

INTRODUCTION



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Detail note on the Theory of Plate Tectonics.

➤ *The Theory of Plate Tectonics*

Plate tectonics is the most important concept in modern geology. This section will introduce you to the concept of plate tectonics, how it works, why it is important and how it is shaping the world today.

➤ *Theory of Plate Tectonics*

When the concept of seafloor spreading came along, scientists recognized that it was the mechanism to explain how continents could move around Earth's surface. Like the scientists before us, we will now merge the ideas of continental drift and seafloor spreading into the theory of plate tectonics.

➤ *Earth's Tectonic Plates*

Seafloor and continents move around on Earth's surface, but what is actually moving? What portion of the Earth makes up the "plates" in plate tectonics? This question was also answered because of technology developed during war times – in this case, the Cold War. The plates are made up of the lithosphere.

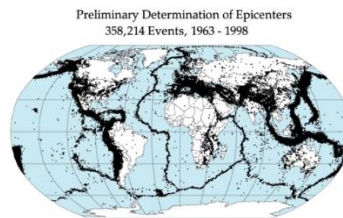


Figure 1. Earthquakes outline the plates.

During the 1950s and early 1960s, scientists set up seismograph networks to see if enemy nations were testing atomic bombs. These seismographs also recorded all of the earthquakes around the planet. The seismic records could be used to locate an earthquake's epicenter, the point on Earth's surface directly above the place where the earthquake occurs.

Earthquake epicenters outline the plates. Mid-ocean ridges, trenches, and large faults mark the edges of the plates, and this is where earthquakes occur (figure 1).

The lithosphere is divided into a dozen major and several minor plates (figure 2). The plates' edges can be drawn by connecting the dots that mark earthquakes' epicenters. A single plate can be made of all oceanic lithosphere or all continental lithosphere, but nearly all plates are made of a combination of both.

Movement of the plates over Earth's surface is termed plate tectonics. Plates move at a rate of a few centimeters a year, about the same rate fingernails grow.

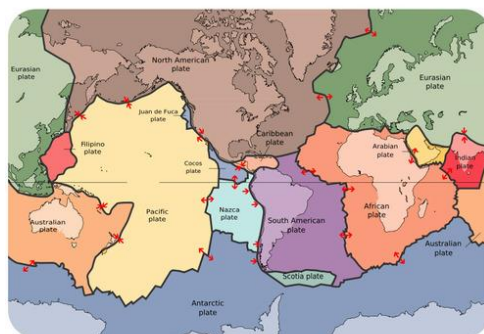


Figure.2

Figure 2. The lithospheric plates and their names. The arrows show whether the plates are moving apart, moving together, or sliding past each other.

➤ How Plates Move

If seafloor spreading drives the plates, what drives seafloor spreading? Picture two convection cells side-by-side in the mantle, similar to the illustration in figure 3.

1. Hot mantle from the two adjacent cells rises at the ridge axis, creating new ocean crust.
2. The top limb of the convection cell moves horizontally away from the ridge crest, as does the new seafloor.
3. The outer limbs of the convection cells plunge down into the deeper mantle, dragging oceanic crust as well. This takes place at the deep sea trenches.
4. The material sinks to the core and moves horizontally.
5. The material heats up and reaches the zone where it rises again.

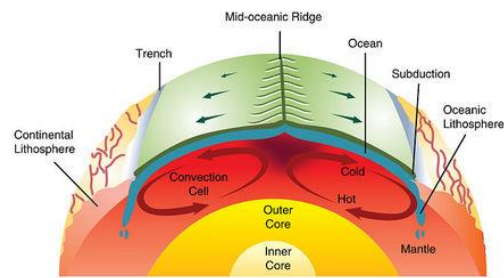


Figure 3.

Figure 3. Mantle convection drives plate tectonics. Hot material rises at mid-ocean ridges and sinks at deep sea trenches, which keeps the plates moving along the Earth's surface.

➤ Plate Boundaries

Plate boundaries are the edges where two plates meet. Most geologic activities, including volcanoes, earthquakes, and mountain building, take place at plate boundaries. How can two plates move relative to each other?

- **Divergent plate boundaries:** the two plates move away from each other.
- **Convergent plate boundaries:** the two plates move towards each other.
- **Transform plate boundaries:** the two plates slip past each other.

The type of plate boundary and the type of crust found on each side of the boundary determines what sort of geologic activity will be found there.

• Divergent Plate Boundaries

Plates move apart at mid-ocean ridges where new seafloor forms. Between the two plates is a rift valley. Lava flows at the surface cool rapidly to become basalt, but deeper in the crust, magma cools more slowly to form gabbro. So the entire ridge system is made up of igneous rock that is either extrusive or intrusive. Earthquakes are common at mid-ocean ridges since the movement of magma and oceanic crust results in crustal shaking. The vast majority of mid-ocean ridges are located deep below the sea (figure 4).



Figure 4.

(Figure 4. (a) Iceland is the one location where the ridge is located on land: the Mid-Atlantic Ridge separates the North American and Eurasian plates; (b) The rift valley in the Mid-Atlantic Ridge on Iceland)

Can divergent plate boundaries occur within a continent? What is the result? In continental rifting (figure 5), magma rises beneath the continent, causing it to become thinner, break, and ultimately split apart. New ocean crust erupts in the void, creating an ocean between continents.



Figure 5.

• **Convergent Plate Boundaries**

When two plates converge, the result depends on the type of lithosphere the plates are made of. No matter what, smashing two enormous slabs of lithosphere together results in magma generation and earthquakes.

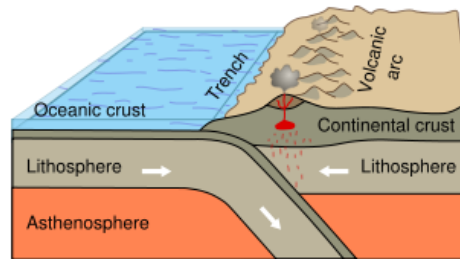
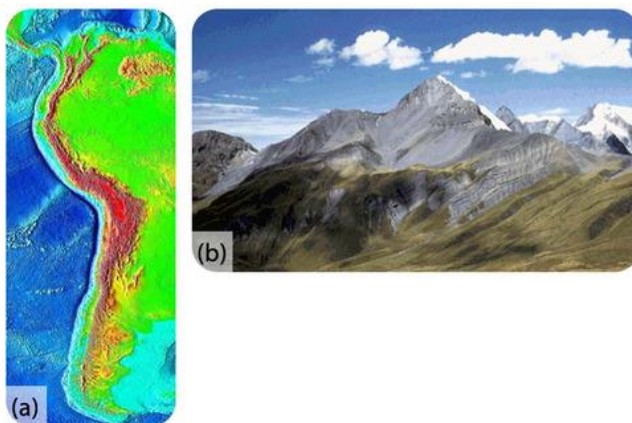


Figure 6. Subduction of an oceanic plate beneath a continental plate causes earthquakes and forms a line of volcanoes known as a continental arc.

a) **Ocean-Continent**

When oceanic crust converges with continental crust, the denser oceanic plate plunges beneath the continental plate. This process, called subduction, occurs at the oceanic trenches (figure 6). The entire region is known as a subduction zone. Subduction zones have a lot of intense earthquakes and volcanic eruptions. The subducting plate causes melting in the mantle. The magma rises and erupts, creating volcanoes. These coastal volcanic mountains are found in a line above the subducting plate (figure 7). The volcanoes are known as a continental arc.



(Figure 7. (a) At the trench lining the western margin of South America, the Nazca plate is subducting beneath the South American plate, resulting in the Andes Mountains (brown and red uplands); (b) Convergence has pushed up limestone in the Andes Mountains where volcanoes are common).

The volcanoes of northeastern California—Lassen Peak, Mount Shasta, and Medicine Lake volcano—along with the rest of the Cascade Mountains of the Pacific Northwest are the result of subduction of the Juan de Fuca plate beneath the North American plate (figure 8). The Juan de Fuca plate is created by seafloor spreading just offshore at the Juan de Fuca ridge.

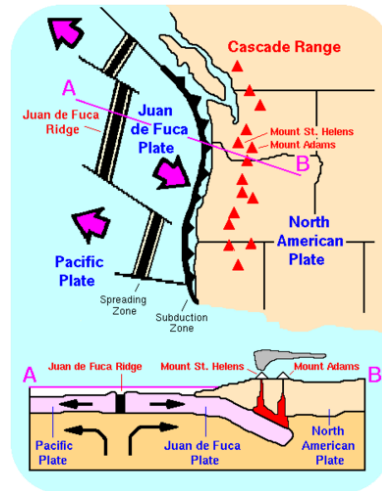


Figure 8. The Cascade Mountains of the Pacific Northwest are a continental arc.

If the magma at a continental arc is felsic, it may be too viscous (thick) to rise through the crust. The magma will cool slowly to form granite or granodiorite. These large bodies of intrusive igneous rocks are called batholiths, which may someday be uplifted to form a mountain range (figure 9).



Figure 9. The Sierra Nevada batholith cooled beneath a volcanic arc roughly 200 million years ago. The rock is well exposed here at Mount Whitney. Similar batholiths are likely forming beneath the Andes and Cascades today.

b) Ocean-Ocean

When two oceanic plates converge, the older, denser plate will subduct into the mantle. An ocean trench marks the location where the plate is pushed down into the mantle. The line of volcanoes that grows on the upper oceanic plate is an island arc. Do you think earthquakes are common in these regions (figure 10)?

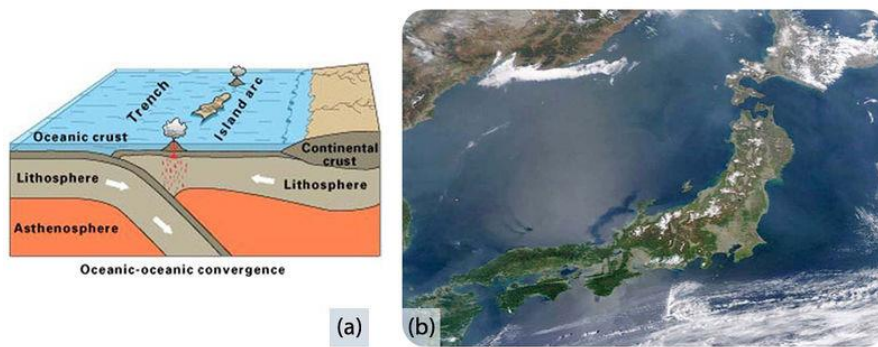


Figure 10. (a) Subduction of an ocean plate beneath an ocean plate results in a volcanic island arc, an ocean trench and many earthquakes. (b) Japan is an arc-shaped island arc composed of volcanoes off the Asian mainland, as seen in this satellite image.

c) Continent-Continent

Continental plates are too buoyant to subduct. What happens to continental material when it collides? Since it has nowhere to go but up, this creates some of the world's largest mountain ranges (figure 11). Magma cannot penetrate this thick crust so there are no volcanoes, although the magma stays in the crust. Metamorphic rocks are common because of the stress the continental crust experiences. With enormous slabs of crust smashing together, continent-continent collisions bring on numerous and large earthquakes.

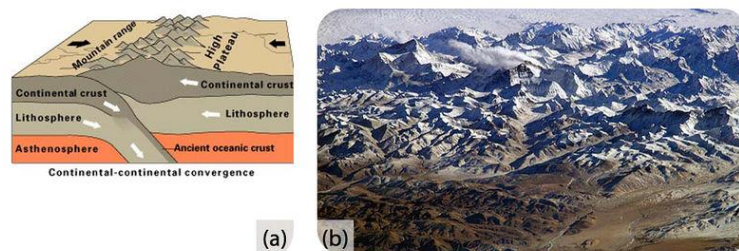


Figure 11. (a) In continent-continent convergence, the plates push upward to create a high mountain range. (b) The world's highest mountains, the Himalayas, are the result of the collision of the Indian Plate with the Eurasian Plate, seen in this photo from the International Space Station.

• Transform Plate Boundaries

Transform plate boundaries are seen as transform faults, where two plates move past each other in opposite directions. Transform faults on continents bring massive earthquakes (figure 12).

California is very geologically active. What are the three major plate boundaries in or near California (figure 13)?

1. A transform plate boundary between the Pacific and North American plates creates the San Andreas Fault, the world's most notorious transform fault.
2. Just offshore, a divergent plate boundary, Juan de Fuca ridge, creates the Juan de Fuca plate.
3. A convergent plate boundary between the Juan de Fuca oceanic plate and the North American continental plate creates the Cascades volcanoes.



(Figure 12. At the San Andreas Fault in California)

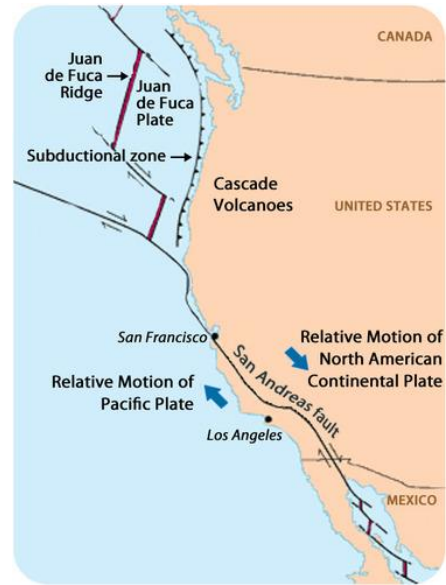


Figure 13. This map shows the three major plate boundaries in or near California.

➤ **Earth's Changing Surface:**

Geologists know that Wegener was right because the movements of continents explain so much about the geology we see. Most of the geologic activity that we see on the planet today is because of the interactions of the moving plates.



Figure 14. Mountain ranges of North America

Remember that Wegener used the similarity of the mountains on the west and east sides of the Atlantic as evidence for his continental drift hypothesis. The Appalachian mountains formed at a convergent plate boundary as Pangaea came together (figure 15).

Before Pangaea came together, the continents were separated by an ocean where the Atlantic is now. The proto-Atlantic ocean shrank as the Pacific ocean grew. Currently, the Pacific is shrinking as the Atlantic is growing. This supercontinent cycle is responsible for most of the geologic features that we see and many more that are long gone (figure 16).



Figure 15.

Figure 15. About 200 million years ago, the Appalachian Mountains of eastern North America were probably once as high as the Himalaya, but they have been weathered and eroded significantly since the breakup of Pangaea.

➤ **Summary:**

- *Plates of lithosphere move because of convection currents in the mantle. One type of motion is produced by seafloor spreading.*
- *Plate boundaries can be located by outlining earthquake epicenters.*
- *Plates interact at three types of plate boundaries: divergent, convergent and transform.*
- *Most of the Earth's geologic activity takes place at plate boundaries.*
- *At a divergent boundary, volcanic activity produces a mid ocean ridge and small earthquakes.*
- *At a convergent boundary with at least one oceanic plate, an ocean trench, a chain of volcanoes develops and many earthquakes occur.*
- *At a convergent boundary where both plates are continental, mountain ranges grow and earthquakes are common.*
- *At a transform boundary, there is a transform fault and massive earthquakes occur but there are no volcanoes.*
- *Processes acting over long periods of time create Earth's geographic features.*

THE END