

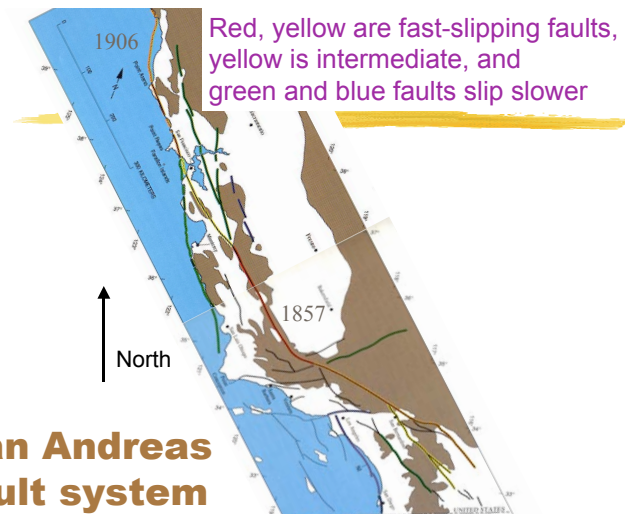


Global tour of quakes

- California
- Rest of country
 - 1960 Chile, 1964 Alaska, 2004 Sumatra
- Biggest quakes
 - 1960 Chile, 1964 Alaska, 2004 Sumatra
- Rest of world
 - Japan, Turkey, India
 - 1755 Lisbon

Big Cal quakes

- Mainly near San Andreas fault
 - A lot near Mendocino Triple Junction
 - Remember tectonics action at a triple junction
 - Some in the Sierra Nevada Mts.
- Takes a large fault to have a magnitude 7+ earthquake
 - So magnitude 6's have a wider distribution



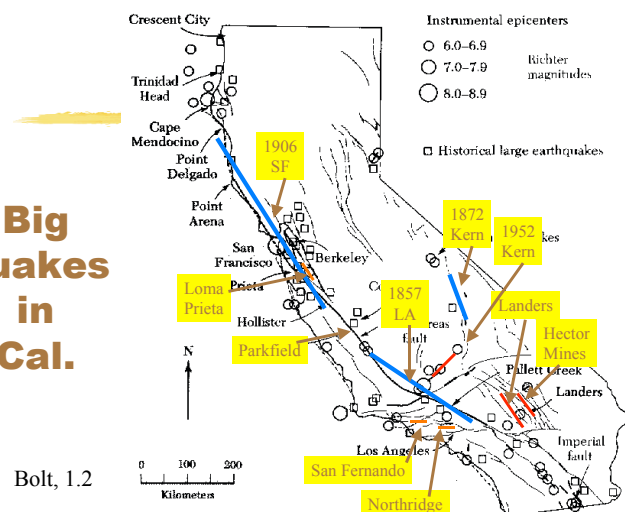
San Andreas fault system

Significant California Earthquakes

- 1857 Fort Tejon
- 1872 Owens Valley
- 1906 San Francisco
- 1933 Long Beach
- 1971 San Fernando
- 1989 Loma Prieta
- 1992 Landers
- 1994 Northridge
- 1999 Hector Mines
- 2004 Parkfield

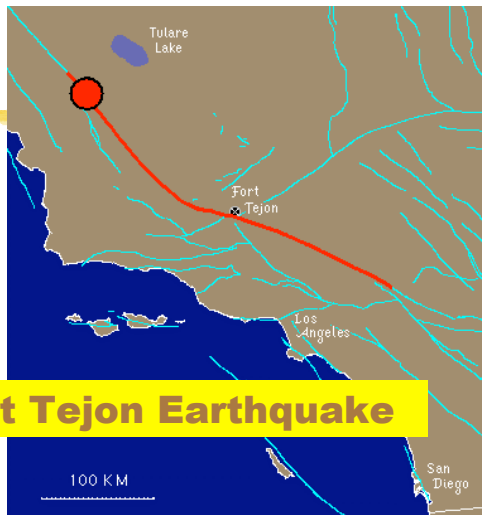


Big quakes in Cal.



This is a
"big one"

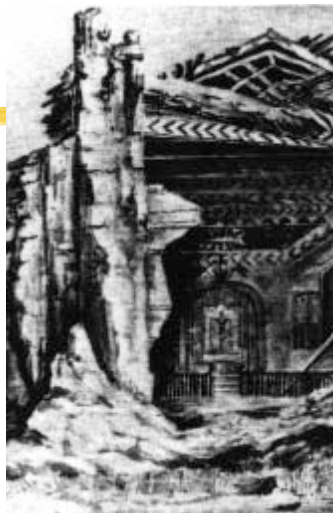
1857 Fort Tejon Earthquake



Felt in Santa Barbara

- 8:22 am, 2 fatalities near fault
- ... universally noticed throughout the city, and was so violent in its vibrations that all of the inhabitants fled from their dwellings, the majority of whom, on bended knees, and hearts throbbing with terror, made fervent supplications that the imminent and impending danger might be providentially averted.
- No damage to speak of in Santa Barbara

A drawing of
Mission Santa
Cruz's Church
after the 1857
earthquake.



A victim of the 1857
Fort Tejon earthquake
on the San Andreas
fault, this tree near
Wrightwood had its
top snapped off,
causing lower
branches to grow
vertically. Tree-ring
dating has been used
to accurately date
past earthquakes.

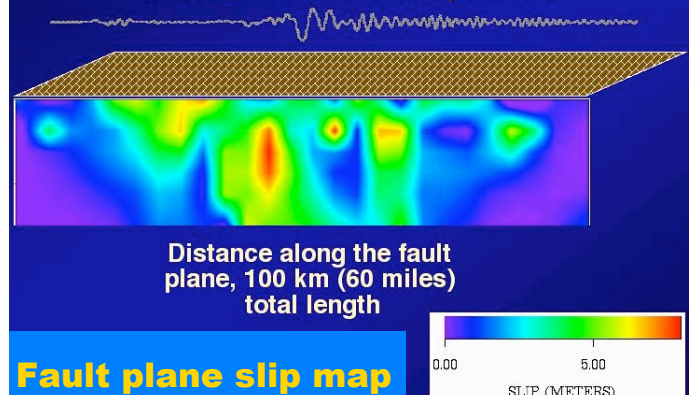


1992 Landers Earthquake

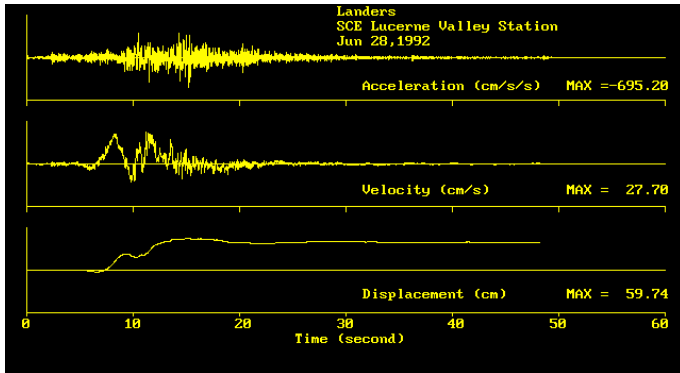
- June 28, 1992
 - in Mojave Desert
- $M_w=7.5$, largest since 1952
 - smaller than 1906 San Francisco
 - bigger than 1994 Northridge
- 70 by 12 km right-lateral, strike-slip rupture on vertical plane, lasted 20 sec
- Displacement (offset, slip) up to 6 m
- Connected 3 separate faults
 - didn't know previously that they could rupture together



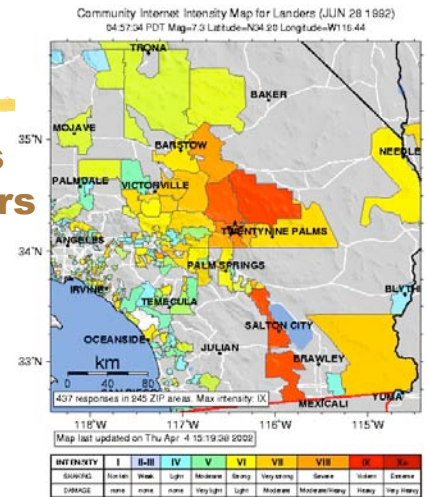
TOTAL SLIP IN THE M7.3 LANDERS EARTHQUAKE



A record of the Landers quake



Felt reports from Landers



Landers fault trace

- Fault scarp of 1992 Landers quake
- $M_w = 7.5$
- Right lateral strike-slip
 - Despite picture (thrust)
- Up to 6 m of offset

Landers scarp



1994 Northridge earthquake

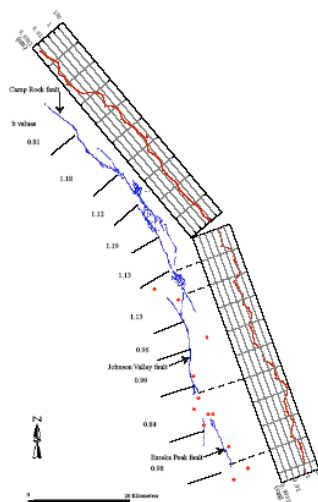
- 4:31 AM, Jan. 17, 1994
- $M_w = 6.7$, 20 by 20 km, 1-2 m slip
- Reverse, thrust fault
- Buried fault
 - focus at deepest part of fault (18 km)
 - rupture did not reach surface
 - on previously unknown fault
- \$40-50 billion damage
- Still a few aftershocks



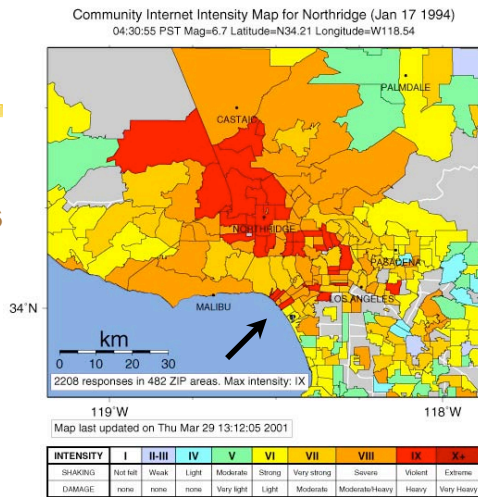
- Connected three separate faults
- Not previously thought possible

Another Lesson: Jumping Faults

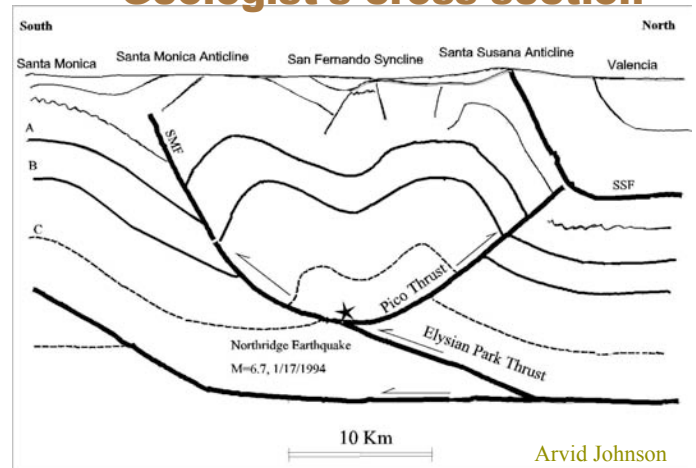
Liu and Sieh



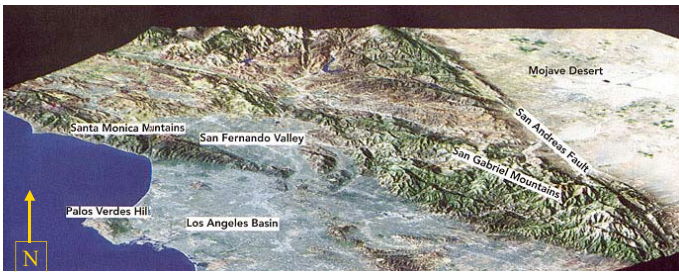
Felt reports



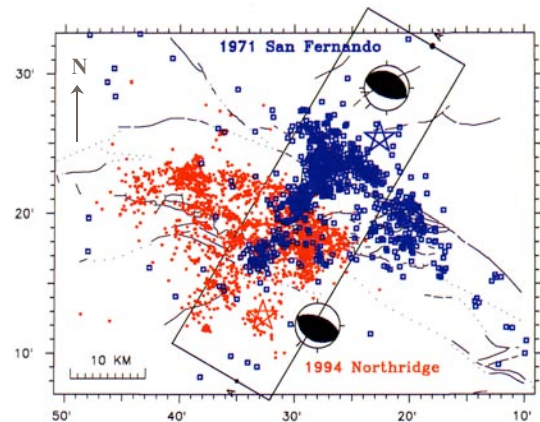
Geologist's cross-section



Topography across Los Angeles

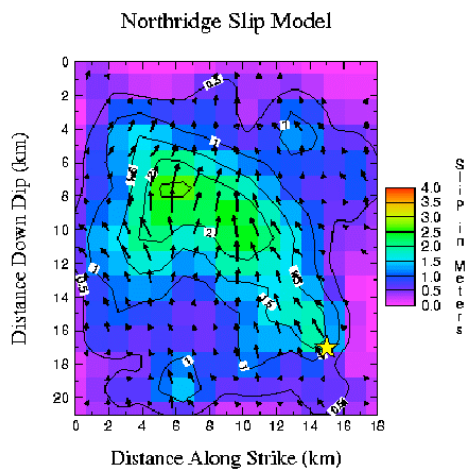


Map view of aftershocks

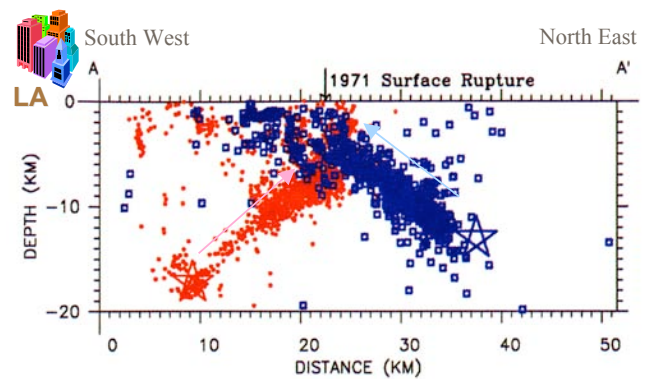


Slip

Thrust faulting
Similar direction
Tapers at edges
Starts at bottom



Cross Section

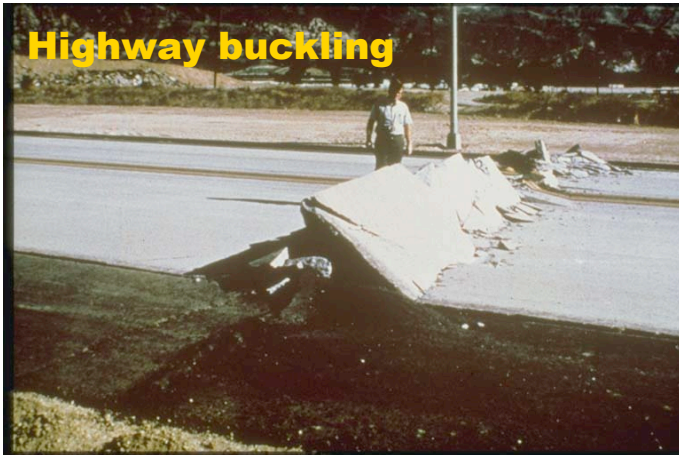
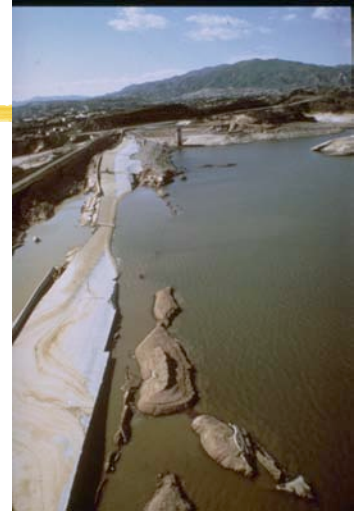


1971 San Fernando quake

- M = 7.1, close to Northridge's magnitude
 - Just a bit farther east than Northridge
 - Shook many Angelenos out of bed
- It reminded us of problems
 - Unexpected damage to some modern buildings
 - Nearly breached a big dam
 - 65 deaths, \$500,000,000 in damage
- It was well photographed
 - Will be featured in some future lectures

Very Near Disaster

- Nearly breached Lower Van Norman Dam
 - At the intersection of 405 & 5
- Evacuated 80,000



[http://www.ngdc.noaa.gov/cgi-bin/seg/m2h7seg/haz_volume1.men#Earthquakes+\(General\)+,I&10](http://www.ngdc.noaa.gov/cgi-bin/seg/m2h7seg/haz_volume1.men#Earthquakes+(General)+,I&10)

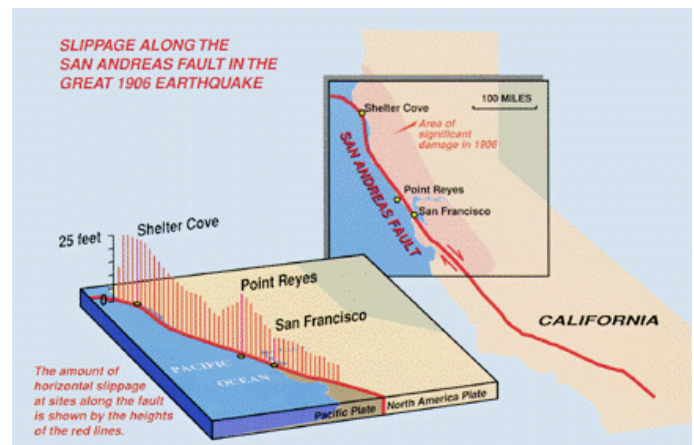


**Overpass
under
construction**

San Fernando Mall in 1971



Big one - 1906 San Francisco



1906 San Francisco quake

- 3000 killed (6 shot for looting)
- 225,000/400,000 homeless
- \$400,000,000 loss, 20% of city's value
- Luckily, many buildings were steel frame
- 400 km rupture, 15 km deep, 5 m slip
- $M = 7.7$, a "Big One"



Please don't riot anymore

(actually Turkey, 1999)



PROCLAMATION BY THE MAYOR

The Federal Troops, the members of the Regular Police Force and all Special Police Officers have been authorized by me to KILL any and all persons found engaged in Looting or in the Commission of Any Other Crime.

I have directed all the Gas and Electric Lighting Co.'s not to turn on Gas or Electricity until I order them to do so. You may therefore expect the city to remain in darkness for an indefinite time.

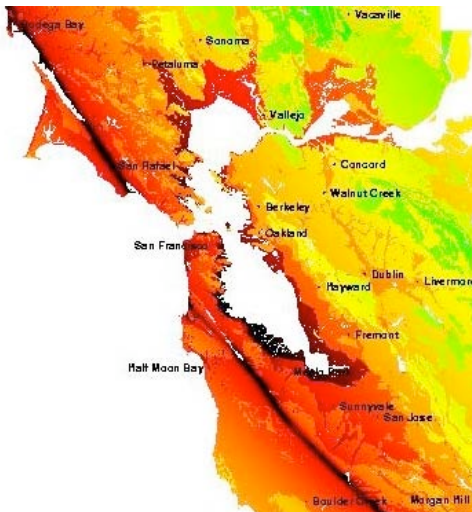
I request all citizens to remain at home from darkness until daylight every night until order is restored.

I WARN all Citizens of the danger of fire from Damaged or Destroyed Chimneys, Broken or Leaking Gas Pipes or Fixtures, or any like cause.

E. E. SCHMITZ, Mayor

Dated, April 18, 1906. ALFRED PHILLIPS, MISSOURI AND SIOUX.

Likely damage pattern



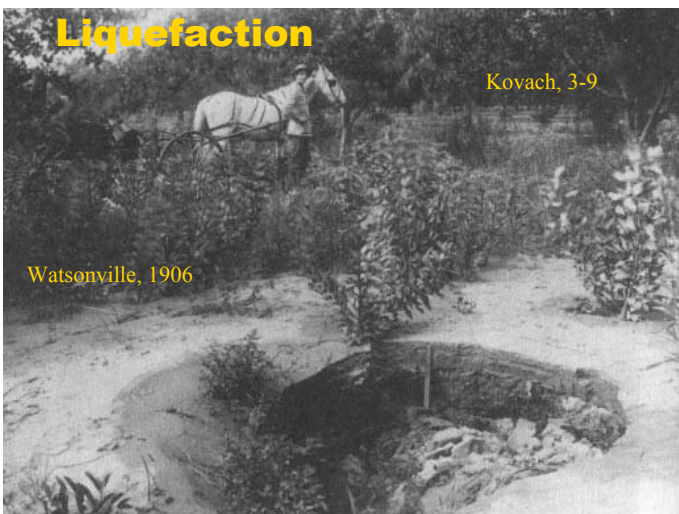
More about SF 1906

- Fire was the biggest problem
 - Water mains broken
- Burned for three days
 - Stopped by dynamited fire breaks
- Caused some new building codes
- Cow-fell-in-a-crack hoax

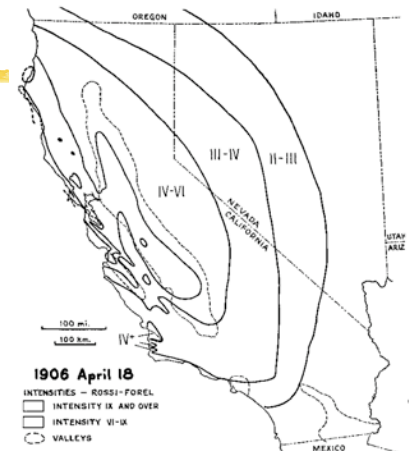
Liquefaction

Kovach, 3-9

Watsonville, 1906



Mercalli intensity pattern 1906 SF



Richter, 28-4



Palace Hotel in San Francisco



Caruso stories and pictures



From The Sketch
SIGNOR CARUSO'S SKETCH OF HIMSELF WATCHING
THE BURNING OF SAN FRANCISCO



From The Sketch
SIGNOR CARUSO'S SKETCH OF HIMSELF DRIVING
TO OAKLAND FERRY AFTER THE DISASTER

1906 SF Panorama- Part 1: Flames



Earthquake, fire, dynamite

1906 SF Panorama- Part 2: Aftermath



Birdseye View of the Ruins of San Francisco.
Supplement to the San Francisco Examiner, May 13, 1906.

Earthquake, fire, dynamite

Escape from the fire



Postcard



Rats!



Reward for Rats!

A REWARD OF FIVE CENTS WILL be paid for every rat, dead or alive, delivered at any of the following stations of the Health Department between the hours of 8 to 10 a.m.

Portsmouth Square
Bay and Van Ness
Thirteenth avenue and Lake street
Nineteenth and Dolores streets
Sixteenth and Bryant streets
Third, between Folsom and Howard streets
O'Farrell near Scott street

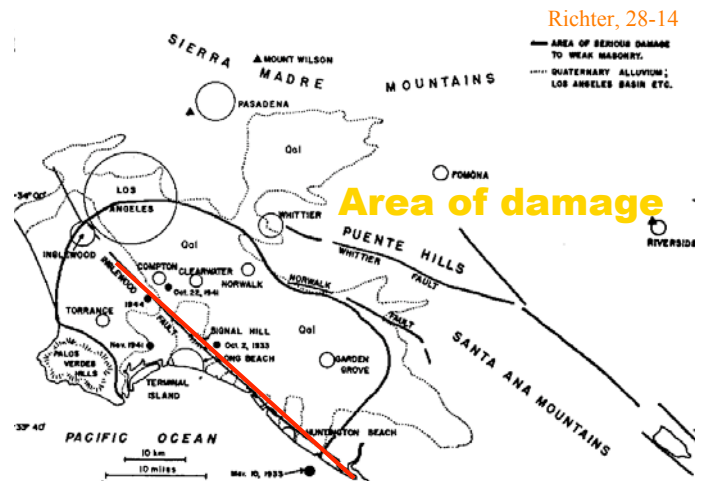
They must be delivered to the stations in tightly covered cans labeled so as to show in what neighborhood they have been caught.

CAUTION—Do not touch with the hands, but use tongs, or a long stick. Traps should be picked up with cloth saturated with kerosene. Drop rats immediately into kerosene, or in the absence of this, into a bucket of water, where they should remain for an hour, after which they may be placed in the cans for delivery.

September 26, 1907

1933 Long Beach quake

- 5:54 pm, M = 6.3, near downtown
 - Timing lucky, since schools were hard hit
- 120 deaths, \$50,000,000 in damage
- A shock, people had forgotten about quakes
 - Led to key improvements in zoning
 - Field Act of 1933
 - Post-1933 buildings much safer than pre-1933



1933 School Damage



Different School

Jefferson Junior High School in Long Beach



Portland Cement Association

Schools Damaged



■ Franklin Junior High School

Before



After

Photo: Historical Society of Long Beach via NISEE Berkeley

Post Office



Not sure, but looks bad.



1872 Owens Valley quake

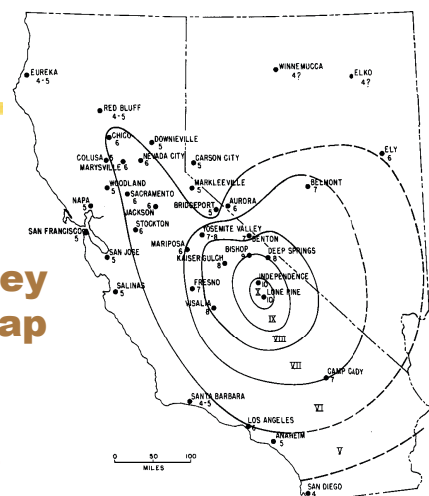
- M = 7.6 !! (big as a “Big One”)
- Devastated Lone Pine
 - Struck at 2:30 am
 - 10% of 300 residents killed
 - 90% of 60 adobe houses destroyed
 - Caused rockfalls across Sierra Nevada Mts.



Other US quakes

- 1959 Hebgen Lake
 - M7.5 event in Utah
- Nevada quakes
 - 1915, 1932, three in 1954
- 1886 Charleston quake
- 1811-12 sequence of quakes in New Madrid

Owens Valley Intensity Map



Yanév, p. 200

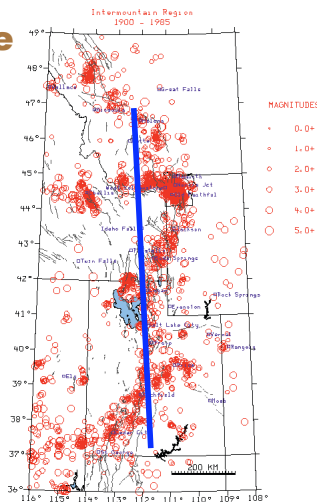
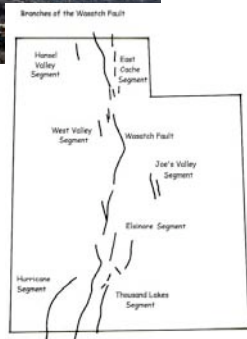
Wasatch fault system

- Nevada, Utah, and Idaho
 - Some very large quakes
 - Less active than West Coast
- Sparse population lessens damage
- 1959 Hebgen Lake quake
- 1954 Nevada sequence most notable
 - 6.6 in July, followed by 6.4 11 hours later
 - 6.8 in August
 - 7.1 in December, followed by 6.8 4 minutes later

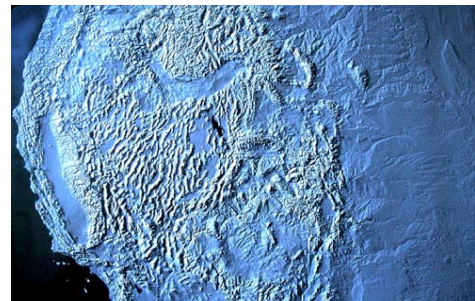
Rest of US

- Wasatch fault zone
 - Utah, Idaho, Montana, Wyoming
 - About 10-25% as active as San Andreas
 - Mainly normal faults
- New Madrid
 - Had some big quakes
 - We don't know how often they strike
 - Every 5000 years? Every 500?
- Charleston, plus a few others
- We'll talk about because of old quakes
 - Next one of my lectures

Wasatch fault zone



Basin and Range Topography



http://geography.sierra.cc.ca.us/booth/California/1_lithosphere/west_relief_map.jpg

Big scarp

1959 Hebgen Lake



Fault scarp



Photo #5 from J.B. Hadley Collection, U.S. Geological Survey
Courtesy of U.S. Geological Survey

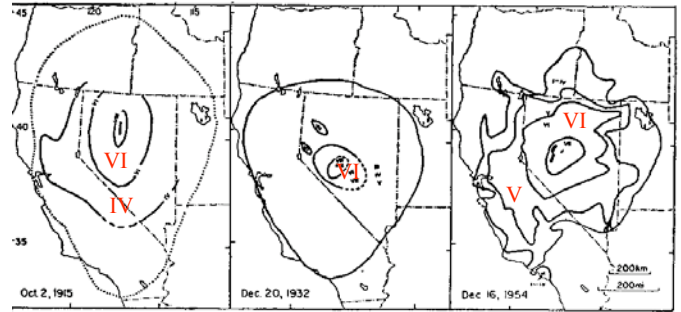
Traffic impediment



Photo by Carl Hayden, Salt Lake Tribune
Courtesy of Utah State Historical Society

Intensities for some Nevada quakes

Richter, 28-16

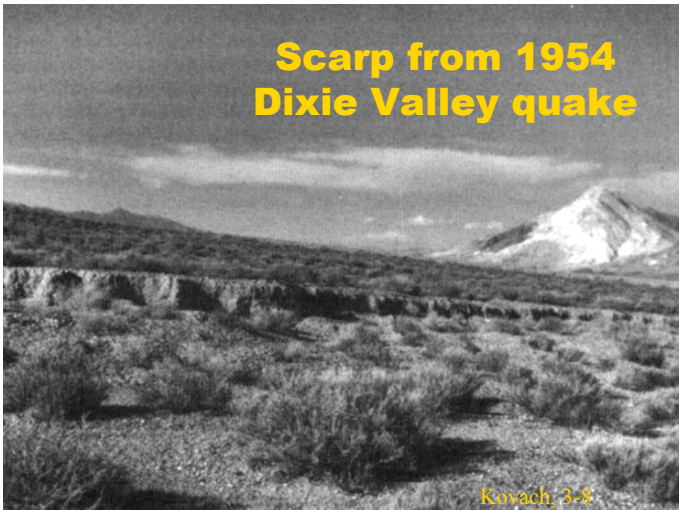


Pleasant Valley

Cedar Mountain

Dixie Valley

Scarp from 1954 Dixie Valley quake



Kovach, 3-8

Another



Big fault scarp



Richter, 28-21A

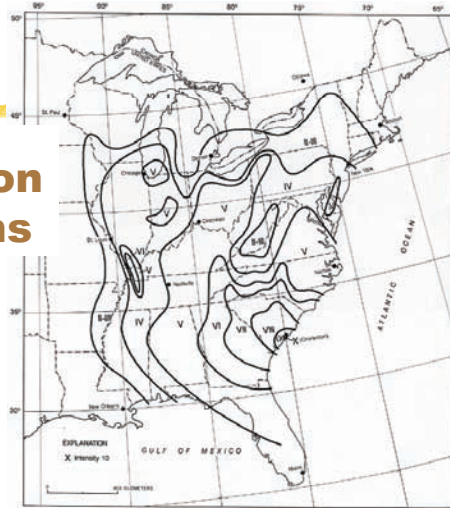
Fairview Peak, 1954

1886 Charleston quake

- We still haven't found the fault
- Magnitude about 7.3, \$5M damage
- 27 deaths? 60 deaths?
- This quake is an concern for public safety
 - Why quake there? Where next? When?
- Claims of earthquake waves

Charleston isoseisms

Yanev, p. 210

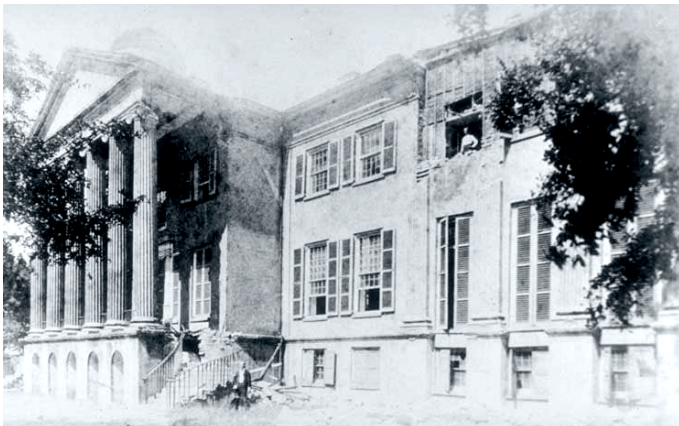


Charleston damage

Bolt



Charleston College



House in Charleston



Wild waves in Charleston in 1886?

. . . The vibrations increased rapidly and the ground began to undulate like a sea. The street was well lighted, having three gas lamps within a distance of 200 feet, and I could see the earth waves . . . distinctly . . . The first wave came from the southwest . . . The waves seemed then to come from both the southwest and northwest and crossed the street diagonally, intersecting each other, and lifting me up and letting me down . . . I could see perfectly and could make careful observations, and I estimate that the waves were at least two feet in height.

Richter, p. 130

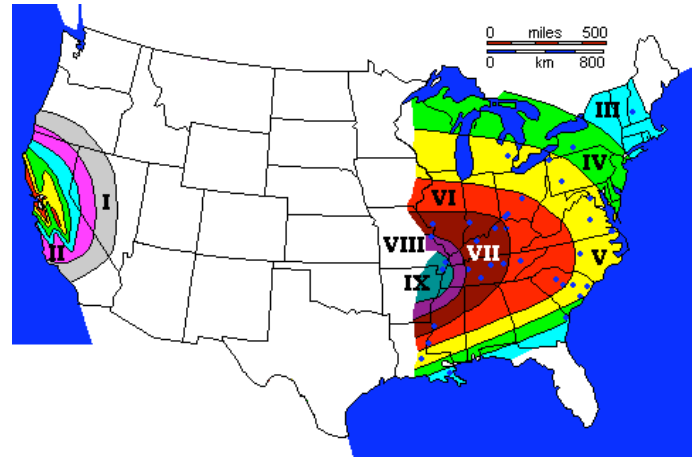
Train off tracks



1811-1812 New Madrid

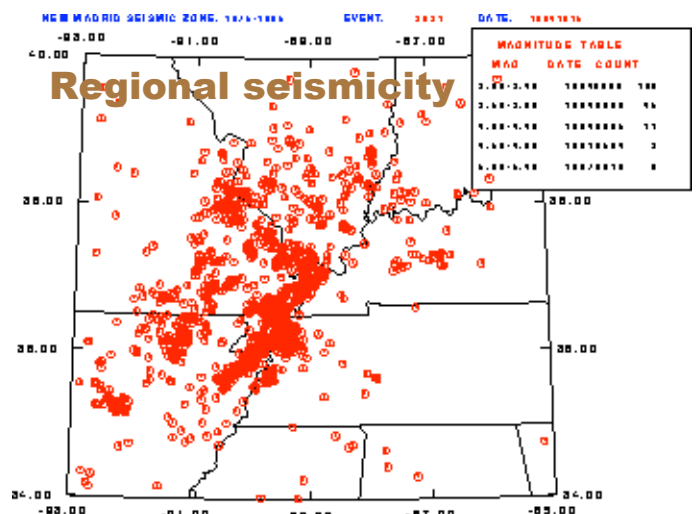
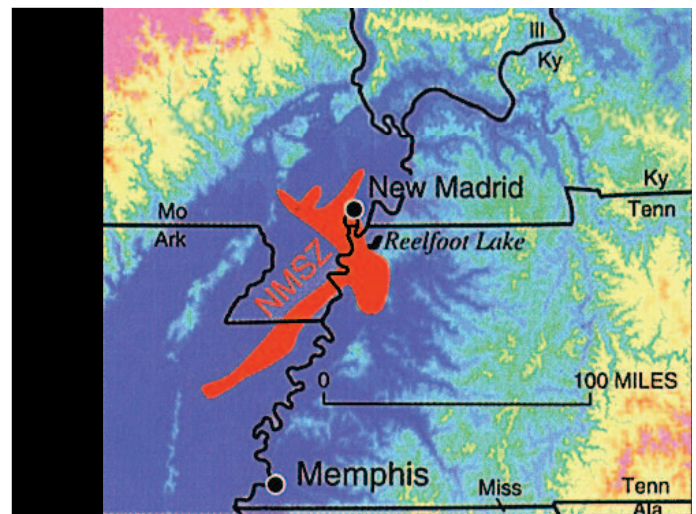
- M8 (M7.2, 7.0) December 1811
- M8 (M7.1) January 1812
- M8 (M7.4) February 1812
- Many other major quakes in this sequence
- Felt across eastern United States
- Used to be considered strongest historic events in US
 - Aside from Alaska

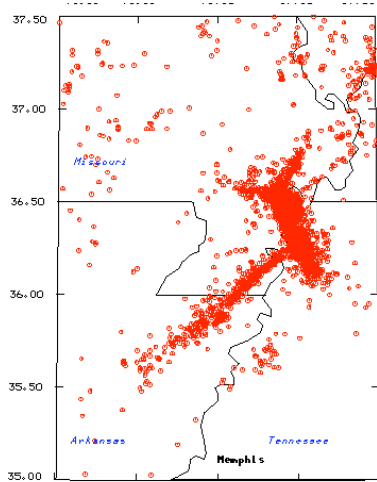
New Madrid intensities



More New Madrid

- Most evidence comes from river pilots, many boats were wrecked
- Signs of quakes are subtle now
 - Submerged cypress trees
 - New ridges that redirect river
 - Continuing aftershocks
- Quakes broke a complicated set of faults
- Recurrence time seems to be >5000 years



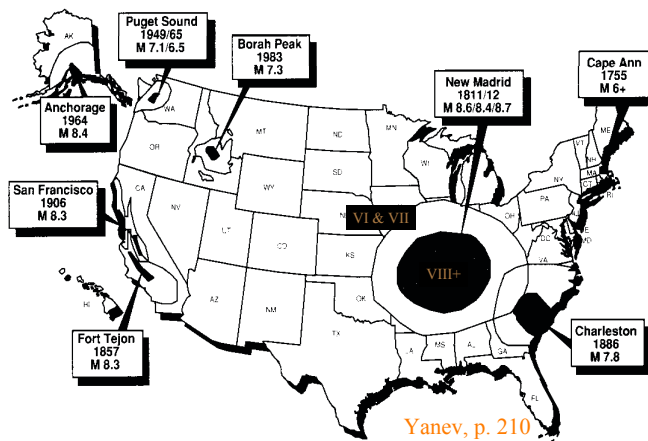


**Zoom in to
see “fault
planes”**

US map of historical intensities

- Eastern quakes have larger zones of shaking
 - Seismic waves travel farther in the east
- Estimation of national quake danger
 - Can use historical pattern of quakes
 - Or can try to predict where future quakes will strike

Intensity maps on national scale

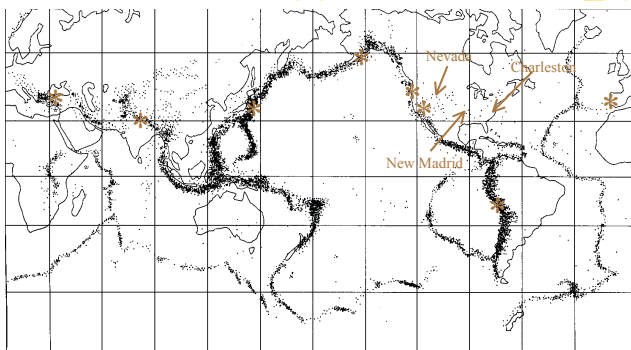


International quakes

- Japan
 - 1923 Tokyo quake, horrific casualties
 - 1995 Kobe most expensive, \$150 billion
- China - 1975 Haichang & 1976 Tangshan
 - Most fatalities, prediction experiment
- India - very active
- Europe - somewhat active

Earthquakes M>5, 1963-1988

Quakes that we've discussed



Keller, 1-5