

**Discover small town charm
on the banks of the**



Mighty Mississippi

New Madrid
MISSOURI

GIANT EARTHQUAKES IN THE MIDWEST: Hazard, Hype & Hard Choices





Collaborators 1990-present

Northwestern

PhD students

Andrew Newman (now Georgia Tech)
John Weber (now Grand Valley State)
Joe Engeln (now Missouri DNR)

Postdocs

Giovanni Sella (now
National Geodetic Survey)
Resty Pelayo

Undergrad/Ms
James Hebden

Grad student field assistants
Gary Acton, Lisa Leffler, Lynn
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Others

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John Schneider
(Geoscience Australia)
Joseph Tomasello (Reeves Firm)
Andres Mendes (AON)
Mike Bevis (Ohio State)
Ken Hudnut (USGS)
Eric Calais (Purdue)
Mian Liu (Missouri)
Qinsong Li (LPI)
Glen Mattioli (Arkansas)

Undergrad field Assistants
Grand Valley State

Field engineers
UNAVCO, JPL

SAN FRANCISCO EARTHQUAKE

April 18, 1906 M 7.8

3000 deaths
28,000 buildings
destroyed
(most by fire)
\$10B damage



“The whole street was undulating as if the waves of the ocean were coming toward me.”

“I saw the whole city enveloped in a pile of dust caused by falling buildings.”

“Inside of twelve hours half the heart of the city was gone”



EMERGENCY RESPONSE



Mayor formed citizen committee & took charge

Army immediately supported police & fire (how well?)

Prompt state, federal, & private aid

Displaced housed in tent cities with services

Free postal service provided

Tendency to blame fire rather than earthquake for damage

Eventually, earthquake damage accepted & safer buildings required



**“If, as they say,
God spanked the
town for being
over frisky**

**Why did he burn
the churches
down and spare
Hotaling's
whiskey?”**

What caused it?

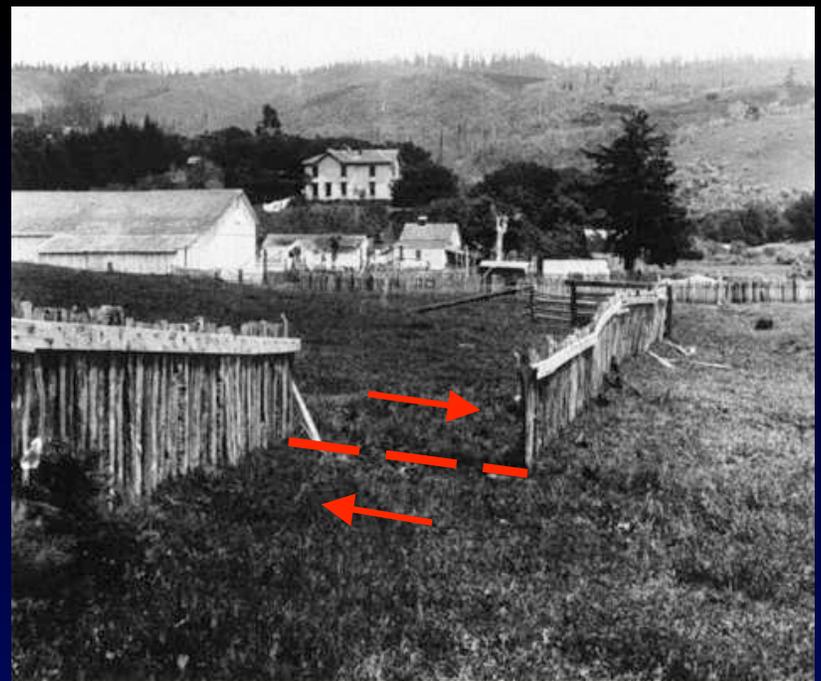
**What shook the
buildings?**

THE GROUND MOVED!

Average 12 feet (4 m)
of motion

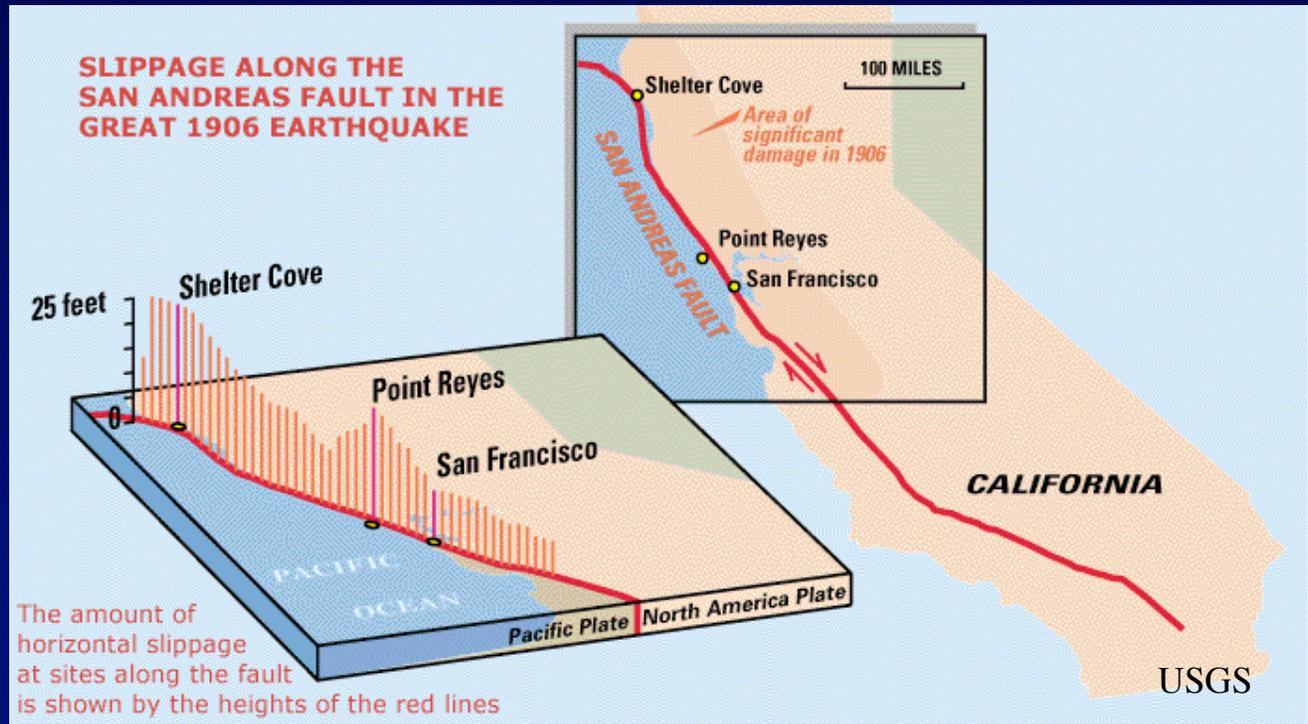
West side moved north

Motion along hundreds of
miles of San Andreas Fault



What is
the fault?

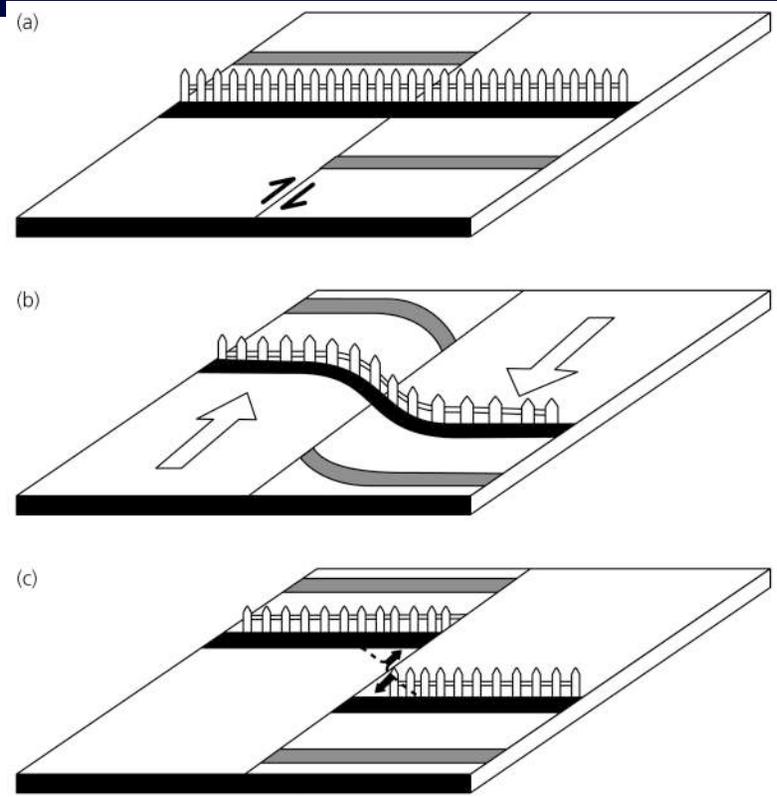
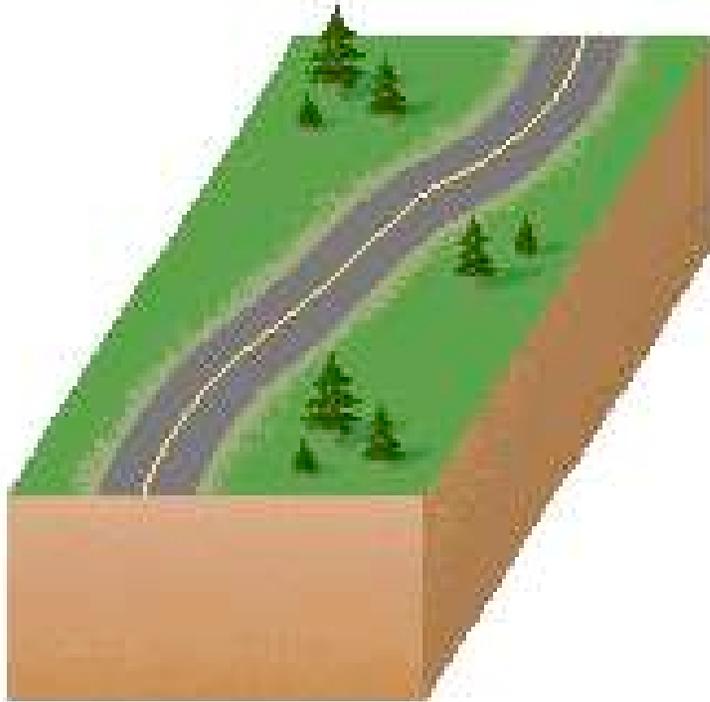
Why
does the
ground
move?



ELASTIC REBOUND

Over many years, rocks on opposite sides of the fault move, but friction on the fault "locks" it and prevents slip

Eventually strain stored is more than fault rocks can withstand, and the fault slips in earthquake

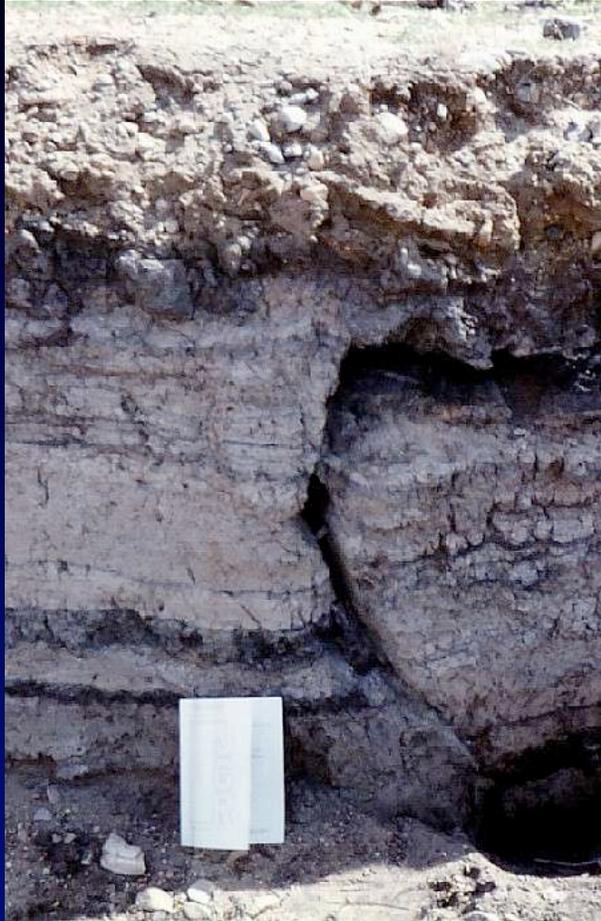


Took 60 years to figure out why this happens!

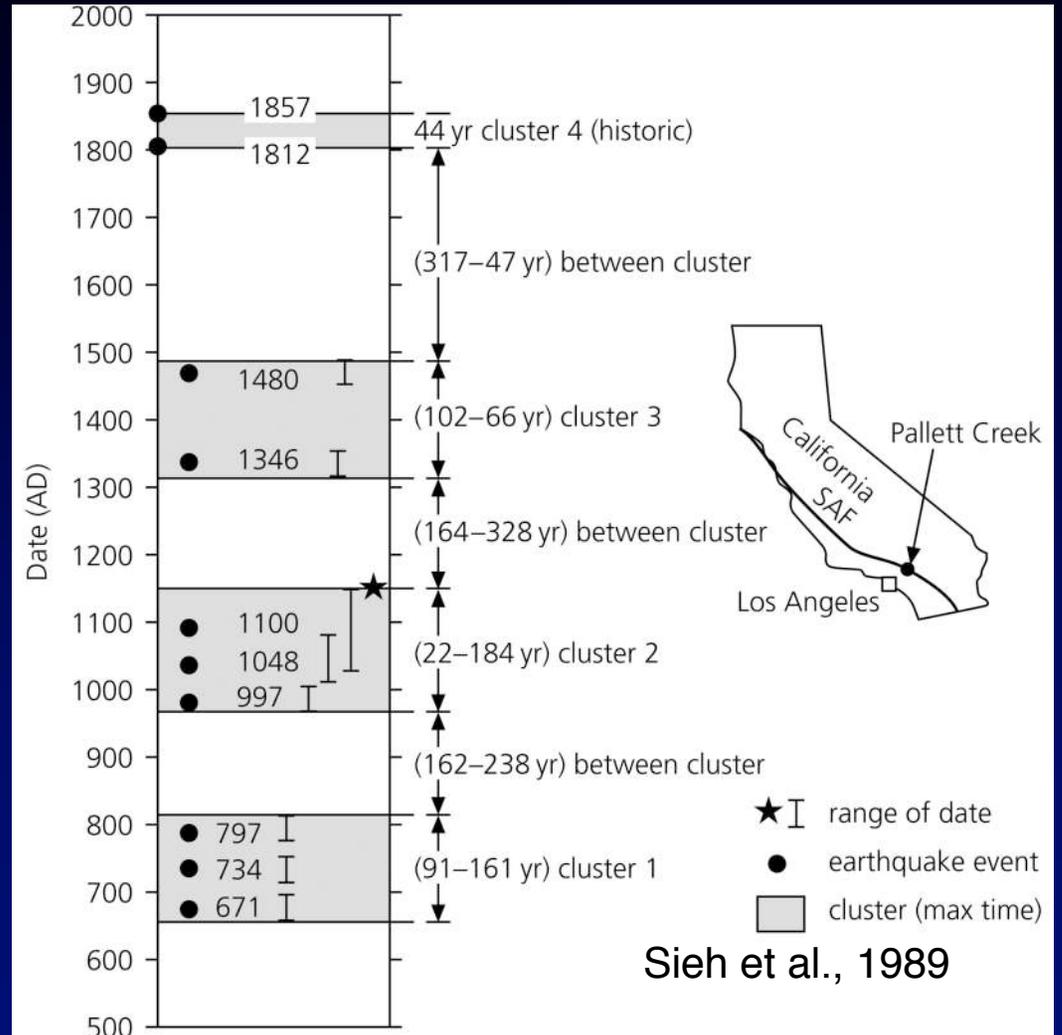


HARD TO PREDICT EARTHQUAKES

time between them is very variable



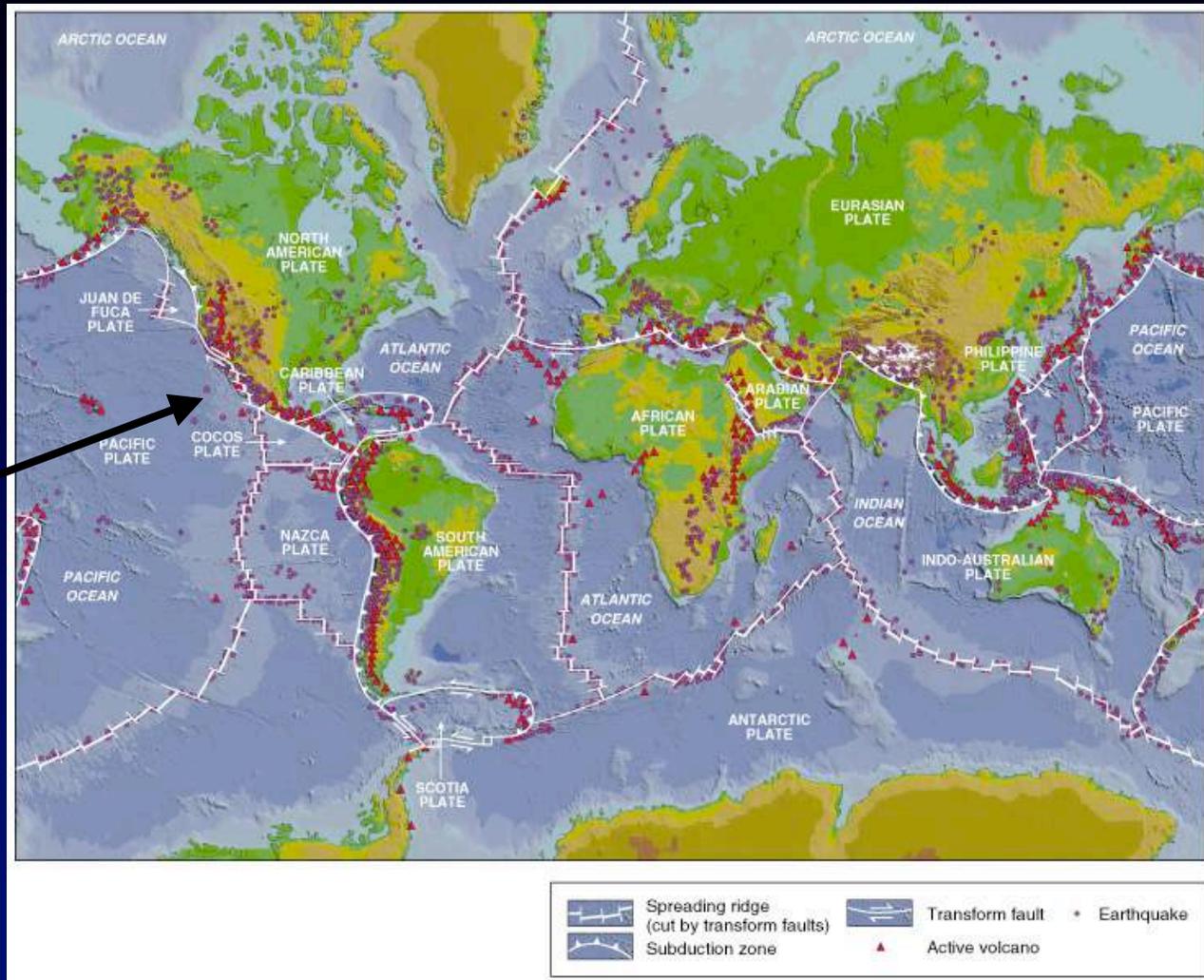
Extend earthquake history with geologic record



$M > 7$ mean 132 yr σ 105 yr
 Estimated probability in 30 yrs 7-51%

EARTH'S SURFACE DIVIDED INTO PLATES

San
Andreas
fault:
boundary
between
Pacific &
North
American
plates



Plates move at a few cm/yr: earthquakes & volcanoes happen at their boundaries

**MOST EARTHQUAKES AT PLATE BOUNDARIES, WHERE MOTION IS FAST
SOME FROM SLOW MOTION INSIDE PLATES**

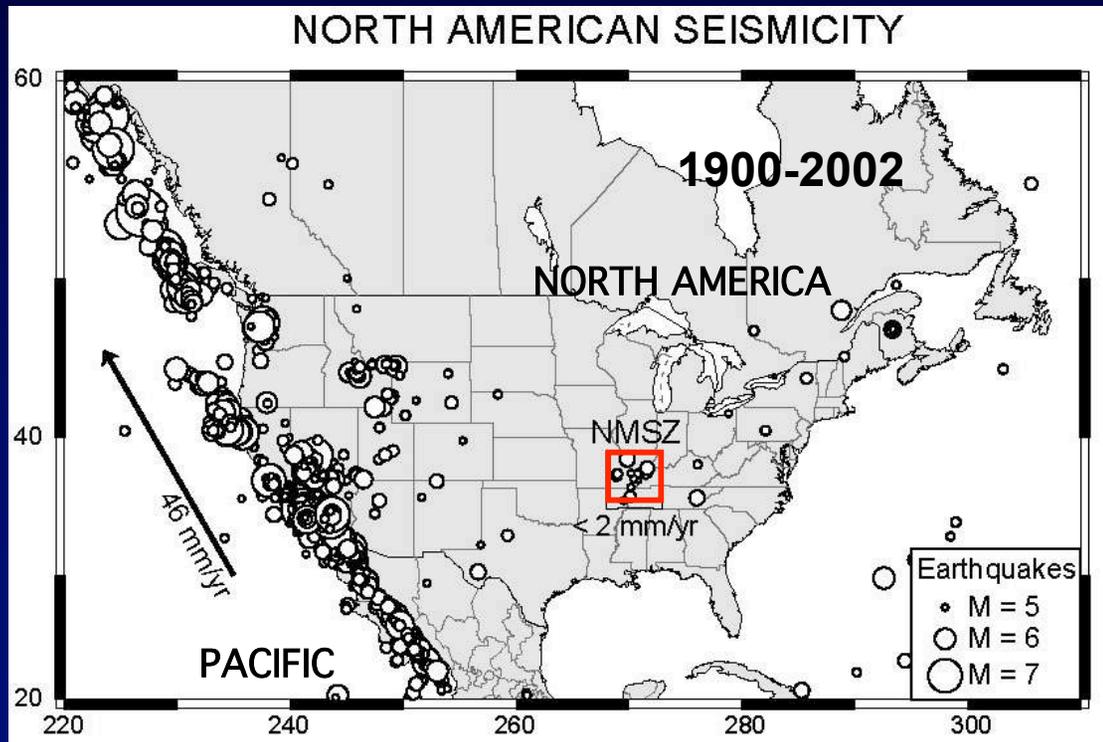
New Madrid seismic zone in central U.S.

M 7 earthquakes in 1811-12

Small earthquakes continue

Big ones might happen again

Don't know why, when, how dangerous



LOTS OF PUBLIC CONFUSION

Countdown to — 'non-quake'?

NU prof takes a last crack at faulting New Madrid fear

By Zay N. Smith
Staff Writer

Geologists everywhere, without exception, have been telling us for months that the earth will not move on Monday for you or anybody else in the Middle West.

It has not done much good. There are still thousands making plans for a Dec. 3 earthquake along the New Madrid fault—

in accordance with the prediction last spring of Iben Browning, New Mexico climatologist and inventor.

But Seth Stein, chairman of Northwestern University's geology department, would like to give it one more try.

Q. All right. Isn't there reason for us to be even the teensiest bit uneasy?

A. "Let me put it this way: Anyone in the Chicago area who has bought earthquake insurance might as well have dumped it on lottery tickets."

Q. The odds are that slim?

A. "Worse. Forget the prediction for a moment. The fact is, earthquake insurance will never be of any use to people in the Chicago area. We are simply too far away from the fault zone. Even when the Big One hits someday, the worst we can expect here is broken windows. And with the typical earthquake rider carrying a percentage deductible that goes into the thousands of dollars—well, you can figure it out. The only people who will ever see any money from such insurance are the insurance companies. Period."

Q. But further south there is a calamity that is going to happen someday. What about that Iben Browning prediction?

A. "We are about to witness

the greatest nonevent since 'The War of the Worlds.' I'll state it as clearly as I can: Browning's prediction has been evaluated and determined to be complete nonsense, without scientific foundation, which is our jargon for: 'It's a crock.' The plain fact is that science is still nowhere near being able to predict earthquakes with any precision. Wish we could. But we can't."

Q. Then why are so many people taking him seriously?

A. "The answer is as close as your TV set. The print media have been fairly responsible with this crackpot—who, by the way, says his tidal theories can also explain the French and Indian Wars and the fall of communism. But I've never seen anything so irresponsible as the local TV news coverage. I've watched whole reports go by without a critical word, not so much as an attempt to put this quack in any perspective."

Q. You sound angry.

A. "I am angry. It was almost funny for a while, but no longer. A great many people have been needlessly frightened. I get panicky calls every day and have to take a few moments—the few moments TV has so rarely taken—and calm each caller. And there is all the needless expense of the earthquake insurance. I would like to see the TV stations called to task after this whole thing doesn't occur. Maybe there should be a class-action suit to recover all those insurance premiums."

Q. So nobody has anything to worry about?

A. "We have a lot to worry about. Another major earthquake will happen someday—nobody knows just when, Iben Browning notwithstanding—along the New Madrid Fault. People have to be prepared. I hope when Monday comes and goes, we can remember that much."

Mysterious 'consultant' still unshaken in disaster view

By William Braden
Staff Writer

Iben Browning, who has predicted that tidal forces will trigger a major Midwestern earthquake this week, describes himself as a "biophysicist, climatologist, inventor."

He also claims to be a "researcher and inventor in the field of optical engineering, information theory, brain physiology, enzymes, climatology and others."

He says he is a "consultant in various fields to numerous business and financial institutions and research organizations" and "holder of numerous U.S. and foreign patents."

It's not clear where the Texas-born, 72-year-old Browning acquired his expertise in climatology, nor to mention seismology.

He says he earned a bachelor's degree at Southwest Texas State Teachers College in 1937, a master's at the University of Texas in 1947 and a doctorate in physiology, genetics and bacteriology at the University of Texas in 1948.

In an idiosyncratic addendum to his entry in *Who's Who in America*, Browning wrote: "Life is so brief that personal

opinions are too transient to be worth anything to mankind. Data, and objective interpretations, are the only contributions with lasting value. Physical achievements, and ideas which constitute tools with which Man can achieve his goals, are significant."

He can be a bit testy when his theories are questioned.

His recent prediction was investigated by a scientific panel appointed by the U.S. Geological Survey, which asked him to provide materials that would help them advise state officials how to respond to the threatened disaster. And he responded in a brief letter to Robert L. Wesson, chief of the agency's Office of Earthquakes, Volcanoes and Engineering. "As for policy," he wrote, "I strongly recommend against one. The government has an unblemished record of screwing up everything it touches."

Browning, a New Mexico resident, identifies himself as president of the Sydnor-Barent Scanner Corp. in Albuquerque. A call to the number listed for the corporation was taken by an answering service for the Browning Newsletter, which Browning has published since 1977. According to the answering service, nobody at the corporation was in.

Browning during 1957-60 was a researcher at the top-secret Sandia National Laboratory near Albuquerque. While there, according to the New Republic, he proposed implanting remote-controlled electrodes in the brains of whales—who could then be equipped with hydrogen bombs and guided into Soviet port cities. There were no whales in New Mexico, so he experimented with donkeys.

As a NASA consultant before the 1969 Apollo moon landing, he reportedly concluded the moon was covered with dust so thick no spacecraft could land on it.



NEW MADRID QUAKES

Following are damaging earthquakes in the New Madrid region (5.0 magnitude or above) in the last 179 years.

Date	Magnitude	Locality
Dec. 16, 1811	8.2	New Madrid, Mo.
Dec. 16, 1811	7.8	New Madrid, Mo.
Jan. 23, 1812	8.1	New Madrid, Mo.
Feb. 7, 1812	8.3	New Madrid, Mo.
June 9, 1838	5.1	Southern Illinois
Jan. 4, 1843	6.4	Marked Tree, Ark.
Oct. 8, 1857	5.1	Southern Illinois
Aug. 17, 1865	5.2	Southeast Missouri
Sept. 27, 1891	5.5	Southern Illinois
April 12, 1895	6.8	Charleston, Mo.
Nov. 4, 1903	5.0	Southeast Missouri
May 26, 1909	5.2	Illinois
Nov. 9, 1968	5.4	South-central Illinois
June 10, 1987	5.0	Southeast Illinois

Source: U.S. Geological Survey



Seth Stein



Iben Browning

Midwest public hears steady drumbeat of alarming earthquake information from government and other sources

Confusing mixture of science & hype:

Large earthquakes occurred in 1811- 1812 (true)

These were the largest ever in the U.S. (hype)

There is a hazard from future earthquakes (true)

The risk is similar to that in California (hype)

Communities must decide whether, as FEMA pushes, adopt building standards as stringent as those in California, or whether the required billions of dollars would be better used elsewhere

“PERFECT STORM”

NATURAL INSTITUTIONAL MOTIVES TEND TO HYPE HAZARD

RESEARCHERS: interested in earthquakes, seek funding

EMERGENCY MANAGERS: well-meaning nonscientists,
draw attention via focus on extreme & unlikely scenarios

QUASI-REGULATORY AGENCIES: USGS, FEMA, etc:
focus on extreme scenarios, don't consider costs of
mandates that don't come from their budgets

MEDIA: Drawn naturally to sensational (disaster chic)

ENGINEERS: Develop codes for earthquake resistant
structures & design buildings to meet them

TAKEN TO EXCESS, YIELD:

GROUPTHINK: a decision making process, where group members go along with consensus. Groupthink causes irrational decisions, where individual doubts are set aside, resulting in a bad decision.

- Discounting warnings that challenge assumptions
- Unquestioned belief in group's morality makes members ignore consequences of their actions
- Pressure to conform on members who disagree
- Shutting down ideas that deviate from the consensus
- Illusion of unanimity about going along with the group
- Mindguards- self-appointed members who shield the group from dissenting opinions



Launch of shuttle Challenger



Vietnam War

“Men readily believe what they wish to.” Julius Caesar

1976 SWINE FLU



U.S. government prepared for epidemic that never materialized.

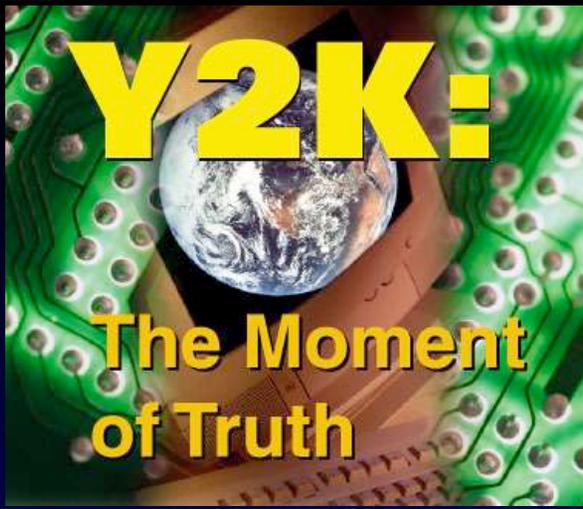
CDC reported "strong possibility" of epidemic. HEW thought "chances seem to be 1 in 2" and projected "virus will kill one million Americans in 1976."

President Ford, facing election, launched program to vaccinate entire population despite critics' reservations.

40 million Americans vaccinated at cost of millions of dollars before program suspended due to reactions to vaccine.

About 500 people had serious reactions and 25 died, compared to one person who died from swine flu.

Ford lost election, so only winners were companies that made vaccine.



Much ado made of possibility that on January 1, 2000 computer systems would fail, because dates used only two digits.

Books and media warned of upcoming disaster, survivalists stockpiled food and guns, and special insurance policies were written.

U.S. government declared a major problem and established major programs headed by FEMA

Few major problems occurred, even among businesses and foreign countries who made little or no preparation.

Estimated \$300 billion spent made Y2K preparations very profitable for computer industry.

Y2K programming outsourced from U.S. fueled growth of India's profitable outsourcing industry at the expense of U.S. programmers' jobs

Act Y2K

Low Tech Survival for High Tech Disaster

"Failure to achieve compliance with the year 2000 will jeopardize our way of life on this planet for some time to come"
Arthur Gross, Chief Information Officer, IRS

A Guide to Safeguard You and Your Family

- Part I Questions and answers to valid Y2K concerns
- Part II What to include in your home supply kit
- Part III What to do if there is a problem with your water
- Part IV What foods contain the essential vitamins and minerals
- Part V Expected shelf life for 45 common foods
- Part VI Where to call for SSN and PEBES statements
- Part VII Phone numbers for vital records (birth, etc.) for all 50 states
- Part VIII How to select a gas powered generator

Predicted Disaster Probabilities



$P(\text{sinking}) = 0$



$P(\text{loss}) = 1/100,000$

“Apocalyptic claims do not have a good track record. And arguments that statistics support such claims - particularly arguments that simple, easily understood numbers are proof that the future holds complex, civilization-threatening changes - deserve the most careful inspection .”

J. Best: More Damned Lies and Statistics: How Numbers Confuse Public Issues

HYPE

Hidden Fury The New Madrid Earthquake Zone

The danger posed by the New Madrid earthquake zone along the Mississippi River.

27 minutes
DVD-R version available
 Color
 Closed Captioned
 Grade Level: 7-12, College, Adult
 US Release Date: 1993
 Copyright Date: 1993
 ISBN (VHS): 1-56029-468-X
 ISBN (DVD): 1-59458-441-9

Produced by Doug Prose/Earth Images Foundation

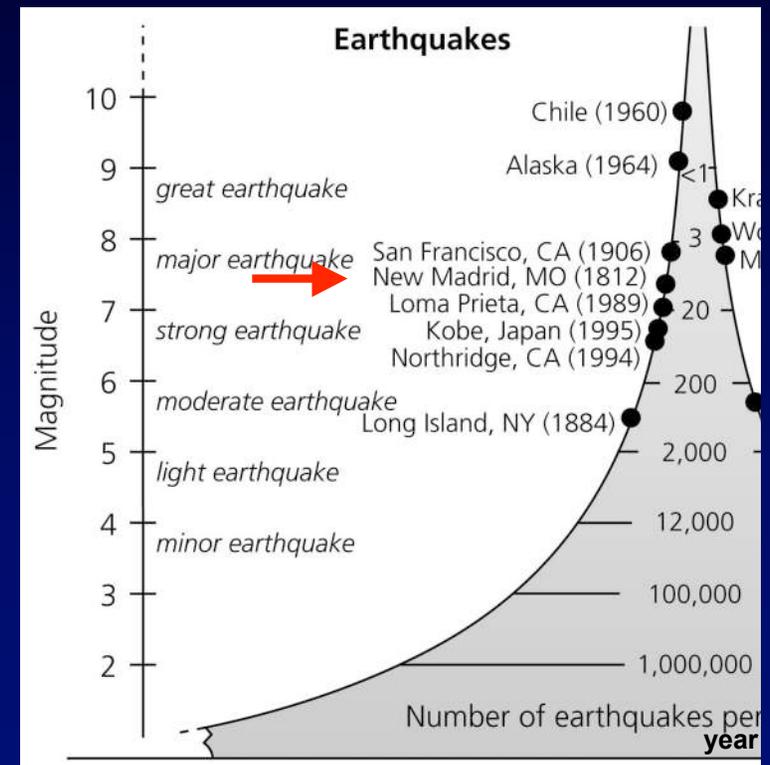


"Interesting, easy to follow, full of good information."
 ***** *Journal of Geological Education*

The New Madrid earthquake zone, located along the Mississippi River near Memphis, Tennessee, has received little attention in recent years. But in 1811 it was the site of the most powerful series of earthquakes ever known on earth. Some two million square miles were affected, and shocks were felt as far away as Montreal, Canada - 1,200 miles from the epicenter.

According to experts, another major earthquake will likely occur in the New Madrid Earthquake Zone in the next 50 years. With the aid of computer graphics, the geologic characteristics of the region and the tectonic nature of earthquakes are explained. Additionally, the relatively stable region of the central United States is compared to the well-known seismicity of California. This is a fascinating science adventure that, for many people, will hit very close to home.

5-10 earthquakes of this size occur on earth each year



Stein & Wyession (2003)
after IRIS

HYPE

Central United States Earthquake Consortium

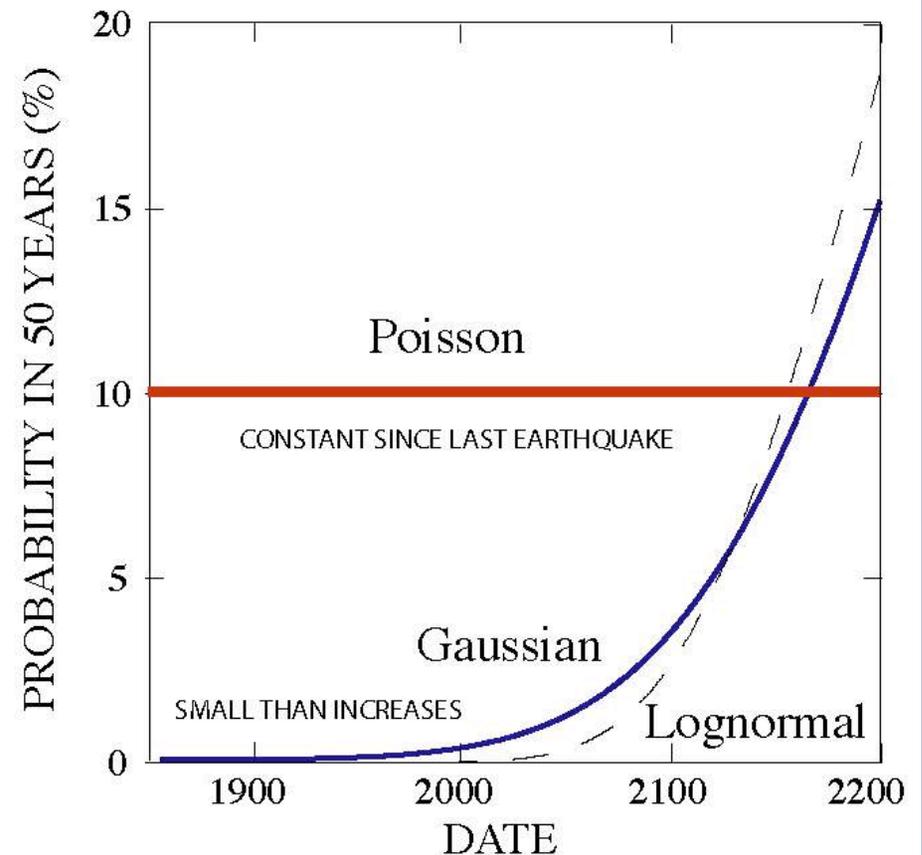
...a partnership to mitigate disasters and save lives

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“Seismologists have predicted a 40-60% chance of a *devastating* earthquake in the New Madrid seismic zone in the next ten years. Those odds jump to 90% over the next 50 years. The potential magnitude of a *catastrophic* New Madrid quake dictates that we approach the preparedness on a regional basis”

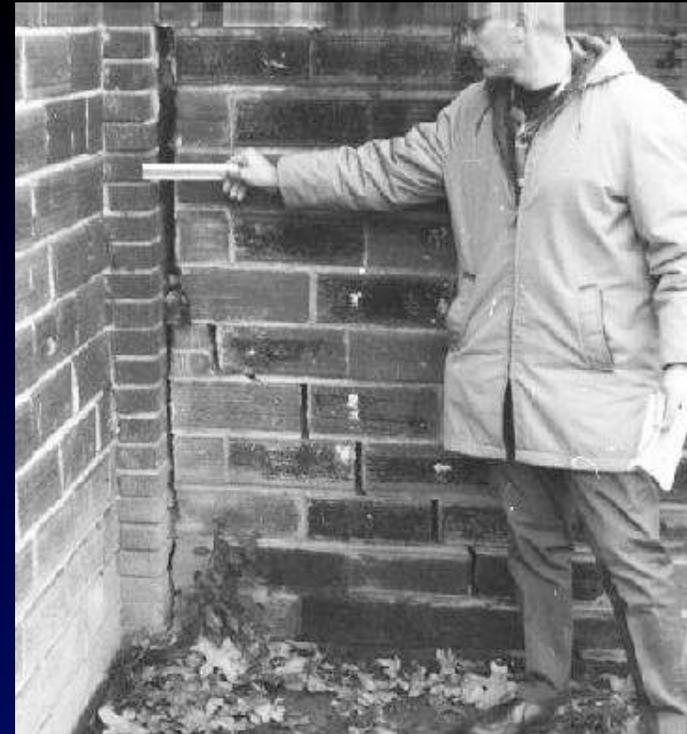
Can get any value, depending on assumptions of magnitude and recurrence

LARGE NEW MADRID EARTHQUAKE



Stein et al., 2003

**“Catastrophic” & “devastating”
defined as $M > 6$... which occurs ~
every 150 years somewhere in the
New Madrid zone - most of which isn’t
densely populated**



**The largest in the past century,
1968 (M 5.5) Illinois
earthquake, caused no
fatalities. Damage consisted
of fallen bricks from chimneys,
broken windows, toppled
television aerials, and cracked
or fallen brick & plaster.**

HYPE

Central United States Earthquake Consortium

...a partnership to mitigate disasters and save lives

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CUSEC Director “James Wilkinson showed an extraordinary knowledge of the danger facing the entire region, subscribing to the consensus that a seismic event is a “when” and not an “if.””

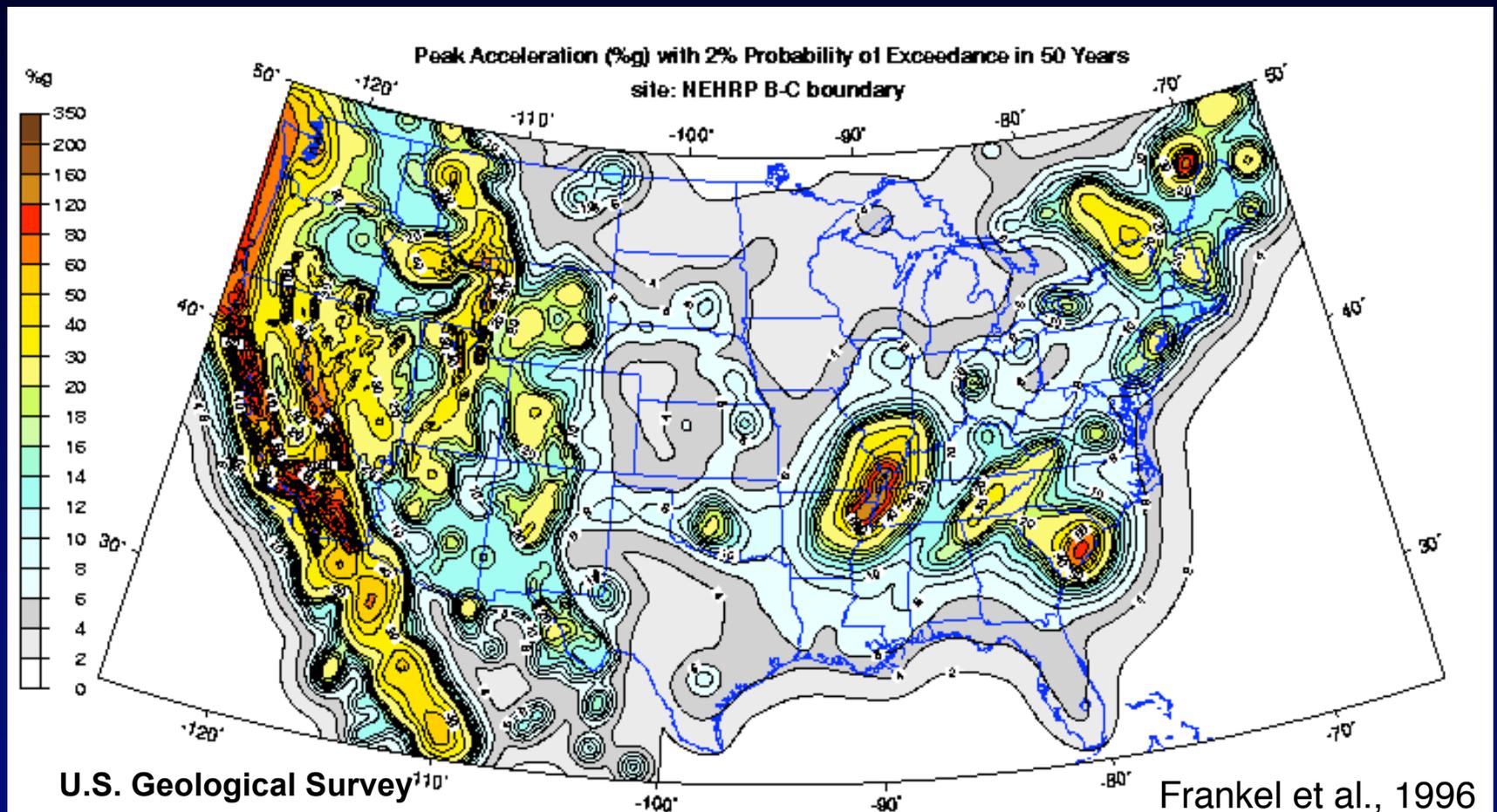
We have no idea whether or not 1811-12 type earthquakes will happen again, or - if so - when

Because we don't understand intraplate earthquakes, geological theory tells us nothing

Data show no sign of strain building up in the ground as we see in other places before large earthquakes

HYPE: NEW MADRID IS AS HAZARDOUS AS CALIFORNIA

Buildings should be built to same standards (FEMA)



Hazard map uses extreme assumptions

CONSEQUENCE



**\$100M seismic retrofit of Memphis VA hospital,
removing nine floors, bringing it to California
standard**

J. Tomasello

What Actually Happened in 1811-1812?

St. Louis

No lives have been lost, nor has the houses sustained much injury, a few chimneys have been thrown down.

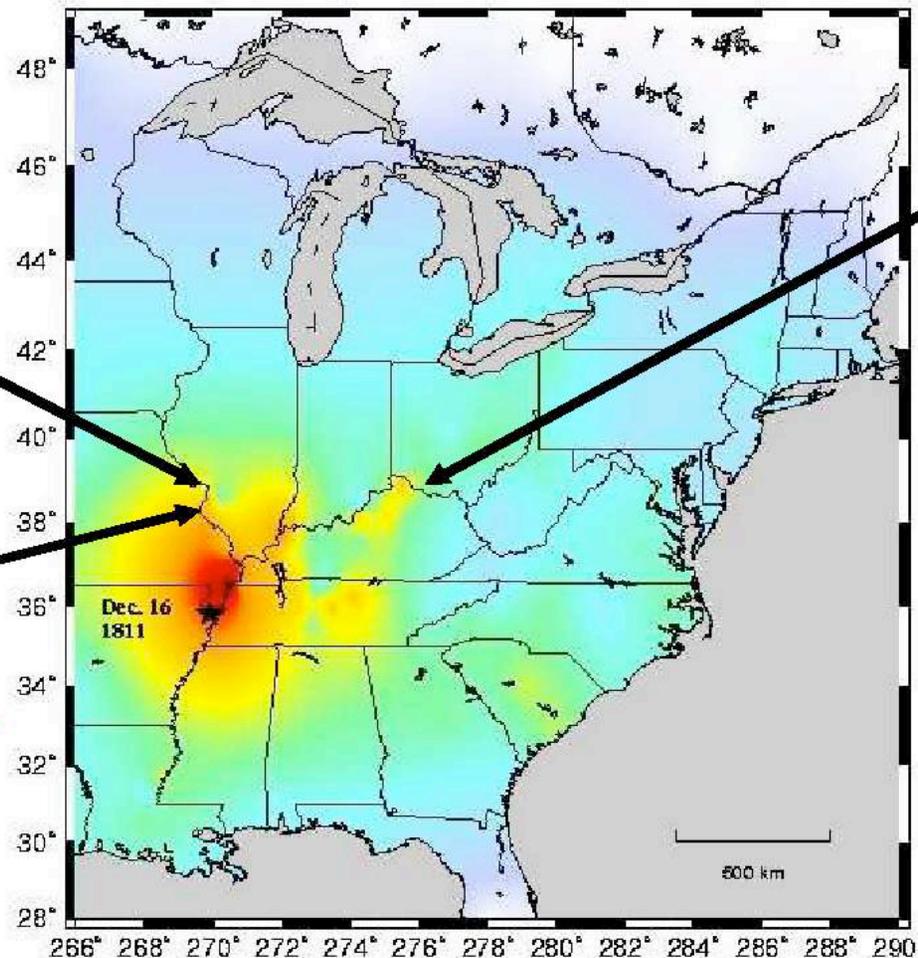
Louisiana Gazette,
Dec. 21, 1811

Ste. Genevieve

Shocks felt,
caused no damage

Rozier, 1850

S. Hough

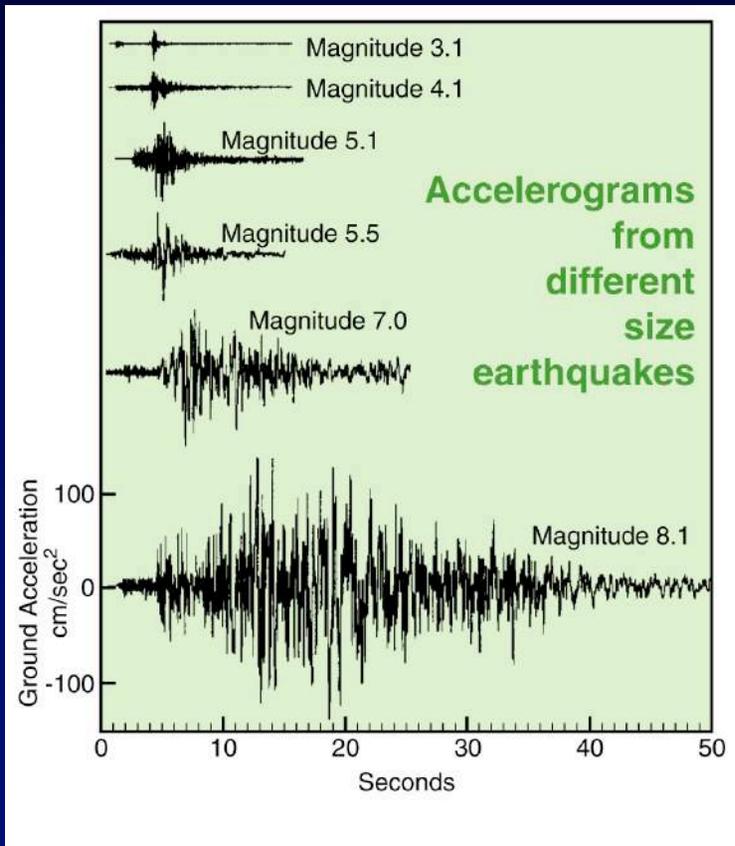


Kentucky hills south of Cincinnati:
Many families ...slept during the shock...
Daniel Drake, 1815

Log cabin collapse at New Madrid; minor damage in St Louis, Nashville, Louisville, etc.
No Boston church bells ring

INTENSITY OF SHAKING IMPLIES MID-MAGNITUDE 7, NOT OFTED QUOTED 8

MAGNITUDE 8 IS MUCH BIGGER THAN MAGNITUDE 7



University of Nevada

MAGNITUDE (M) DEPENDS ON FAULT AREA x SLIP

LOMA PRIETA 1989

M 6.9
slip 2 m



NEW MADRID 1811-12

M 7.3
slip 4 m

M 7.0
slip 2 m

M 7.5
slip 5 m



150 km

SAN FRANCISCO 1906

M 7.8
slip 4 m



"the big one"

SUMATRA 2004

M 9.3
slip 11 m

fault length

fault width

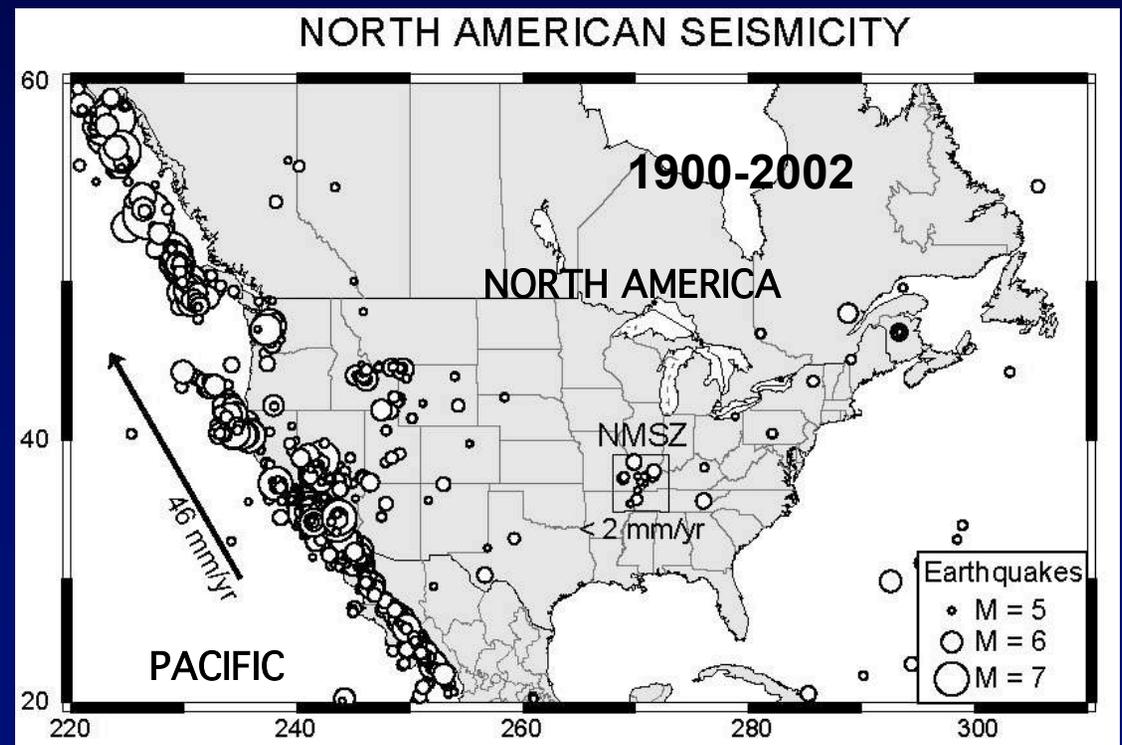
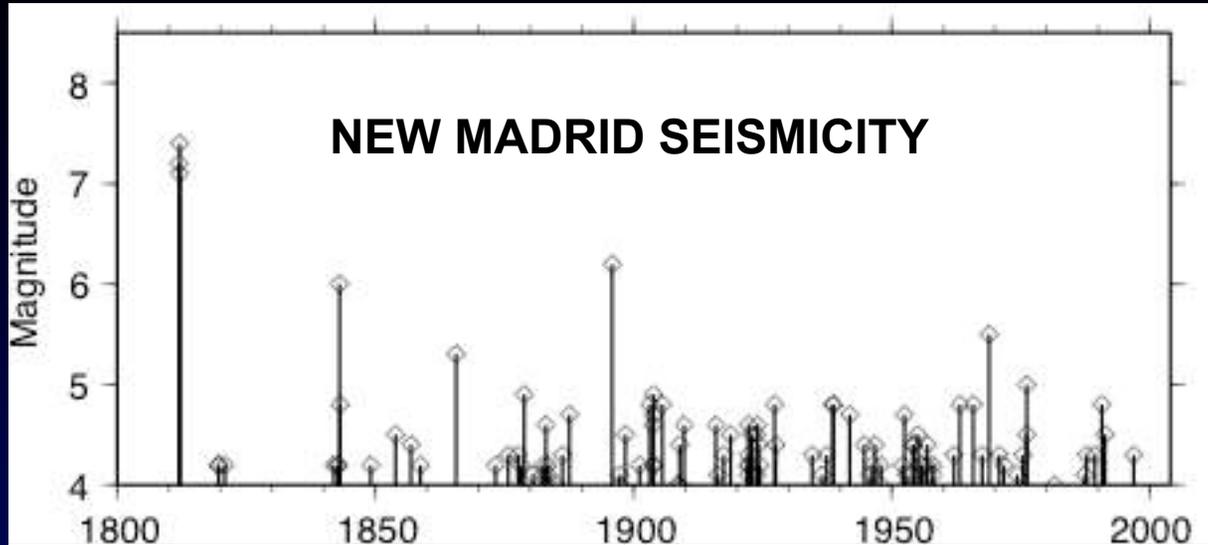
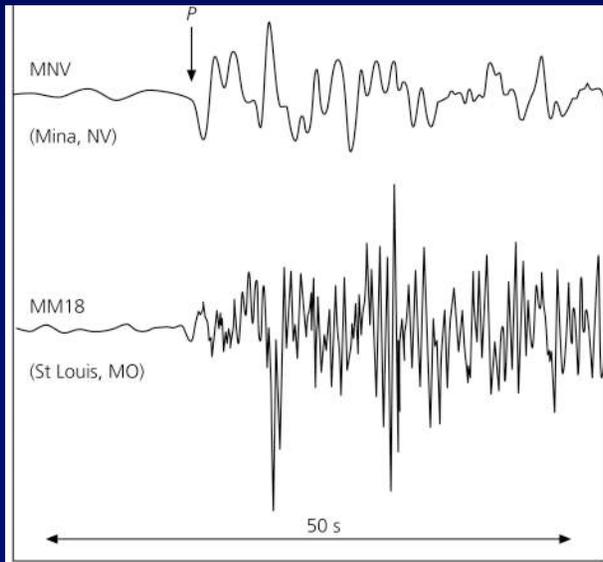
Seismicity 1/30-1/100 California rate, due to different motion rates

$M > 5$ ~ every 15 yr

$M > 6$ ~ every 150 yr

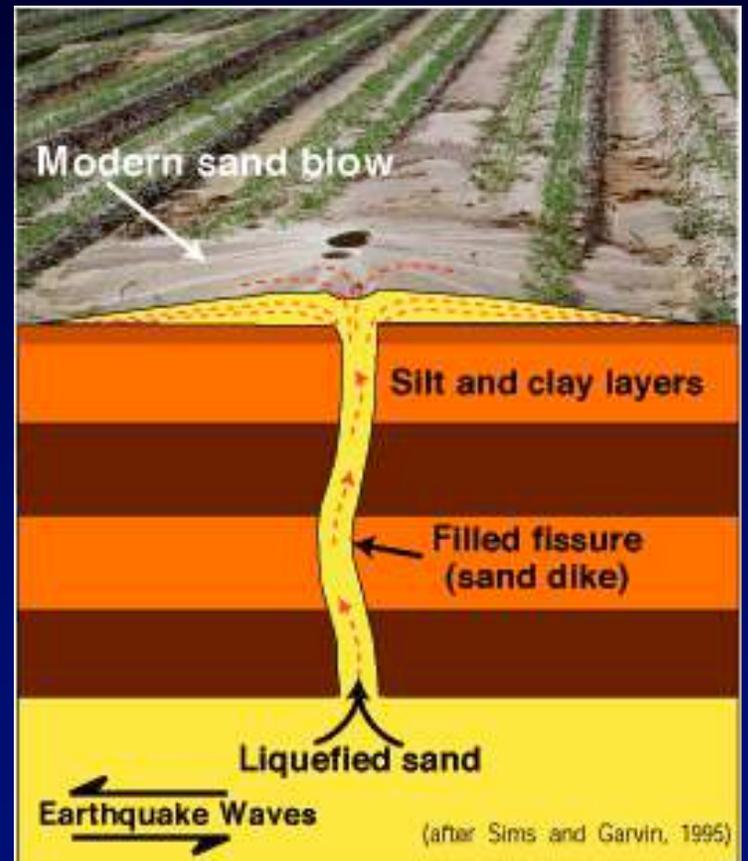
$M > 7$ in 1811-12

Seismic energy propagates better than in California



EARTHQUAKE HISTORY

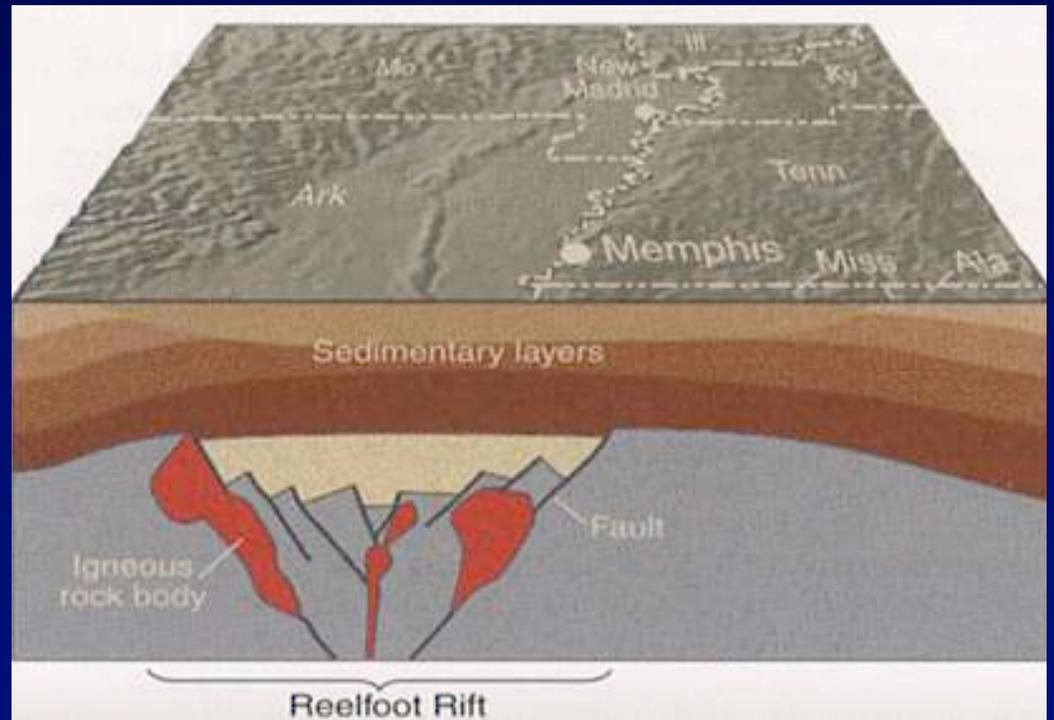
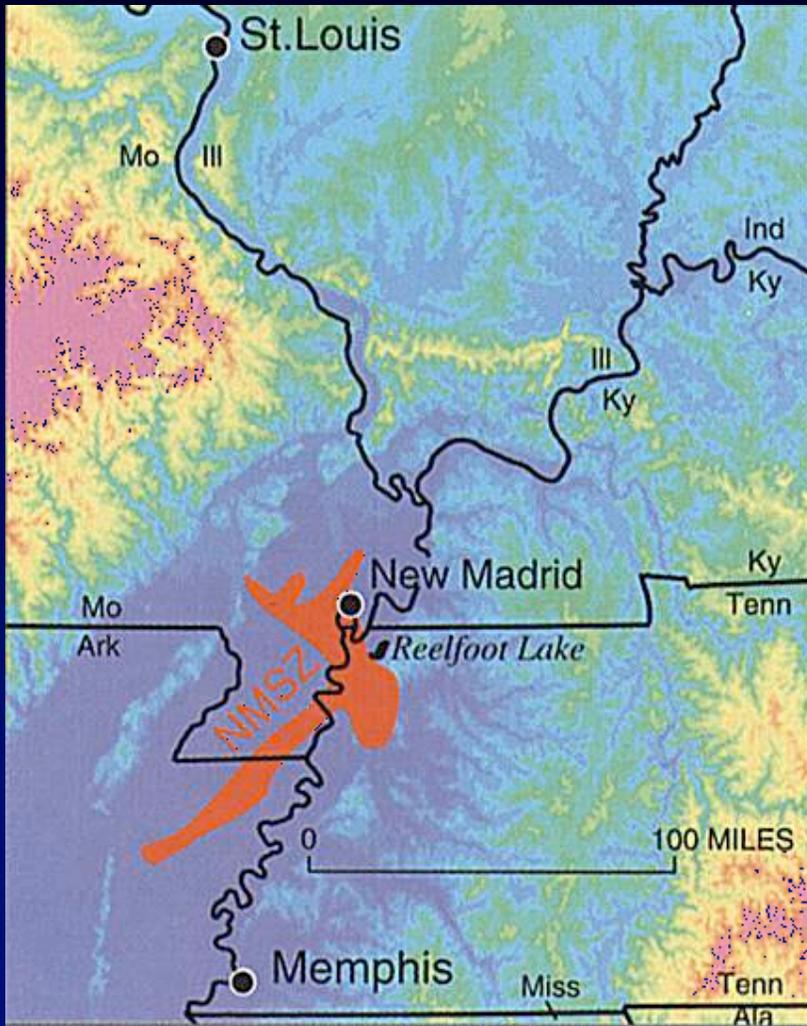
Paleoseismology - in this area primarily paleoliquefaction - shows events ~ 1450 and 900 AD



Sand blows in New Madrid area (USGS)

WHY EARTHQUAKES AT NEW MADRID? STANDARD EXPLANATION:

Associated with
subsurface faults in
ancient (750 Myr old)
failed Reelfoot rift



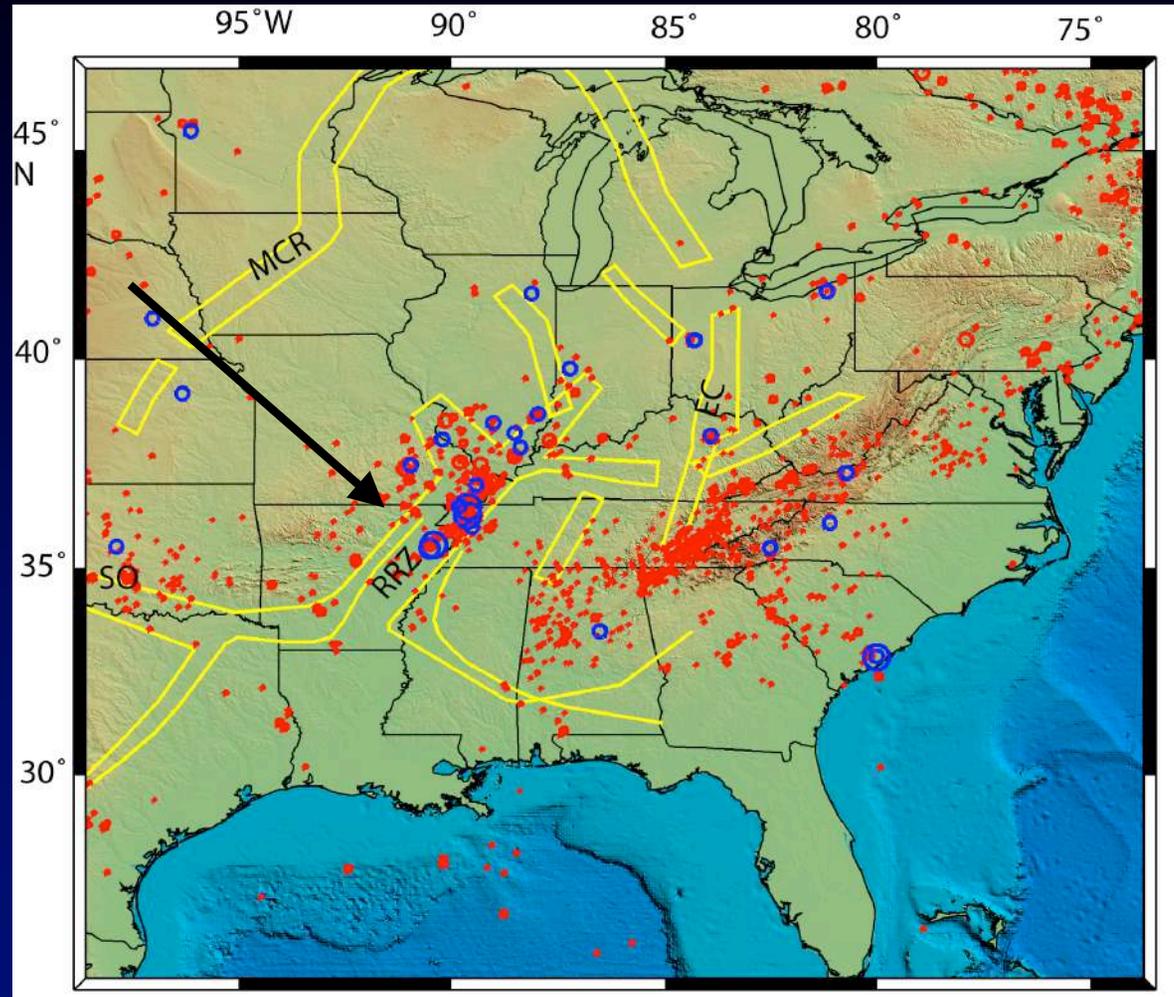
PROBLEM: LOTS OF FAILED RIFTS

Unclear why earthquakes here rather than other fossil features

Seems to have become active (for some reason) within past few Kyr

Unclear how long it will last

Probably migrates among similar features

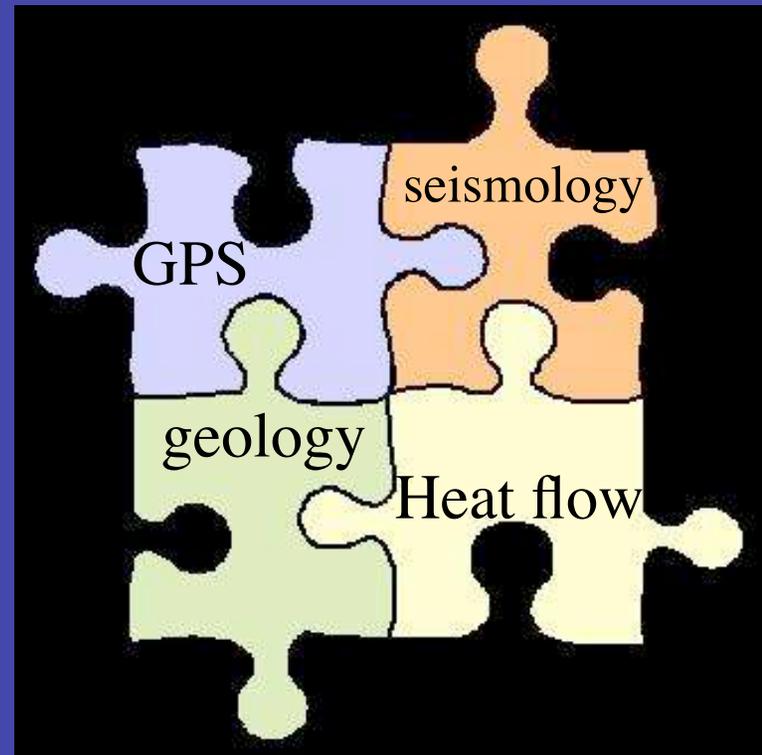


○ Historical ○ Instrumental

MAKING SENSE OF ALL THIS

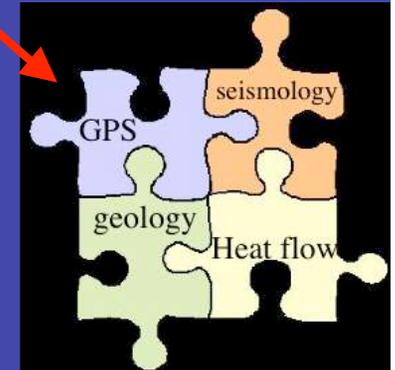
Recent data, taken together,
suggest that

- It will be a very long time until large earthquakes like 1811-12 recur.
- Earthquake hazard is much smaller than claimed
- New Madrid zone may be shutting down after recent cluster of large earthquakes in the past 1000 years.





GPS: GLOBAL POSITIONING SYSTEM



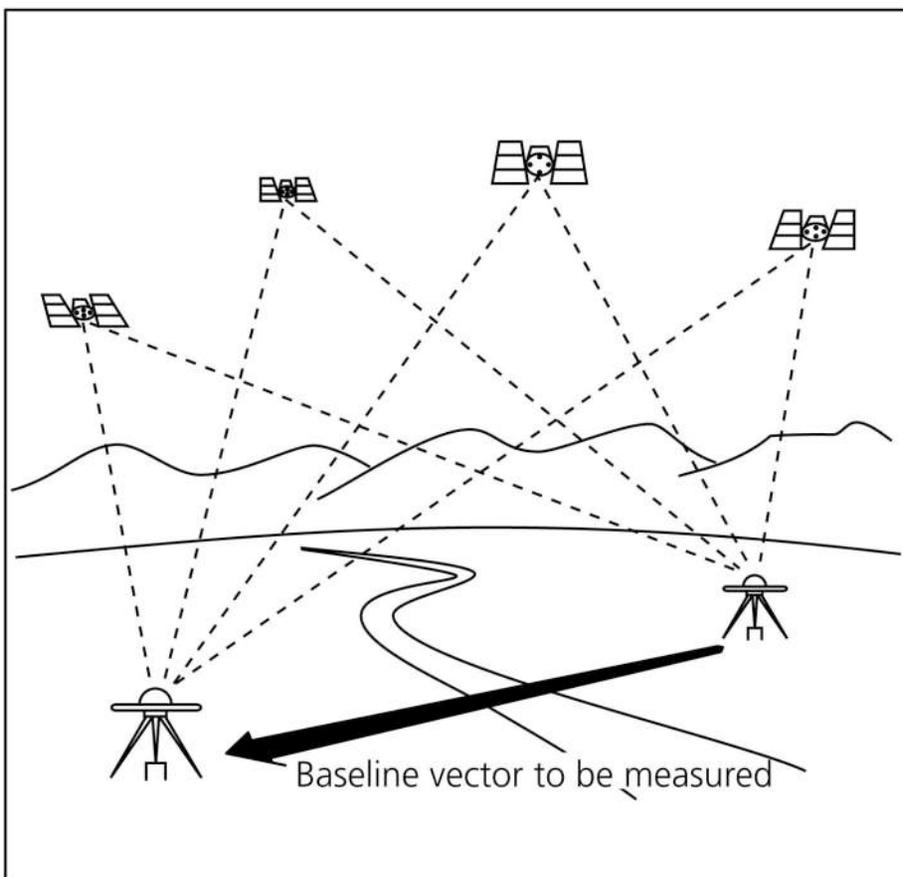
24 Satellites

5-8 overhead most of the world

Transmit radio signals

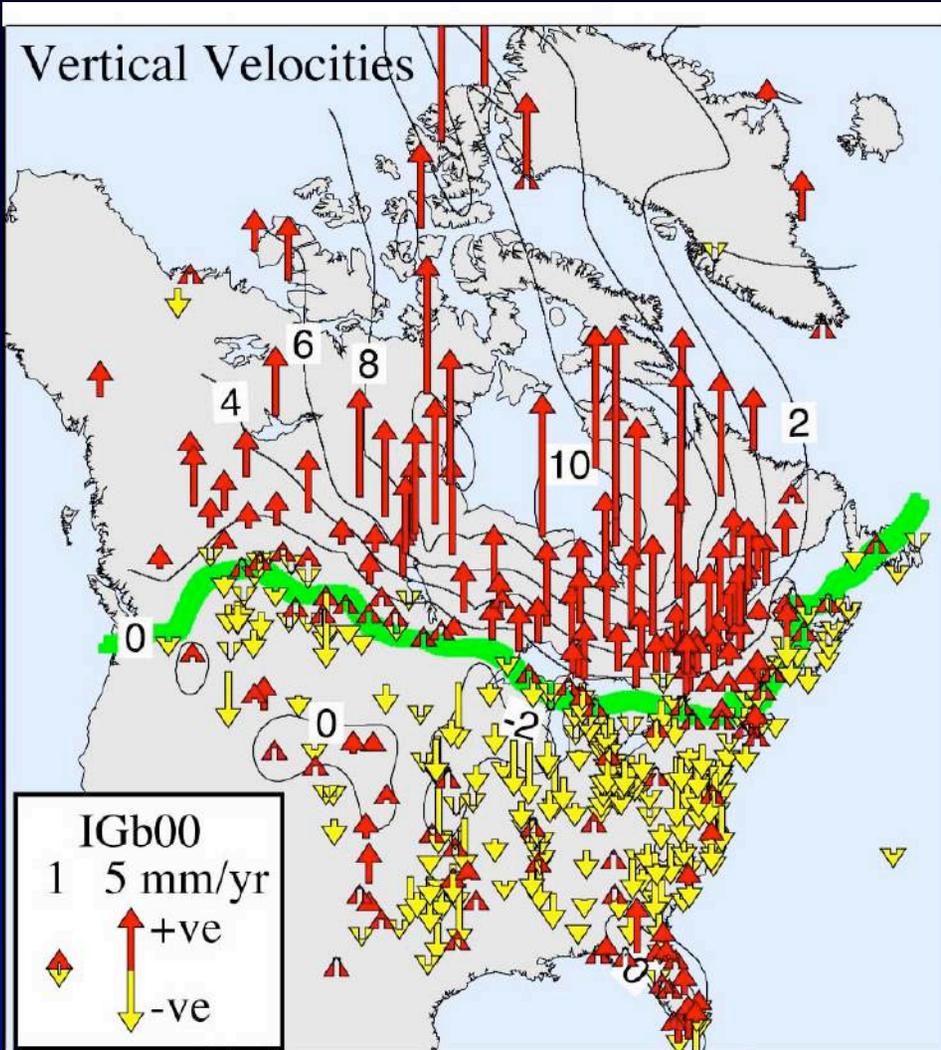
Receivers on ground find position from time signals arrive

For tectonics, find motions to 1 mm/yr from changes in position over time



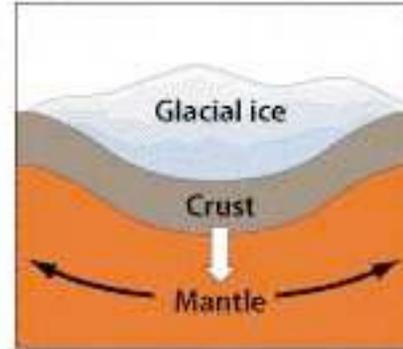
Stein & Wysession, 2003

The most visible GPS motion in Eastern North America is post-glacial rebound



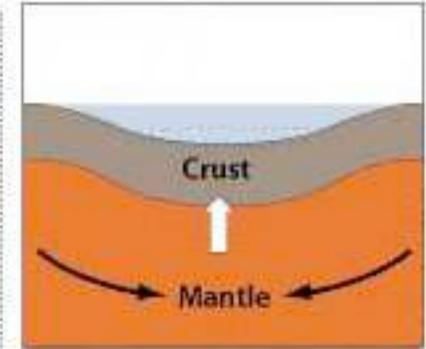
Sella et al., 2007

EARTH'S RECOVERY FROM THE ICE AGE



① 20,000+ years ago
Glacial ice sheets blanket vast regions of the Earth, causing the Earth's crust to sink from the weight of the ice.

Chicago Tribune



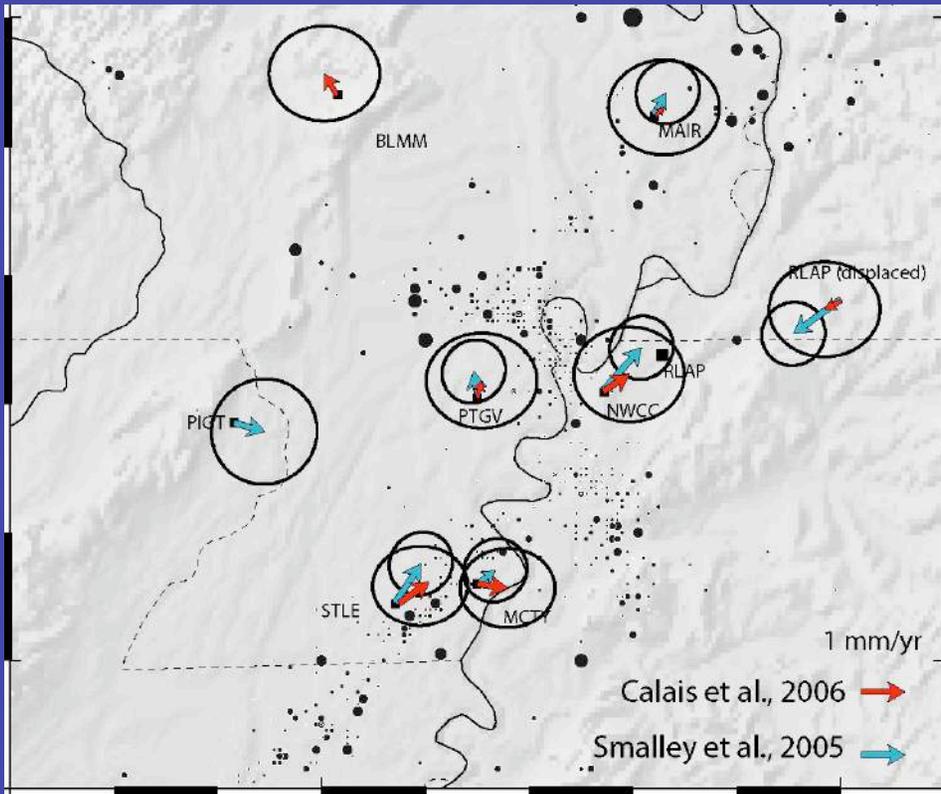
② 12,000 years ago
As glaciers melt, the land rebounds. Canadian land rises (above). Chicago sinks as the mantle under the city flows back into Canada.

Canada rises & US sinks

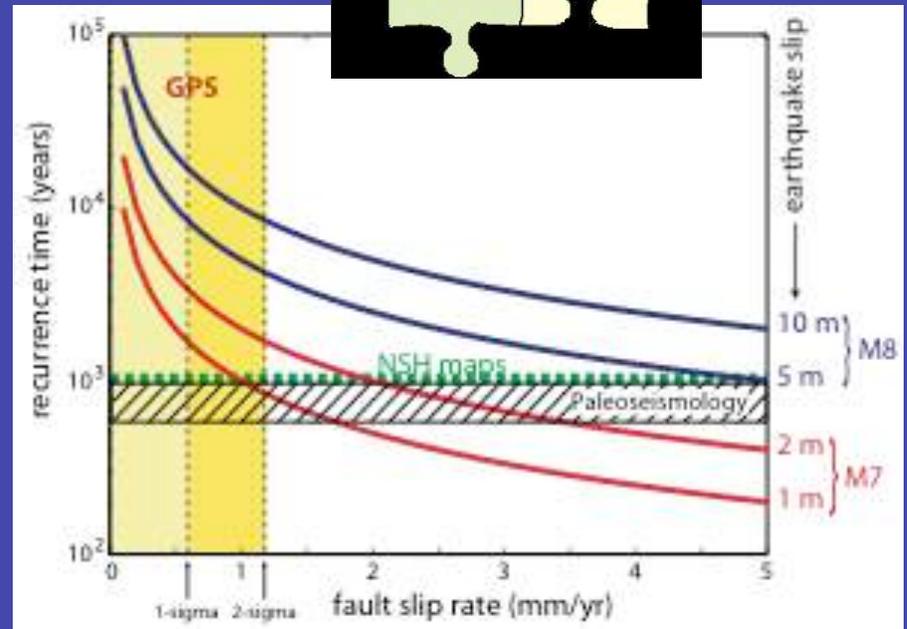
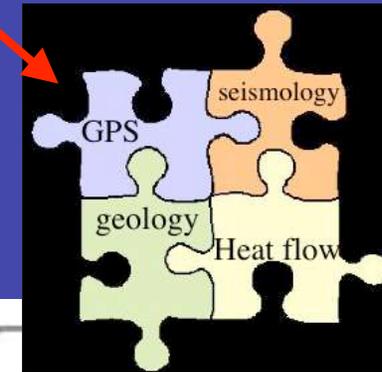
Hinge line agrees with lake level data



NEW MADRID GPS SITES SHOW LITTLE OR NO MOTION



Motions with respect to the rigid North American plate, are small, < 2 mm/yr, and generally within their error ellipses. These data do not require motion, and restrict any motion to being very slow.



Thus a very long time would be needed to store up the slip needed for a future large earthquake

For steady motion, M 7 is at least hundreds of years away. M 8 would thousands.

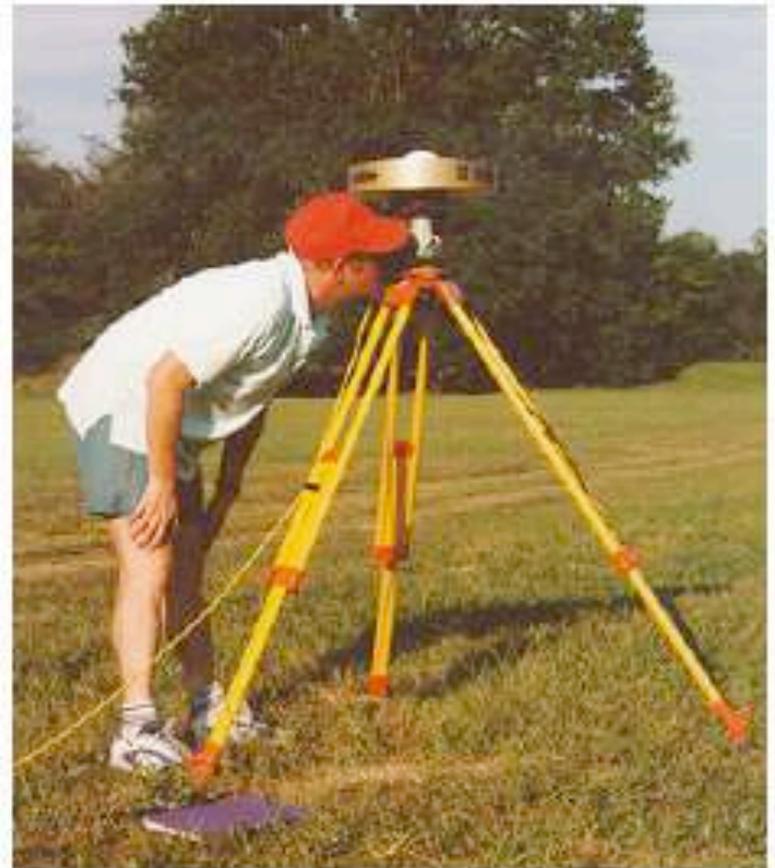
2 Centuries Later, Good News for Quake Area, Maybe

The New York Times Science, Tuesday, April 27, 1999. By Sandra Blakeslee

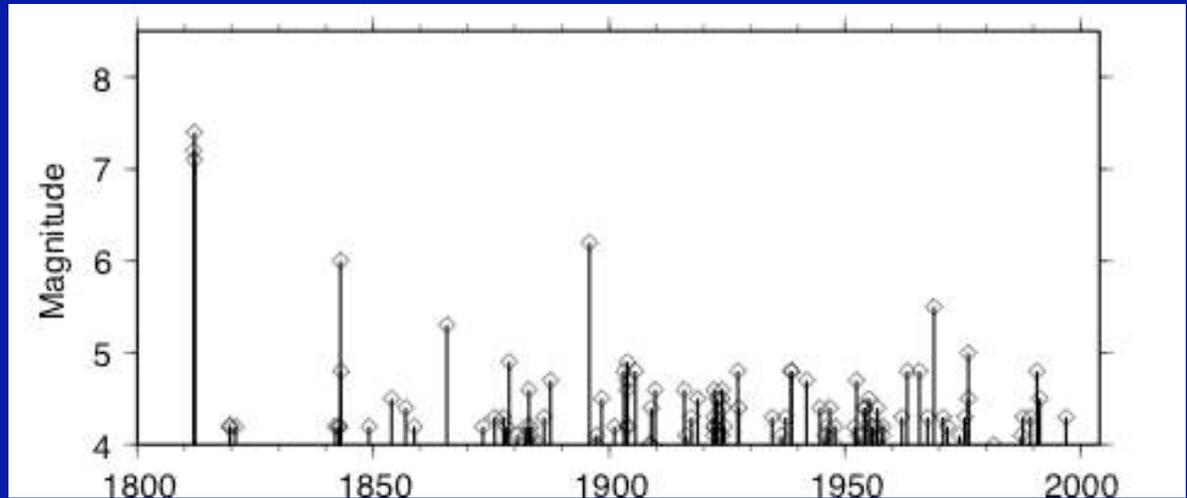
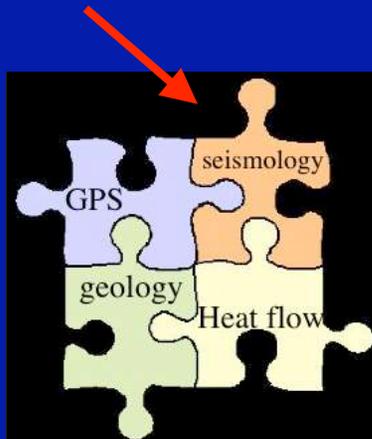
Midwesterners who worry about earthquakes got some good news last week: their risk of catastrophe may have been vastly overstated.

New measurements taken around New Madrid, MO - the epicenter of devastating earthquakes in 1811 and 1812 - show that the ground there is scarcely moving. According to many scientists, this means that it will take 2,500 to 10,000 years before another very large earthquake could occur in the region, although smaller, less damaging earthquakes are possible.

"The motions are small to zero," said Dr. Seth Stein, a professor of geological sciences at Northwestern University in Evanston, Ill., who made the new measurements. Earlier evidence showing rapid regional ground motion, a geologic sign that large quakes are probable, "was based on honest scientific errors," Dr. Stein said.

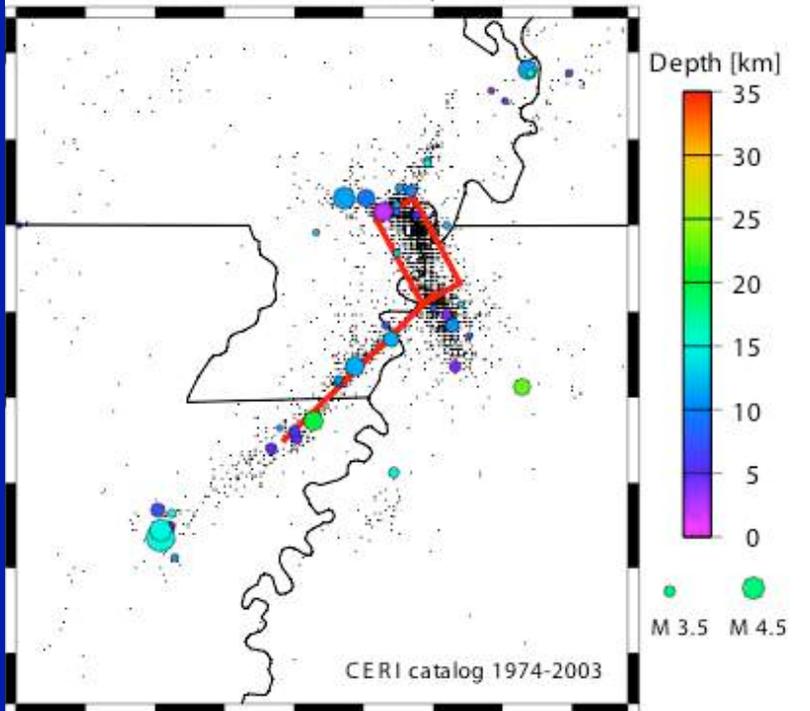


NEW MADRID SEISMICITY: 1811-12 AFTERSHOCKS?



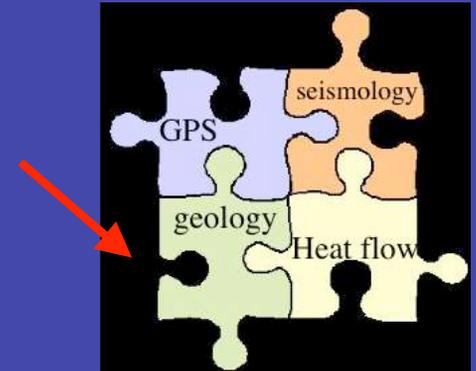
Stein & Newman, 1994

Central US Earthquake Depths
M \geq 3 events sized and depth coded



Ongoing seismicity looks like aftershocks of 1811-12, as suggested by the fact that the rate & size are decreasing. Moreover, the largest are at the ends of the presumed 1811-12 ruptures

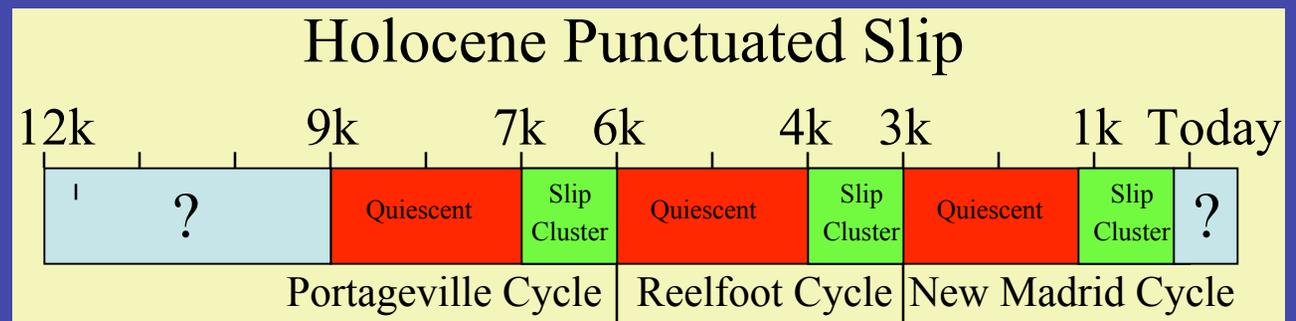
GEOLOGY IMPLIES NEW MADRID EARTHQUAKES ARE EPISODIC & CLUSTERED



The absence of significant fault topography, and other geological data, imply that the recent pulse of activity is only a few thousand years old.

This is consistent with results from other continental interiors

New Madrid
earthquake
history inferred
from
Mississippi
river channels



Holbrook et al., 2006

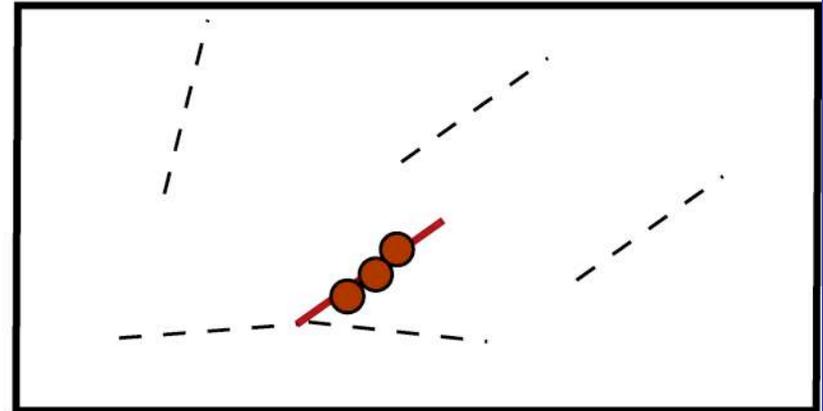
IN GENERAL, CONTINENTAL INTRAPLATE EARTHQUAKES MIGRATE AND ARE EPISODIC & CLUSTERED

“Large continental interior earthquakes reactivate ancient faults ... geological studies indicate that earthquakes on these faults tend to be temporally clustered and that recurrence intervals are on the order of tens of thousands of years or more.” (Crone et al., 2003)

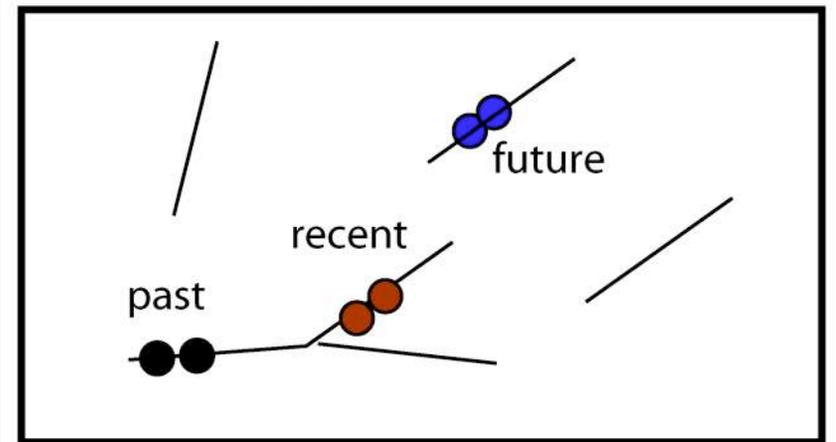


Meers fault, Oklahoma
Active 1000 years ago,
dead now

LONG TERM SEISMICITY ON WEAK ZONE

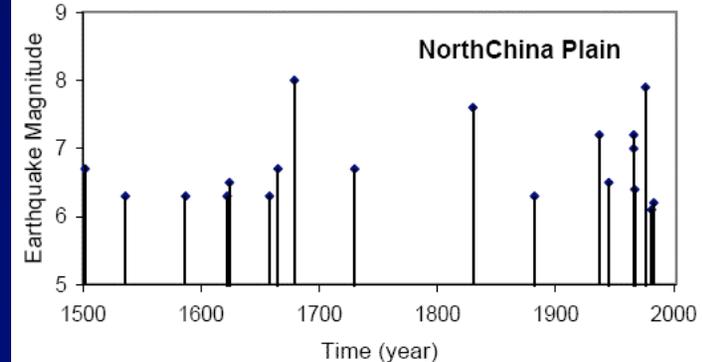
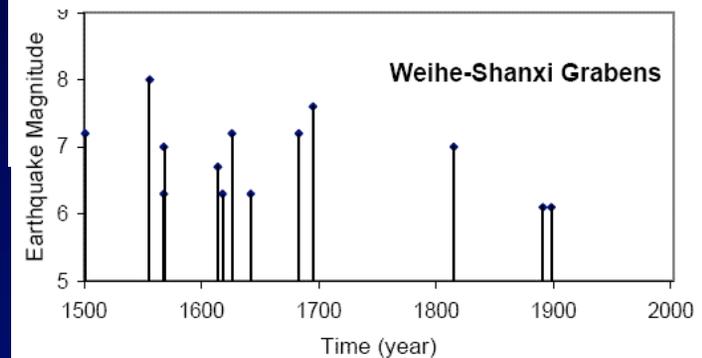
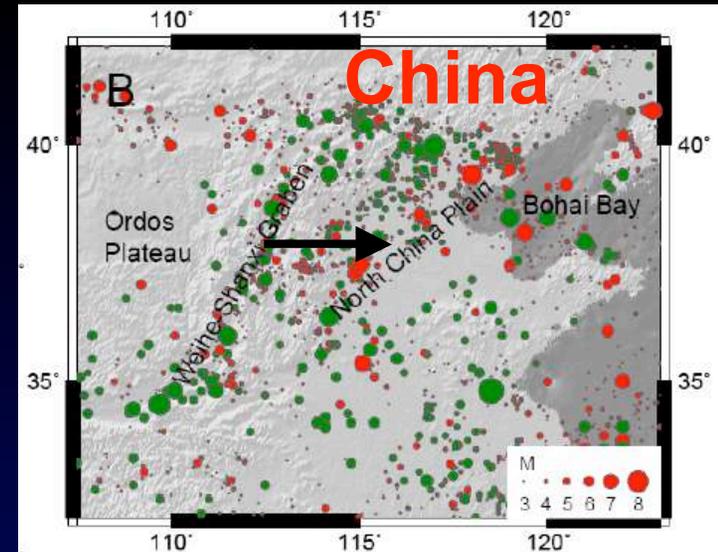
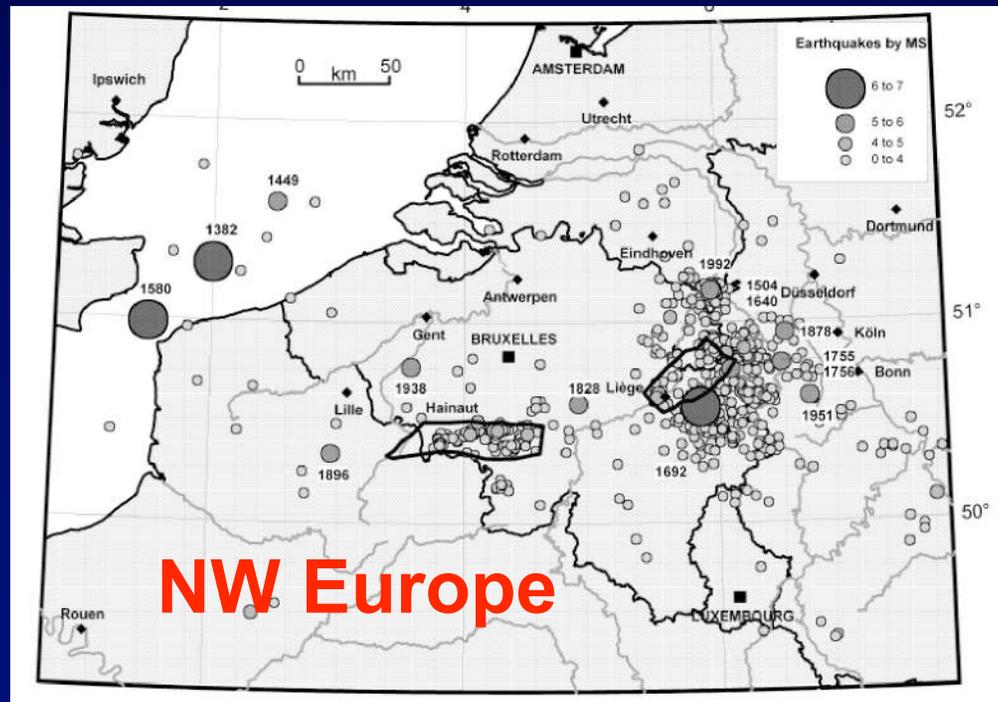


SEISMICITY MIGRATES BETWEEN ZONES
OF SIMILAR STRENGTH

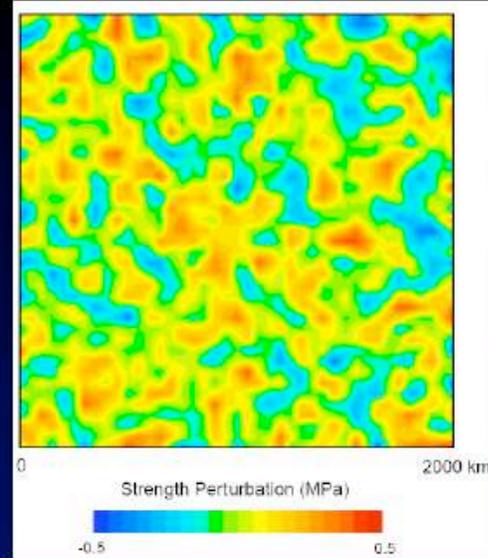
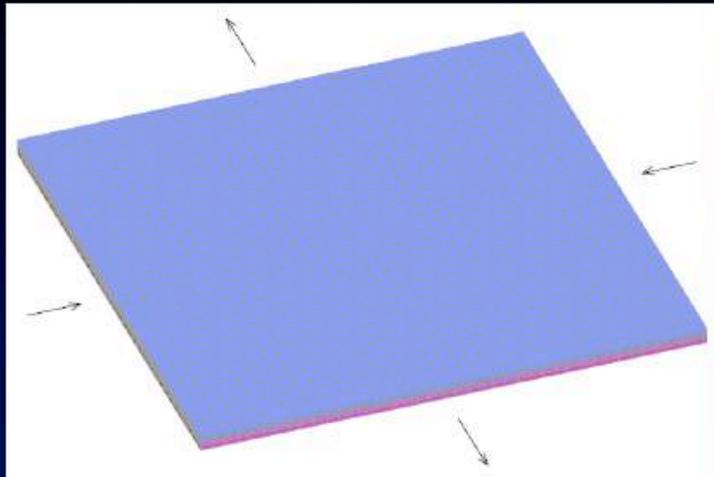


MIGRATING SEISMICITY

“During the past 700 years, destructive earthquakes generally occurred in different locations, indicating a migration of seismicity with time.”
 (Camelbeeck et al., 2007)



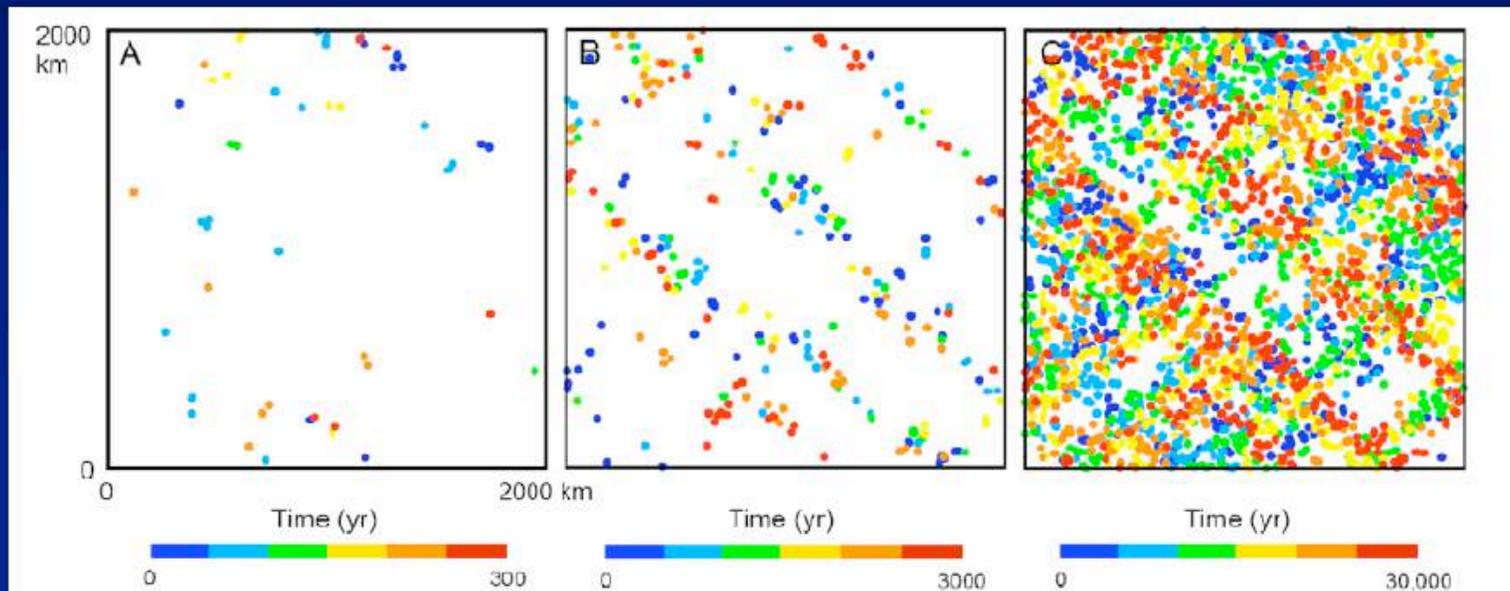
Li, Liu & Stein, 2008



NUMERICAL MODEL FOR INTRAPLATE EARTHQUAKES

Li, Liu & Stein,
2008

In a few hundred years, earthquakes appear to be clusters scattered in the region. In few thousand years, clusters connect and form belts. In tens of thousands of years, earthquakes are scattered in the whole region.



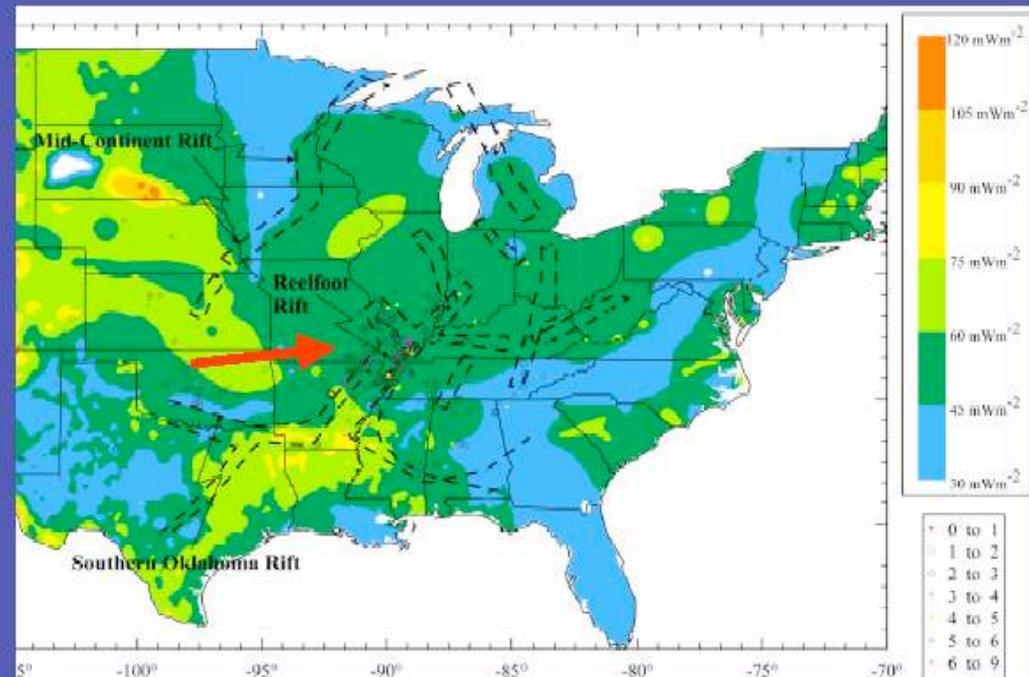
Suggested that NMSZ is hotter and thus weaker than surroundings, so weak lower crust and mantle concentrate stress and seismicity here in the upper crust.

NEW MADRID ISN'T SPECIAL



Analysis of thermal data shows NMSZ no hotter and weaker than its surroundings

Favors seismicity episodic & migrating among many similar fossil weak zones.



HOW STRONGLY SHOULD WE BUILD?

Stronger building reduces damage, but costs more

Resources used for stronger building aren't available for other purposes

Balance for any location depends on hazard there

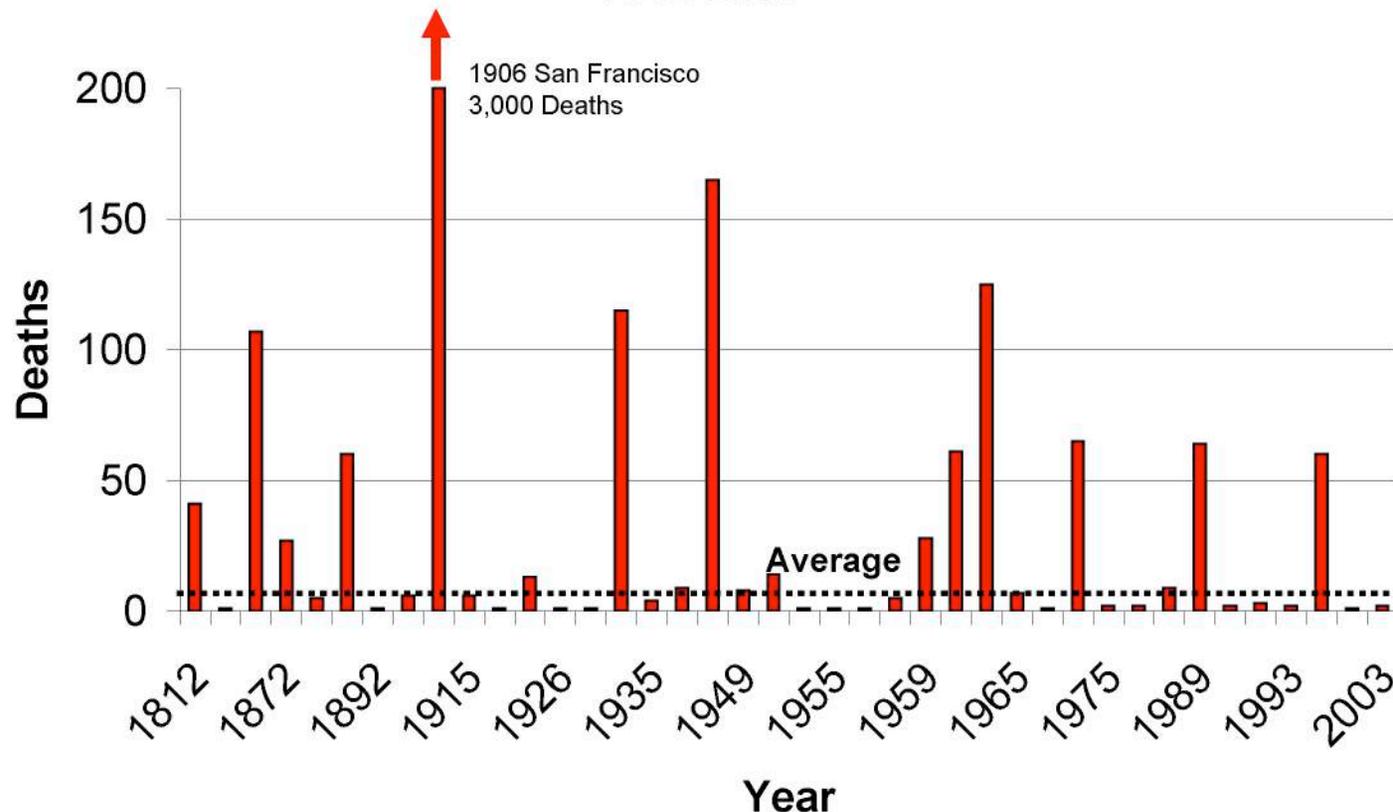


Memphis



St Louis

Annual Deaths in the United States from Earthquakes 1812-2003



U.S. average 10-20 deaths per year, but can be many more for large earthquake

Some foreign countries much more (more people living along plate boundary, weaker construction)

U.S. EARTHQUAKES

Infrequent, but occasionally major, fatalities and damage

Moderate (M 6.7) 1994 Northridge earthquake: 58 deaths, \$20B damage

Challenge: find mitigation strategy that balances cost of safer construction with benefits, given other possible uses of resources

Tough problem!

Table 1.2-3. Some causes of death in the United States, 1996.

Heart Attack	733,834
Cancer	544,278
Stroke	160,431
Lung disease	106,143
Pneumonia/Influenza	82,579
Diabetes	61,559
Motor vehicle accidents	43,300
AIDS	32,655
Suicide	30,862
Liver disease/Cirrhosis	25,135
Kidney disease	24,391
Alzheimer's	21,166
Homicide	20,738
Falling	14,100
Poison	10,400
Drowning	3,900
Fires	3,200
Suffocation	3,000
Bicycle accidents	695
Severe Weather ¹	514
In-line skating ²	25
Football ²	18
Skateboards ²	10
Earthquakes (1811-1983) ³	9
Earthquakes (1984-1998)	9

¹From the National Weather Service (property loss due to severe weather is \$10-15 B/year, comparable to the Northridge earthquake, and individual hurricanes can go up to \$25 B.

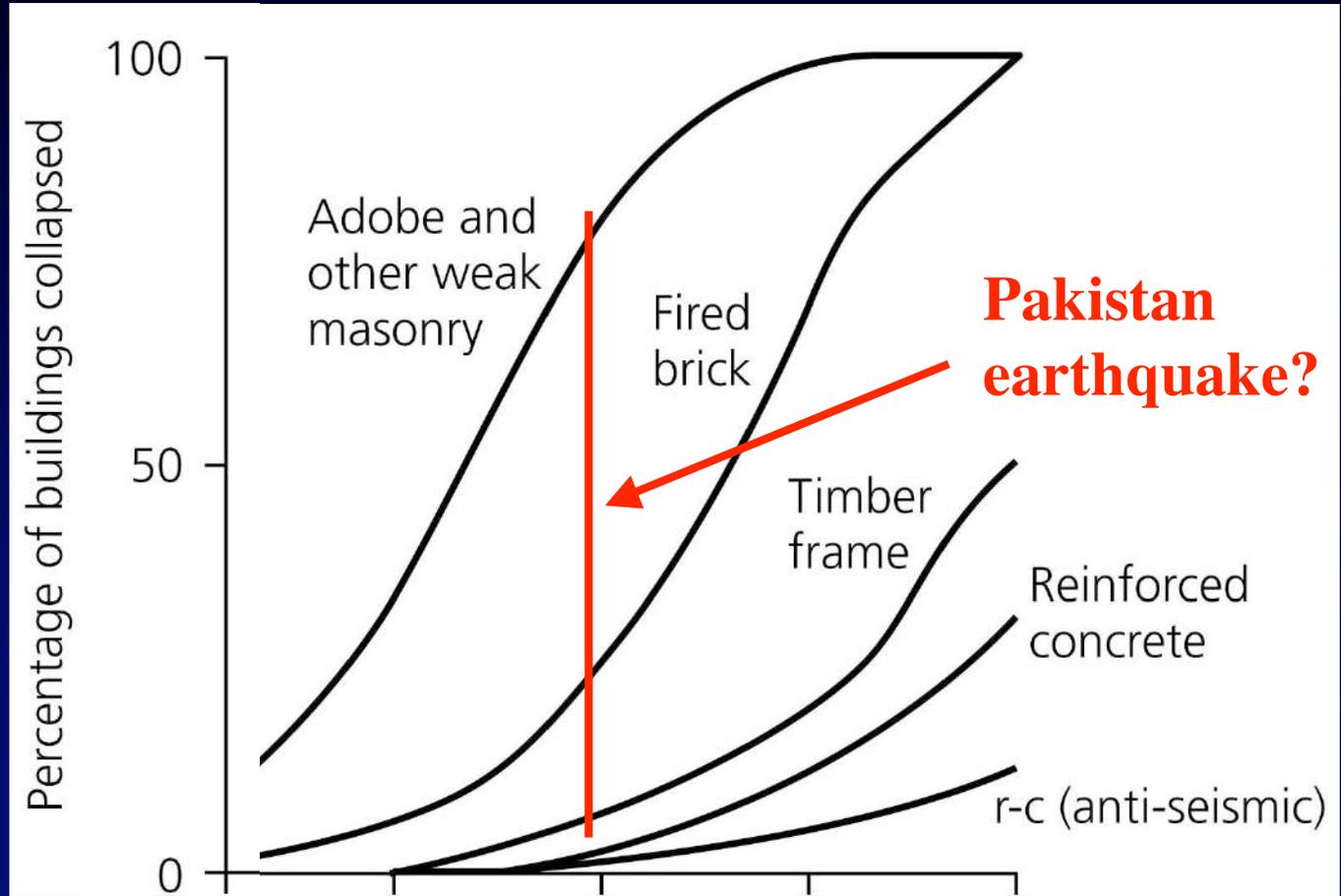
²From the Consumer Product Safety Commission

³From Gere and Shah [1984].

All others from the National Safety Council and National Center for Health Statistics.

DAMAGE DEPENDS ON BUILDING TYPE

RESISTANT CONSTRUCTION REDUCES EARTHQUAKE RISKS



Pakistan earthquake?

Pigs had it wrong

STRONGER SHAKING (%g) →

"Earthquakes don't kill people; buildings kill people."

ADOBE



12/03 Bam, Iran
M 6.6 27,000 deaths

BRICK



10/05 Pakistan M 7.6
80,000 deaths

CONCRETE



2/71 San Fernando,
California M 6.6 65 deaths

IS NEW MADRID MORE DANGEROUS THAN CALIFORNIA?

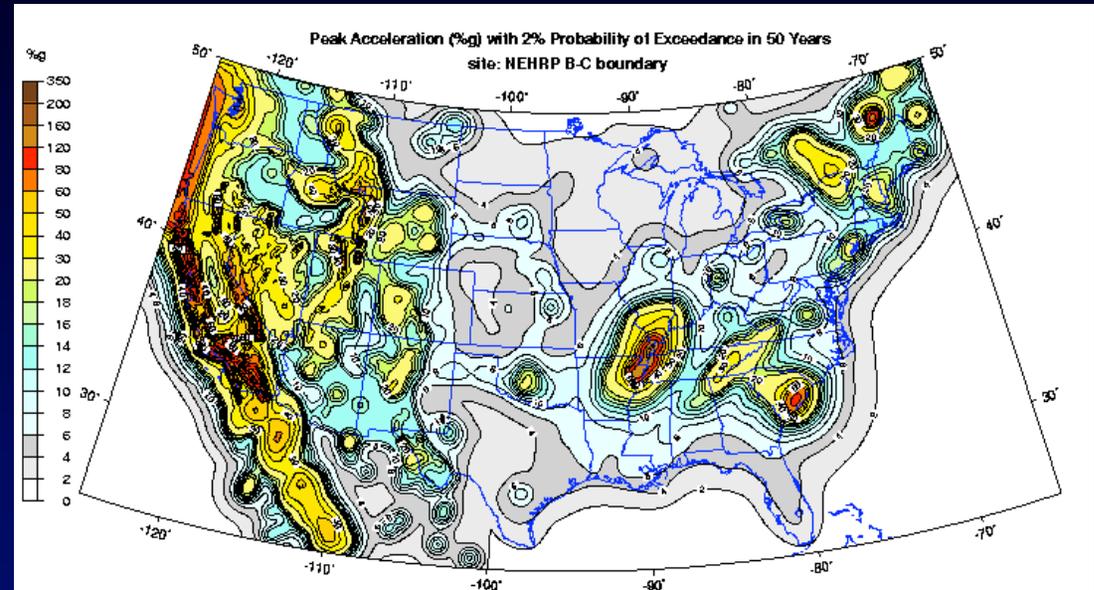
Quantify as maximum shaking (acceleration) expected
in some time period

Need to estimate:

Where and how often
earthquakes will occur

How large they will be

How much ground motion
they will produce



These aren't well understood,
especially in intraplate regions
where large earthquakes are rare,
so hazard estimates have
considerable uncertainties and it
will be a long time before we
know how well they've done

"A game of chance against
nature of which we still don't
know all the rules"

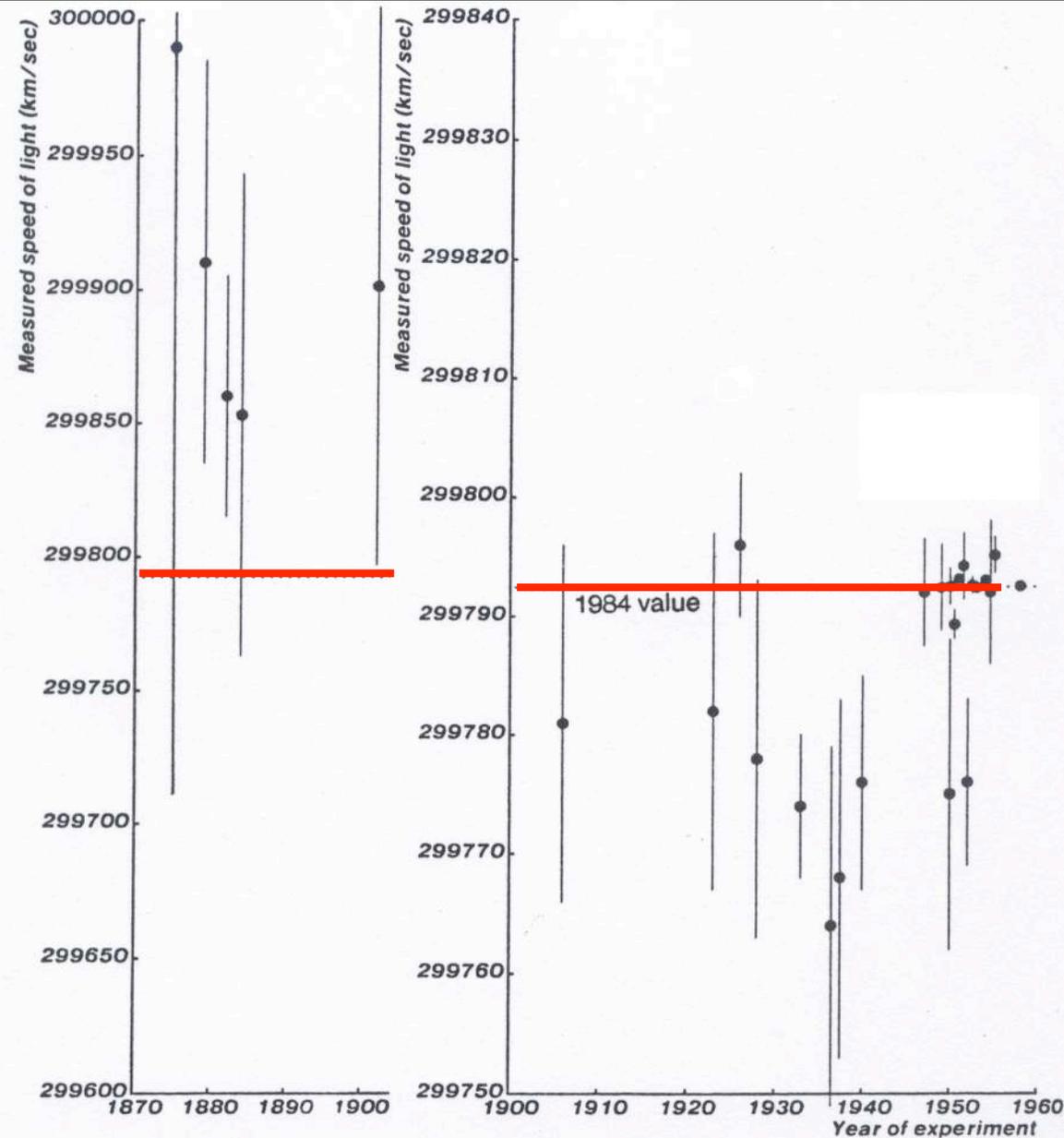
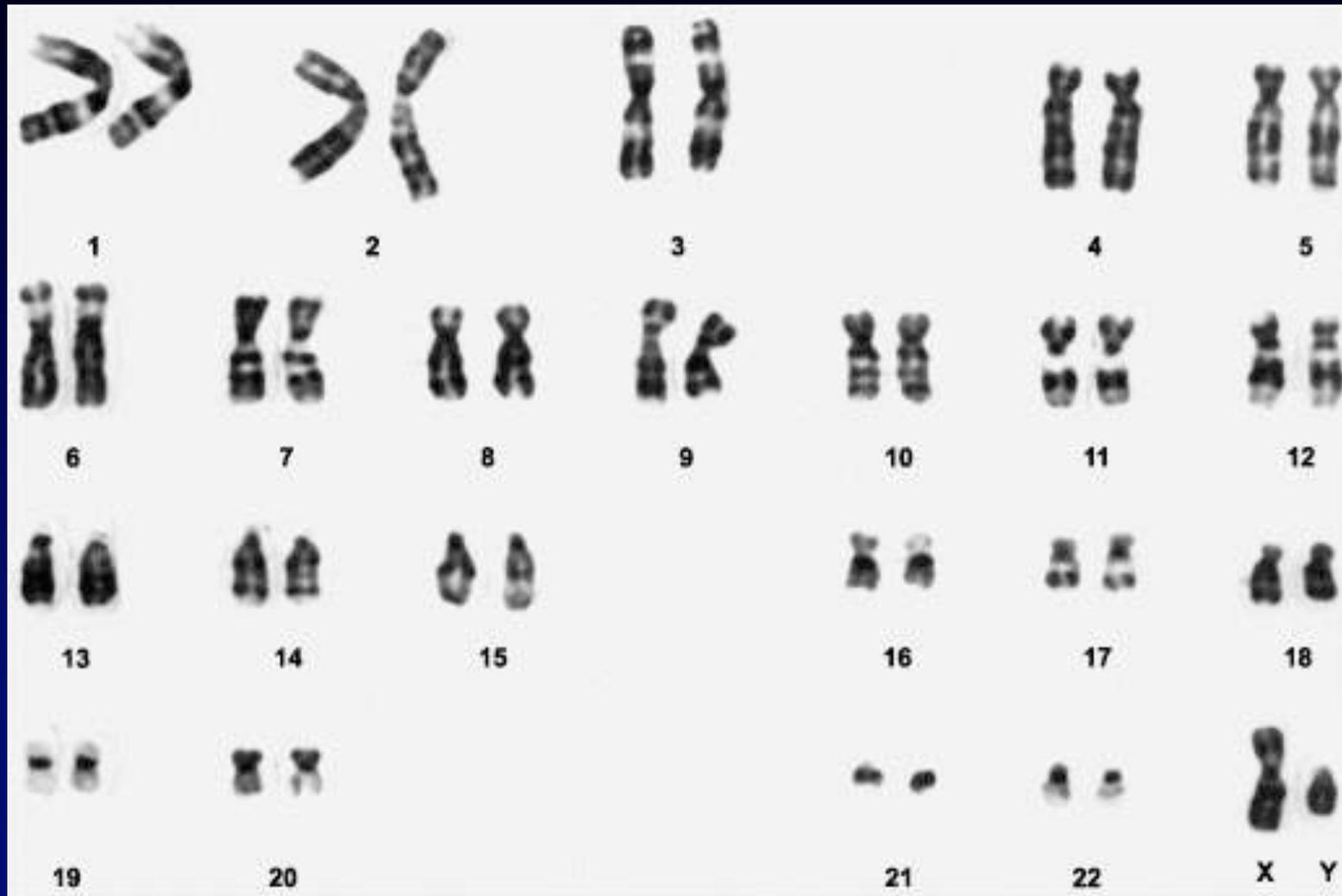


Figure 4.1. Experimental measurements of the speed of light between 1875 and 1960. Vertical bars show reported uncertainty as standard error. Horizontal dashed line represents currently accepted value. Less than 50% of the error bars enclose the accepted value, instead of the expected 70%. From Henrion and Fischhoff, 1986.

Uncertainties are hard to assess and generally underestimated

Underestimated uncertainty and bias in measured speed of light 1875-1960

Number of human chromosome pairs



1921-1955: 24

Now: 23

HIGH MODELED HAZARD RESULTS FROM ASSUMPTIONS

- Redefined from maximum acceleration predicted at 10% probability in 50 yr to 2% in 50 yr (1/ 500 yr to 1/2500 yr)

Arbitrary choice on policy grounds

- Large magnitude of 1811-12 and thus future large earthquakes

Uncertainty in interpreting intensity data

-High ground motion in large events

Lack of data

- *Time-independent recurrence of large events*

Don't understand how to best model recurrence

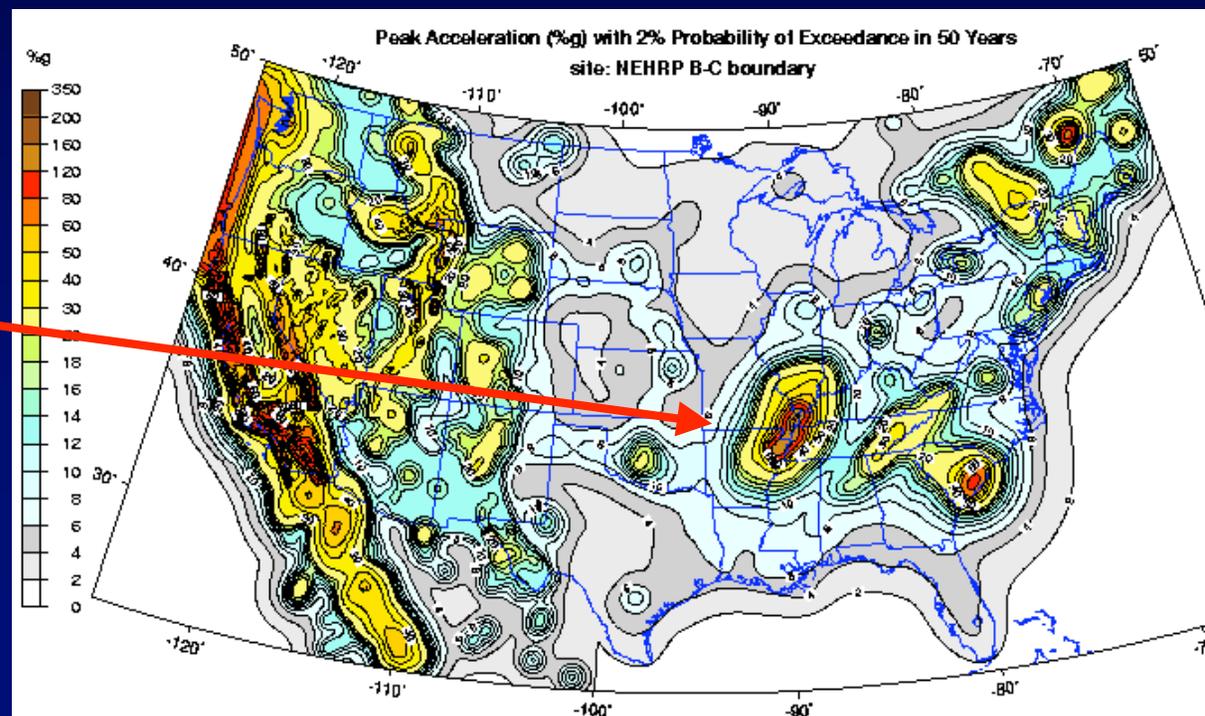
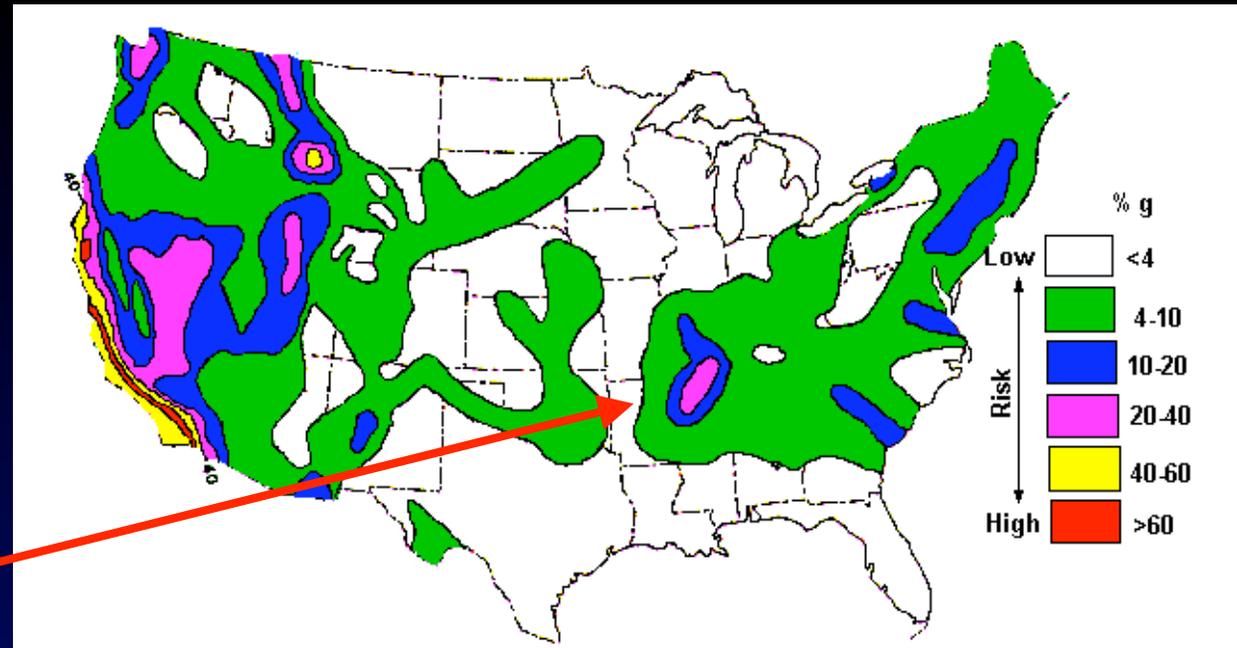
Algermissen et al., 1982

Hazard redefined

from maximum
acceleration
predicted at
10% probability
in 50 yr
(1/500 yr)

to much higher
2% in 50 yr
(1/2500 yr)

Frankel et al., 1996

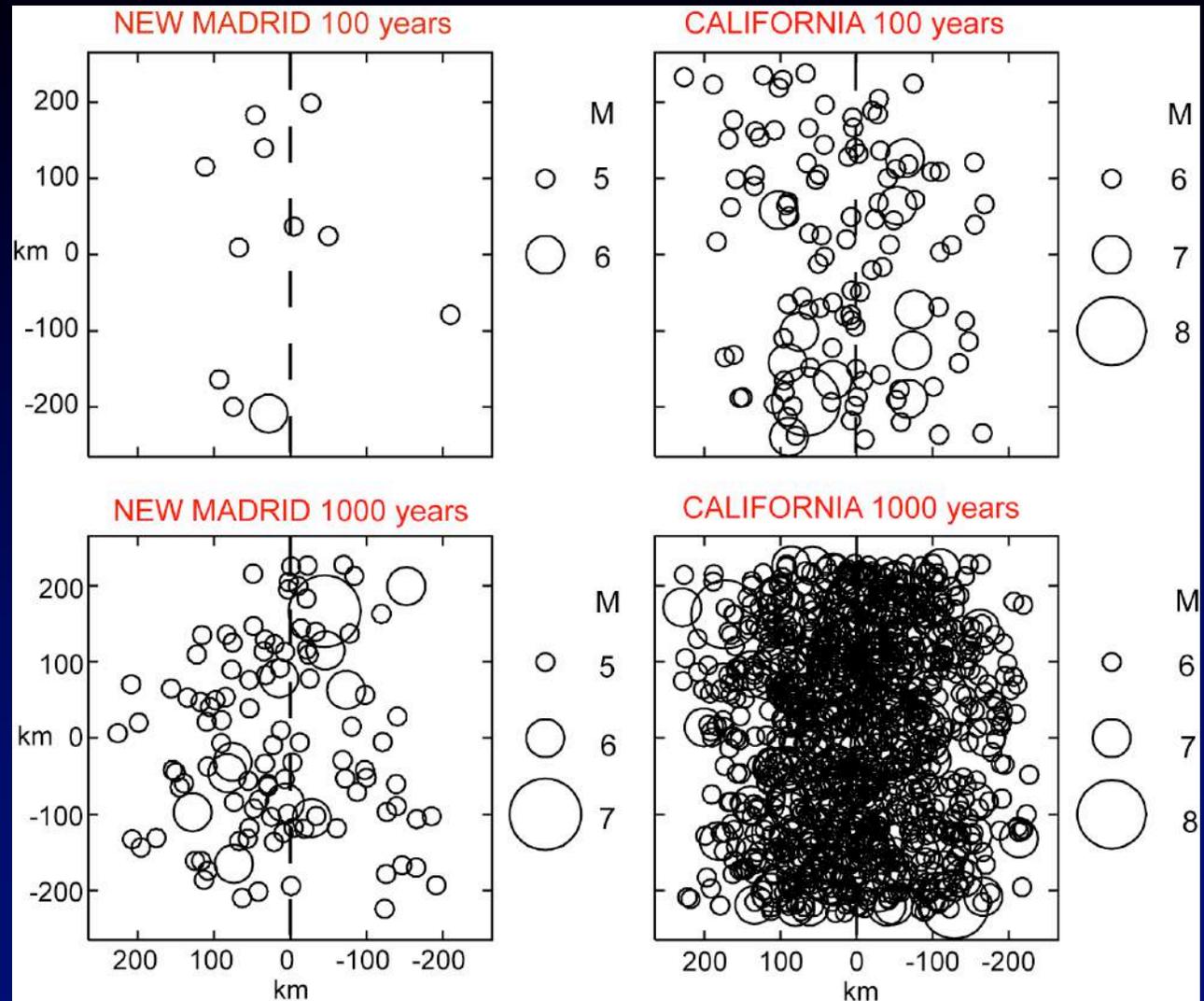


ASSUMED HAZARD DEPENDS ON DEFINITION TIME WINDOW

Over 100 years,
California site
much more likely
to be shaken
strongly than
NMSZ one

Over 1000 years,
more NMSZ sites
shaken strongly
once; many in
California shaken
many times

Short time
relevant for
buildings with 50-
100 yr life

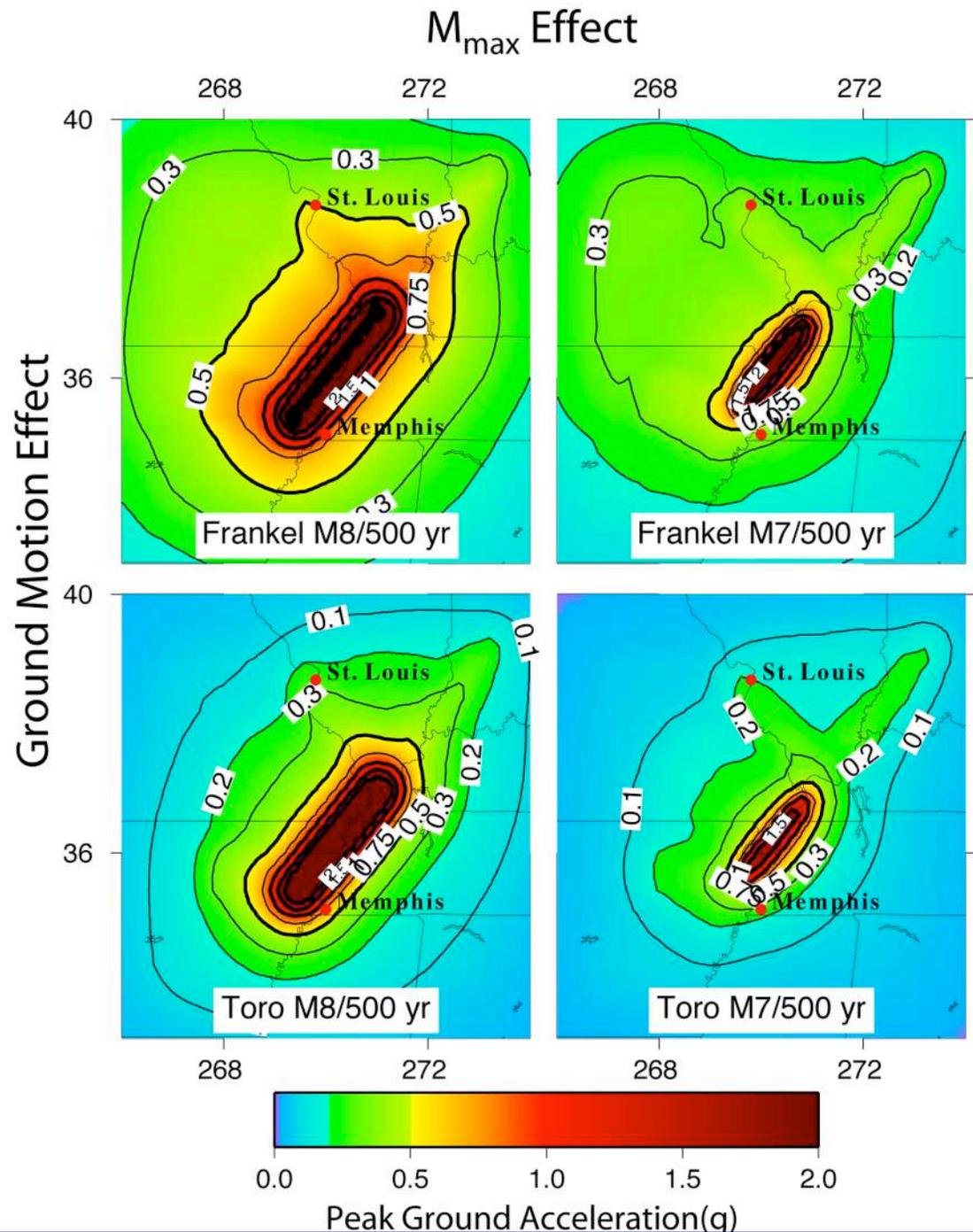


Shaken areas MMI > VII

Random seismicity simulation including seismicity & ground motion differences

**PREDICTED
HAZARD
DEPENDS ON
ASSUMED
MAXIMUM
MAGNITUDE OF
LARGEST
EVENTS AND
ASSUMED
GROUND
MOTION MODEL**

Newman et al., 2001



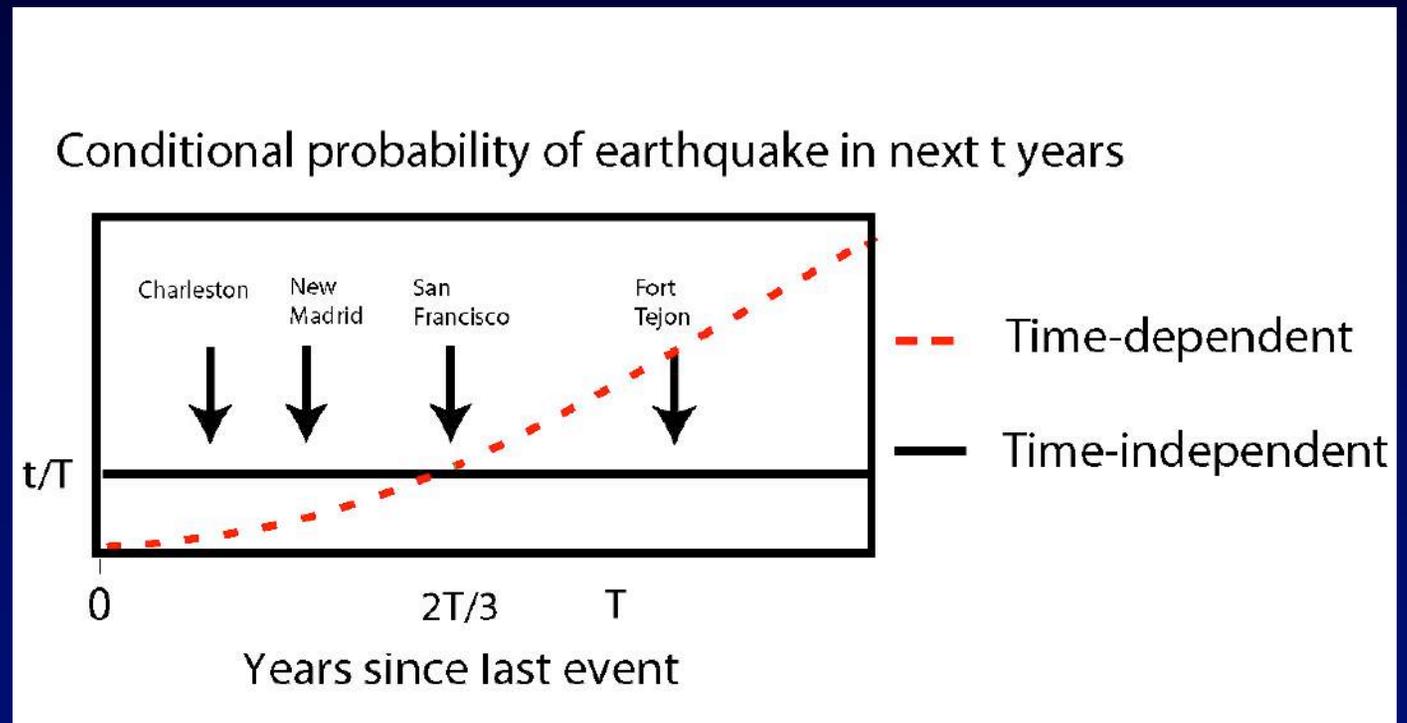
ASSUMED HAZARD DEPENDS ON EARTHQUAKE PROBABILITY ASSUMPTION

Constant since last event: time independent

Small after last event, then grows: time dependent

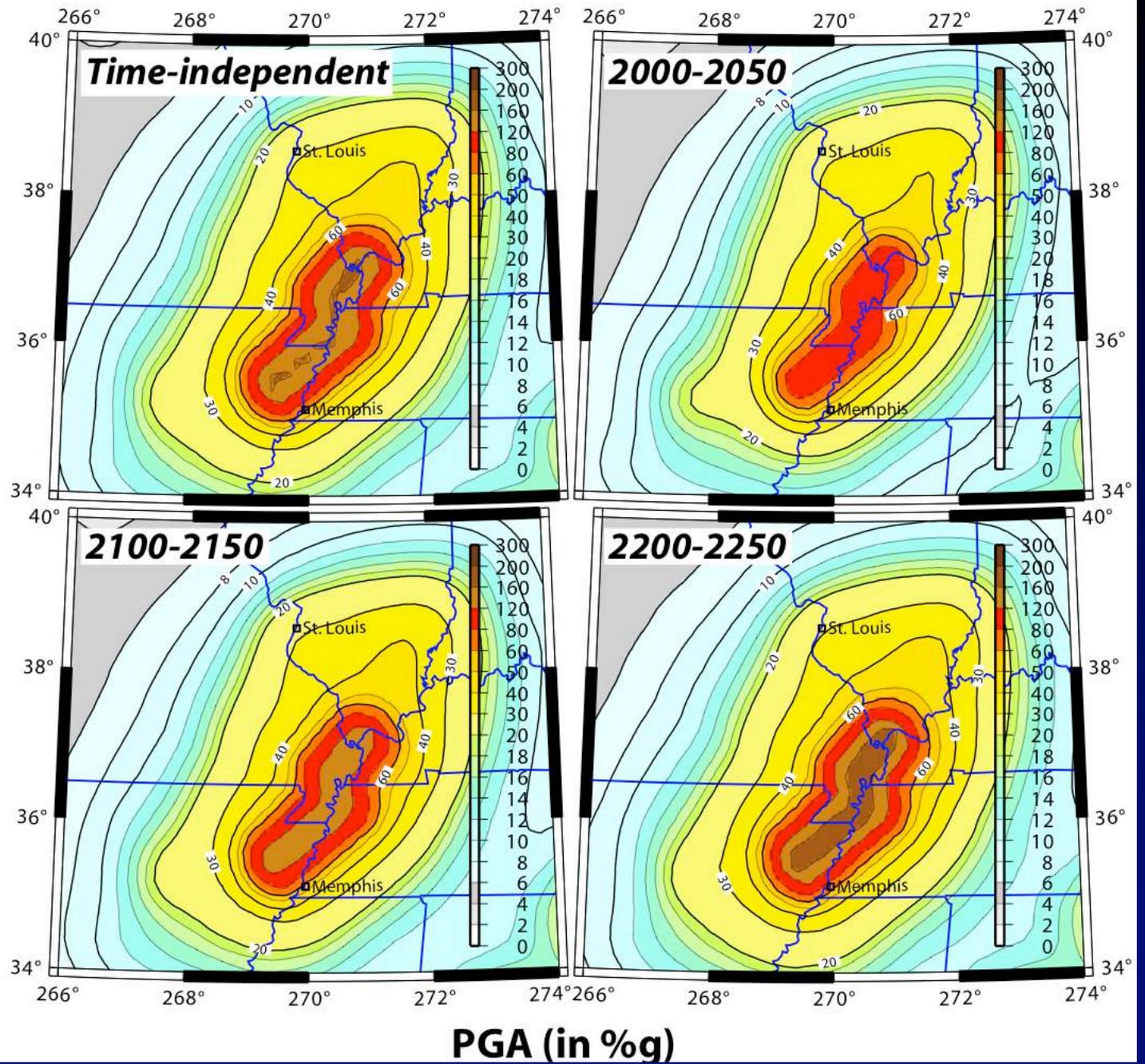
Time dependent lower until $\sim 2/3$ mean recurrence

Charleston & New Madrid early in their cycles so time dependent predicts lower hazard



2% in 50 yr
(1/2500 yr)

Hebden & Stein, 2008



SHOULD MEMPHIS BUILDINGS MEET CALIFORNIA STANDARD?

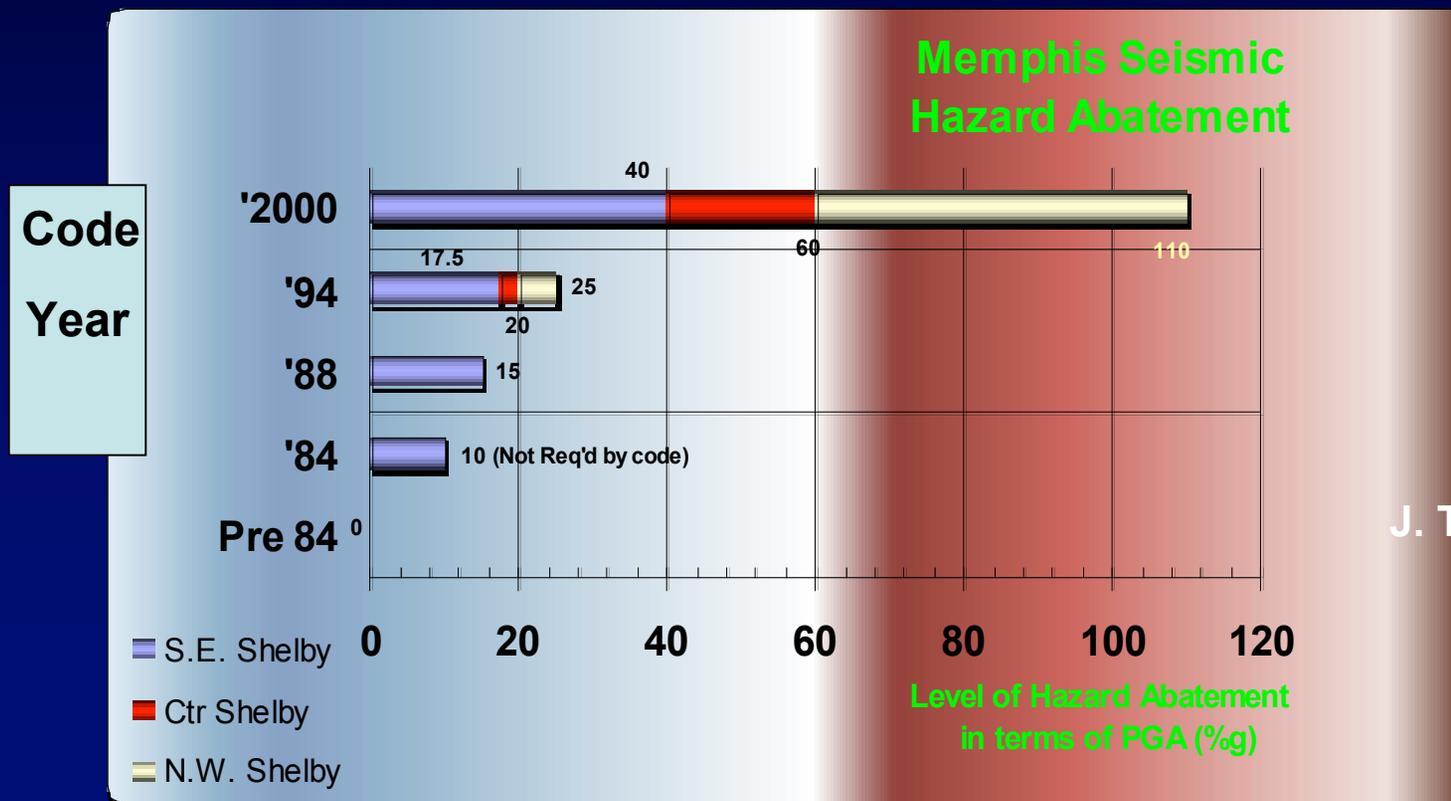
New building code IBC 2000, urged by FEMA, would raise to California level

Essentially no analysis of costs & benefits of new code

Initial estimates suggest cost likely to exceed benefits

Careful study needed to see if justified or more moderate standard better

Code should be neither too weak nor too strong

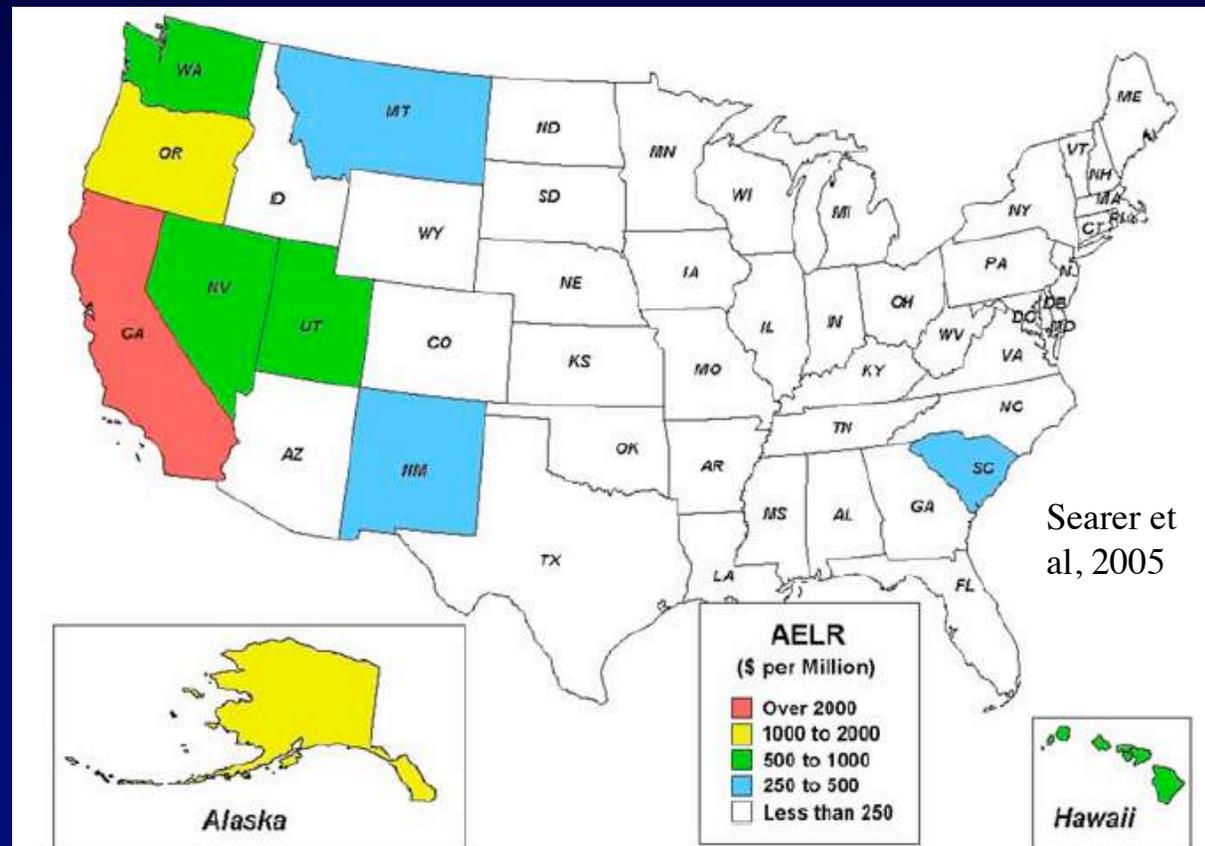


BUILDING RISK COMPARISON

Estimate **annual earthquake loss ratio (AELR)**, ratio of annualized earthquake loss to the replacement cost of all buildings in the area.

Memphis and St. Louis values ~1/5 - 1/10 of those for San Francisco and Los Angeles. Memphis 32nd among major U.S. cities; St. Louis 34th.

Since ratios are equivalent to the fractional risk of building damage, estimate predicts **NMSZ buildings 5-10 times less likely to be damaged during their lives than ones in California.**



IN FORMULATING EARTHQUAKE POLICY, CONSIDER TWO PRINCIPLES:

“There's no free lunch”

Resources used for one goal aren't available for another.

Easy to see in the public sector, where there are direct tradeoffs. Funds spent strengthening schools aren't available to hire teachers, upgrading hospitals may mean covering fewer uninsured (~\$1 K/yr), stronger bridges may result in hiring fewer police and fire fighters (~\$50 K/yr)...

“There's no such thing as other people's money”

Costs are ultimately borne by society as a whole. Imposing costs on the private sector affects everyone via reduced economic activity (firms don't build or build elsewhere), job loss (or reduced growth), and resulting reduction in tax revenue and thus social services.

PROBLEM: BIASING HAZARD ESTIMATES

Estimates biased toward high ("conservative") values distort policy decisions by favoring seismic safety over other valuable resource uses.

Don't want poor education in earthquake-safe schools, or to turn away patients from earthquake-safe hospitals

Need careful balance

Editorial 9/01: Crucial decision nearson building code

September 1, 2003

Memphis Mayor Willie Herenton and Shelby County Mayor A C Wharton are among local elected officials and builders who suggest further study before the enactment of seismic provisions in the proposed International Building Code of 2003. Mayors from across West Tennessee have joined an effort to generate more information about the costs and benefits of the provisions, which surely would be useful in this important decision-making process.

Advertisement

As Wharton notes, dollars that are applied to protection against earthquakes could otherwise be spent on education or health care. Supporting tough new seismic guidelines is a difficult stand for elected officials who must answer to taxpayers for costs that could discourage development, increase pressure to raise taxes and make less money available for public services that produce immediate and tangible results.

Sponsored Links

Summary

Tough science challenge in understanding intraplate earthquakes

Looks like a very long time until a major 1811-12 style NMSZ earthquake

New Madrid earthquake hazard greatly overestimated

Current cycle of large events may be ending

Billions of dollars needed to build to California standards would likely do more good if spent otherwise

Don't rush to get wrong answer as fast as possible

Need careful study to develop cost-effective policy

Good science needed for sensible hazard policy