Earthquakes & Their Impacts in Central U.S.

Robert A. Bauer

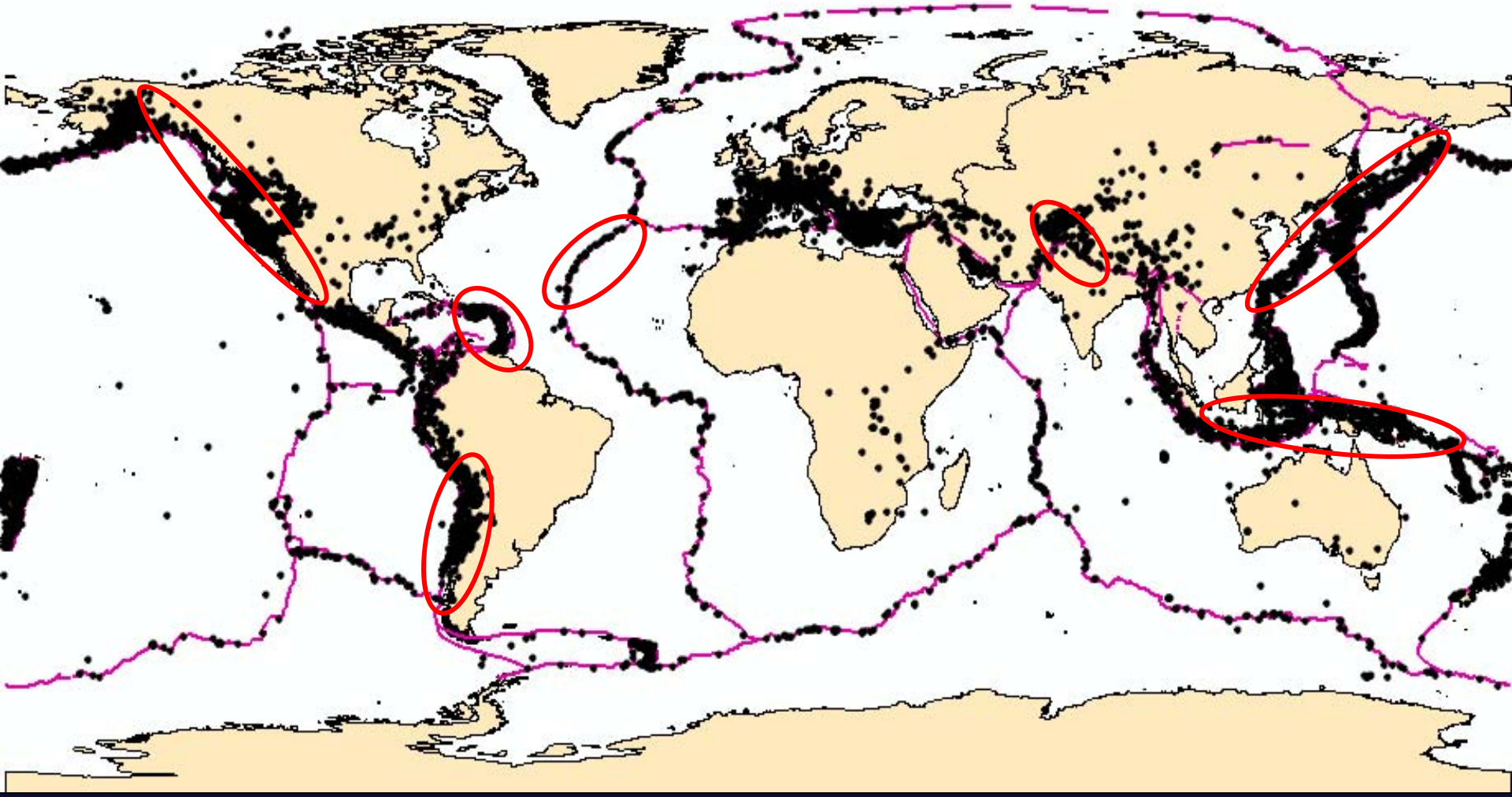
Illinois State Geological Survey

Institute of Natural Resource Sustainability

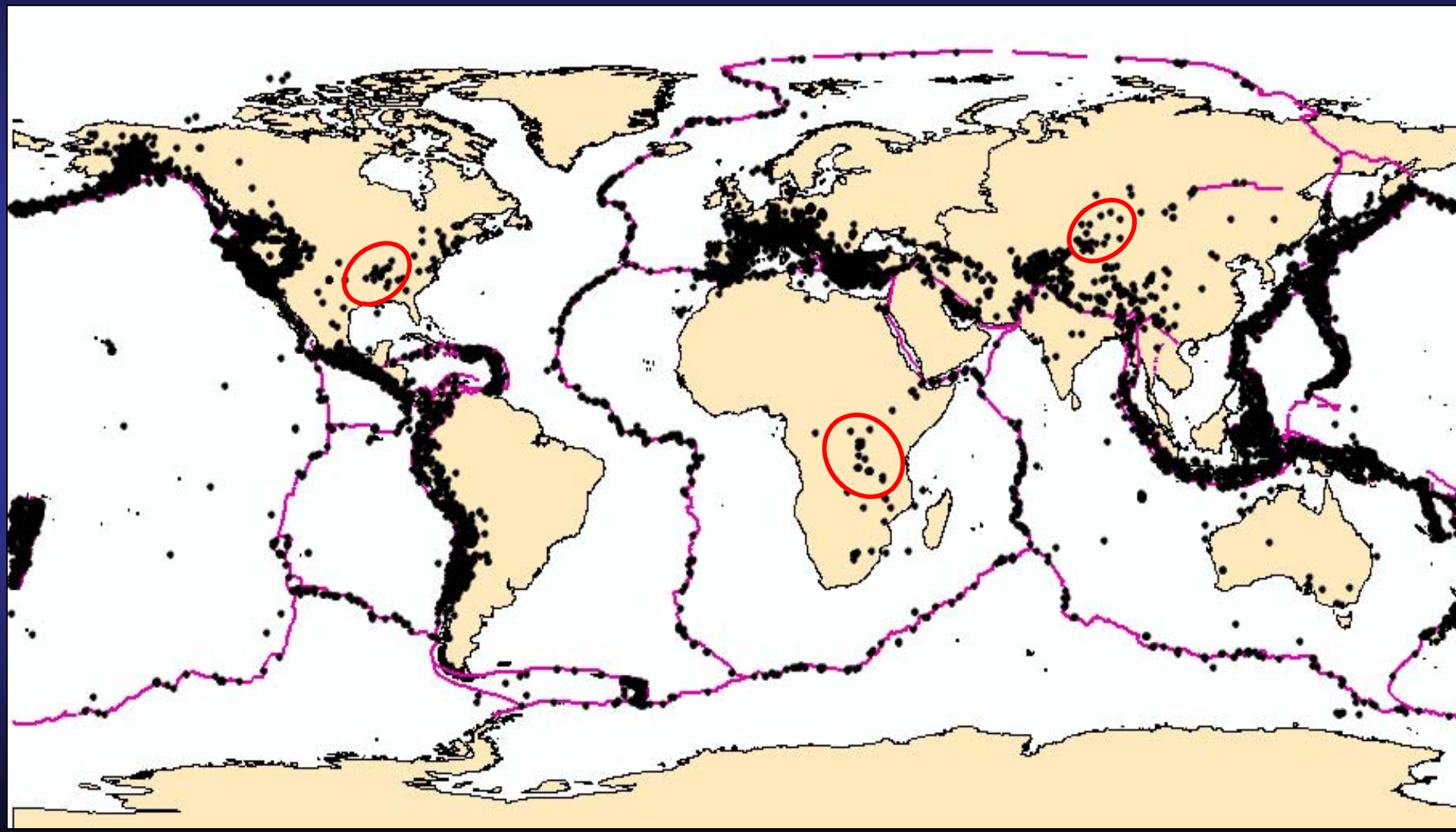
Earthquakes in the Central U.S.

- Why do we have them?
- Where do we have them?
- What do we know about pre-historic earthquakes?
- What controls the location of damage?
- What do we expect?

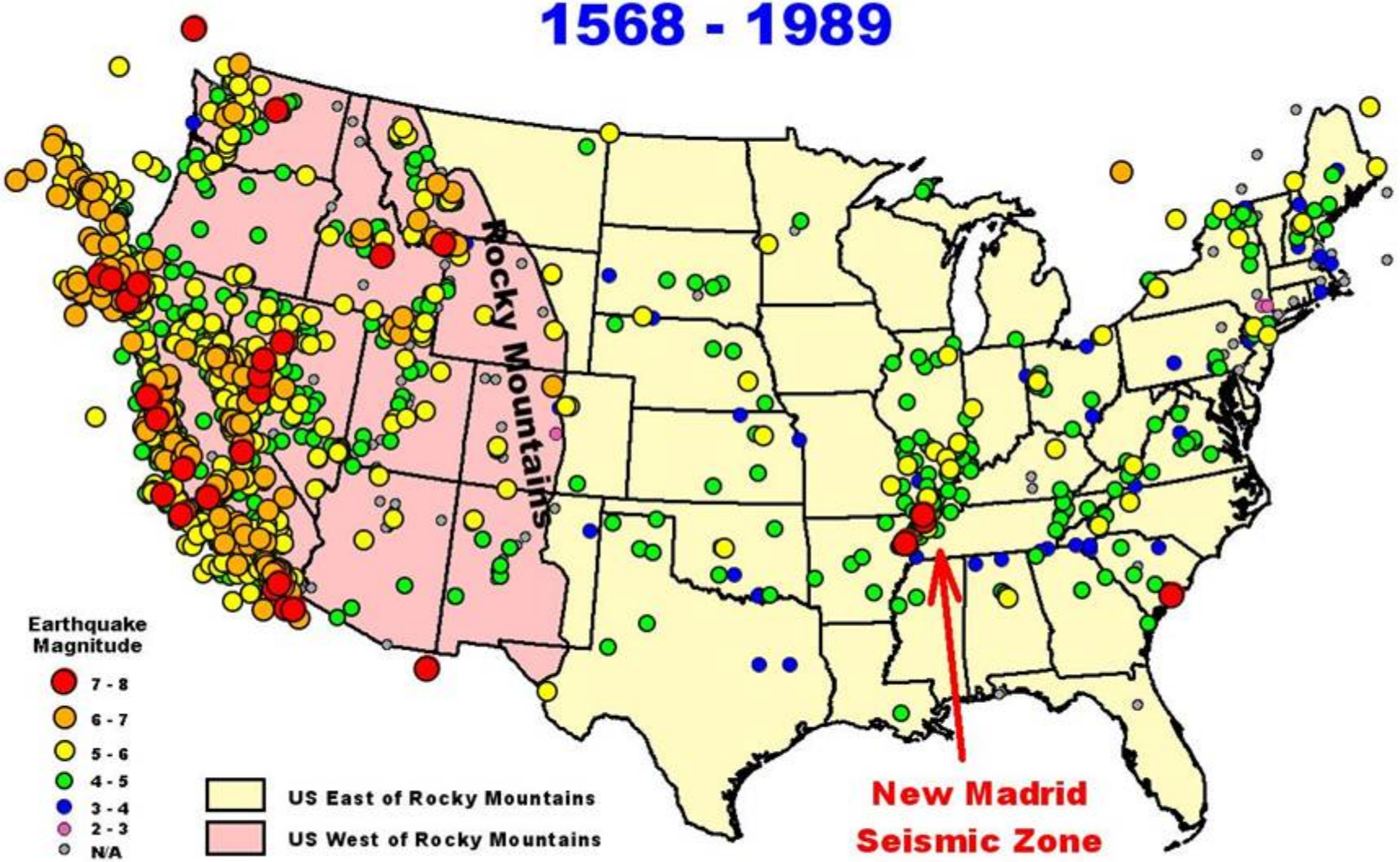
Plate Boundaries and Earthquakes

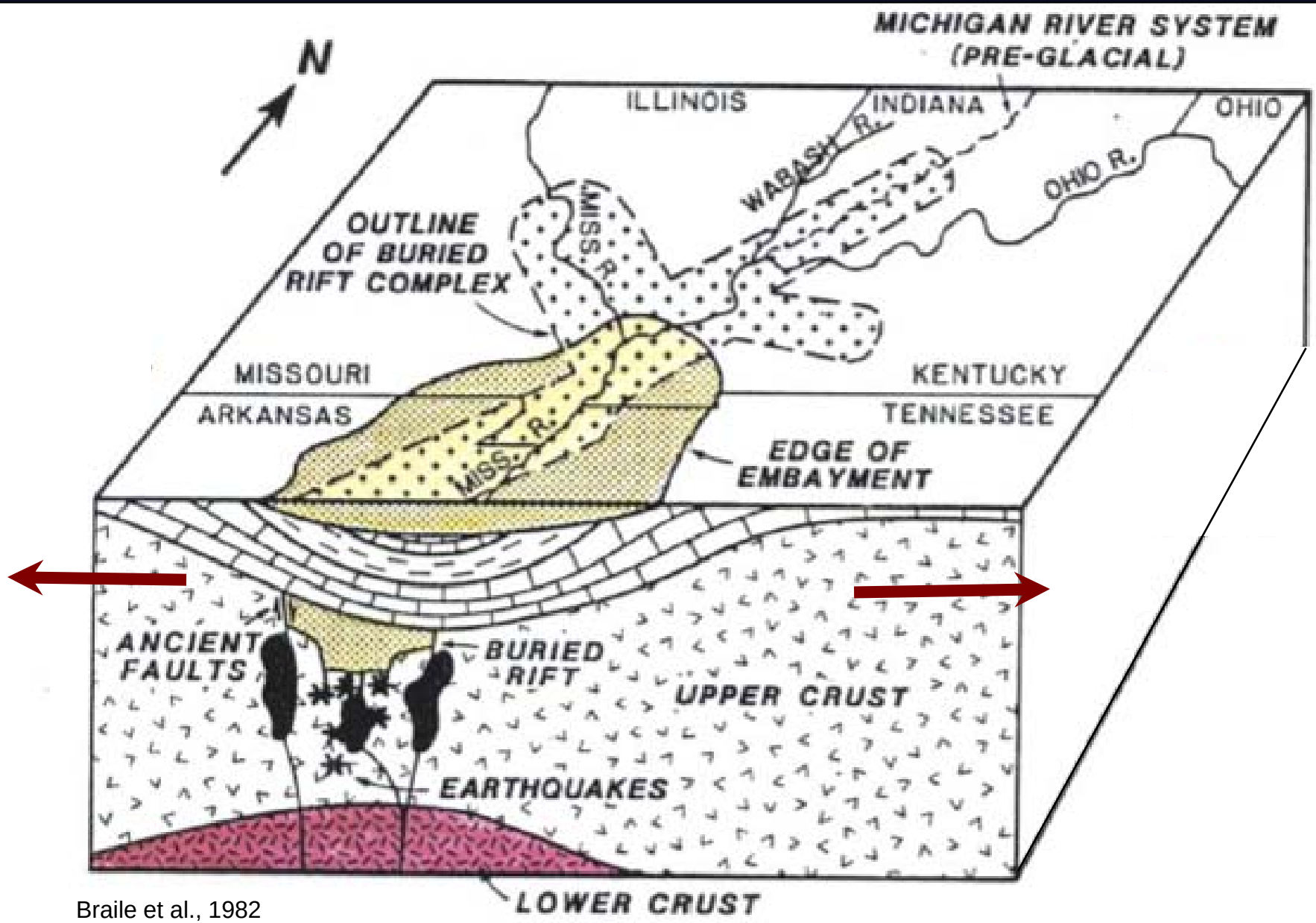


Intraplate Earthquakes

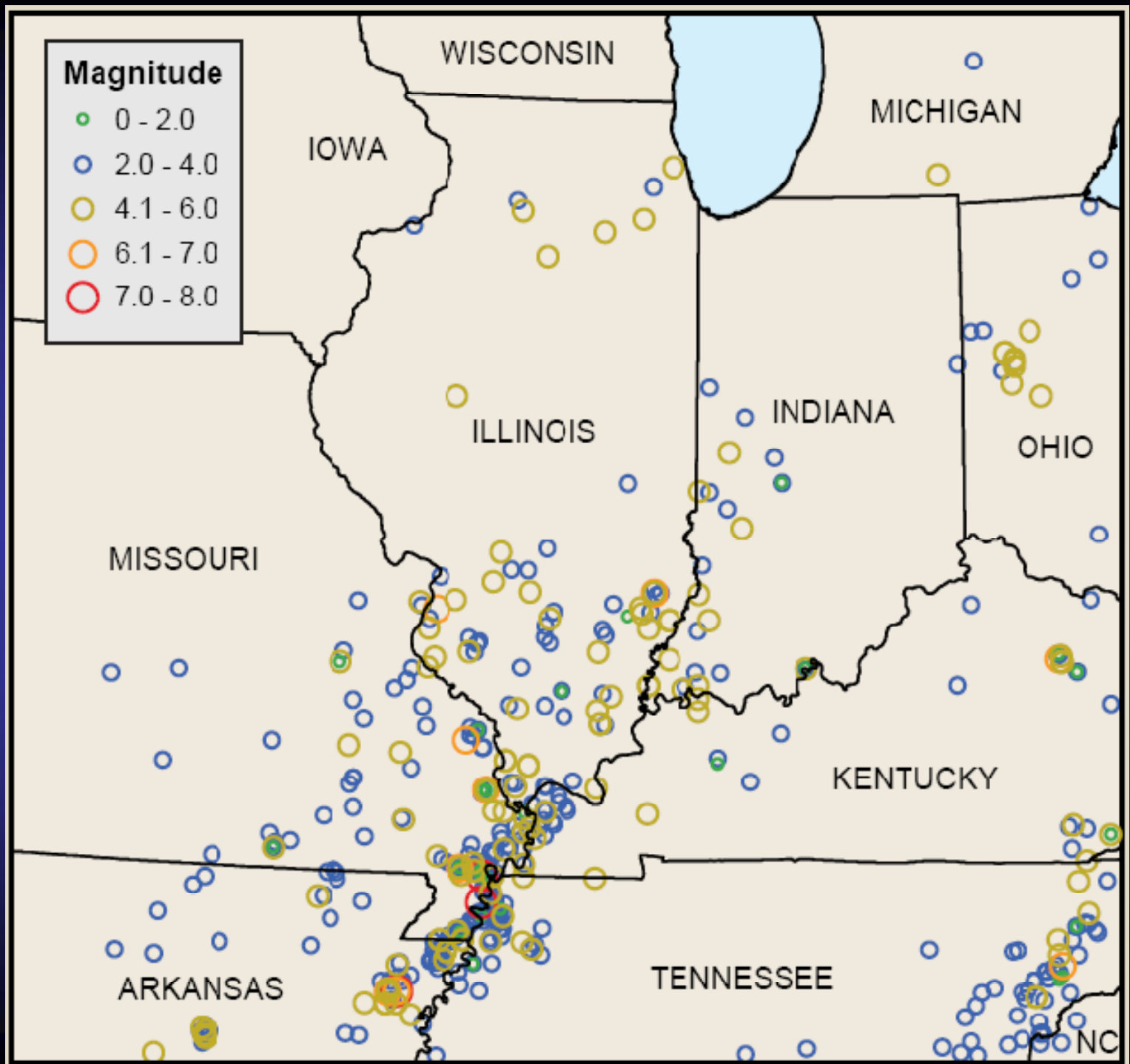


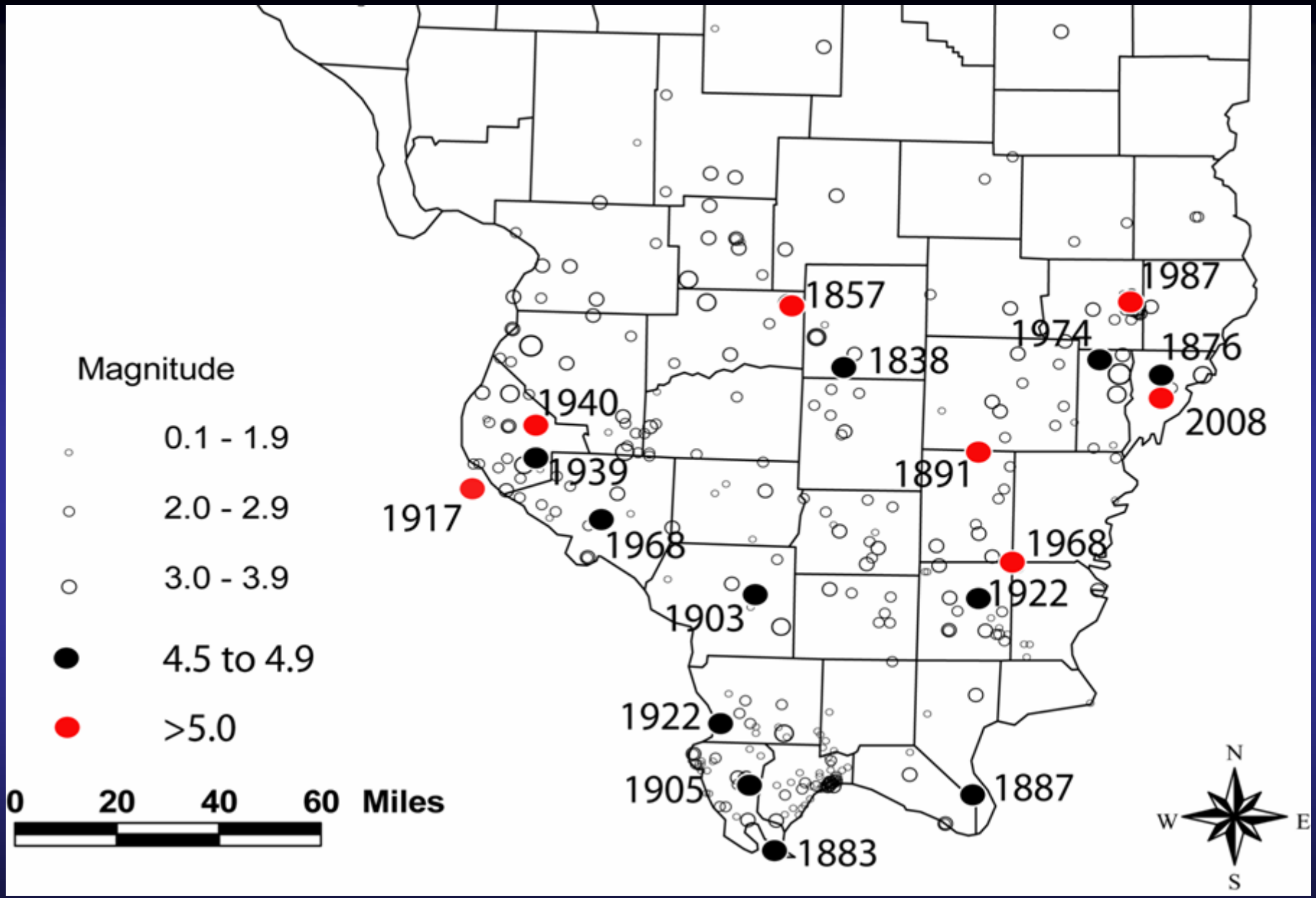
Significant United States Earthquakes
1568 - 1989

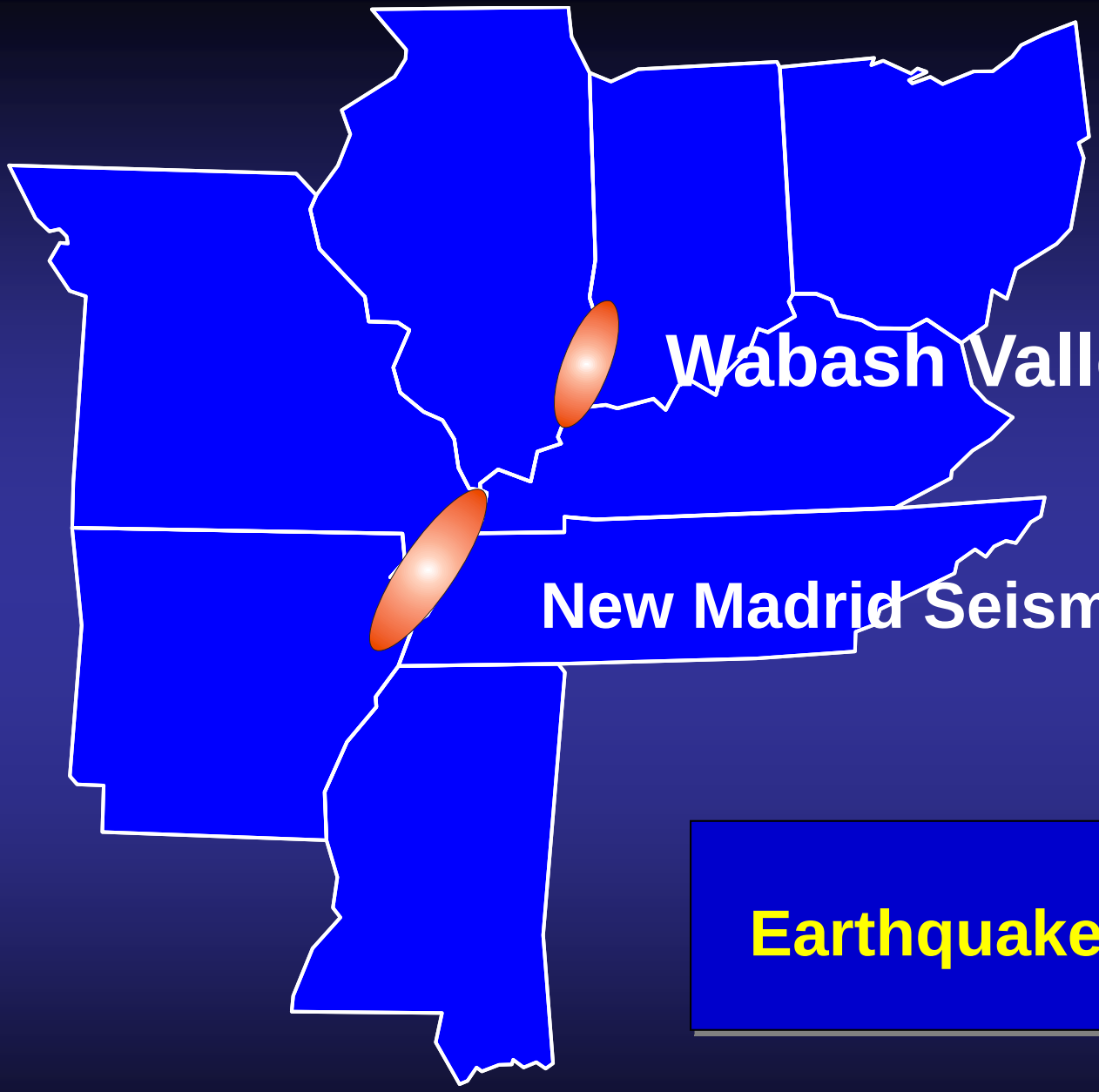




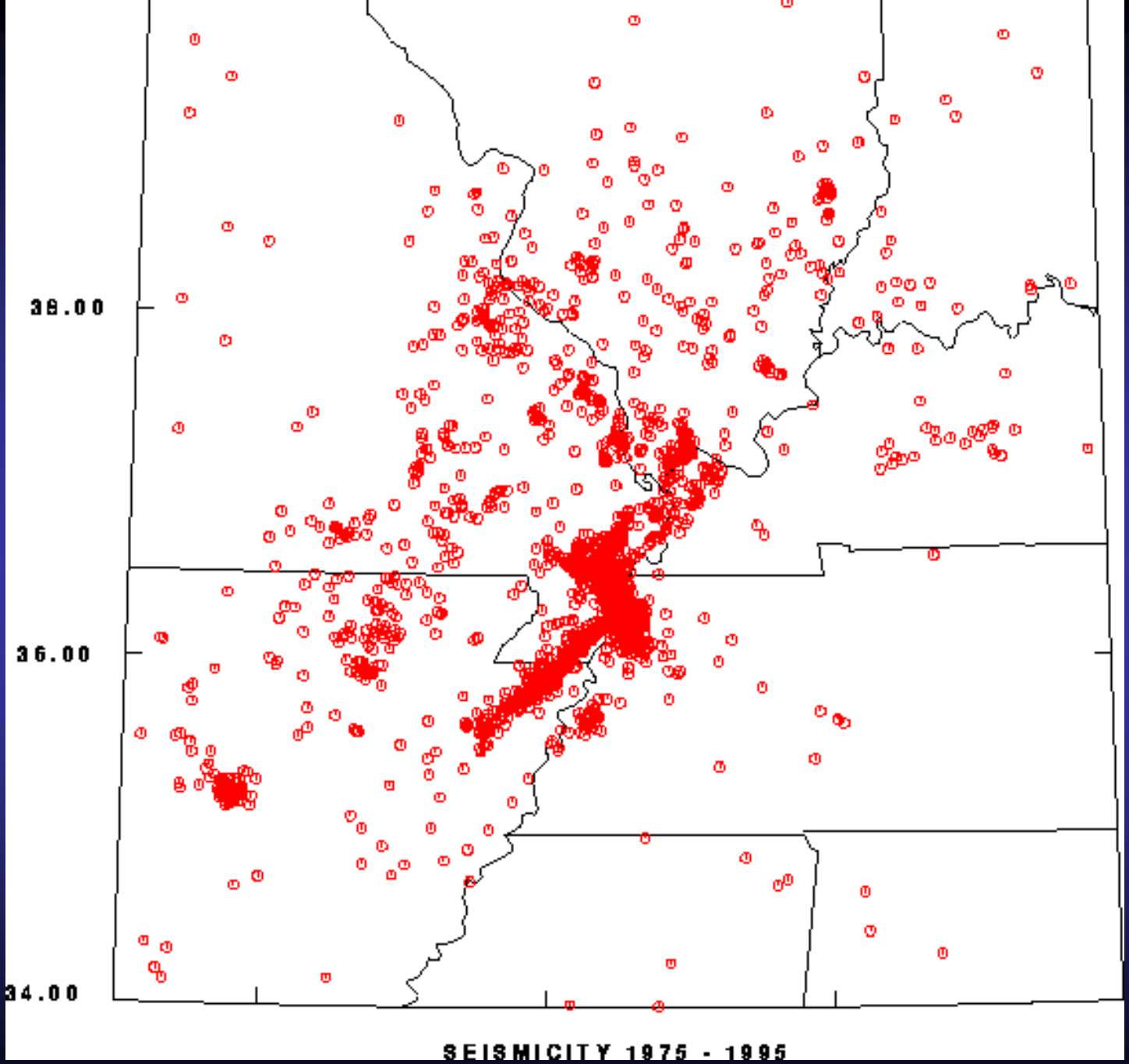
Braile et al., 1982


Magnitude
0 - 2.0
2.0 - 4.0
4.1 - 6.0
6.1 - 7.0
7.0 - 8.0
WISCONSIN
MICHIGAN
IOWA
ILLINOIS
INDIANA
OHIO
MISSOURI
KENTUCKY
ARKANSAS
TENNESSEE
NC

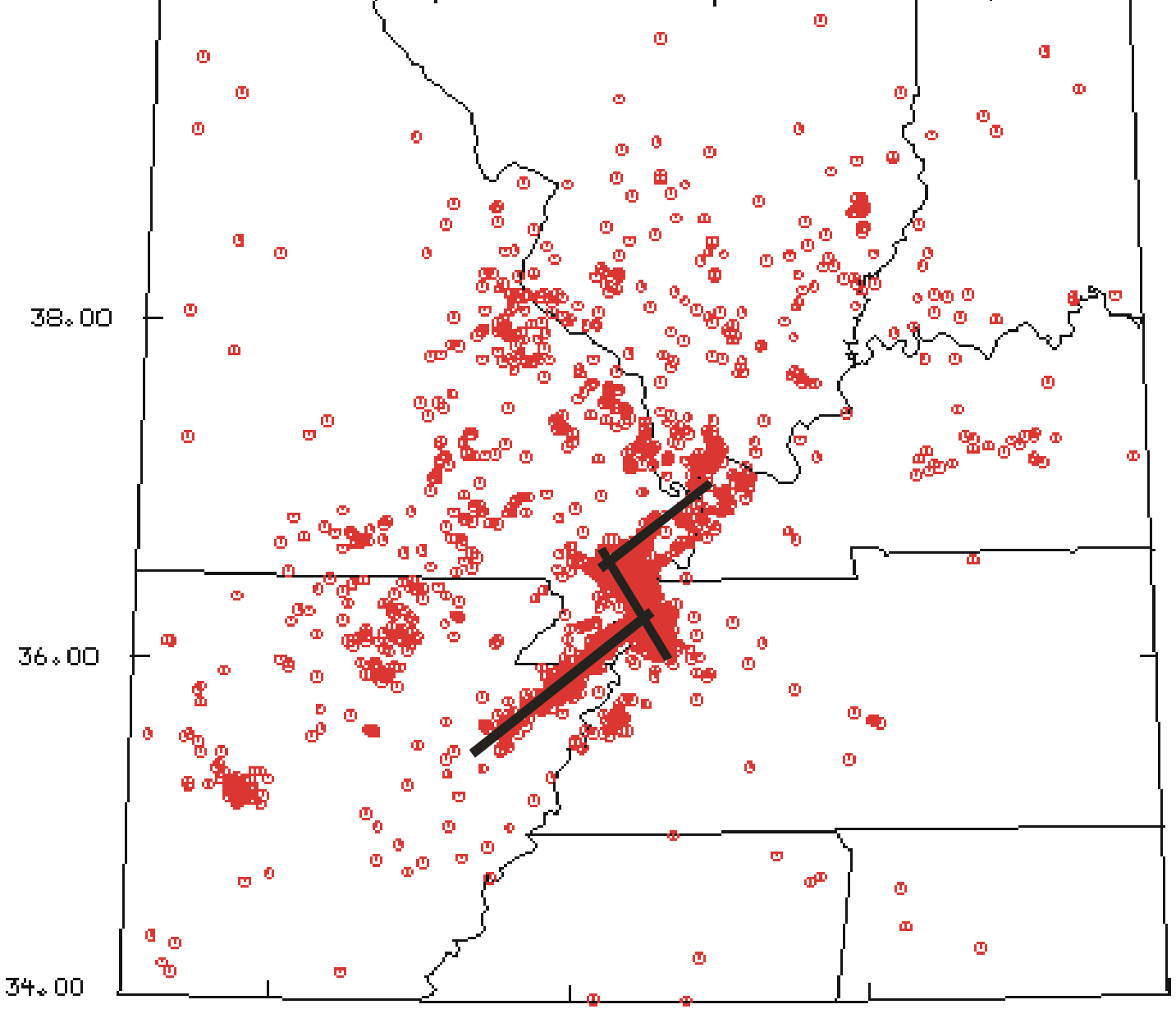

Magnitude
0.1 - 1.9
2.0 - 2.9
3.0 - 3.9
4.5 to 4.9
>5.0
0 20 40 60 Miles
1857
1987
1974
1838
1876
1940
2008
1939
1891
1917
1968
1968
1903
1922
1922
1905
1887
1883
N
W
E
S

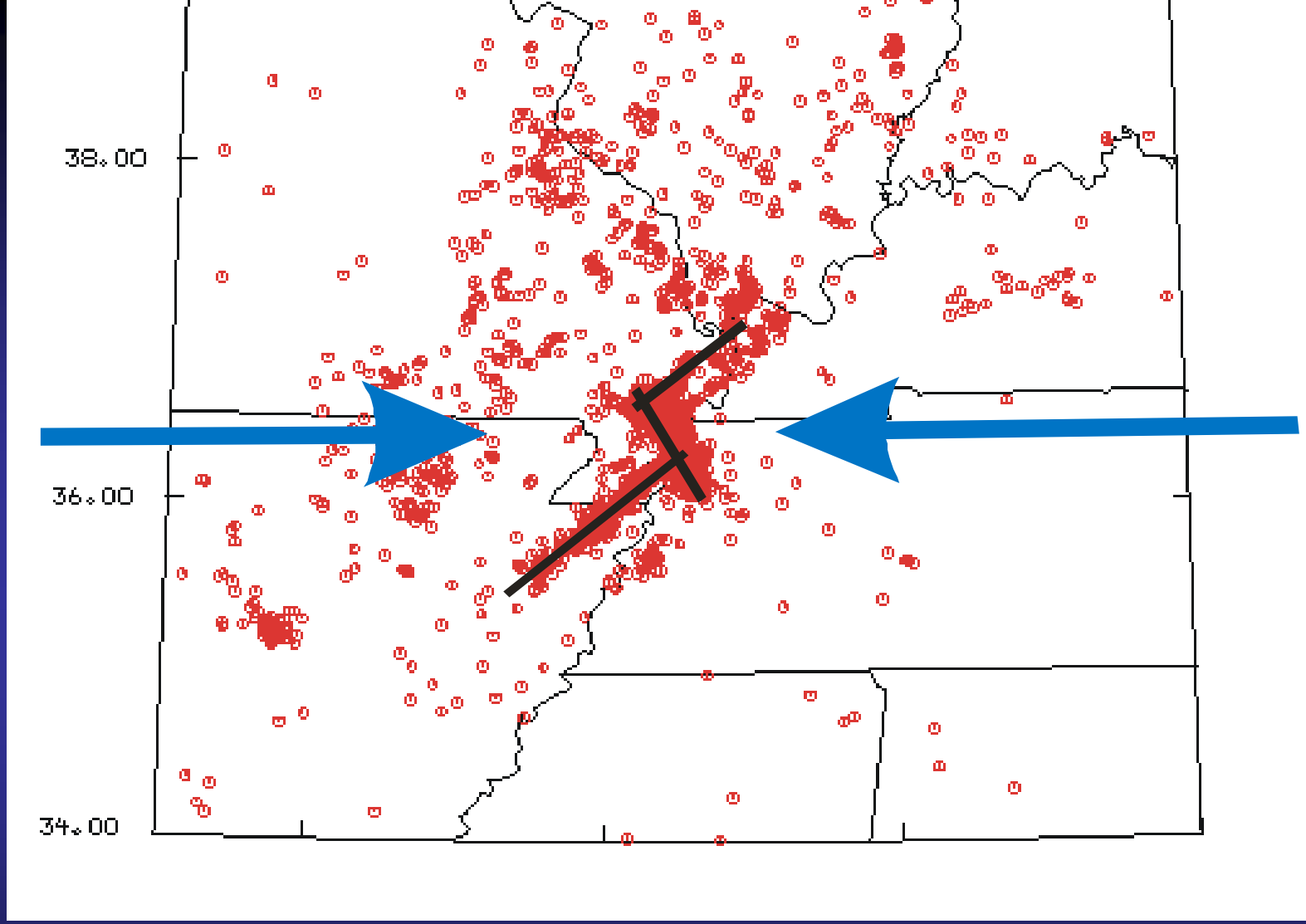


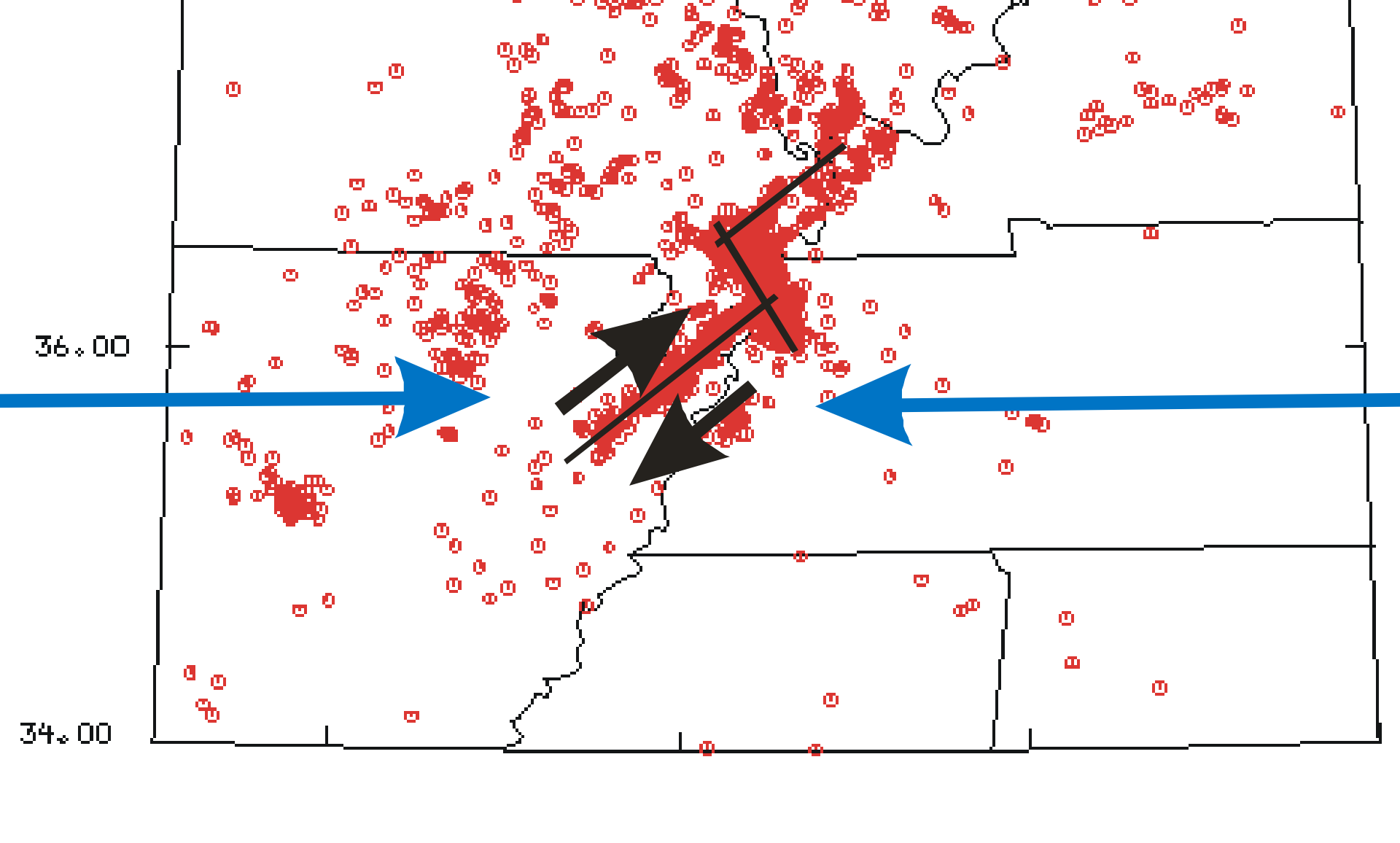
Earthquake Zones

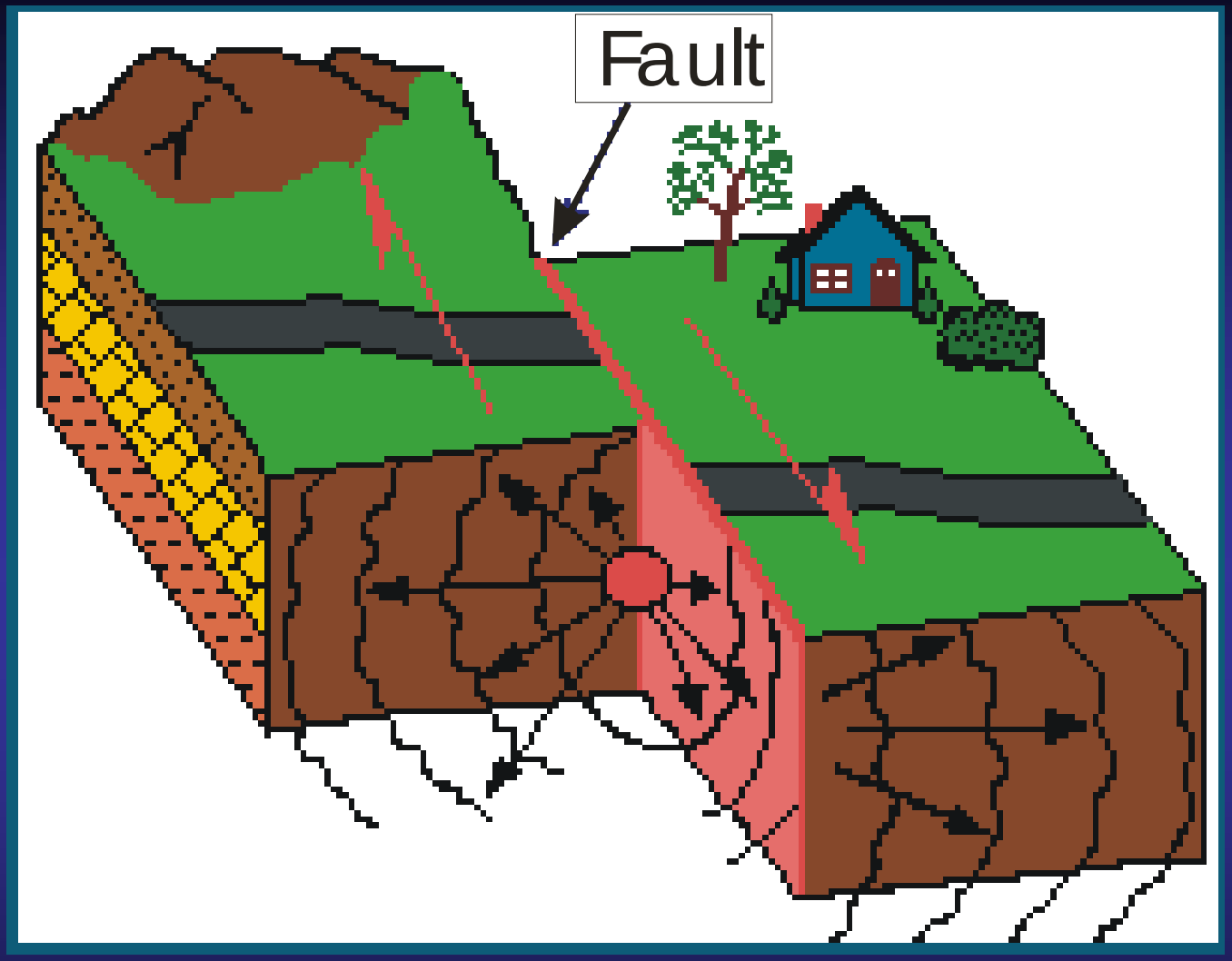


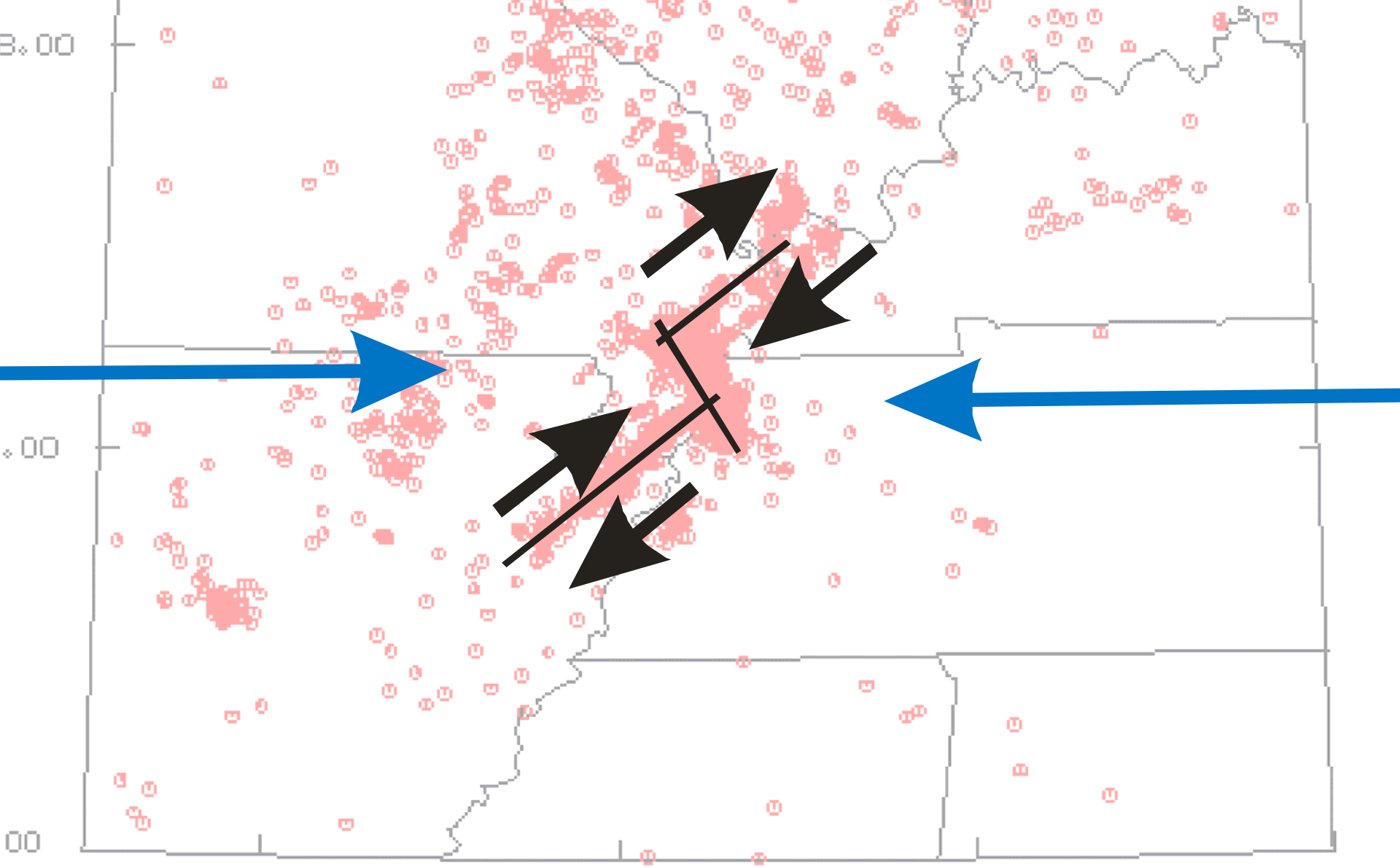
SEISMICITY 1975 - 1995

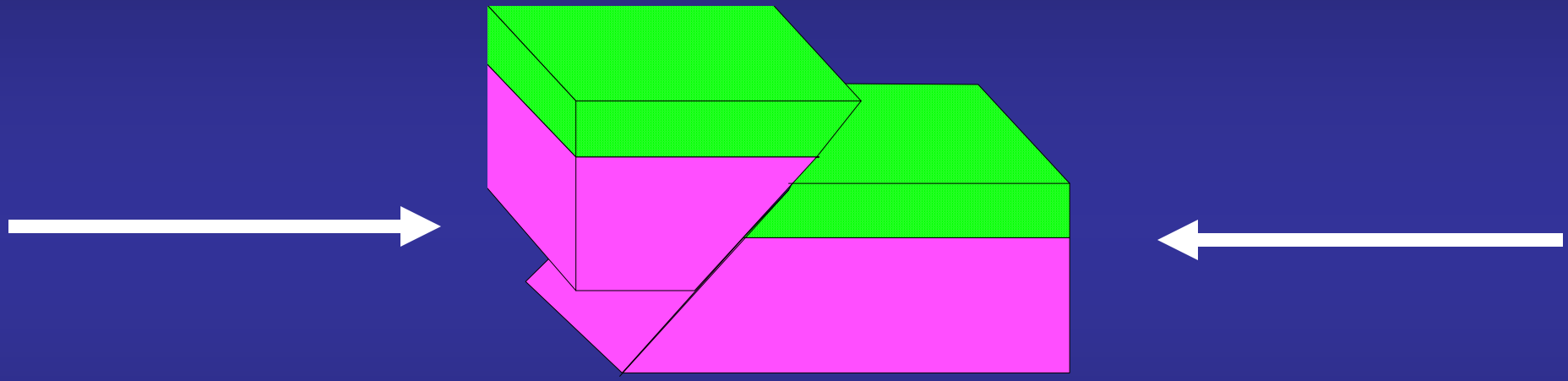

38.00
36.00
34.00


38.00
36.00
34.00


36.00
34.00

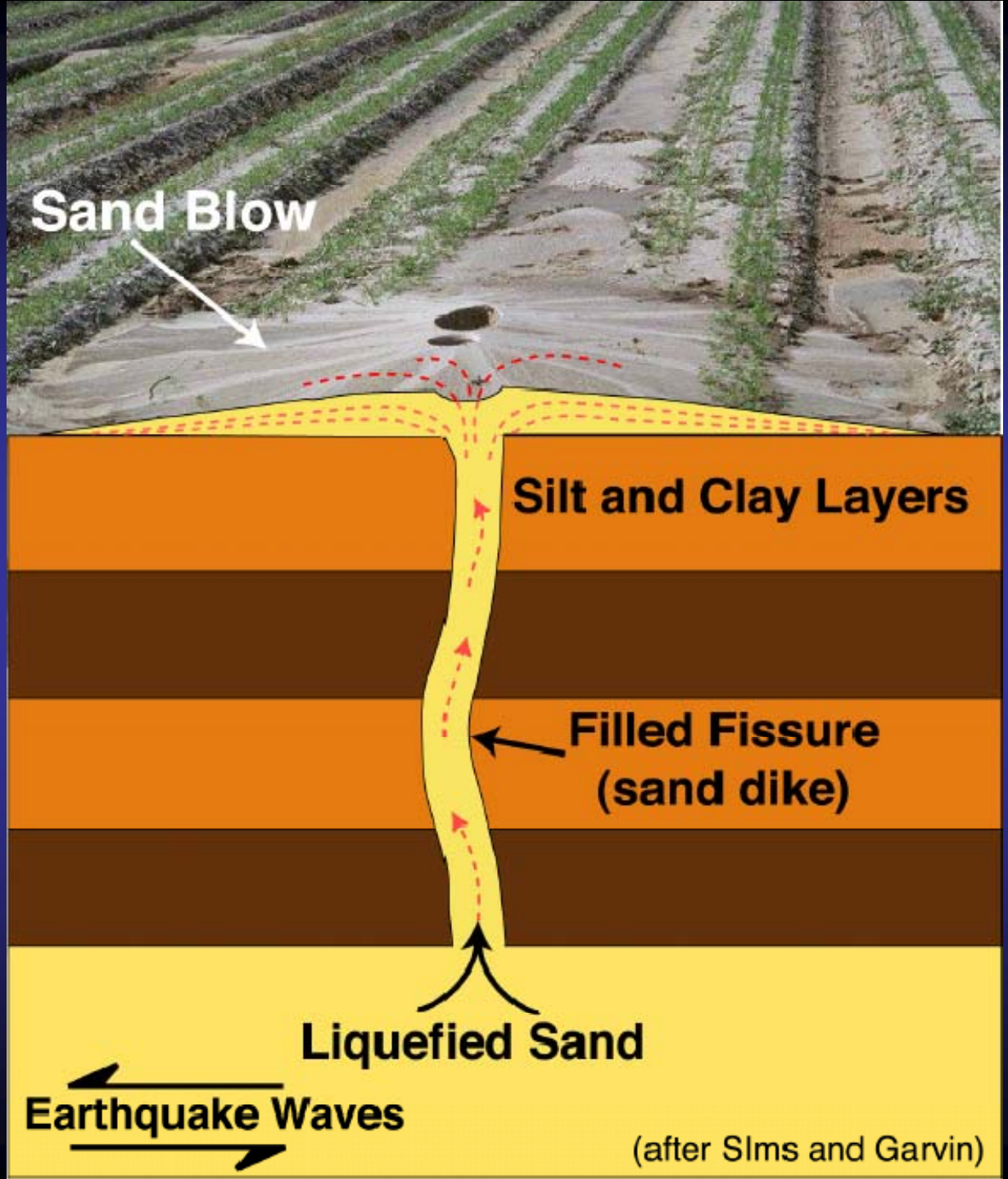

Fault


3.00
.00
00




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

How do we know about pre-historic earthquakes


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


Sand and gravel vented
onto paleosurface

Wabash Valley Area

Large earthquakes recorded in sediments, occurred about:

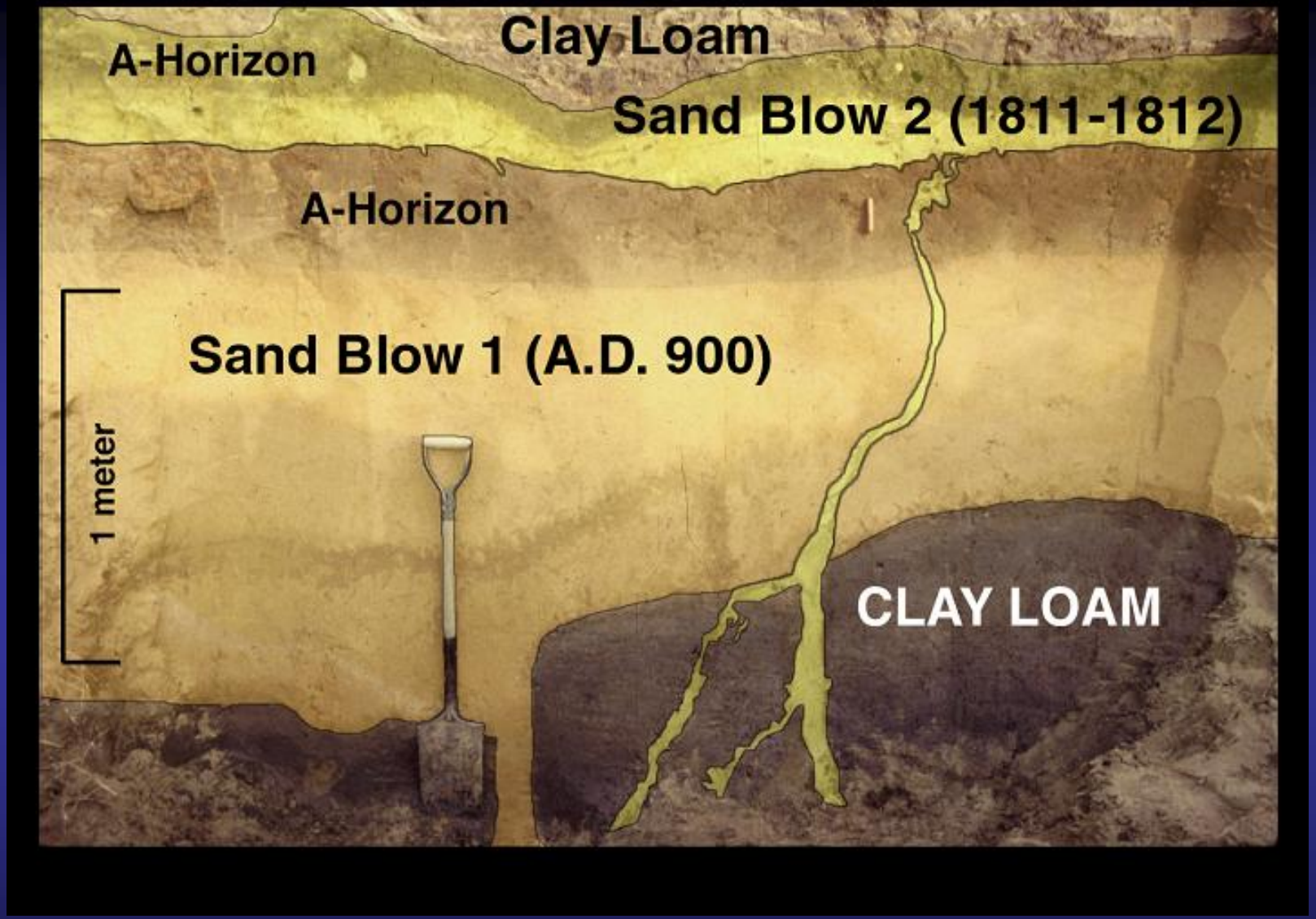
2,000 years ago – M 6.2

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


A-Horizon
Clay Loam
Sand Blow 2 (1811-1812)
A-Horizon
Sand Blow 1 (A.D. 900)
1 meter
CLAY LOAM

New Madrid Events

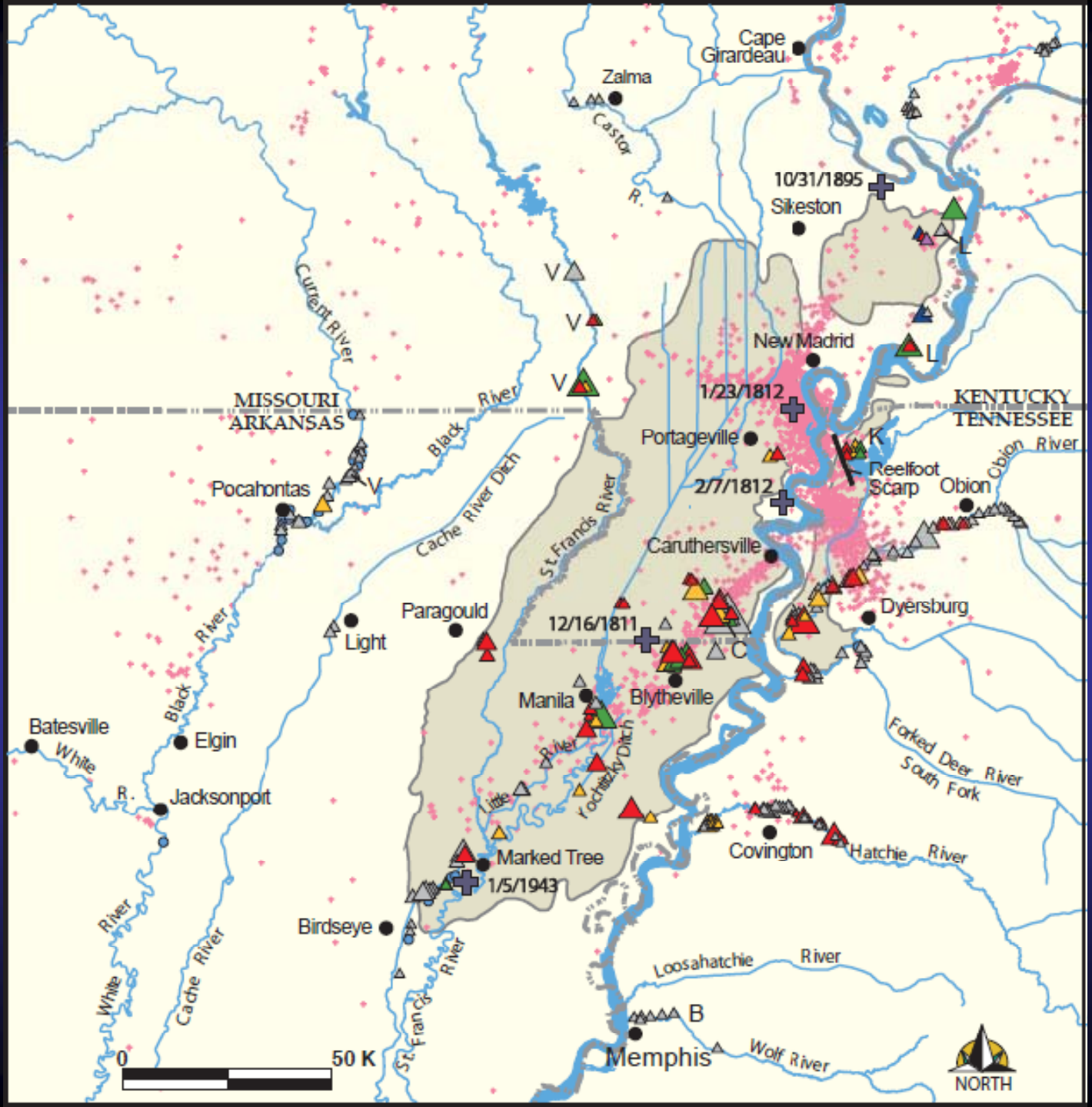
Sediments show repeat events occurred about :

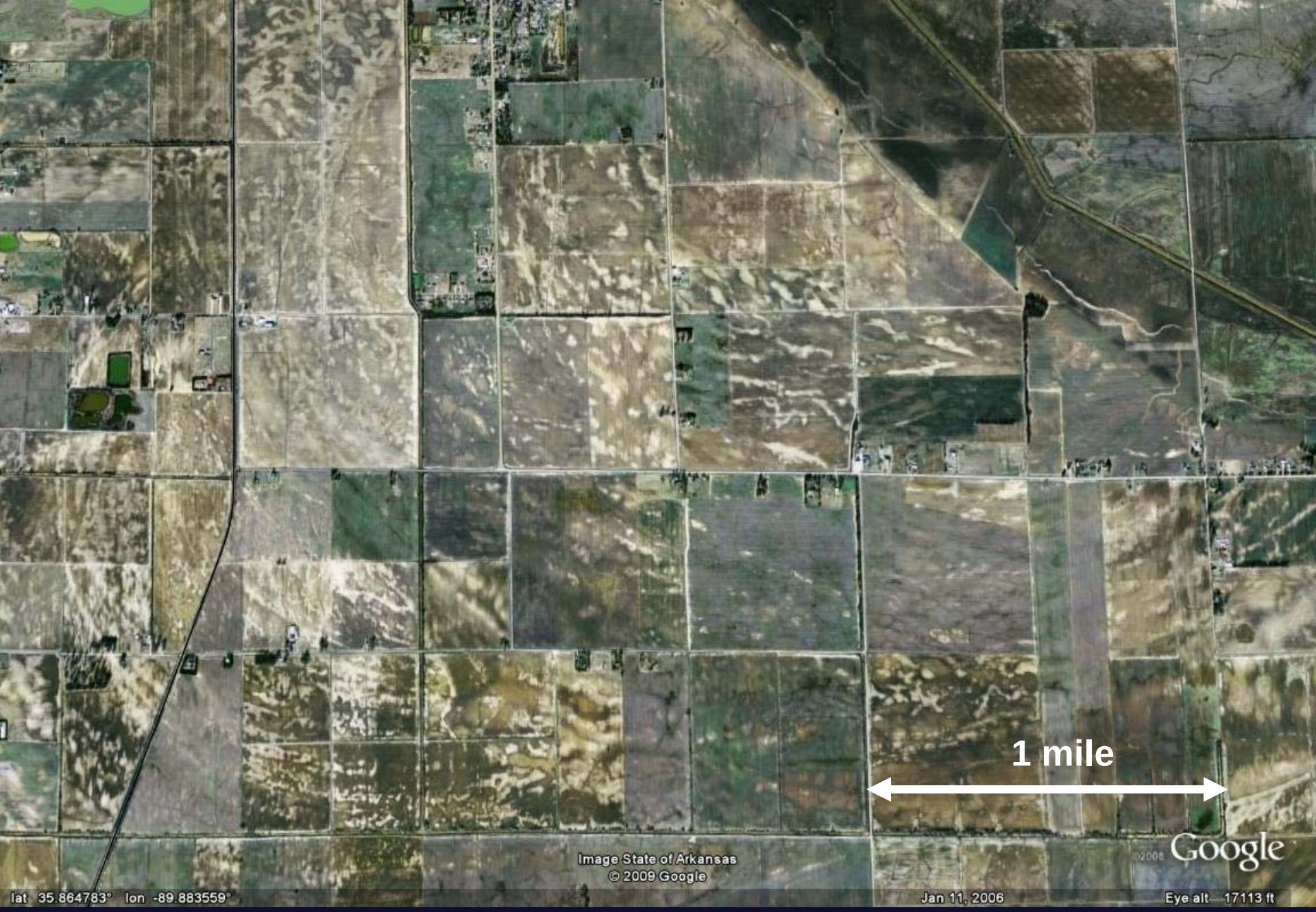
200 years ago (1811-1812)

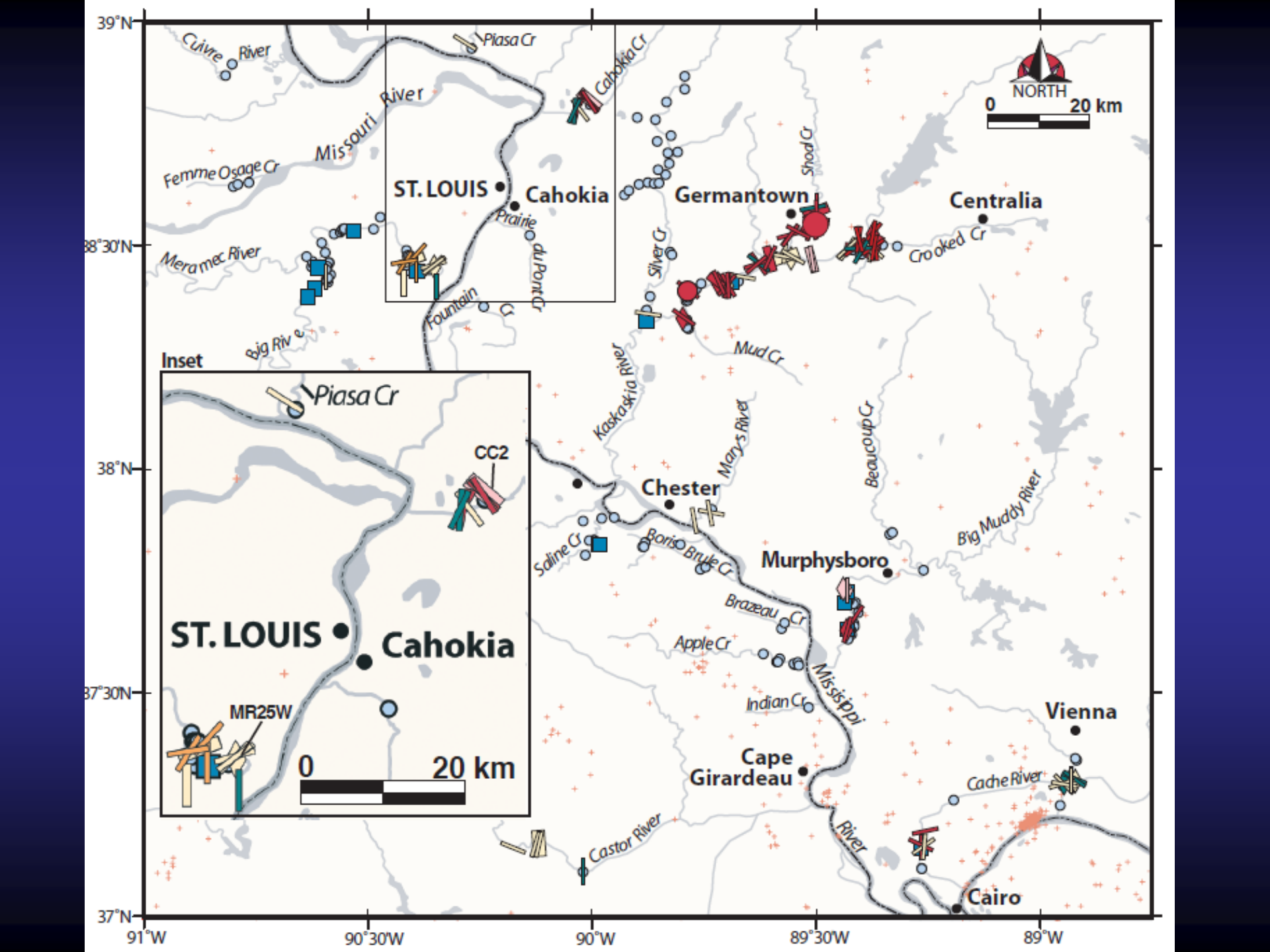
550 years ago

1,100 years ago

1,700 years ago


Cape Girardeau
Zalma
Castor R.
10/31/1895
Sikeston
New Madrid
1/23/1812
Portageville
2/7/1812
Caruthersville
12/16/1811
Paragould
Light
Pocahontas
MISSOURI
ARKANSAS
KENTUCKY
TENNESSEE
Current River
Black River
Cache River Ditch
St. Francis River
Obion River
Obion
Reelfoot Scarp
Dyersburg
Manila
Blytheville
Little River Ditch
Batesville
White R.
Elgin
Jacksonport
Forked Deer River South Fork
Covington
Hatchie River
Marked Tree
1/5/1943
Birdseye
Loosahatchie River
Memphis
Wolf River
0
50 K
NORTH


1 mile
Image State of Arkansas
© 2009 Google
©2008 Google
lat 35.864783° lon -89.883559°
Jan 11, 2006
Eye alt 17113 ft


39°N
38°30'N
38°N
37°30N
37°N
91°W
90°30'W
90°W
89°30'W
89°W
Cuivre River
Piasa Cr
Cahokia Cr
Missouri River
Femme Osage Cr
ST. LOUIS
Cahokia
Prairie du Pont Cr
Meramec River
Fountain Cr
Big River
Shoal Cr
Germantown
Centralia
Silver Cr
Crooked Cr
Mud Cr
Kaskaskia River
Mary's River
Beaucoup Cr
Big Muddy River
Chester
Saline Cr
Boris Brule Cr
Murphysboro
Brazeau Cr
Apple Cr
Indian Cr
Mississippi River
Vienna
Cape Girardeau
Cache River
Castor River
Cairo
NORTH
0
20 km
Inset
Piasa Cr
CC2
ST. LOUIS
Cahokia
MR25W
0
20 km

Cahokia Creek

18 miles

NE of St. Louis

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

INTENSITY

Is an evaluation of the

effects,

observations,

and

experiences

in an area.

6 - Strong - trees sway; loose objects overturn or fall

7 - Very Strong - walls crack; plaster falls

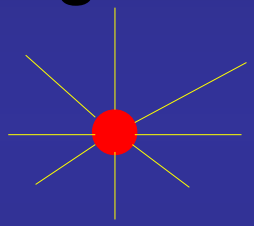
8 - Destructive - masonary cracks; chimneys fall; poorly constructed buildings damaged; water well levels may change

9 - Ruinous - some houses collapse where ground begins to crack; pipes break open

FACTORS AFFECTING GROUND MOTION

Distance

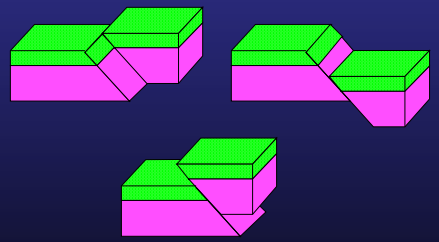
Magnitude



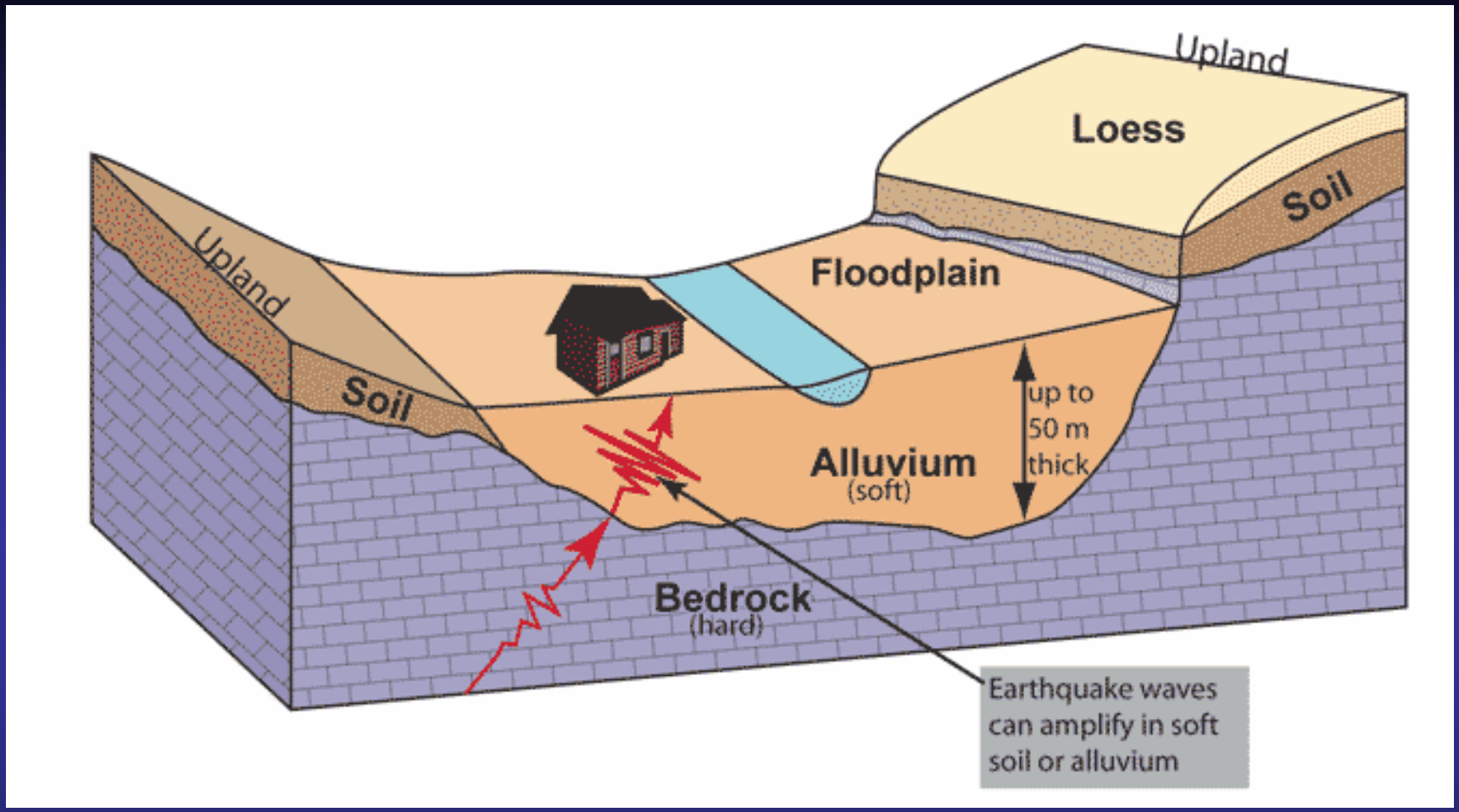
Condition
of rock along
transmission path

Local Soil
Conditions

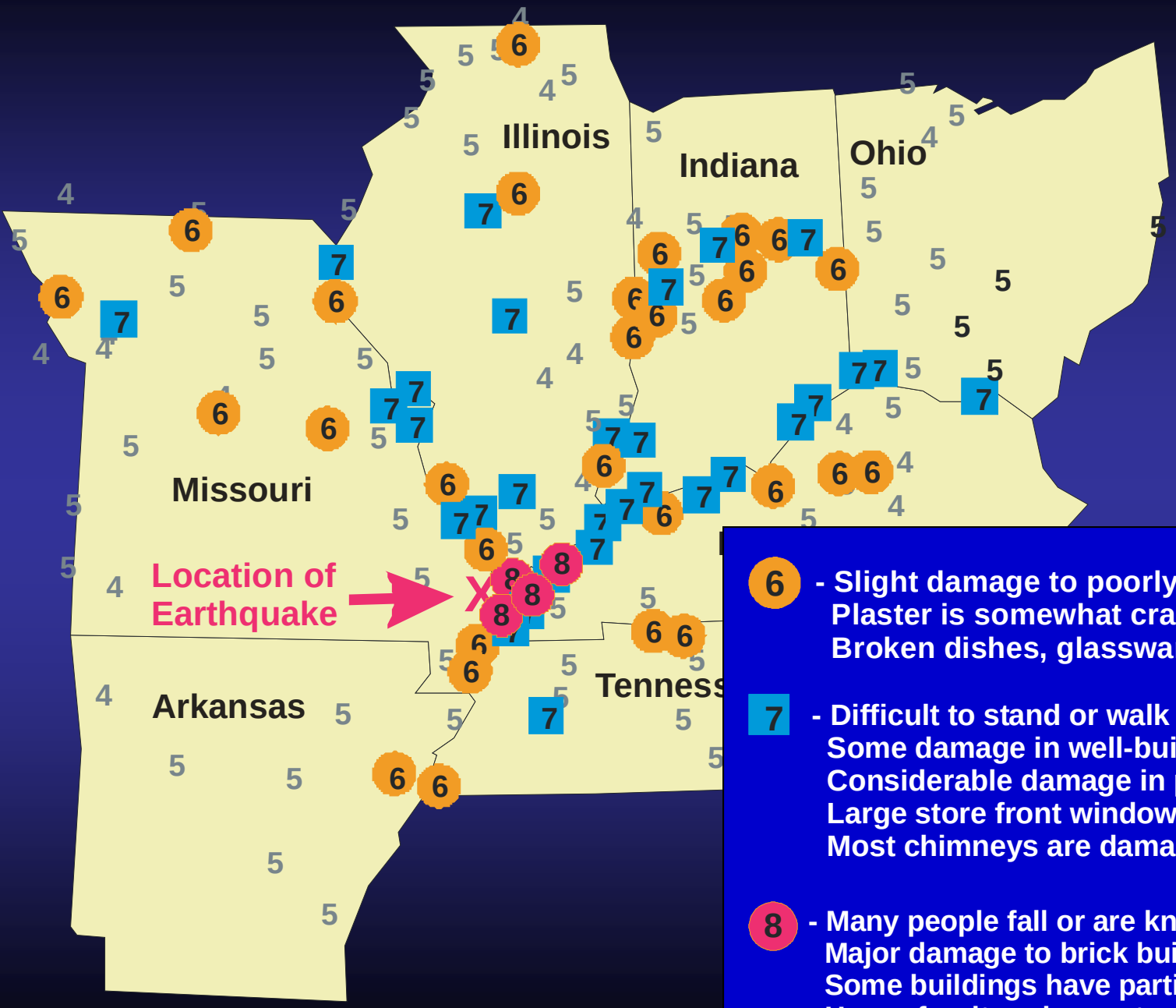
Source
mechanism



Duration of Shaking


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

What was felt in different cities during the Oct. 31, 1895 Mag. 6.2 Earthquake



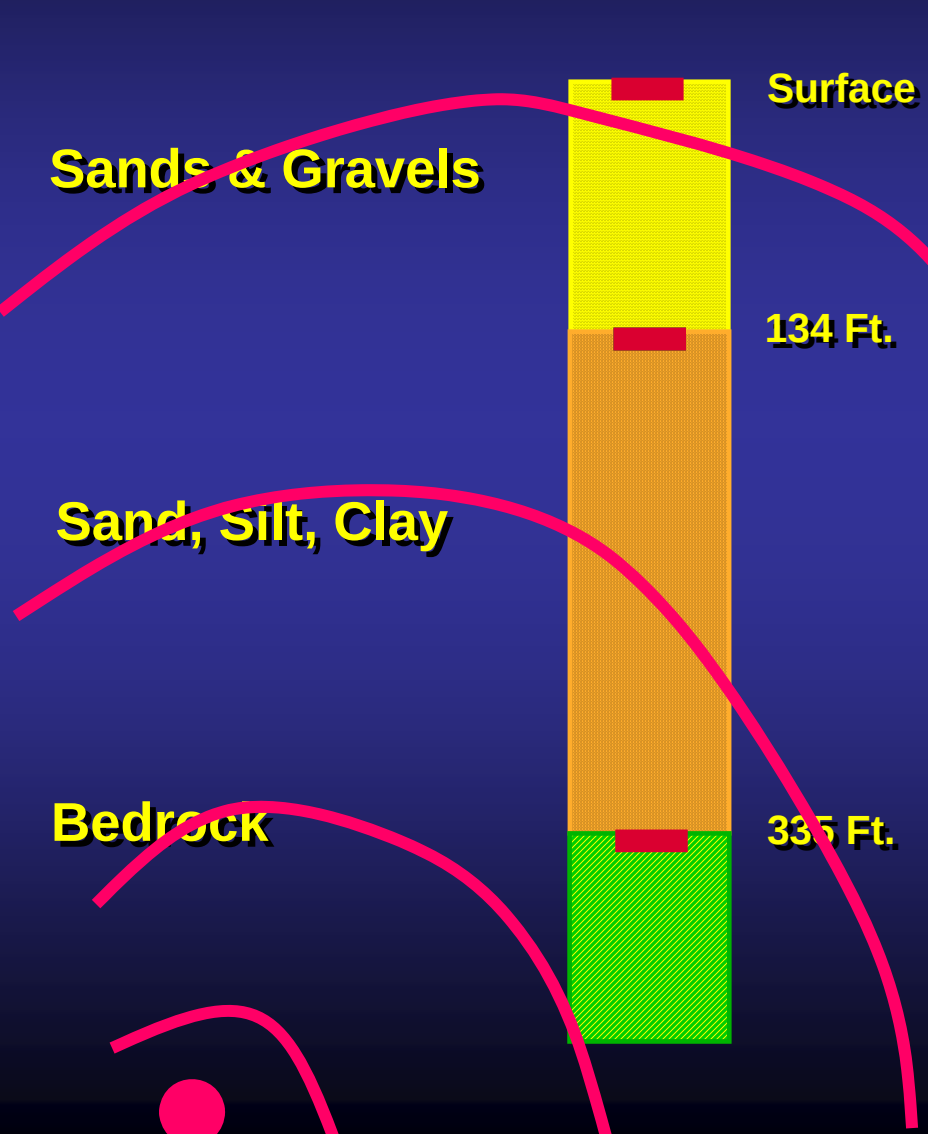
6 - Slight damage to poorly built buildings
Plaster is somewhat cracked
Broken dishes, glassware and some windows

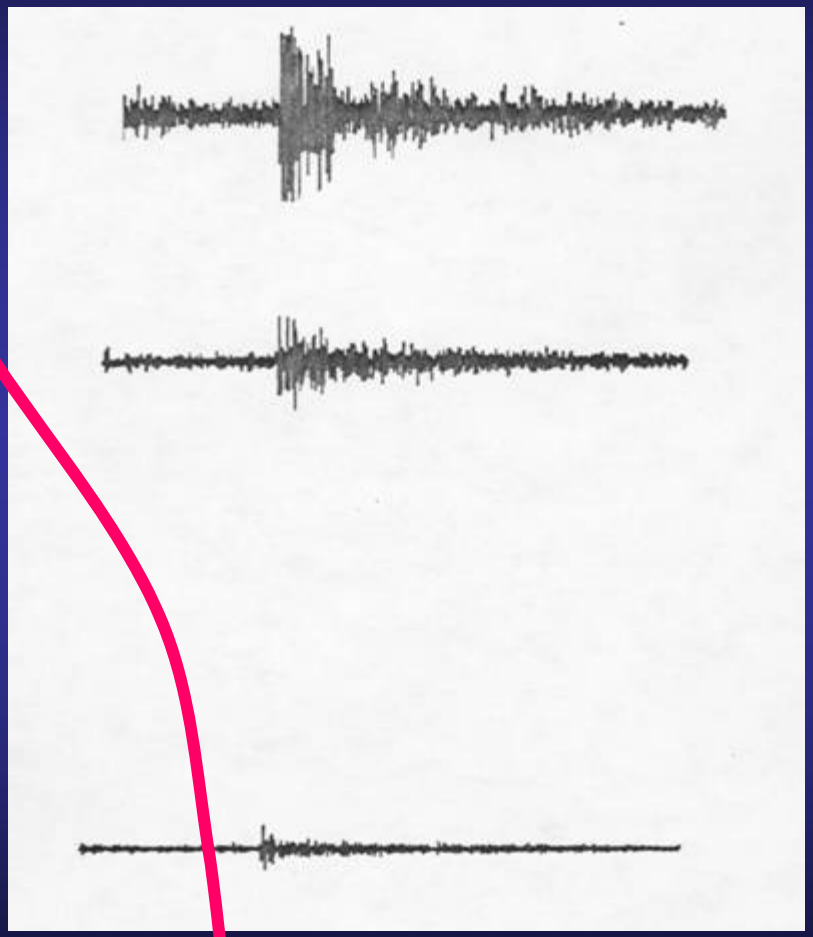
7 - Difficult to stand or walk
Some damage in well-built buildings
Considerable damage in poorly built buildings
Large store front windows break
Most chimneys are damaged/top of walls fall

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

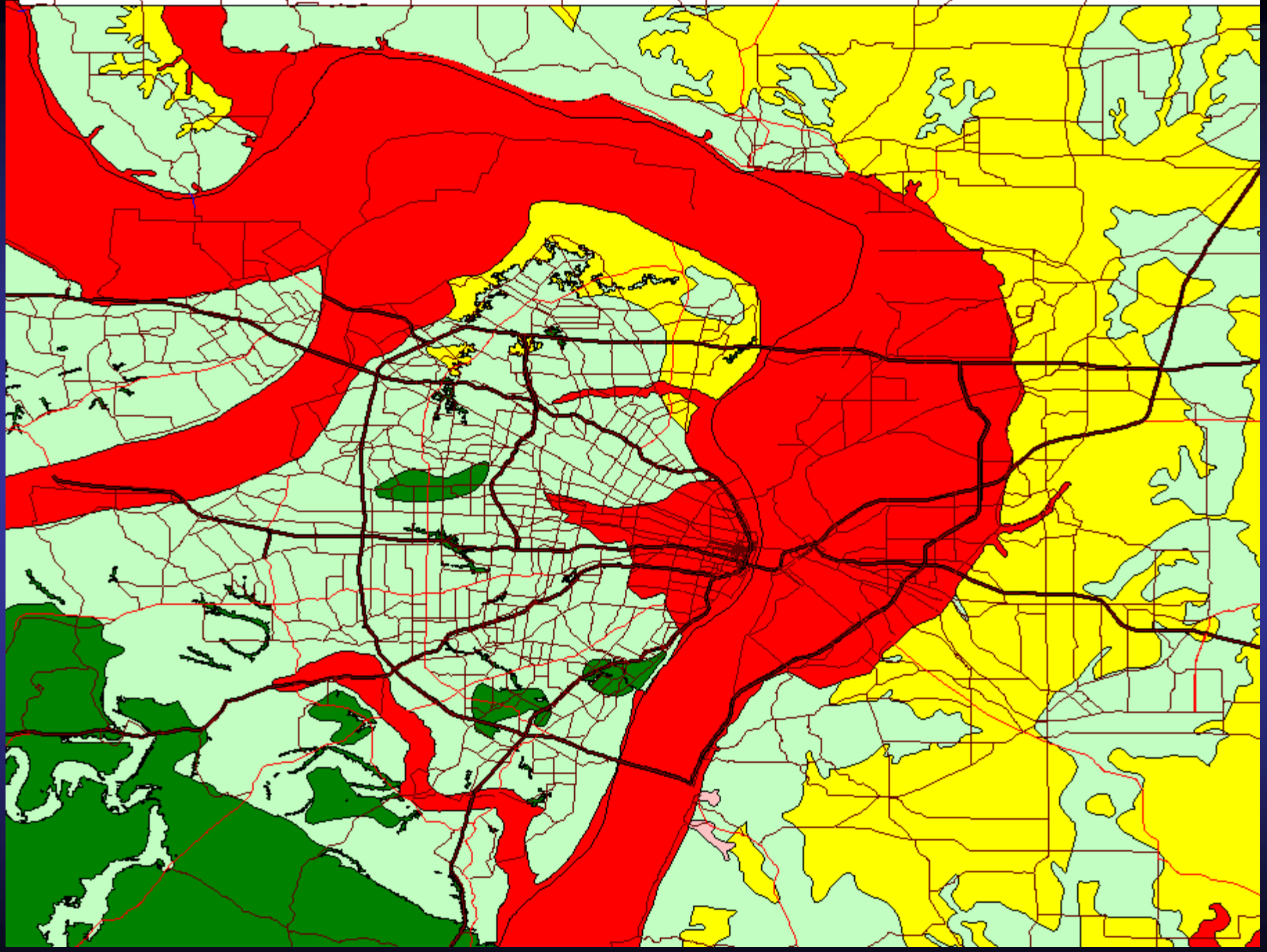
SOUTHERN ILLINOIS EARTHQUAKE

Feb. 5, 1994 - Monitored in Paducah, KY



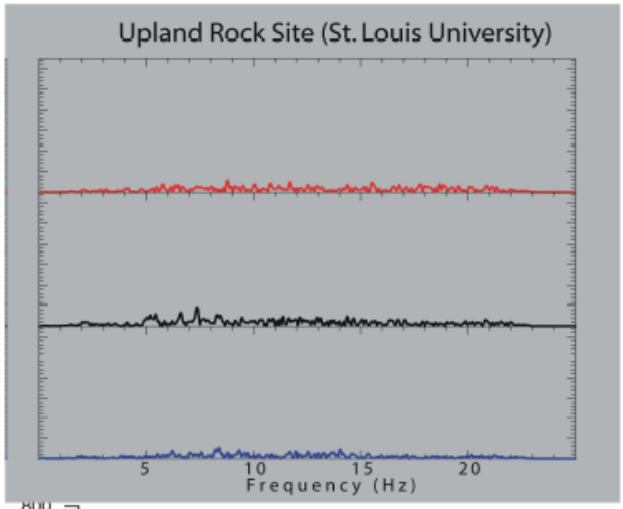


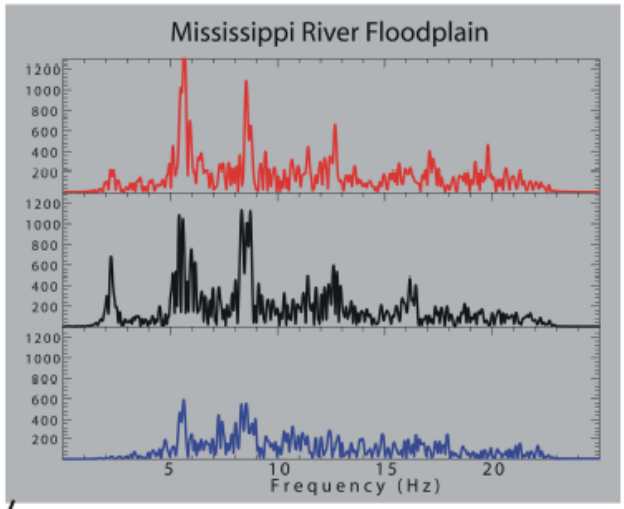
Kentucky Geological Survey &
University of Kentucky



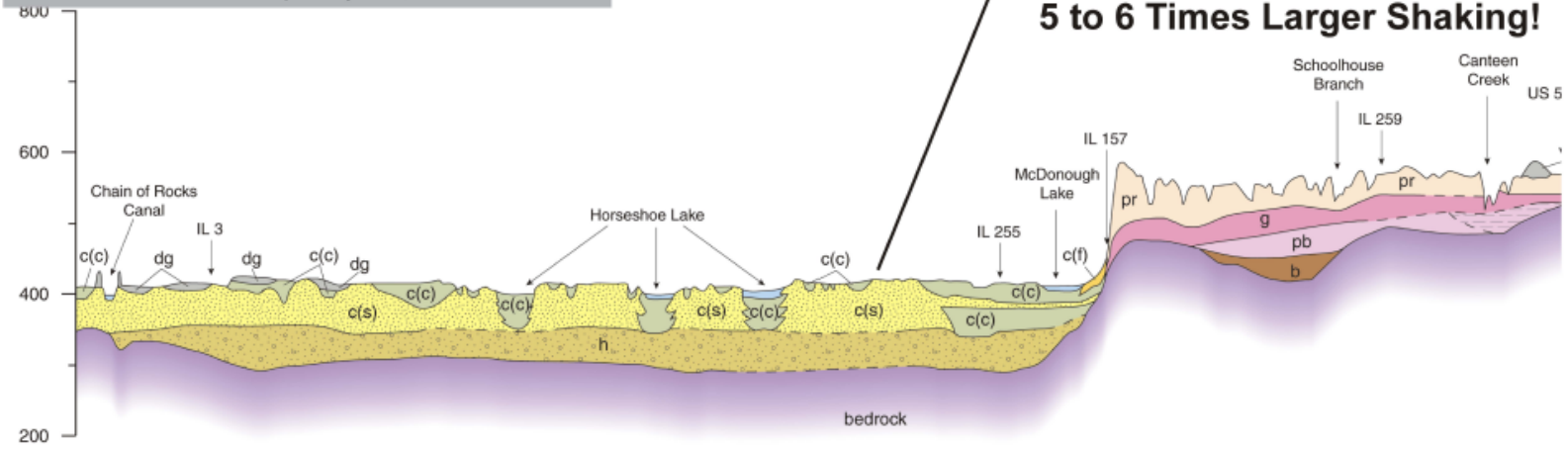
Bedrock **Floodplain**

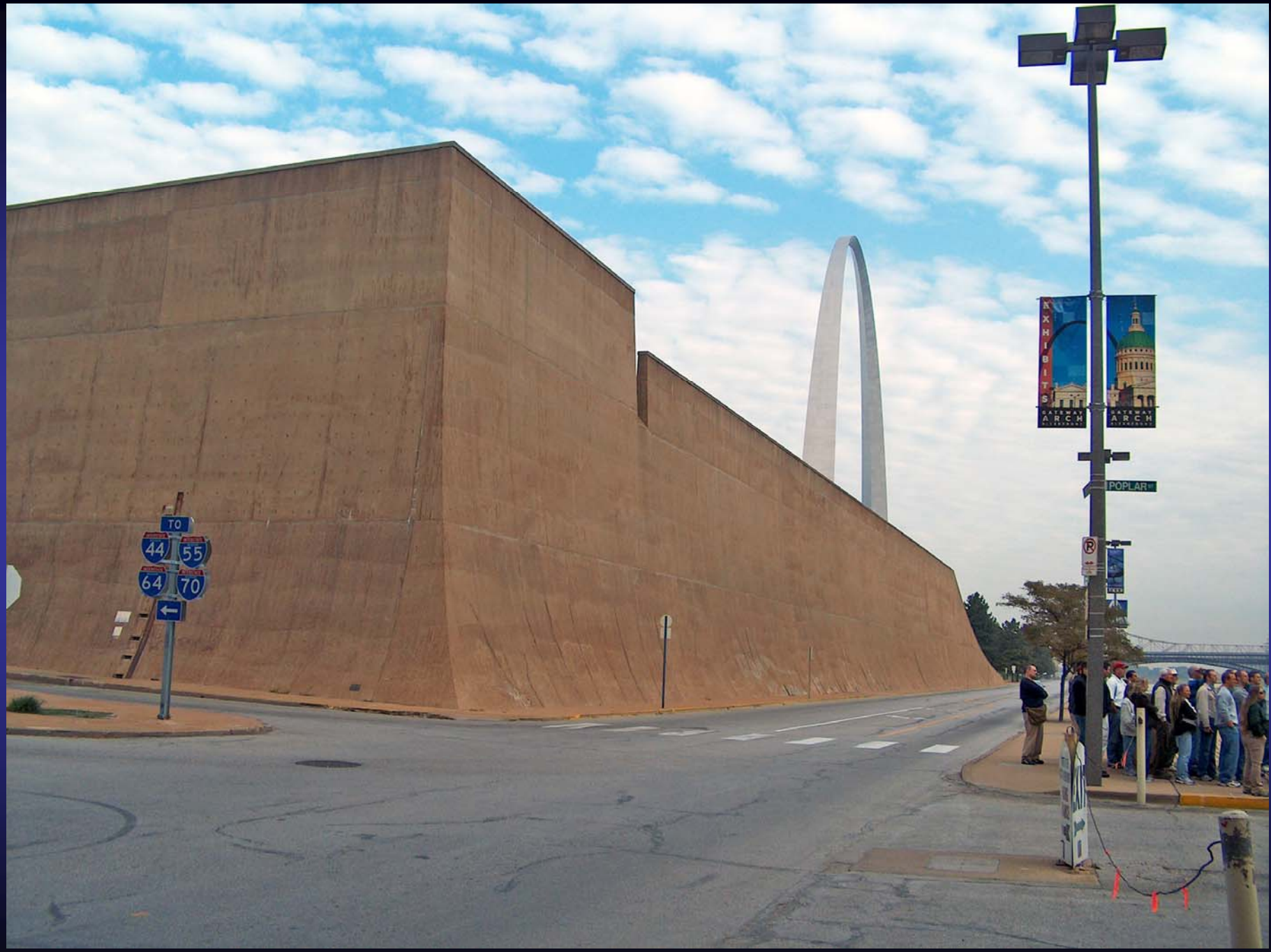
Soft, Wet, Thick Sand = More Earthquake Shaking!



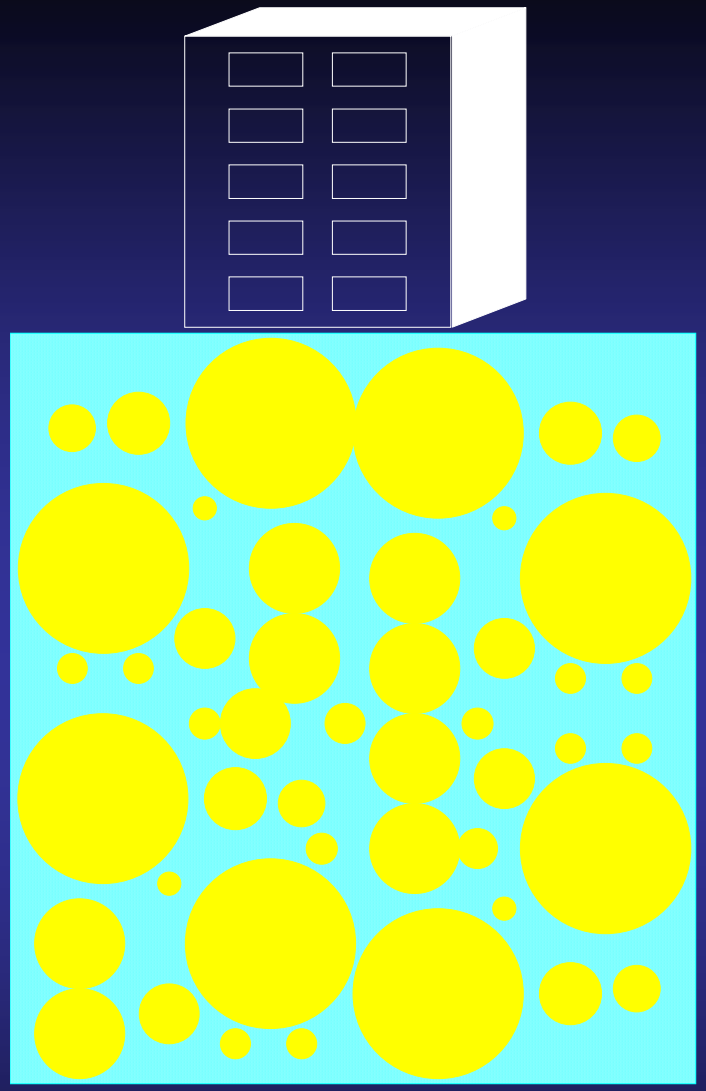


5 to 6 Times Larger Shaking!

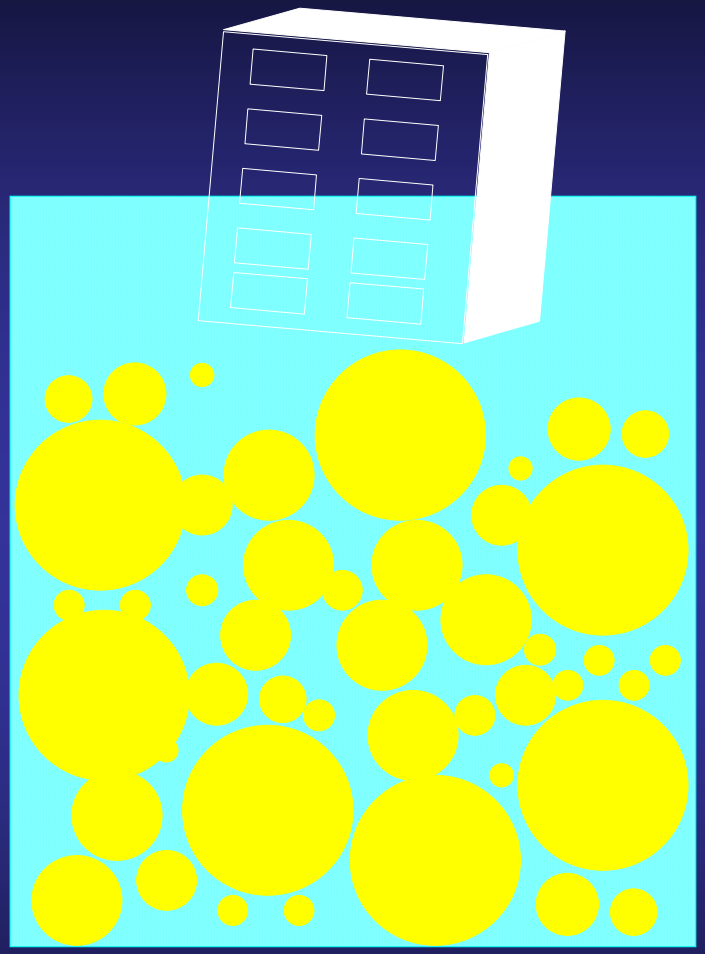



TO
44
55
64
70
EXHIBITS
GATEWAY ARCH
GATEWAY ARCH
POPLAR

Lateral Spreading of Levee



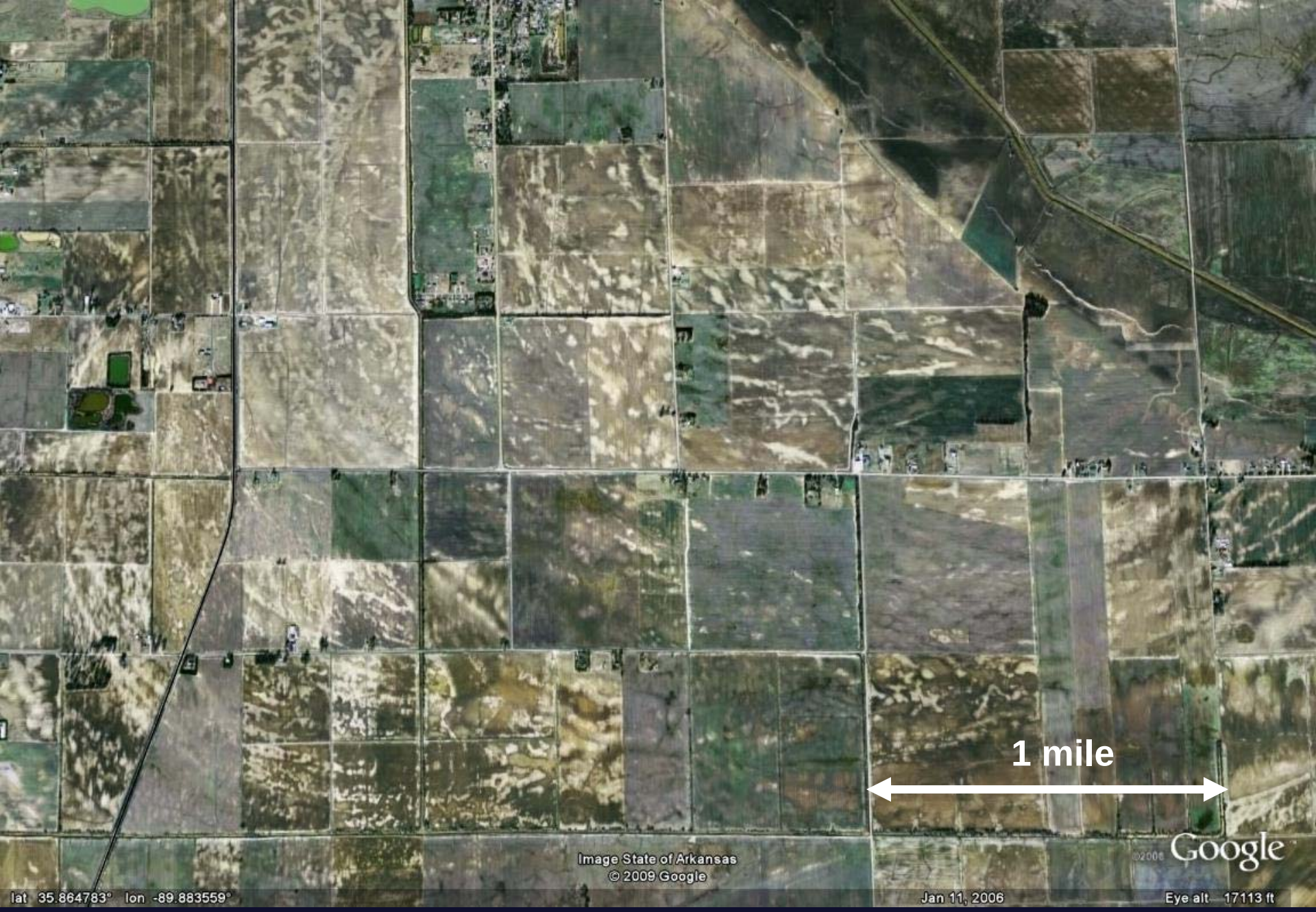
Initial State

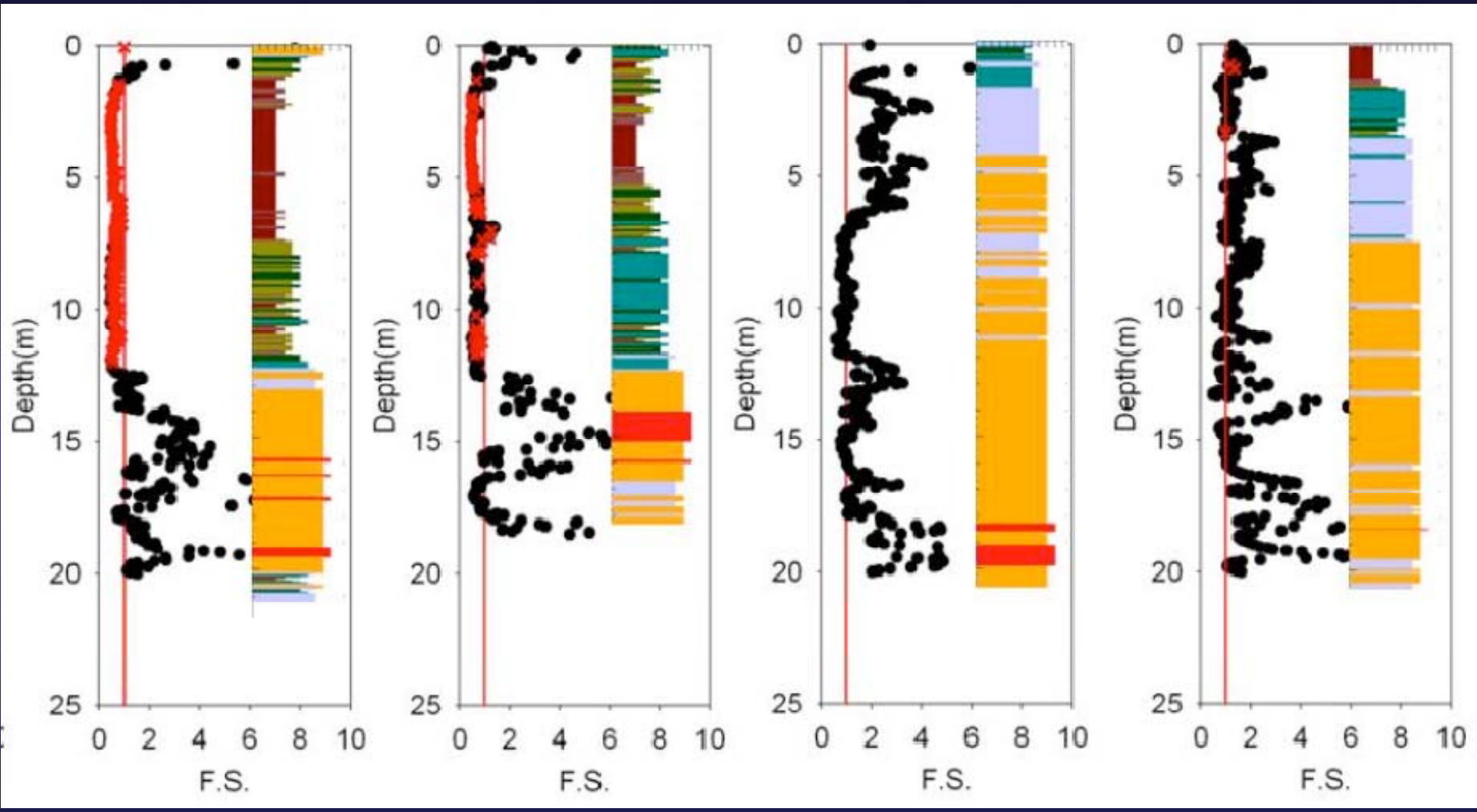


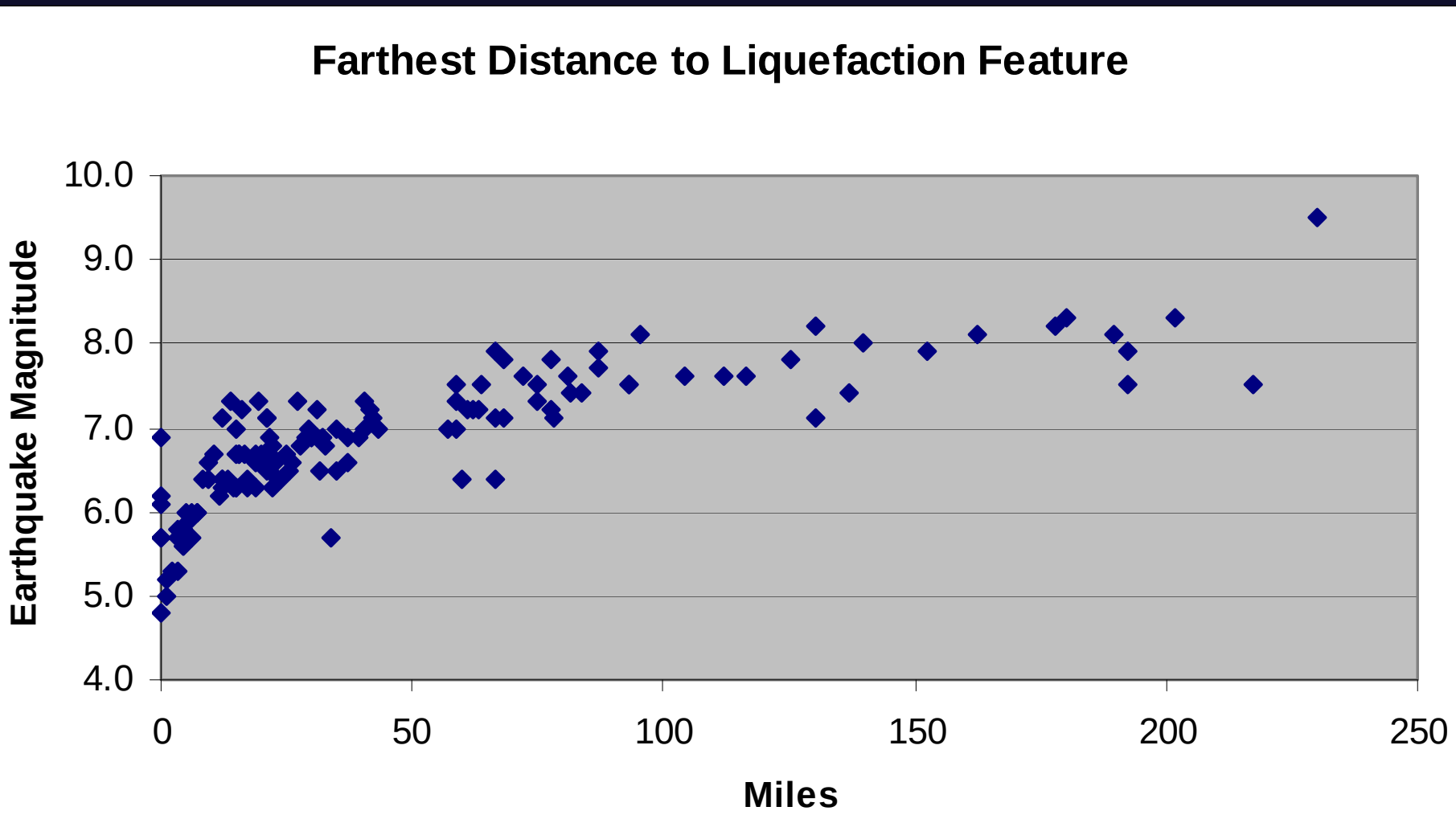
SHAKE


CHIGUAYANTE
HUALPEN
A 200 MTS

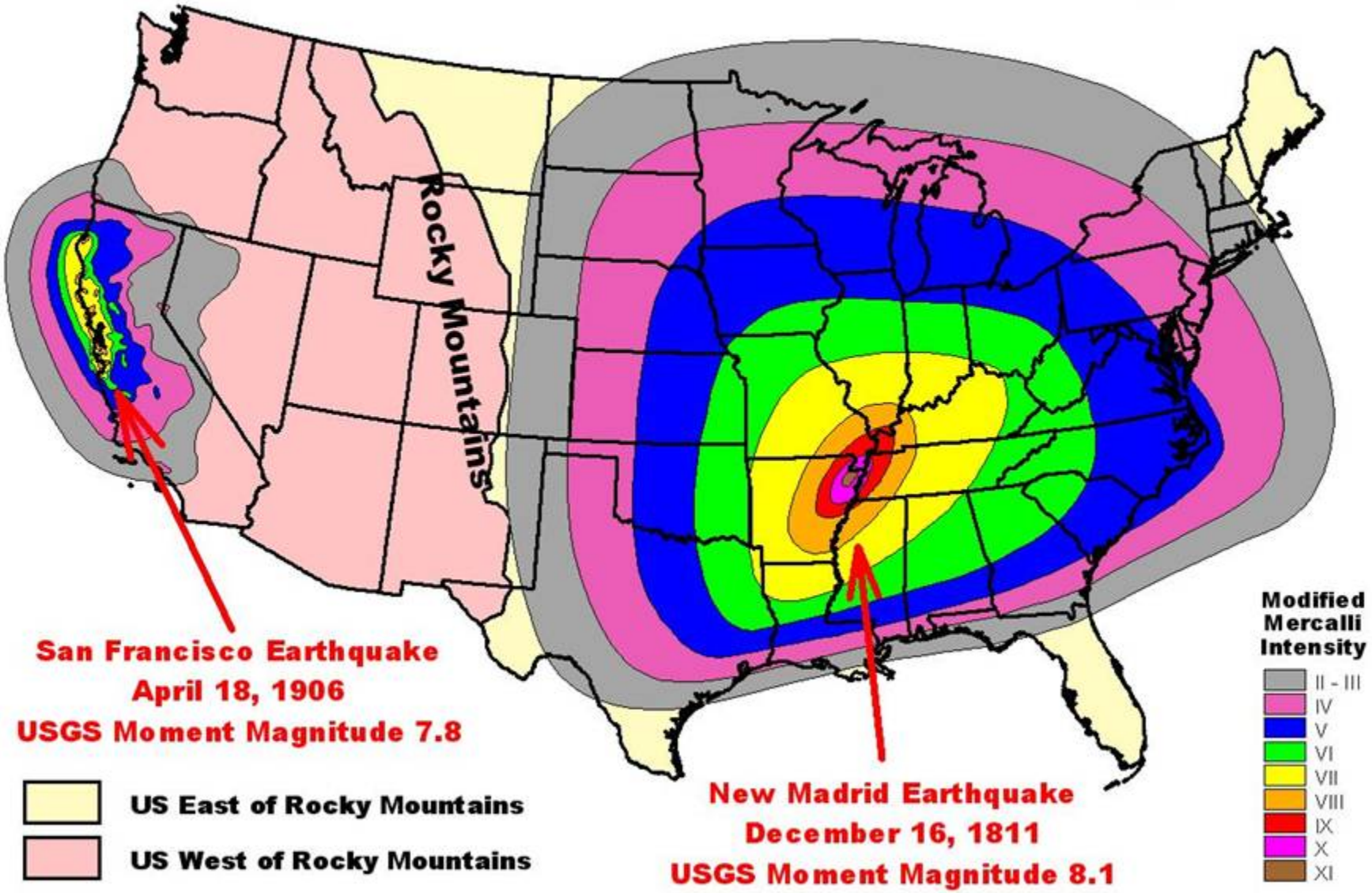
Liquefaction Caused Road to Sink


1 mile
Image State of Arkansas
© 2009 Google
©2008 Google
lat 35.864783° lon -89.883559°
Jan 11, 2006
Eye alt 17113 ft


Depth(m)
0
5
10
15
20
25
0 2 4 6 8 10
F.S.

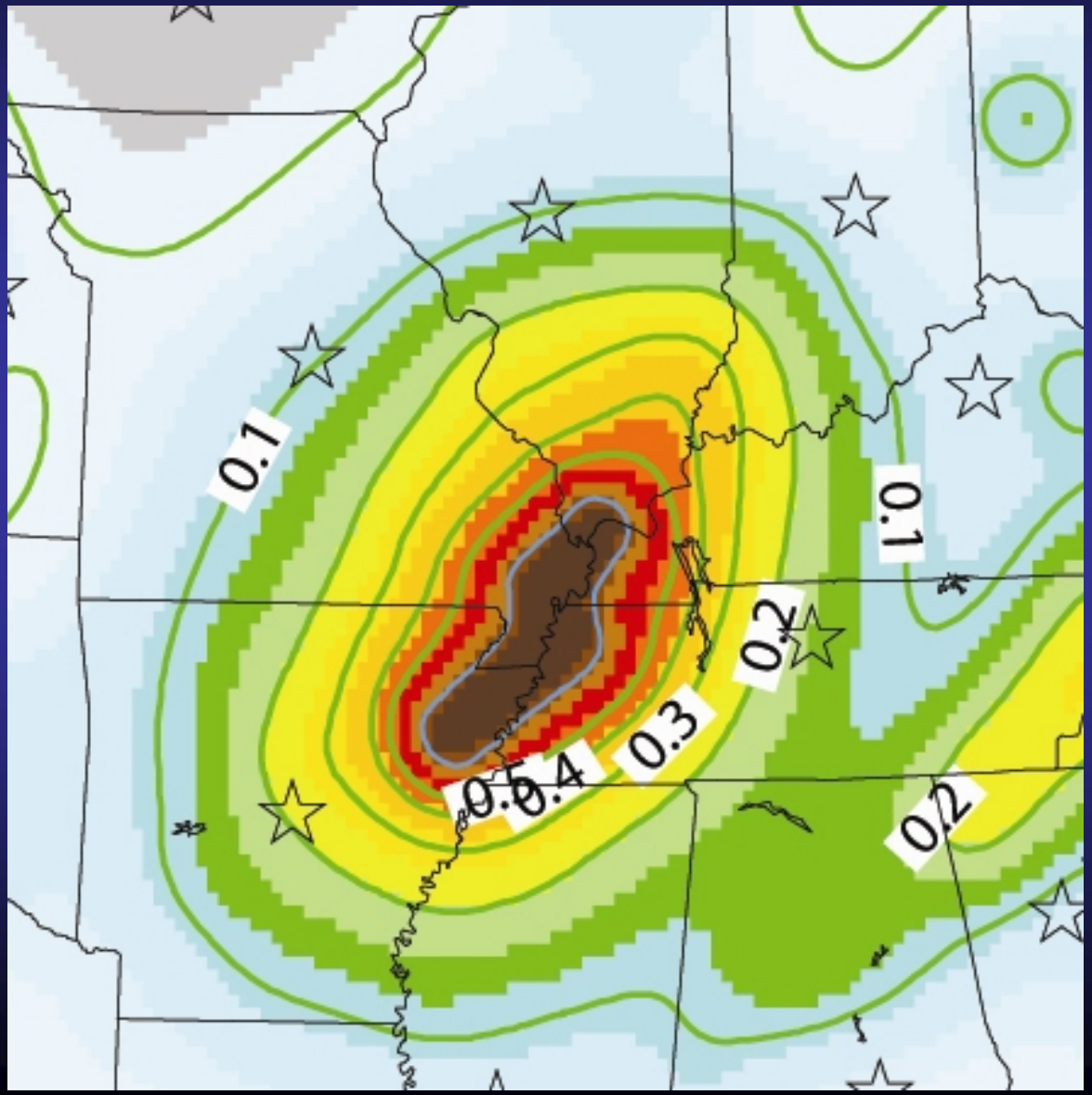

Farthest Distance to Liquefaction Feature
Earthquake Magnitude
10.0
9.0
8.0
7.0
6.0
5.0
4.0
0
50
100
150
200
250
Miles

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



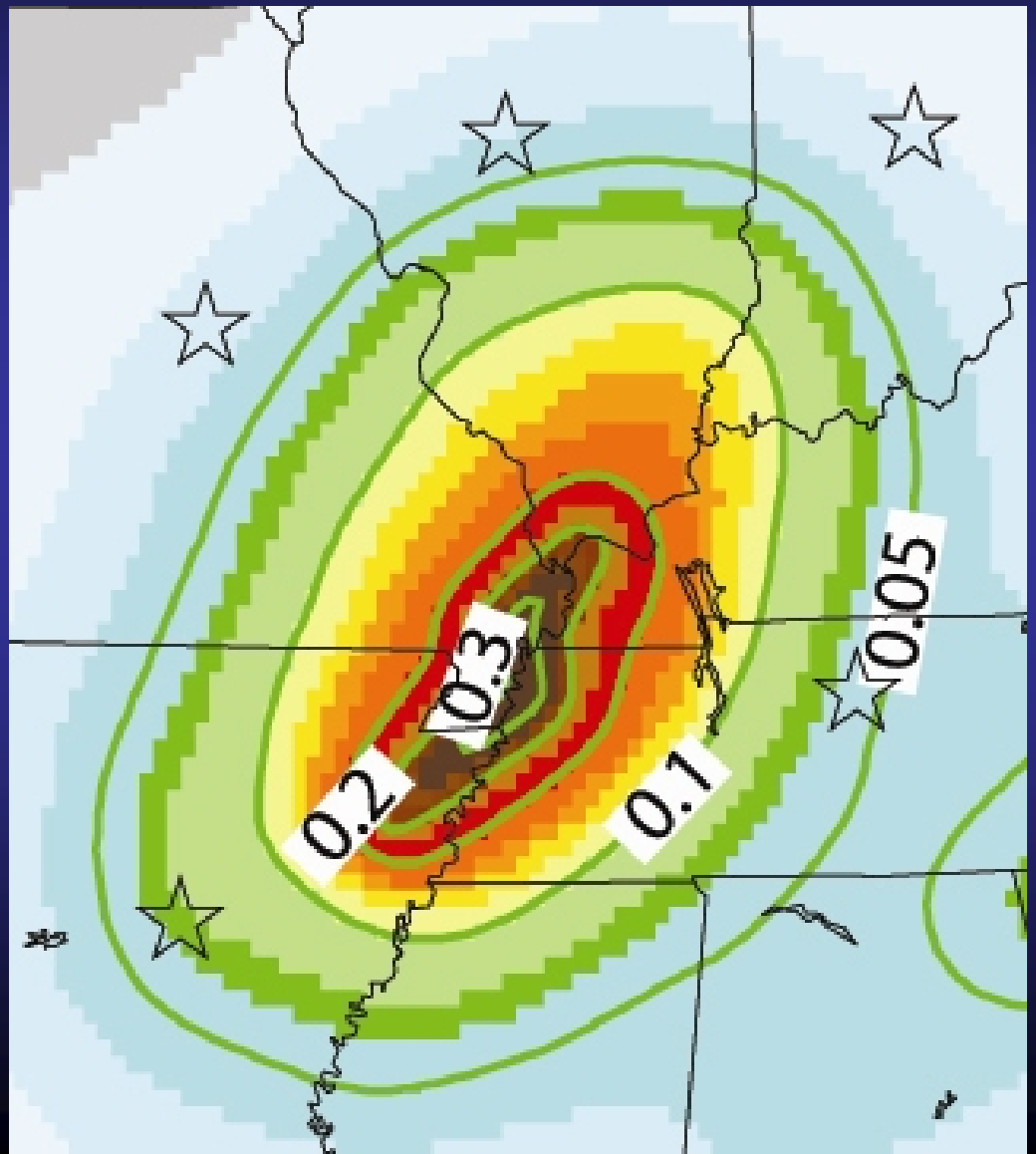
Hazard probability map. 1 chance in 2,475 to exceed acceleration values in any year. Values in g on BEDROCK.

PGA 2008

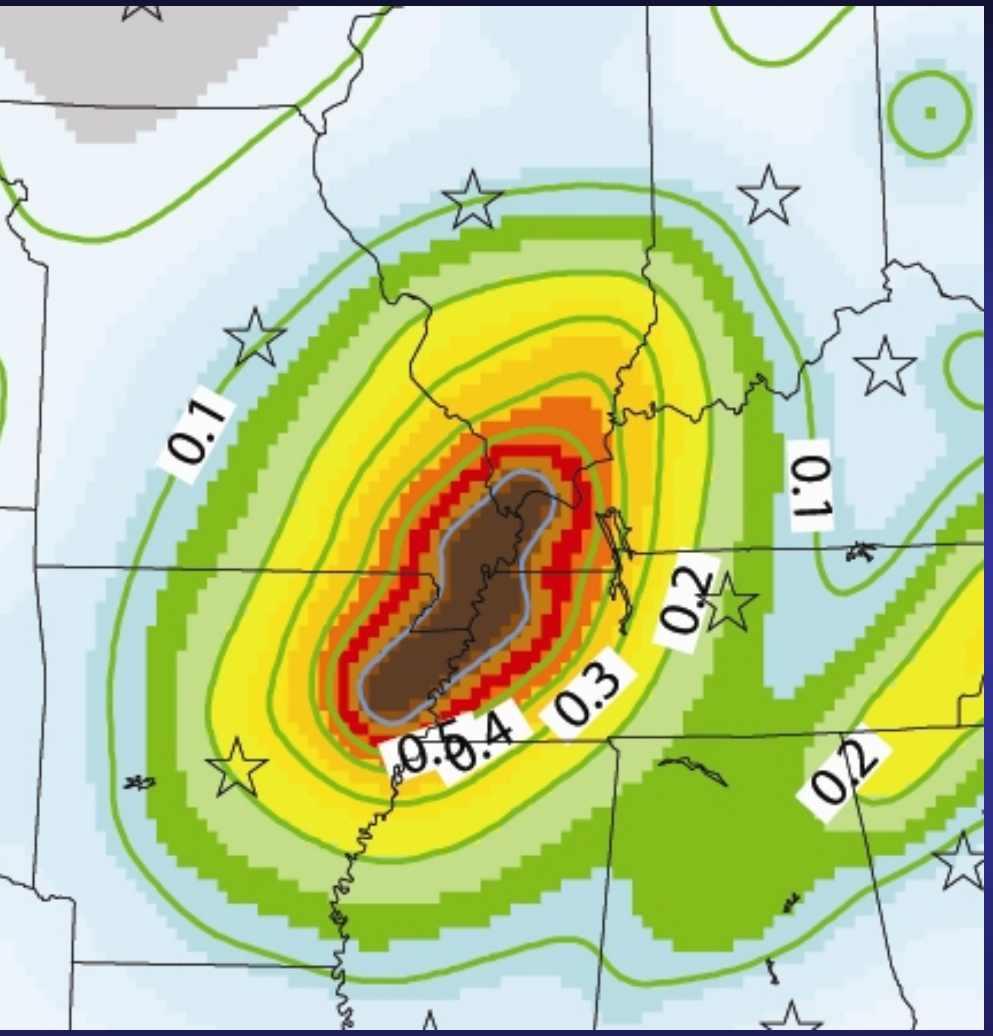


Hazard probability map. 1 chance in 475 to exceed acceleration values in any year. Values in g on BEDROCK.

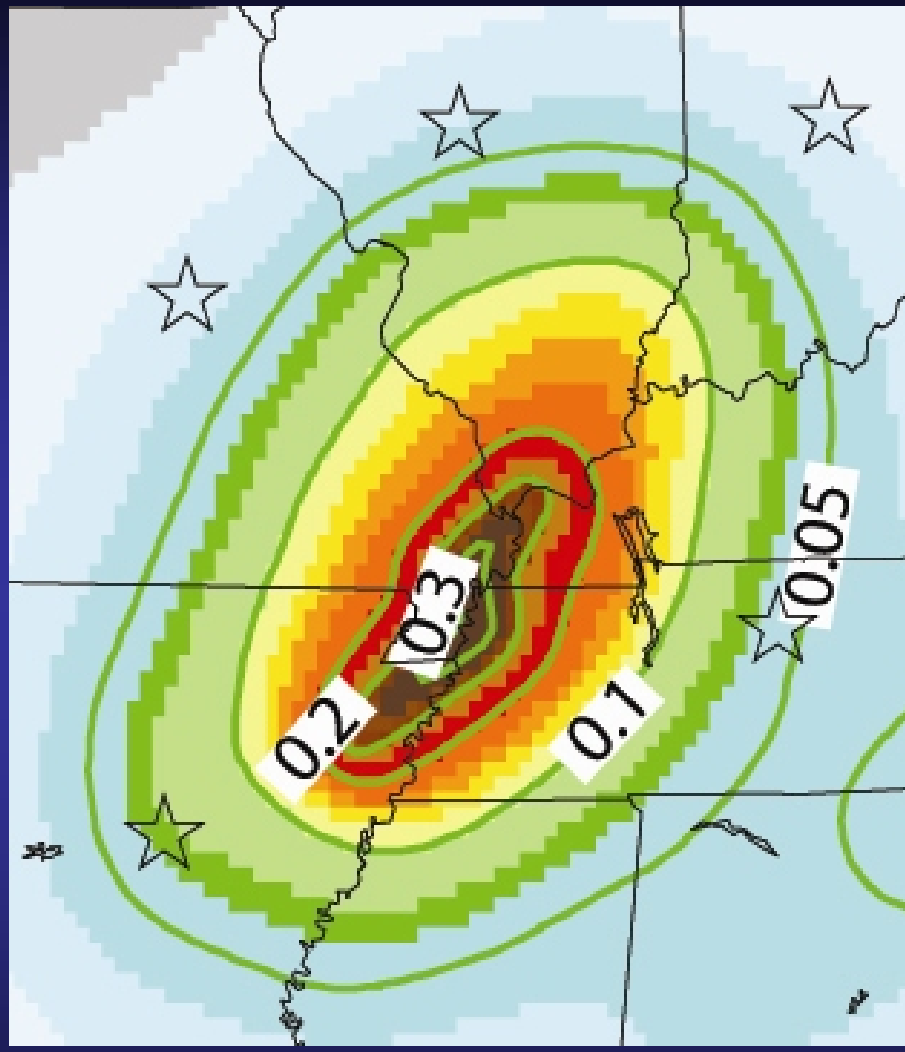
PGA 2008

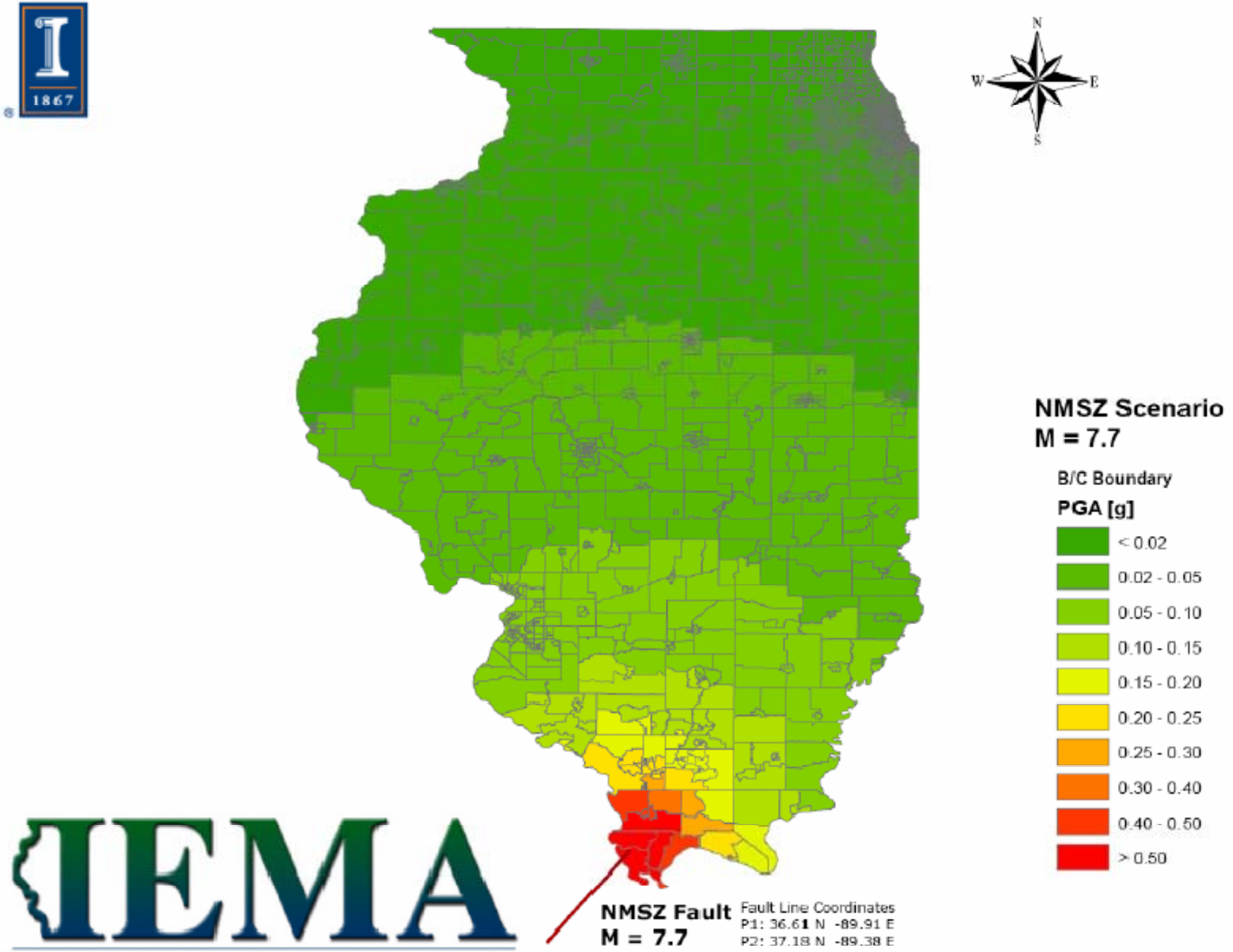


1 chance in 2,475 in any year

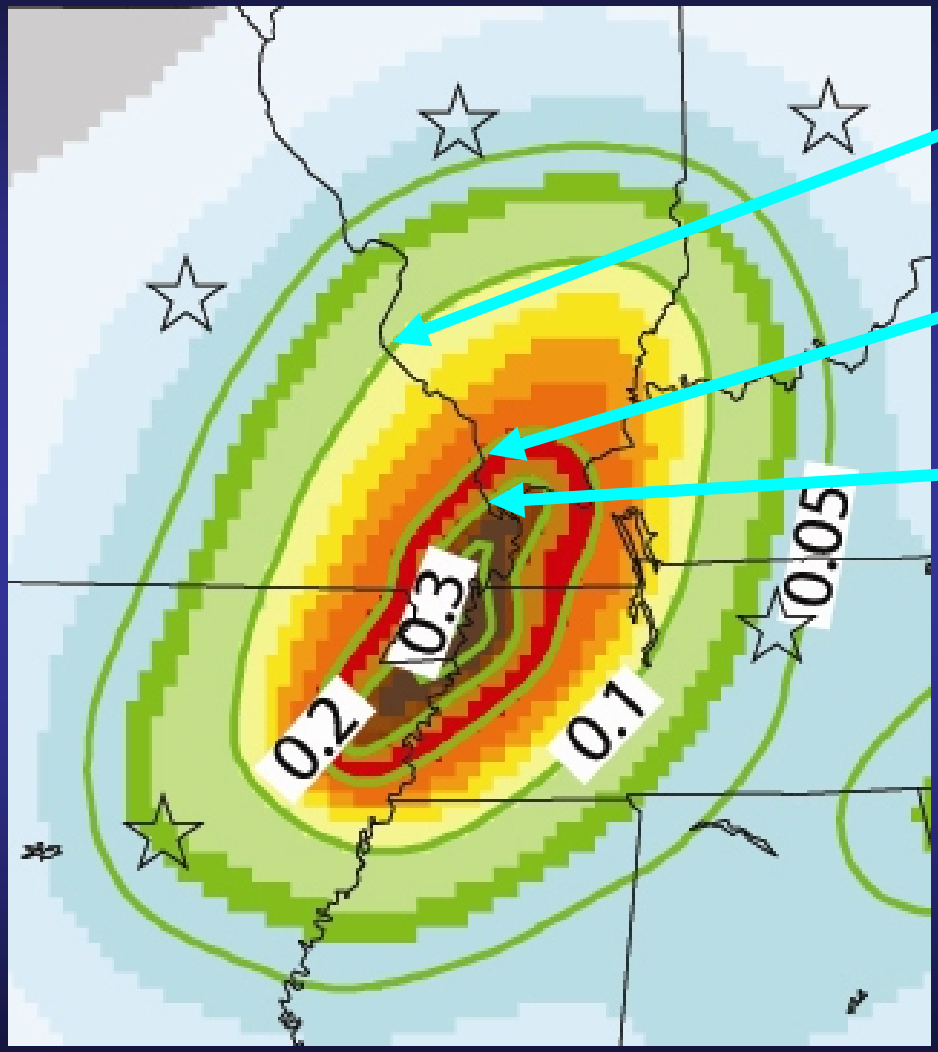


1 chance in 475 in any year




N
W
E
S
NMSZ Scenario
M = 7.7
B/C Boundary
PGA [g]
< 0.02
0.02 - 0.05
0.05 - 0.10
0.10 - 0.15
0.15 - 0.20
0.20 - 0.25
0.25 - 0.30
0.30 - 0.40
0.40 - 0.50
> 0.50
NMSZ Fault
M = 7.7
Fault Line Coordinates
P1: 36.61 N -89.91 E
P2: 37.18 N -89.38 E
IEMA
ILLINOIS EMERGENCY MANAGEMENT AGENCY

Levee failures from ground liquefaction without amplifying bedrock ground motions



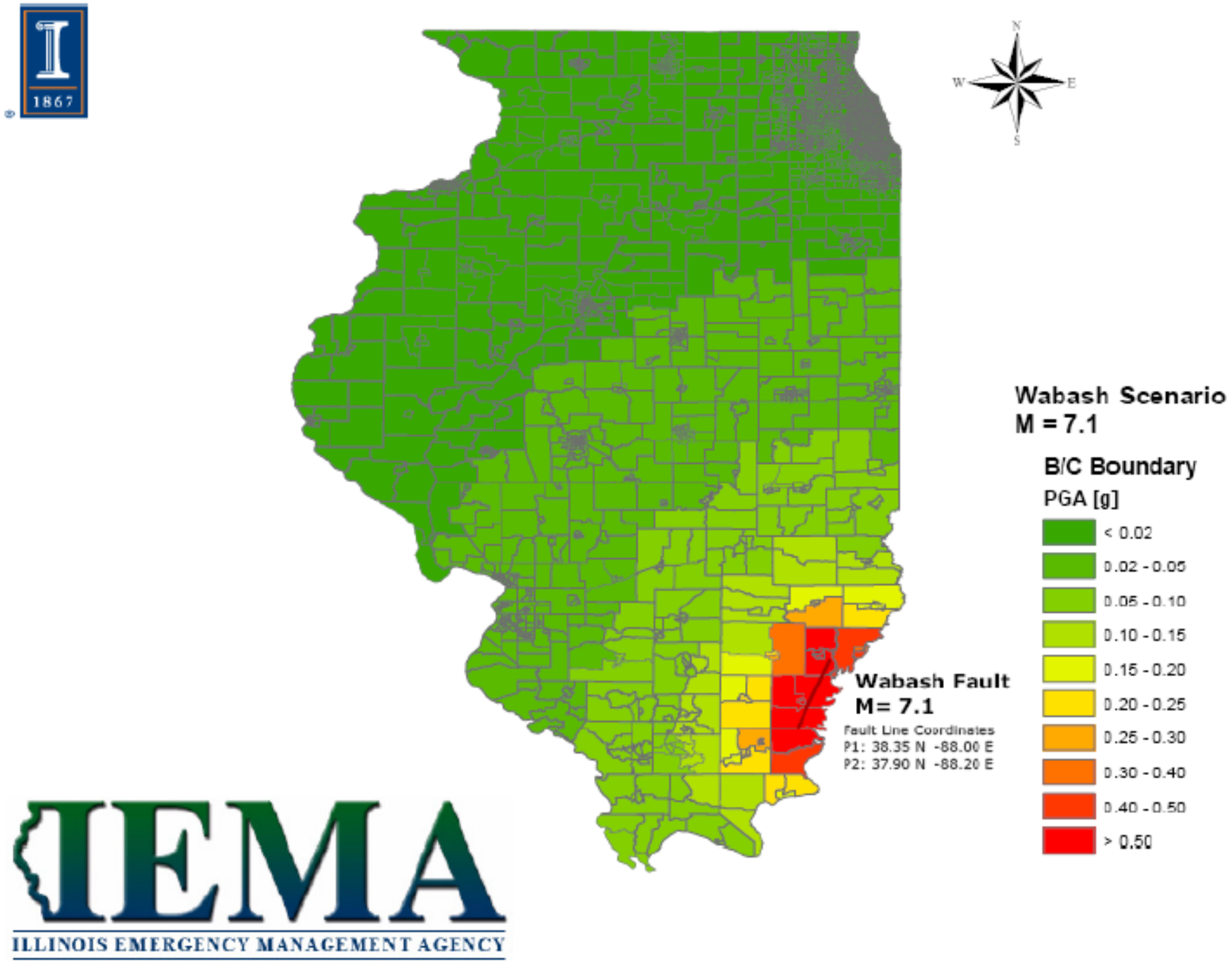
0 to 3 failures/100 miles*

3 to 10 failures/100 miles

15 to 30 failures/100 miles

1 chance in 475 in any year

*Estimates from Sacramento-San JoaQuin Delta levee system **not** site specific analysis for Central US.


N
W
E
S
Wabash Scenario
M = 7.1
B/C Boundary
PGA [g]
< 0.02
0.02 - 0.05
0.05 - 0.10
0.10 - 0.15
0.15 - 0.20
0.20 - 0.25
0.25 - 0.30
0.30 - 0.40
0.40 - 0.50
> 0.50
Wabash Fault
M= 7.1
Fault Line Coordinates
P1: 38.35 N -88.00 E
P2: 37.90 N -88.20 E
1867
IEMA
ILLINOIS EMERGENCY MANAGEMENT AGENCY

Earthquake Shaking Levels for Structural Damage to Levees

Estimated in recent study at Mid-America Earthquake Center

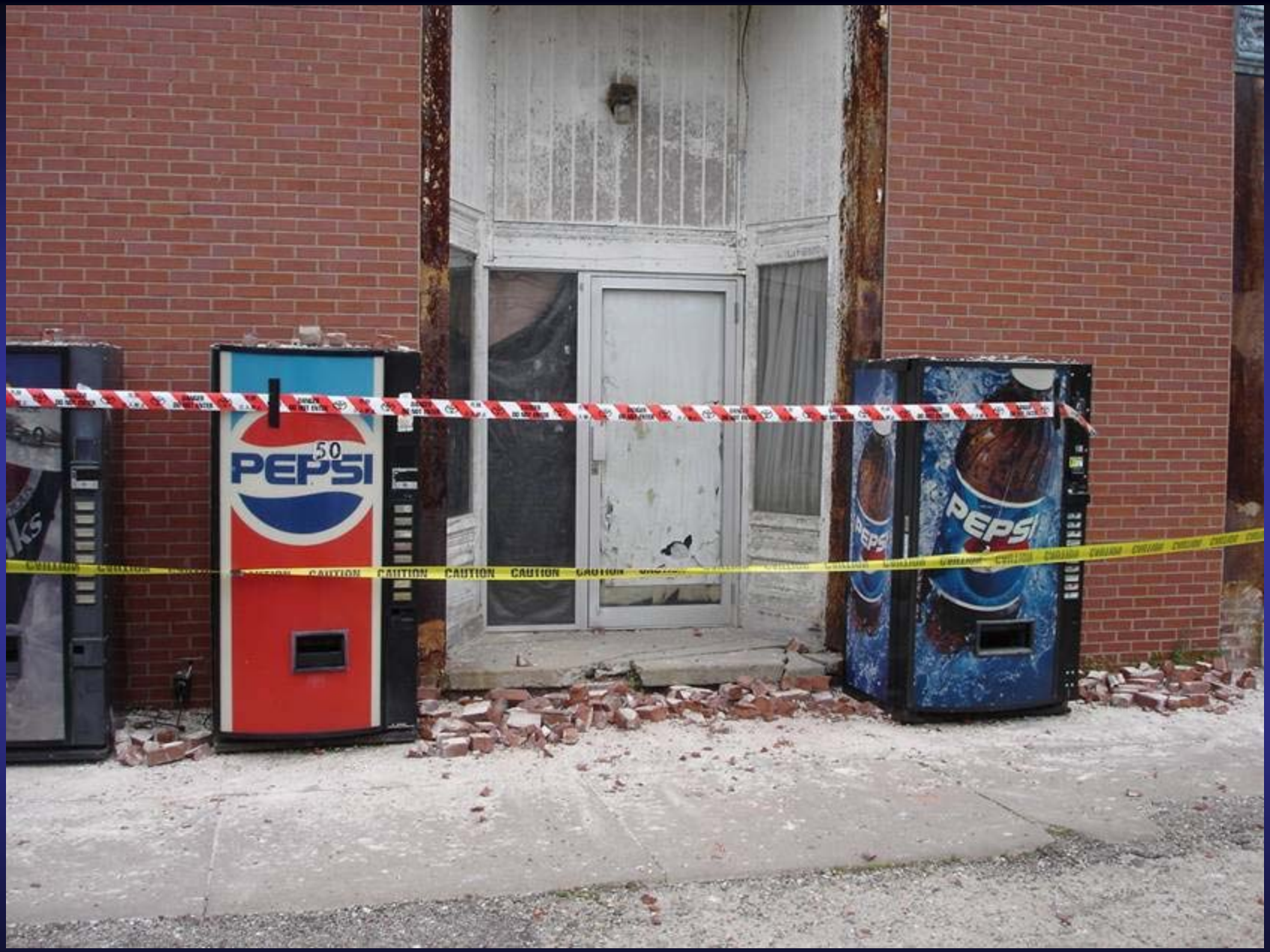
Slight damage starts at 0.3g

IN THE UNITED STATES

If Indoors – STAY there &

We Drop, Cover and Hold On!

Seattle 2001



Bellmont, IL

4.5 mi (7.5 km)

photo: ISGS

Bone Gap, IL

5 mi (8 km)

photo: ISGS

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

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

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

Mt Carmel, IL

7 mi (11 km)

photo: ISGS

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

West Salem, IL

8 mi (13 km)

photo: ISGS

New Harmony, IN **22 mi (35 km)** **photo: Norm Hester**

USGS Revised 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