# Chapter 19

## Earthquakes

### Section 19.1: Forces Within Earth

**Vocabulary:**

- Stress
- Strain
- Elastic Deformation
- Plastic Deformation
- Fault
- Seismic Wave
- Primary Wave
- Secondary Wave
- Focus
- Epicenter

### Objectives:

- **Define** stress and strain as they apply to rocks.
- **Distinguish** among the three types of movement of faults.
- **Contrast** the three types of seismic waves.

### Main Idea:

- **Faults** form when the forces acting on rock exceed the rock's strength.

### Real-World Link:

- If you bend a paperclip, it takes on a new shape.
- If you bend a stick, it will eventually break.
- The same is true of rocks; they either bend or break.

# Section 19.1

## Forces Within Eartth

## Stress and Strain

- Along boundaries between two tectonic plates, rocks in the crust often resist movement.
- Over time, stress builds up.

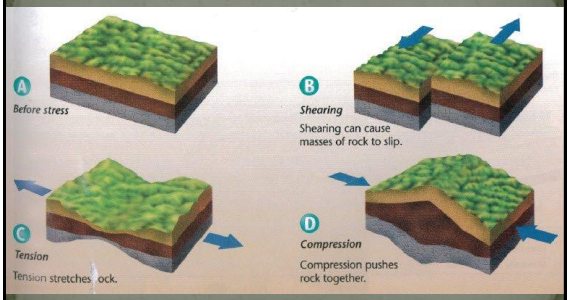
## Stress and Strain

- Stress is the total force acting on crustal rocks per unit of area.
- When stress overcomes the strength of rocks, movement occurs along fractures in the rocks.

## Stress and Strain

- There are three kinds of stress that act on Earth's rocks:
  - Compression
  - Tension
  - Shear

## Stress and Strain




## Stress and Strain

- The deformation of materials in response to stress is called strain.

## Stress and Strain

- Even though rocks can be twisted, squeezed, and stretched, they fracture when stress and strain reach a critical point.
- At these breaks, rock can move, releasing the energy built up as a result of stress.
- Earthquakes are a result of this movement and release of energy.

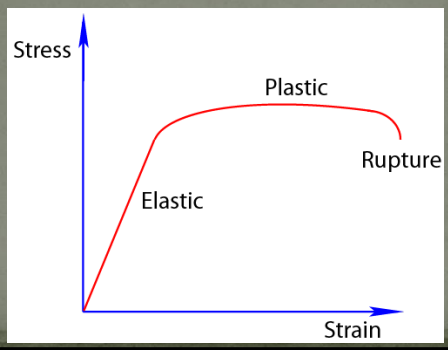
# Elastic Deformation

- Under low stress, a material shows elastic deformation.
- Elastic deformation is caused when a material is compressed, bent, or stretched.
- If the stress is reduced back to zero, the deformation of the rock disappears.

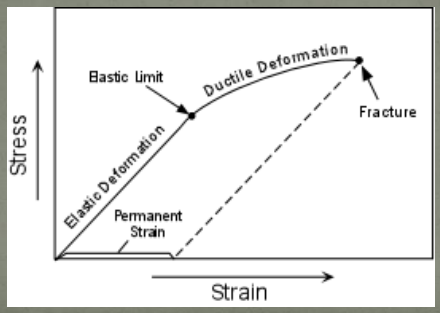
# Plastic Deformation

- When stress builds up past a certain point, called the elastic limit, rocks undergo plastic deformation.
- Unlike elastic deformation, plastic deformation produces permanent deformation.
- When plastic deformation is exceeded, an earthquake occurs.

# Stress-Strain Curve




# Stress-Strain Curve




# Plastic Deformation

- When stress builds up past a certain point, called the elastic limit, rocks undergo plastic deformation.
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# Faults

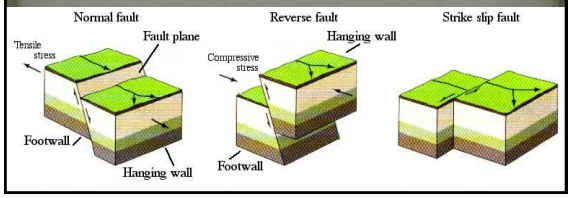
- Crustal rocks fail when stresses exceed the strength of the rocks.
- The resulting movement occurs along a weak region in the rock known as a fault.
- A fault is any fracture or system of fractures along which the Earth moves.

# Types of Faults

- There are three main types of faults that occur based on compression, tension, and shear stress.
  - Reverse Fault
  - Normal Fault
  - Strike-Slip Fault

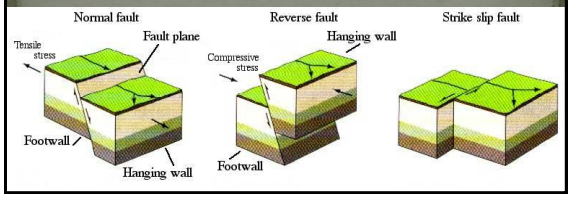
# Reverse Faults

- **Reverse faults** form as a result of horizontal and vertical compression.



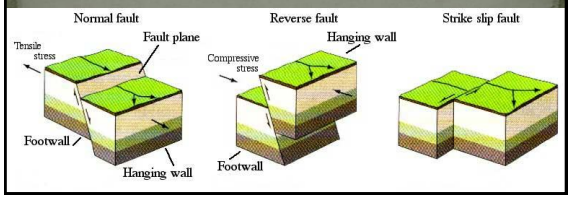

# Normal Faults

- **Normal faults** form as a result of horizontal and vertical tension.



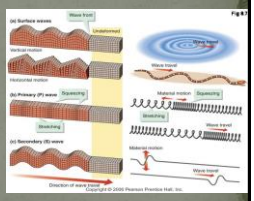

# Strike-Slip Faults

- **Strike-Slip faults** form as a result of horizontal shear.




# Tomorrow:

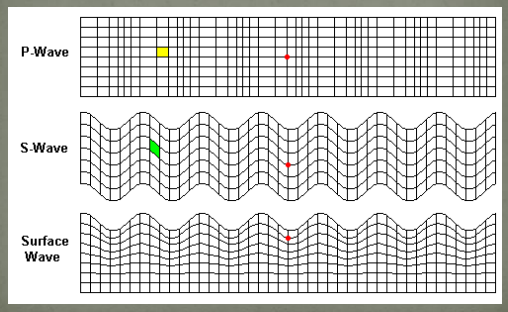
- Earthquake (seismic) Waves:
  - Primary Waves
  - Secondary Waves
  - Surface Waves



# Earthquke Waves

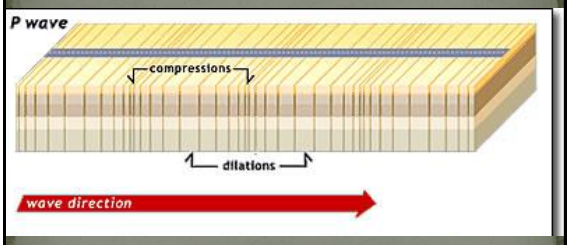
- The vibrations of the ground produced during an earthquake are called seismic waves.
- Every earthquake generates three types of seismic waves.
  - Primary Waves
  - Secondary Waves
  - Surface Waves

# Earthquke Waves



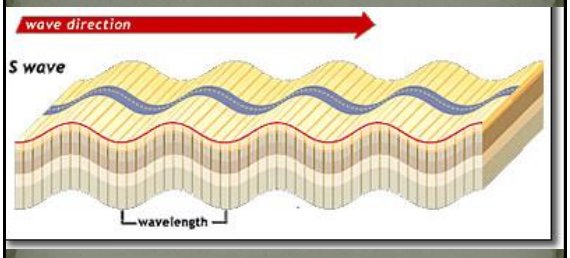

# Primary Waves

- Also referred to as P-waves, primary waves squeeze and push rocks in the direction along which the waves are traveling.
- The compressional movement of P-waves is similar to the movement along a loosely coiled wire. (Sound also moves in compressional waves)




# Secondary Waves

- Secondary waves, called S-waves are named with respect to their arrival times. They are slower than P-waves, so they are the second set of waves to be felt.
- S-waves have a motion that causes rocks to move at right angles in relation to the direction of the wave.



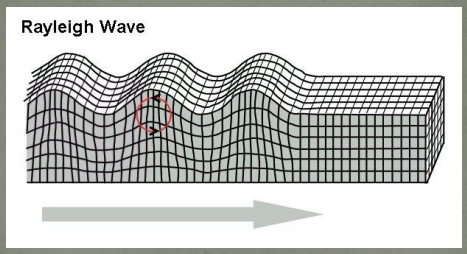
# P-waves and S-waves

- Primary and secondary waves both pass through Earth's interior.
- For this reason, they are also called body waves.

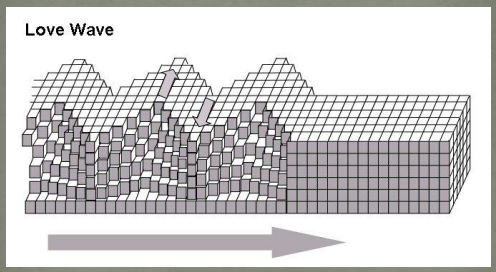
# Surface Waves

- The third and slowest type of wave are surface waves, which travel only along Earth's Surface
- Surface waves can cause the ground to move sideways and up and down like ocean waves.
- These waves usually cause the most destruction because they cause the most movement of the ground, and take the longest time to pass.

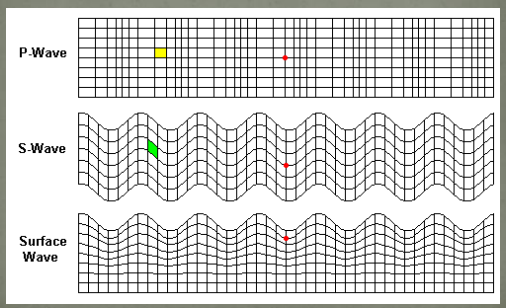
# Surface Waves




# Surface Waves



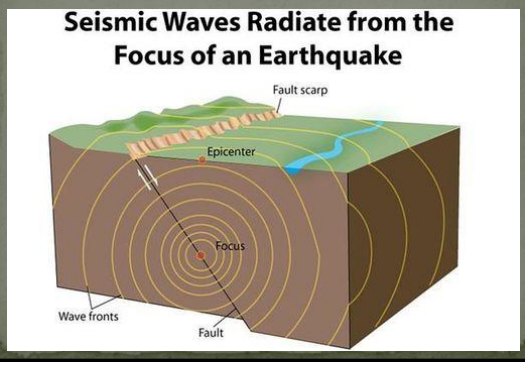

# Earthquke Waves




# Generation of Seismic Waves

- The point at which seismic waves originate is the focus of the earthquake.
- The point on Earth's surface directly above the focus is the epicenter.
- Surface waves originate from the epicenter and spread out.

## Generation of Seismic Waves




## Seismic Waves and Earth's Interior

- When you look in a mirror, you see yourself because light waves reflect off your face to the mirror and back to your eyes.
- Similarly, seismic waves travel through Earth reflect off structures inside Earth, which allows these structures to be imaged.

## Seismic Waves and Earth's Interior

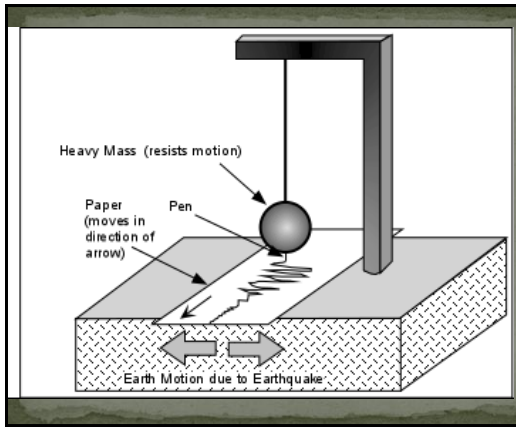
- Seismic waves can be used to make images of the internal structure of Earth.

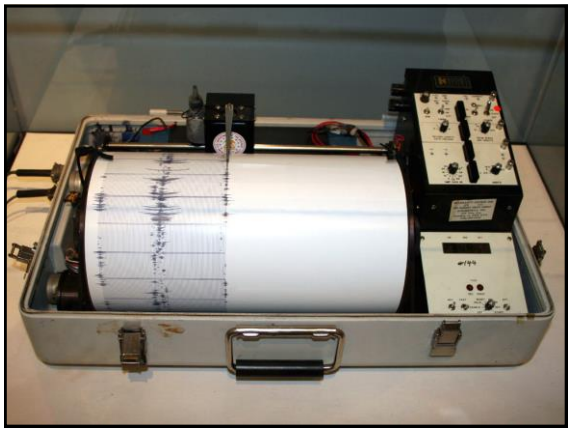
## Vocabulary:

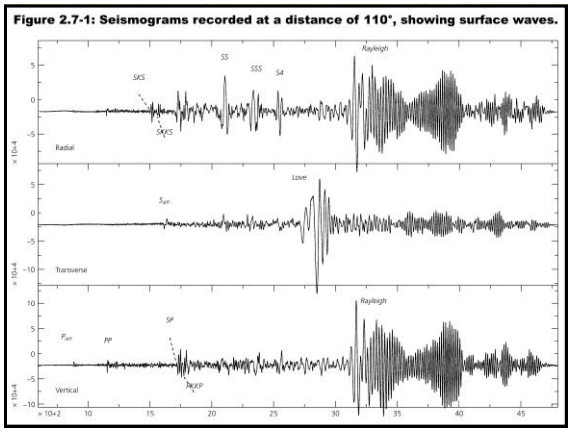
- **Richter scale:** A numerical rating system that measures the energy of the largest seismic waves (magnitude) that are produced during an earthquake.
- **Seismometer:** An instrument that measures and records the intensity of an earthquake.
- **Seismogram:** The information recorded by a seismograph.

**Understanding the Richter Scale**

| Richter Magnitude | Feels like KG of TNT | Extra Information |
|---|---|---|
| 0-1 | 0.6-20 kilograms of dynamite | We can not feel these. |
| 2 | 600 kilograms of dynamite | Smallest quake people can normally feel. |
| 3 | 20,000 kilograms of dynamite | People near the epicenter feel this quake. |
| 4 | 60,000 kilograms of dynamite | This will cause damage around the epicenter. It is the same as a small fission bomb. |
| 5 | 20,000,000 kilograms of dynamite | Damage done to weak buildings in the area of the epicenter. |
| 6 | 60,000,000 kilograms of dynamite | Can cause great damage around the epicenter. |
| 7 | 20 billion kilograms of dynamite | Creates enough energy to heat New York City for one year. Can be detected all over the world. Causes serious damage. |
| 8 | 20 billion kilograms of dynamite | Causes death and major destruction. Destroyed San Francisco in 1906. |
| 9 | 20 trillion kilograms of dynamite | Rare, but would causes unbelievable damage! |

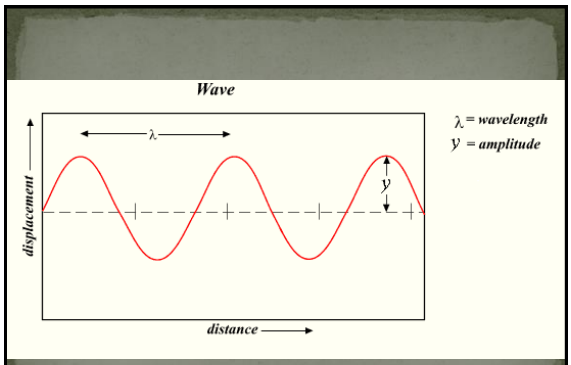






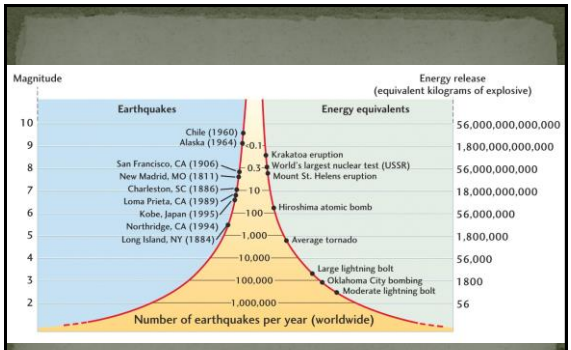

## Magnitude and intensity

- The **magnitude** of a wave is how much energy is released by the wave. It can be measured by the Richter Scale and the Moment Magnitude Scale.
- **Amplitude** is the height of a wave.
- The numbers on the Richter scale are determined by the amplitude.




## Moment Magnitude Scale

- The **moment magnitude scale** is a rating scale that measures the energy released by an earthquake, but also takes in account for the size of the fault rupture, the amount of movement along the fault, and the rock's stiffness.



# Modified Mercalli scale

- The **modified Mercalli scale** is a numerical system from I to XII which rates the type of damage and other effects of an earthquake as noted by observers during and after its occurrence.

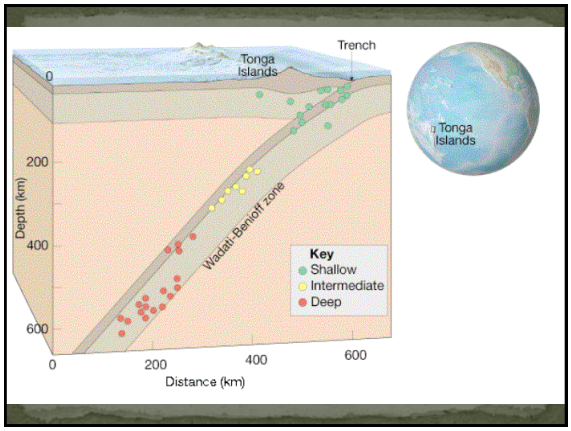
| | |
|---|---|
| I. Instrumental | Not felt by many people unless in favourable conditions. |
| II. Weak | Felt only by a few people at best, especially on the upper floors of buildings. Delicately suspended objects may swing. |
| III. Slight | Felt quite noticeably by people indoors, especially on the upper floors of buildings. Many do not recognize it as an earthquake. Standing motor cars may rock slightly. Vibration similar to the passing of a truck. Duration estimated. |
| IV. Moderate | Felt indoors by many people, outdoors by few people during the day. At night, some awakened. Dishes, windows, doors disturbed; walls make cracking sound. Sensation like heavy truck striking building. Standing motor cars rock noticeably. Dishes and windows rattle alarmingly. |
| V. Rather Strong | Felt outside by most, may not be felt by some outside in non-favourable conditions. Dishes and windows may break and large bells will ring. Vibrations like large train passing close to house. |
| VI. Strong | Felt by all; many frightened and run outdoors, walk unsteadily. Windows, dishes, glassware broken; books fall off shelves; some heavy furniture moved or overturned; a few instances of fallen plaster. Damage slight. |
| VII. Very Strong | Difficult to stand; furniture broken; damage negligible in building of good design and construction; slight to moderate in well-built ordinary structures; considerable damage in poorly built or badly designed structures; some chimneys broken. Noticed by people driving motor cars. |
| VIII. Destructive | Damage slight in specially designed structures; considerable in ordinary substantial buildings with partial collapse. Damage great in poorly built structures. Fall of chimneys, factory stacks, columns, monuments, walls. Heavy furniture moved. |
| IX. Violent | General panic; damage considerable in specially designed structures, well designed frame structures thrown out of plumb. Damage great in substantial buildings, with partial collapse. Buildings shifted off foundations. |
| X. Intense | Some well built wooden structures destroyed; most masonry and frame structures destroyed with foundation. Rails bent. |
| XI. Extreme | Few, if any masonry structures remain standing. Bridges destroyed. Rails bent greatly. |
| XII. Cataclysmic | Total destruction - Everything is destroyed. Lines of sight and level distorted. Objects thrown into the air. The ground moves in waves or ripples. Large amounts of rock move position. Landscape altered, or leveled by several meters. In some cases, even the routes of rivers are changed. |

# Earthquake Intensity

- The intensity of an earthquake depends on the **amplitude** of the <u>surface waves</u> generated.
- Intensity of an earthquake decreases as the distance from the **epicenter** increases.

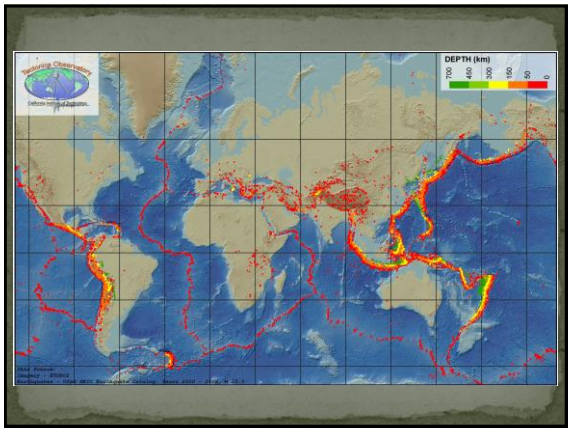
# Earthquake Intensity

- Another factor that determines the intensity of an earthquake is the depth of its focus.
- Earthquakes can be classified as shallow, intermediate or deep, depending on the location of the focus.




# Seismic Belts

- The majority of the world's earthquakes occur along narrow seismic belts that separate large regions with little or no seismic activity.


DEPTH (km)
700
450
300
150
50
0