Measuring the Size of an Earthquake

- Would like a measure of energy release
- Measure amplitude of seismic waves
  - Larger Eq -> larger amplitude
- Need logarithmic scale – enormous range
  - Factor of 10 in ground movement per step
  - Factor of 30 energy increase per step

M	Amplitude of wave	Energy	Number per year
1	1	1	
2	10	30	
3	100	900	
4	1000	27,000	20,000
5	10,000	810,000	2000
6	100,000	24,300,000	200
7	1,000,000	729,000,000	20
8	10,000,000	21,870,000,000	<1

Earthquake Frequency

- Four earthquakes in the twentieth century met or exceeded magnitude 9.0.
  - 1952 in Kamchatka (M = 9.0).
  - 1957 in the Aleutian Island (M = 9.1).
  - 1964 in Alaska (M = 9.2).
  - 1960 in Chile (M = 9.5).

Earthquake Hazard

- Seismic events are most common along plate boundaries.
- Earthquakes associated with hot spot volcanism pose a hazard to Hawaii.
- Earthquakes are common in much of the intermontane western United States (Nevada, Utah, and Idaho).
- Several large earthquakes jolted central and eastern North America in the nineteenth century (New Madrid, Missouri, 1811 and 1812).

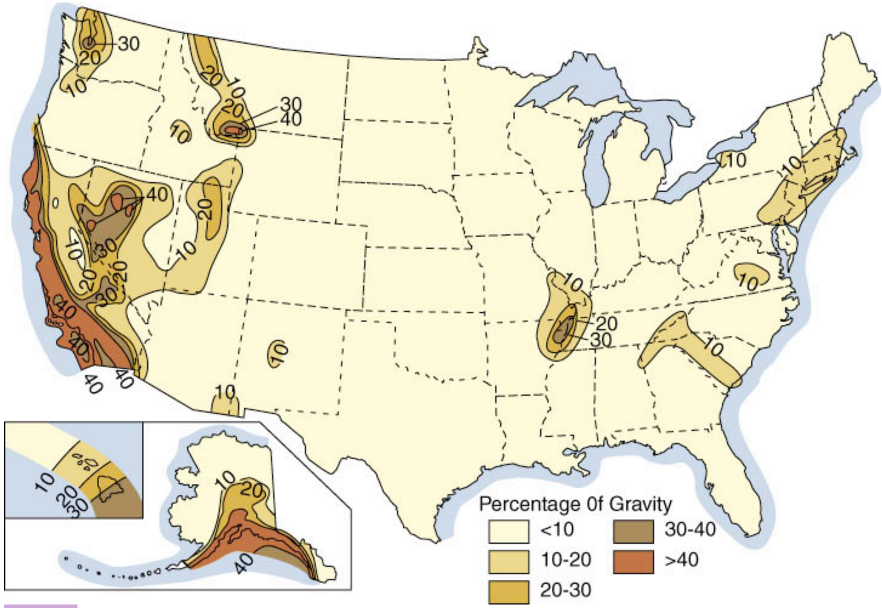


Figure 10.10

Earthquake Disasters

- In Western nations, urban areas that are known to be earthquake-prone have special building codes that require structures to resist earthquake damage.
  - However, building codes are absent or ignored in many developing nations.
- In the 1976 T'ang Shan earthquake in China, 240,000 people lost their lives.

Earthquake Disasters

- Eighteen earthquakes are known to have caused 50,000 or more deaths apiece.
- The most disastrous earthquake on record occurred in 1556, in Shaanxi province, China, where in estimated 830,000 people died.

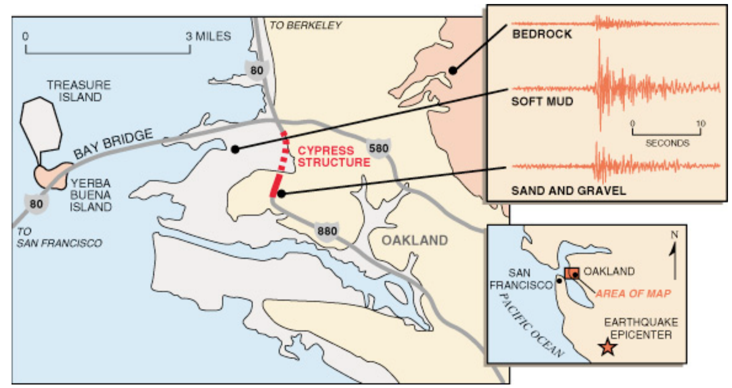
Earthquake Damage

- Primary effects:
  - Ground motion results from the movement of seismic waves.
  - Where a fault breaks the ground surface itself, buildings can be split or roads disrupted.

Earthquake Damage

- Secondary effects:
  - Ground movement displaces stoves, breaks gas lines, and loosens electrical wires, thereby starting fires.
  - In regions of steep slopes, earthquake vibrations may cause regolith to slip and cliffs to collapse.
  - The sudden shaking and disturbance of water-saturated sediment and regolith can turn seemingly solid ground to a liquid mass similar to quicksand (liquefaction).
  - Earthquakes generate seismic sea waves, called tsunami, which have been particularly destructive in the Pacific Ocean.

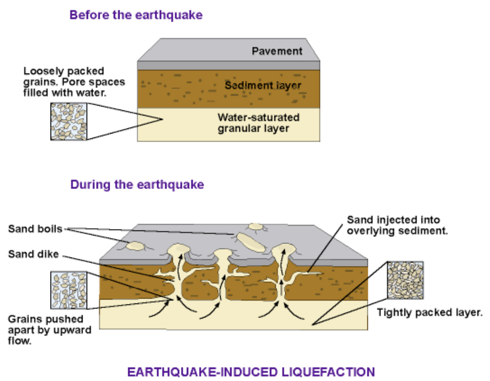
Site affects shaking amplitude



The Alaska Way Viaduct's twin in Oakland CA

Construction Standards Issue in Seattle

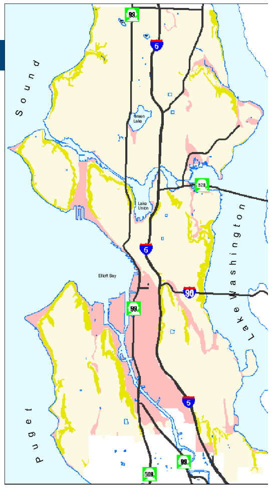
Soft soil is subject to liquefaction

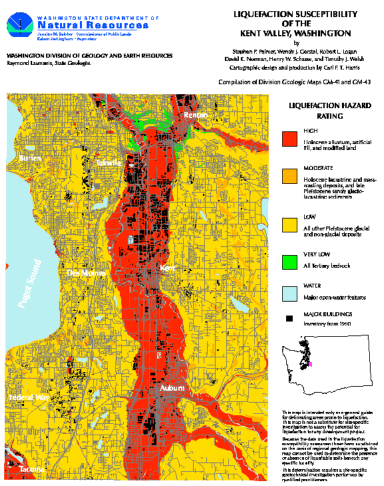


Liquefaction in Niigata, Japan, 1964

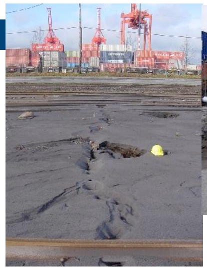
Good building performance requires a good foundation

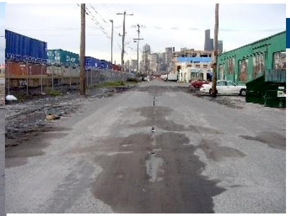
Liquefaction hazard in Seattle area





Liquefaction during the Nisqually earthquake



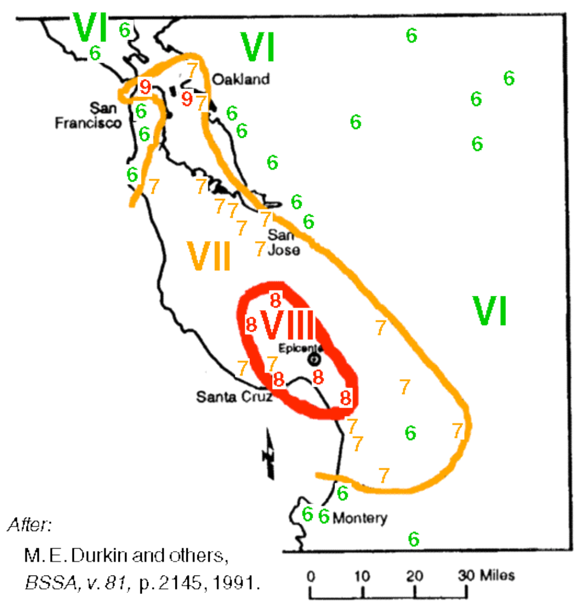


- Show Tsunami video

Modified Mercalli Scale

- Based on the extent of damage caused by quakes.
- 12 intensity levels in the modified Mercalli scale.
  - I, II, III, IV, …., XII
- Intensity depends on:
  - Distance from epicenter
  - Magnitude
  - Local conditions
  - Construction standards

Modified Mercalli Intensity Scale	
I	Recorded only by seismographs
II and III	Felt by some people who are indoors
IV	Felt by many people; windows rattle
V	Slight building damage; plaster cracks, bricks fall
VI and VII	Much building damage; chimneys fall; houses move on foundations
VIII and IX	Serious damage, bridges twisted, wall fractured; many masonry buildings collapse
XI	Great damage; most buildings collapse
XII	Total damage, waves seen on ground surface, objects thrown into the air



After:
M. E. Durkin and others,
BSSA, v. 81, p. 2145, 1991.

World Distribution of Earthquakes

- Subduction zones have the largest quakes.
- The circum-Pacific belt, where about 80 percent of all recorded earthquakes originate, follows the subduction zones of the Pacific Ocean.
- The Mediterranean-Himalayan belt is responsible for 15 percent of all earthquakes.

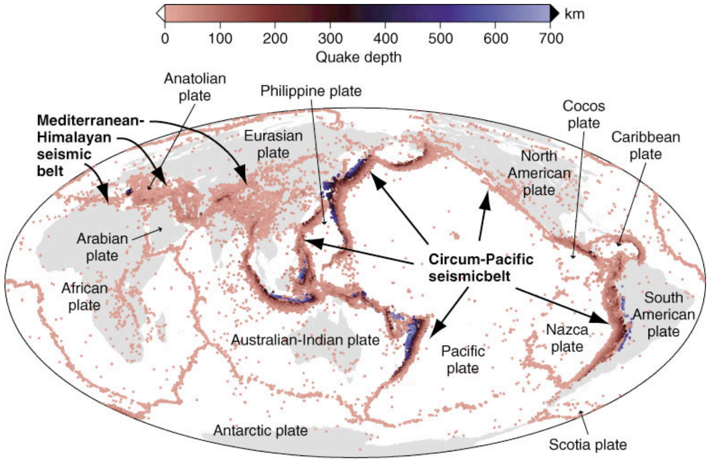


Figure 10.15

Depth of Earthquake Foci

- Most foci are no deeper than 100 km. down in the Benioff zone, that extends from the surface to as deep as 700 km.
- No earthquakes have been detected at depths below 700 km. Two hypotheses may explain this.
  - Sinking lithosphere warms sufficiently to become entirely ductile at 700 km depth.
  - The slab undergoes a mineral phase change near 670 km depth and loses its tendency to fracture.

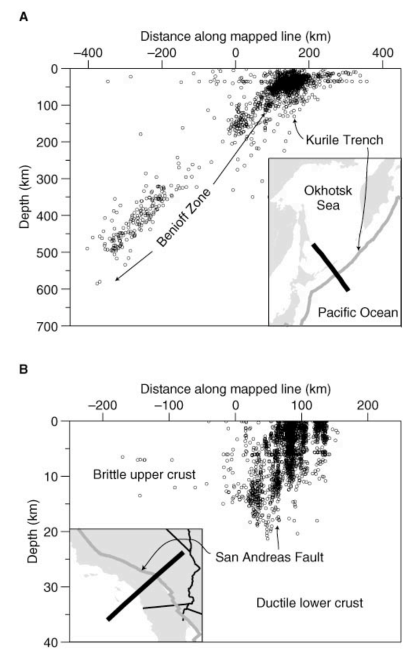


Figure 10.16

First-Motion Studies Of The Earthquake Source

- If the first motion of the arriving P wave pushes the seismometer upward, then fault motion at the earthquake focus is toward the seismometer.
- If the first motion of the P wave is downward, the fault motion must be away from the seismometer.
- S-waves and surface waves also carry the signature of earthquake slip and fault orientation and can provide independent estimates of motion at the earthquake focus.

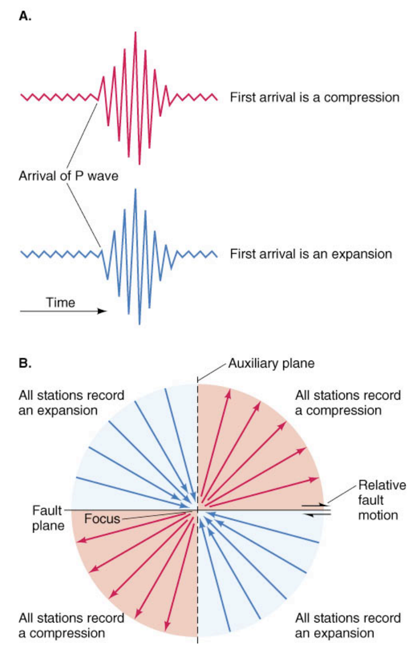


Figure 10.17

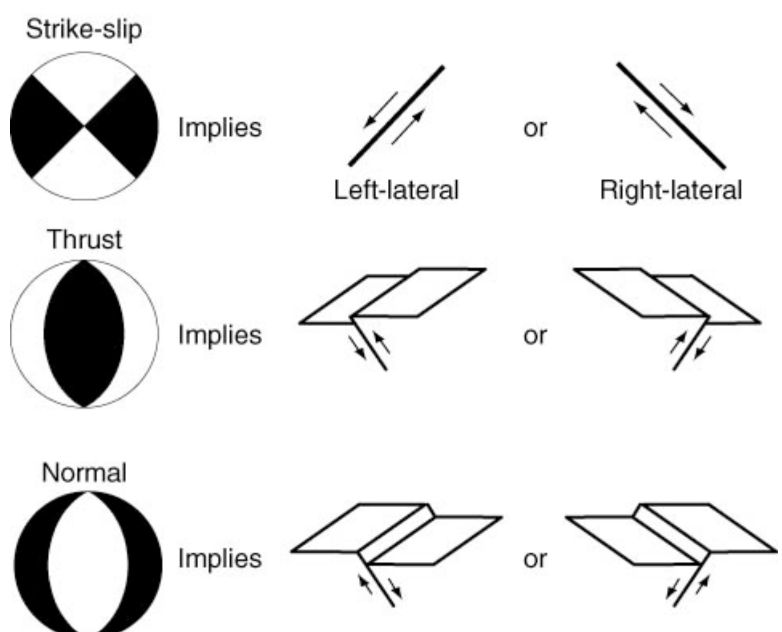


Figure 10.18

Earthquake Forecasting And Prediction

- ***Forecasting*** identifies both earthquake-prone areas and probabilities for future events.
  - Great progress in this work
- Earthquake ***prediction:*** an attempt to estimate precisely time, place, and severity.
  - Remains an elusive goal

Earthquake Cycle and Forecasts

- Earthquake forecasting is based largely on elastic rebound theory and plate tectonics.
- Stress accumulates due to plate motion. If all faults failed at the same stress level, then forecasts would be relatively simple
- Currently, seismologists use plate tectonic motions and Global positioning System (GPS) measurements to monitor the accumulation of strain in rocks near active faults.

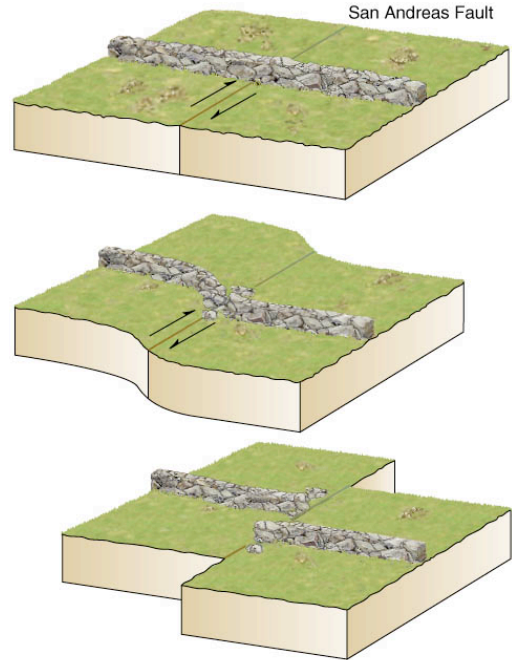
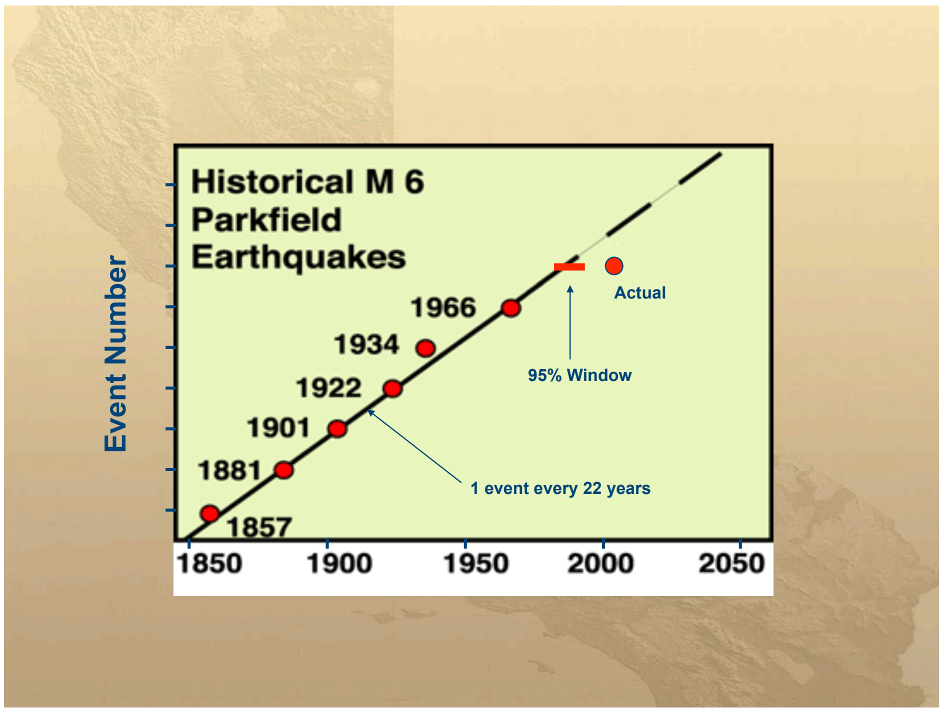


Figure 10.19



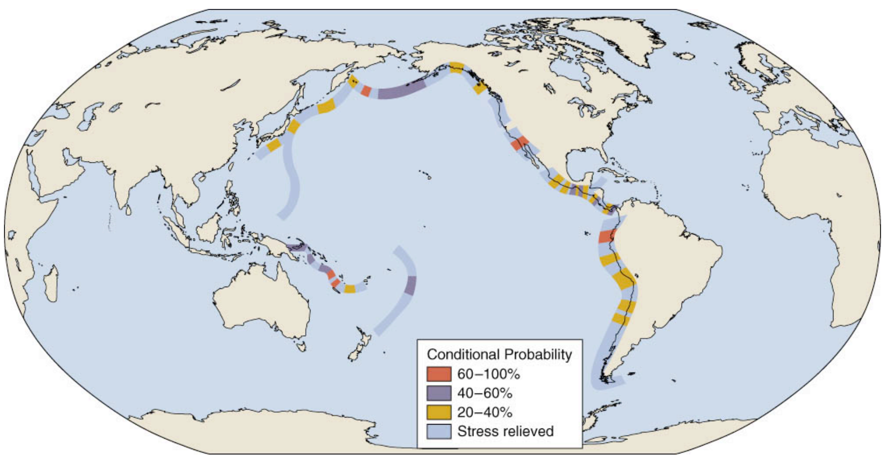


Figure 10.20

Earthquake Prediction

- Few successes.
- Based on precursors:
  - Foreshocks preceding some large earthquakes
  - Suspicious animal behavior.
  - Unusual electrical signals.
  - Water table changes, enhanced radon release
  - Changes in P and S wave velocities
  - Many other possibilities

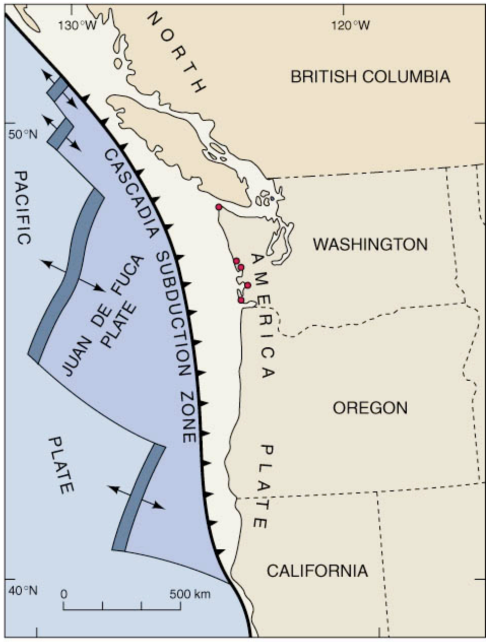


Figure B02

Cascadia "The Big One"

- When was the last Big One?
  - January 26, 1700 approx. 9 pm
  - M = 9+
- How soon before the next?
  - 7 in last 3500 years suggested in one study
    - As close together as 200 years, as far apart as 1000 years
  - More than 20 in a recent study
    - No more than about 200 years between events

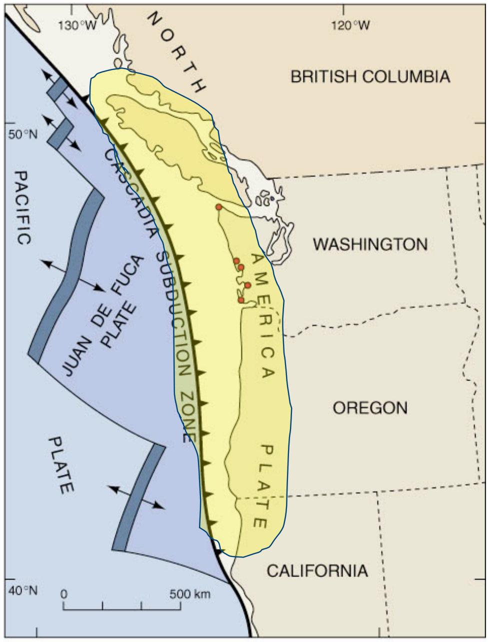
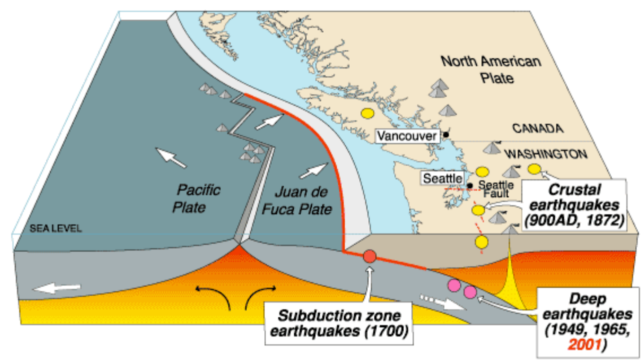


Figure B02

Cascadia earthquake sources



Source	Affected area	Max. Size	Recurrence
Subduction Zone	W.WA, OR, CA	M 9	500-600 yr
Deep Juan de Fuca plate	W.WA, OR,	M 7+	30-50 yr
Crustal faults	WA, OR, CA	M 7+	Hundreds of yr?