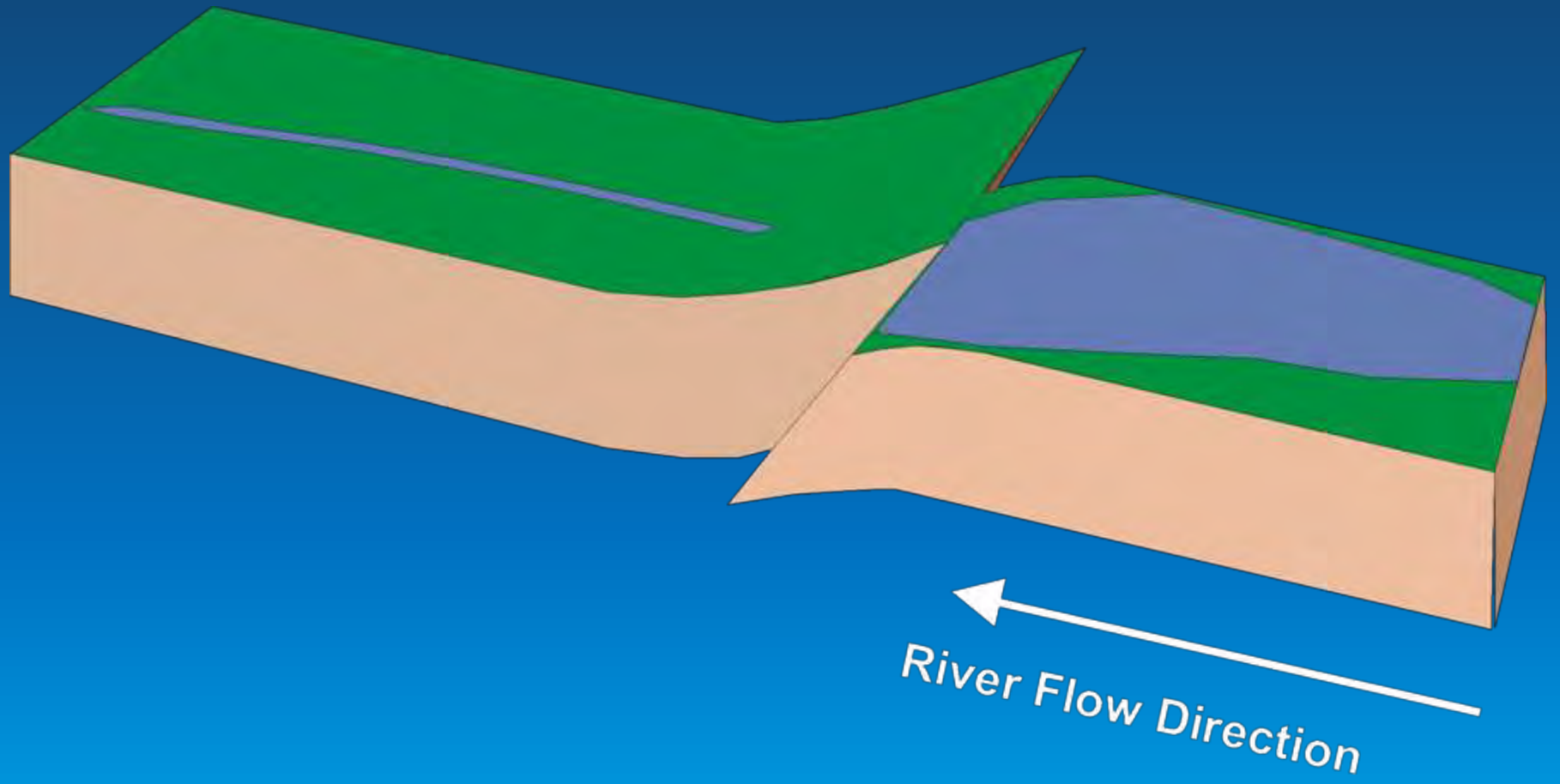


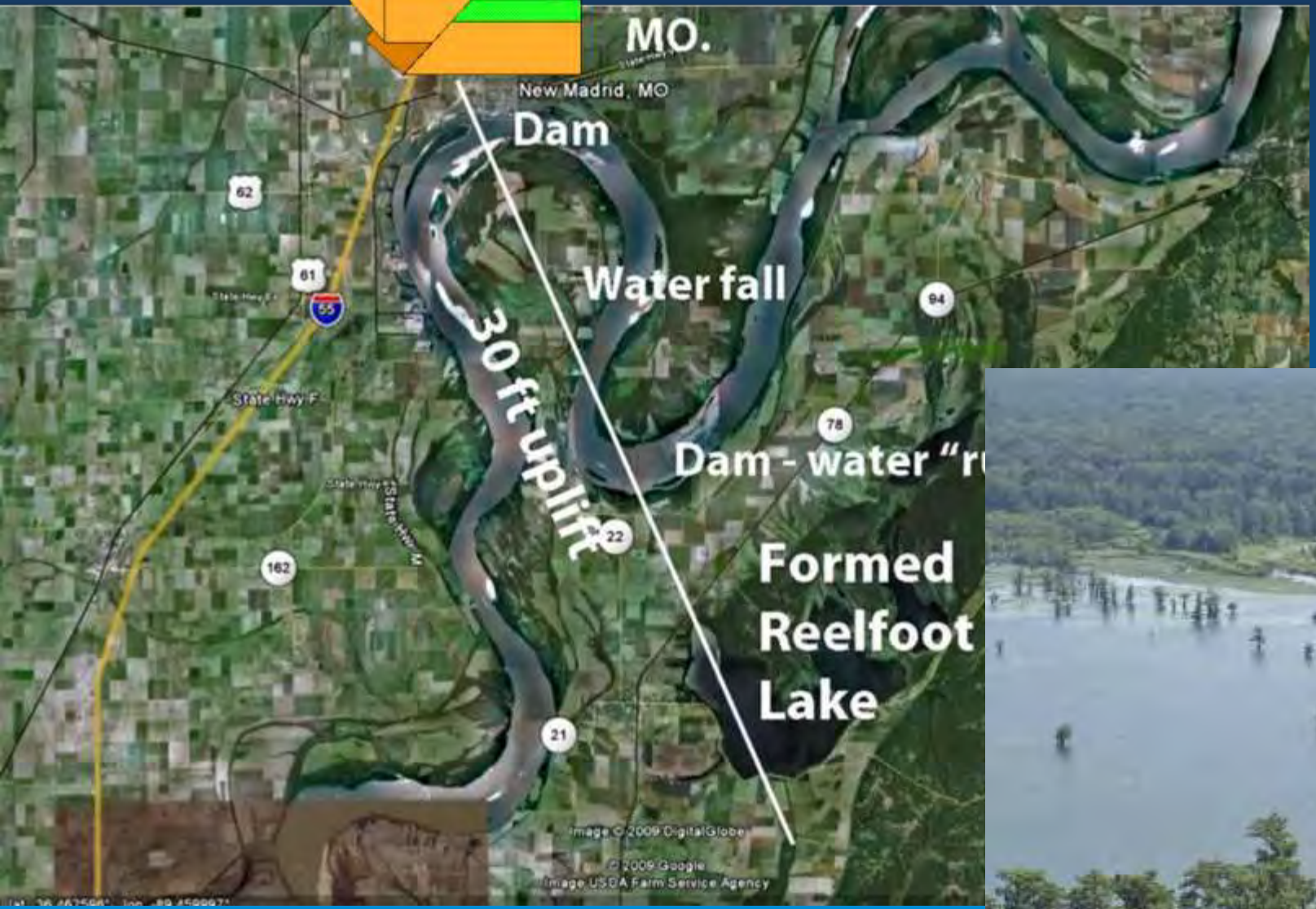

**Feb. 7, 1812**



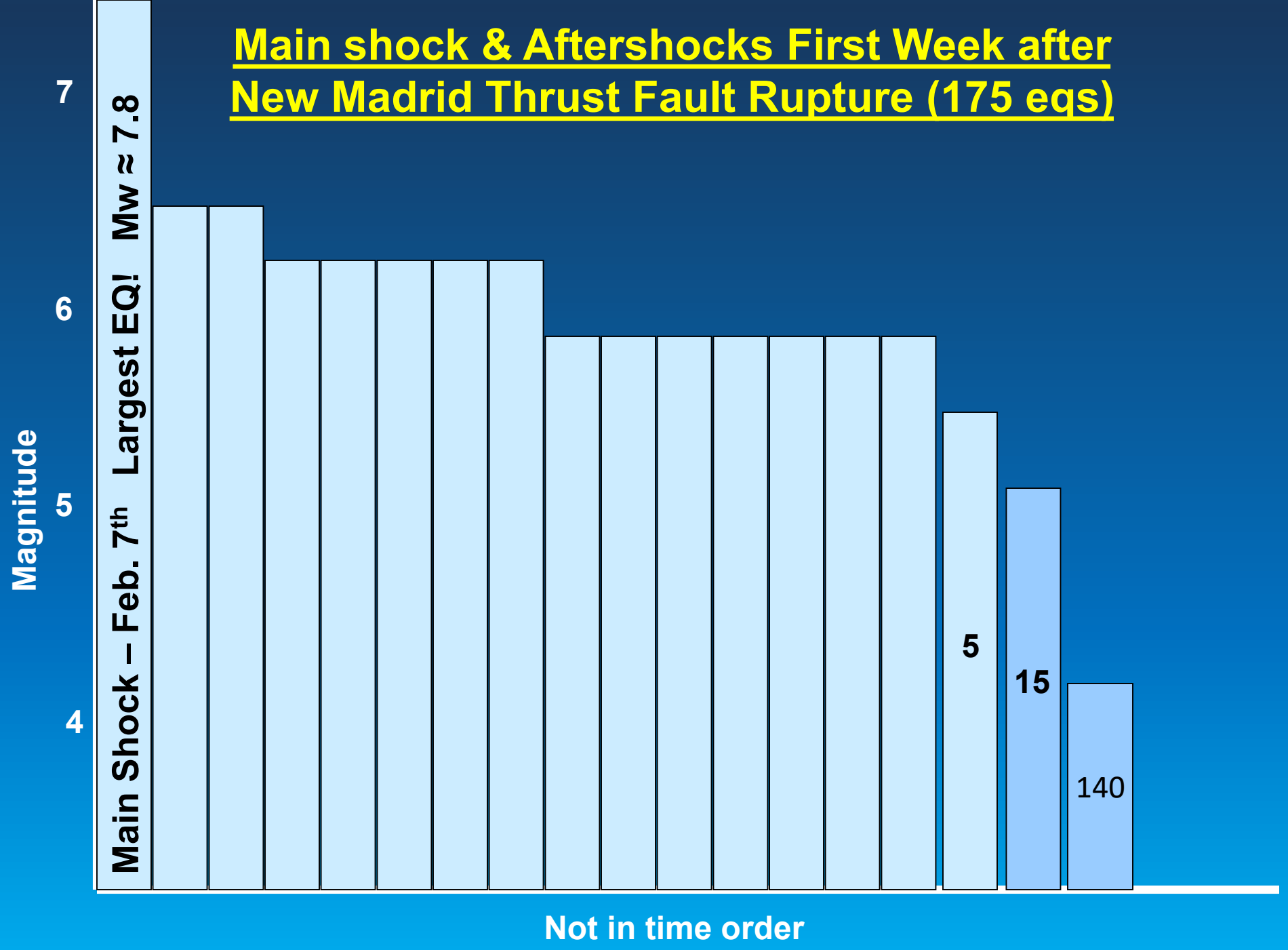

MO.
New Madrid, MO
Dam
Water fall
30 ft uplift
Dam - water "runs" backward
Formed
Reelfoot
Lake
TN.
62
61
55
94
78
157
22
162
21
State Hwy F
State Hwy M
Image © 2009 DigitalGlobe
© 2009 Google
Image USDA Farm Service Agency
Google


River flow direction


River Flow Direction

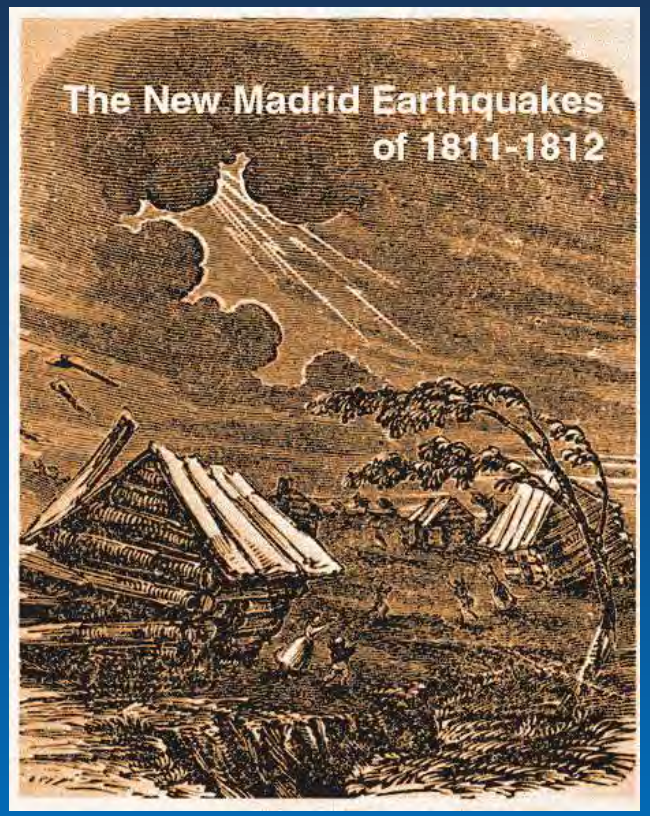

MO.
New Madrid, MO
Dam
Water fall
30 ft uplift
Dam - water "r
Formed
Reelfoot
Lake
62
61
55
State Hwy F
94
78
22
162
21
Image © 2009 DigitalGlobe
© 2009 Google
Image USDA Farm Service Agency

# Main shock & Aftershocks First Week after New Madrid Thrust Fault Rupture (175 eqs)



**On barge – during the shock he saw the water in the river at some places boiled up 12 to 15 feet higher than the surface of the surrounding river…. He saw cotton-wood trees 18 or 24 inches through snapped off…..he thinks at least 200 acres of land along the margin of the river, fell in.**

Letter written by a gentleman from W. Tennessee




Mw ≈ 7.8

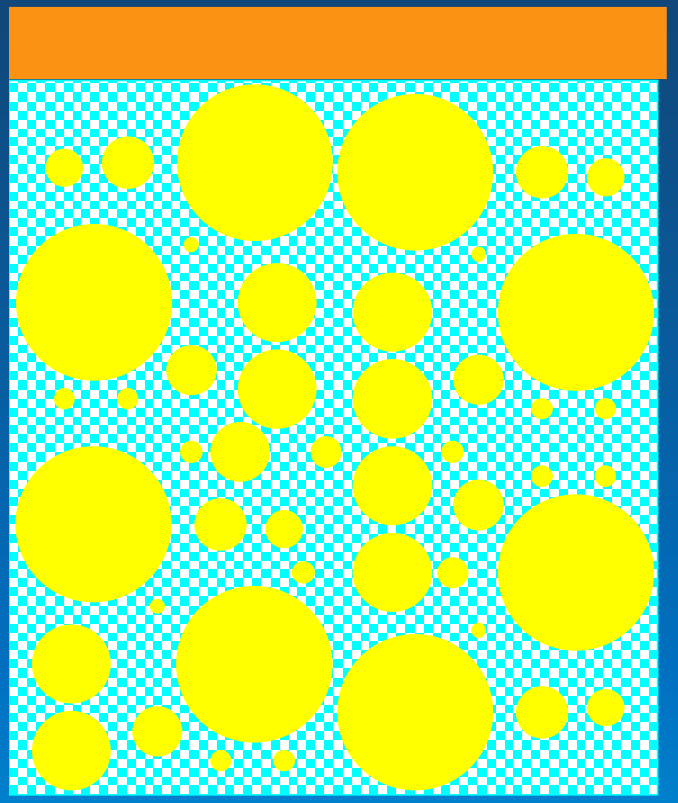
Feb.7th 4 am "a concussion took place so much more violent than those that had proceeded it, that it was dominated the hard shock. At first the Mississippi seemed to recede from its banks, and its waters gathering up like a mountain, leaving for the moment many boats, which were here on their way to New Orleans, on bare sand, in which time the poor sailors made their escape from them. It then rising fifteen to twenty feet perpendicularly, and ..the boats left on the sand were now torn from their moorings and suddenly driven up a little creek..to a distance in some instances, of nearly a quarter of a mile."

Eliza Bryan 1816

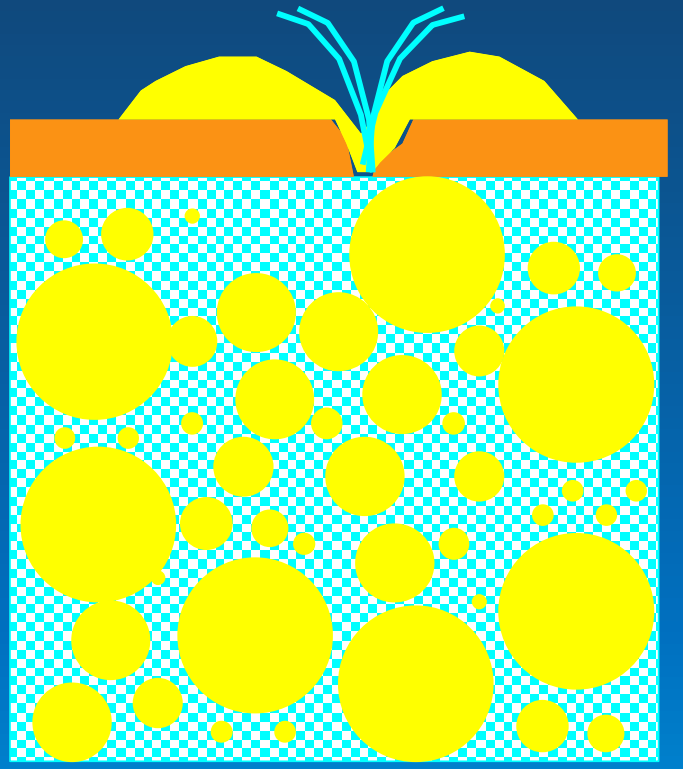
# What do we know about pre-historic earthquakes

SAND BOIL

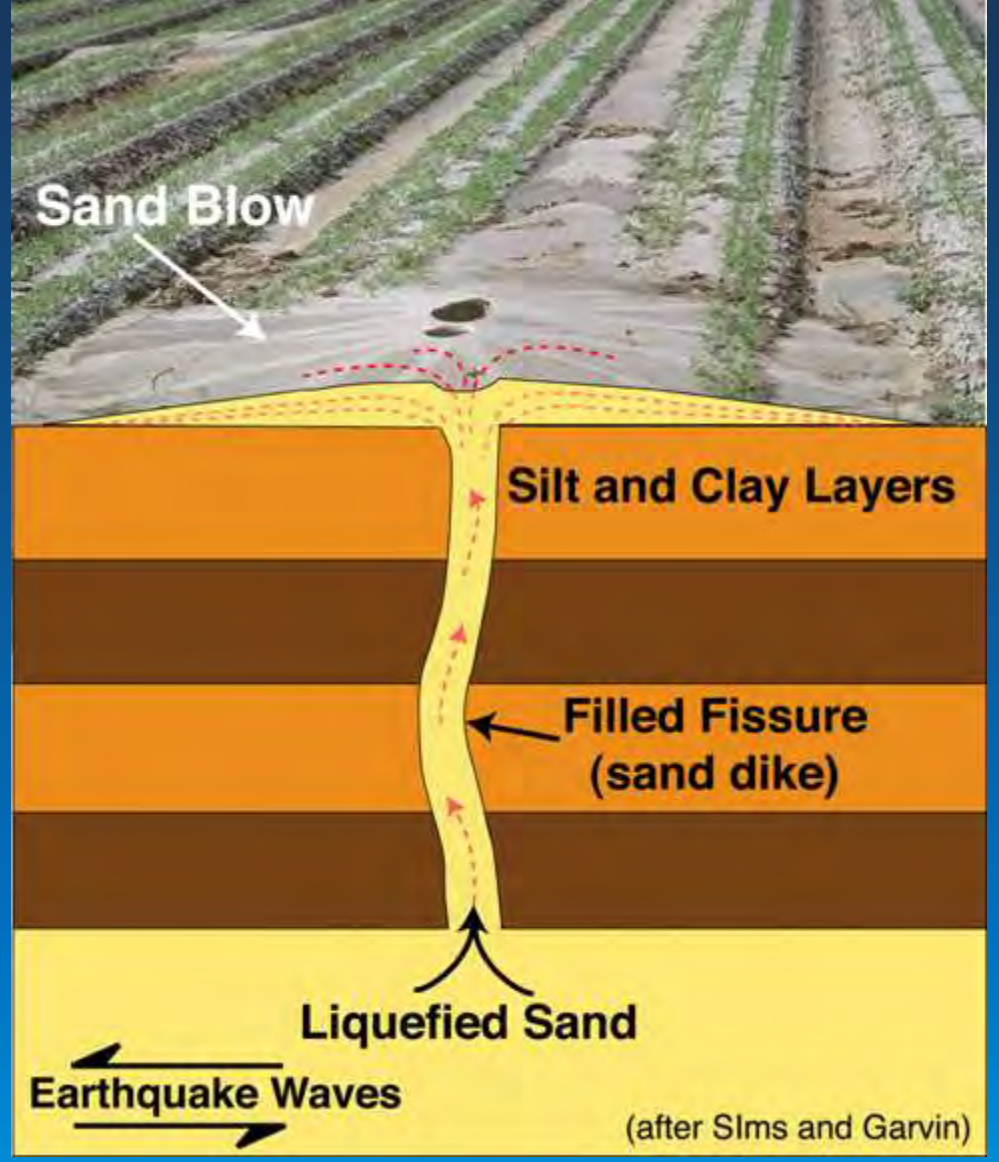
WATER SPOUTS

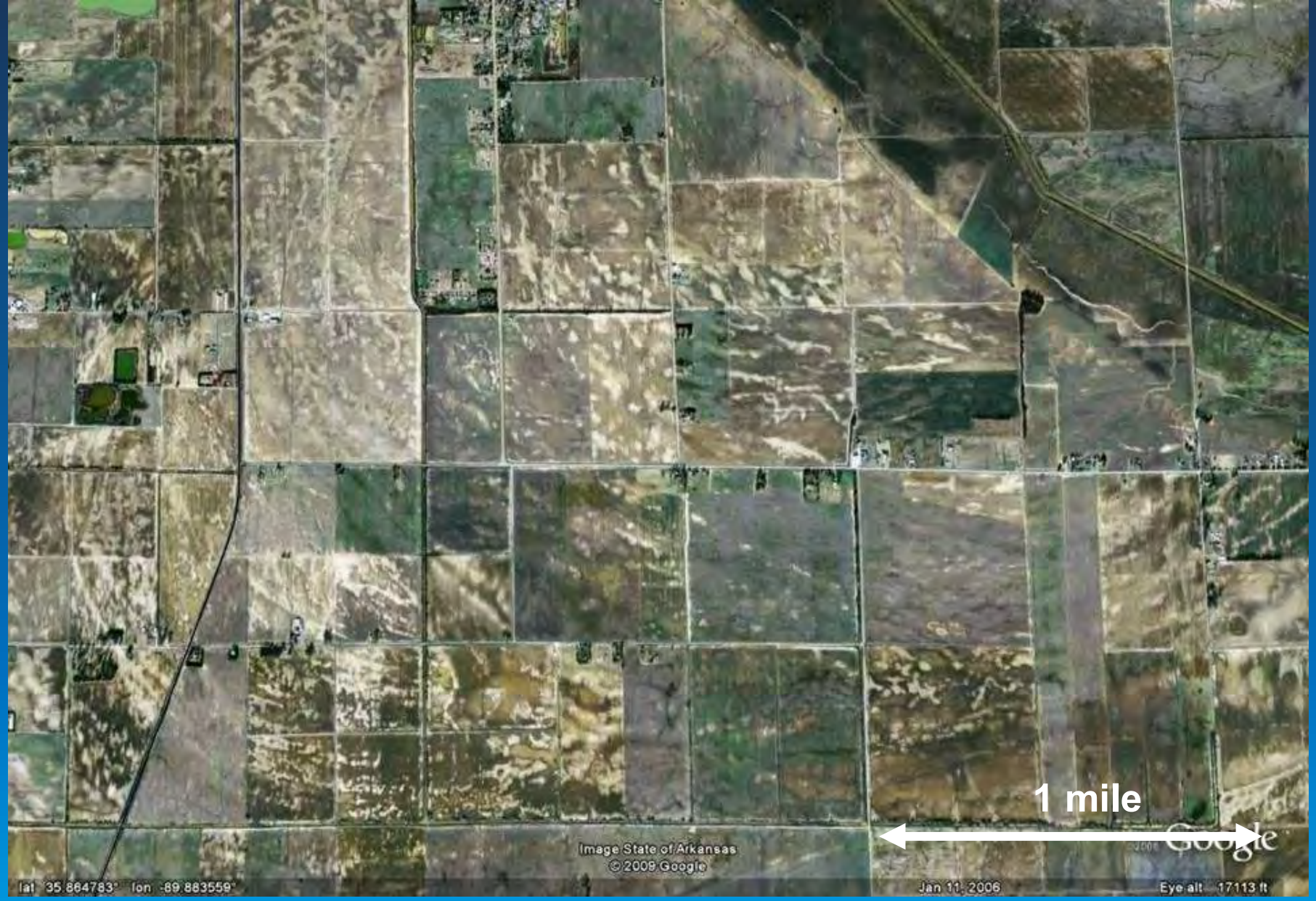


Initial State

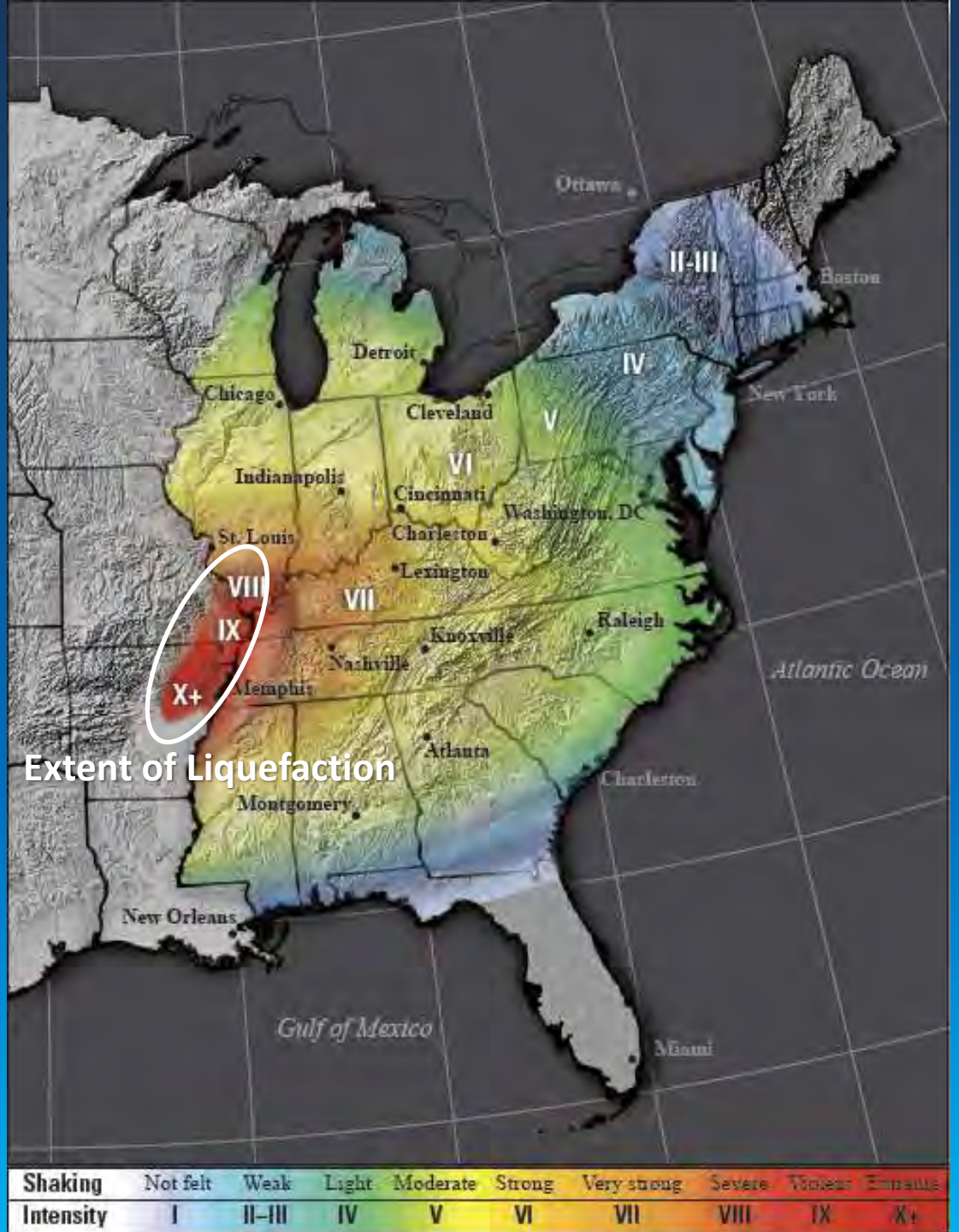


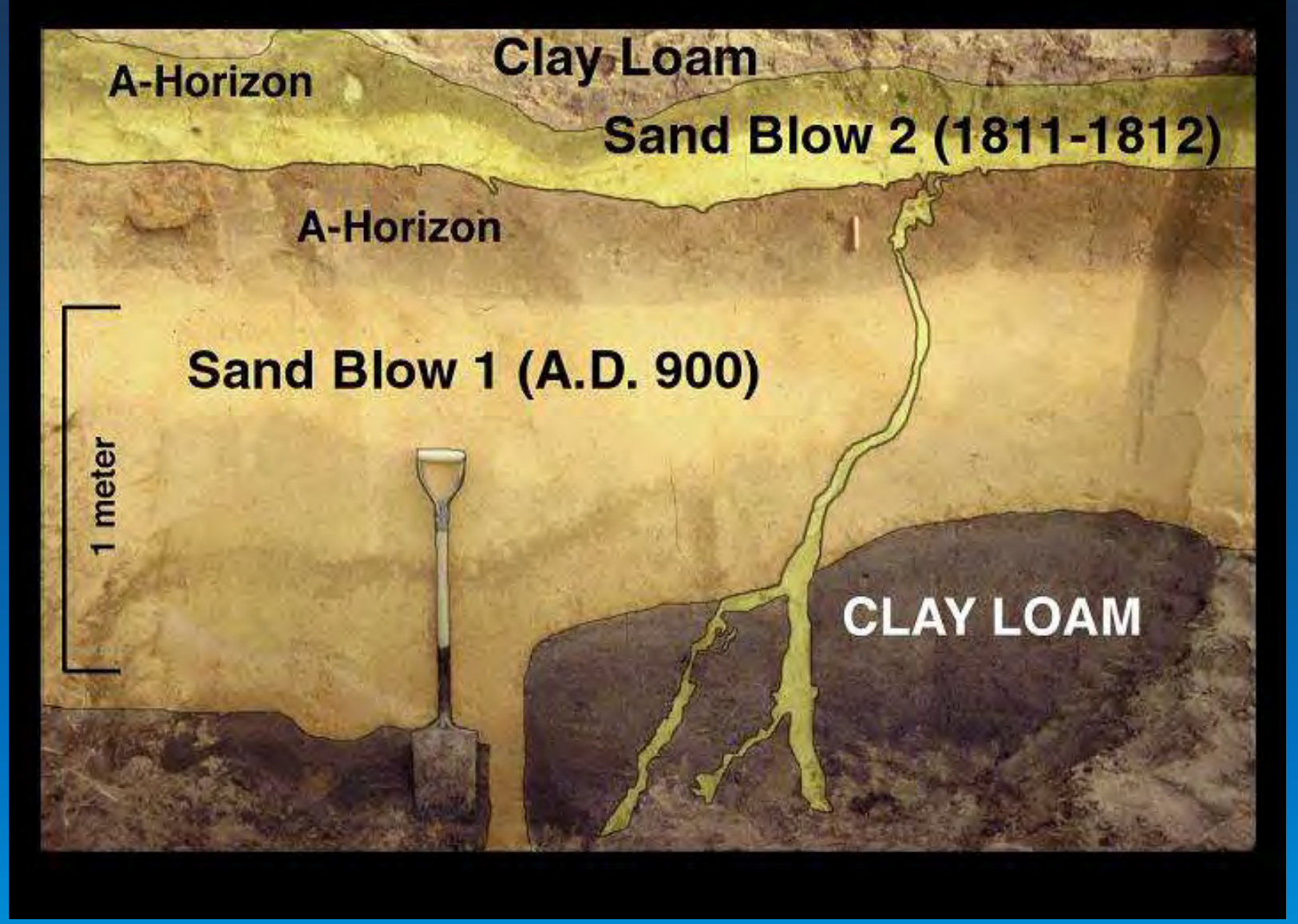
SHAKE


Sand Blow
Silt and Clay Layers
Filled Fissure
(sand dike)
Liquefied Sand
Earthquake Waves
(after SIms and Garvin)

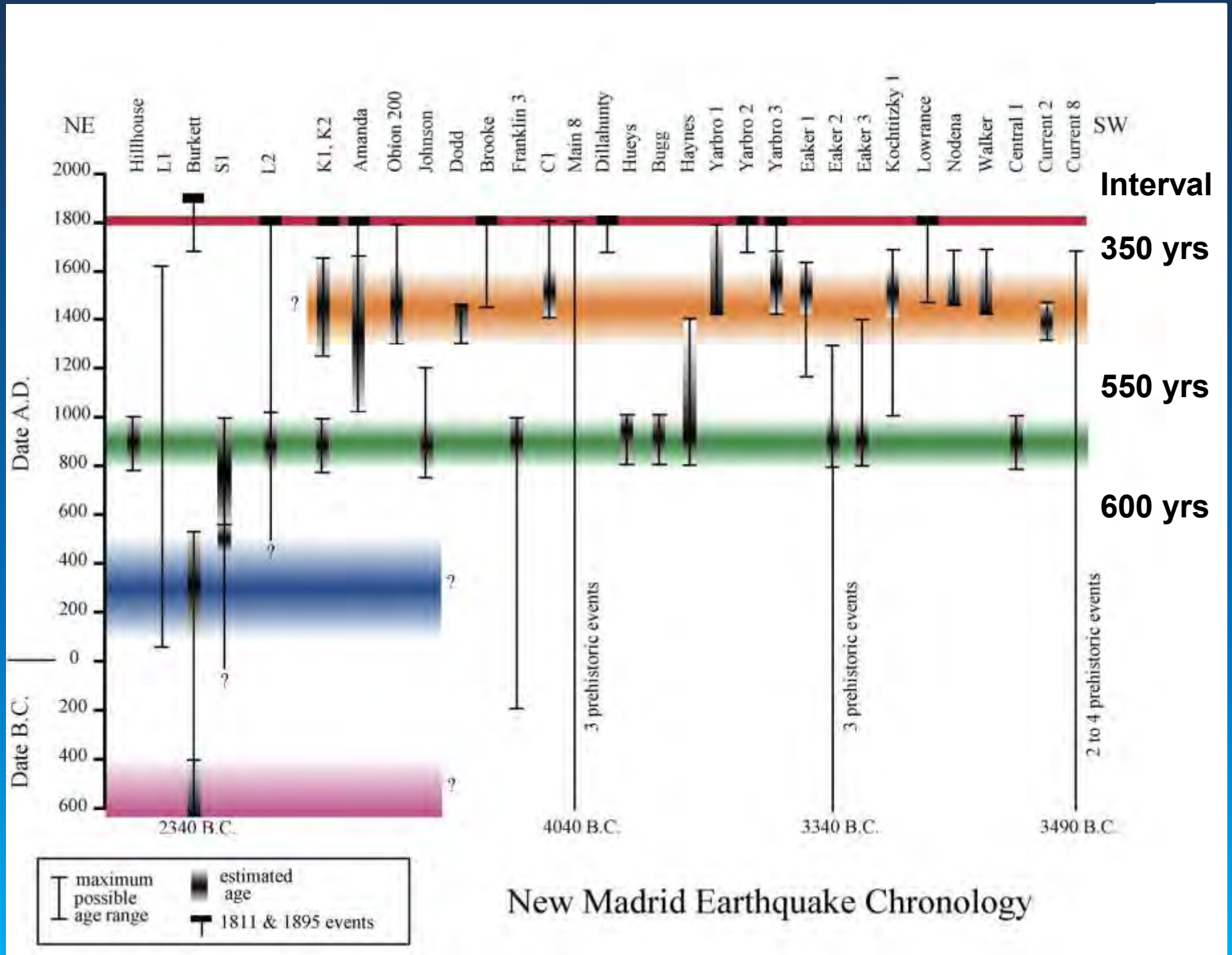



**“Cracks are yet in the earth in place 18 feet wide..such large quanitities of white sand have been thrown up that in many places that was formerly rich land looks like a sand beach.”**


Ottawa
II-III
Boston
Detroit
IV
Chicago
Cleveland
New York
V
VI
Indianapolis
Cincinnati
Washington, DC
St. Louis
Charleston
Lexington
VIII
VII
IX
Raleigh
Knoxville
Nashville
Atlantic Ocean
X+
Memphis
Atlanta
Extent of Liquefaction
Charleston
Montgomery
New Orleans
Gulf of Mexico
Miami
Shaking
Not felt
Weak
Light
Moderate
Strong
Very strong
Severe
Violent
Extreme
Intensity
I
II–III
IV
V
VI
VII
VIII
IX
X+




New Madrid Seismic Zone


NE
SW
Hillhouse
L1
Burkett
S1
L2
K1, K2
Amanda
Obion 200
Johnson
Dodd
Brooke
Franklin 3
C1
Main 8
Dillahunty
Hueys
Bugg
Haynes
Yarbro 1
Yarbro 2
Yarbro 3
Eaker 1
Eaker 2
Eaker 3
Kochtitzky 1
Lowrance
Nodena
Walker
Central 1
Current 2
Current 8
Interval
350 yrs
550 yrs
600 yrs
Date A.D.
2000
1800
1600
1400
1200
1000
800
600
400
200
0
Date B.C.
200
400
600
?
3 prehistoric events
3 prehistoric events
2 to 4 prehistoric events
2340 B.C.
4040 B.C.
3340 B.C.
3490 B.C.
maximum possible age range
estimated age
1811 & 1895 events
New Madrid Earthquake Chronology


Wabash Valley Seismic Zone

# Wabash Valley Area

**Large earthquakes recorded in sediments, occurred about:**

**2,000 years ago ≈ M 6.2**

**4,000 years ago ≈ M 6.3**

**6,100 years ago ≈ M 7.1**

**12,000 years ago ≈ M 6.6**

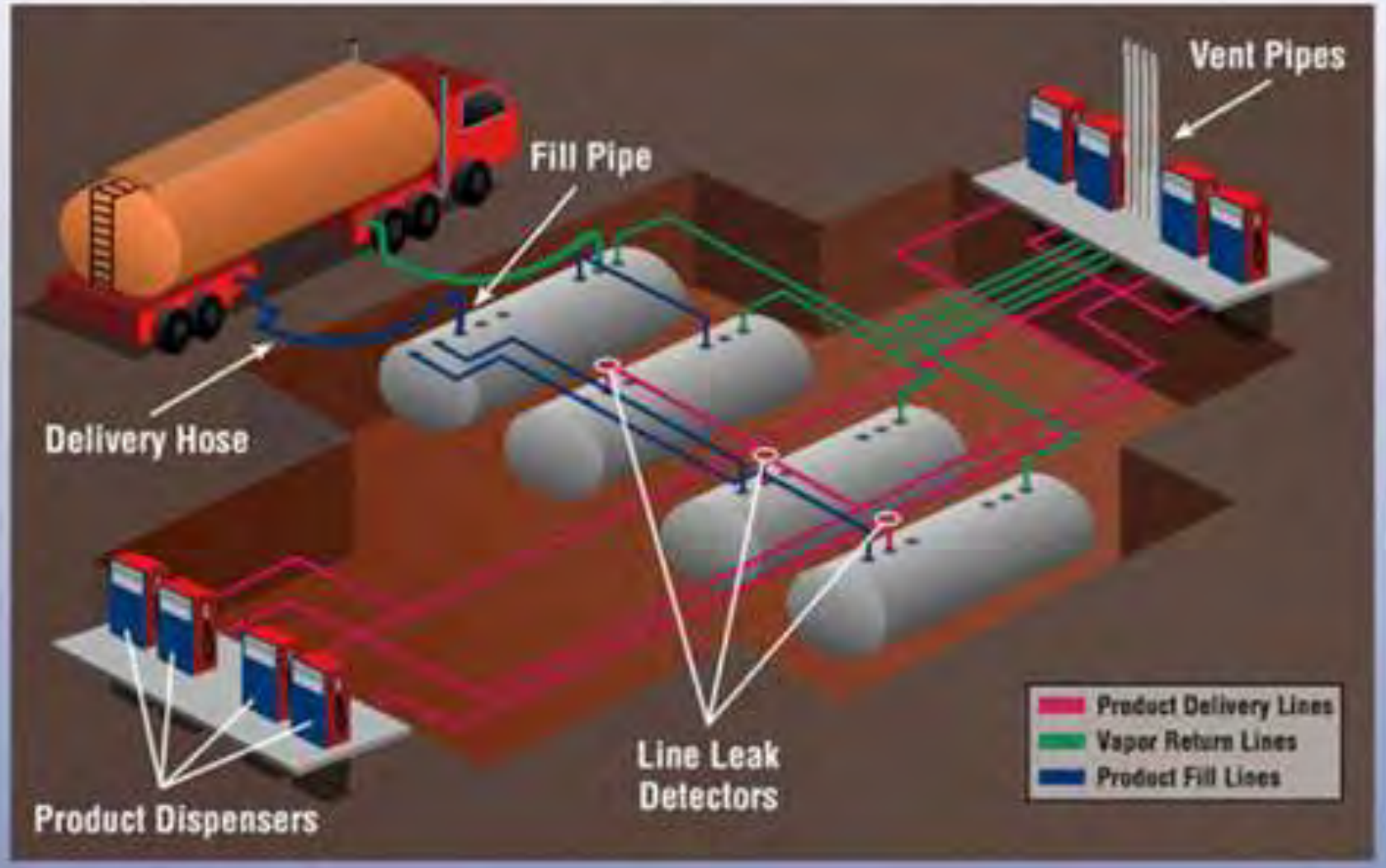
**20,000 years ago**

ISGS liquefaction on YouTube:
http://www.youtube.com/watch?v=cONq231dn6w&list=UULssUm0Hors6IqWyWiVSEFA&feature=share


EXITSURF
SQUARE › GONDOLA › SQUARE STUNNING 360° VIEWS


DAKAR
F 650 GS

# Typical Four-Tank Station

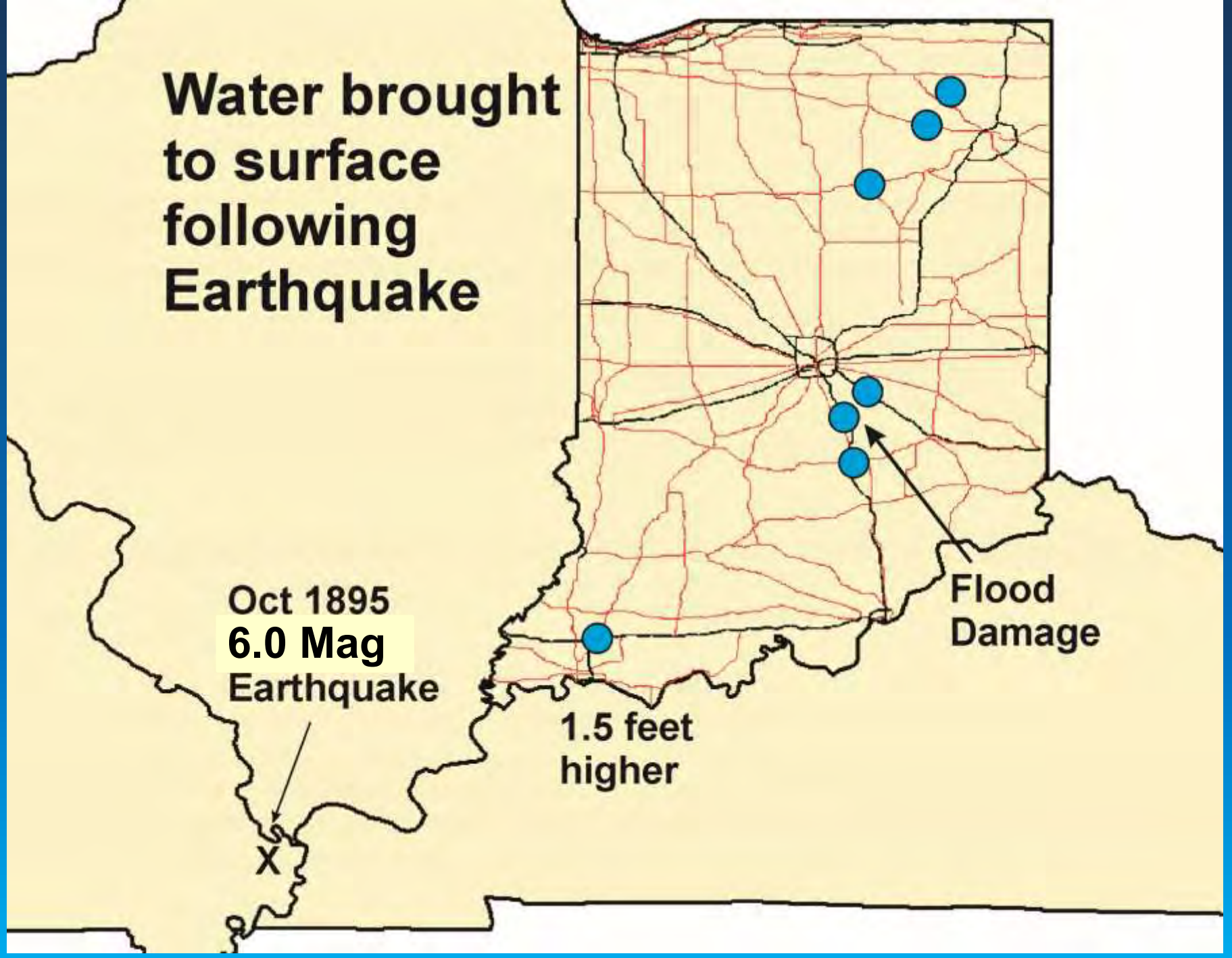



water
WOF
DUNLOP

Lawrence, Kansas Sep. 2005 after heavy rains

Sewer lines floats in liquefaction area pushing manholes up

# Lateral Spreading


Water brought to surface following Earthquake
Oct 1895
6.0 Mag
Earthquake
X
1.5 feet higher
Flood Damage

**“Honey Creek, that had been dry for several weeks, suddenly filled with clear, cold water that spread beyond the banks, sweeping away fences and doing considerable damage to crops.”**

The Courier Journal Louisville, Nov. 1, 1895

# Bhuji, India 2001

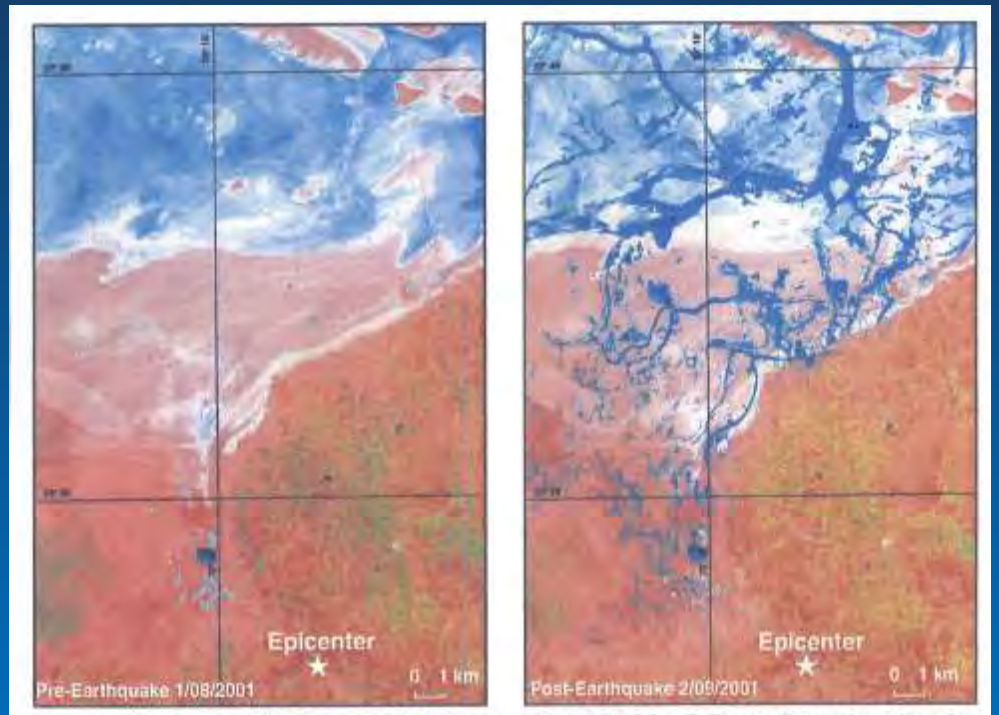



**Figure 5** *Landsat TM image of January 26, 2001 Mw 7.7 earthquake showing distribution of liquefaction. Image on left taken before earthquake. Image on the right shows accumulation of surface water produced during widespread liquefaction. Subsidence of the ground surface may also have occurred due to compaction and consolidation and tectonic down-warping. (Raw scene courtesy of Ken Hudnut and Zhong Lu, USGS. Image processing by Andrew Barron, William Lettis & Associates.)*

# Approaches to bridges settle


FORD
RALPH PRATER FORD

Elevated water tank

## Generators have to be refueled


Main shock damage

## Additional damage with aftershock

Inspection of buildings
Green-yellow-red cards

Green – safe to occupy

Yellow – conditional

Red – no entry

Has to be re-inspected after major aftershocks card has DATE & TIME

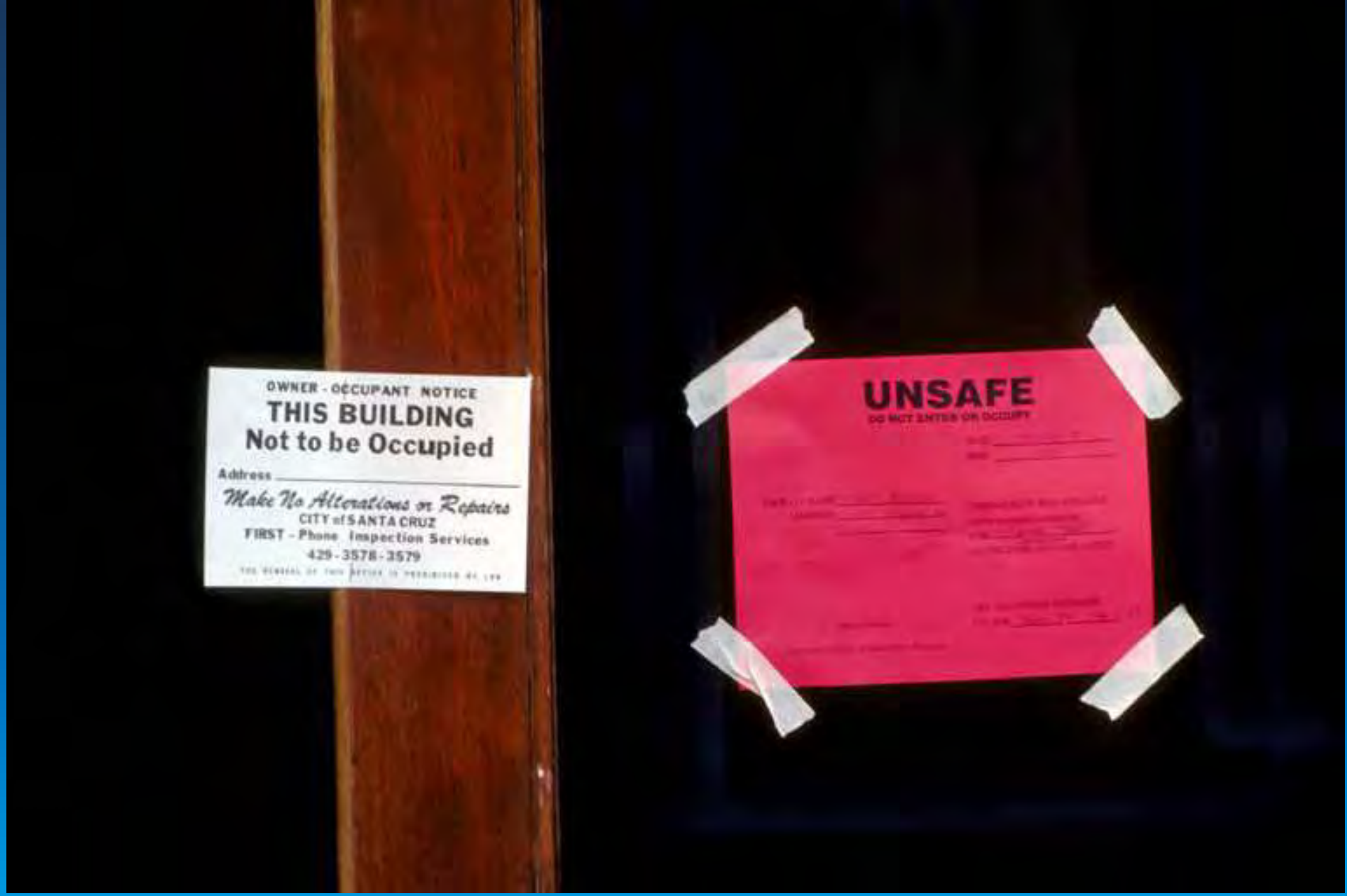



Figure 11-2 A RESTRICTED USE tag with restrictions noted as "Public may enter. Stay clear of taped off areas and construction."

## Seattle 2001 – Mag 6.8
## 40 miles away & 30 miles deep


**Move away from buildings**
**Be aware of aftershocks!**


VIRGINIA DEPARTMENT
OF TRANSPORTATION

Floating roofs on Naptha tanks - Turkey

Bridge is fine – utilities are damaged – Kobe, Japan

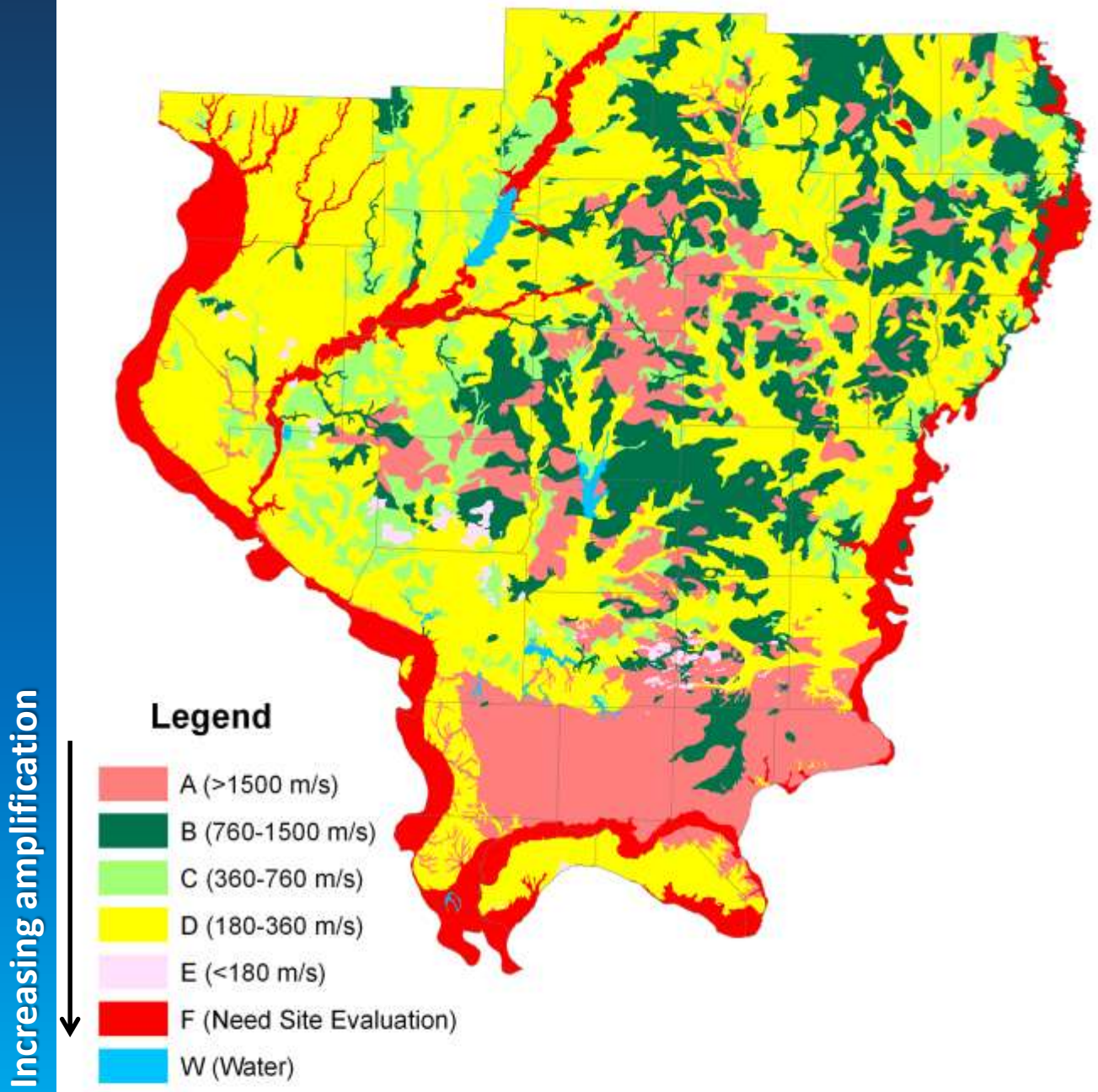

Boulanger


Flexible connection
開
閉
Boulanger

Separator and Oil & Brine Water Tanks


PING & Marine
JEWELLER
TENDE GEMTIME

BUILDINGS CLOSE TO ONE ANOTHER THAT BEGIN TO SWAY MAY COLLIDE OR POUND ONE ANOTHER TO DESTRUCTION.

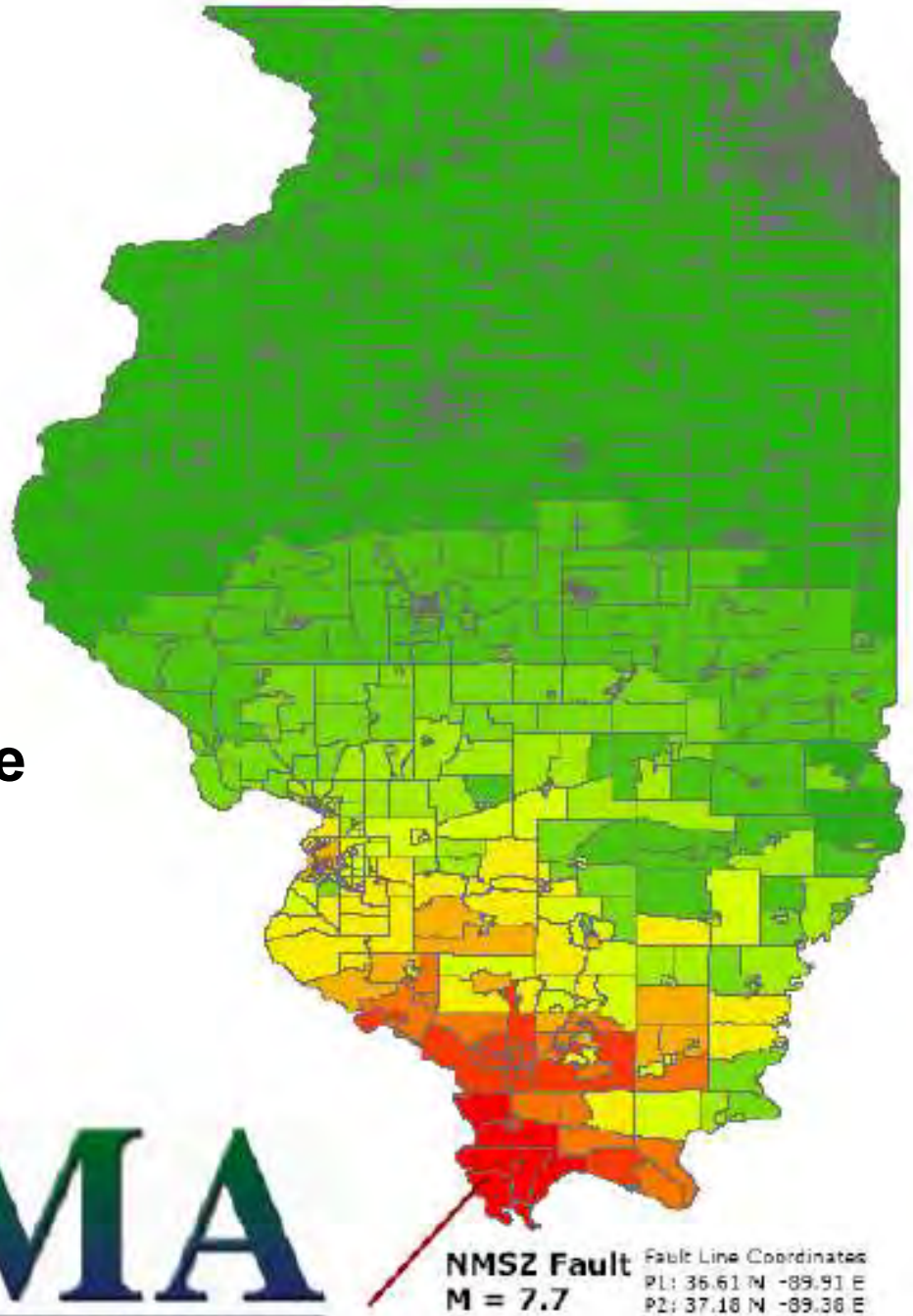

Legend
A (>1500 m/s)
B (760-1500 m/s)
C (360-760 m/s)
D (180-360 m/s)
E (<180 m/s)
F (Need Site Evaluation)
W (Water)
Increasing amplification

**Magnitude**

**7.7**

**New Madrid**

**Seismic Zone**




**Shaking for 2 Story Buildings**

**NMSZ Scenario**
**M = 7.7**

**Surface - Site Class**
**Sa T = 0.2 sec [g]**

| | |
|---|---|
| VI | < 0.10 |
| | 0.10 - 0.15 |
| | 0.15 - 0.20 |
| VII | 0.20 - 0.25 |
| | 0.25 - 0.30 |
| | 0.30 - 0.40 |
| VIII | 0.40 - 0.50 |
| | 0.50 - 0.70 |
| IX | 0.70 - 1.00 |
| | > 1.00 |

IEMA

ILLINOIS EMERGENCY MANAGEMENT AGENCY

# Mag. 7.7 on New Madrid

## Estimated Damage in Illinois

Slight damage = 67,000 structures - small cracks in masonry chimneys and masonry veneer

Moderate = 41,000 - large cracks in chimneys toppling of tall masonry chimneys

Extensive = 10,000 - toppling of most brick chimneys, permanent lateral movement of floors & roof, cracks in foundations, partial collapse of soft story floors.

Complete = 20,000 - may collapse or be in imminent danger of collapse

# Mag. 6.3 on New Madrid

Estimated Damage in Illinois

Slight damage = 9,000 structures - small cracks in masonry chimneys and masonry veneer

Moderate = 2,000 - large cracks in chimneys toppling of tall masonry chimneys

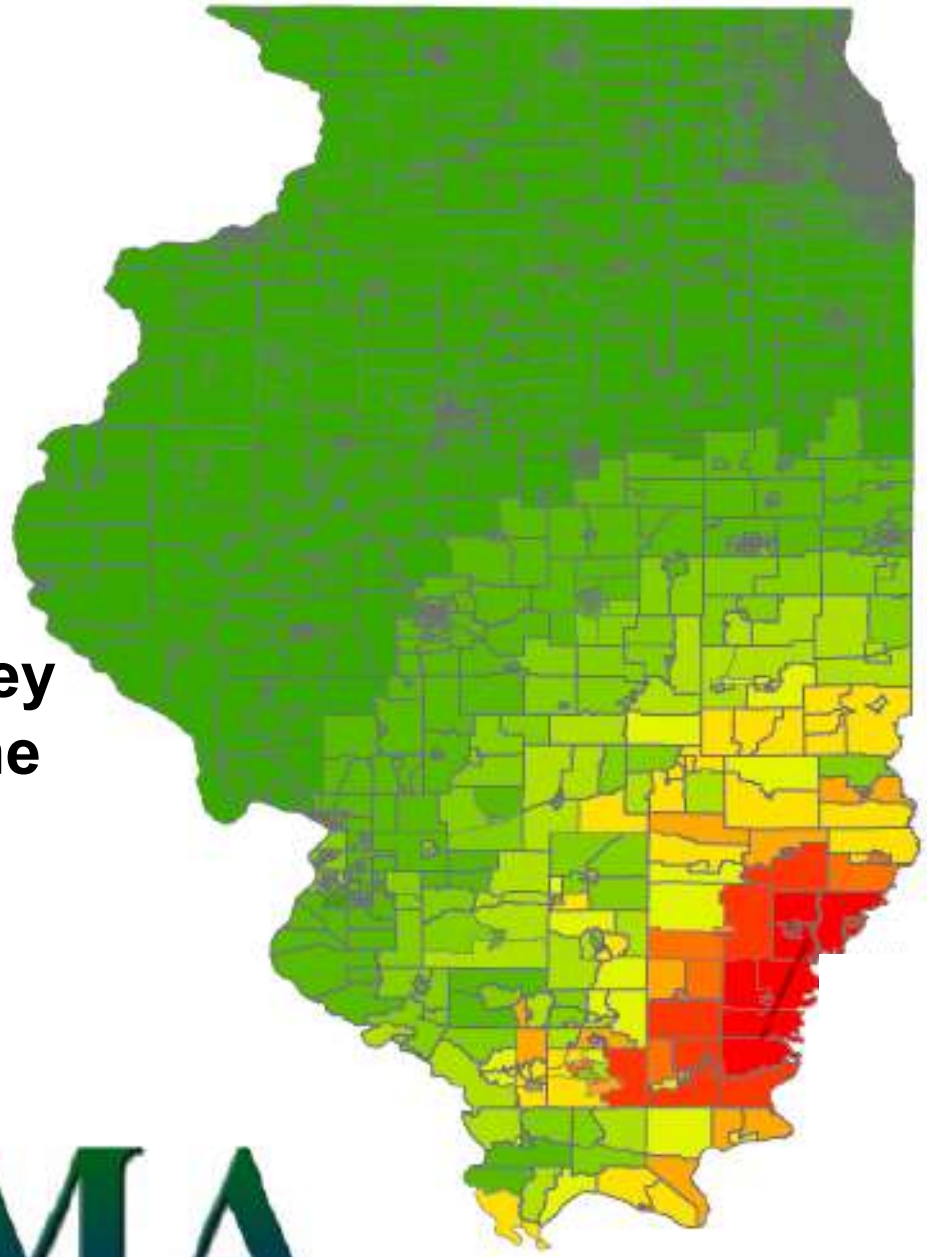
Extensive = 300 - toppling of most brick chimneys, permanent lateral movement of floors & roof, cracks in foundations, partial collapse of soft story floors.

Complete = 1,800 - may collapse or be in imminent danger of collapse

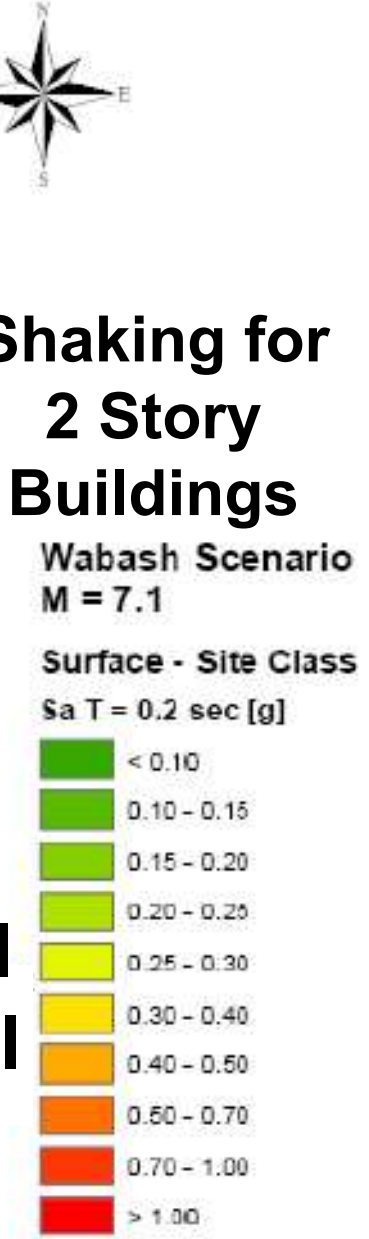
**Magnitude**

**7.1**

**Wabash Valley Seismic Zone**



**Shaking for 2 Story Buildings**




VI
VII
VIII
IX

IEMA
ILLINOIS EMERGENCY MANAGEMENT AGENCY

# Mag. 7.1 in Wabash Valley

Estimated damage in Illinois

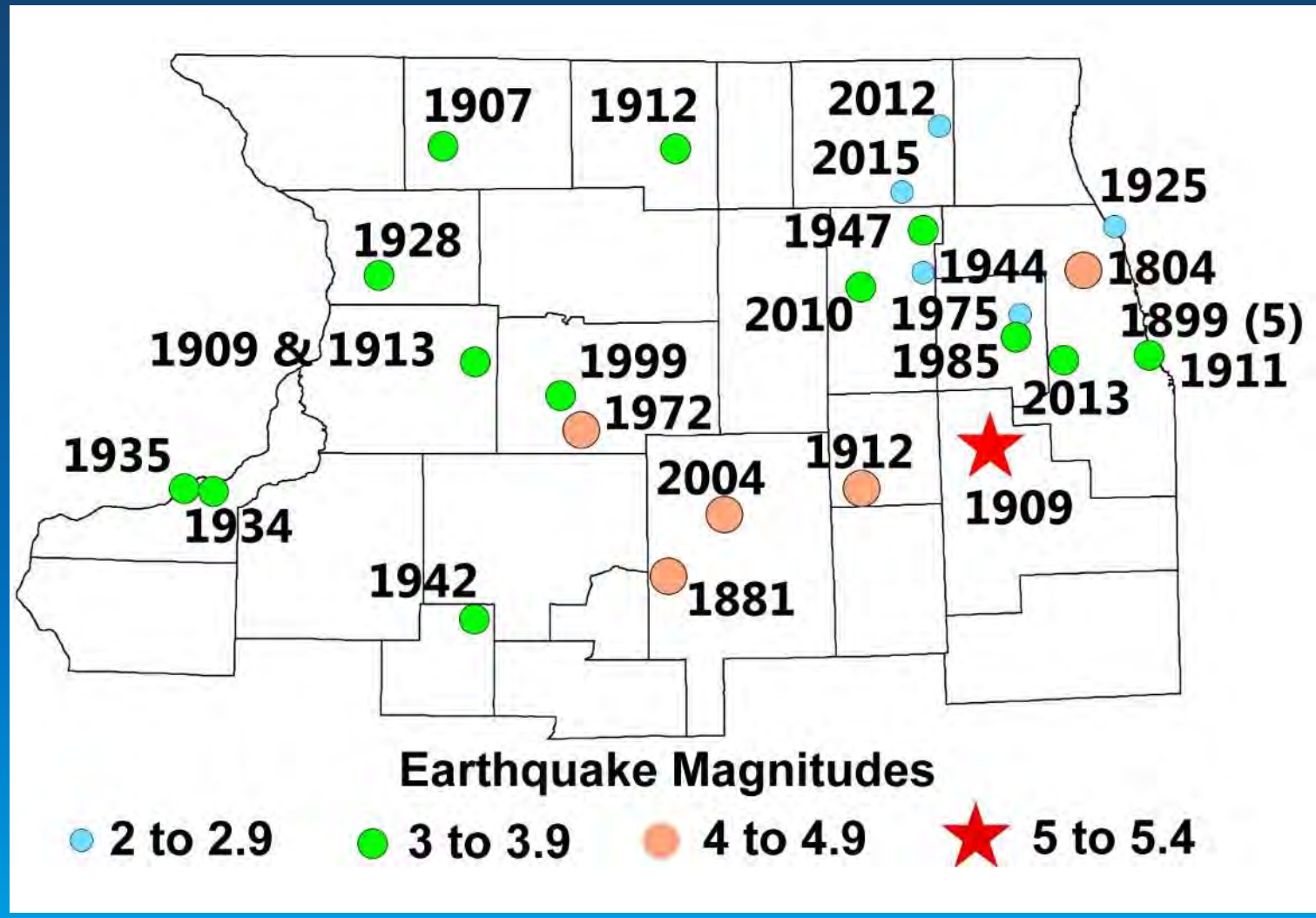
Slight damage = 40,000 structures - small cracks in masonry chimneys and masonry veneer

Moderate = 19,000 - large cracks in chimneys toppling of tall masonry chimneys

Extensive = 4,000 - toppling of most brick chimneys, permanent lateral movement of floors & roof, cracks in foundations, partial collapse of soft story floors.

Complete = 6,500 - may collapse or be in imminent danger of collapse

# State, Counties & Cities Hazard Mitigation Plans



# City of Chicago All-Hazard Mitigation Plan – 2006

5.3 magnitude earthquake at 1909 earthquake site

~ Intensity VI

Damage to structures:

Slight damage = 13,210 structures - small cracks in masonry chimneys and masonry veneer

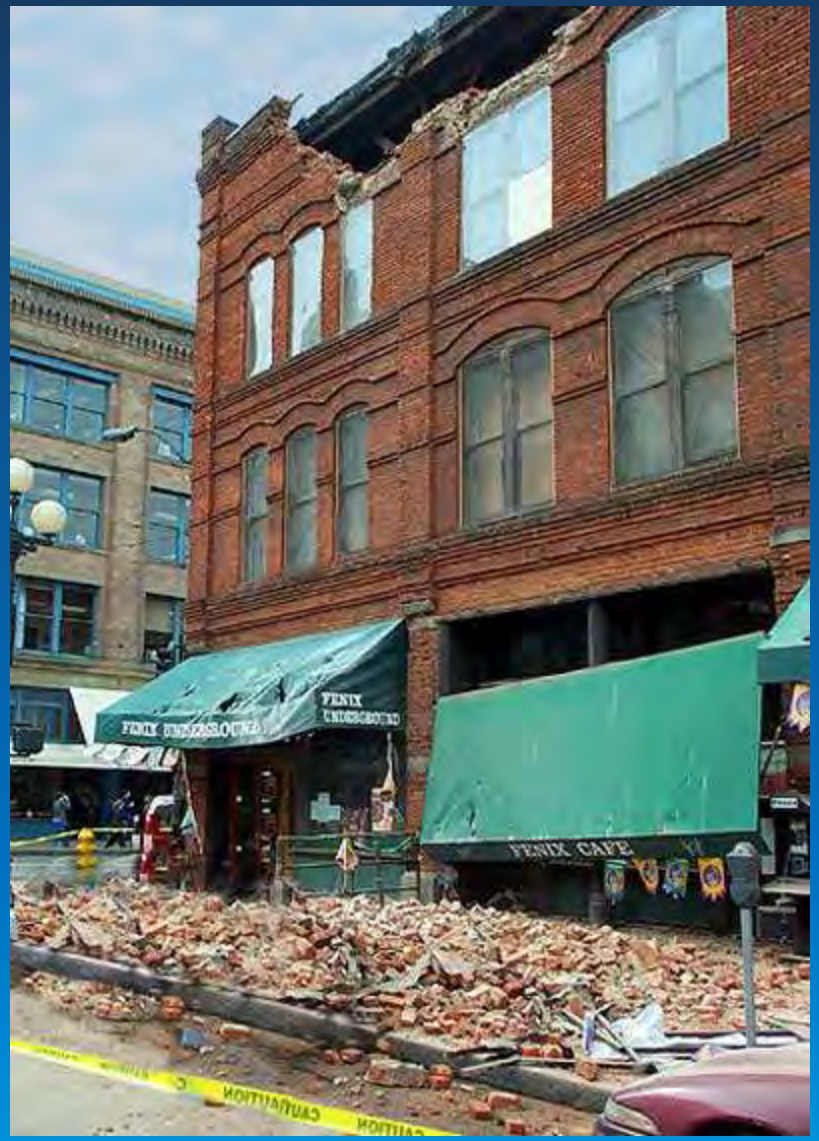
Moderate = 3,776 - large cracks in chimneys toppling of tall masonry chimneys

**Extensive** = **549** - toppling of most brick chimneys, permanent lateral movement of floors & roof, cracks in foundations, partial collapse of soft story floors.

**Complete** = **54** - may collapse or be in imminent danger of collapse


U. S. POST OFFICE
BONE GAP. ILLINOIS 62815


**Seattle 2001 – Mag 6.8**
**40 miles away & 30 miles deep**


FENIX
FENIX CAFE
CAUTION

**Bridgeport, IL** **20 mi (32 km)** photo: Lawrence County EMA

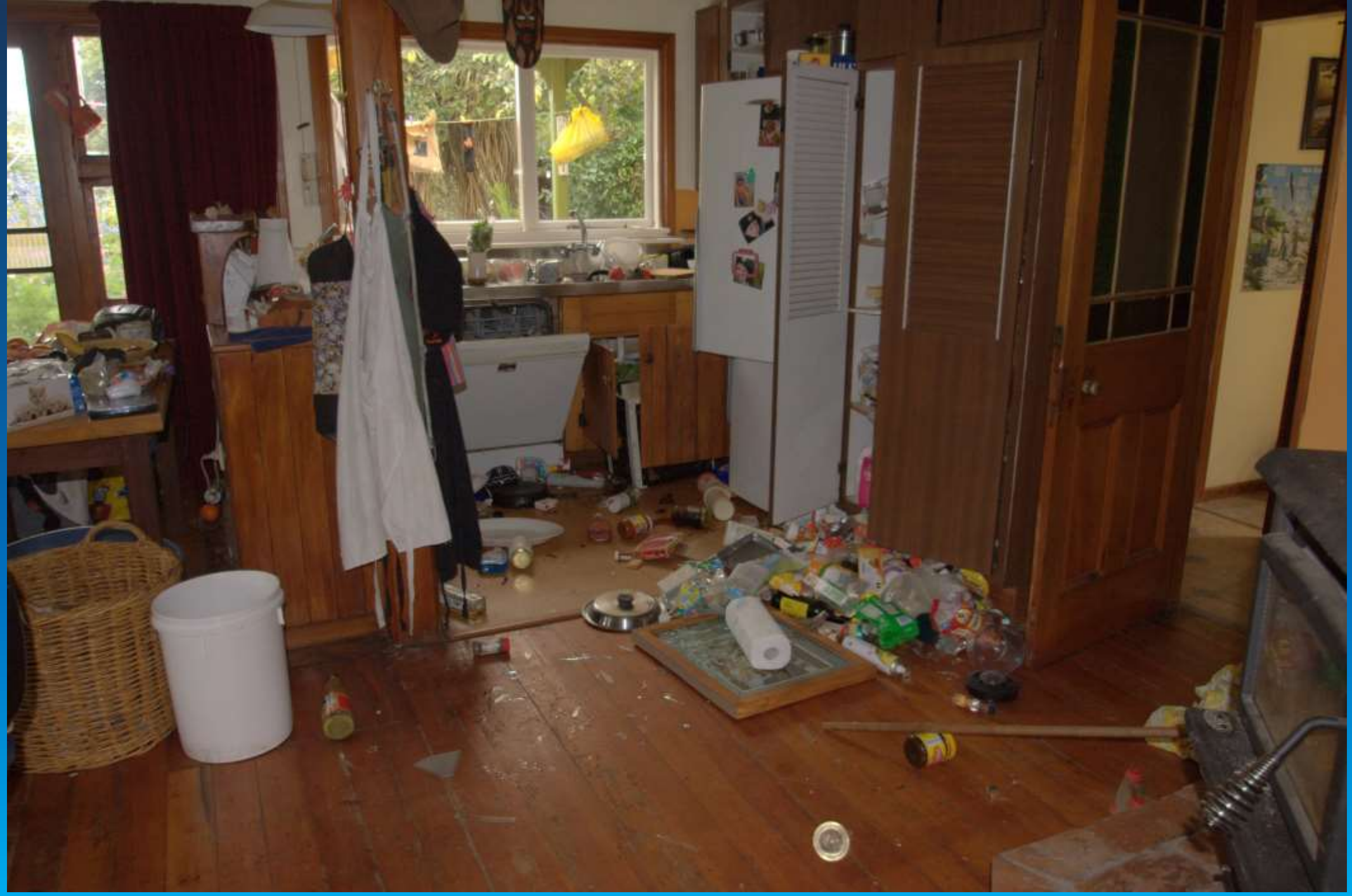
# Terra Cotta pieces for building exteriors - Chicago

# Non-Structural Damage That May Be Encountered

**Non-structural interior disruption**

# Partition Wall Damage


COUPON
FIESTA
4
3 69



## If Outside

Move back away from buildings,
power lines, trees, etc.

## IN THE UNITED STATES

If Indoors – STAY there &

Drop, Cover and Hold On!


**Bellmont, IL** **4.5 mi (7.5 km)** photo: ISGS

**Mt Carmel, IL** **7 mi (11 km)** photo: ISGS

**West Salem, IL** **8 mi (13 km)** photo: ISGS

**West Salem, IL**

**8 mi (13 km)**

photo: ISGS

# Why Prepare?

We are hearing that:

The New Madrid Zone is shutting down!

It is Dead!

There are no mountains in New Madrid

The 100-200 New Madrid earthquakes per year are aftershocks

Waste of time and money to prepare for earthquakes

# There are no mountains

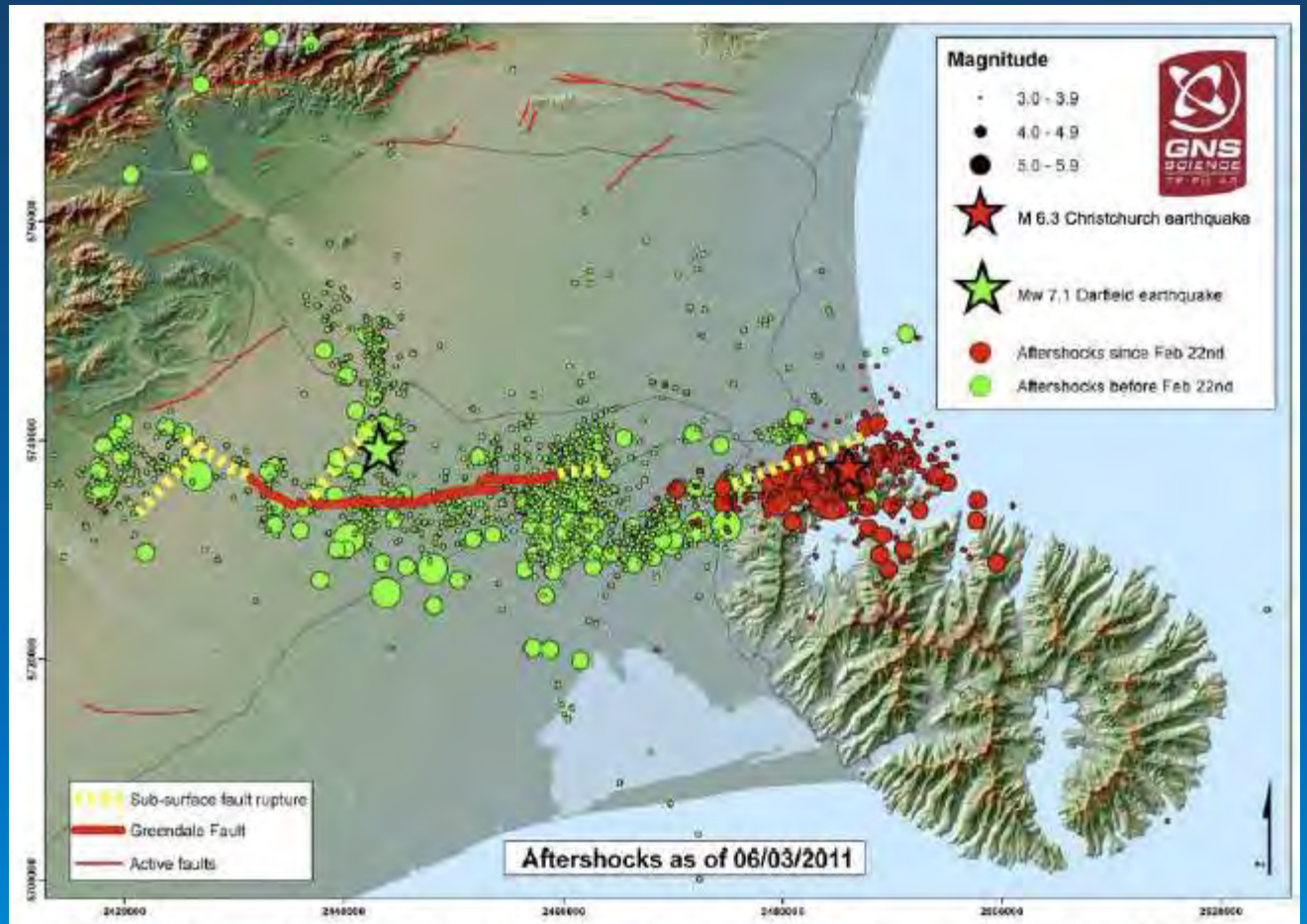


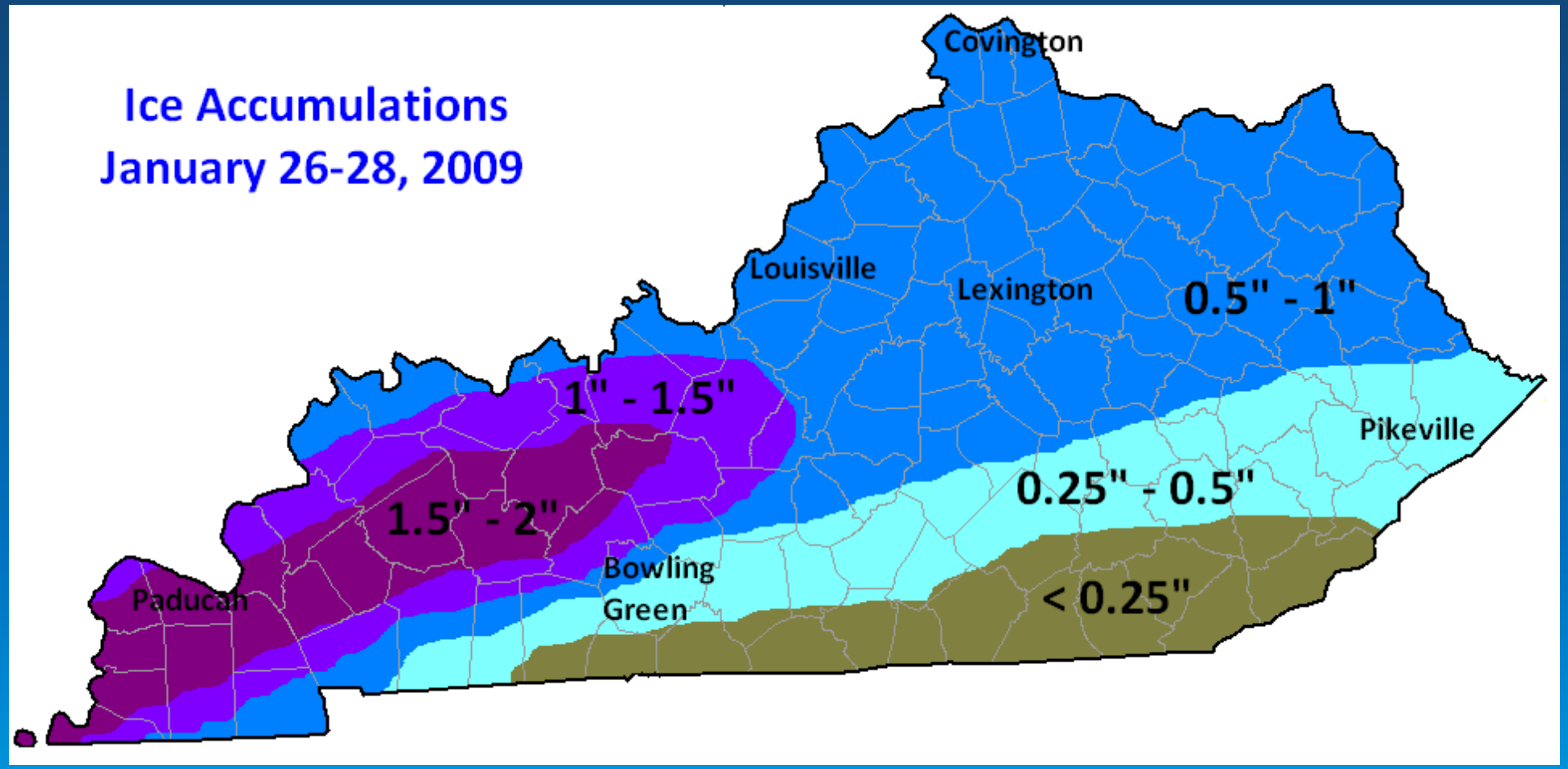

***Figure 1.*** *Location of epicenter and aftershock sequence from the M 7.1 September 4, 2010, Darfield (Canterbury) and M 6.3 February 22, 2011, Christchurch earthquakes (source: GNS).*

# Waste of time and money to prepare for earthquakes

- ESF #1 - Transportation
- ESF #2 - Communications
- ESF #3 - Public Works and Engineering
- ESF #4 - Firefighting
- ESF #5 - Emergency Management
- ESF #6 - Mass Care, Housing, and Human Services
- ESF #7 - Resource Support
- ESF #8 - Public Health and Medical Services
- ESF #9 - Urban Search and Rescue
- ESF #10 -Oil and Hazardous Materials Response
- ESF #11 -Agriculture and Natural Resources
- ESF #12 -Energy
- ESF #13 -Public Safety and Security
- ESF #14 -Long-Term Community Recovery and Mitigation
- ESF #15 -External Affairs

# Kentucky National Guard
# 2008 Earthquake Exercise

## Scenario - NO communications with Western KY


Ice Accumulations
January 26-28, 2009
Covington
Louisville
Lexington
0.5" - 1"
1" - 1.5"
Pikeville
0.25" - 0.5"
1.5" - 2"
Bowling
Green
Paducah
< 0.25"

# Ice-Quake 2009

# USGS probabilities for a 50 year window:

- Repeat of 1811-1812 (M 7.5-8.0)
  - ~7 to 10% chance

- Magnitude 6.0 and greater
  - ~25 to 40% chance

# Lesson Learned?

# Wenchuan earthquake 2008

Longmenshan fault

M = 7.9

Intensity = IX to X

69,226 deaths

216,000 buildings destroyed – 6,900 schools

GPS only ~1mm/yr

Major events 2,000-10,000 years

Hazard map set at about Intensity = VII or mag in 5s

# Japan Coast Tsunami History

| Year | Height |
|---|---|
| 869 | > 124 feet |
| 1611 | 65 feet |
| 1896 | 124 feet |
| 1933 | 94 feet |
| 1960 | 17 feet |

# What height should area prepare for?

~ every 1,000 years tsunami of ~ 124 feet

Last one 1896

Every 100 years ~17 feet = 5.3 m

Some prepared for:

“Disaster attacks when you forget”


***Figure 5.*** *Tsunami height marker, 1960 Chile tsunami, Ofunato Town (in 2010). The sign reads: “Disaster attacks when you forget” (photo: R. Eisner).*

# 2011 Tsunami 124 to 131 feet

# Christchurch  Feb. 22, 2011

## Strong earthquake close to city:

- 6.3 magnitude, Intensity = X,  6 miles from city center
- 181 dead
- Exceeds building code design for 1 chance in 2,500 yr design (0.04% chance in any year)
- $16-$23 billion (US) in damage
- 25% of buildings in Central Business District razed by emergency orders & 25% more expected to be razed by owners

Preparation means knowing what to do!

**IN THE UNITED STATES**

If Indoors – STAY there &

Drop, Cover and Hold On!

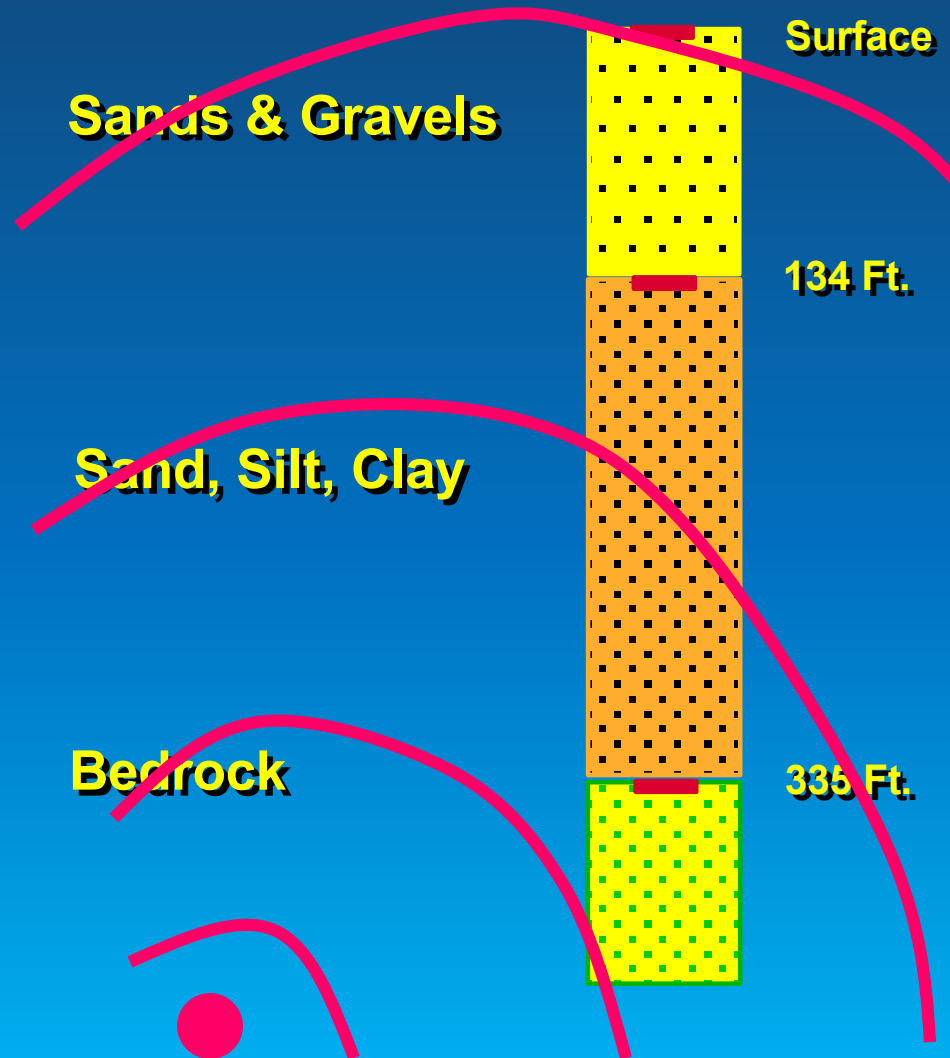
If Outside

Move back away from buildings,
power lines, trees, etc.

# This is where I want to be during an Earthquake!

# SOUTHERN ILLINOIS EARTHQUAKE

## Feb. 5, 1994 - Monitored in Paducah, KY





Kentucky Geological Survey &
University of Kentucky

# USGS Automated First Report
## reported in 10 to 15 minutes

### Earthquake Details

| | |
|---|---|
| Magnitude | 4.3 |
| Date-Time | Wednesday, February 10, 2010 at 09:59:34 UTC<br>Wednesday, February 10, 2010 at 03:59:34 AM at epicenter<br>Time of Earthquake in other Time Zones |
| Location | 41.978°N, 88.597°W |
| Depth | 5 km (3.1 miles) set by location program |
| Region | ILLINOIS |
| Distances | 6 km (4 miles) WNW (292°) from Virgil, IL<br>8 km (5 miles) E (94°) from Sycamore, IL<br>8 km (5 miles) N (1°) from Maple Park, IL<br>14 km (8 miles) ENE (67°) from DeKalb, IL<br>35 km (22 miles) NW (315°) from Aurora, IL<br>77 km (48 miles) WNW (282°) from Chicago, IL |
| Location Uncertainty | horizontal +/- 12.8 km (8.0 miles); depth fixed by location program |
| Parameters | NST= 11, Nph= 11, Dmin=171.4 km, Rmss=0.86 sec, Gp=151°,<br>M-type="Nuttli" surface wave magnitude (mbLg), Version=6 |
| Source | USGS NEIC (WDCS-D) |
| Event ID | us2010snay |

https://earthquake.usgs.gov/ens/

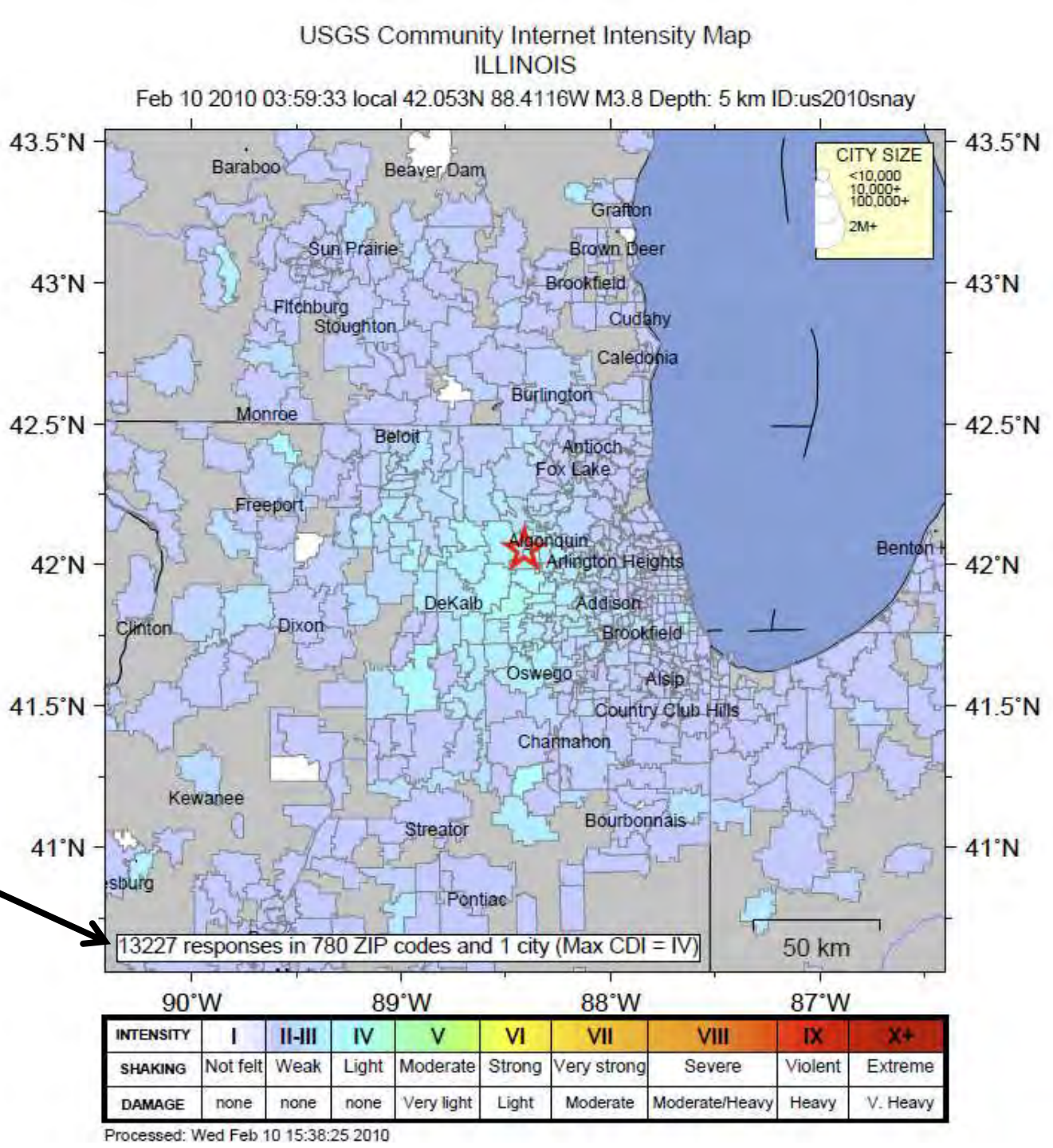
# USGS

## Did You Feel It?

People report experiences

Displayed in Intensities by Zip Code

Presented with First Report & continually updated



USGS
science for a changing world

Earthquake Shaking: Yellow Alert

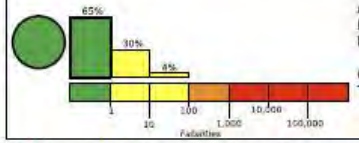
USAID FROM THE AMERICAN PEOPLE

# M 6.0, NLE 2011 Mt. Carmel M6.0 Scenario

Origin Time: Tue 2011-05-16 14:02:00 UTC (10:02:00 local)
Location: 38.30°N 87.80°W Depth: 10 km

**PAGER Version 1**
Created: 22 minutes after earthquake

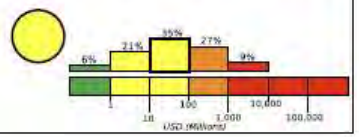
## Estimated Fatalities




Yellow alert level for economic losses. Some damage is possible and the impact should be relatively localized. Estimated economic losses are less than 1% of GDP of the United States. Past events with this alert level have required a local or regional level response.

Green alert level for shaking-related fatalities. There is a low likelihood of casualties.

## Estimated Economic Losses



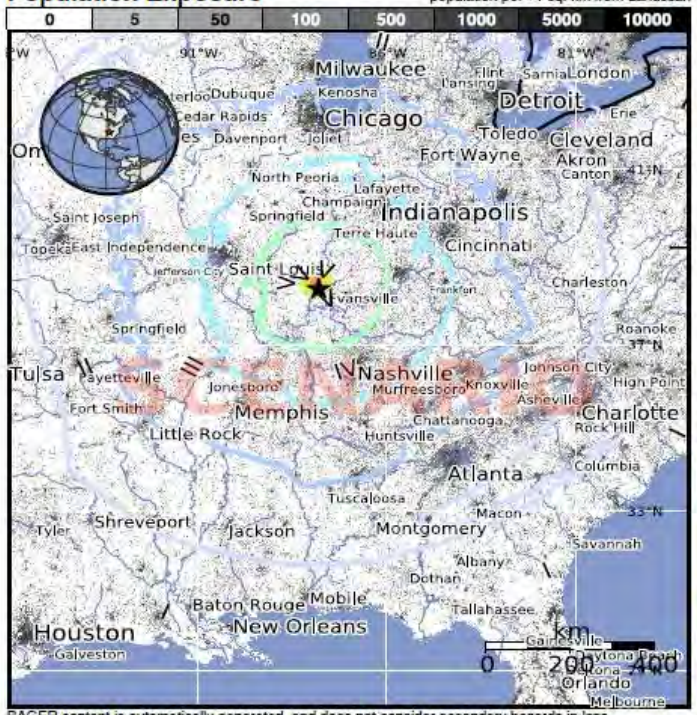

## Estimated Population Exposed to Earthquake Shaking

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| ESTIMATED POPULATION EXPOSURE (k = x1000) | | 51,898k* | 71,975k | 12,107k | 2,088k | 18k | 18k | 2k | 0 | 0 |
| 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




**Structures:**
Overall, the population in this region resides in structures that are resistant to earthquake shaking, though some vulnerable structures exist.

**Historical Earthquakes (with MMI levels):**

| Date | Dist. (km) | Mag. | Max MMI(#) | Shaking Deaths |
|---|---|---|---|---|
| 1976-03-25 | 371 | 5.0 | VI(40k) | 0 |
| 1980-07-27 | 337 | 5.0 | VI(44k) | 0 |
| 1987-06-10 | 58 | 5.1 | VII(5) | 0 |

## Selected City Exposure

from GeoNames.org

| MMI | City | Population |
|---|---|---|
| VII | Mount Carmel | 8k |
| VI | Albion | 2k |
| VI | Grayville | 2k |
| VI | Owensville | 1k |
| V | Sumner | 1k |
| V | Bridgeport | 2k |
| IV | Indianapolis | 773k |
| III | Nashville | 531k |
| II | Memphis | 650k |
| II | Columbus | 737k |
| I | Atlanta | 423k |

bold cities appear on map (k = x1000)

PAGER content is automatically generated, and does not consider secondary hazards in loss calculations. Limitations of input data, shaking estimates, and loss models may add uncertainty.
http://earthquake.usgs.gov/pager

Event ID: usNLE2011MtCarmel6.0_se

# USGS PAGER

**P**rompt
**A**ssessment of
**G**lobal
**E**arthquakes for
**R**esponse

Estimate of Fatalities & Economic Losses

Intensity by City & population

**Many good preparation related publications available for Home & Work Sites:**

**FEMA & IEMA**

**Red Cross**

**Earthquake related Societies**

**May consider non-structural retrofits for continuity of operation:**

**Flexible fuel lines to generators**
**Generator properly affixed to pads**
**Roof top AC**
**Hot water tanks**
**Storage racks for servers**
**Overhead suspended ceilings and light fixtures**
**Sprinkler systems**
**Computer CPUs**

**Homes prepared for disasters**
**Supplies**
**Non-structural retrofits**
**Family exercises – where to turn off gas & water**

Earthquake Safety Guide for Homeowners
http://www.disastersrus.org/emtools/earthquakes/fema-530.pdf

Earthquake Safety Checklist
https://www.fema.gov/media-library-data/15101536763 17-82124ab3b0a31ea239f60acc8d46c2ba/FEMA_B-526_Earthquake_Safety_Checklist_110217_508.pdf

Reducing the risks of Nonstructural Earthquake Damage – A Practical Guide
https://www.fema.gov/media-library-data/1398197749343-db3ae43ef771e639c16636a48209926e/FEMA_E-74_Reducing_the_Risks_of_Nonstructural_Earthquake_Damage.pdf

SCENARIOS with IMPACTS PER COUNTIES

Impact of New Madrid Seismic Zone Earthquakes on the Central USA, ~~Vol. 1 &~~ Vol. 2 – only use Vol. 2
https://www.ideals.illinois.edu/handle/2142/14810

Comprehensive Seismic Loss Modeling for the State of Illinois, 2007.
https://www.ideals.illinois.edu/handle/2142/8783


rabauer@illinois.edu