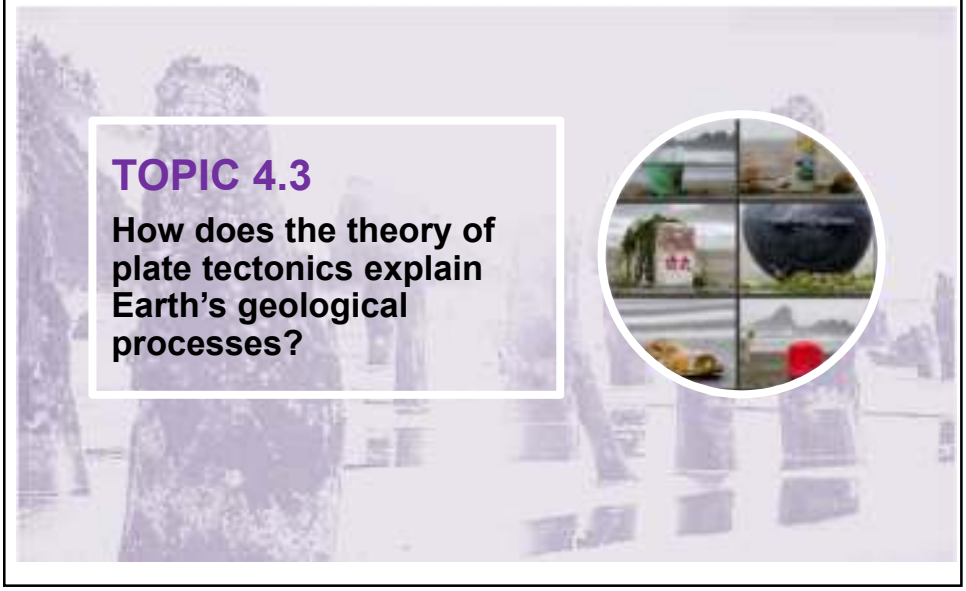
UNIT 4

The theory of plate tectonics explains Earth's geological processes



TOPIC 4.3

How does the theory of plate tectonics explain Earth's geological processes?

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Topic 4.3: How does the theory of plate tectonics explain Earth's geological processes?

- Theory of plate tectonics:
  - Explains how earthquakes, volcanoes, and mountain ranges are linked together
  - Allows scientists to explain how, where, and sometimes when these geologic processes occur

Objects that have washed up on the shoreline of B.C. due to the 2011 earthquake and tsunami in Japan.

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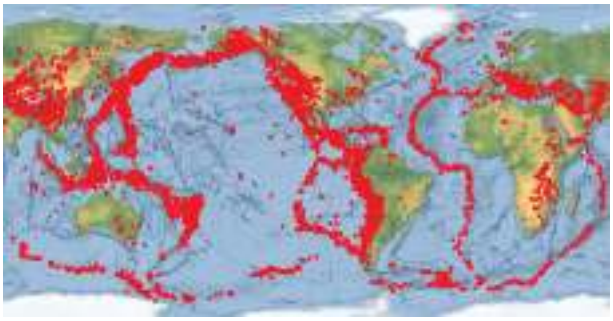
Concept 1: Most earthquakes occur near tectonic plate boundaries.

- Almost all earthquakes occur along plate boundaries
  - Location of greatest stress on the rock in Earth's crust

Figure 4.13: Almost 80% of all major earthquakes occur in the Circum-Pacific seismic belt.



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Earthquakes

- Movements in Earth's crust can squeeze, stretch, or twist the rock, which applies pressure to the rock
  - When pressure is applied to quickly or is larger than the strength of the rock, the rock breaks
  - Stored energy in the rock is released as an earthquake

Road damage due to an earthquake

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Earthquakes Happen at Faults

- **Earthquake**: ground-shaking release of energy when a break in the crust occurs
  - Usually occur when rocks suddenly shift along a break in the rock (**fault**), releasing built-up pressure
  - Fault line: the line along the surface of the ground where the break in rock happens

The San Andreas Fault in California, where the Pacific plate slides past the North American plate

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Types of Faults: Reverse Fault

- Forms when rock is squeezed together and one block rides up to overlap other block
- Crust is shortened horizontally

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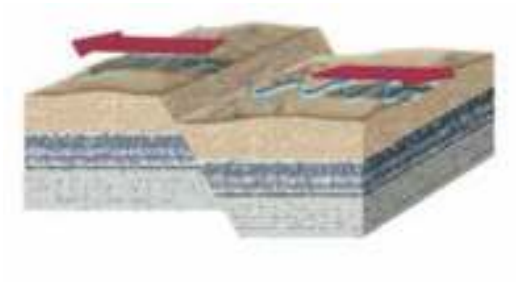
Types of Faults: Normal Fault

- Forms when rock is pulled apart and one block slips downward
- Crust is lengthened



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Types of Faults: Strike-Slip Fault

- Forms when blocks of rock move past each other horizontally

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Discussion Questions

- Describe the relationship between the locations of tectonic plates and the locations of major earthquakes.
- What happens at a fault?

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Discussion Questions

- You find out that a friend's parents are considering buying a house near a fault line.
  - Make a list of three questions they should find answers to before buying the house.

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Concept 2: Movement along faults produces seismic waves.

- What happens in Earth's interior when an earthquake occurs?

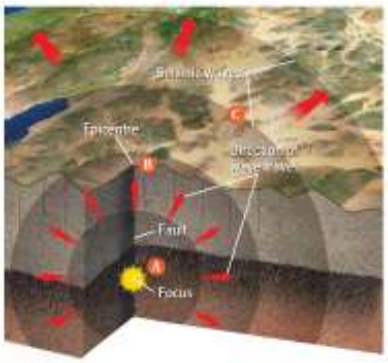

Figure 4.14

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Focus: Where the Earthquake Starts

- An earthquake starts at a location called the **focus**
  - The point where breakage of rock inside Earth first happens

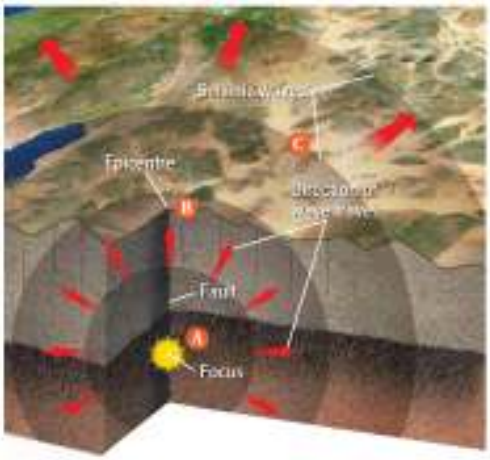

Figure 4.14: (A) The focus is the location where an earthquake starts.

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Seismic Waves

- As the earthquake occurs, rocks along a fault move into a new position
  - Cause vibrations called **seismic waves**
  - Seismic waves leave the focus in all directions

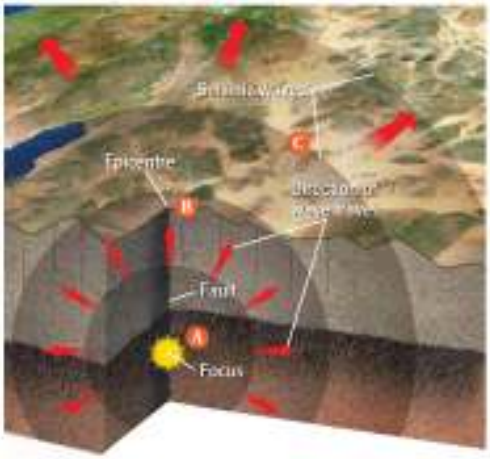

Figure 4.14: (B) Seismic waves leave the focus in all directions

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Epicentre

- **Epicentre**: the point on Earth's surface above where an earthquake starts (above the focus)
  - People often refer to the epicentre when describing where an earthquake has occurred

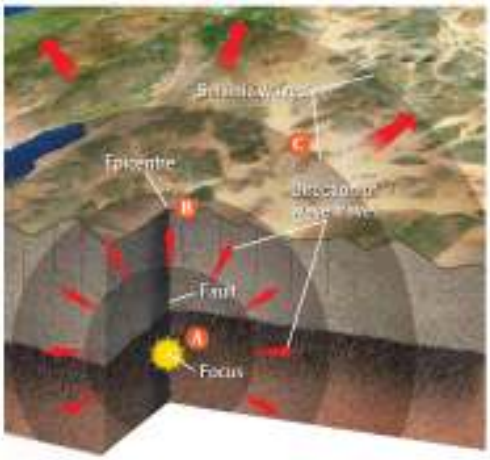

Figure 4.14: (C) Epicentre of an earthquake

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Types of Seismic Waves

- **Seismic waves**: vibrations caused by release of energy during an earthquake
  - Three types of seismic waves:
    - Primary waves (P waves)
    - Secondary waves (S waves)
    - Surface waves (L waves)

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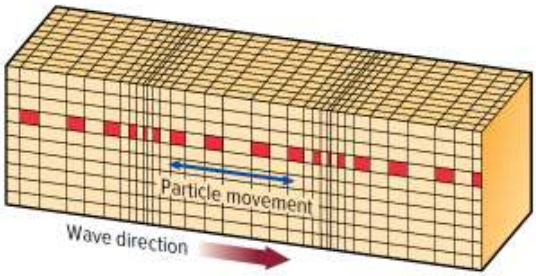
Primary Waves (P waves)

- Move the fastest
- Are the first ones detected in an earthquake
- Cause rock particles to move forward and backward
- Can travel through liquids and solids



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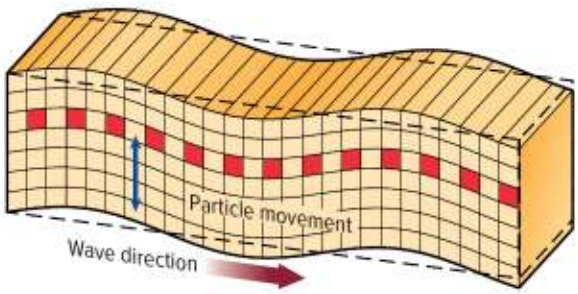
Secondary Waves (S waves)

- Move slower than P waves
- Cause rock particles to move up and down
- Can only travel through solids



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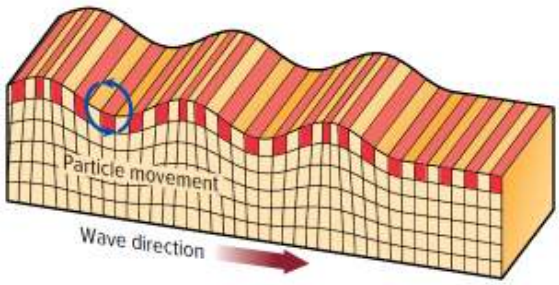
Surface Waves (L waves)

- Slowest of the three waves
- On the surface and often cause the greatest damage
- Cause rock particles to move up and down, and side to side
- Can travel along the surface of Earth (not through Earth's interior)



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How Earthquakes Are Measured

- **Seismograph**: an instrument that measures and records seismic waves (ground vibrations)
  - Composed of:
    - A seismometer (detects ground motion)
    - A device that amplifies and records the signal

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Historic Seismographs

- Early models used a seismometer made of a suspended mass in a frame
- Only records ground movement parallel to the red arrows (only records a single direction)

Figure 4.15: (A) Historic seismograph

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Modern Seismographs

- Contain three electronic seismometers to record north-south, east-west, and up-down motion
- Seismic data from many seismographs are uploaded to computers
  - Information determines strength and location of the earthquake

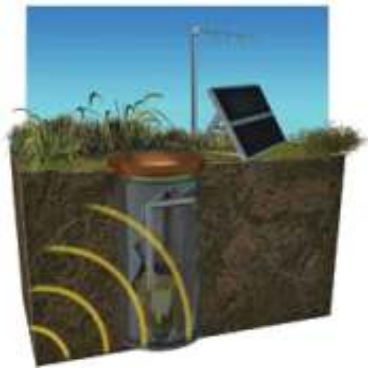

Figure 4.15: (B) Modern seismograph

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Magnitude of an Earthquake

- **Magnitude**: a number that represents the strength of an earthquake
- **Richter scale**: a scale for reporting the strength of an earthquake (magnitude)
  - Based on the size of the largest seismic waves that are formed
  - Higher number means greater strength of earthquake

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Richter Scale

- Each number on the Richter scale represents a 10-fold difference
  - Example: a magnitude-8 earthquake is 10 times larger than a magnitude-6 earthquake
  - Earthquakes less than magnitude-4 do not cause damage

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Discussion Questions

- Where is the epicentre of an earthquake?
- Why do you think seismographs are buried and placed far from highly populated areas?

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Concept 3: Most volcanoes occur where oceanic crust collides with another plate.

- **Volcano**: opening in Earth's surface where magma and other materials are released
  - Eruptions send hot gases and ash into the air
- **Lava**: magma that has been released onto Earth's surface

Figure 4.16: Mount St. Helens in Washington State erupted in 1980. This was the last major eruption near B.C.

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How Volcanoes Form at Plate Boundaries

- Most volcanoes form at convergent boundaries
- Two locations where volcanoes can form:
  - Oceanic-oceanic convergent boundary
  - Oceanic-continental convergent boundary

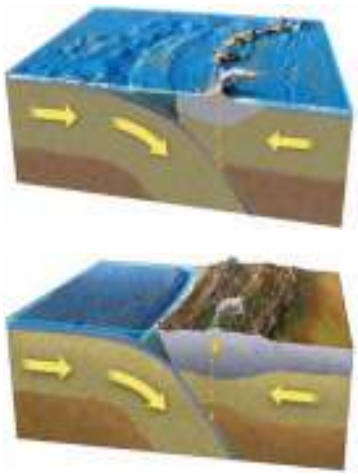

Figure 4.17: (Top) Oceanic-oceanic convergent boundary; (Bottom) Oceanic-continental convergent boundary

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Volcano Formation: Oceanic-Oceanic Convergent Boundary

- Oceanic crust from one plate collides with oceanic crust from another plate
- One plate subducts beneath the other plate
- Oceanic trench forms where one plate subducts beneath another
- Magma rises to the upper plate and some is released onto the surface (lava)

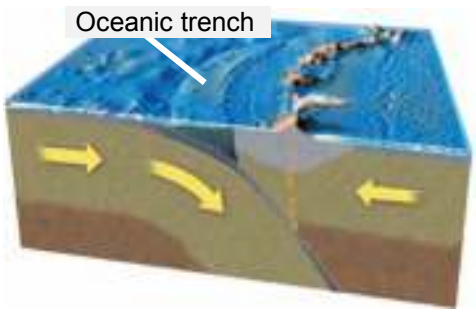

Figure 4.17A

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Volcano Formation: Oceanic-Oceanic Convergent Boundary

- Over time, erupted lava and ash build up and form a curved group of volcanic islands (volcanic island arcs)
  - Example: Aleutian Islands of Alaska

Figure 4.17A: The Aleutian Islands formed from the collision between the Pacific plate and the North American plate

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Volcano Formation: Oceanic-Continental Convergent Boundary

- Oceanic crust collides with continental crust
- Plate of oceanic crust subducts beneath the continental crust of another plate
- Volcanoes form on the surface of continental crust
- Magma can rise to the surface and cause an eruption

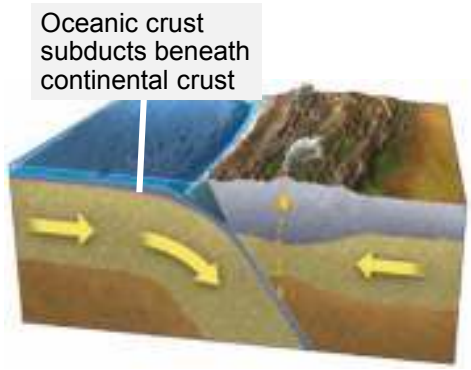

Figure 4.17B

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Volcano Formation: Oceanic-Continental Convergent Boundary

- Pressures produce cause squeezing of crust for hundreds of kilometers
  - Causes crust to fold and crumple, producing large volcanic mountain ranges
  - Example: Coast Mountain Range includes a series of dormant volcanoes

Figure 4.17 The Coast Mountain Range was formed from the collision between the Juan de Fuca plate and the North American plate

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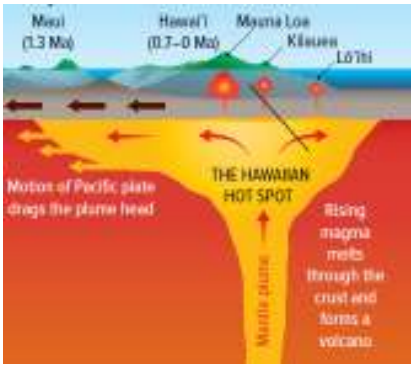
Hot Spot Volcanoes

- Tectonic plates can move over fixed areas called hot spots, creating a trail of volcanic islands
- Hot spots: hot regions of Earth's mantle where magma rises to the surface by breaking through weak parts of the lithosphere
  - Volcanoes can form above hot spots as the magma rises and melts through the crust



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Formation of Hot Spot Volcanoes

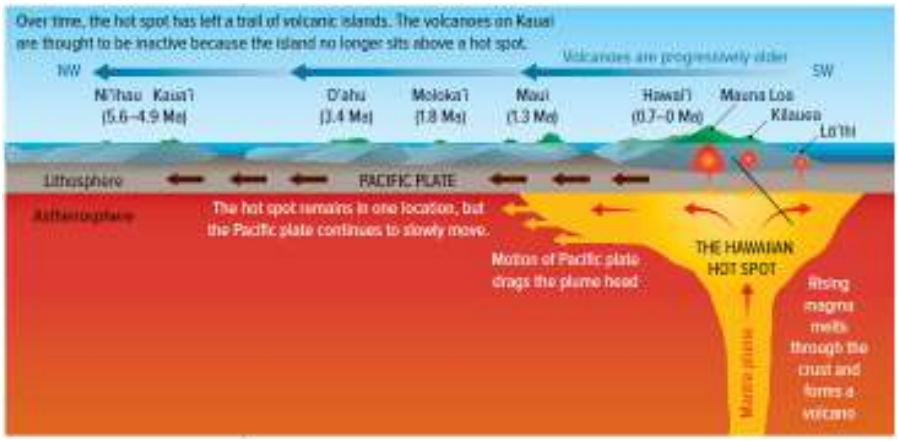

Figure 4.18: The volcanic islands of Hawaii are thought to have formed from a hot spot.

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Discussion Questions

- What is a volcano?
- According to the theory of plate tectonics, describe two ways that volcanoes can form at plate boundaries.

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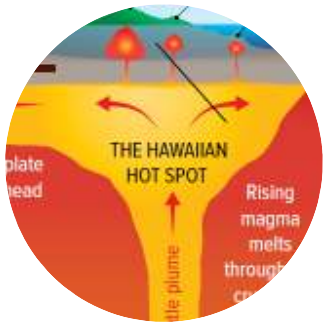
Discussion Questions

- What is a hot spot?
- How do hot spots support the theory of plate tectonics?



TOPIC 4.3 How does the theory of plate tectonics explain Earth's geological processes?

Concept 4: Mountain ranges can also form when continental crust collides.

- Tectonic plate movements and collisions can also produce mountains that are not volcanoes
  - Example: Rocky Mountains are a result of tectonic plate collisions

Figure 4.19: The Rocky Mountains run from B.C. to New Mexico in the United States.

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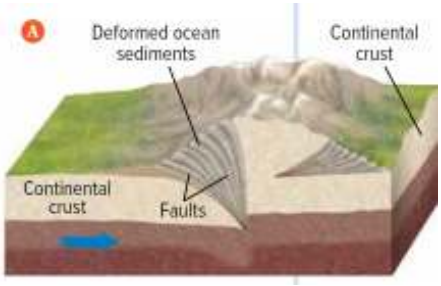
Continental Crust Collisions

- Massive mountain ranges are formed when two plates of continental crust collide
  - One plate is shoved beneath the edge of the other plate (continental crust is not easily subducted beneath the other plate, like oceanic crust)
  - Impact causes a large area to be pushed up, forming mountains

Figure 4.20A: The collision of two plates places large pressures on the plates. This produces faults and causes the crust to be deformed.



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Continental Crust Collisions: Himalayan Mountain Range

- Himalayan Mountain Range
  - Tallest mountain range on Earth
  - Formed from a collision between the Eurasian plate and Indian plate
  - Fast movement of the Indian plate would have caused a violent collision

Figure 4.20B: Formation of the Himalayan Mountain Range

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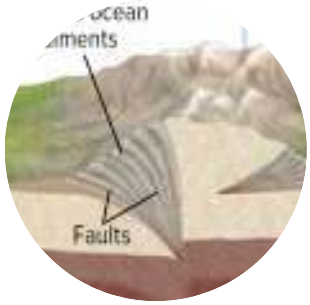
Discussion Questions

- Draw and label a sketch of a convergent plate boundary involving two plates of continental crust.
- Why does the collision between plates of continental crust differ from what happens when oceanic crust collides with continental crust?



TOPIC 4.3 How does the theory of plate tectonics explain Earth's geological processes?

Summary: How does the theory of plate tectonics explain Earth's geological processes?

- Most earthquakes occur near tectonic plate boundaries.
- Movement along faults produces seismic waves.
- Most volcanoes occur when oceanic crust collides with another plate.
- Mountain ranges can also form when continental crust collides.