The theory of plate tectonics is the unifying theory that explains Earth's geological processes.

- How does the movement of Earths tectonic plates cause observable changes and effects?
- How does tectonic plate movement effect you locally?

Student Objectives

Statement	Beginning	Approaching	Meeting	Succeeding	Exceeding
I can describe the layers of the Earth (crust, mantle, outer core, inner core)					
I can describe the types of plate boundaries (convergent, divergent, and transform)					
I can describe how volcanoes and trenches form					
I can describe how mountain ranges form					
I can describe how earthquakes occur					
I can relate tectonic processes to local geological events					
I have an earthquake safety kit					

Summary of Key Points

Continental Drift Theory

- Various pieces of evidence indicate that the continents were once joined but later drifted to their current positions.
    1. The continental shelves of the continents can be aligned like a jigsaw puzzle.
    2. Regions of some continents that are far apart have similar rocks, mountain ranges, fossils, and patterns of paleo-glaciation.

Plate Tectonics Theory and Convection

- The process of sea floor spreading provides a mechanism for continental drift.
    1. The continents are attached to huge slabs of rock, known as tectonic plates.

Earths Layers and Convection

- Earth has distinct layers.
- When the tectonic plates move across Earth's surface, they carry the continents with them.

Plate Interactions

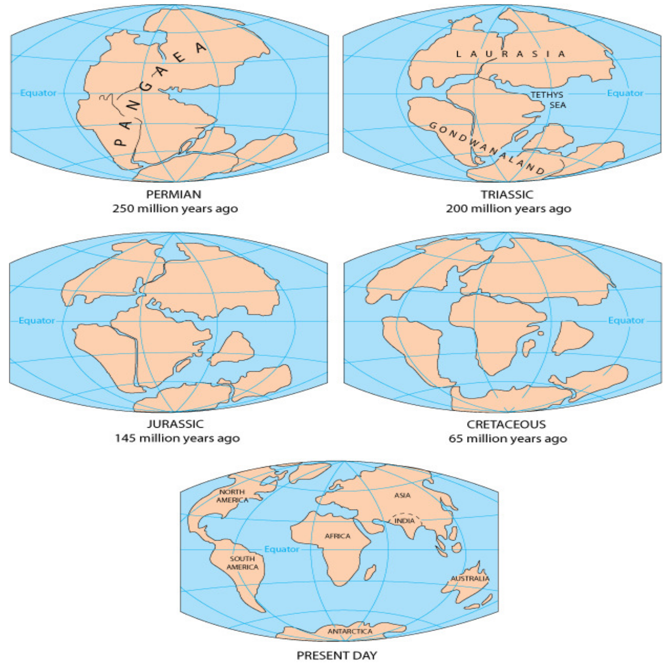
- Convection currents from the asthenosphere push magma to Earth's surface, causing tectonic plates to move and sometimes converge.
- When tectonic plates converge, one plate may slide beneath the other or the edges of the plates may crumple, forming mountains.
- Tectonic plates can also diverge, or spread apart, forming rifts on land and ridges in the oceans.

Volcanoes and Earthquakes

- Tectonic plates may begin to slide past one another at a transform boundary, resulting in the build-up of pressure, which may be released as an earthquake.
- Volcanoes occur at tectonic plate boundaries or over geologic hot spots, where magma is coming up through Earth's crust.

Plate Tectonics

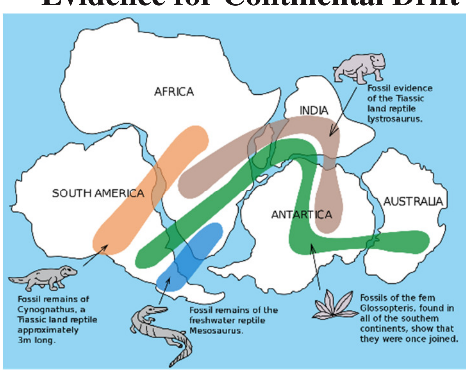
Theory of Continental Drift



1. **The Jigsaw Puzzle Fit**

- The **Continental Drift Theory**
    - *Alfred Wegener* proposed that continents moved around on Earth's surface and were at one time joined together.
    - Pangea: **Supercontinent** "all Earth." (The shape of the continents suggests that they might fit together like jigsaw pieces).

2. **Matching Geological Structures and Rocks, Matching Fossils,** and **Climatic Evidence for Continental Drift**



There were matching geologic features, such as:

- *mountain ranges and rocks*
- *matching fossils* (representing species that could not cross oceans)
- *different climates in the past*, such as coal deposits in Antarctica, which is now too cold to support plant life, and evidence of glaciers in parts of Africa, where it is now too warm for glaciers to form.

The distribution of glacial features can be best explained if the continents were part of Pangaea.

- **Paleoglaciation** is a term describing past periods of extensive glaciations that covered most of the continent

Quick Check#1

1. What did Wegener notice about the shapes of continents that led him to suggest that continents were able to move?

____

____

____

2. List three forms of evidence besides continent shape that gave support to the idea of continental drift,

____

____

____

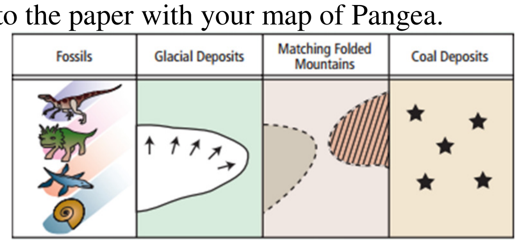
Activity: Piecing Together Pangea

Scientists have used many separate lines of evidence to determine how the continents might once have fit together. In this activity, too, will use various pieces of evidence to reconstruct the supercontinent Pangea.

Question:
How did the continents fit together before Pangea broke apart?

Materials:
- Photocopy of continents
- Scissors
- 21.5 cm x 28 cm sheet of paper
- glue

Procedure:
1. Obtain a photocopy of the continents from your teacher. Cut out each continents, trimming the pieces just to the edge of the dotted lines. The dotted lines represent the true continental edges, the continental shelves.
2. Use the clues provided in the legend below and the shapes of the continents to help you reconstruct Pangea. Piece together the continent shapes into a supercontinent on a separate piece of paper, but do not glue them down yet.
3. Once you assembled your pieces, check with your teacher before gluing them on to the blank sheet of paper.
4. Copy the legend below onto the paper with your map of Pangea.



5. Clean up and put away the materials you have used.

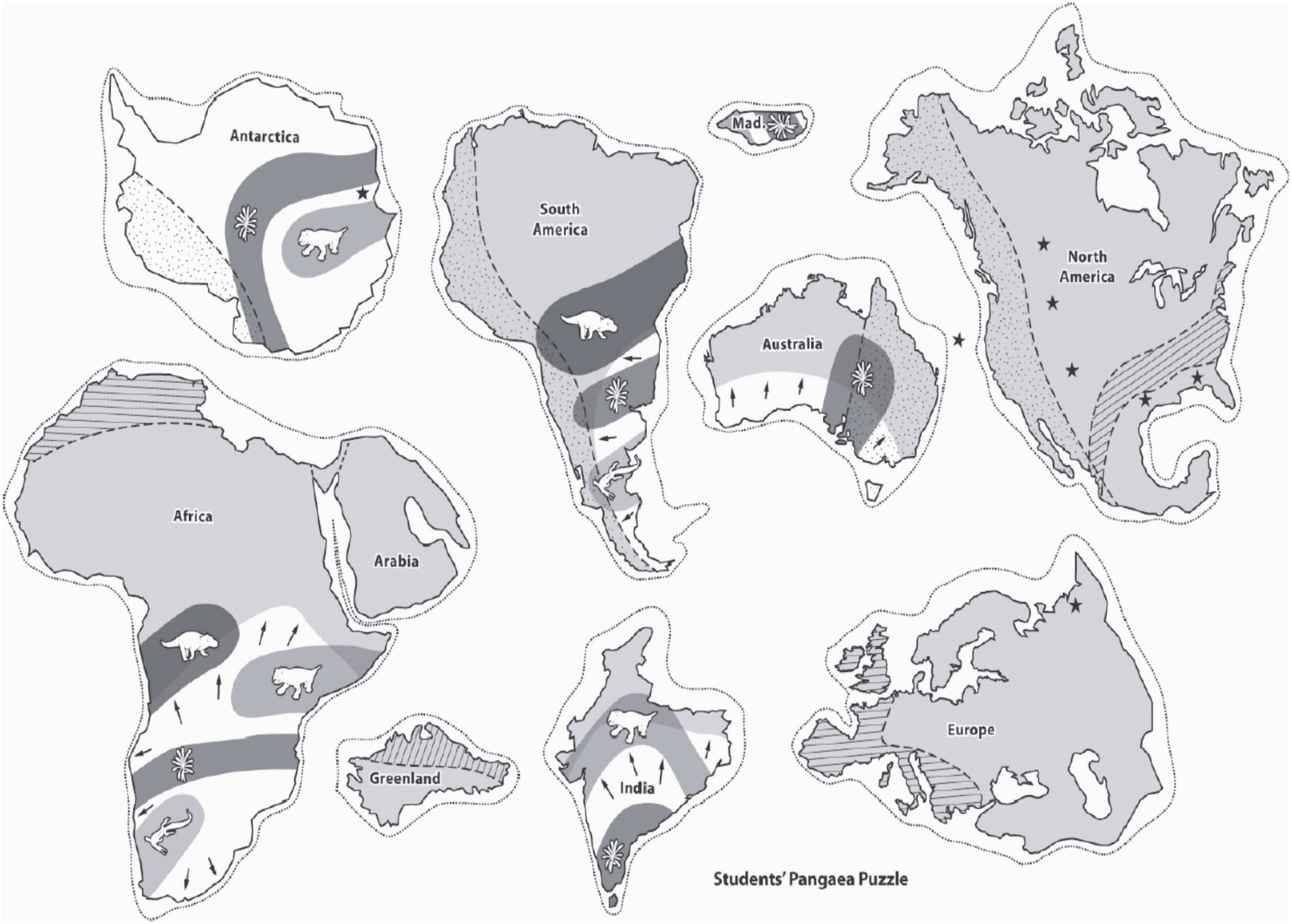
Analyze:
1. Which continents were easiest to fit together? Explain why.
2. Of the pieces of the evidence that you used to reconstruct Pangea, which provided the best clues as to how the continents were once joined? Justify your answer.
3. a) Were there any pieces of Pangea that you found difficult to place?
   b) If so, what other evidence would have helped you to place these pieces?

Conclude and Apply:
1. a) In a few sentences, summarize the steps you took to reconstruct Pangea.

   b) How was the process you took similar to the method Alfred Wegener used to support continental drift theory?

2. Why did you use several pieces of evidence to reconstruct Pangea, not just one?

3. a) Hypothesize where the continents might have be situated in 200 million years.
   b) Describe how ecosystems of British Columbia's west coast might change as a result. Justify your answers.



Students' Pangaea Puzzle

Theory of Plate Tectonics

1. Wegener's evidence for continental drift did not explain how entire continents could change locations, so his theory was rejected by scientists of his time.

2. Wegener and the other scientists of his time did not know that Earth's surface is broken into large, rigid, movable slabs of rock called **tectonic plates** that slide over a layer of partly molten rock.

3. New scientific equipment developed since the 1940s has allowed scientists to gather evidence from the sea floor and **THE MID-OCEAN RIDGE.**

Evidence from mapping the sea floor: When explorers began to map the ocean floor, they discovered undersea mountain running north to south down the length of the Atlantic Ocean, which they named the *Mid-Atlantic Ridge.*

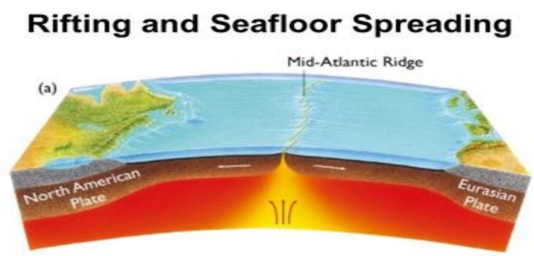
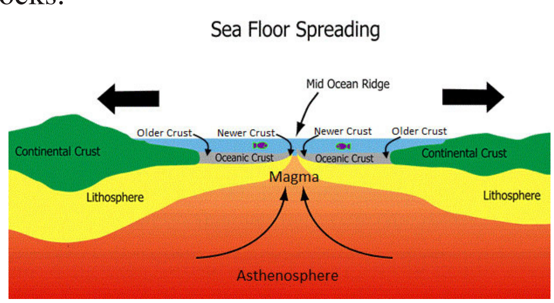
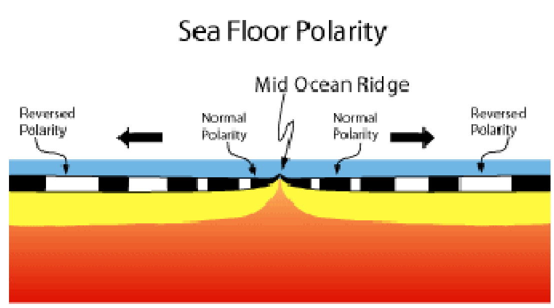


Fig. 20.4a

Evidence from ocean rock and sediments: Rocks taken from the Mid-Atlantic Ridge were younger than other ocean rocks.

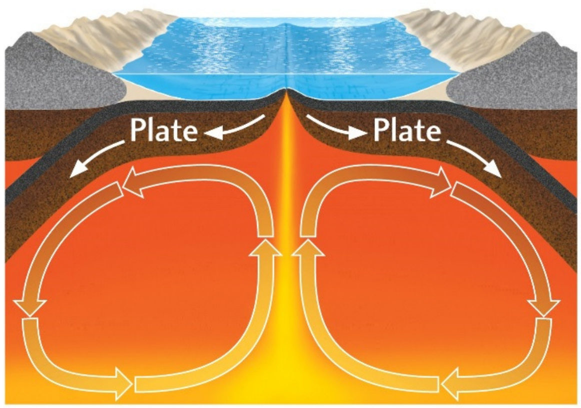


Evidence from paleomagnetism: The direction of Earth's **magnetic polarity** can experience a **magnetic reversal** over thousands of years

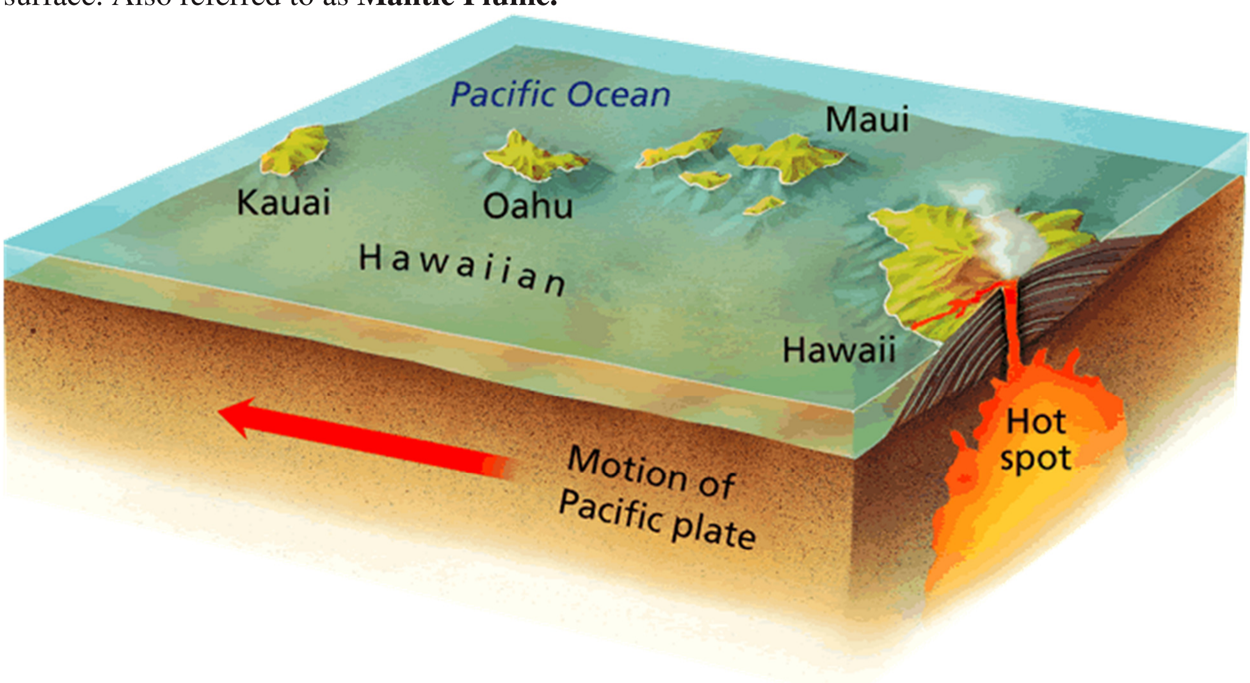


J. ***Tuzo Wilson*** combined the concepts of sea floor spreading and paleomagnetism to explain continental drift, laying the groundwork for the **Plate Tectonic Theory:**

- The **Plate Tectonic Theory** states that Earth's surface is broken into large plates that move apart and then rejoin, sliding over the semi-fluid rock below.
- There are about 12 major tectonic plates and many smaller ones.
- **Mantle convection** is thermal energy transfer in the mantle where hot, light magma rises and cold, dense magma sinks. This rotation of magma cause movement of the plates (**this is the one question Wegener could not answer)
- Heat to keep the mantle molten comes from radioactive elements.



A geologic **hot spot** is the location of excess radioactivity, causing magma to rise to Earth's surface. Also referred to as **Mantle Plume.**



The Hawaiian Islands formed as a tectonic plate passed over a hot spot and magma rose up from under Earth's surface.

Quick Check #2

1. Why were Wegener's ideas about continental drift originally rejected?

2. Explain the implications of evidence from each of the following areas.

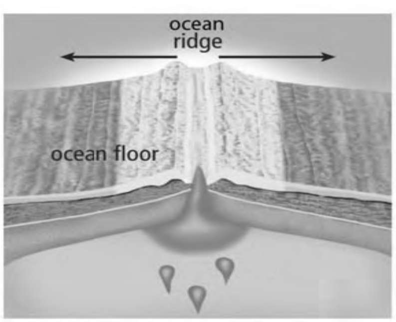
(a) mapping the sea floor

(b) analyzing ocean rock and sediments

(c) paleomagnetism

3. How did the Hawaiian Islands form?

4. What does the theory of plate tectonics state?



5. Which feature is shown in the diagram?

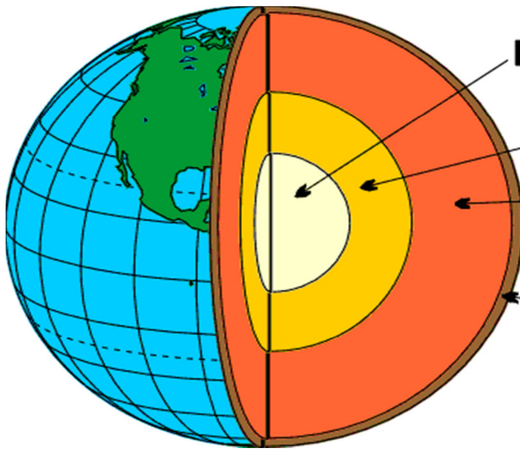
A. hot spot
B. sea floor
C. paleoglaciation
D. jigsaw fit

5. What is the source of energy for convection currents and hot-spot activity in Earth's mantle?

Layers of the Earth

From the surface to the very center of the earth is about 6500 km. The 4 major layers of the earth include the:

- Crust
- Mantle
- Outer Core
- Inner Core



1. **Crust**: outer solid rock layer (The crust is the first layer of the earth).

▪ **Continental crust – 50 km thick (average)**
Made from a less dense type of rock called granite

▪ **Oceanic crust – 10 km thick**
Made from a dense rock called basalt.

The crust doesn't even make up 1% of the earth!

2. **Mantle**: Approx. **2900 km thick**
85% of the total mass of the Earth.

▪ **Lithosphere :** Solid *Crust + Upper-Upper Mantle*

▪ **Asthenosphere:** Molten *Upper Mantle*

3. **Outer core**: Approx. **2200 km thick**
Made from liquid iron and nickel

4. **Inner core**: Approx. **1300 km thick**
Made from mostly iron and nickel , the tremendous pressure keeps it solid.
Heat from Earth's core helps produce convection currents and hot-spot activity.

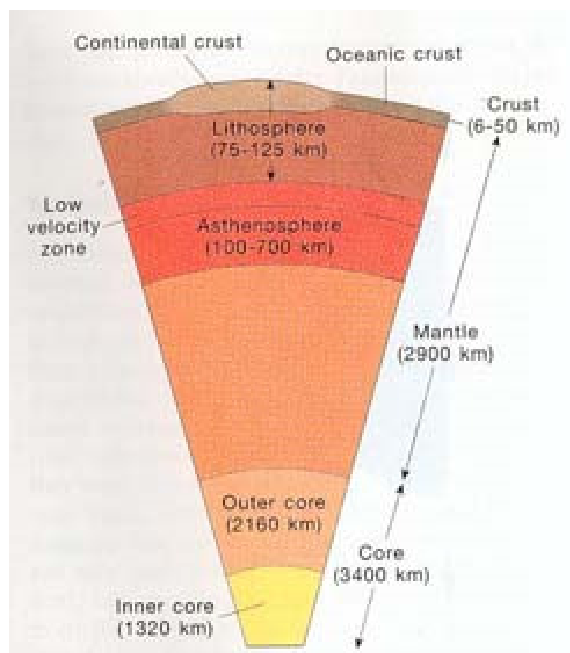
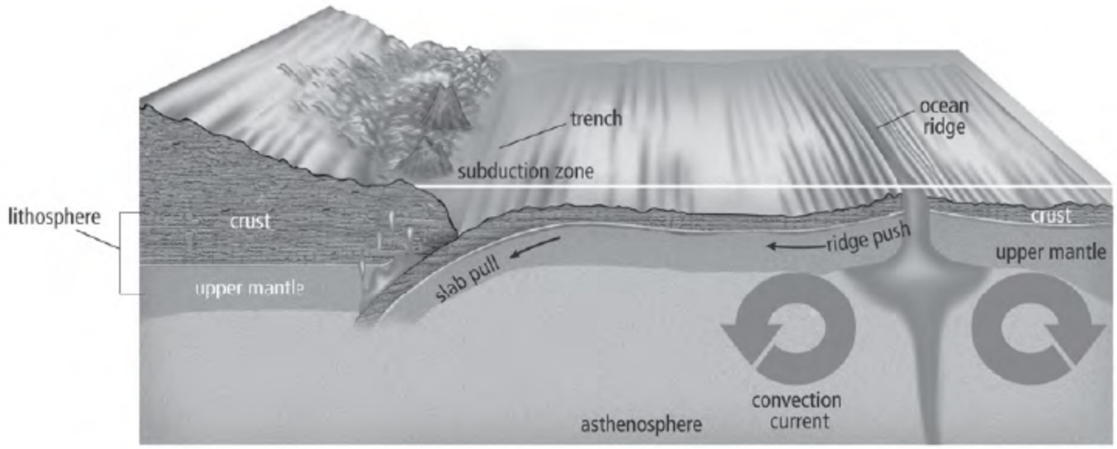


Plate Motion



1. Tectonic plates make up the lithosphere, which floats on the asthenosphere

- The **lithosphere** is the crust and upper portion of the mantle.
- The **asthenosphere** is the molten layer of the upper mantle.

2. There are about 12 major tectonic plates and many smaller ones.

- Tectonic plates are all moving at the same time.

3. Mantle convection is thermal energy transfer in the mantle where hot, light magma rises and cold, dense lithospheric plate material sinks.

- Heat to keep the asthenosphere molten comes from radioactive elements.
-

4. Continents, attached to the tectonic plates, float on the magma of the asthenosphere.

5. Rising magma can reach the surface at spreading ridges (in the oceans) or **rift valleys** (on land).

- The magma cools when it reaches the surface, solidifies, and is pushed aside as new magma pushes from below.
- In a process called **ridge push,** the spreading mid-ocean ridge pushes the rest of the tectonic plate it is on away from the ridge.

6. Subduction is the action of one tectonic plate pushing below another tectonic plate

- A more dense oceanic plate subducts under a lighter continental plate.
- The dense, subducting plate material pulls the rest of the attached plate toward the subduction zone and down into the mantle, a process called **slab pull**.

7. Along with convection currents and ridge push, slab pull helps keep tectonic plates in motion.

8. A **plate boundary** is the location where two plates meet and move relative to each other.

Quick Check #1

1. Name the four layers of Earth, in order from the inside out.

(a) ______________________ (b)______________________

(c) ______________________ (d)______________________

2. What is the difference between the densities of oceanic crust and continental crust?

____

____

3. What is the source of energy for convection currents and hot-spot activity in Earth's mantle?

____

____

4. In terms of the crust and the mantle, describe:

(a) the lithosphere

____

(b) the asthenosphere

____

5. What is a mantle plume?

____

____

____

6. How does a rift valley form?

____

____

7. What happens in subduction?

____

____

____

Plate Interactions

1. **Divergent**

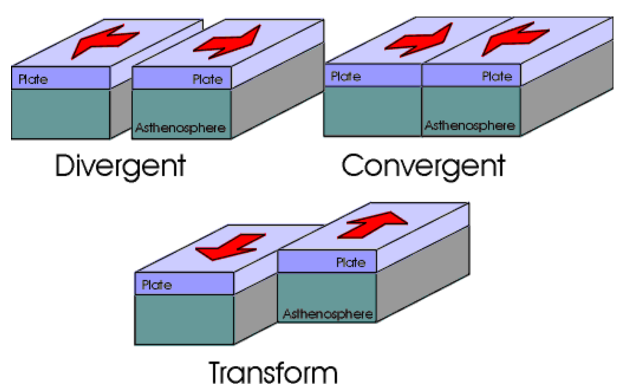
(moves apart/spreads/extensional)

2. **Convergent**

(moves together/collides/compressional)

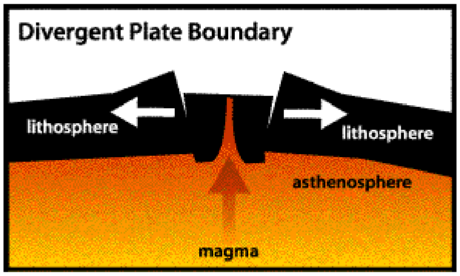
3. **Transform**

(moves in opposite directions, horizontally/sliding)



1. Divergent plate boundaries are areas where tectonic plates are spreading apart.

- Ocean ridges such as the Mid-Atlantic Ridge are examples of divergent plate boundaries.
- Diverging plates at the East African Rift are slowly breaking Africa into pieces.



2. Convergent plate boundaries are areas where tectonic plates collide.

- A **subduction zone** is a zone representing a convergent plate boundary, where one tectonic plate subducts beneath and is destroyed by the other overriding tectonic plate.
  - – Large earthquakes and volcanoes are found in subduction zones.
- A **trench** is a long narrow depression in the ocean floor that marks a convergent plate boundary and is part of a subduction zone.

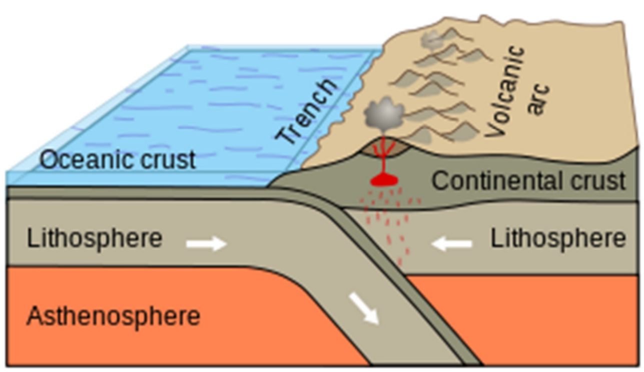
There are 3 types of Convergent Plate boundaries found in the world:

<u>*A. Oceanic-Continental Plate Convergence*</u>

- Oceanic plate subducts under the continental plate, forming a trench.
- Cone-shaped volcanoes can form from magma seeping to the surface.
  A **volcano** is an opening in Earth's surface that, when active, spews out gases, chunks of rock, and melted rock.

<u>Local Significance</u>

The volcanic belt of the Pacific Northwest has formed as a result of the oceanic-continental convergence between Juan de Fuca Plate (oceanic) and the North American Plate (continental).



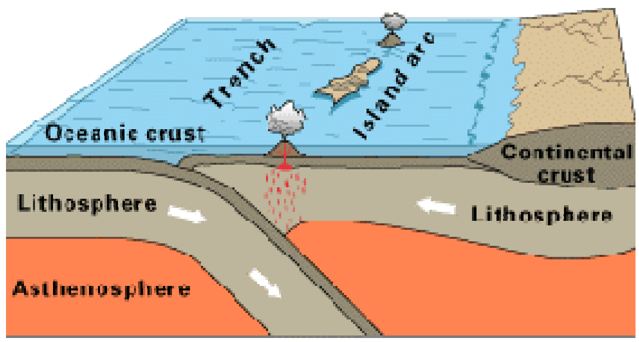
Oceanic-Continental convergence

B. Oceanic-Oceanic Plate Convergence

- The cooler, denser plate subducts under the warmer, less dense plate

Real World

- This may produce a **volcanic island arc**, which is a long chain of volcanic islands, such as those found in Japan, Indonesia, and Alaska's Aleutian islands.



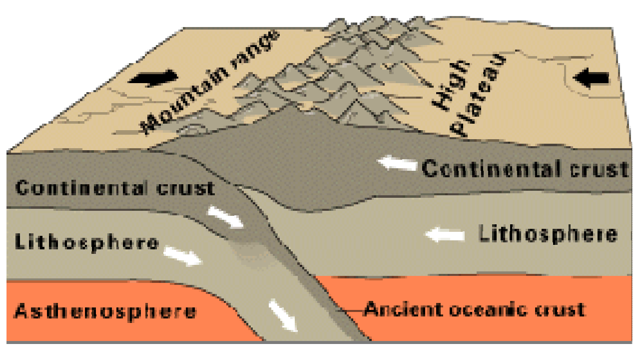
Oceanic-oceanic convergence

C. Continental-Continental Plate Convergence

• Since both plates are continental plates, their densities are similar.
• As they collide, their edges fold and crumple, forming Mountains.

Real World

• The Himalayas are the world's youngest (and tallest) mountain range and are still growing taller today.



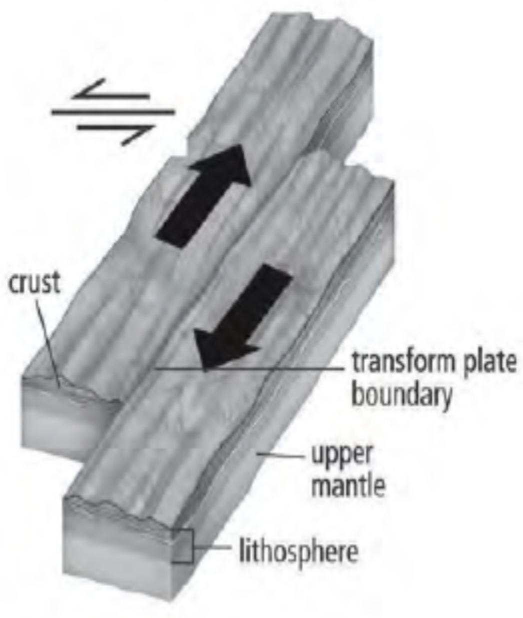
Continental-continental convergence

3. Transform plate boundaries are areas where tectonic plates slide horizontally past each other

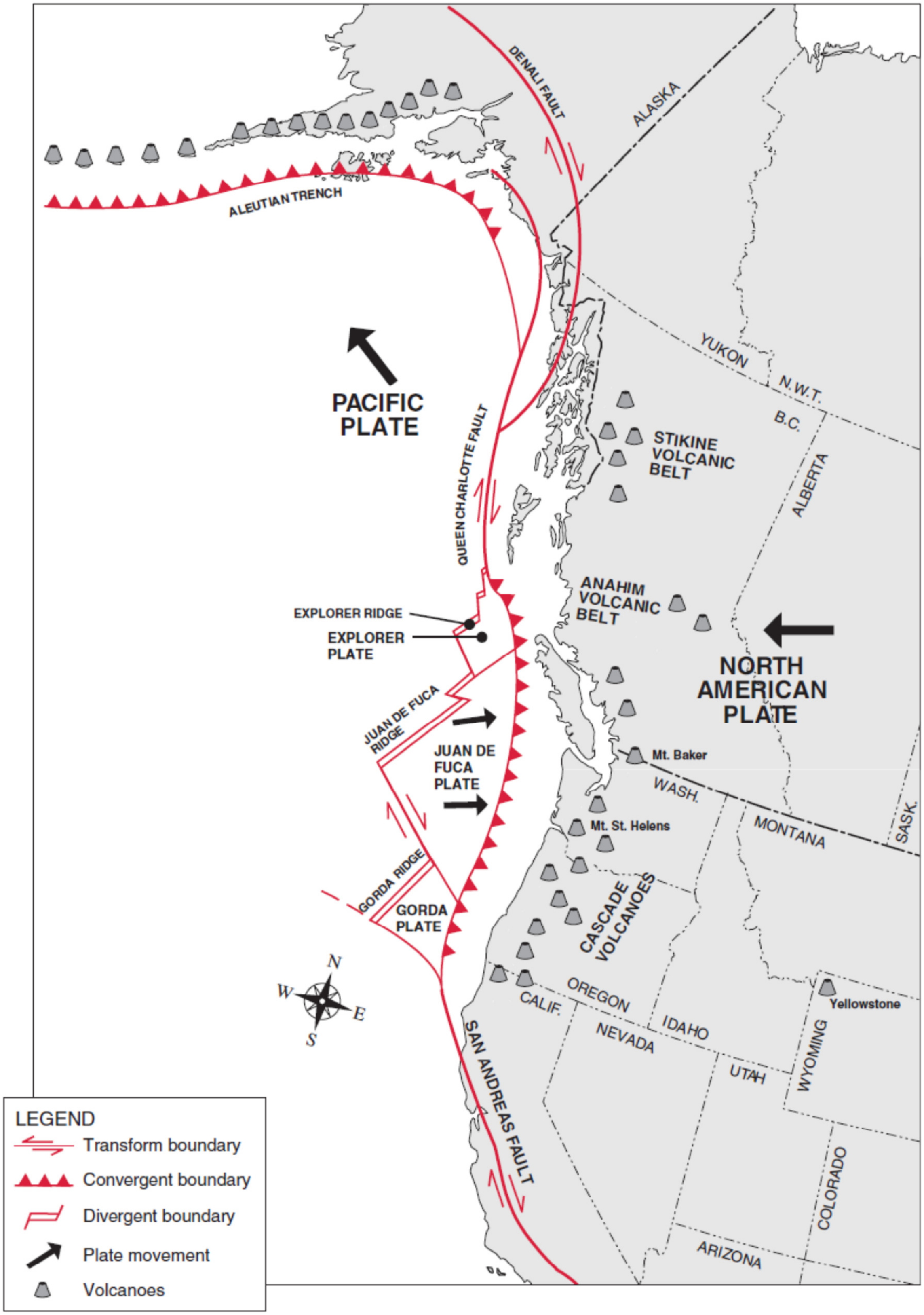
- No mountains or volcanoes form, but earthquakes and faults may result.
  A **fault** is a break or fracture in rock layers due to movement on either side.

Real World

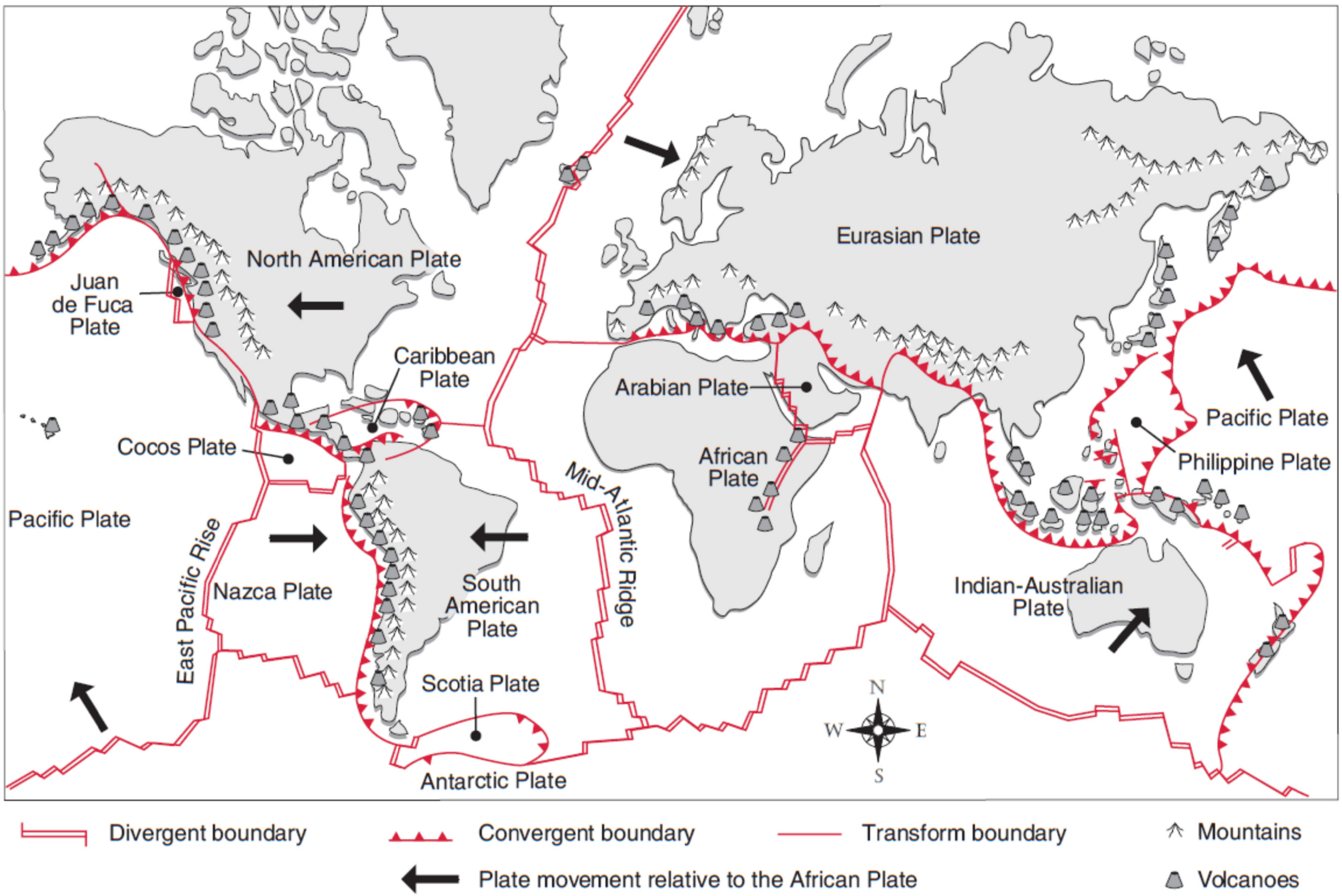
- Transform plate boundaries are usually are found near ocean ridges but may also be found on land, such as the San Andreas Fault in California.



MAP OF THE PACIFIC COAST OF NORTH AMERICA



WORLD TECTONIC PLATE BOUNDARIES MAP



Quick Check# 2

1. List three kinds of plate interactions.

____

____

____

2. Identify the geographical features that are typical of

(a) two oceanic plates converging

____

____

(b) an oceanic plate and a continental plate converging

____

____

(c) two continental plates converging

____

____

(d) two continental plates diverging

____

____

(e) two oceanic plates diverging

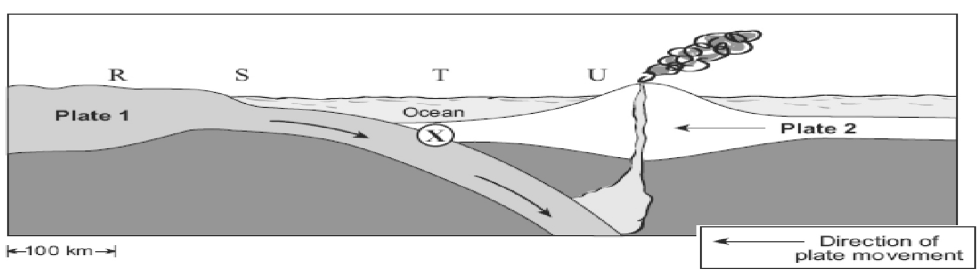
____

____

3. What is the relative motion that occurs between two plates that meet at a transform boundary?

____

____



Use the above diagram to answer question 4.

(a) What type of plate boundary is shown at X in the diagram? ____________________________

(b) What type of tectonic plate is Plate 1? ________________ Plate 2? _____________________

(c) Under which location (R, S, T, or U) would you find the deepest focus earthquakes? Explain.

____

____

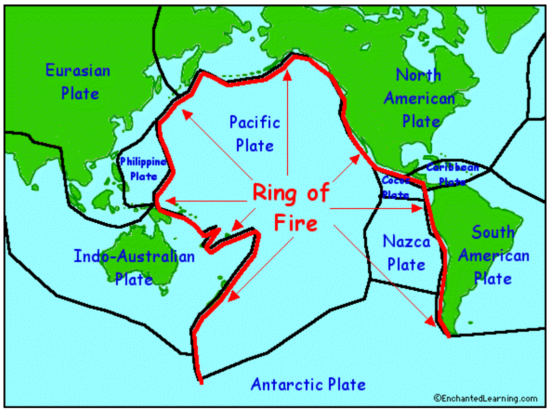
(d) What type of volcano would you expect near location U? ____________________________

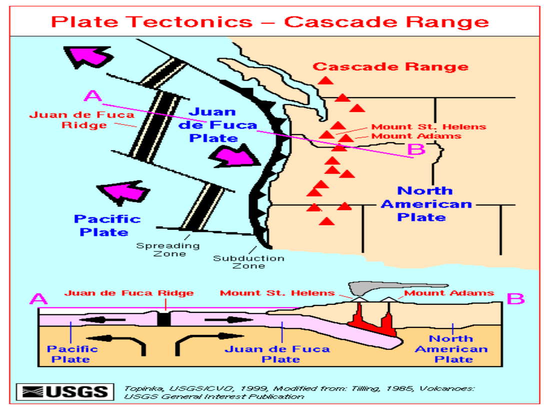
Earthquakes

1. An **earthquake** is a shaking of the ground as the result of a sudden release of energy in Earth's crust.

2. About 80 percent of earthquakes occur in a ring bordering the Pacific Ocean (Ring of Fire).

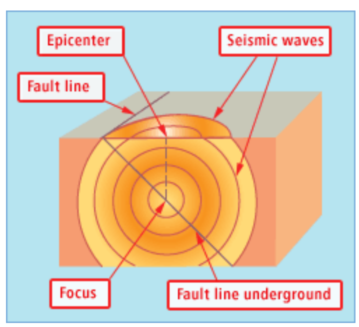
- **Local Significance:** The Juan de Fuca convergent plate boundary west of Vancouver Island has many earthquakes.





3. The **focus** of an earthquake is where the pressure is finally released.

- The **epicentre** is the point on the surface directly above the focus.



4. Earthquakes occur at various depths, depending on the plates involved (Table 12.1).

- Earthquakes at the surface tend to cause more damage.

TABLE 12.1 Classification of Earthquakes

Classification	Depth of Focus
Shallow focus	0 to 70 km
Intermediate focus	70 to 300 km
Deep focus	Greater than 300 km

Seismic Waves

Energy released by an earthquake produces vibrations called ***seismic waves.***

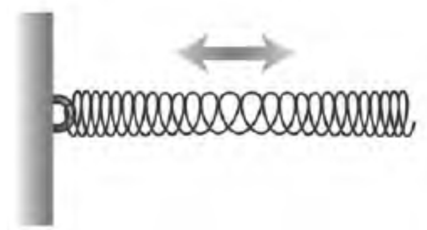
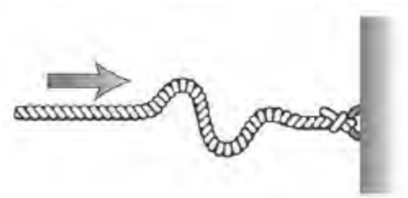
- Seismic waves reveal the source and strength of an earthquake.
- Seismic waves also help us learn about the composition and size of Earth's interior layers since the waves behave differently in different layers.

1. **Primary waves (P-waves): Compressional motion-underground**
   • P-waves travel through solids, liquids, and gases.
   • P-waves are the fastest (6km/s)

2. **Secondary waves (S-waves): Up-down or side-side motion-underground**
   • S-waves travel through solids but <u>not</u> liquids.
   • S-waves are slower and are the second waves to arrive after an earthquake (3.5km/s).

3. **Surface waves (L-waves)** are seismic waves that ripple along Earth's surface like ripples on a pond
   • L-waves usually cause more structural damage than P-waves.
   • L-waves are the slowest and the last waves to arrive after an earthquake.

Summary: Fill in the Chart

Wave	Full Name	Description	Ground Motion Sketch
P			
S			
L			

Quick Check #3

1. What is the difference between the focus of an earthquake and the epicentre of an earthquake?

____

____

____

2. What are three kinds of earthquake waves and how do they differ?

(a)

____

____

(b)

____

____

(c)

____

____

Measuring Earthquakes

Richter Scale: Scientists measure earthquakes using the Richter scale. This scale, invented in 1934 by California scientist Charles Richter, measures the magnitude of an earthquake, and the result is a number from 0 to 10, as measured on a machine called a **seismograph.**

An increase of 1 in magnitude = 10X stronger

Example: A magnitude 6 earthquake is 100× more powerful than a magnitude 4 earthquake.

RICHTER SCALE

Magnitude	Description	What it feels like	Frequency
Less than 2.0	Micro	Normally only recorded by seismographs. Most people cannot feel them.	Millions per year.
2.0–2.9	Minor	A few people feel them. No building damage.	Over 1 million per year.
3.0–3.9	Minor	Some people feel them. Objects inside can be seen shaking.	Over 100,000 per year.
4.0–4.9	Light	Most people feel it. Indoor objects shake or fall to floor.	10,000 to 15,000 per year.
5.0–5.9	Moderate	Can damage or destroy buildings not designed to withstand earthquakes. Everyone feels it.	1,000 to 1,500 per year.
6.0–6.9	Strong	Wide spread shaking far from epicenter. Damages buildings.	100 to 150 per year.
7.0–7.9	Major	Wide spread damage in most areas.	10 to 20 per year.
8.0–8.9	Great	Wide spread damage in large areas.	About 1 per year.
9.0–9.9	Great	Severe damage to most buildings.	1 per 5-50 years.
10.0 or over	Massive	Never Recorded.	Never recorded.

Earthquake-Grab-and-Go Kit

Over the weekend, create a kit for yourself and encourage family members to create one as well.

Take a picture of your kit with yourself in it and bring it in on Monday to share.

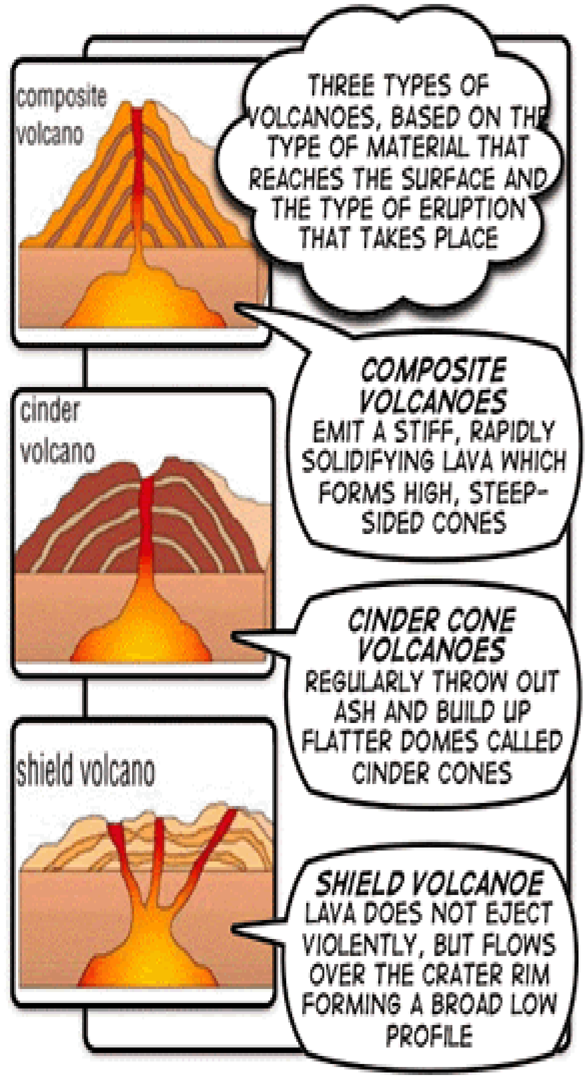
Every person in your family should have their own customized evacuation kit at home and at work. Think of what other possible items you may need in case of an emergency (ie. medication, glasses, documents, pet food for pet). Keep the kits by the front door, where they will be easy to find if you need to evacuate quickly.

Check your kits twice per year to replace any expired food, batteries, and medicine. A good reminder to check is when changing your clocks for daylight savings in the spring and fall.

- Backpack or tote bag (to carry the kit items)
- Blanket or sleeping bag
- 2 Garbage bags
- Bottled water
- Candles and matches or a lighter
- Clothing and shoes (one change, comfortable and all-season)
- First aid kit (at least some bandages and gauze)
- Flashlight and batteries
- Food that requires no cooking
- Money (including coins)
- Playing cards and games
- Radio and batteries, or crank radio (to listen to news and public advisories)
- Toilet paper and personal hygiene supplies
- Whistle

Volcanoes

The movement of tectonic plates causes volcano formation.



1. Composite volcanoes are found along plate boundaries and are made of layers of ash and lava, which is magma on Earth's surface.

Real World:

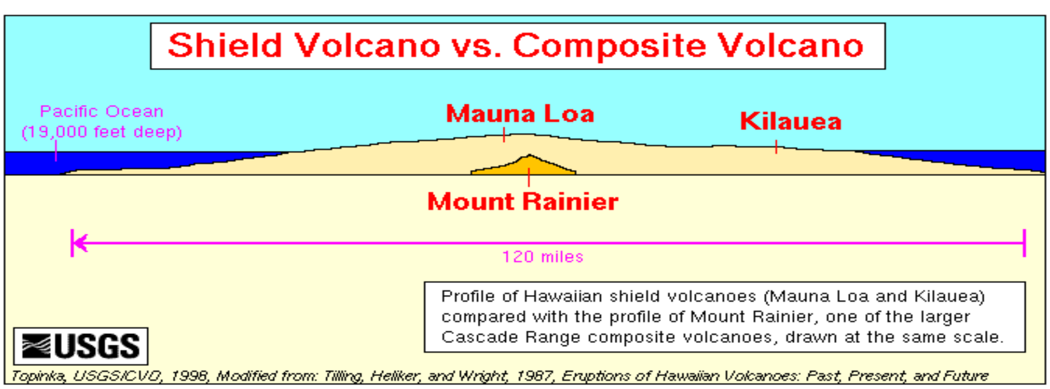
- Mt. Fuji in Japan,
- Mt. Rainier & Mt. St. Helens in Washington

2. Shield volcanoes form over hot spots. Lava flows out from a hot spot and forms a low, wide cone.

Real World:

- The Hawaiian Islands (see Data Pages) are an example of a chain of shield volcanoes.
- The Anahim Volcanic Belt (see Data Pages) formed over a hot spot in the middle of British Columbia.

3. Rift eruptions occur along long cracks in the lithosphere, such as along the Mid-Atlantic Ridge.



Name ____Block _______

Bill Nye Volcano Video

1. **The first volcanic eruption Bill talks about is called ________________________________.**
2. **This volcano is located ____________________________ and it erupted in ________________________________.**
3. **Volcanoes usually occur ______________________________.**
4. **Hawaii was formed on ________________________________.**
5. **The Hawaiian Islands form an almost perfectly straight chain of islands because ____ ____.**
6. **The name of a hole in a lava field where you can see the lava is ____________________________________.**
7. **The names of the three types of volcanoes are ________________________________, ________________________________, and ________________________________.**
8. **Mt. St. Helens, which is on a plate boundary, was much more explosive than Mt. Kilauea in Hawaii because ____ ____.**
9. **The reason scientists study volcanoes is ____ ____.**
10. **The two types of Lava are ________________________________ and _______________________________.**
11. **A volcano that hasn't erupted in 200 years is called ____________________________.**

Quick Check # 4

1. List three types of volcanoes and state where each is found.

____

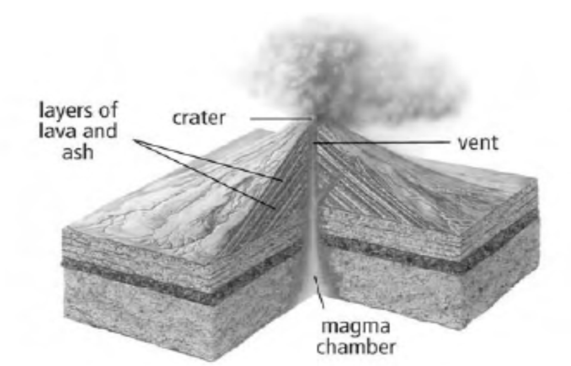
____

____

Refer to Map of the Pacific Coast of North America on page 10 of your Data Pages. Find the Juan de Fuca Plate, which is a small triangular plate that has a different kind of plate boundary on each side.

2. What will happen to the Juan de Fuca plate in the distant future?

A. It will be subducted under the North American plate and melt.
B. It will get larger and push the North American plate east as it moves west.
C. It will form an island arc.
D. It will remain basically unchanged.



3. What kind of volcano is shown in the diagram?

A. composite
B. shield
C. rift
D. hot spot