

# EARTHQUAKES

# Earthquakes



March, 2011. Near Fukushima, Japan

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This tsunami was triggered by a 9.1 magnitude quake off the coast of Honshu.

## Reading Assignment

- Chapter 8 – Earthquakes and Earth's Interior.
- Write down the answers to the Concept Check questions.

# Learning Objectives

- <https://macearthscience.weebly.com/42-earthquakes.html>

# Earthquakes 101

- <https://macearthscience.weebly.com/42-earthquakes.html>

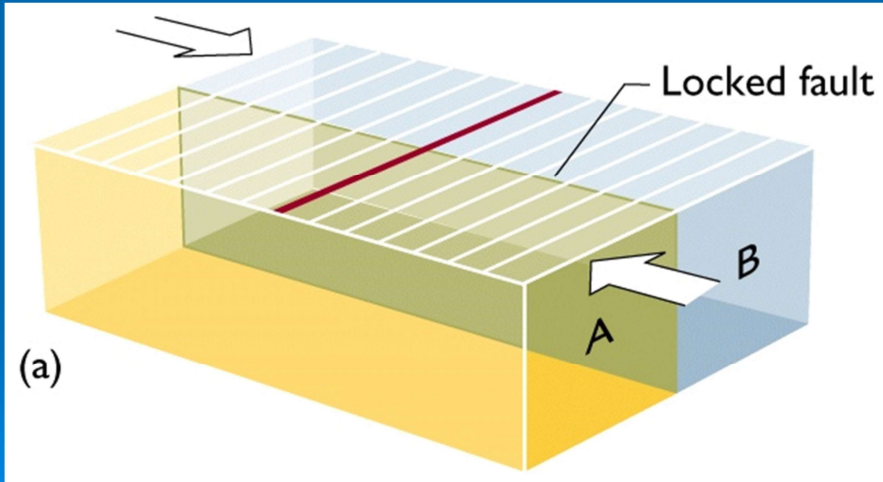
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- Click link, watch movie.

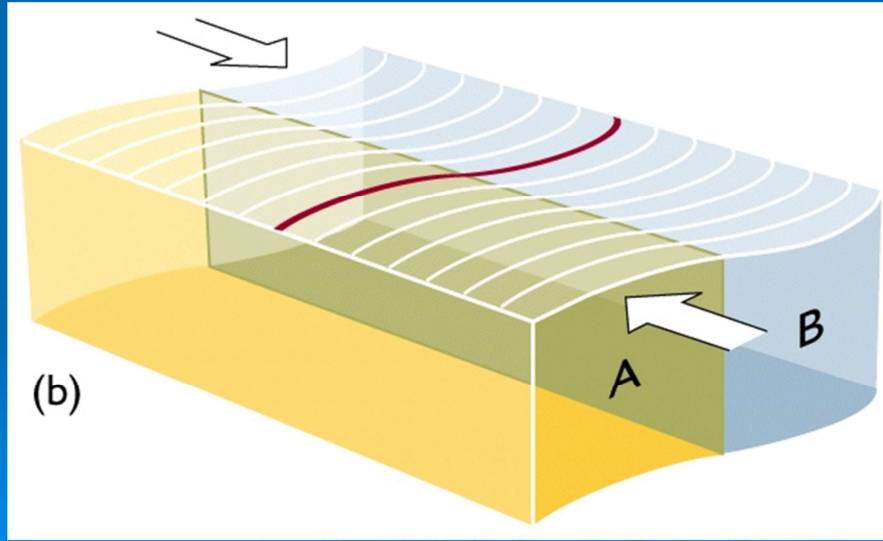
# Earthquake

- Vibration of Earth produced by a sudden release of energy.
- Associated with movements along *faults*.
- Often preceded by *foreshocks*.
- Often followed by *aftershocks*.
- These are sometimes called *tremors*

# Elastic Rebound Theory

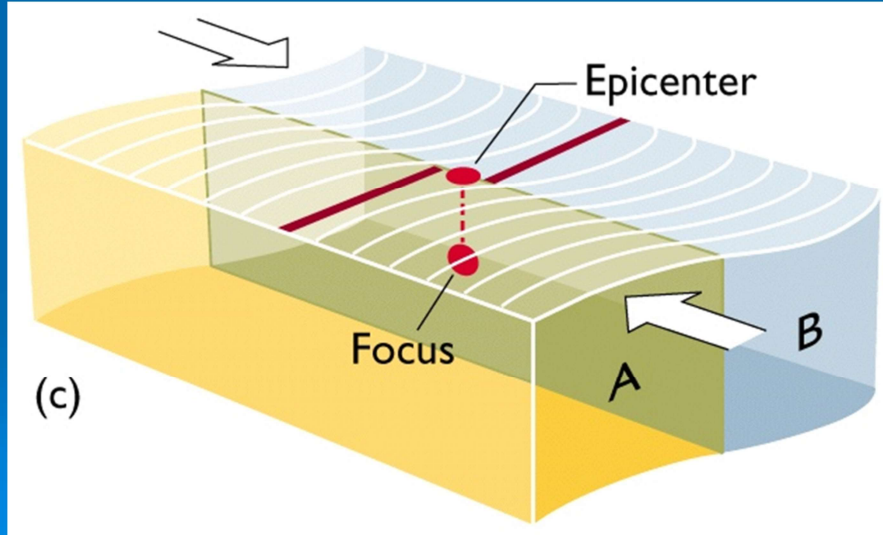


# Elastic Rebound Theory

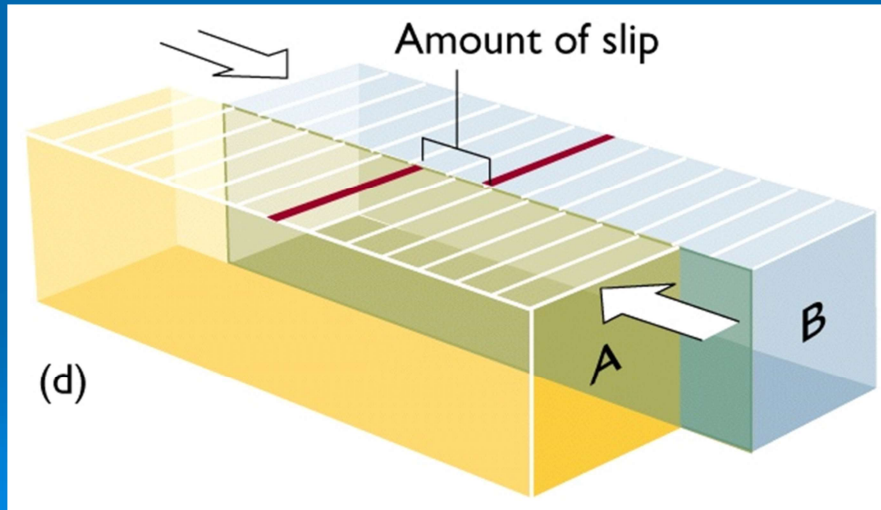




# Elastic Rebound Theory



# Elastic Rebound Theory



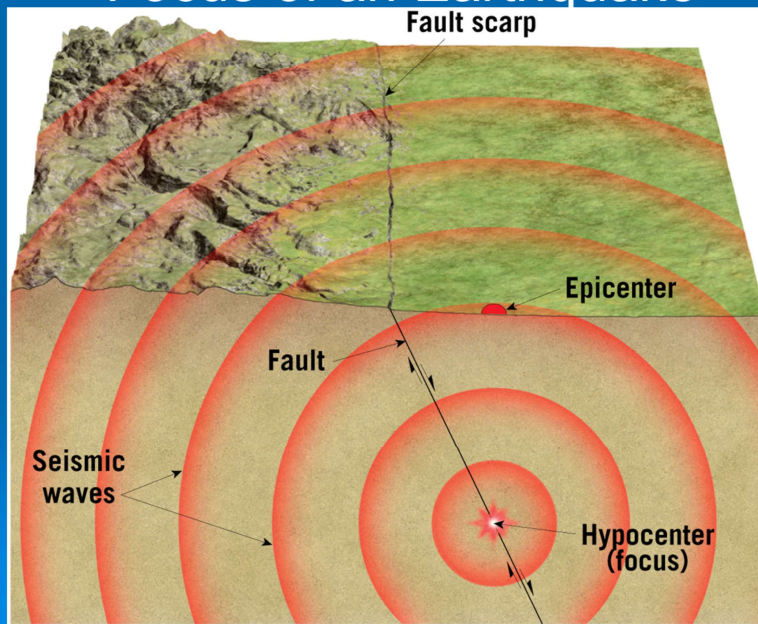
# Demonstration

## ➤ Elastic Rebound

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- Bend ruler over table; release.

# Seismic Waves Radiate from the Focus of an Earthquake

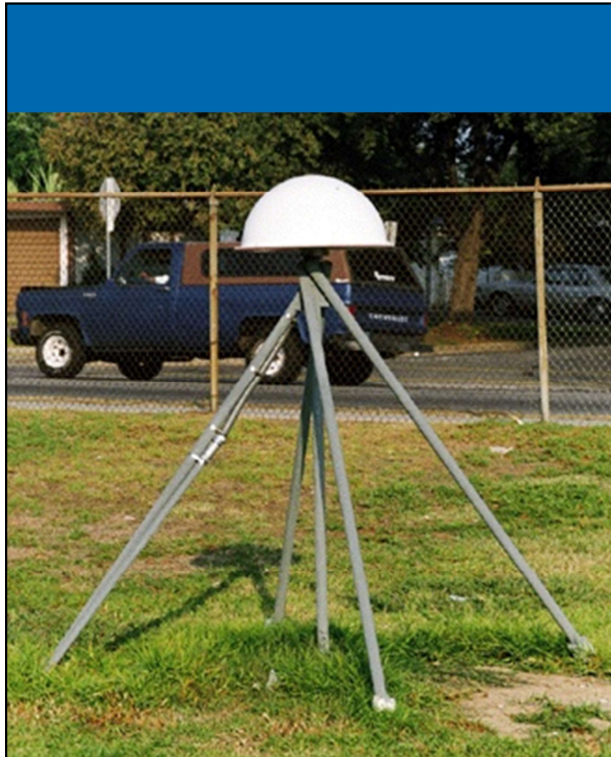


# Seismology

- Study of the propagation of mechanical energy; released by earthquakes and explosions through the Earth.
- When energy is released in this fashion, waves of motion (like the effect of a pebble tossed into a pond) are set up in the rocks surrounding the source of the energy (the focus).

# Seismic waves

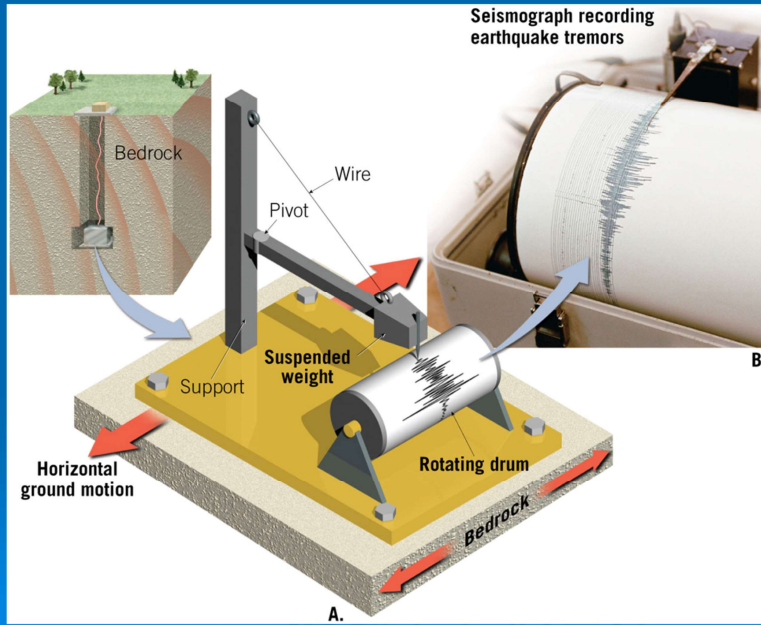
- Waves are started because of initial tension or compression in the rock.
- Instruments used to measure these waves are called seismographs.



# Global Positioning System (GPS) to Monitor Ground Motion

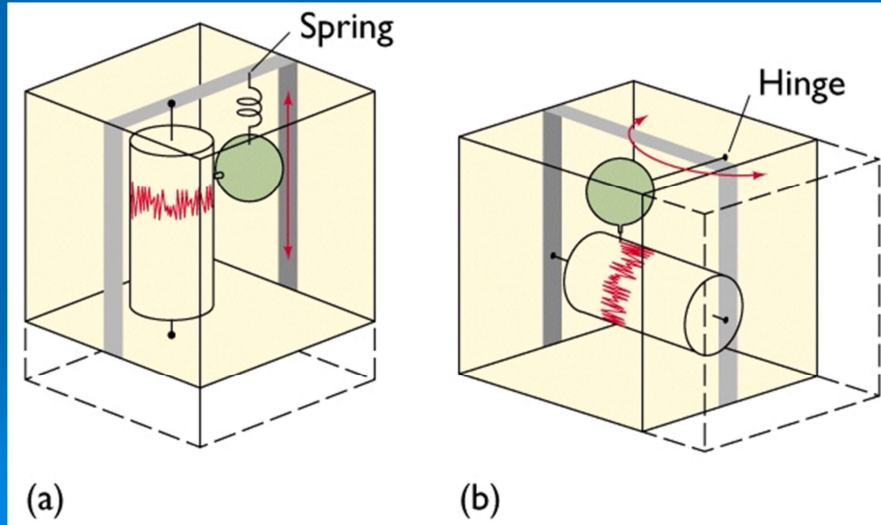
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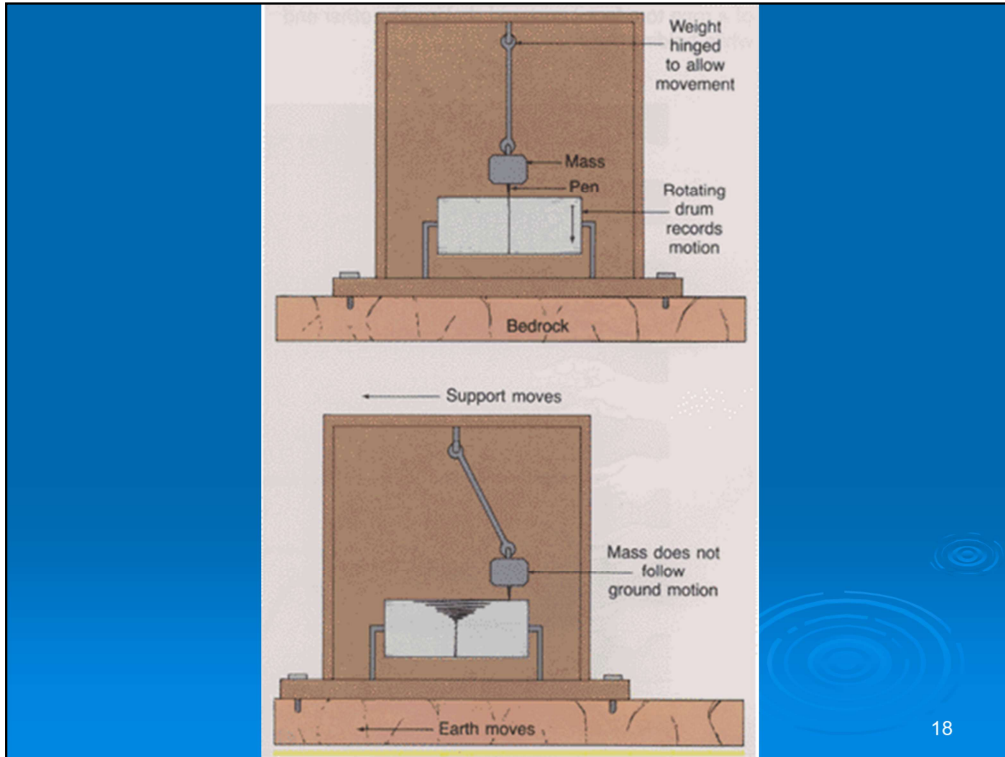
# Seismograph





# Seismographs Record Vertical or Horizontal Ground Motion





# Modern Seismograph



Kinematics

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## Check Questions

- A small earthquake called a(n) foreshock often precedes a major earthquake by days or even weeks.
- The source of an earthquake is called the focus.
- The “springing back” of a rock after it has been deformed is termed elastic rebound.

# Earthquake Waves

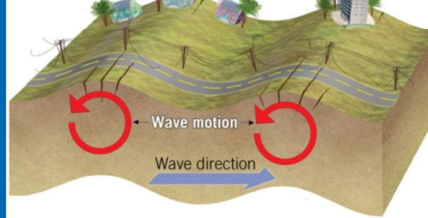


- *P waves (Primary. Push-Pull)* 6–8 km/s.
  - Parallel to direction of movement
  - Similar to sound waves.
  - Travel through all parts of the Earth.
- *S waves (Secondary. shear)* 4–5 km/s.
  - Perpendicular to direction of movement
  - Do not pass through liquids or gases.

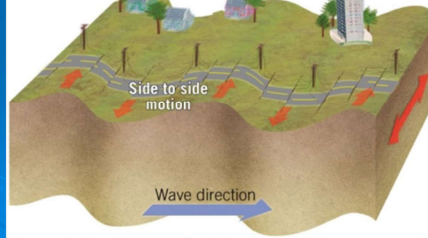
# Earthquake Waves

- Surface waves
  - 2-3 km/s
  - Complex motion
  - Cause majority of damage.

A. One type of surface wave travels along Earth's surface similar to rolling ocean waves. The red arrows show the movement of rock as the wave passes.



B. A second type of surface wave moves the ground from side to side and can be particularly damaging to building foundations.



# Demonstration

- Different Types of Waves with a slinky.

# Earthquake Waves

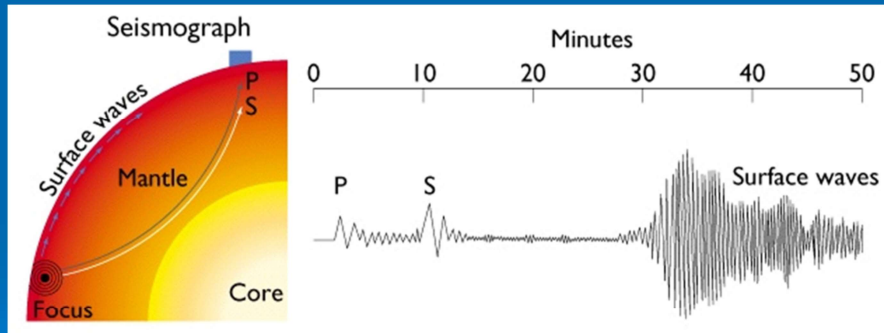


## ➤ Summary

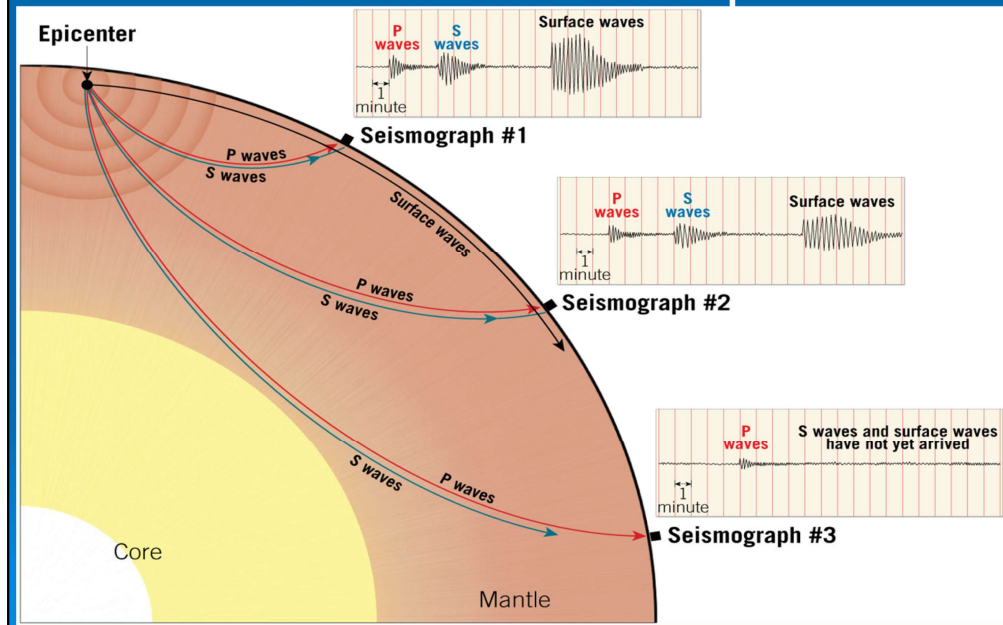
- <https://macearthscience.weebly.com/42-earthquakes.html>



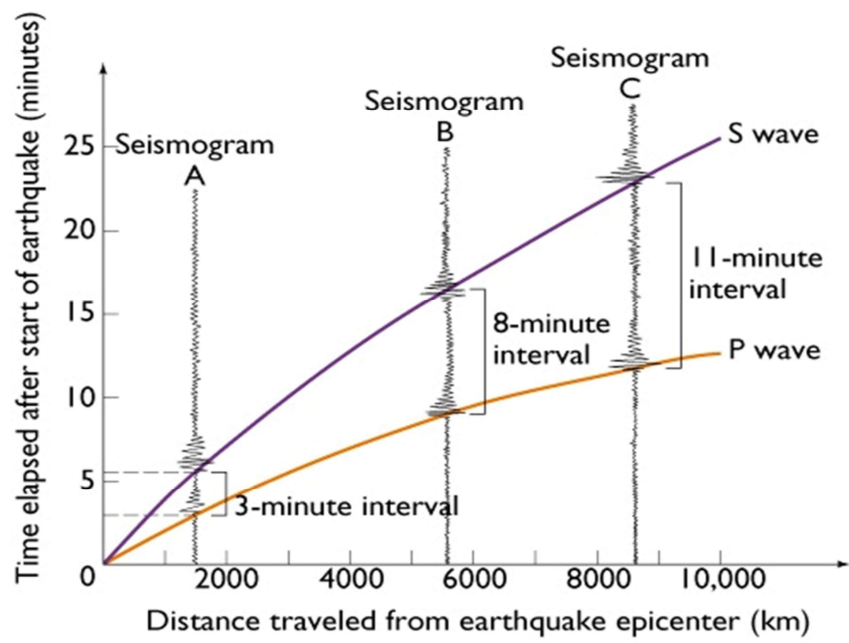
# Seismograph Record and Pathway of Three Types of Seismic Waves



# Time Lag Between S and P waves as with Distance from Epicenter



# Seismic Travel-time Curve



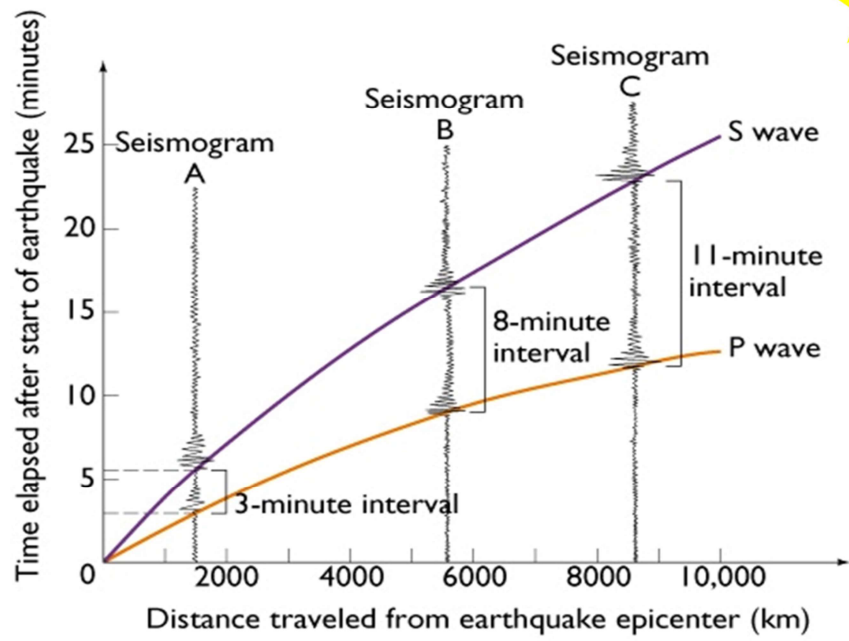
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## Locating an Epicenter

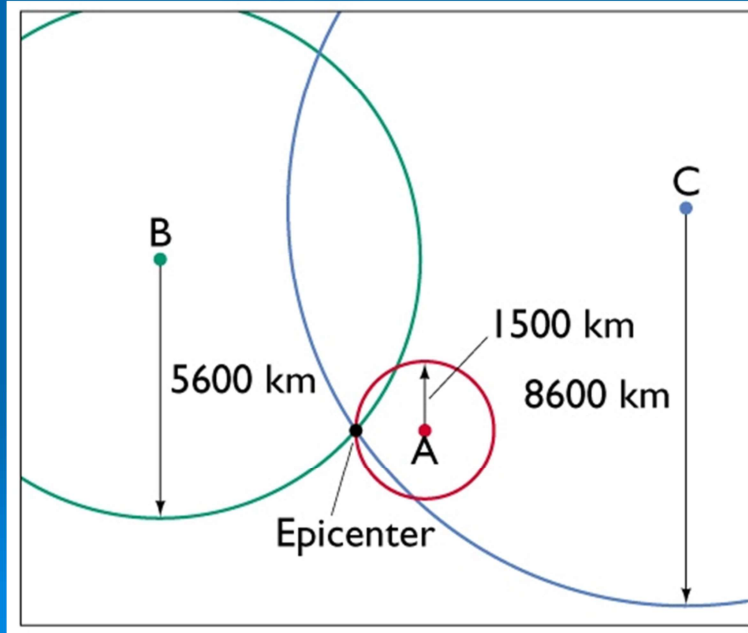


- The difference between the arrival times of the P and S waves at a recording station is a function of the distance from the epicenter.
- Therefore, you need three stations to accurately determine the location of an epicenter.

# Seismic Travel-time Curve



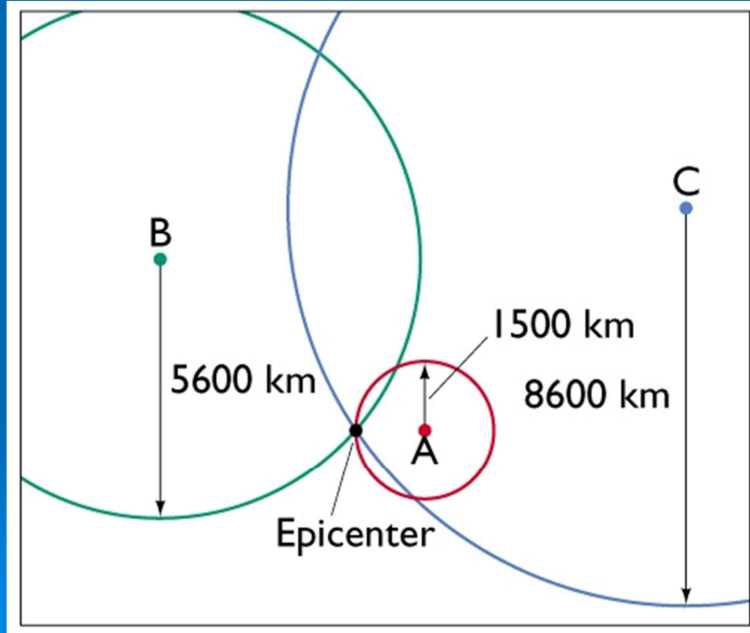
# Locating the Epicenter



Why do you need three stations?

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# Locating the Epicenter





# Activity

- Determining the Epicenter of an Earthquake.

# Honshu earthquake

➤ Gmail

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- There were HUNDREDS of aftershocks from the Great Honshu Quake of 2011.



- Slides removed.

# Earthquake Intensity and Magnitude



## ➤ Mercalli Intensity Scale

- Assesses damage at a specific location
- Depends on:
  - Strength of the quake
  - Distance from the Epicenter
  - Nature of the surface material
  - Building design

# Modified Mercalli Intensity Scale

- I Not felt
- II Felt only by persons at rest
- III–IV Felt by persons indoors only
- V–VI Felt by all; some damage to plaster, chimneys
- VII People run outdoors, damage to poorly built structures
- VIII Well-built structures slightly damaged; poorly built structures suffer major damage
- IX Buildings shifted off foundations
- X Some well-built structures destroyed
- XI Few masonry structures remain standing; bridges destroyed
- XII Damage total; waves seen on ground; objects thrown into air

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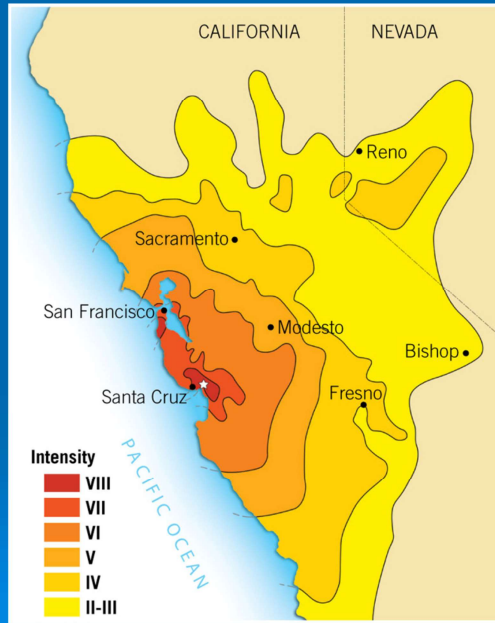
# 1989 Loma Prieta Quake

➤ <https://macearthscience.weebly.com/42-earthquakes.html>

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- Good video on the World Series Quake of 1989. Click link, watch video.

# Seismic Intensity Map, Loma Prieta 1989



# Earthquake Intensity and Magnitude



## ➤ Magnitude

- Concept introduced by Charles Richter in 1935
- Richter Scale - Measures the amplitude of the largest wave from a seismogram
- Scale is *logarithmic*:
  - Increase 1 unit = 10 times greater shaking
  - Increase 1 unit = 30 times greater energy



# Richter scale



- Largest quake ever recorded = 9.5 (off coast of Chile, 1960).
  - There is some discrepancy as to where the “top” of the Richter scale is.
- Biggest in your lifetimes => 9.1 (off east coast of Honshu, Japan. March, 2011)
- Earthquakes less than  $M = 2$  are not felt by people.
- **BIG EARTHQUAKES RELEASE THOUSANDS / MILLIONS OF TIMES MORE ENERGY THAN SMALL TREMORS!!**

## Determining Richter Scale Magnitude

### Magnitude vs. Ground Motion and Energy

Magnitude Change	Ground Motion Change (amplitude)	Energy Change (approximate)
4.0	10,000 times	1,000,000 times
3.0	1000 times	32,000 times
2.0	100 times	1000 times
1.0	10.0 times	32 times
0.5	3.2 times	5.5 times
0.1	1.3 times	1.4 times

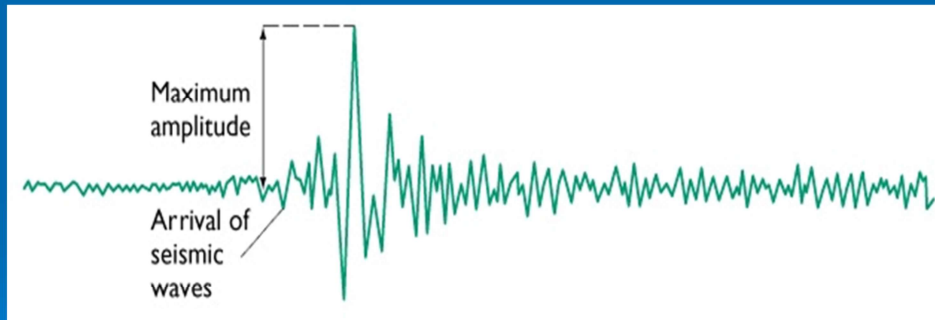
# Honshu Earthquake

- <https://macearthscience.weebly.com/42-earthquakes.html>

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- Click link, watch video.

# Maximum Amplitude of Ground Shaking Determines Richter Magnitude



# Annual Earthquake Occurrence

Frequency and Energy Released by Earthquakes of Different Magnitudes

Magnitude (Mw)	Average Per Year	Description	Examples	Energy Release (equivalent kilograms of explosive)
9	<1	<b>Largest recorded earthquakes</b> —destruction over vast area massive loss of life possible	Chile, 1960 (M 9.5); Alaska, 1964 (M 9.0); Japan, 2011 (M 9.0)	56,000,000,000,000
8	1	<b>Great earthquakes</b> —severe economic impact large loss of life	Sumatra, 2006 (M 8.6); Mexico City, 1980 (M 8.1)	1,800,000,000,000
7	15	<b>Major earthquakes</b> —damage (\$ billions) loss of life	New Madrid, Missouri 1812 (M 7.7); Turkey, 1999 (M 7.6); Charleston, South Carolina, 1886 (M 7.3)	56,000,000,000
6	134	<b>Strong earthquakes</b> —can be destructive in populated areas	Kobe, Japan, 1995 (M 6.9); Loma Prieta, California, 1989 (M 6.9); Northridge, California, 1994 (M 6.7)	1,800,000,000
5	1319	<b>Moderate earthquakes</b> —property damage to poorly constructed buildings	Mineral, Virginia, 2011 (M 5.8); Northern New York, 1994 (M 5.8); East of Oklahoma City, Oklahoma, 2011 (M 5.6)	56,000,000
4	13,000	<b>Light earthquakes</b> —noticeable shaking of items indoors, some property damage	Western Minnesota, 1975 (M 4.6); Arkansas, 2011 (M 4.7)	1,800,000
3	130,000	<b>Minor earthquakes</b> —felt by humans, very light property damage, if any	New Jersey, 2009 (M 3.0); Maine, 2006 (M 3.8)	56,000
2	1,300,000	<b>Very minor earthquakes</b> —felt by humans, no property damage		1,800
	Unknown	<b>Very minor earthquakes</b> —generally not felt by humans, but may be recorded		56

Data from USGS

# Earthquake Destruction



- Factors that determine destruction:
  - Magnitude of the quake
  - Proximity to population
- Destruction from:
  - Buildings falling
  - Tsunamis (seismic sea waves)
  - Landslides
  - FIRE!
- “Earthquakes don’t kill people, buildings kill people”

## Check Questions

- The type of earthquake wave that travels along the outer layer of the Earth is the surface wave.
- An increase in one unit on the Richter scale results in ten times greater shaking and thirty times more energy released.

# Activity

- Lab book  
(page 134 – 137)



## San Francisco, 1906

- Richter (est.) 7.8
- Ruptured 290 miles of northern section of San Andreas fault causing the ground to shift up to 6 meters in some places.
- Violent shaking lasted 45 to 60 seconds
- More than 3,000 died, 225,000 were left homeless, and 28,000 buildings were destroyed.
- FIRE was the biggest killer.

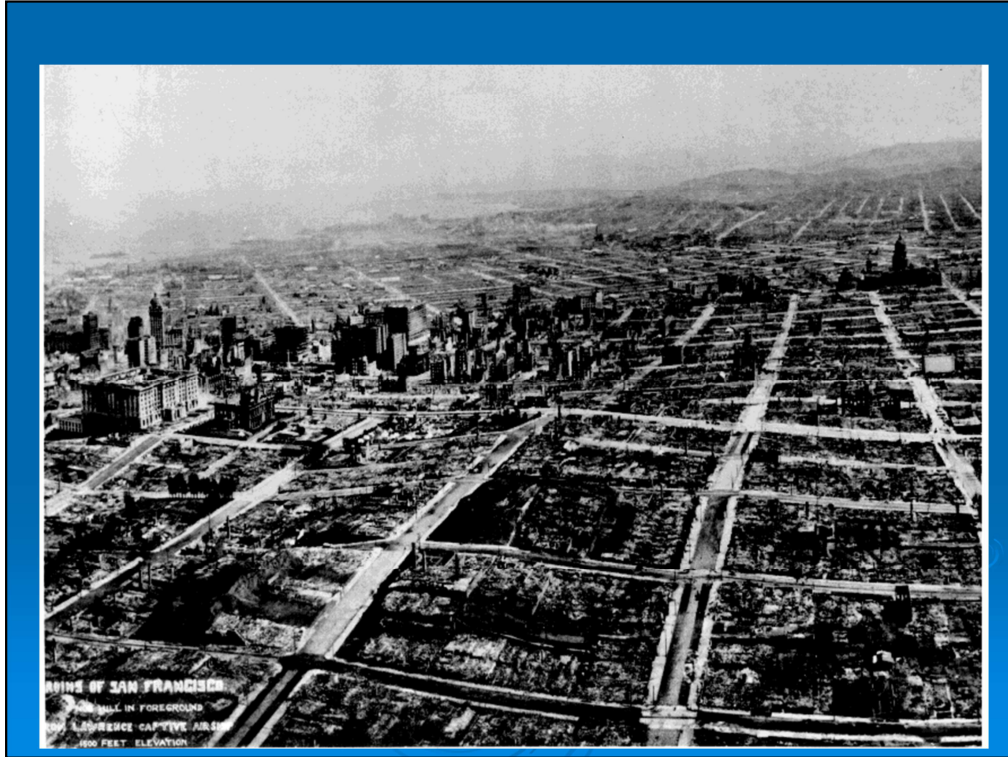
# San Francisco, 1906



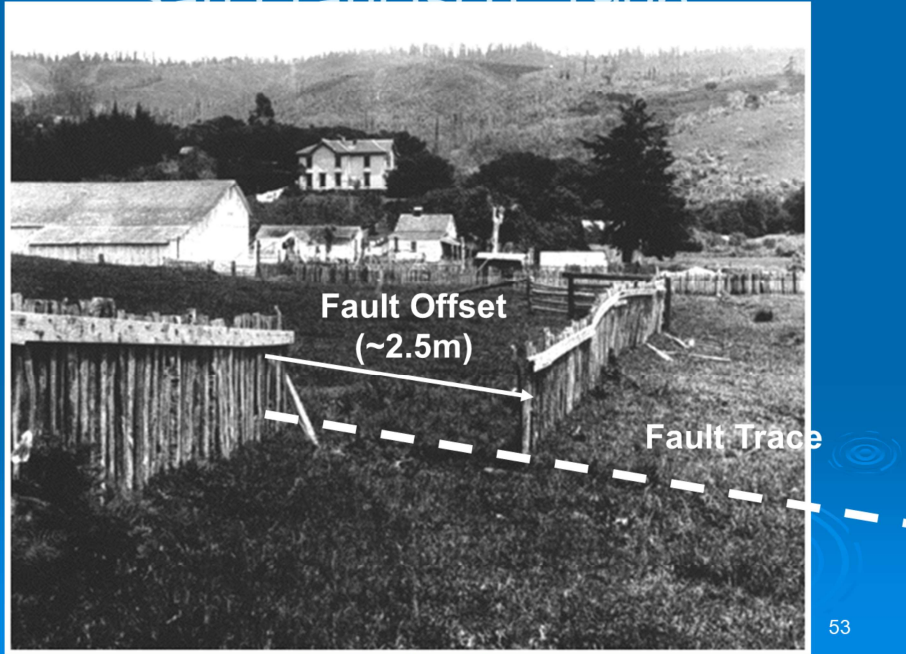
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# San Francisco, 1906





# San Francisco 1906



# S PROCLAMATION 906 BY THE MAYOR

The Federal Troops, the members of the Regular Police Force and all Special Police Officers have been authorized by me to KILL any and all persons found engaged in Looting or in the Commission of Any Other Crime.

I have directed all the Gas and Electric Lighting Co.'s not to turn on Gas or Electricity until I order them to do so. You may therefore expect the city to remain in darkness for an indefinite time.

I request all citizens to remain at home from darkness until daylight every night until order is restored.

I WARN all Citizens of the danger of fire from Damaged or Destroyed Chimneys, Broken or Leaking Gas Pipes or Fixtures, or any like cause.

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**E. E. SCHMITZ, Mayor**

Dated, April 18, 1906.

ALTYATER PRINT. MISSION AND 220 STS.

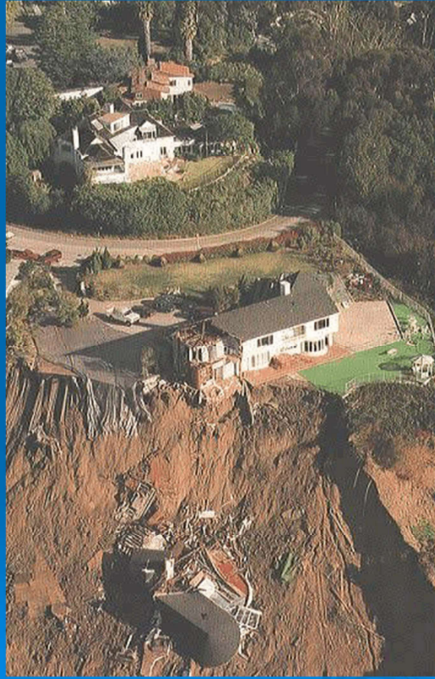


This big quake in 1906  
significantly relieved the stress  
along the San Andreas fault for  
@ 50 years



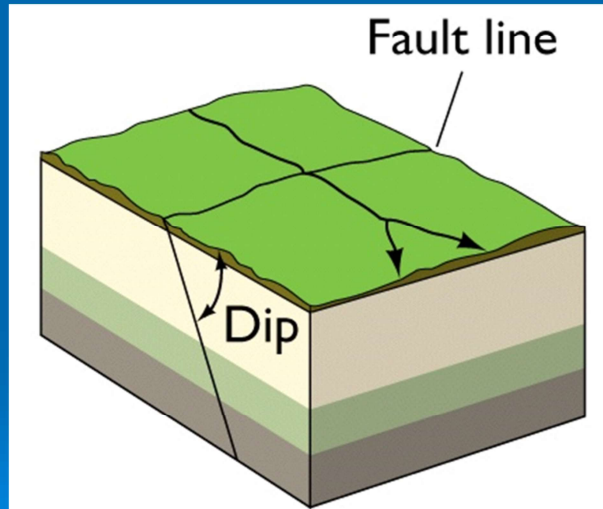
# Tsunami





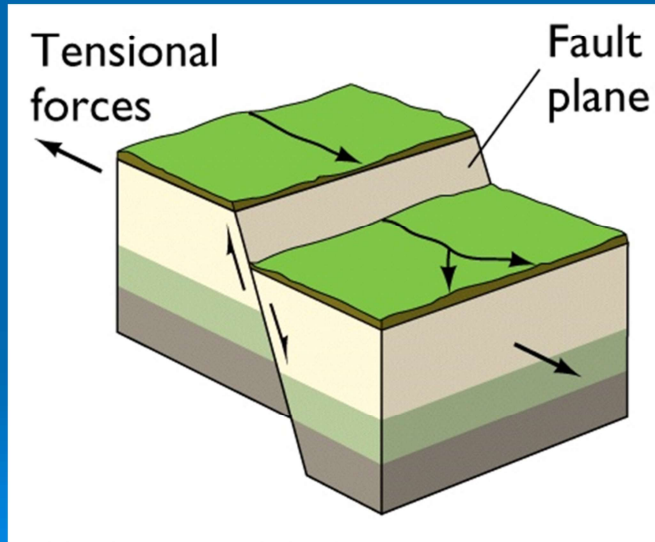
# Landslide

# Before Fault Movement

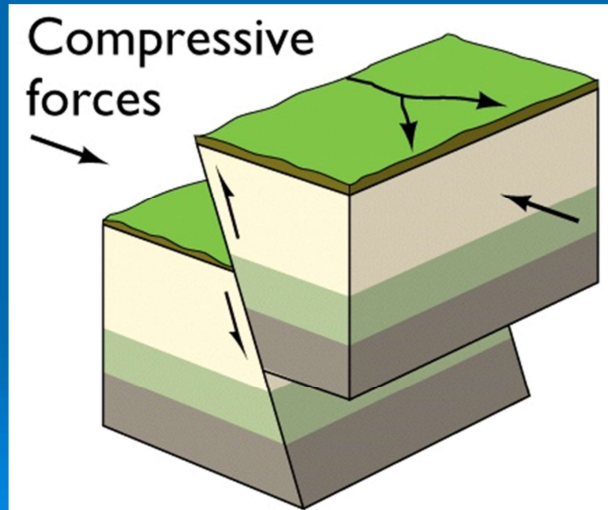


(a)

# Normal Fault

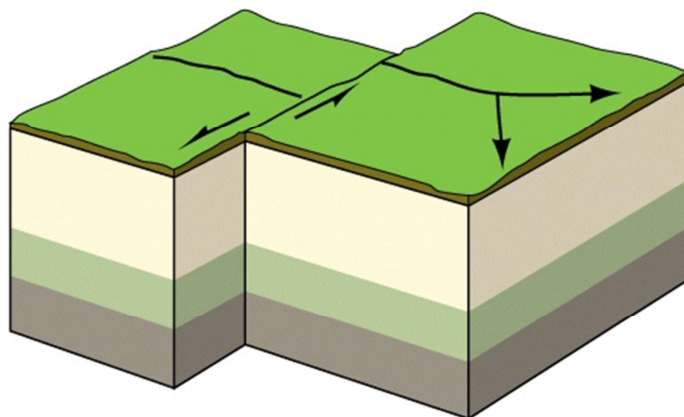


# Thrust (reverse) Fault



# Strike-slip Fault

Shearing forces



# San Andreas Fault



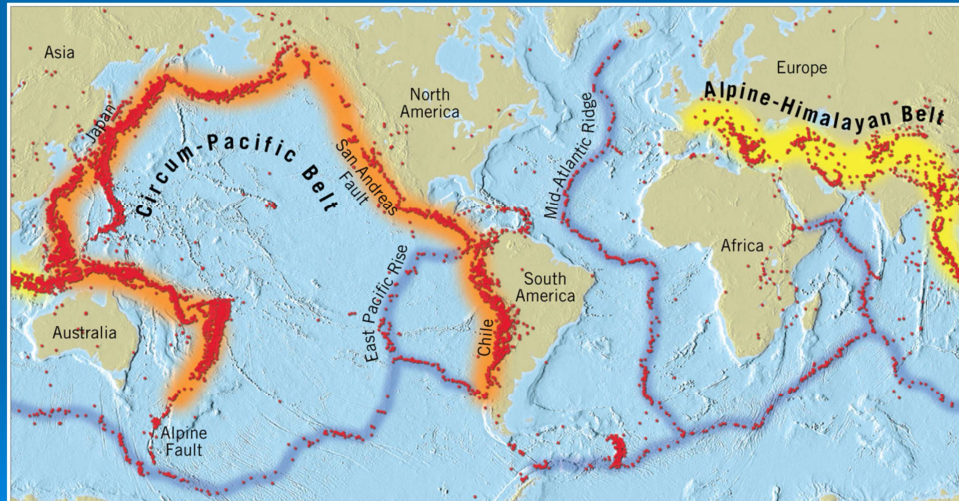
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# Distribution of earthquakes

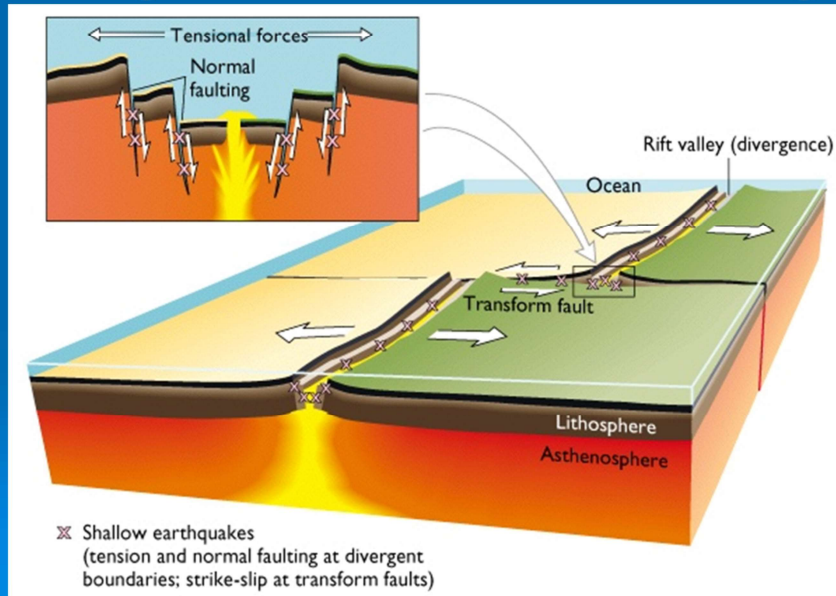
- *Not random*
- Focused around plate margins  
(but also seen in plate interiors)



# Global Earthquake Belts

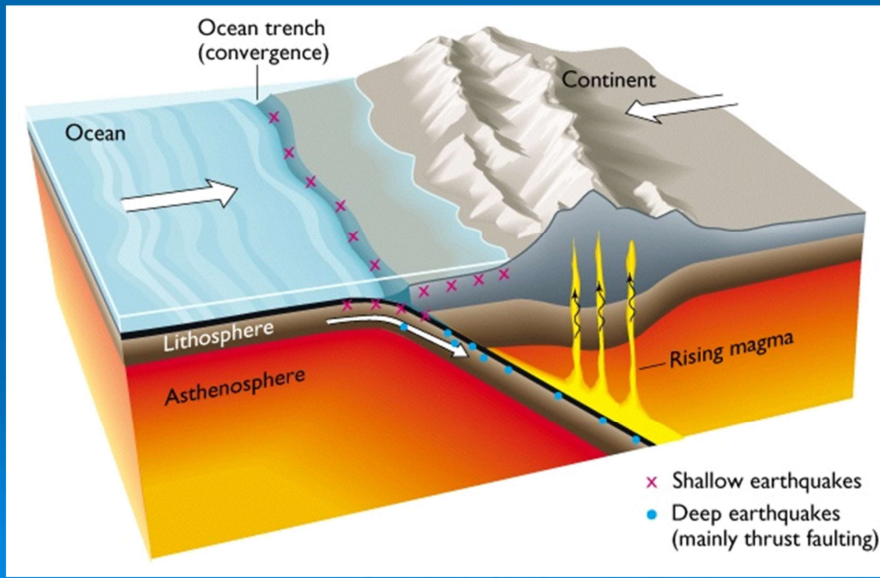


# Earthquakes Associated with Divergent and Transform Margins



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# Earthquakes Associated with Convergent Plate Margins

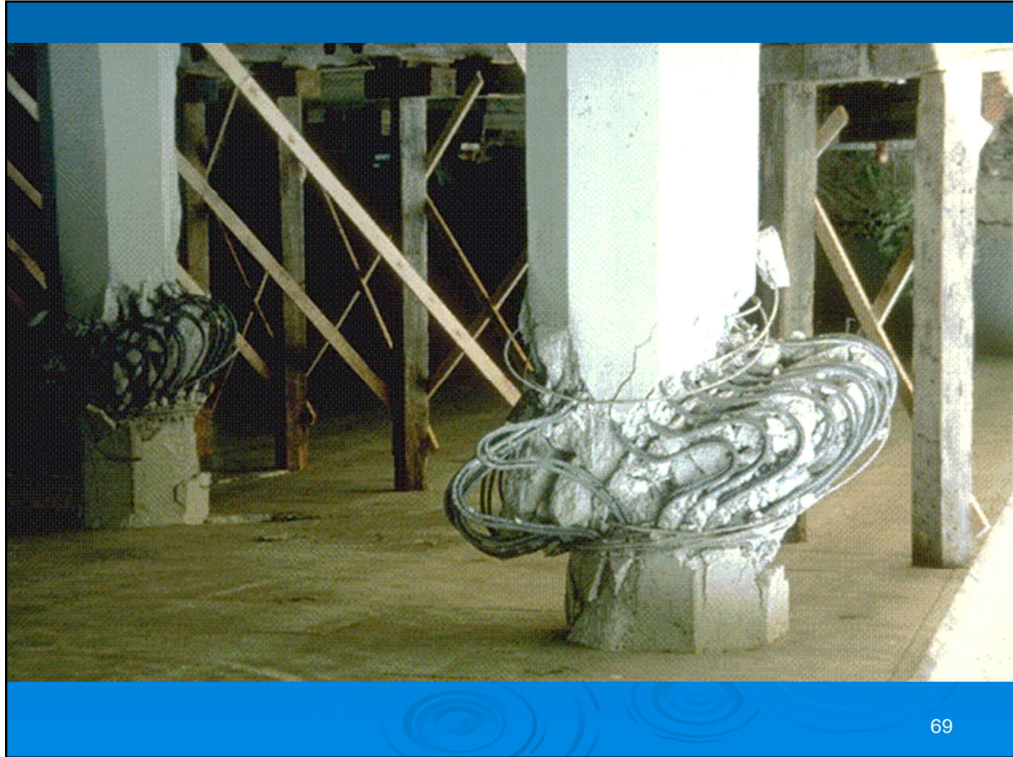


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## Effects of the 1994 Northridge, CA, Earthquake



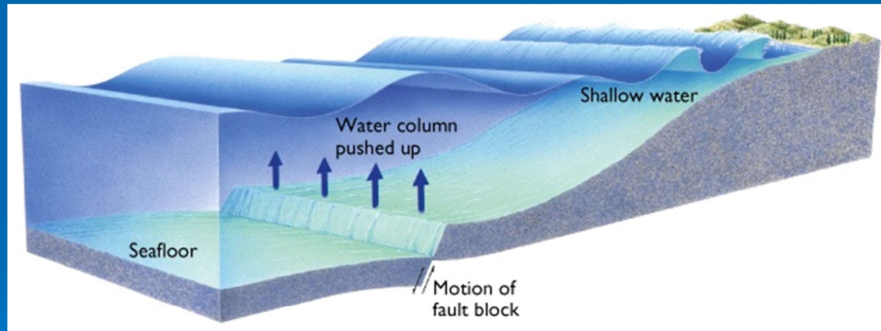
1994 Chronmo Sohn/Sohn/Photo Resewarchers, Inc



# 1995 Kobe, Japan, Earthquake



# Generation of a Tsunami





Brian Cassoy/AP Photo

# Destruction Caused by 1998 Tsunami, Papua New Guinea



# Tsunami Barrier in Taro, Japan



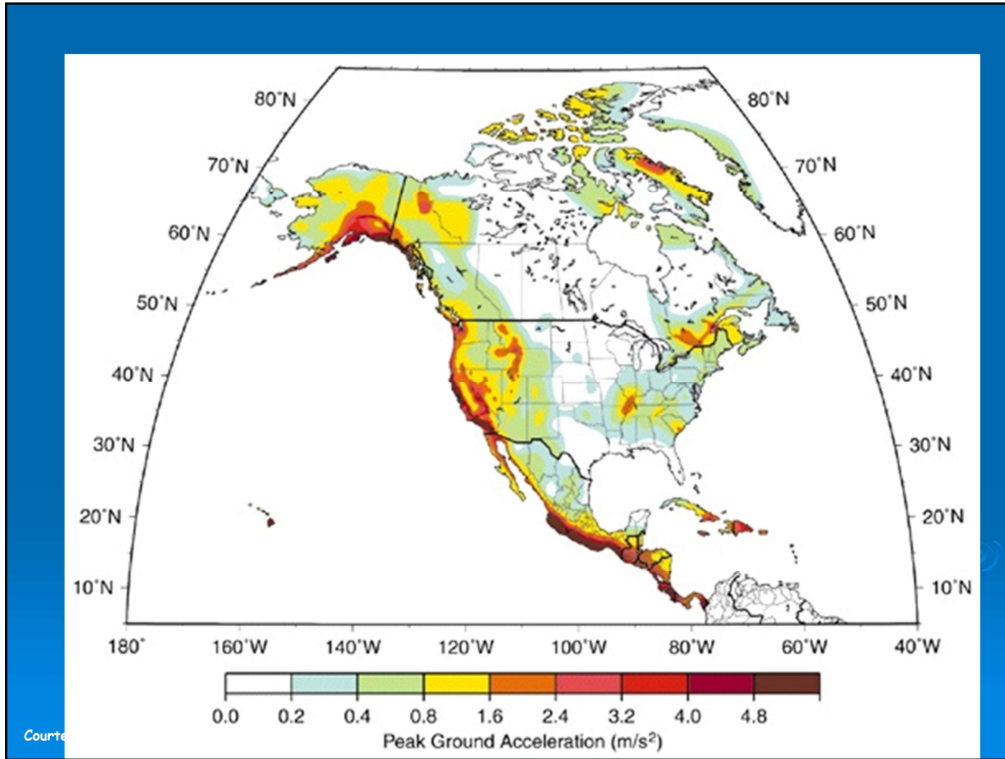
Courtesy of Taro, Japan

# Earthquake prediction

Long term—imprecise (can be done)

Short term—precise (very difficult)

We can't stop earthquakes, so we have to be prepared for them.





# New Housing Built Along the 1906 Trace of the San Andreas Fault

# Demonstrating Earthquake Safety in Japan



## Animated Map



- All Earthquakes 2001 – 2015
- <https://macearthscience.weebly.com/42-earthquakes.html>

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- Click link, watch animation.



- Slides removed.