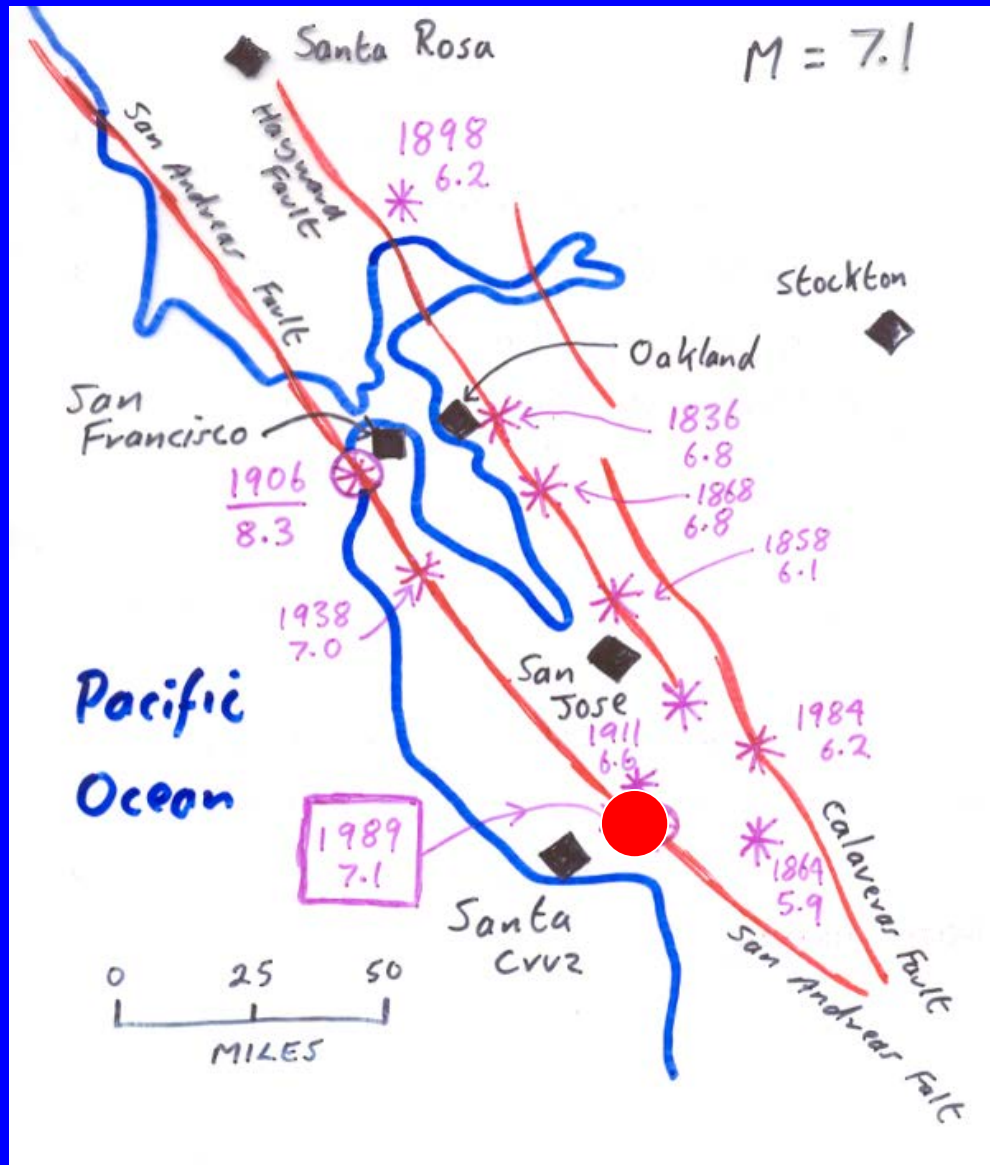


# VIDEO

## The 2011 Japanese Earthquake and Tsunami

- Why was it so large and devastating?
- Why so short a warning?
- Why did tsunami precautions fail?
- What happened elsewhere?

# The Loma Prieta Earthquake (1989)



Location of the magnitude 7.1 Loma Prieta earthquake along the San Andreas Fault (near Santa Cruz).

# Damage due to Ground Shaking



Collapse of sides of un-reinforced masonry buildings.  
5 people killed in cars underneath

# Damage due to slumping and liquefaction especially in the Marina District



Many houses sustained cracks and were shifted on their foundations.



This one moved 10 cms



(more on slumping and liquefaction)



Ground movement caused differential settling of buildings.



Liquefaction magnified the effects of the earthquake causing collapse of buildings



Others were totally destroyed or had to be demolished





Liquefaction resulted in the collapse of 51 spans of the double-decked Interstate 880. Forty one motorists were crushed to death.



The upper deck of the San Francisco Oakland Bay Bridge also collapsed.

....and of course there were fires



Rubble after a fire in the Marina District. As in 1906, water mains burst and water had to be pumped from a fireboat in order to fight fires.

Nine people died in the Marina District as a result of building collapse and fires.



# EARTHQUAKE DAMAGE

Each year, on average, there are:-

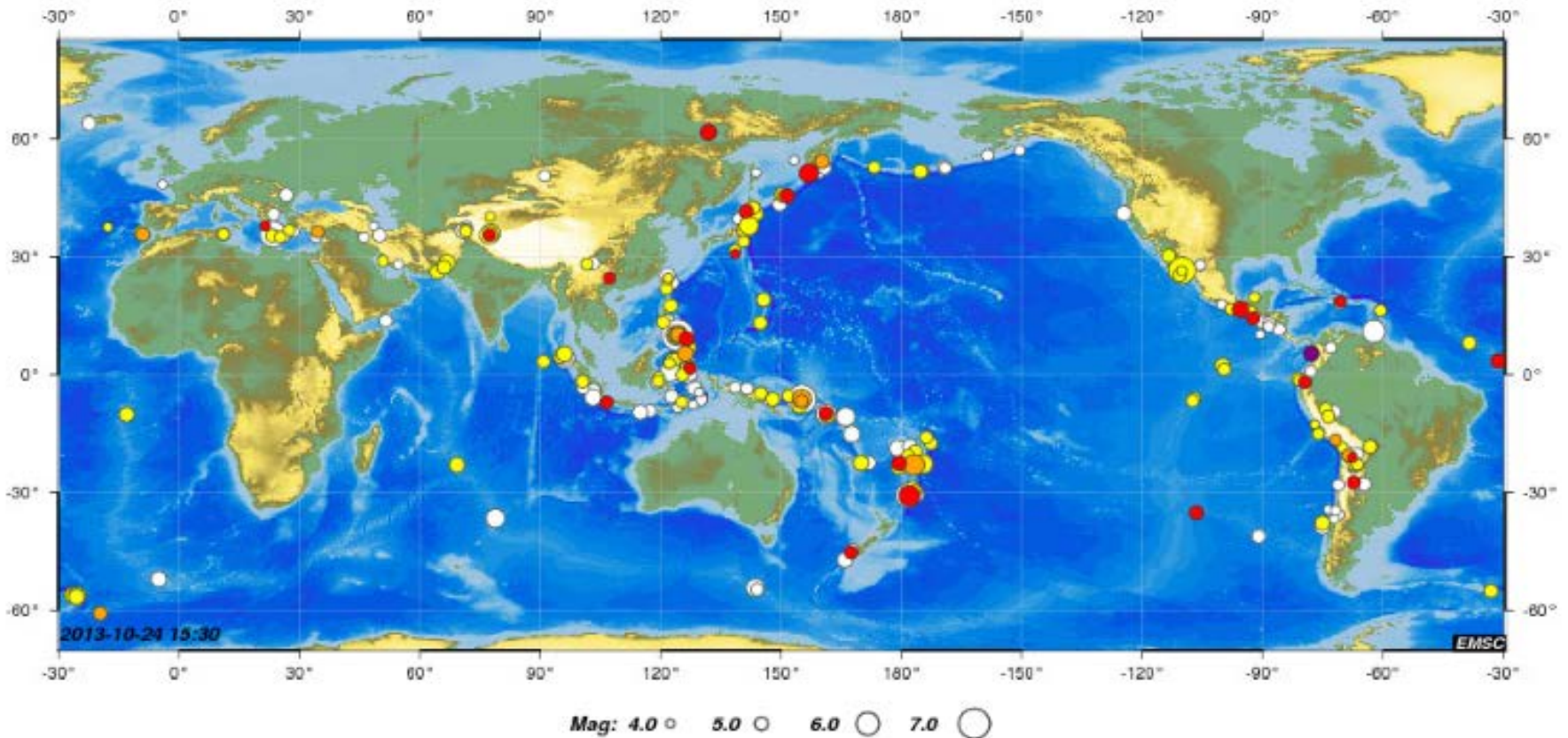
- ❑ About 100 earthquakes with  $M > 6$ .
- ❑ About 20 earthquakes with  $M > 7$ .

(in other words about two a week for  $M > 6$  earthquakes and one every three weeks for those with  $M > 7$ )

# The Last Two Weeks

Choose your map :  Last 1h  Last 24h  Last 48h  Last week  Last 2 weeks

340 earthquakes on this map



**M > 3**

# Causes of Damage

- Faulting
- Ground Shaking
- Differential Ground Settling
- Liquefaction
- Slumping, Landslides, Avalanches
- Floods from broken dams, levees etc.
- Floods and damage from Tsunamis
- Fires



# Damage due to Faulting



Railway track buckled by faulting. Guatemala 1976 (M = 7.5)



Freeway damaged by faulting. San Fernando, 1971 (M = 6.7)

# Faulting



Almaden Winery 1.5 cm/yr



Hollister, CA



Hayward Fault, Hayward

Curb  
movement  
over 20 yrs



These are all examples of **fault creep**



# Ground Shaking



Factory collapse, Italy 1980  
(M = 6.9)



Total collapse of Buddhist temple, while modern quake resistant buildings are left standing. Kobe, Japan 1995  
(M = 6.9)



Store collapse  
Northridge, CA  
1994 (M = 6.8)





Supposedly quake resistant building has supports sheared at base by horizontal shaking. El Centro, CA 1979 (M = 6.9)



Oakland Bridge collapse. Loma Prieta, CA 1989 (M = 7.1)



San Fernando, CA 1971  
( $M = 6.7$ )  
Collapse of freeway  
overpass.



Bridge collapse, Niigata, Japan  
1964 ( $M = 7.4$ )

# Ground Movement

Ground movement occurs during earthquakes to varying degrees:-

- Differential settling
- Slumping
- Landslides
- Avalanches

*LOW*



*HIGH*

Liquefaction plays a very important role in all of these, involving poorly consolidated and water-logged ground.



# Ground Settling



Caracas, Venezuela 1967  
(M = 6.7)



Niigata, Japan 1964 (M = 7.4)



Kobe, Japan 1995  
(M = 6.9)

# Slumping



Alaska 1964  
Slumping led to ground movement, buckling rail lines.



Washington, 1965 (M = 6.5)  
Ground slid away from beneath Union Pacific railroad





Anchorage, Alaska, 1964  
School drops almost one story due to slumping.



Anchorage, Alaska, 1964  
Street level drops about 10 feet and moves 14 feet horizontally due to liquefaction.





Montana, 1959  
Road slumps into lake



Anchorage, Alaska, 1964  
Liquefaction causes ground to  
slide 2000 ft and chaotically  
break up at Turnagain Heights.

# Landslides



Earthquake triggered landslide blocks road in Northern California.  
(M = 6.2)



Debris slide partially blocks highway at Palm Springs, CA  
(M = 6.0)



# Fires

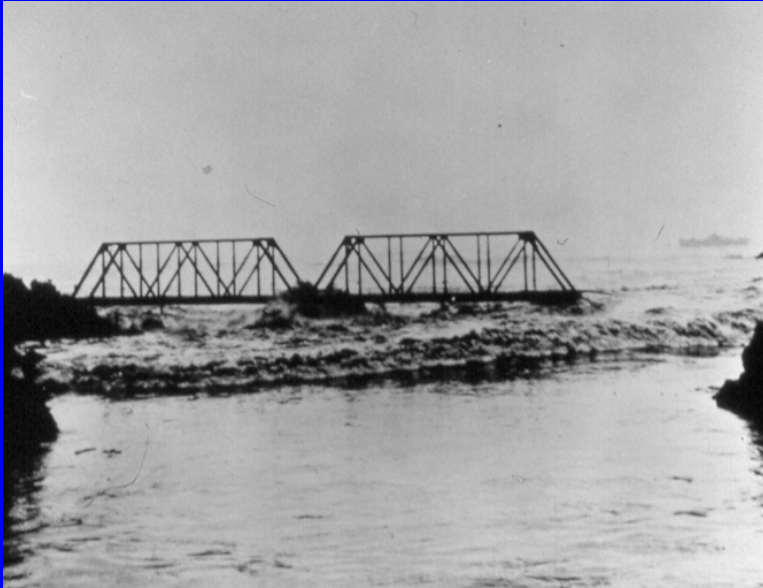


Kobe, Japan 1995 (M = 6.9)  
The earthquake occurred at 5:46 a.m. - five hours later, much of Kobe was on fire with about 150 simultaneous fires.



Collapsed buildings prevent firefighters from getting to fires. Also, there was no water pressure due to burst pipes.

# Tsunamis



Hilo, Hawaii, 1946  
Waves (15 feet) damage  
bridge.



Indonesia, 1992  
This was the site of a village  
on the island of Babi.  
Everything was destroyed by  
80 foot waves.



# Flooding

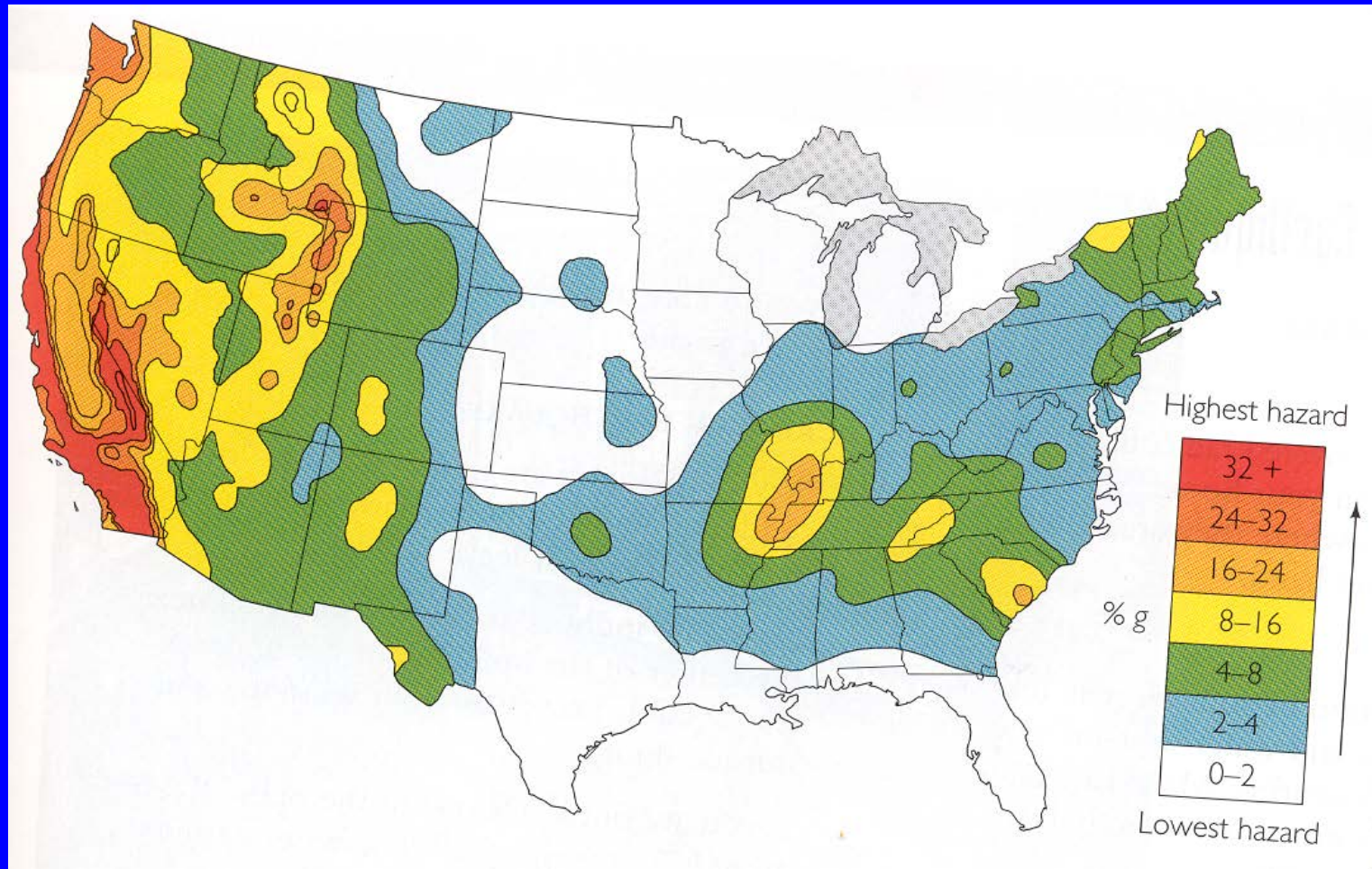


San Fernando, CA, 1971  
Partial collapse of dam  
resulted in evacuation of  
residents down-stream.



Flooding in Kobe, Japan, 1995  
due to subsidence caused by  
liquefaction.

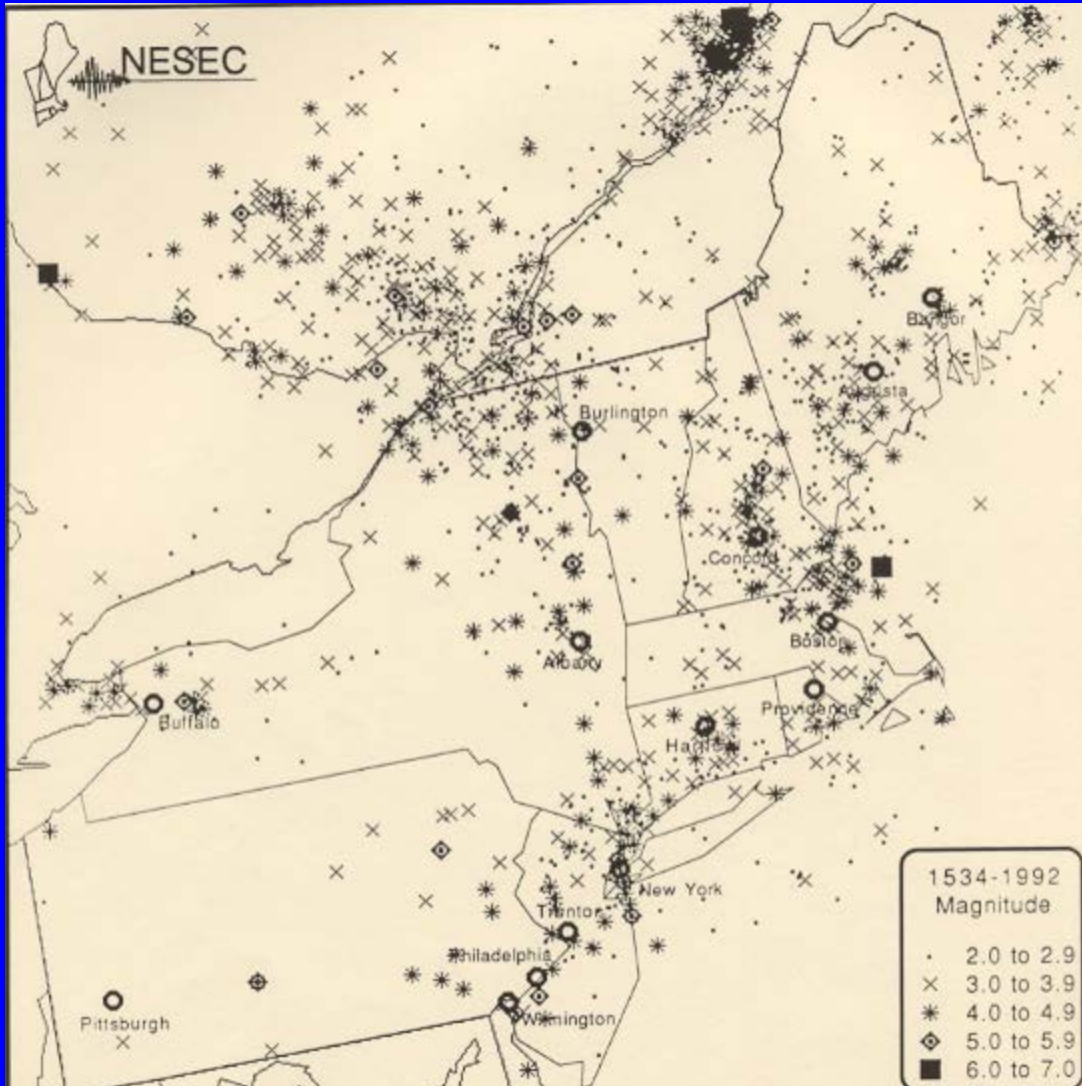
# Can Earthquakes Occur in New England?



(Brightest colors imply highest risk from earthquakes)



# New England Earthquakes



Most have been small ( $M = 2 - 4$ ), but there have been larger ones ( $M = 5 - 7$ ).

Note how the earthquakes tend to cluster in zones

# New England Earthquakes

Typically, there can be as many as 20-30 earthquakes each year in New England and surrounding areas.

Most of these are small (magnitude 2-3) and are rarely felt (perhaps about 5 each year).

***There have, however, been some big ones***



# The Big Ones!

- 1633, St. Lawrence, Canada
- 1727, Newbury, Massachusetts
- 1755, Cape Ann, Massachusetts
- 1791, Moodus, Connecticut
- 1925, Quebec, Canada
- 1945, Ossipee, New Hampshire
- 1944, Massena, New York
- 1982, Central New Hampshire
- 1983, Northern New York

(these were estimated to be between 5 and 7 on the Richter scale)

# What are our chances?

- Earthquakes of magnitude 5 and above are potentially damaging.
- The probability for such an earthquake is about 1 in 20 (about 1 every 20 years).
- The probability of a large earthquake (like Cape Ann, magnitude about 6.5) is about 1 in 200 (about 1 every 200 years).
- It has been estimated that a repeat of a Cape Ann earthquake could cause \$2-5 billion in damage to Boston.