

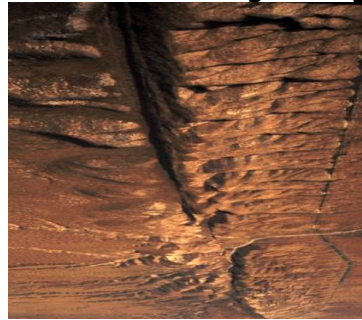
Topic 5: The Dynamic Crust (workbook p. 65-85)

Evidence that Earth's crust has shifted and changed in both the past and the present is shown by:

- sedimentary horizontal rock layers (strata) are found at high elevations: since sedimentary rock is formed under water, uplift of the crust must have occurred to raise these layers
- fossils: fossils of marine organisms are found in sedimentary rock at high elevations
- tilted, bent or folded layers (strata): some sedimentary rock layers are tilted, or folded or bent from their original flat, horizontal formation



- Faults: breaks or cracks in rock that shows movement along its edge



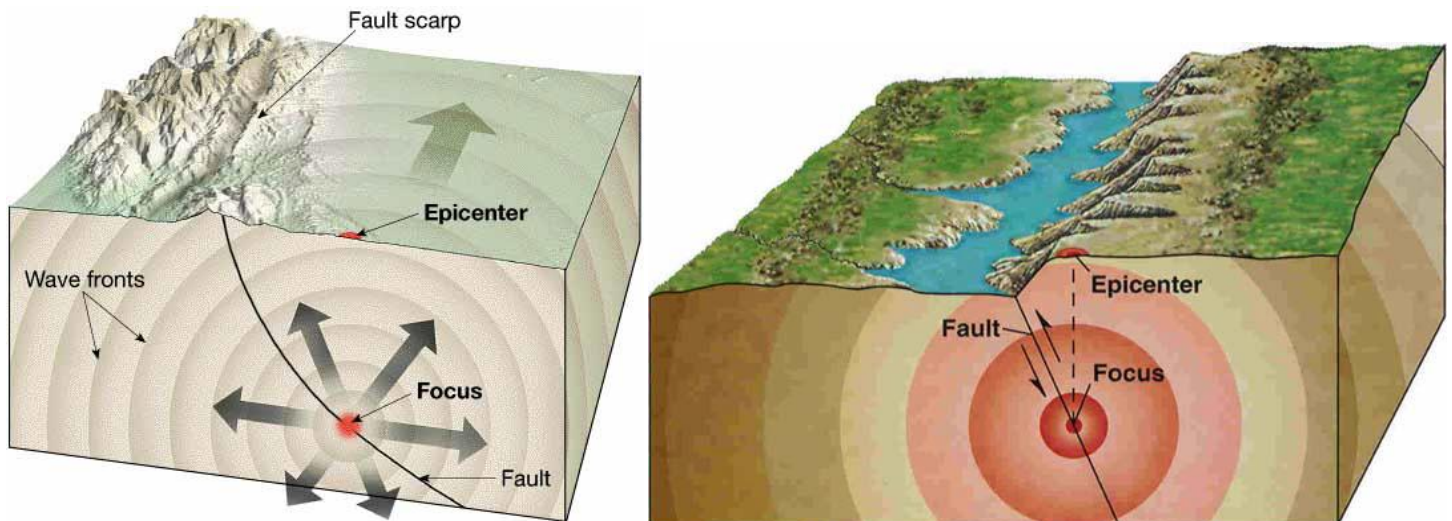
- Volcanoes: eruptions cause changes in Earth's surface.
- Changes in bench mark elevations that show vertical crustal movement.
- Geosynclines: Ex.: sediment accumulating in the center of the Gulf of Mexico is causing it to sink or subside
- Earthquakes recur in the same areas or zones

EARTHQUAKES occur when crustal forces put stress on rock (for example, when two crustal plates move against each other). This stress is stored as potential energy, and builds up to a point where it is finally relieved—in the form of an earthquake. During an earthquake, potential energy is converted to kinetic energy in the form of vibrations, sound and heat.

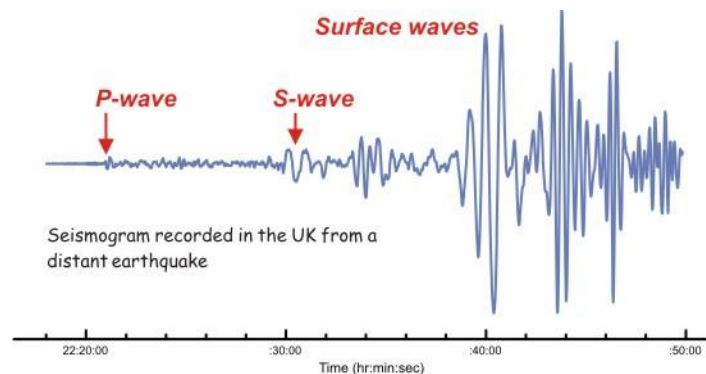
Earthquake Waves

The energy from an earthquake is transmitted in waves that move out in all directions from the earthquake's point of origin. These waves are called **seismic waves**. The point of origin is called the **focus**, and is usually found deep within the Earth's crust.

Shallow focus: surface to 60 km below; Intermediate focus: 60 km to 450 km below the surface; Deep focus: 450 km to 700 km below the surface



The spot on the surface directly above the focus is the **epicenter**. **Seismographs** are instruments that detect, record and measure wave energy. The graph produced by a seismograph is a **seismogram**.

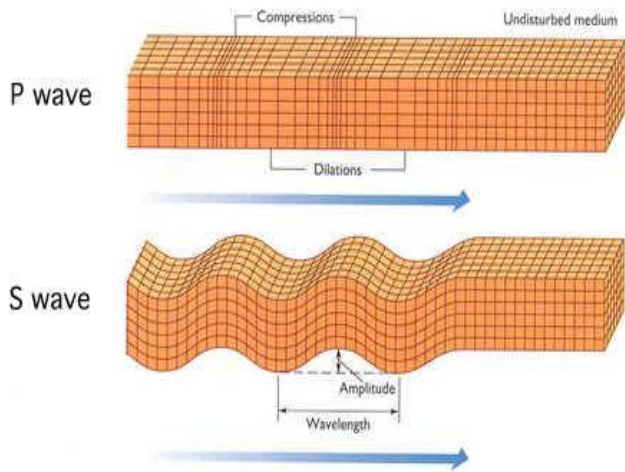


Types of Seismic Waves

Three different types of waves are generated by earthquakes: **P, S and surface waves**. P and S waves travel below the surface. The shaking and vibrations felt during an earthquake are surface waves, created when P and S waves come up to the surface.

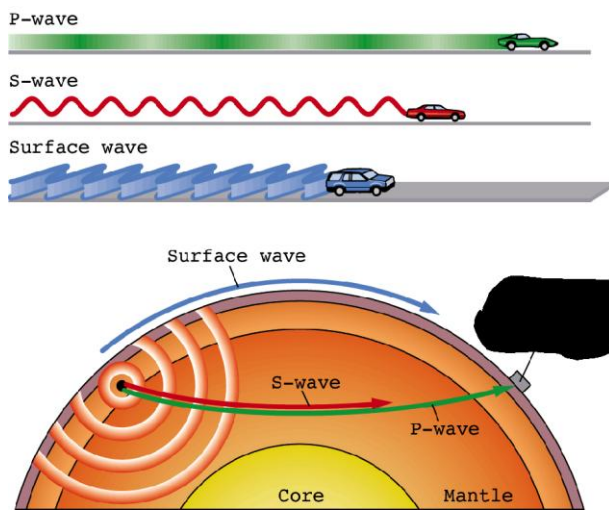
P Waves (or Primary Waves) are compressional waves, travel faster than S waves, and travel through solids and liquids. The more dense the material, the faster a P wave travels; the deeper into the Earth, the faster they travel.

S Waves (Shear or Secondary Waves) are transverse waves, and can only travel through solids. They travel slower than P waves (around 3 km/sec slower) so they take longer to reach an observer.



P waves are compressional waves that move parallel to the medium (the material through which a wave moves). Sound is carried by compressional waves.

S waves are transverse waves that move perpendicular to the medium motion. An ocean wave is an example of a transverse wave: the water (the medium) moves up and down but the wave travels toward the shore.



Calculating Distance from the Epicenter using P and S wave Arrival Time (ESRT p. 11)

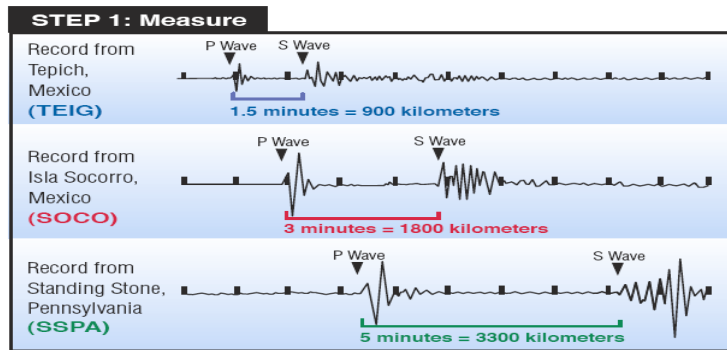
The graph on p. 11 of the ESRT shows arrival time of P and S waves at various distances from the epicenter. The farther an observer is from the epicenter, the longer it takes the P and S waves to arrive. P waves will always arrive before S waves because they travel faster.

For example, if you were 2,000 km from the epicenter (read on the horizontal, x axis), the P wave would arrive 4 minutes after the earthquake occurs; the S wave would arrive approx. 3.5 minutes later.

To find distance from the epicenter, you must find the place on the graph where the vertical distance between the P and S wave lines is the equal to the difference in their arrival time.

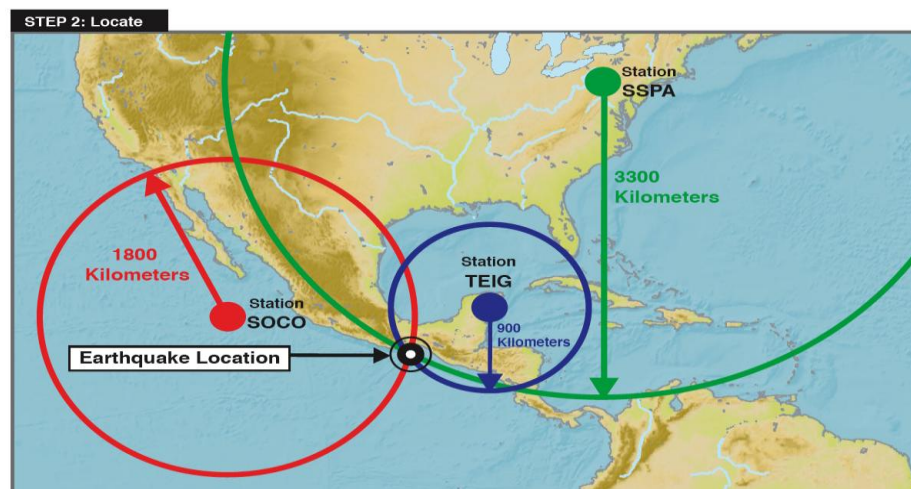
--After you've calculated the difference between P and S wave arrival times, use the scale on the vertical (y) axis to mark this time difference on a piece of paper.

--Slide the two marks on the paper between the plotted P and S wave graph lines. When you reach the spot where they align, read the horizontal scale to find the distance from the epicenter.



--To find the **origin time** of the earthquake (the time when it actually occurred), simply subtract the P wave travel time from the time the P wave arrived.

--**3 different seismograms from 3 different stations** are required to determine the exact epicenter. A circle is drawn around each of 3 stations using the distance from the epicenter as the circle's radius. Where the circles intersect is the earthquake's epicenter.



Earthquake Intensity: Two different scales are used to measure intensity.

Mercalli Scale (1-12) measures the intensity of an earthquake relative to the observed damage done to objects and structures in a particular area.

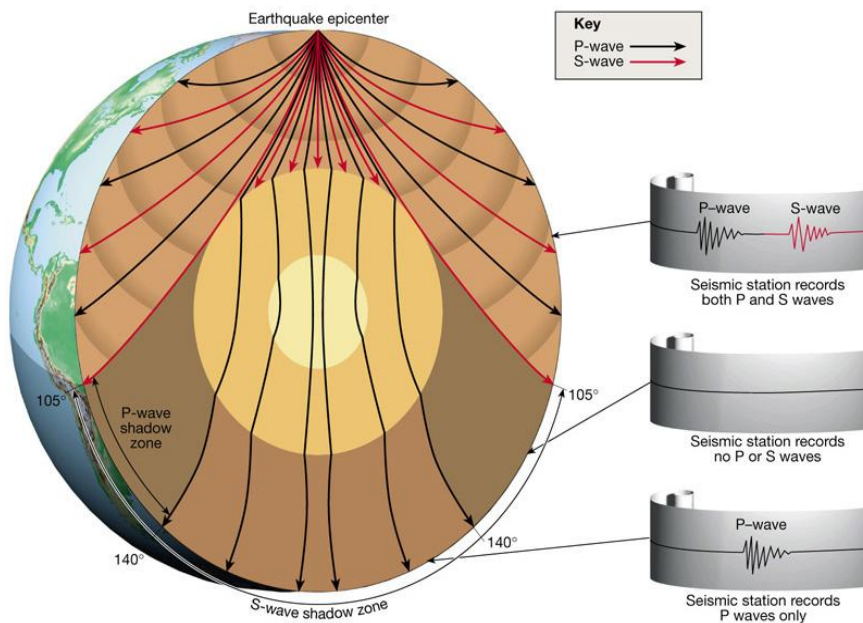
Richter Scale (1-9) is based on the magnitude (amplitude or height) of the energy waves generated by an earthquake and recorded by a seismograph. Each increase of 1 on the scale equals 10 times the wave magnitude. For example, an earthquake measuring 6 on the scale has 10 times more energy than one measuring 5 on the scale, and 100 times more energy than an earthquake measuring 4 on the scale.

Richter Magnitude	Earthquake effects
0-2	Not felt by people
2-3	Felt little by people
3-4	Ceiling lights swing
4-5	Walls crack
5-6	Furniture moves
6-7	Some buildings collapse
7-8	Many buildings destroyed
8-Up	Total destruction of buildings, bridges and roads

Less than 2.0	Micro	Micro earthquakes, not felt	Continual
2.0-2.9	Minor	Generally not felt, but recorded	1,300,000 per year (est.)
3.0-3.9		Often felt, but rarely causes damage	130,000 per year (est.)
4.0-4.9	Light	Noticeable shaking of indoor items, rattling noises Significant damage unlikely	13,000 per year (est.)
5.0-5.9	Moderate	Can cause major damage to poorly constructed buildings over small regions. At most slight damage to well-designed buildings	1,319 per year
6.0-6.9	Strong	Can be destructive in areas up to about 160 kilometres (99 mi) across in populated areas	134 per year
7.0-7.9	Major	Can cause serious damage over larger areas	15 per year
8.0-8.9	Great	Can cause serious damage in areas several hundred kilometres across	1 per year
9.0-9.9		Devastating in areas several thousand kilometres across	1 per 10 years (est.)
10.0+	Massive	Never recorded, widespread devastation across very large areas.	Extremely rare (Unknown/May not be possible)

Model of the Earth's Crust and Interior

The inferred composition of Earth's interior is based upon global seismographic readings. When charted, these readings show a shadow zone—an area on the surface of the Earth where no P or S waves can be detected. These observations led to the deduction that the Earth's outer core is liquid, since S waves cannot travel through liquids.



Lithosphere: the uppermost region of the Earth; solid rock. The lithosphere is the crust and the rigid mantle beneath it. Average depth = 100 km. Crust = 10-30 km.

Asthenosphere: runs from the bottom of the lithosphere to about 250 km depth. The asthenosphere is the source of magma, and is about 10% molten rock—just enough to allow the solid rock within the asthenosphere to flow very slowly. **The asthenosphere has convection currents that causes crustal plates to move.**

Mantle: solid rock. This is shown by an increase in S-wave speed at depths between 400 and 700km, showing that the rock is more dense.

Outer Core: inferred to be liquid because S waves cannot be detected. Iron-rich material (more dense material moved to Earth's center).

Inner Core: solid, composed of iron and nickel. Both P and S waves can pass through the inner core.

The Theory of Continental Drift

Scientist Alfred Wegener proposed that Earth's continents were not always situated where they are now found. He theorized that the continents were once all connected into one large land mass he called **Pangaea**, which, through time, broke apart to form present-day continents. He based his theory on the following evidence:

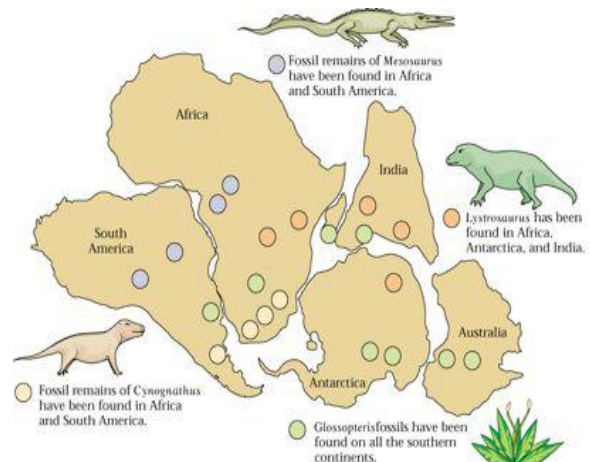
Continents fit together like puzzle pieces. For example, South America seems to fit into the west coast of Africa.

Rock composition and age. For example, rock material found in Brazil is similar in composition and age to rock material in western Africa.

Fossils: both plant and animal fossils on either side of the Atlantic are similar. Fossils of the same land-dwelling organism have been found in both South American and Africa, now separated by an ocean.

Mountains: the Appalachians are the same rock type and age of a European mountain range, and thus seem to be a continuation of that range.

Evidence of continental climate change: coal was found in Antarctica. Since coal is made from the remains of plant and animal material, Antarctica must have once been closer to the Equator to sustain lush vegetation and animal life.



Mid-Ocean Ridges are mountain ranges that are found over long distances of the ocean floor. These areas have heavy earthquake activity. The age of the rock material found at the center of the ridge is younger than that farther away from the center.

Mid-ocean ridges form when lava flows out from the asthenosphere to fill the space between two crustal plates moving away from each other. The lava hardens to form a ridge. The process is repeated over and over as the plates continue to move apart, forming new rock material between the plates and pushing older material away from the center. This process is known as **sea-floor spreading** (more crust is added to the ocean floor).

Iron atoms found in the lava that fills the ridge's center orient themselves to Earth's north and south magnetic fields, and provide evidence that during certain periods of Earth's history, the magnetic fields switch polarity. The "stripes" formed on either side of the ridge's center provide a history of the polarity reversal in Earth's magnetic field.

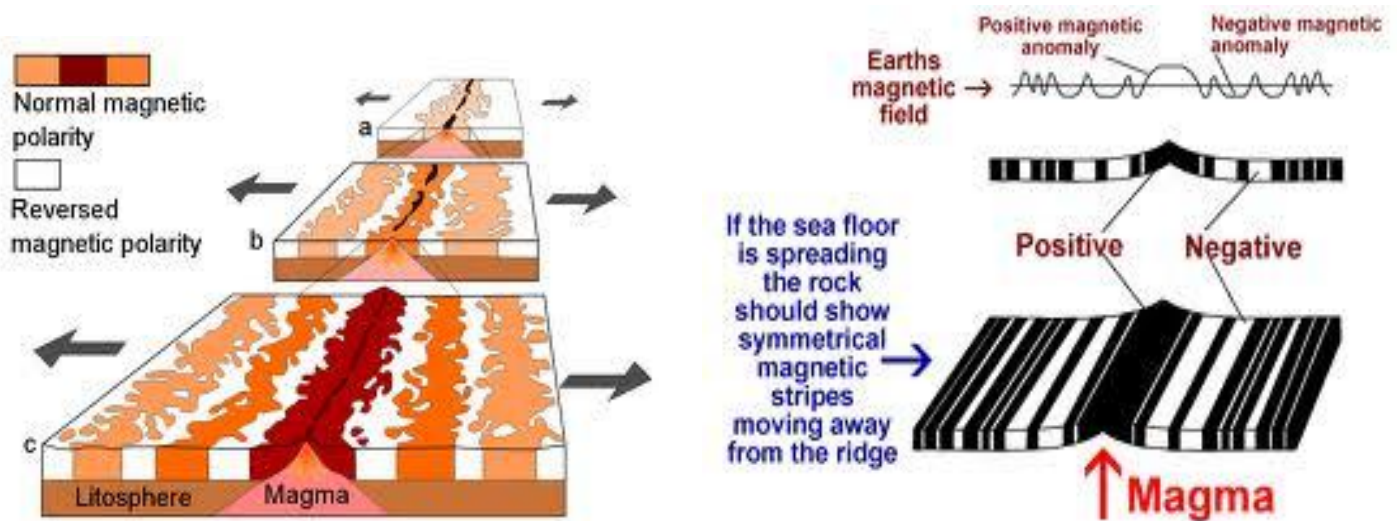
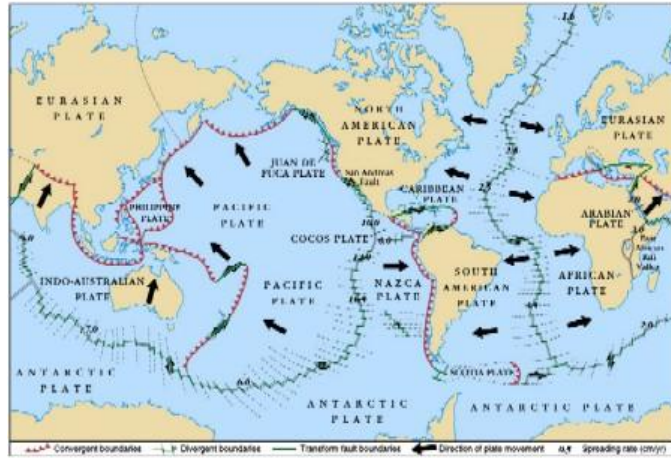


Plate Movement

Earth's crust is broken into 20 pieces called plates. These plates can move toward one another, away from one another and slide past one another, driven by convection currents that form in the asthenosphere upon which they "float." Plates may consist of ocean crust, continental crust, or a combination of the two.

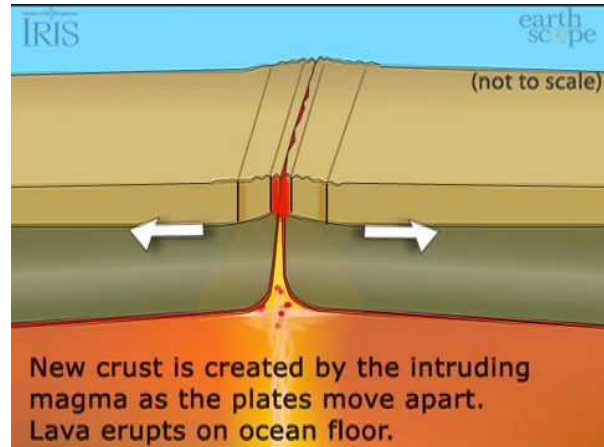
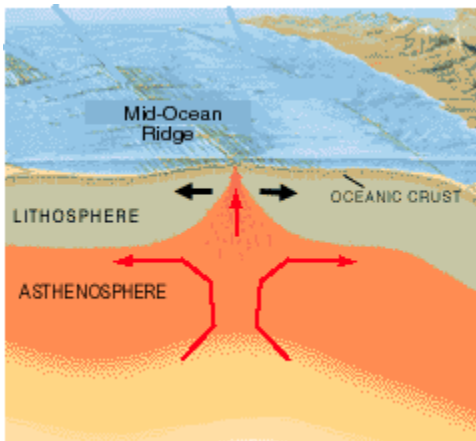
The distance between cities on the same plate remains constant, but the distance between cities on different plates may change. For example, New York is moving farther away from London each year.



(See page 5 ESRT)

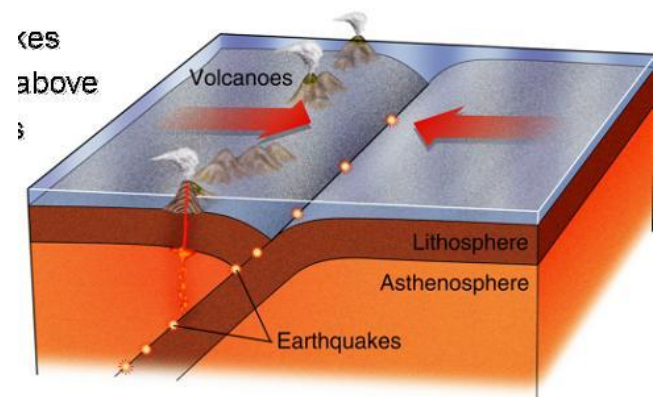
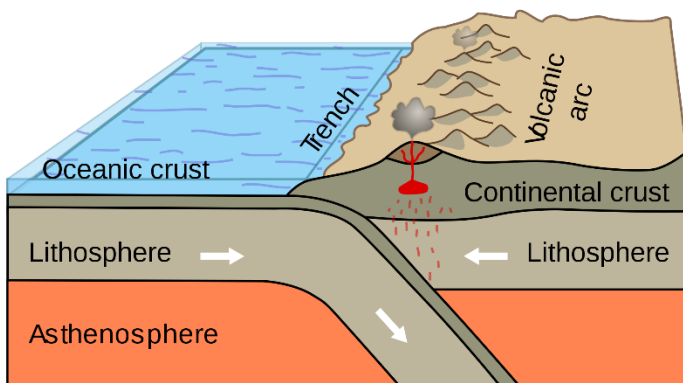
Types of Plate Boundaries: There are 3 different types of boundaries between plates.

Divergent boundaries occur when plates move apart from one another:



Divergent boundaries form mid-ocean ridges, sea-floor spreading, and continental rift zones.

Convergent boundaries occur when plates move toward each other.



(b) Convergent boundary
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Convergent ocean or ocean-continental plate boundaries form trenches, volcanic islands, or coastal volcanic mountain ranges (for example, the Cascade Mountains in the northwest). These formations occur when the more dense plate moves underneath or **subducts** under the less dense plate.

When two continental plates converge they form mountain ranges—such as the Alps and the Himalayas.

Transform boundaries occur when plates slide past one another. Transform faults most often form in ocean basins. The **San Andreas fault** in California is a transform fault that formed as the Pacific Plate slid past the North American plate.

