EARTHQUAKE CASE HISTORIES (07)

I Main Topics for next two lectures

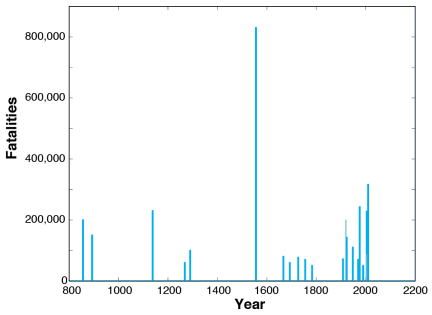
A Recognition of earthquake hazards from case histories

B Key case histories

II Recognition of earthquake hazard

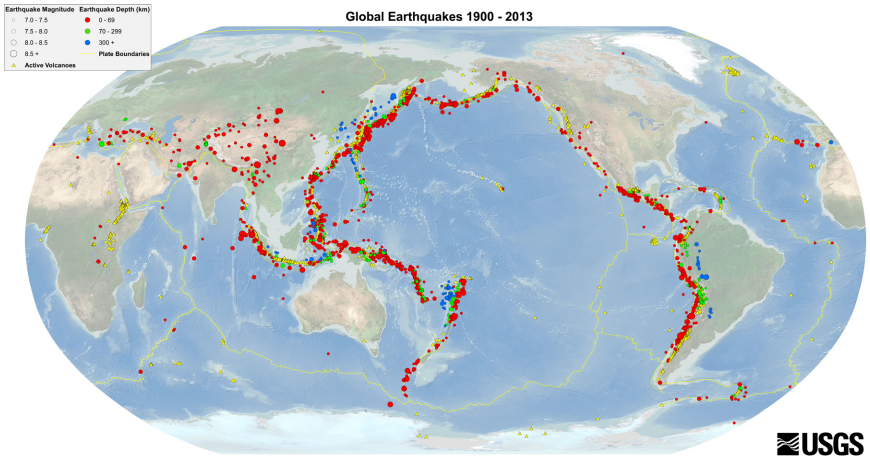
A Fatalities From Earthquakes since 800

Date	Location	Deaths	Magnitude
856	Iran	200000	
893	Iran	150000	
1138	Syria	230000	
1268	Asia Minor	60000	
1290	China	100000	
1556	China	830000	8
1667	Caucasia	80000	
1693	Italy	60000	7.5
1727	Iran	77000	
1755	Portugal	70000	8.7
1783	Italy	50000	
1908	Italy	72000	7.2
1920	China	200000	7.8
1923	Japan	142800	7.9
1948	Turkmenistan	110000	7.3
1970	Peru	70000	7.9
1976	China	242769	7.5
1990	Iran	50000	7.4
2004	Sumatra	227898	9.1
2005	Pakistan	86000	7.6
2008	China	87587	7.9
2010	Haiti	316000	7



http://earthquake.usgs.gov/earthquakes/world/most_destructive.php

B World Seismicity Map 1900-2013



http://earthquake.usgs.gov/earthquakes/world/seismicity_maps/index.php

III Key Case Histories (Historic record)

A Owens Valley, 1872

B San Francisco, 1906

C San Fernando, 1971

D Loma Prieta, 1989

E Parkfield, CA, 2004

http://en.wikipedia.org/wiki/1872_Lone_Pine_earthquake

A Owens Valley, 1872

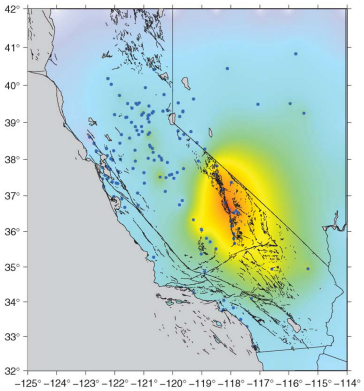
- **Date March 26, 1872; 2:30 AM**
- **Magnitude 7.6 – 8.0 M_L**
- **Epicenter 36.7°N 118.1°W**
- **Total damage $250,000**
- **Max. intensity X (*Intense)***
- **Casualties 27**

http://en.wikipedia.org/wiki/1872_Lone_Pine_earthquake

From Hough and Hutton, 2008

A Owens Valley, 1872

1 Epicenter at Lone Pine at base of Mt. Whitney. Second greatest(?) historical California earthquake. Rupture length of 100+ km.



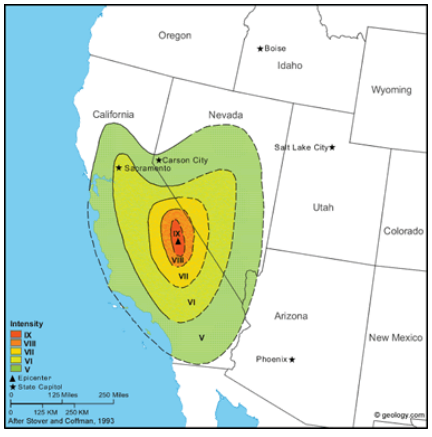
PERCEIVED SHAKING	Not felt	Weak	Light	Moderate	Strong	Very strong	Severe	Violent	Extreme
POTENTIAL DAMAGE	none	none	none	Very light	Light	Moderate	Moderate/Heavy	Heavy	Very Heavy
PEAK ACC.(%g)	*<.17*	*.17-1.4*	*1.4-3.9*	*3.9-9.2*	*9.2-18*	18–34	34–65	65–124	>124
PEAK VEL.(cm/s)	<0.1	0.1–1.1	1.1–3.4	3.4–8.1	8.1–16	*16-31*	*31-60*	*60-116*	*>116*
INSTRUMENTAL INTENSITY	I	II-III	IV	V	VI	VII	VIII	IX	X+

From Hough and Hutton, 2008

A Owens Valley, 1872

2 Felt from Oregon to Mexico to Salt Lake City

3 Damage 300 miles NNW of epicenter



http://geology.com/earthquake/california.shtml

A Owens Valley, 1872

4 Key Lessons

a Wood-frame construction resilient; unreinforced masonry weak. In Lone Pine (population 250-300), 23 killed, 50+ injured, most in the collapse of unreinforced masonry. 52 of 59 buildings wholly or partly destroyed, including every adobe, brick, or stone building.

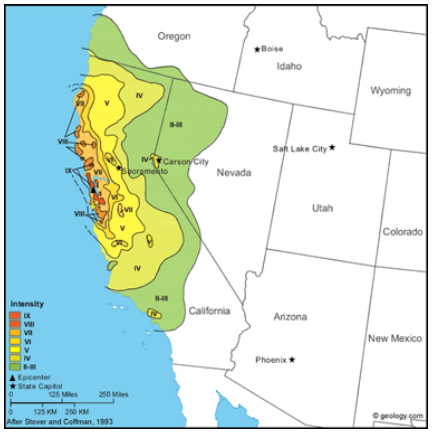
b Caused G.K. Gilbert (1884) to recognize faulting hazard in Salt Lake City

http://pasadena.wr.usgs.gov/office/hough/Owens/1872-photo1.JPG

http://pasadena.wr.usgs.gov/office/hough/Owens/1872-photo5.JPG

B San Francisco, 1906

- Date April 18, 1906; 5:12 AM
- Magnitude 7.8 M_w
- Depth 8 km (5.0 mi)
- Epicenter 37.75°N 122.55°W
- Max. intensity X - Intense
- Casualties 3,000+
- Rupture length of 476 km (296 miles)
- Damage:
  - ~$500 million
  - ~$13 billion in 2014 dollars



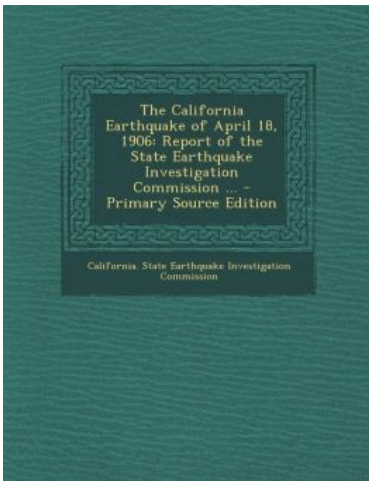
http://geology.com/earthquake/california.shtml

B San Francisco, 1906

2 Key Lessons (Report of the State Earthquake Investigation Commission)

http://content.cdlib.org/ark:/13030/hb1h4n989f/

http://publicationsonline.carnegiescience.edu/publications_online/earthquake_volume/default.html



http://img1.imagesbn.com/p/9781293759776_p0_v1_s260x420.JPG

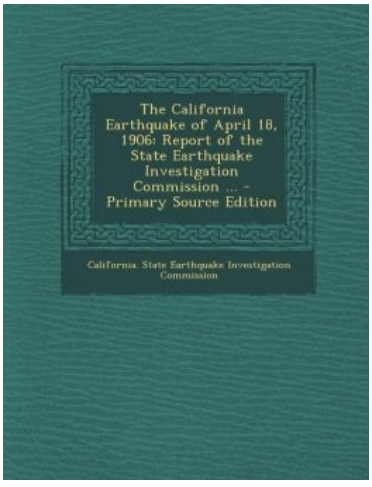
B San Francisco, 1906

2 Key Lessons

a Establishment of elastic rebound theory as earthquake mechanism (vol. 2, p. 27)

b Calculation of energy release (vol. 2, p. 22)

c Estimate of regional principal stress field (vol. 2, p. 22-28)



http://img1.imagesbn.com/p/9781293759776_p0_v1_s260x420.JPG

B San Francisco, 1906

2 Key Lessons

d Rupture along a pre-existing previously identified fault (the San Andreas fault)

e Significance of Hayward fault

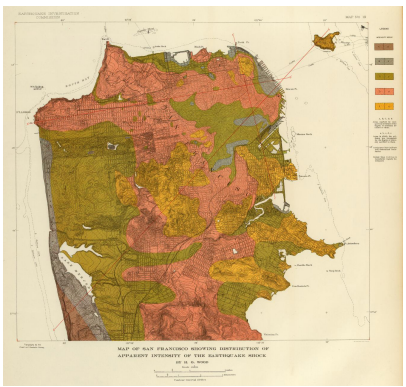
f Estimation of ~100 year recurrence interval (vol. 2, p. 18-19)

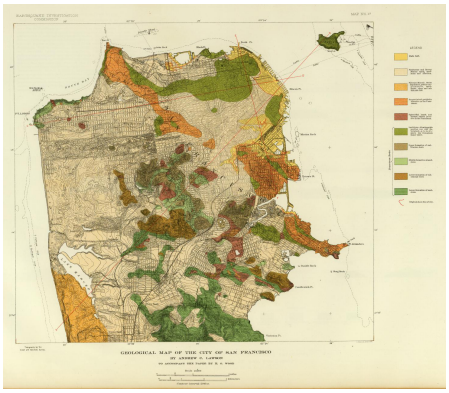
http://www.davidrumsey.com/luna/servlet/view/all/where/San+Andreas+Fault+(Calif.)?sort=Pub_List_No_InitialSort%2CPub_Date%2CPub_List_No%2CSeries_No

B San Francisco, 1906

2 Key Lessons

g Association between shaking intensity and and surficial geology; beginning of characterization (vol. 2, p. 49-56)





http://www.davidrumsey.com/maps1151061-31130.html

http://www.davidrumsey.com/luna/servlet/detail/RUMSEY~8~1~31132~1151063:San-Francisco-intensity-of-earthqua

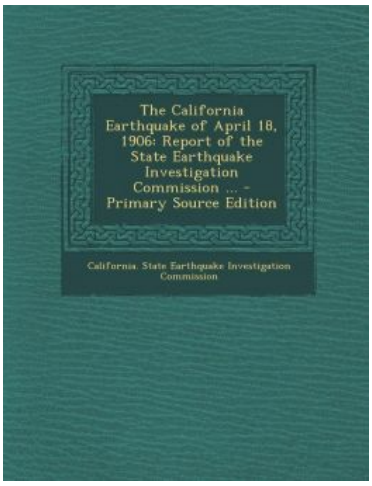
B San Francisco, 1906

2 Key Lessons

h Difference in attenuation characteristics vs. East coast quakes (i.e. Charleston 1886)

i Resilience of wood-frame construction and flaws of unreinforced masonry

j Documentation of effect on ground water



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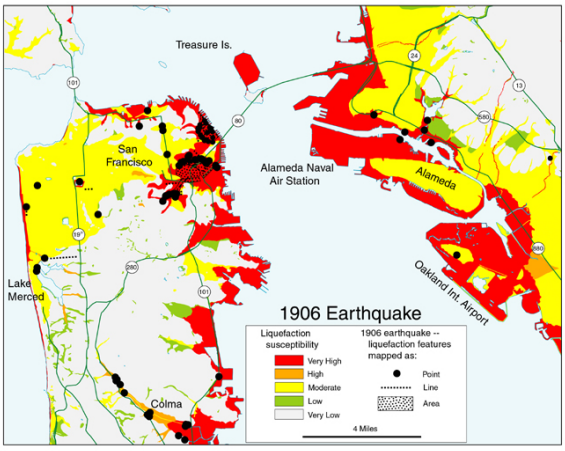
B San Francisco, 1906
Map of Liquefaction



https://geomaps.wr.usgs.gov/sfgeo/liquefaction/effects.html

C San Fernando, 1971

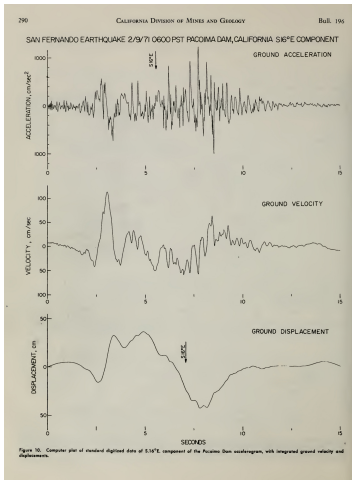
- **Date February 9, 1971, 6:00:41 AM**
- **Duration 12 seconds**
- **Magnitude 6.5–6.7 M_w [2][3]**
- **Depth 13 km (8.1 mi)**
- **Epicenter 34.41°N 118.40°W**
- **Type Oblique-slip**
- **Total damage $553 million**
- **Max. intensity XI (*Extreme*)**
- **Peak acceleration 1.25*g* at *Pacoima Dam***
- **Landslides Yes**
- **Casualties 64 killed (out of 7 million in affected area)**
- Rupture length of ~15 km

http://en.wikipedia.org/wiki/1971_San_Fernando_earthquake

http://geology.com/earthquake/california.shtml

C San Fernando, 1971 Key Lessons

1 First instrumental recording of vertical accelerations >1g



https://archive.org/details/sanfernandocalif00oakerich

C San Fernando, 1971
Key Lessons

2 Numerous houses damaged by ground rupture.

3 Resilience of wood-frame construction highlighted again. Casualties in personal residences less than 1 in a million.

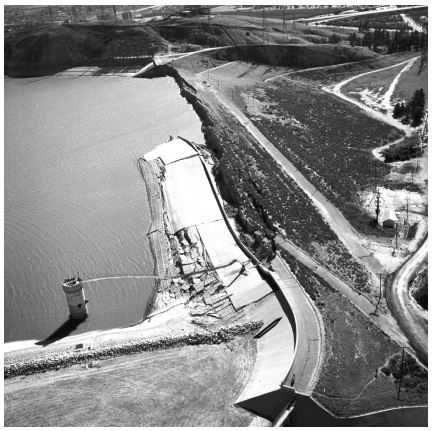
4 Initiated Alquist-Priolo Act

http://blogs.kqed.org/science/2013/11/22/california-slow-to-map-dangerous-earthquake-faults/sylmar-1971-house-2/

C San Fernando, 1971
Key Lessons

5 Near failure of Van Norman dam

6 Gave major boost to review of safety of dams in U.S.



http://en.wikipedia.org/wiki/1971_San_Fernando_earthquake

C San Fernando, 1971
Key Lessons

7 Graphic evidence of potential for freeway disruption

8 Graphic evidence of inadequacy of "flexible first story" design. Other buildings built to code generally did well

http://en.wikipedia.org/wiki/1971_San_Fernando_earthquake

D Loma Prieta, CA

- **Date October 17, 1989**
- **Origin time 5:04:15 PDT**
- **Duration 8 – 15 seconds**
- **Magnitude 6.9 M_w**
- **Depth 19 km (12 mi)**
- **Epicenter 37.04°N 121.88°W**
- **Type Oblique-slip**
- **Total damage $5.6 – 6 billion**
- **Max. intensity IX (*Violent)***
- **Peak acceleration .65*g* (*at epicenter)***
- **Tsunami Yes**
- **Landslides 1,000 – 4,000**
- **Foreshocks 5.3 M_L June 27, 1988; 5.4 M_L August 8, 1989**
- **Casualties 63 killed, 3,757 injured**

http://en.wikipedia.org/wiki/1989_Loma_Prieta_earthquake

http://geology.com/earthquake/california.shtml

D Loma Prieta, CA

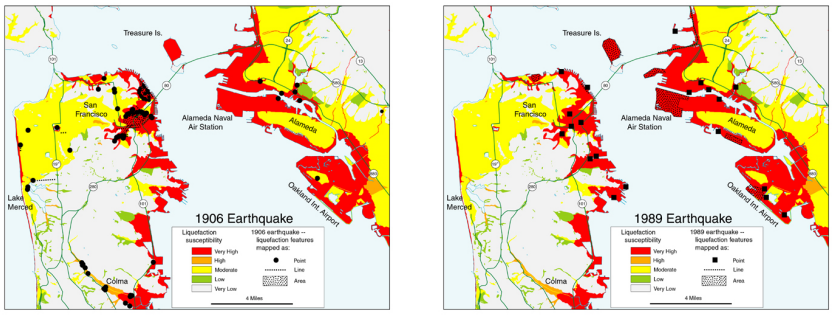
https://www.youtube.com/watch?v=FW-TkpvKPl0

D Loma Prieta, CA

https://www.youtube.com/watch?v=0lAXStQCjr8

D Loma Prieta, CA
Maps of Liquefaction: 1906 and 1989

1906 **1989**



https://geomaps.wr.usgs.gov/sfgeo/liquefaction/effects.html

D Loma Prieta, CA
Key Lessons

1 The location and style of ground response and ground water response could have been predicted in many areas based on what happened in 1906

2 Rupture similar to what had been mapped previously

3 Tremendous increase in ability/ speed to determine the location, extent, and energy release (i.e. physical parameters) based on seismologic and geodetic information

D Loma Prieta, CA
Key Lessons

4 Resilience of wood-frame construction and flaws of unreinforced masonry demonstrated again

5 Houses should be bolted to their foundations

D Loma Prieta, CA
Key Lessons

6 No precursor recognized

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On the reported magnetic precursor of the 1989 Loma Prieta earthquake

Jeremy N. Thomas[a,b,*], Jeffrey J. Love[a], Malcolm J.S. Johnston[c]

[a] Geomagnetism Program, U.S. Geological Survey, Denver, CO, United States
[b] Department of Earth and Space Sciences, University of Washington, Seattle, WA, United States
[c] Earthquake Hazards Program, U.S. Geological Survey, Menlo Park, CA, United States

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ABSTRACT

Among the most frequently cited reports in the science of earthquake prediction is that by Fraser-Smith et al. (1990) and Bernardi et al. (1991). They found anomalous enhancement of magnetic-field noise levels prior to the 18 October 1989 Loma Prieta earthquake in the ultra-low-frequency range (0.0110–10.001 Hz) from a ground-based sensor at Corralitos, CA, just 7 km from the earthquake epicenter. In this analysis, we re-examine all of the available Corralitos data (21 months from January 1989 to October 1990) and the logbook kept during this extended operational period. We also examine 1.0-Hz (1-s) data collected from Japan, 0.0167-Hz (1-min) data collected from the Fresno, CA magnetic observatory, and the global *Kp* magnetic-activity index. The Japanese data are of particular importance since their acquisition rate is sufficient to allow direct comparison with the lower-frequency bands of the Corralitos data. We identify numerous problems in the Corralitos data, evident from both straightforward examination of the Corralitos data on their own and by comparison with the Japanese and Fresno data sets. The most notable problems are changes in the baseline noise levels occurring during both the reported precursory period and at other times long before and after the earthquake. We conclude that the reported anomalous magnetic noise identified by Fraser-Smith et al. and Bernardi et al. is not related to the Loma Prieta earthquake but is an artifact of sensor-system malfunction.

E Parkfield, 2004

1 Similar prior earthquakes of M≈6: 1881, 1901, 1922, 1934, 1966

2 Mean inter-event time of 21.8 ± 5.2 years

3 Forecast in 1985 for a 1988 (± 5 years) quake

4 Predicted earthquake of M=6.0 occurred in 2004

http://en.wikipedia.org/wiki/Parkfield_earthquake