Seismic Hazards 1

Lecture Objectives

-importance of seismic engineering/science for mitigation
-introduction to seismic monitoring

-2 main topics:
-case study of seismic mitigation; engineering, science and lessons learned

-ongoing debate on seismic mitigation

Northridge 1994 Earthquake

-next reading (2 class sessions):

http://greenwood.cr.usgs.gov/pub/open-file-reports/ofr-96-0263/

Introduction (p 2-4)
Assisting recovery…(p 6-10)
Studying the setting…(p 12-67)
Communicating…(p 70-78)

Seth Stein (Northwestern U.)

Seismological Research Letters, 2004

"No Free Lunch"

"No such thing as other people's money"

Overall: the need for cost-benefit analysis

Main Issues

1. Why are hazard issues ultimately economic/social?

2. How many people in the U.S. die from earthquakes?

3. What are the uncertainties in predictions?

4. Should estimates be biased for safety?

5. Should hazard estimates be peer-reviewed?

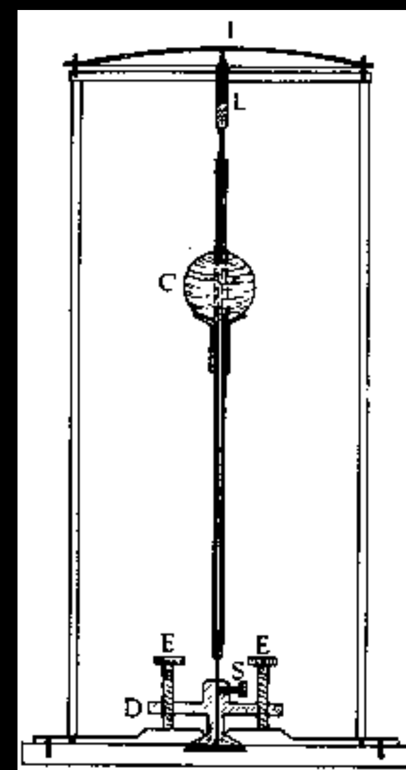
6. Should seismic hazard engineering be treated on the same timescale as other hazards?

7. What other disciplines should be considered ?

Seismology Basics

Earthquake measurement: ~2000 years by Chinese scientists

James Forbes (Scotland, 1844): invented seismometer



Faraday's Law: electromagnetic sensor

Geophysics: began as a discipline late 1800's; dedicated journal in 1874

What Do We Know?

Lots:

- -Earth overall composition
- -slip-related motion of earthquakes

Little:

- -Earth's spatial (small scale) composition;
- -general relationship of earthquakes to tectonic settings;
- -very little about actual faulting process;
- -no ability to predict earthquakes on less than 100 year timescale;
- -few methods to even estimate seismic hazards.

Simplifications: everything! P, S waves, elastic rock, magnitudes.

Earthquakes “mostly” occur near plate boundaries, but types of earthquakes vary due to boundary types

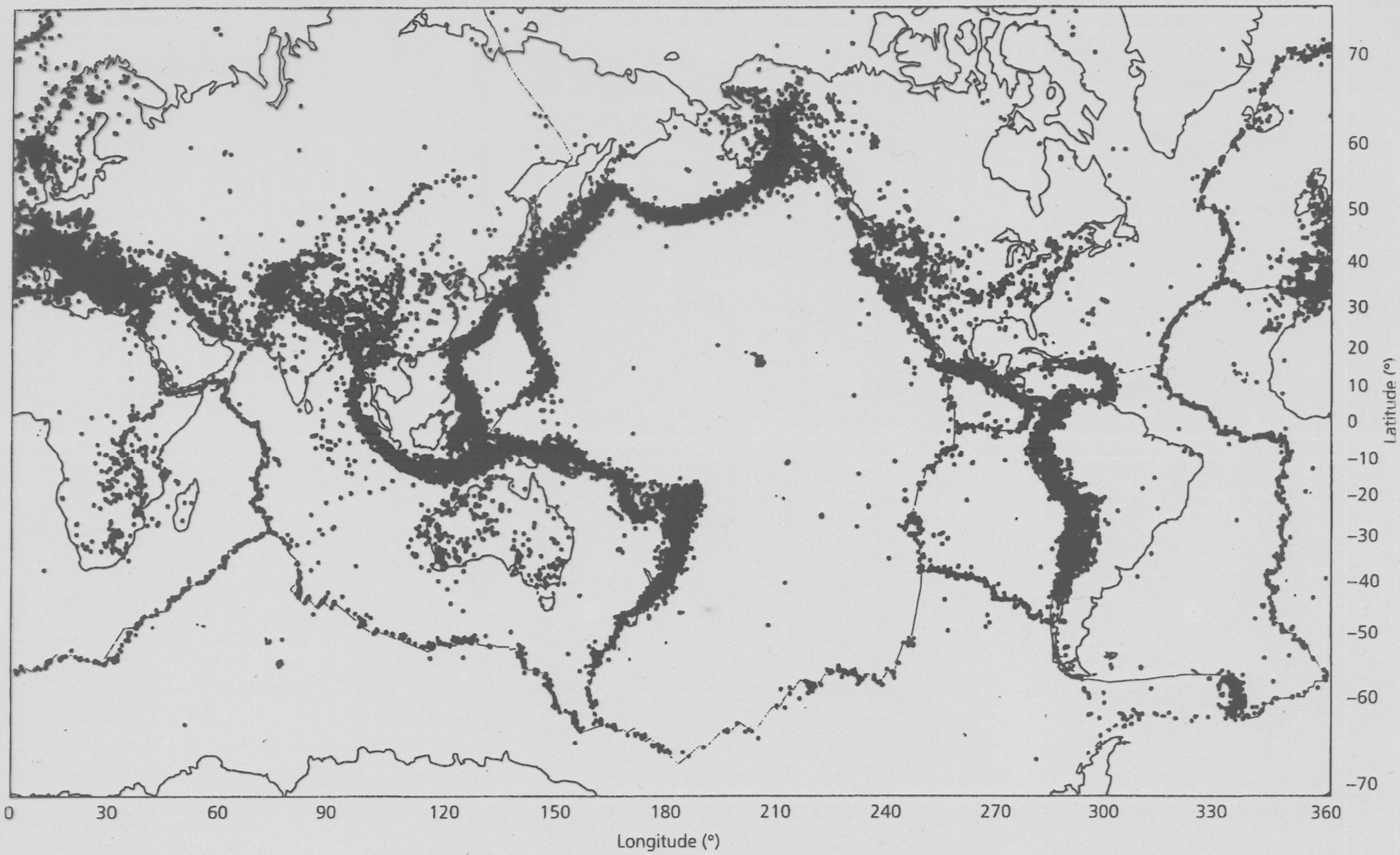


Fig. 1.2-1 Map showing epicenters of all earthquakes during 1963–95 with magnitudes of $m_b \geq 4$. Most earthquakes occur along the boundaries between tectonic plates. Where these boundaries are distinct, the earthquakes occur within narrow bounds. More diffuse plate boundaries, like the Himalayan plateau between India and China, show a much broader distribution of epicenters.

Earthquakes release more energy than volcanoes!
On a human time scale, earthquakes are the most powerful natural events on earth.

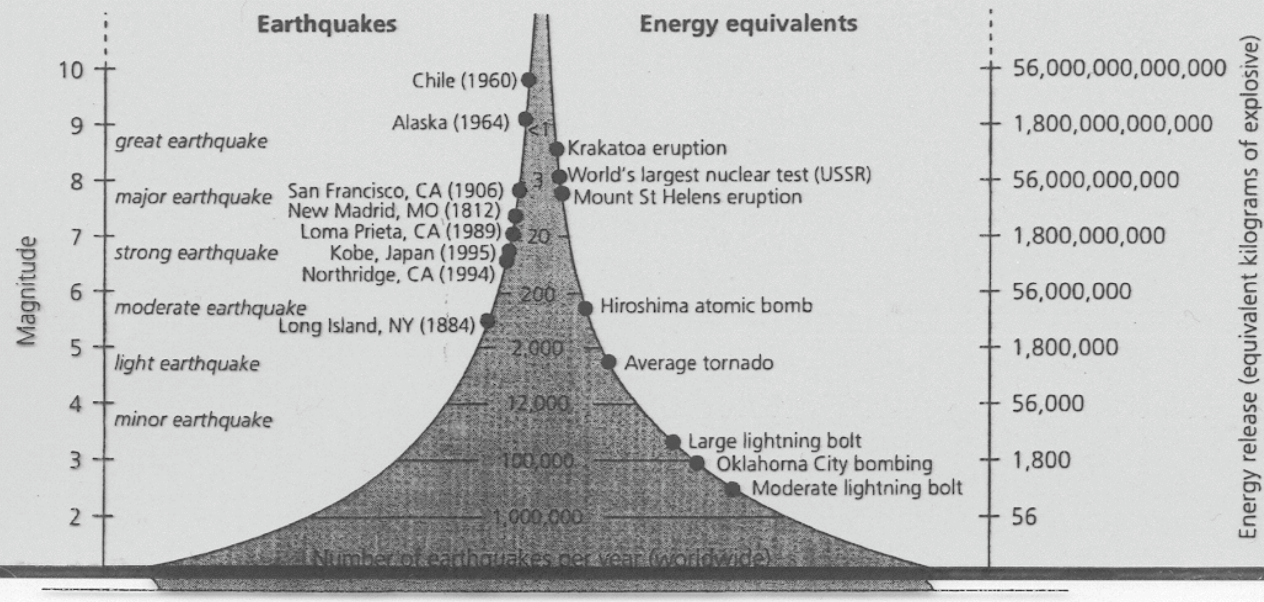


Fig. 1.2-2 Comparison of frequency, magnitude, and energy release of earthquakes and other phenomena. The magnitude used is moment magnitude, M_w. (After Incorporated Research Institutions for Seismology.)

Wanna bet? You can predict that a large (M 6) earthquake, +/- 1 day, will strike the Earth.

Table 1.2-1 Numbers of earthquakes per year.

Earthquake magnitude (M_s)	Number per year	Energy released (10^{15} J/yr)
≥8.0	0–1	0–1,000
7–7.9	12	100
6–6.9	110	30
5–5.9	1,400	5
4–4.9	13,500	1
3–3.9	>100,000	0.2

Based upon data from the US Geological Survey National Earthquake Information Center. Energy estimates are based upon an empirical formula of Gutenberg and Richter (Gutenberg, 1959), and the magnitude scaling relations of Geller (1976), and are very approximate.

It's very unlikely that a U.S. citizen will be killed by an earthquake

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

Cause of death	Number of deaths
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] per year	9
Earthquakes (1984–98), per year	9

[1] From the National Weather Service (property loss due to severe weather is $10–15 billion/yr, comparable to the Northridge earthquake, and that from individual hurricanes can go up to $25 billion).
[2] From the Consumer Product Safety Commission.
[3] From Gere and Shah (1984).
All others from the National Safety Council and National Center for Health Statistics.

[4] Many seismologists have faced situations like explaining to apprehensive telephone callers that the danger of earthquakes is small enough that the callers' upcoming family vacations to Disneyland are not suicidal ventures.

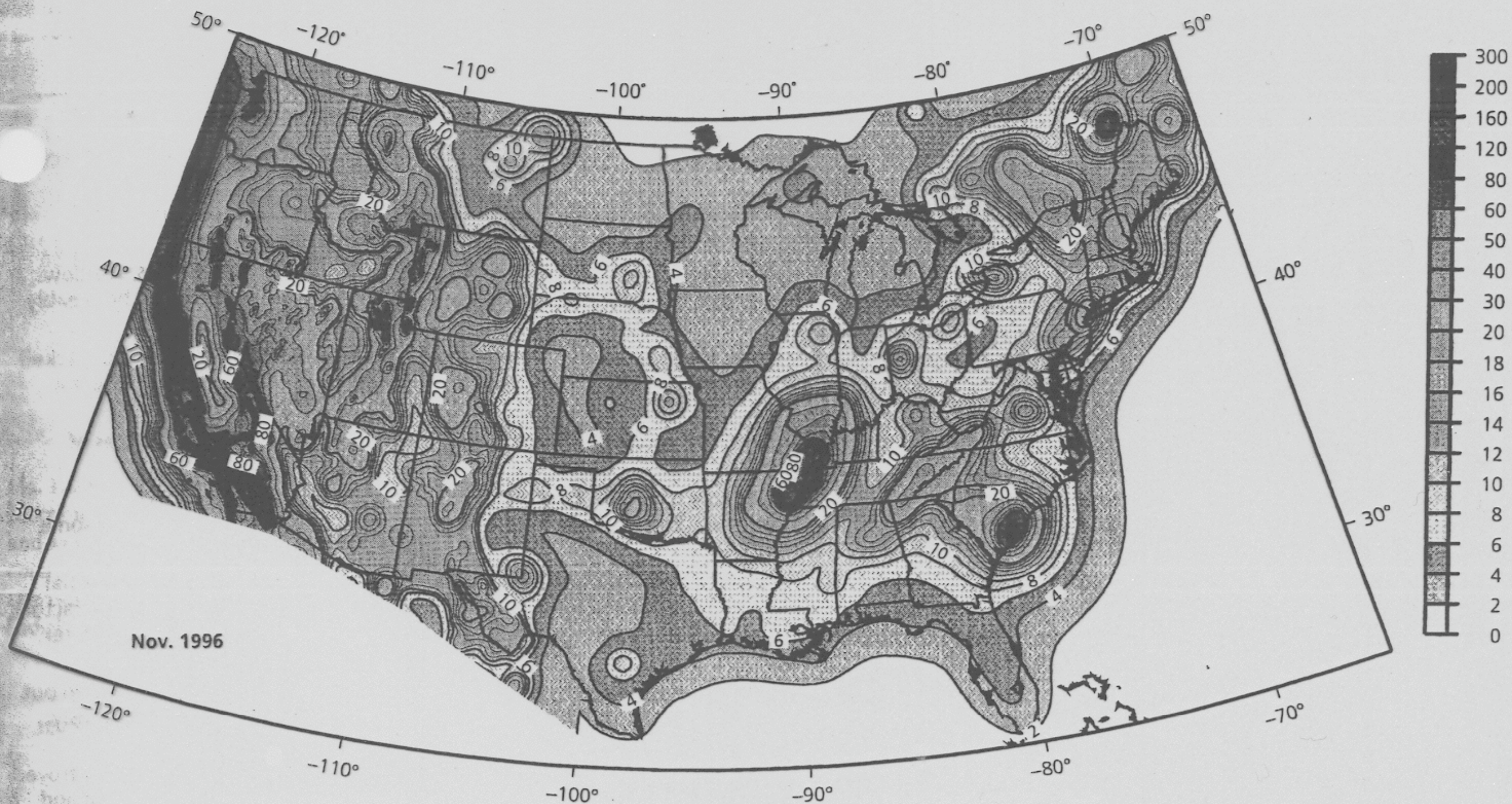


Fig. 1.2-3 A map of estimated earthquake hazards in the United States. The predicted hazards are plotted as the maximum acceleration of ground shaking expected at a 2% probability over a 50-year period. Although the only active plate boundaries are in the western USA, other areas are also shown as having significant hazards. (Courtesy of the US Geological Survey.)

? 2% probability of exceedance over the next 50 years = once during the next 2500 years

Predictions based on past behavior ("probabalistic") can be very difficult with earthquakes, because they often occur in anti-statistical clusters.

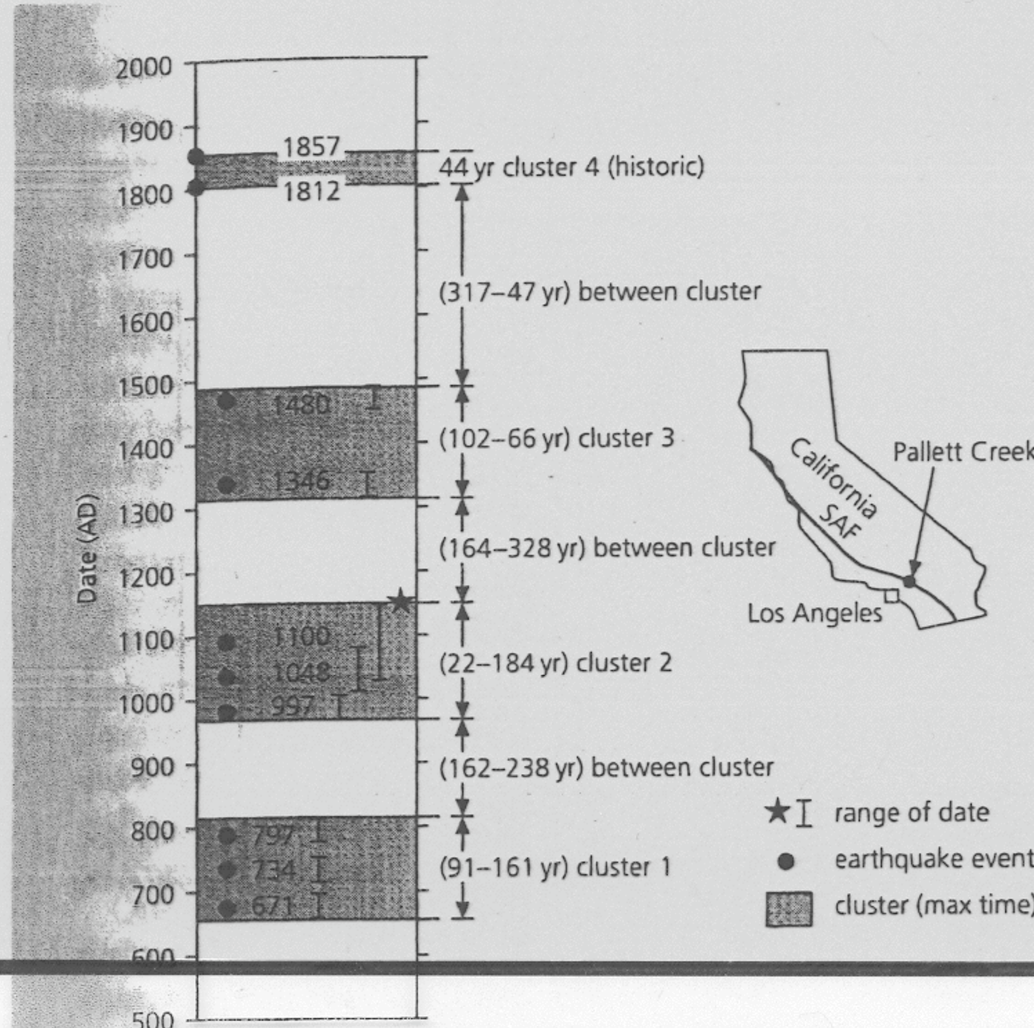


Fig. 1.2-15 Paleoseismic time series of earthquakes along the San Andreas fault near Pallett Creek, California, inferred from sedimentary deposits by Sieh *et al.* (1989). The sequence shows earthquake clusters separated by longer time intervals, illustrating the complexity of earthquake recurrence. (Keller and Pinter, *Active Tectonics: earthquakes, uplift, and the landscape*, © 1996. Reprinted by permission of Pearson Education.)