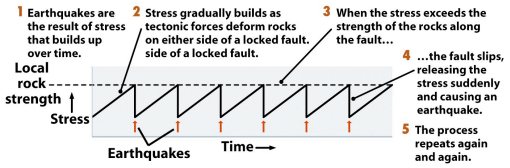
Earthquakes

Incoming tsunami from M=9.3 Sumatra EQ – 12/26/04 Death toll > 250,000

Earthquake "cycle" – repeating, but irregular

STRESS BUILDS UNTIL IT EXCEEDS ROCK STRENGTH



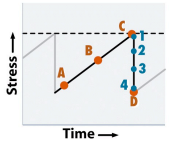
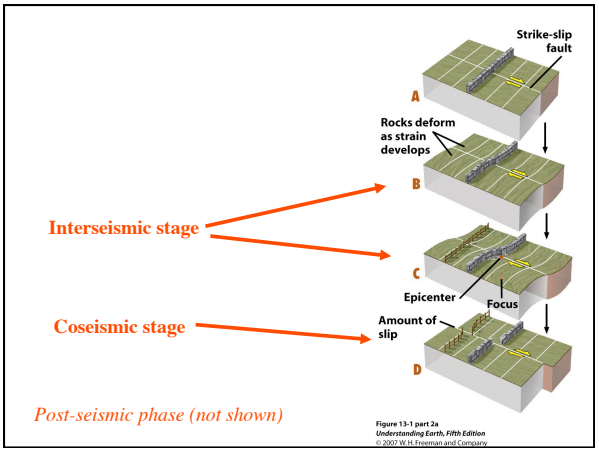
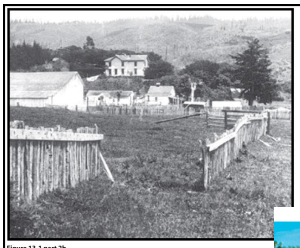


Figure 13-1 part 1
Understanding Earth, Fifth Edition
© 2007 W.H.Freeman and Company



Post-seismic phase (not shown)

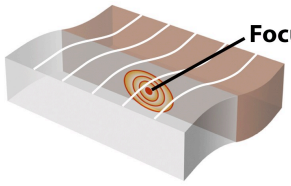
Figure 13-1 part 2a
Understanding Earth, Fifth Edition
© 2007 W.H.Freeman and Company



A fence built across the San Andreas fault near Bolinas, California, is offset by nearly 3 m after the great San Francisco earthquake of 1906.

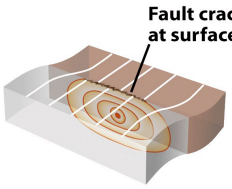
Figure 13-1 part 2b
Understanding Earth, Fifth Edition
© 2007 W.H.Freeman and Company

Rupture process – what happens ?



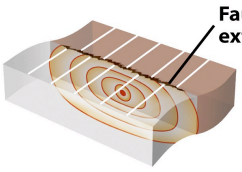
0 Seconds
Rupture expands circularly on fault plane, sending out seismic waves in all directions.

Figure 13-1 part 3a
Understanding Earth, Fifth Edition
© 2007 W.H.Freeman and Company



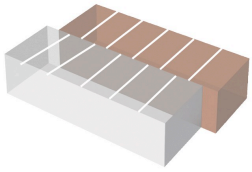
5 Seconds
Rupture continues to expand as a crack along the fault plane. When the rupture front reaches the surface, displacements occur along the fault trace, and rocks at the surface begin to rebound from their deformed state.

Figure 13-1 part 3b
Understanding Earth, Fifth Edition
© 2007 W.H.Freeman and Company



10 Seconds
The rupture front progresses down the fault plane, reducing the stress and allowing the rocks on either side to rebound. Seismic waves continue to be emitted in all directions as the fault propagates.

Figure 13-1 part 3c
Understanding Earth, Fifth Edition
© 2007 W.H.Freeman and Company



20 Seconds
Rupture has progressed along the entire length of the fault. The fault has reached its maximum displacement, and the earthquake stops.

Figure 13-1 part 3d
Understanding Earth, Fifth Edition
© 2007 W.H.Freeman and Company

Synopsis

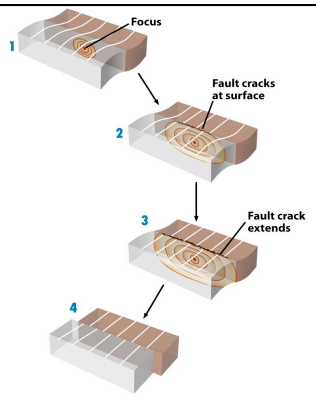


Figure 13-1 part 3
Understanding Earth, Fifth Edition
© 2007 W.H.Freeman and Company

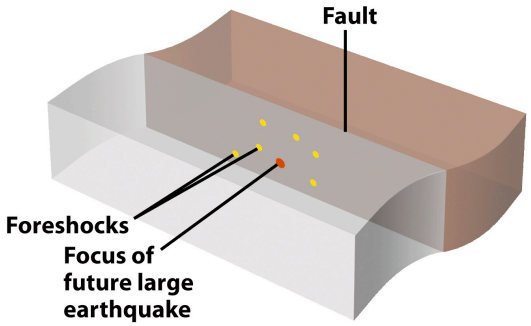


Figure 13-3 part 1
Understanding Earth, Fifth Edition
© 2007 W.H.Freeman and Company

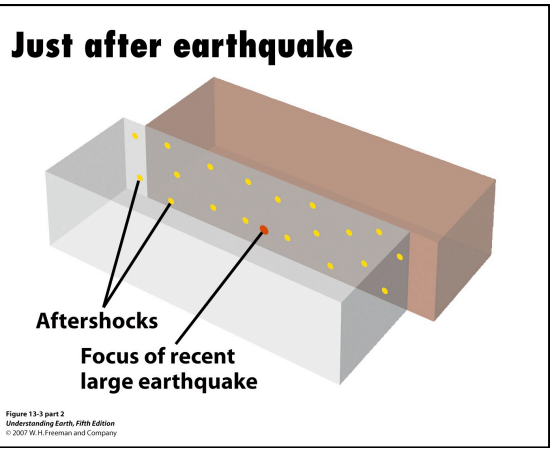


Figure 13-3 part 2
Understanding Earth, Fifth Edition
© 2007 W.H.Freeman and Company

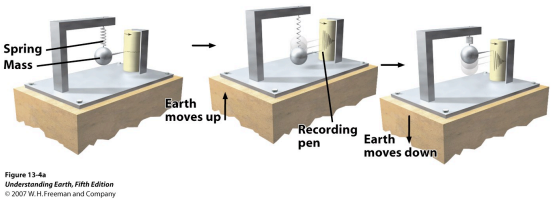
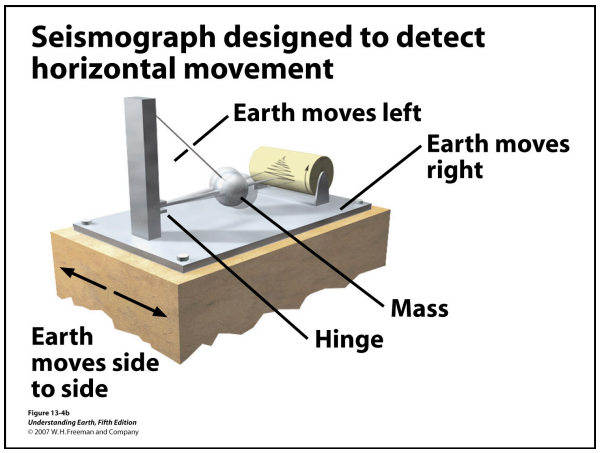
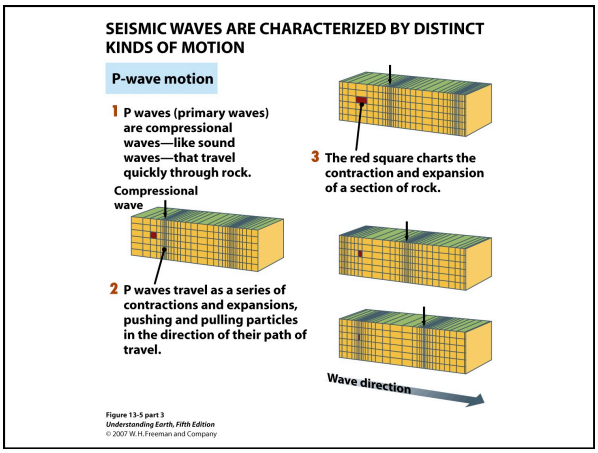
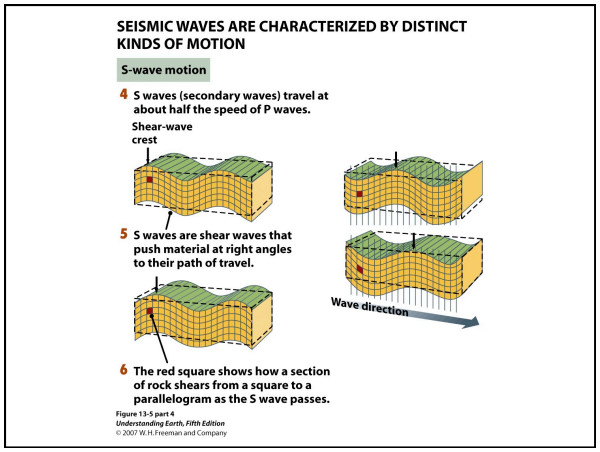
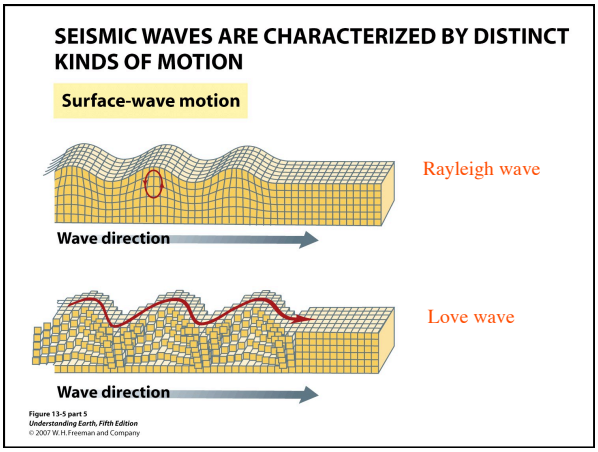


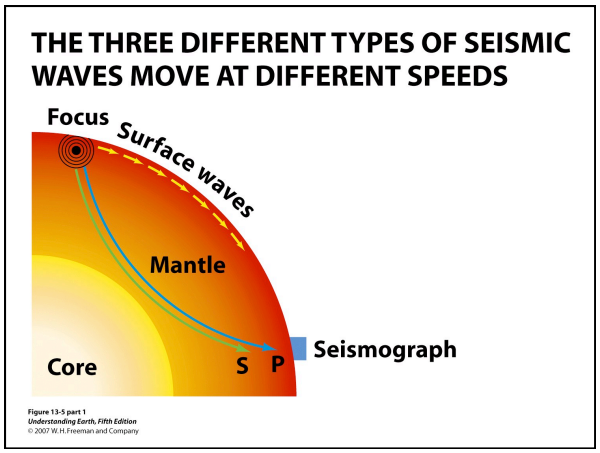
Figure 13-4a
Understanding Earth, Fifth Edition
© 2007 W.H.Freeman and Company

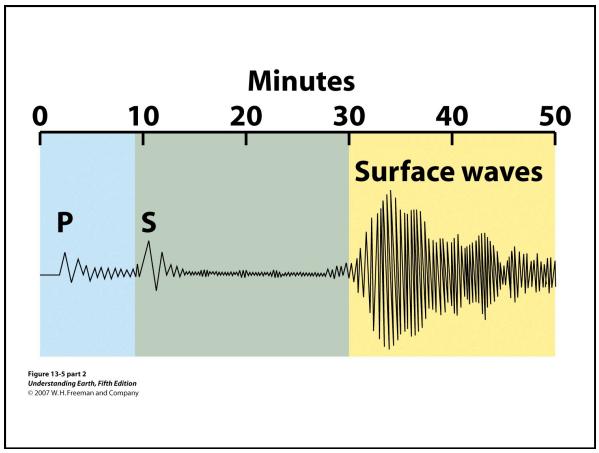

Seismograph designed to detect horizontal movement
Earth moves left
Earth moves right
Mass
Hinge
Earth moves side to side
Figure 13-4b
Understanding Earth, Fifth Edition
© 2007 W.H. Freeman and Company

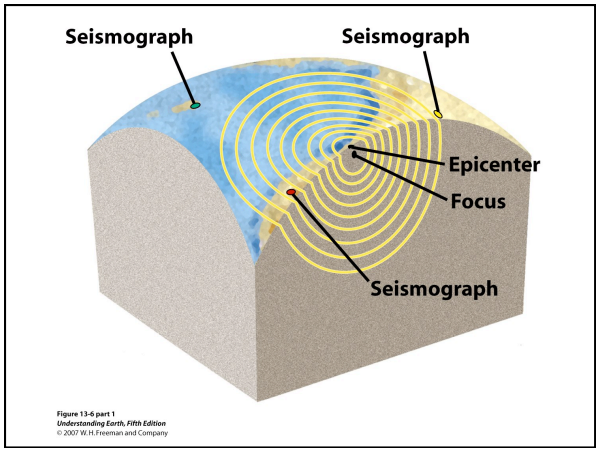

SEISMIC WAVES ARE CHARACTERIZED BY DISTINCT KINDS OF MOTION
P-wave motion
1 P waves (primary waves) are compressional waves—like sound waves—that travel quickly through rock.
Compressional wave
2 P waves travel as a series of contractions and expansions, pushing and pulling particles in the direction of their path of travel.
3 The red square charts the contraction and expansion of a section of rock.
Wave direction
Figure 13-5 part 3
Understanding Earth, Fifth Edition
© 2007 W.H. Freeman and Company

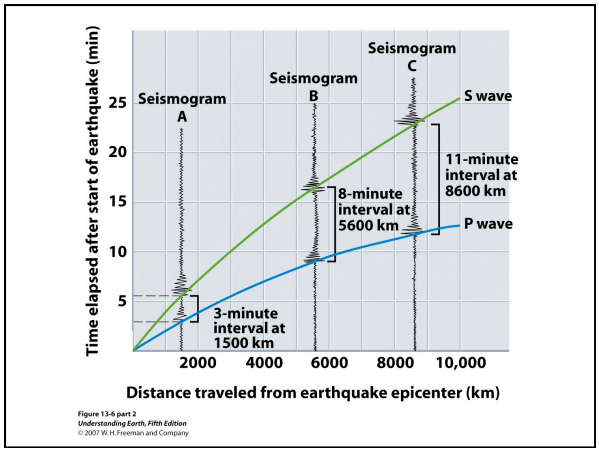

SEISMIC WAVES ARE CHARACTERIZED BY DISTINCT KINDS OF MOTION
S-wave motion
4 S waves (secondary waves) travel at about half the speed of P waves.
Shear-wave crest
5 S waves are shear waves that push material at right angles to their path of travel.
6 The red square shows how a section of rock shears from a square to a parallelogram as the S wave passes.
Wave direction
Figure 13-5 part 4
Understanding Earth, Fifth Edition
© 2007 W.H. Freeman and Company


SEISMIC WAVES ARE CHARACTERIZED BY DISTINCT KINDS OF MOTION
Surface-wave motion
Rayleigh wave
Wave direction
Love wave
Wave direction
Figure 13-5 part 5
Understanding Earth, Fifth Edition
© 2007 W.H. Freeman and Company


THE THREE DIFFERENT TYPES OF SEISMIC WAVES MOVE AT DIFFERENT SPEEDS
Focus
Surface waves
Mantle
Core
S
P
Seismograph
Figure 13-5 part 1
Understanding Earth, Fifth Edition
© 2007 W.H.Freeman and Company


Minutes
0
10
20
30
40
50
Surface waves
P
S
Figure 13-5 part 2
Understanding Earth, Fifth Edition
© 2007 W.H.Freeman and Company


Seismograph
Seismograph
Epicenter
Focus
Seismograph
Figure 13-6 part 1
Understanding Earth, Fifth Edition
© 2007 W.H.Freeman and Company


Time elapsed after start of earthquake (min)
25
20
15
10
5
Seismogram A
Seismogram B
Seismogram C
S wave
P wave
11-minute interval at 8600 km
8-minute interval at 5600 km
3-minute interval at 1500 km
2000
4000
6000
8000
10,000
Distance traveled from earthquake epicenter (km)
Figure 13-6 part 2
Understanding Earth, Fifth Edition
© 2007 W.H.Freeman and Company

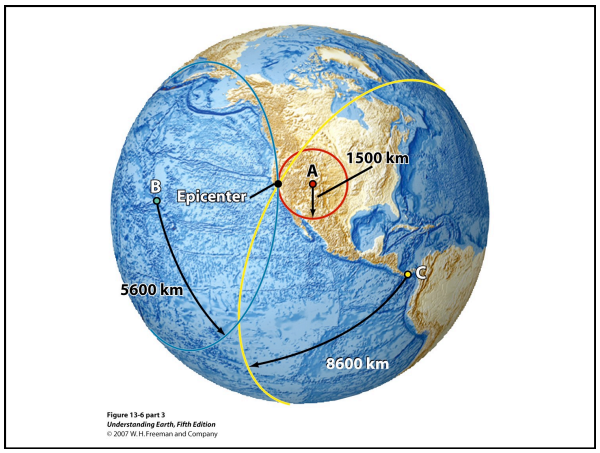
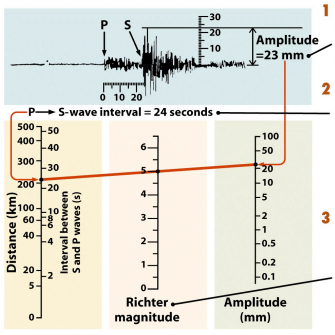


Figure 13-6 part 3
Understanding Earth, Fifth Edition

Estimating earthquake magnitudes

Richter magnitude (below) no longer used.



1. A geologist measures the amplitude of the largest seismic wave (23 mm)…
2. …and the time interval between the P-wave and S-wave arrivals (24 s) to determine the distance from the epicenter to the station (210 km).
3. By plotting the two measurements on these graphs and connecting the points, the geologist determines the Richter magnitude of the earthquake (5.0).

Figure 13-7
Understanding Earth, Fifth Edition

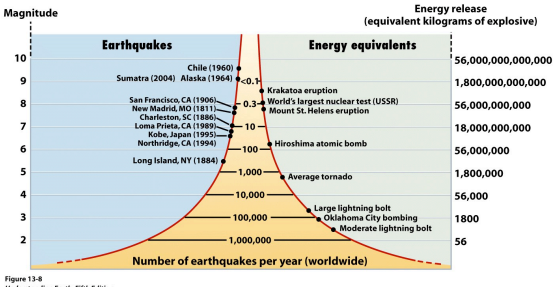


Figure 13-8
Understanding Earth, Fifth Edition

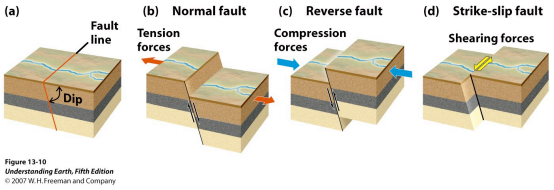


Figure 13-10
Understanding Earth, Fifth Edition

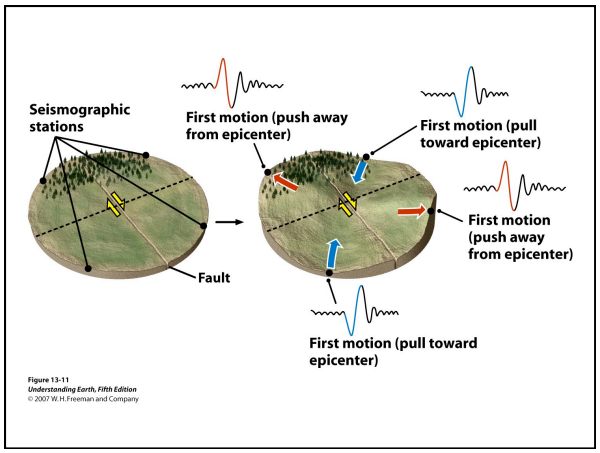


Figure 13-11
Understanding Earth, Fifth Edition

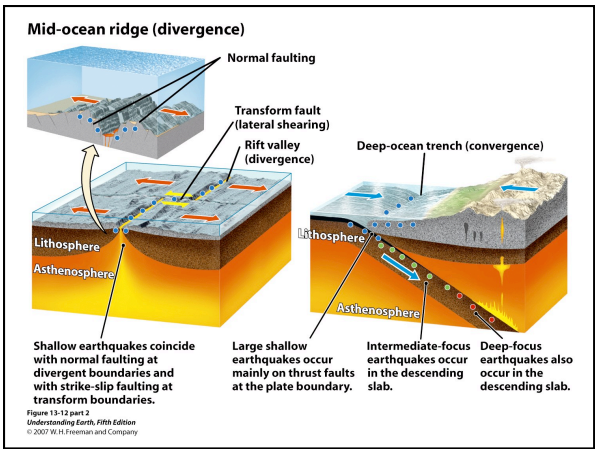


Figure 13-12 part 2
Understanding Earth, Fifth Edition

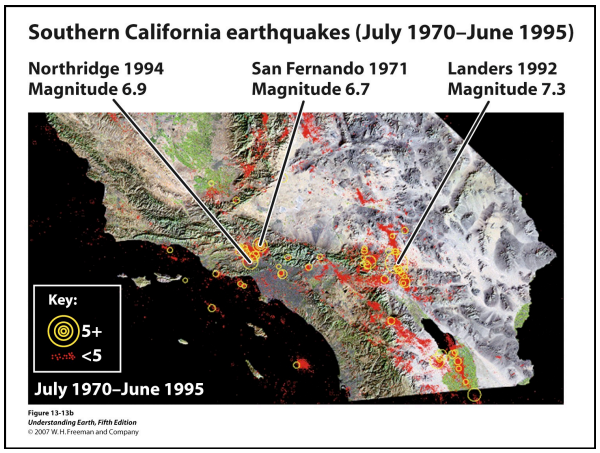


Figure 13-13b
Understanding Earth, Fifth Edition

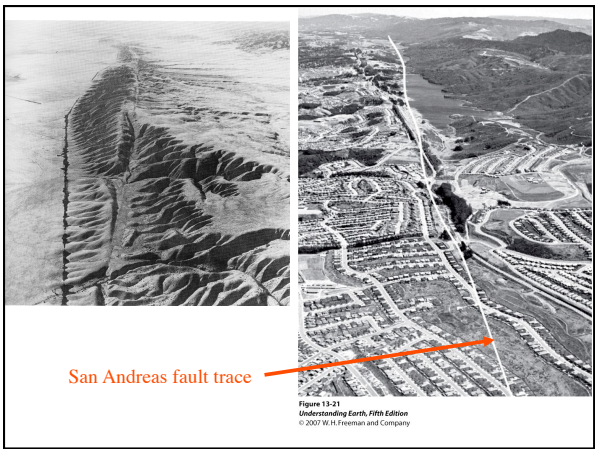
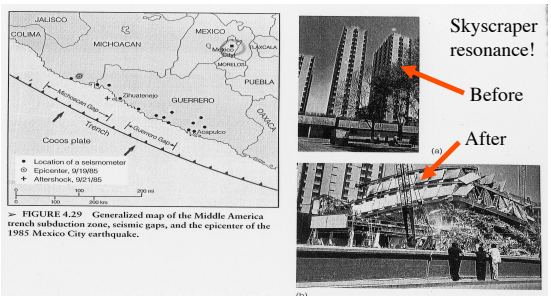


Figure 13-21
Understanding Earth, Fifth Edition

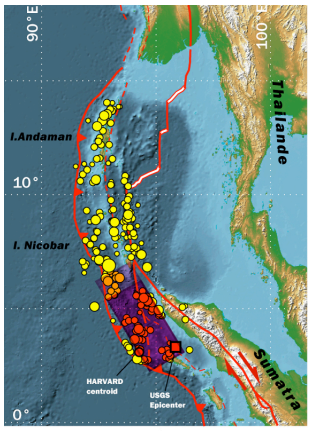
Collapsed portion of the Nimitz freeway, Oakland. Built on bay muds, it fell down during the Oct. 17, 1989 Loma Prieta M=7.1 earthquake

Figure 13-15
Understanding Earth, Fifth Edition
© 2007 W.H.Freeman and Company



➢ FIGURE 4.29 Generalized map of the Middle America trench subduction zone, seismic gaps, and the epicenter of the 1985 Mexico City earthquake.

Acapulco 1985 M=8.1 EQ – Mexico City effects – 5000 dead, $10 billion damage



M=9.2 Dec. 26, 2004 Sumatra earthquake
(rupture area defined by 2-week aftershocks)

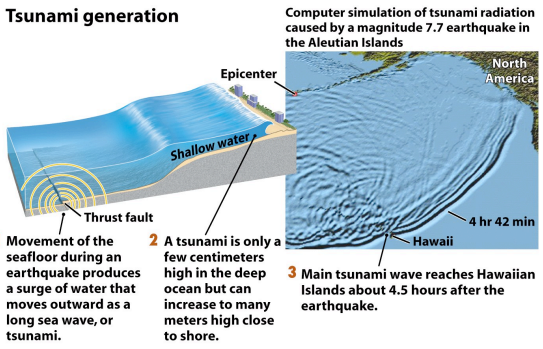
energy release equal to ~23,000 atomic bombs dropped on Hiroshima

700 mile rupture length. For reference, M=8.0 eqs in 1857 and 1906 along San Andreas ruptured about 200-300 miles of the fault

The Dec. 26, 2004 tsunami coming onshore in Thailand.

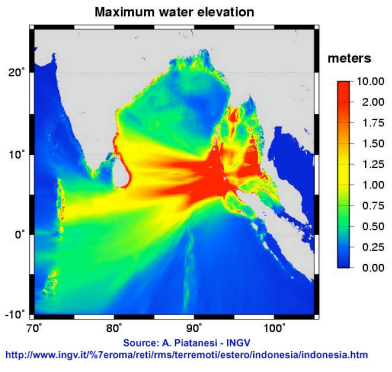
The approximate death toll of 228,000 that day was one of the worst five natural disasters of modern times

Tsunami wavelengths are 100s of km, so they mimic temporary increase in sea level. Not just like a really big ocean wave – more devastating.

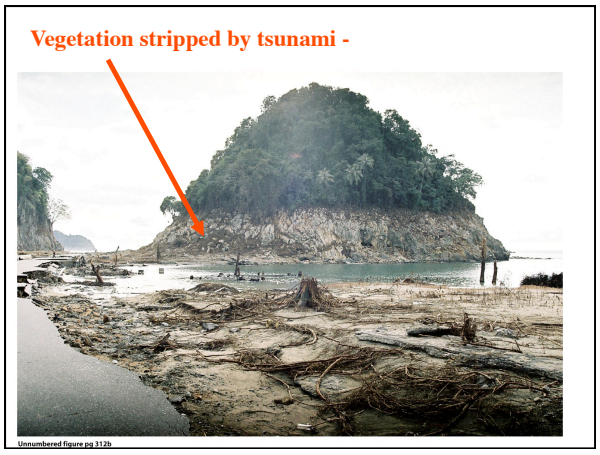


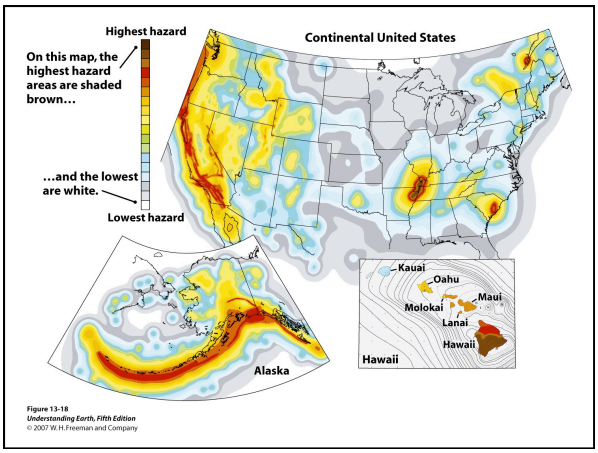
Tsunami heights for 12/26/04 earthquake

For reference, 10 meters is 33 feet.



Coastal Sumatra near epicenter one week after the earthquake.


Vegetation stripped by tsunami -
Unnumbered figure pg 312b


Highest hazard
On this map, the highest hazard areas are shaded brown…
…and the lowest are white.
Lowest hazard
Continental United States
Kauai
Oahu
Maui
Molokai
Lanai
Hawaii
Hawaii
Alaska
Figure 13-18
Understanding Earth, Fifth Edition
© 2007 W.H.Freeman and Company