Section Objectives

- **Summarize the theory of plate tectonics.**
- **Compare the characteristic geologic activities that occur along the three types of plate boundaries.**
- **Explain the possible role of convection currents in plate movement.**
- **Summarize the theory of suspect terranes.**

4.2 The Theory of Plate Tectonics

By the 1960's, accumulated evidence supporting the hypothesis of continental drift and seafloor spreading led to the formulation of a more far-reaching theory. This theory is called **plate tectonics.** The theory of plate tectonics not only describes continental movement but also proposes a possible explanation of why and how continents move. The term *tectonics* comes from the Greek word *tektonikos*, meaning ''construction.'' Tectonics is the study of the formation of features in the earth's crust.

The earth's crust consists of two types—**oceanic crust** and **continental crust.** Material on the ocean floor forms oceanic crust. Continental crust makes up the continental landmasses.

The oceanic and continental crust and the rigid upper mantle make up the **lithosphere.** It forms the thin outer shell of the earth. Beneath the lithosphere lies the **asthenosphere,** a layer of plastic rock, that is, solid rock that slowly flows (like putty) when under pressure. According to the theory of plate tectonics, the lithosphere is broken into separate plates that ride on the denser asthenosphere much like blocks of wood float on water. The continents and oceans are carried along as ''passengers'' on the moving lithospheric plates. Most lithospheric plates are composed of both continental and oceanic crust.

To date, about 30 lithospheric plates have been identified. Some plates are moving toward each other, some are moving apart, and some are sliding past each other. This constant movement has created the earth's major surface features, such as mountain ranges and deep-ocean trenches.

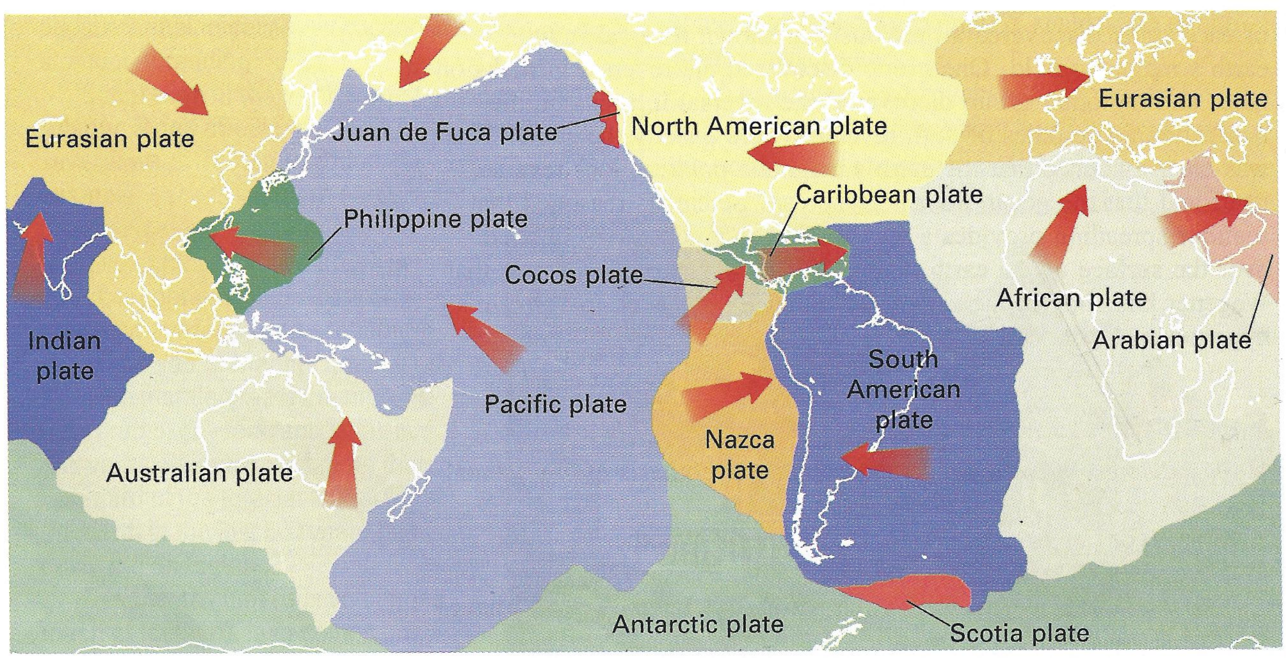


Figure 4–4. This map shows the location and movement of various lithospheric plates.

Lithospheric Plate Boundaries

Many changes in the earth's crust originate along lithospheric plate boundaries. The boundaries of the plates are not always easy to identify. As you can see in Figure 4–4, the familiar outlines of the continents and oceans depicted on maps do not always resemble the outlines made by the plate boundaries. Plate boundaries may be in the middle of the ocean floor, around the edges of continents, or within continents. There are three types of plate boundaries, each of which is associated with a characteristic type of geologic activity.

Divergent Boundaries

The geologic activity that occurs along plate boundaries differs according to the way plates move in relation to each other. For example, two plates moving away from each other form a **divergent** (die-VUR-junt) **boundary.** As the plates move apart, molten rock from the asthenosphere rises and fills the space between the plates. As the molten rock cools, it hardens onto the edges of the separating plates and creates new oceanic crust. Most divergent boundaries are found on the ocean floor. The locations of these spreading boundaries follow the mid-ocean ridges.

In the center of a mid-ocean ridge is a narrow valley formed as the plates separate. This formation is called a **rift valley.** Other rift valleys may form where continents are separated by plate movement. For example, the Red Sea occupies a huge rift valley formed by the separation of the African plate and the Arabian plate.

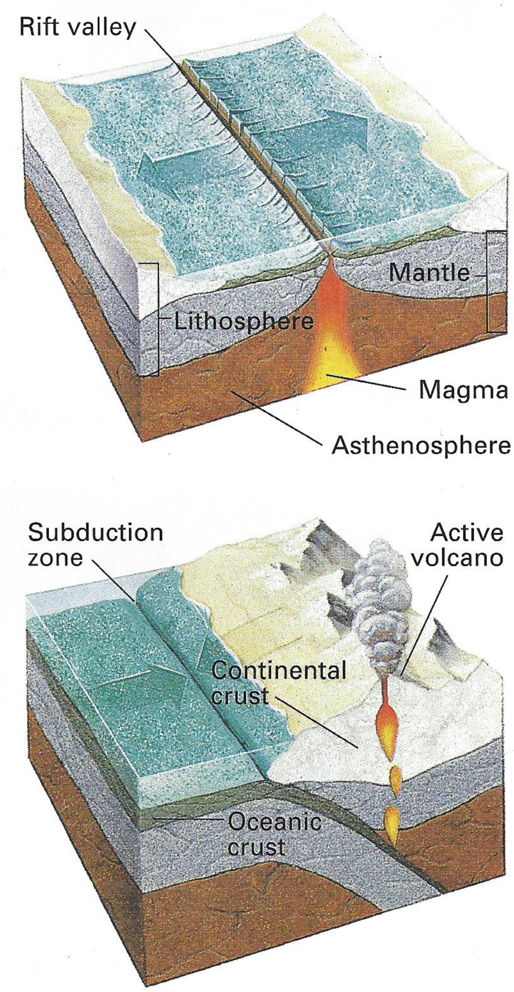


Figure 4–5. At divergent boundaries (top), plates separate. Plates collide at convergent boundaries (bottom).

Convergent Boundaries

As seafloor spreading pulls plates apart at one boundary, those plates push into neighboring plates at other boundaries. The direct collision of one plate with another makes another type of plate boundary—a **convergent** (kun-VUR-junt) **boundary.**

Three types of collisions can occur at convergent boundaries. One type occurs when a plate with oceanic crust at its leading edge collides with a plate with continental crust at its edge. Because oceanic crust is denser, it is *subducted,* or forced under the less dense continental crust, as shown in Figure 4–5. Scientists refer to the region along a plate boundary where one plate moves under another plate as a **subduction** (sub-DUK-shun) **zone.** A deep **ocean trench** generally forms along a subduction zone. As the oceanic plate moves down into a subduction zone, it melts and becomes part of the mantle material. Some of the magma formed rises to the surface through the continental crust and produces volcanic mountains.

A second type of collision occurs when two plates with continental crust at their leading edges come together. During this type of collision, neither plate is subducted because the two plates have the same density. Instead, the colliding edges are crumpled and uplifted, producing large mountain ranges. Scientists are convinced that the Himalayas were formed by this type of collision.

The third type of collision along convergent boundaries occurs between oceanic crust and oceanic crust. A deep ocean trench also

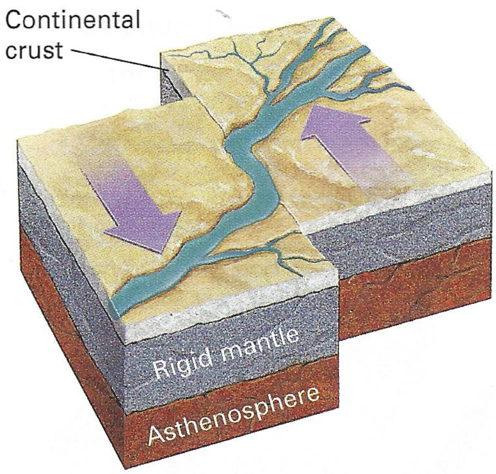


Figure 4–6. Plates scrape past each other at transform fault boundaries. Note the change in the course of the river as the plates move past each other.

forms when one of these plates is subducted. Part of the subducted plate melts, and the resulting molten rock rises to the surface along the trench to form a chain of volcanic islands, called an **island arc.**

Transform Fault Boundaries

A plate boundary called a **transform fault boundary** forms where two plates are grinding past each other. The plate edges usually do not slide along smoothly. Instead, they scrape together and move in a series of sudden spurts of activity separated by periods of little or no motion. A major transform fault boundary is the San Andreas fault in California.

Causes of Plate Motion

Many earth scientists think that the movement of lithospheric plates is due to **convection,** the transfer of heat through the movement of heated fluid material. This same process occurs when you place a pot of water on the stove to boil. As the water at the bottom of the pot heats up, it expands and becomes less dense than the cool water above it. The cool water, which is now denser than the warm water, sinks and forces the warm water to the surface. This cycle of warm water rising and cool water sinking to replace it is called a **convection current.**

Scientists think a similar process results in convection currents within the asthenosphere. Heat from the earth's core and mantle causes some material in the lower asthenosphere to become hotter and therefore less dense than the material above it. The hot material rises. When this hot material reaches the base of the lithosphere, it cools. When the molten material cools, it becomes more dense and starts to sink. The cooling material is pushed to the side by new hot

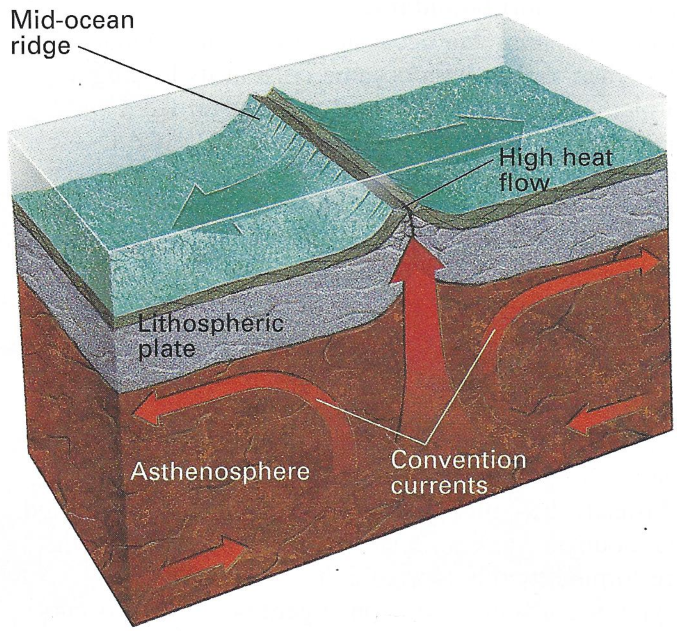


Figure 4–7. Scientists think that convection currents are the mechanism that moves lithospheric plates

material that rises. As the process continues, the lithospheric plate is carried along with the moving material, as shown in Figure 4–7.

Evidence for the existence of convection currents in the asthenosphere comes from recent studies of the ocean floor. Scientists have measured the amount of heat leaving rocks at various points in the lithosphere. They have found this heat flow to be higher along plate boundaries where two plates are moving apart than it is elsewhere on the ocean floor. If hot convection currents are rising along these plate boundaries as the theory suggests, these temperature differences can be explained.

Though convection currents can explain some aspects of plate movement, questions remain. Scientists asked whether convection currents alone are strong enough to move the plates at the rates suggested by geological evidence. If not, they speculated, another mechanism may be responsible.

INVESTIGATE!

To learn more about convection currents, try the In-Depth Investigation on pages 80–81.

SMALL-SCALE INVESTIGATION

Lithospheric Plate Boundaries

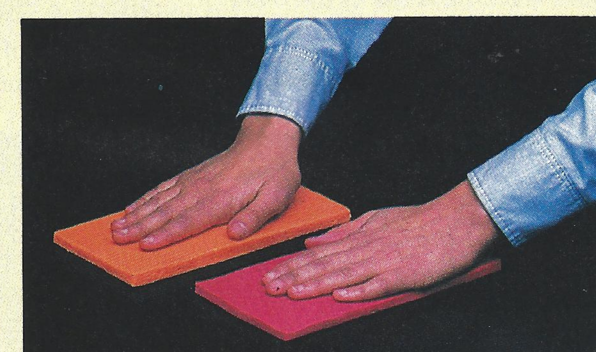
The movement of lithospheric plates has created many of the earth's topographical features. You can demonstrate the results of plate movement by using clay models of lithospheric plates.

Materials

ruler, paper, scissors, rolling pin or rod, modeling clay (2–3 lb.), plastic knife, lab apron

Procedure

1. Draw two 10×20 cm rectangles on your paper, and cut them out.
2. Use a rolling pin to flatten out two pieces of clay until they are about 1 cm thick. Cut each piece into a 10×20 cm rectangle. Place a paper rectangle on each piece of clay.
3. Place the two clay models side by side on a flat surface, paper side down. Place your hands directly on top of each piece, as shown, and slowly push the models together until the edges begin to buckle and rise off the surface of the table.
4. Turn the clay models around so that the unbuckled edges are touching. If these edges have been slightly deformed during Step 3, smooth them out before proceeding.



5. Place one hand on each clay model. Apply only slight pressure toward the seam. Slide one clay model forward and the other model backward about 7 cm.
6. Repeat Step 5 three more times, alternating the direction in which you push each model.

Analysis and Conclusions

1. What type of plate boundary are you demonstrating with the model in Step 3?
2. What type of plate boundary are you demonstrating in Steps 5 and 6?
3. How does the appearance of the facing edges of the models in the two processes compare? How do you think these processes might affect the appearance of the earth's surface?

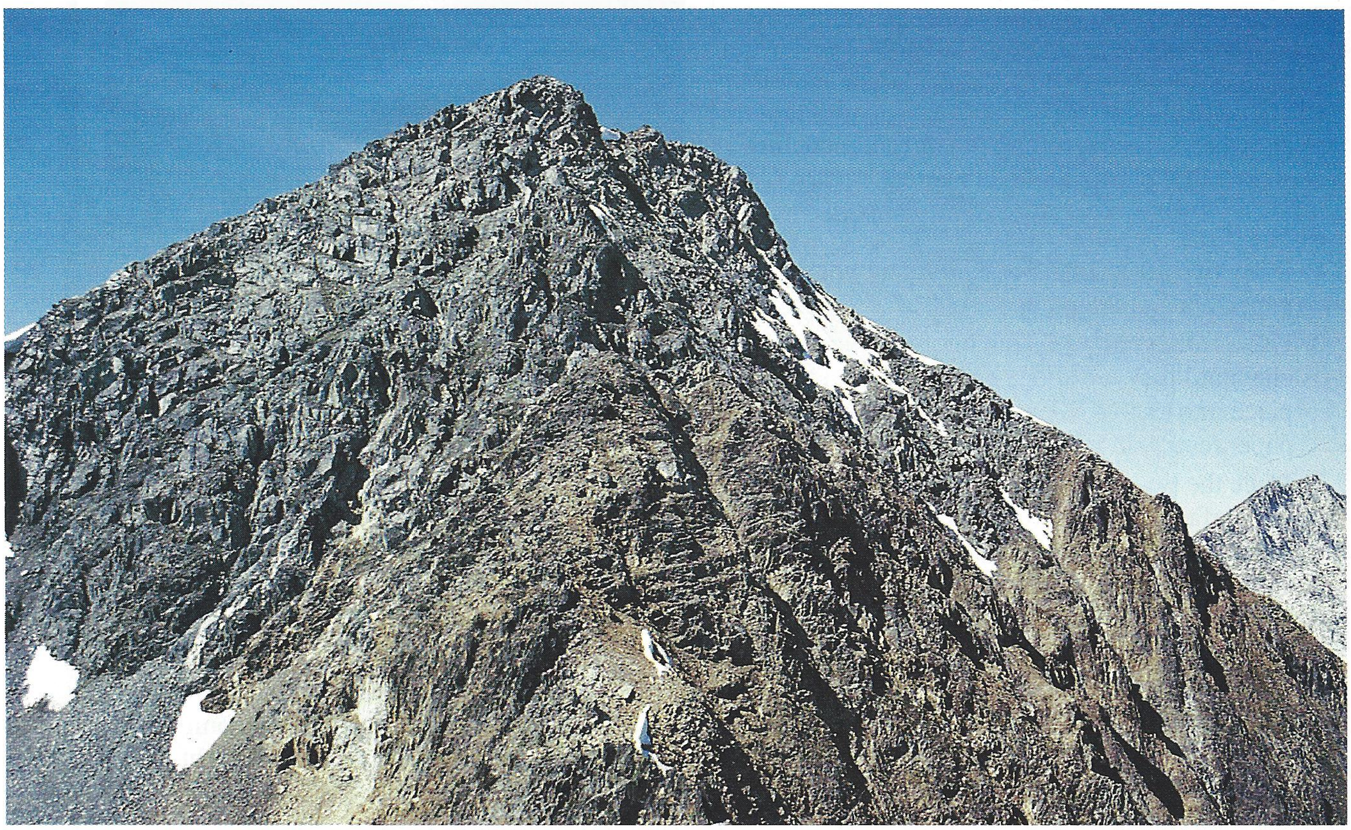
Suspect Terranes

Alfred Wegener's hypothesis of continental drift was an attempt to explain how the continents arrived at their present locations. The theory of plate tectonics refined Wegener's hypothesis, suggesting the actual mechanisms by which the continents might move. Neither continental drift nor plate tectonics, however, can explain how the continents were formed.

New discoveries are providing some possible explanations of how continents formed. These new discoveries provide the basis for the **theory of suspect terranes.** Simply put, this theory suggests that the continents are actually a patchwork of **terranes**—pieces of lithosphere, each with its own distinct geologic history. Each terrane has three identifying characteristics. First, a terrane contains rock and fossils that differ from the rock and fossils of neighboring terranes. Second, there are major faults at the boundaries of a terrane. Finally, the magnetic properties of a terrane do not match those of neighboring terranes.

Geologists have found evidence to support the suspect terrane theory. Northern California is a good place to observe this evidence. Geologists have found 10 different terranes in the San Francisco Bay area alone. For example, in the hills of Palo Alto, there is fossil evidence of coral atolls—tropical ocean islands made up of coral, the skeletons of sea organisms. Farther south lies a terrane called Permanette. The limestone of Permanette contains fossils that prob-

Figure 4–8. The rocks of the Slide Mountain terrane are fragments of the ancient ocean floor that are now part of North America.



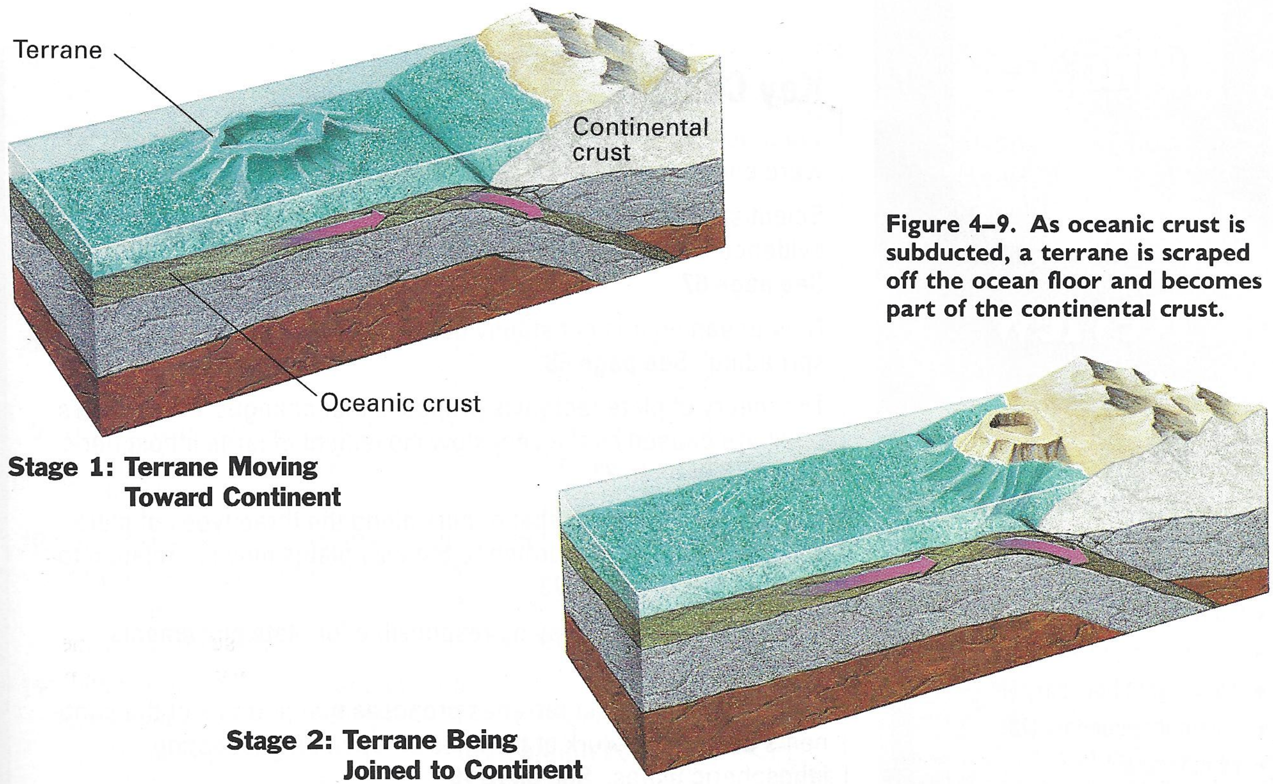


Figure 4–9. As oceanic crust is subducted, a terrane is scraped off the ocean floor and becomes part of the continental crust.

ably originated from the ocean depths near the equator. The theory of suspect terranes explains how tropical coral atolls and equatorial ocean fossils became part of the geology of northern California.

According to the suspect terrane theory, blocks of terranes are carried along on the ocean floor by the action of seafloor spreading to a lithospheric plate boundary where subduction is occurring. As the plate with oceanic crust moves under the plate with continental crust, the terranes are scraped off the descending ocean floor, as shown in Figure 4–9. Some terranes may form mountains, while others simply add to the surface area of a continent.

When Alfred Wegener first proposed his hypothesis of continental drift, he could not have imagined the explosion of scientific inquiry it would inspire. Like many hypotheses, continental drift raised more questions than it answered. The theories of plate tectonics and suspect terranes are attempts to answer some of those questions.

Section 4.2 Review

1. Summarize the theory of plate tectonics.
2. Name and describe the three types of plate boundaries.
3. Describe the three types of plate collisions that occur along convergent boundaries.
4. How might convection currents cause plate movement?
5. Explain how mountains on land can be composed of rocks that contain fossils of animals that lived in the ocean.