

# Earthquakes

- What is an earthquake?
  - A vibration

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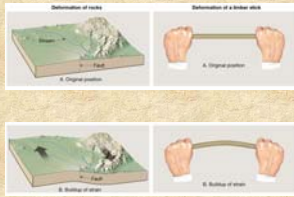
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# Elastic Rebound

- An earthquake is the vibration of the earth produced by the rapid release of energy
- Over time, stresses build up within rock units
- Rock units can withstand only a limited amount of stress and therefore may break over time
- The theory that explains the mechanism behind earthquakes is known as the elastic rebound theory



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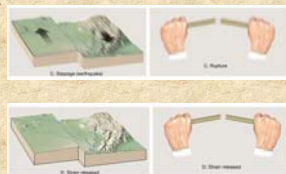
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# Elastic Rebound

- As stress is applied to rocks, they begin to behave elastically (the return to their original shape if the stress is relieved)
- If too much stress is applied, the rock units will undergo rupture
- After rupture, the rocks snap back to an original non-stressful state and in doing so release a vibration through the earth
- These vibrations are what we feel as earthquakes



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## Elastic Rebound



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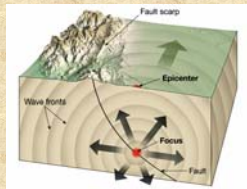
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## Earthquakes

- Earthquakes are associated with movement along fractures in the earth's crust called faults
- The point of origin for an earthquake is the focus and the point on the earth's surface directly above the focus is the epicenter



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## Seismic Waves

- When an earthquake occurs, the energy of the stress is released in the form of seismic waves
- The seismic waves originate from the focus and travel outward in all directions
- There are three dominant waves
  - Primary (P) wave
  - Secondary (S) wave
  - Surface wave

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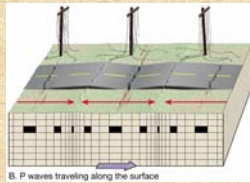
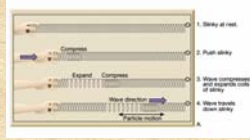
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## Seismic Waves

- Primary (P) waves
  - Fastest waves; travel ~16,000 mph
  - Generated as the ground in the vicinity of an earthquake is compressed
  - Propagate as a push-pull motion through medium
  - Travels rapidly through solids and more slowly through liquids and gases




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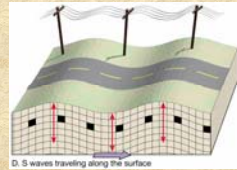
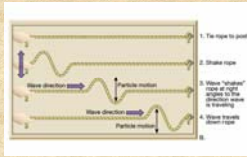
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## Seismic Waves

- Secondary (S) waves
  - Propagate as a shearing motion through medium; particles move at right angles to wave movement
  - Generated by sliding or shearing motion during an earthquake
  - Can only travel through solids




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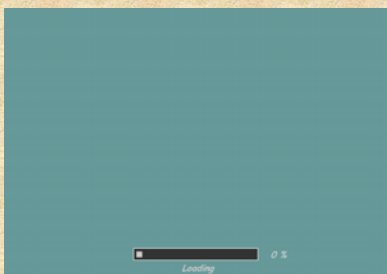
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## Seismic Waves




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## Seismic Waves

- Surface waves
  - Travel along the surface during an earthquake
  - Slowest waves
  - Cause most surface damage

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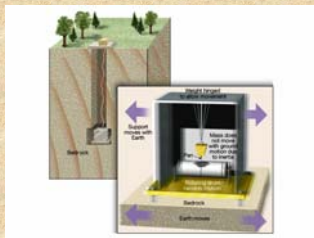
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## Seismometers

- Seismometers were developed to measure the strength, or magnitude, of earthquakes
- By analyzing the markings on a seismograph, the location of an earthquake can be identified



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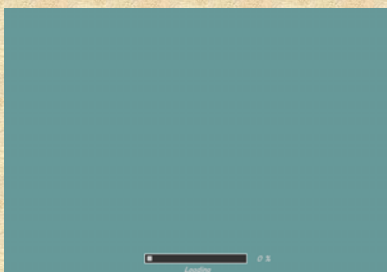
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## Seismometers



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## Locating Earthquakes

- The development of the seismograph has allowed geologists to locate the epicenter of earthquakes
- This is important because many earthquakes take place in remote and unpopulated regions (even in the ocean basins)
- Despite their formation away from populated areas, earthquakes can still have a devastating effect on people
  - December 26, 2004 Indonesia tsunami

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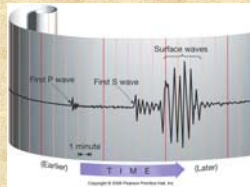
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## Locating Earthquakes

- To locate an earthquake, a geologist must determine the arrival time difference between the P wave and the S wave
- In this example, there is a 5 minute difference in the arrival of the P wave and the S wave




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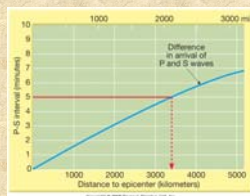
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## Locating Earthquakes

- Using the travel-time graph and the difference in arrival time (5 minutes), a determination is made regarding the distance to the epicenter (in this example, distance to epicenter is approximately 3400 km)




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## Locating Earthquakes

- This technique will provide distance to the epicenter for one seismic station but direction is still unknown
- At least two other seismic stations must complete the same procedure in order for the epicenter to be located

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## Locating Earthquakes




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## Measuring Earthquakes

- Historically, there have been two primary methods
  - Mercalli scale
    - Measured earthquakes according to the amount of damage they caused

Table 6.1 Modified Mercalli Intensity Scale

I	Not felt except by a very few under especially favorable circumstances.
II	Felt only by a few persons at rest, especially on upper floors of buildings.
III	Felt quite noticeably indoors, especially on upper floors of buildings, but many people do not recognize it as an earthquake.
IV	During the day felt indoors by many, outdoors by few. Sensation like heavy truck striking building.
V	Felt by nearly everyone, many awakened. Disturbances of trees, poles, and other tall objects sometimes noticed.
VI	Felt by all, many frightened and run outdoors. Some heavy furniture moved; few instances of fallen plaster or damaged chimneys. Damage slight.
VII	Everybody runs outdoors. Damage negligible in buildings of good design and construction; slight-to-moderate in well-built ordinary structures; considerable in poorly built or badly designed structures.
VIII	Damage slight in specially designed structures; considerable in ordinary substantial buildings with partial collapse; great in poorly built structures. (Fall of chimneys, factory stacks, columns, monuments, walls.)
IX	Damage considerable in specially designed structures. Buildings shifted off foundations. Ground cracked conspicuously.
X	Some well-built wooden structures destroyed. Most masonry and frame structures destroyed. Ground badly cracked.
XI	Few, if any, (masonry) structures remain standing. Bridges destroyed. Broad fissures in ground.
XII	Damage total. Waves seen on ground surfaces. Objects thrown upward into air.

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## Measuring Earthquakes

- Richter scale
  - Developed by Charles Richter in the early 1930s
  - Earthquakes measured by analyzing the amplitude of seismic waves
  - Earthquakes measured by analyzing the amplitude of the largest seismic waves
  - 10-point logarithmic scale
  - Each unit on scale represents a 10-fold difference in magnitude and a 30-fold difference in energy released

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## Destruction from Earthquakes: Ground Shaking

- The most obvious result of earthquakes is the shaking of the ground surface
- This causes considerable damage to buildings and other structures



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## Destruction from Earthquakes: Ground Shaking



[http://www.fema.gov/kids/p\\_eq08.htm](http://www.fema.gov/kids/p_eq08.htm)

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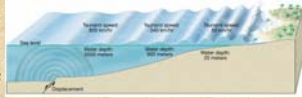
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## Destruction from Earthquakes: Tsunami

- Earthquakes under the ocean may result in the formation of very large waves that can cause immense damage on land
- These waves are known as tsunamis
- On the ocean, it would be difficult to detect; as the wave approaches land it gets more narrow and taller



[http://ffden-2.phys.uaf.edu/645fall2003\\_web.dir/elena\\_suleimani/runup4.mov](http://ffden-2.phys.uaf.edu/645fall2003_web.dir/elena_suleimani/runup4.mov)

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## Tsunami



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## Tsunami



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## Destruction from Earthquakes: Landslides

- Earthquakes can lessen the cohesive properties of soil and lead to landslide events



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## Destruction from Earthquakes: Liquefaction

- Earthquakes can also lead to liquefaction
  - In this instance, the soil behaves like a liquid



<http://www.ocwashington.edu/~liquefaction/selectpic/qual/riqstud4/riqthebuilding.jpg>

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## Destruction from Earthquakes: Fire

- Earthquakes can damage not only buildings but also pipelines which may result in explosions and fire hazards



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## Predicting Earthquakes

- Can people predict earthquakes?
  - Answer: Yes and No
  - Predictability possible on a long-term scale
    - Look at distribution and times of occurrences
  - Prediction not possible on a short-term scale

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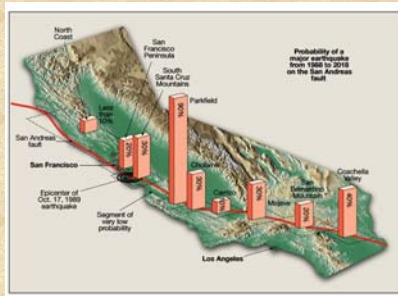
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## Predicting Earthquakes



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## Interior of the Earth

- By studying the propagation and reception of seismic waves around the globe, seismologists have developed a good idea about the structure of the interior of the earth
- Earth has four primary layers
- The material comprising each layer has a different density than that above and/or below it
- This density difference causes the seismic waves to be refracted (bent) as they travel through the earth

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## Interior of the Earth

- Crust
  - Thin, uppermost layer
  - Comprised of continental crust and oceanic crust
  - Continental crust is generally 30-40 km thick (thicker in mountainous regions) and made of mostly felsic rock
  - Oceanic crust is generally 5-6 km thick and made of mostly mafic rock

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## Interior of the Earth

- Mantle
  - ~2900 km thick
  - Composed of peridotite (ultramafic rock)

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## Interior of the Earth

- Outer core
  - ~2300 km thick
  - Believed to be liquid
    - P waves apparently slowed and S waves disappear
  - Flow of liquid in outer core believed to generate the earth's magnetic field
  - Composed mostly of iron

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## Interior of the Earth

- Inner core
  - ~1200 km thick
  - Solid
  - Composed mostly of iron and nickel
  - Very dense

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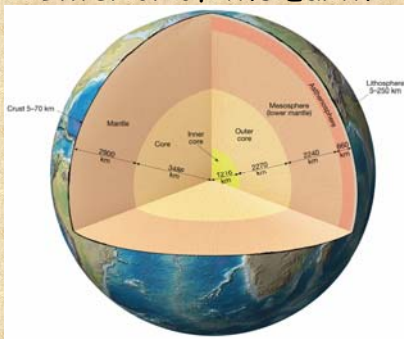
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## Interior of the Earth



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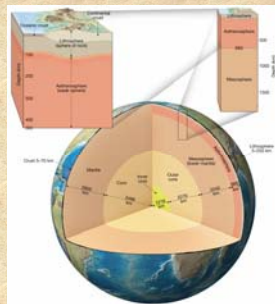
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## Interior of the Earth

- Lithosphere
  - From earth surface to ~100 km
  - Solid, rigid, brittle portion of crust and upper mantle
- Asthenosphere
  - From ~100 km to ~700 km
  - Hot, plastic, capable of flow



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