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

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

Global tour of quakes

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

San Andreas fault system

Red, yellow are fast-slipping faults, yellow is intermediate, and green and blue faults slip slower

Big quakes in Cal.

Bolt, 1.2
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

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

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 it’s top snapped off, causing lower branches to grow vertically. Tree-ring dating has been used to accurately date past earthquakes.

1992 Landers Earthquake

Total Slip in the M7.3 Landers Earthquake

Fault plane slip map
A record of the Landers quake

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

Felt reports from Landers

Another Lesson: Jumping Faults

Liu and Sieh
Felt reports

Topography across Los Angeles

Map view of aftershocks

Slip

Cross Section

Thrust faulting
Similar direction
Tapers at edges
Starts at bottom
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

Highway buckling

San Fernando Mall in 1971

Big one - 1906 San Francisco

Overpass under construction

http://www.ngdc.noaa.gov/cgi-bin/m2h?seg/men+Earthquakes+(General)+,I&10
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)

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

Likely damage pattern

Liquefaction

Watsonville, 1906

Mercalli intensity pattern 1906 SF

Richter, 28-4
After quake, before fire

Caruso stories and pictures

1906 SF Panorama- Part 1: Flames

1906 SF Panorama- Part 2: Aftermath

Escape from the fire

Earthquake, fire, dynamite

Earthquake, fire, dynamite
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

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.

- Fourteenth Street
- Front and Van Buren
- Thirteenth Avenue and Lake Street
- Seventeenth and DuBois streets
- Sixteenth and Bryant streets
- Third between Olive and Hillard streets
- O’Farrell near Front Street

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

CAUTION: Do not touch with the hand, but use tongs, or a long stick. Tongs should be picked up with cloth saturated with kerosene. Dry 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

Richter, 28-14

Area of damage
Schools Damaged

- Franklin Junior High School

Before

After

Photo: Historical Society of Long Beach via NISEE Berkeley

Post Office

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

Not sure, but looks bad.

Owens Valley Intensity Map

Yanev, 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

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**Wasatch fault zone**

**Basin and Range Topography**

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

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**Big scarp**

1959 Hebgen Lake

**Fault scarp**

Traffic impediment

Intensities for some Nevada quakes

Richter, 28-16

Pleasant Valley
Cedar Mountain
Dixie Valley

Scarp from 1954
Dixie Valley quake

Another

1886 Charleston quake

- We still haven’t found the fault
- Magnitude about 7.3, $5M damage
- 27 deaths? 60 deaths?
- This quake is a concern for public safety
  - Why quake there? Where next? When?
- Claims of earthquake waves
Wild waves in Charleston in 1886?

... The vibrations increased rapidly and the ground began toundulate 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
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

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

Regional seismicity
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