

Plate Tectonics

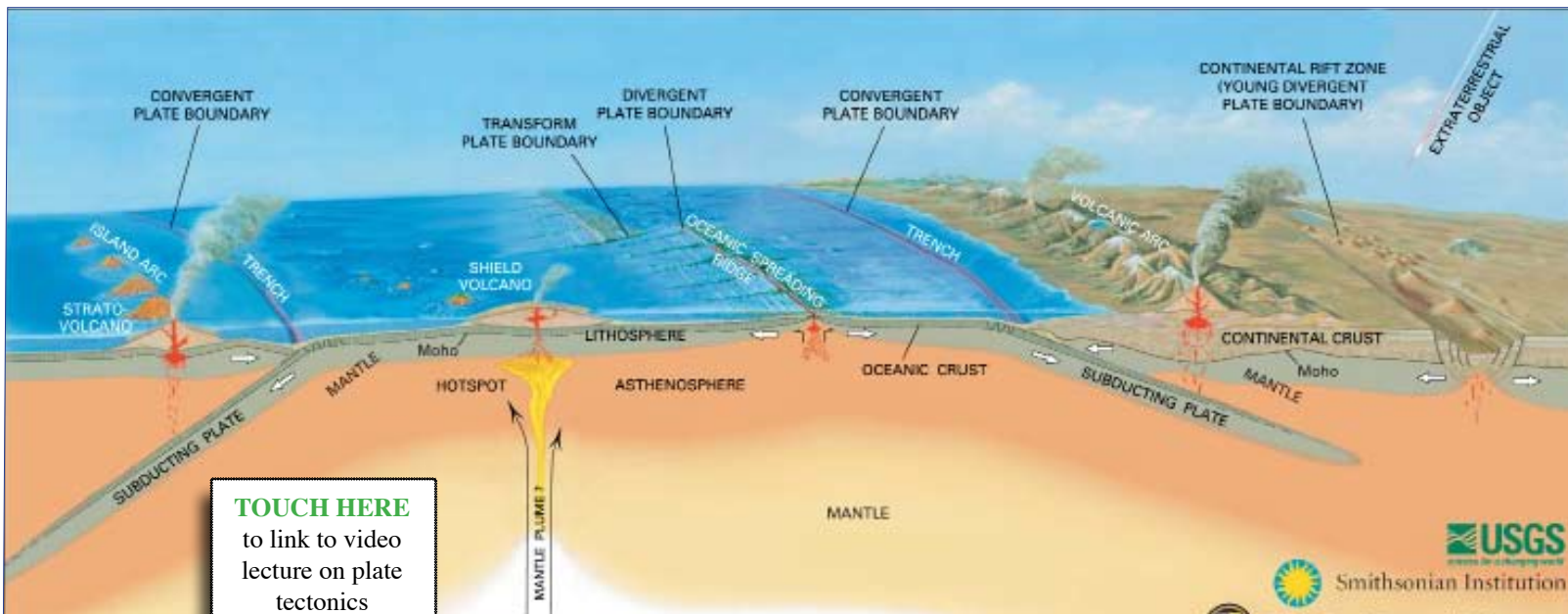
Plate tectonics theory describes how the lithosphere of the Earth is broken into various plates. These plates drift on the asthenosphere at very slow rates. As plates move away from each other the lithosphere thins and tears. At these divergent plate boundaries new oceanic lithosphere is created in the gaps from upwelling magma from the mantle. This upwelling magma forms mid-ocean ridges, long mountain chains that mark the boundaries between diverging plates.

The static size of the Earth implies that crust must be destroyed at about the same rate it is being created. Plate tectonics provides the mechanism to recycle the Earth's crust. Destruction (recycling) of crust takes place along convergent boundaries where plates are moving toward each other, and

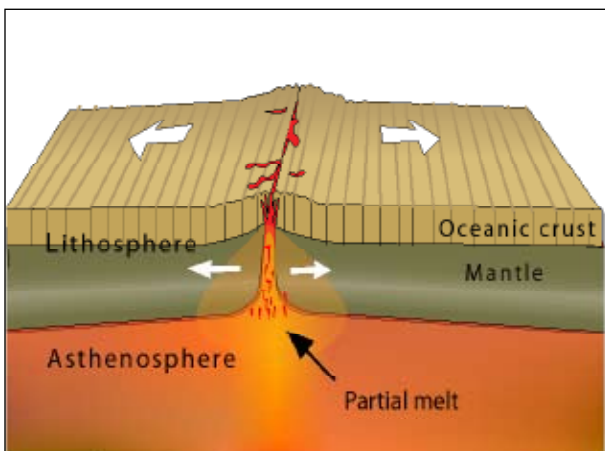
sometimes one plate sinks (is subducted) beneath another. The location where the sinking of a plate occurs is called a subduction zone. A transform boundary is where plates slide past each other with no creation or destruction of lithosphere.

Plate Margin Examples

There are three general types of plate boundaries: divergent, convergent, and transform. Each general type has multiple 'species': divergent boundaries can be spreading ocean ridges or continental rift zones; convergent boundaries can occur between two oceanic plates, an oceanic and continental plate, or between two continental plates.



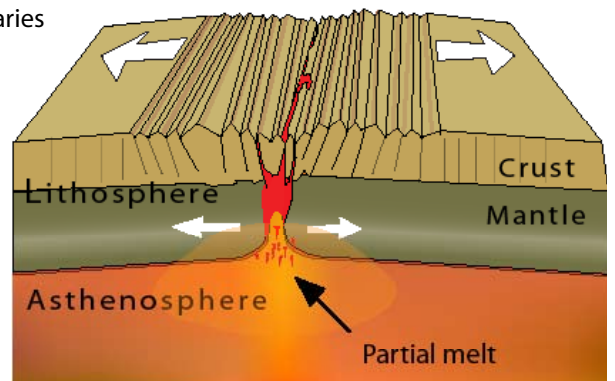
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to link to video
lecture on plate
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Fast-spreading ridges—Mountain chain forms along the crest of the ridge. High heat and magma input making the ridge bouyant. New crust is added both as dikes and as erupted lava (Ex. East Pacific Rise).

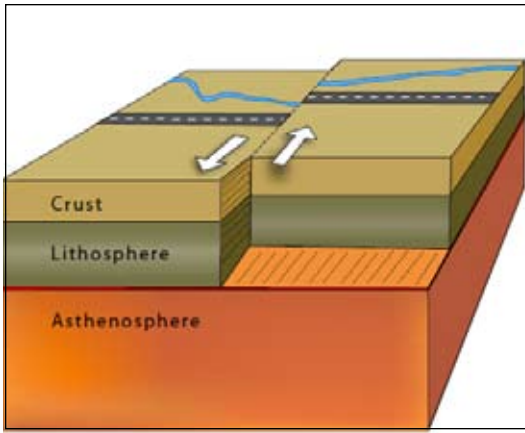
Divergent Margins

Divergent boundaries occur where plates are moving apart. Hot mantle rock rises and partial melting occurs. New crust is created by the magma pushing up from the mantle.



Slow-spreading ridges form valleys on the ridge crests. Lower heat input (Ex. Mid-Atlantic Ridge). The early onset of extension forms a basin-and-range province of parallel mountains and valleys dispersed across a broad uplifted area.

*NOTE: on these drawings, the crust appears separate from the lithosphere. The crust is part of the lithospheric plate.

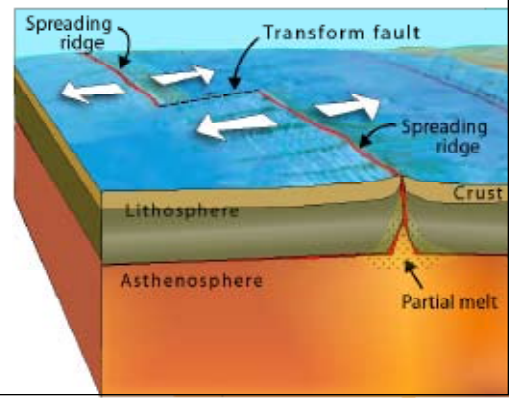


Transform Margins

Two plates slide against each other.

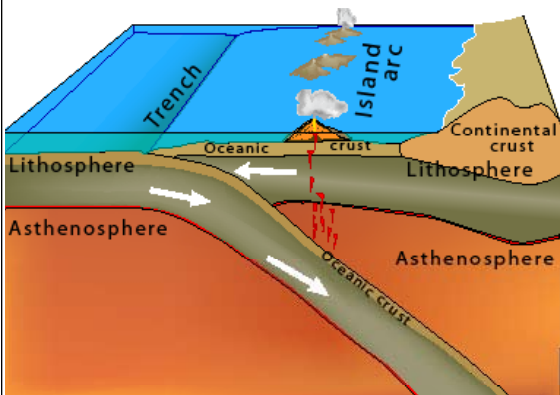
Left: Offset seen on the road and stream crossing the fault (Example: San Andreas Fault, California)

Right: Transform faults also form the margin between offset spreading ridges.

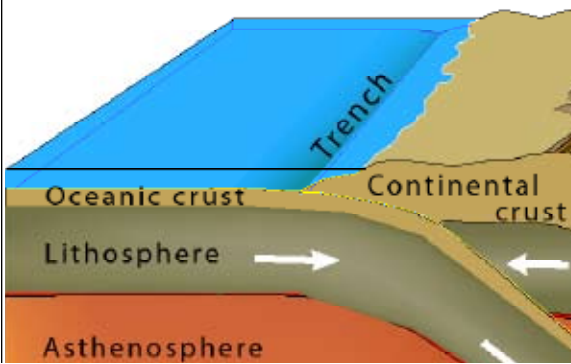


Convergent Margins

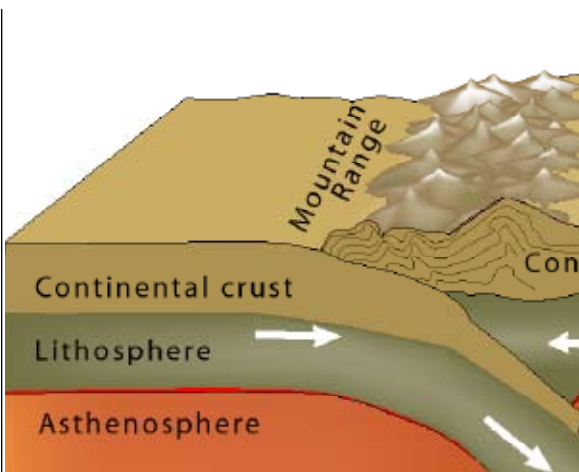
Crust is destroyed as two plates move towards each other. The heavier plate dives (subducts) beneath the more-bouyant plate.



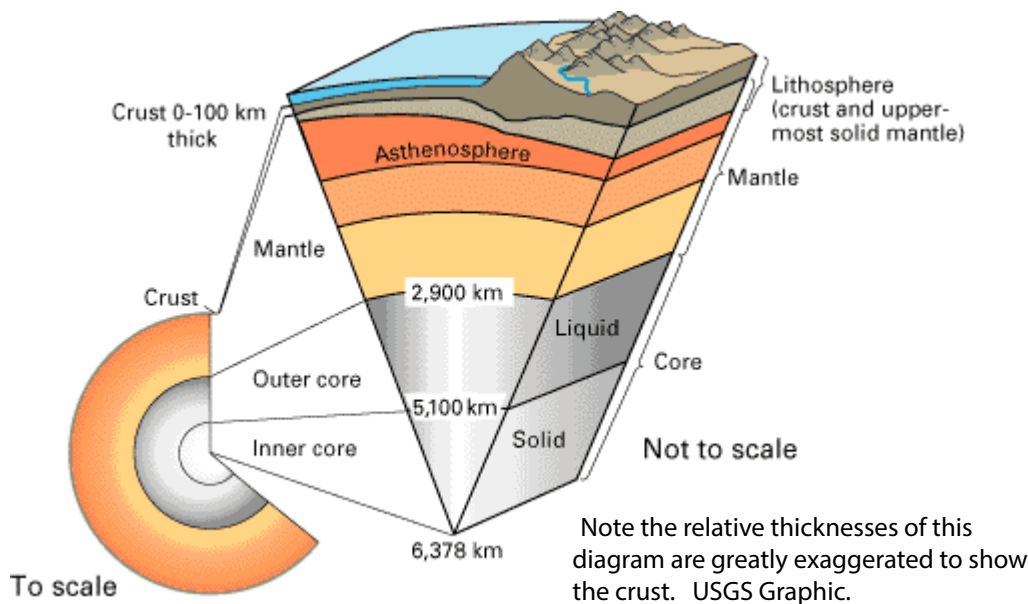
Oceanic-oceanic convergence—When two oceanic plates converge, one subducts beneath the other, and in the process a trench is formed. (Example: The Marianas Trench, the Challenger Deep, at the southern end of the Marianas Trench, plunges deeper into the Earth's interior (nearly 11,000 m) than Mount Everest, the world's tallest mountain, rises above sea level (about 8,854 m).) Inboard of the overlying plate a volcanic arc forms. This is because water being released from the subducting slab facilitates melting of the overlying mantle. The melt rises to form volcanoes. (Ex. the Aleutian Islands.)



Oceanic-Continental convergence—An oceanic plate converges on a continental plate and the denser crust of the oceanic plate sinks beneath the more-bouyant continental plate. In this type of convergence, trenches, strong, destructive earthquakes and the rapid uplift of mountain ranges are common. Water released from subducting slab facilitates melting. Rising melt builds volcanic arc. (Examples: Juan de Fuca plate subducting beneath the North American plate off shore in the Pacific Northwest. Off the coast of South America along the Peru-Chile trench, the oceanic Nazca Plate is being subducted beneath the South American Plate. In turn, the overriding South American Plate is being lifted up, creating the towering Andes mountains.)



Continental-continental convergence—When two continents meet head-on, neither is subducted because the continental rocks are relatively light and, resist downward motion. Instead, the crust tends to buckle and be pushed upward or sideways. (Example: The Himalayan mountain range dramatically demonstrates one of the most visible and spectacular consequences of plate tectonics. The Himalayas, towering as high as 8,854 m above sea level, form the highest continental mountains in the world.)



The Earth's Layers

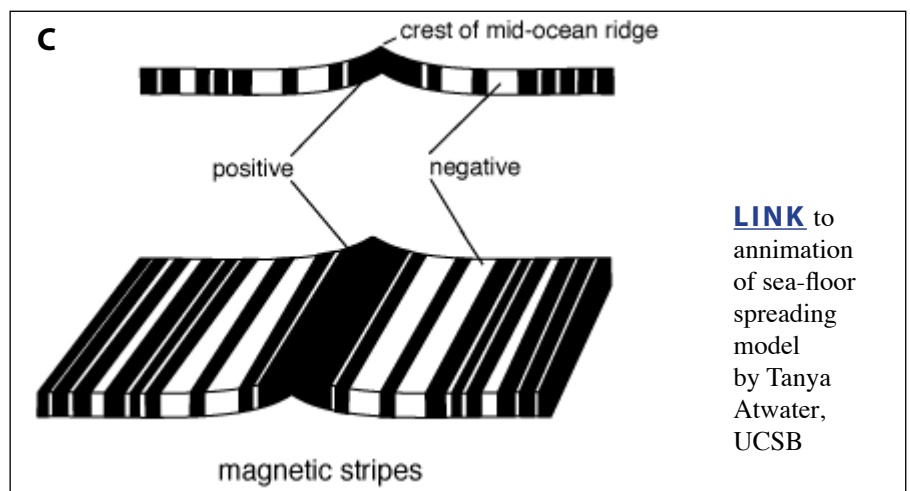
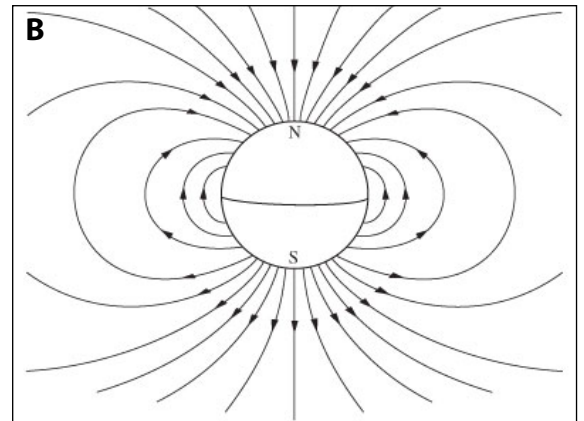
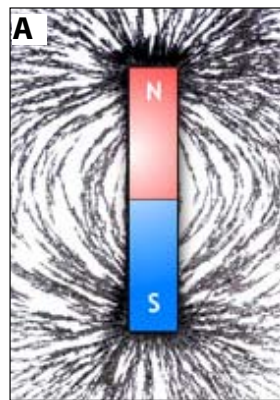
The Earth is a layered planet consisting of crust, mantle, and an inner and outer core. Approximately 100 km of the outermost part is a rigid layer called the lithosphere, which includes the crust and uppermost mantle. This lithosphere is broken into a number of large and small plates (slabs) that move over a 'plastic' (more accurately called viscoelastic) layer in the upper mantle called the asthenosphere. The movement of these plates is called plate tectonics.

Earth's Magnetic Field

Most of the Earth's magnetic field is caused by motions of liquid metal in the outer core as the planet rotates. The Earth's magnetic field is similar to that generated by a simple bar magnet (Fig. A). The field behaves as if the magnet were located through the axis of the Earth's rotation. Currently, it is inclined about 11 degrees from the geographic axis of rotation. However, magnetic north is not fixed, and the location drifts at rates up to 0.2 degrees per year.

At present, the lines of force of the Earth's magnetic field are normal polarity (Fig. B). The negative magnetic pole is in the Northern Hemisphere and the positive magnetic pole is in the Southern Hemisphere. However, the Earth's magnetic field periodically reverses; i.e. the north magnetic pole becomes the south pole and vice versa. The Earth has experienced periods of this reversed polarity alternating with times of normal polarity.

These magnetic fields are recorded on the ocean floor (Fig. C). Magmas contain iron-bearing minerals such as magnetite which acts like a compass. As these iron-rich magmas cool, they become magnetized in the direction of the surrounding magnetic field. As magma rises to form new ocean floor at a mid-ocean spreading center, it records the polarity of the magnetic field existing at the time magma crystallized. As spreading pulls the new oceanic lithosphere apart, stripes of approximately the same size are carried away from the ridge on each side. Seafloor maps of magnetic anomalies can be used to compare and establish mid-ocean ridge spreading rates.



[LINK](#) to animation of sea-floor spreading model by Tanya Atwater, UCSB

What drives the plates?

The jury is still out on exactly how plates are propelled by mantle convection. What is known is that the upwards motion of hot mantle below spreading ridge in concert with slab pull (subduction) at the margin of the plates are important factors. For a discussion on this, go to USGS's 'unanswered questions' about convection and plate tectonics.

Vocabulary to accompany IRIS' [Animations: Plate Boundaries](#)

(from [USGS Visual Glossary](#) and [Photo Glossary of Volcanic words](#))

Accretionary wedge—Sediments, the top layer of material on a tectonic plate, that accumulate and deform where oceanic and continental plates collide. These sediments are scraped off the top of the down-going oceanic crustal plate and are appended to the edge of the continental plate.

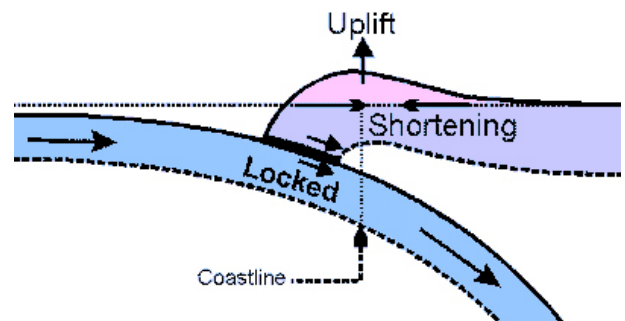
Asthenosphere—the ductile part of the earth just below the lithosphere, including the lower mantle. The asthenosphere is about 180 km thick.

Basalt— a hard, black volcanic rock with *less than* about 52 weight percent silica (SiO₂) and high amounts of heavy elements like iron and magnesium and low sodium and potassium (see **Rhyolite** below). This magma has a high temperature and low viscosity and tend to Erupted at spreading ridges.

Crust—the outermost major layer of the earth, ranging from about 10 to 65 km in thickness worldwide. The uppermost 15-35 km of crust is brittle enough to produce earthquakes. Oceanic crust is thinnest; continental crust is thickest.

Lithosphere—the outer solid part of the earth, including the crust and uppermost mantle. The lithosphere is about 100 km thick, although its thickness is age dependent (older lithosphere is thicker). The lithosphere below the crust is brittle enough at some locations to produce earthquakes by faulting, such as within a subducted oceanic plate.

Locked fault—a fault that is not slipping because frictional resistance on the fault is greater than the shear stress across the fault (it is stuck). Such faults may store strain for extended periods that is eventually released in an earthquake when frictional resistance is overcome.



Mantle—the part of the earth's interior between the metallic outer core and the crust.

Mid ocean ridge—the fracture zone along the ocean bottom where molten mantle material comes to the surface, thus creating new crust. This fracture can be seen beneath the ocean as a line of ridges that form as molten rock reaches the ocean bottom and solidifies.

Plate Tectonics—the theory supported by a wide range of evidence that considers the earth's crust and upper mantle to be composed of several large, thin, relatively rigid plates that move relative to one another. Slip on faults that define the plate boundaries commonly results in earthquakes. Several styles of faults bound the plates, including thrust faults along which plate material is subducted or consumed in the mantle, oceanic spreading ridges along which new crustal material is produced, and transform faults that accommodate horizontal slip (strike slip) between adjoining plates.

Subduction— the process of the oceanic lithosphere colliding with and descending beneath the continental lithosphere.

Subduction zone—the place where two lithospheric plates come together, one riding over the other. Most volcanoes on land occur parallel to and inland from the boundary between the two plates.

Tectonic plates— the large, thin, relatively rigid plates that move relative to one another on the outer surface of the Earth.