I What Is Plate Tectonics?

Topic 1 Moving Plates Cover the Globe

The discovery that continents and ocean basins could be separated into parts that can then move about has led to a new understanding of Earth's outer layer. Scientists now know that Earth's surface consists of a number of rigid, but moving, pieces called *plates.* In some areas, the plates are moving away from each other. In other areas, the plates are moving together. The study of the formation and movement of these plates is called **plate tectonics.**

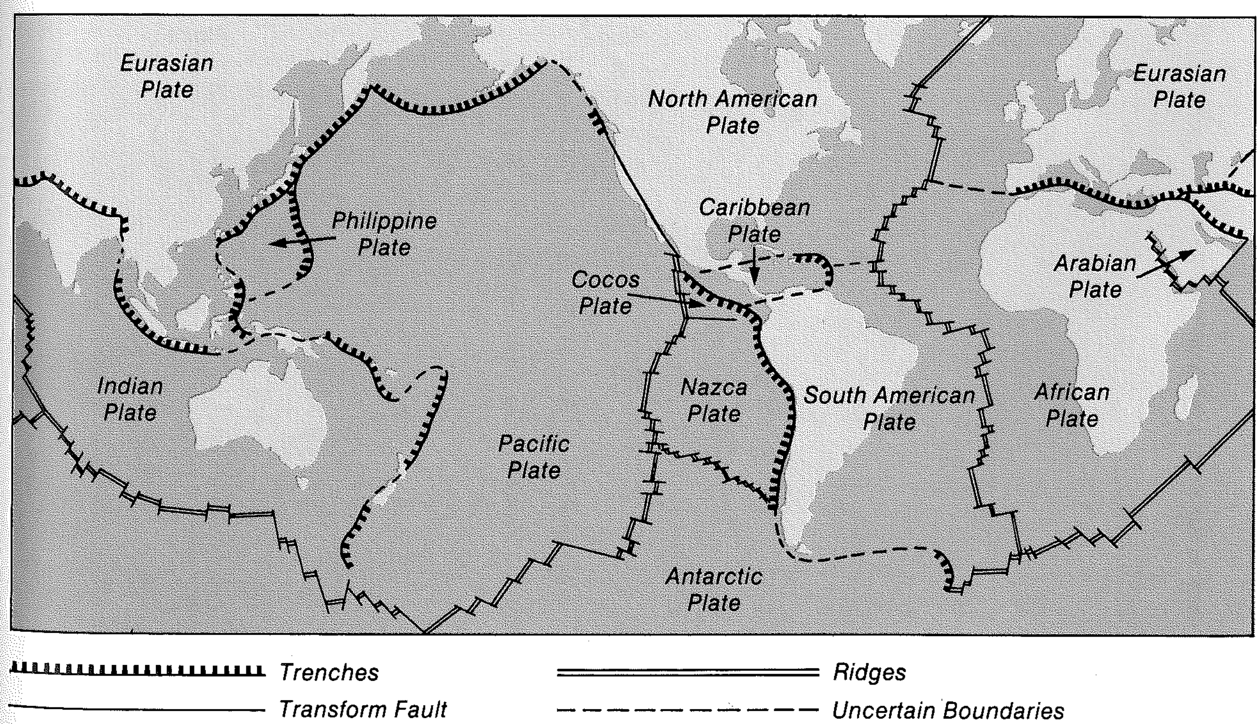
Earth's surface is divided into a dozen major plates and several minor plates. Some of the plates are moving toward each other, and some are moving apart. The South American Plate and the African Plate are moving apart. Other plates are moving together. The Indian Plate is colliding with the Eurasian Plate, and the Nazca Plate is sliding under the South American Plate. In California, the Pacific Plate and the North American Plate are sliding past each other.

OBJECTIVES

A Define *plate tectonics* and describe the relative motions of several plates.

B Locate and describe the lithosphere and the asthenosphere and relate both to plate tectonics.

13.1 The major plates and some of the minor plates are labeled on the map below. Notice that the large plates include both oceans and landmasses.



Topic 2 How Thick Are the Plates?

Plate tectonics has expanded the model of Earth's interior as described in Chapter 1. The crust and mantle were originally thought to represent two distinctly different materials. Now it is known that the crust and the uppermost portion of the mantle are very similar in both rock composition and physical properties. Together they make up a single solid layer called the **lithosphere.** The lithosphere is rigid but broken into plates that move with respect to one another. It is about 100 kilometers thick.

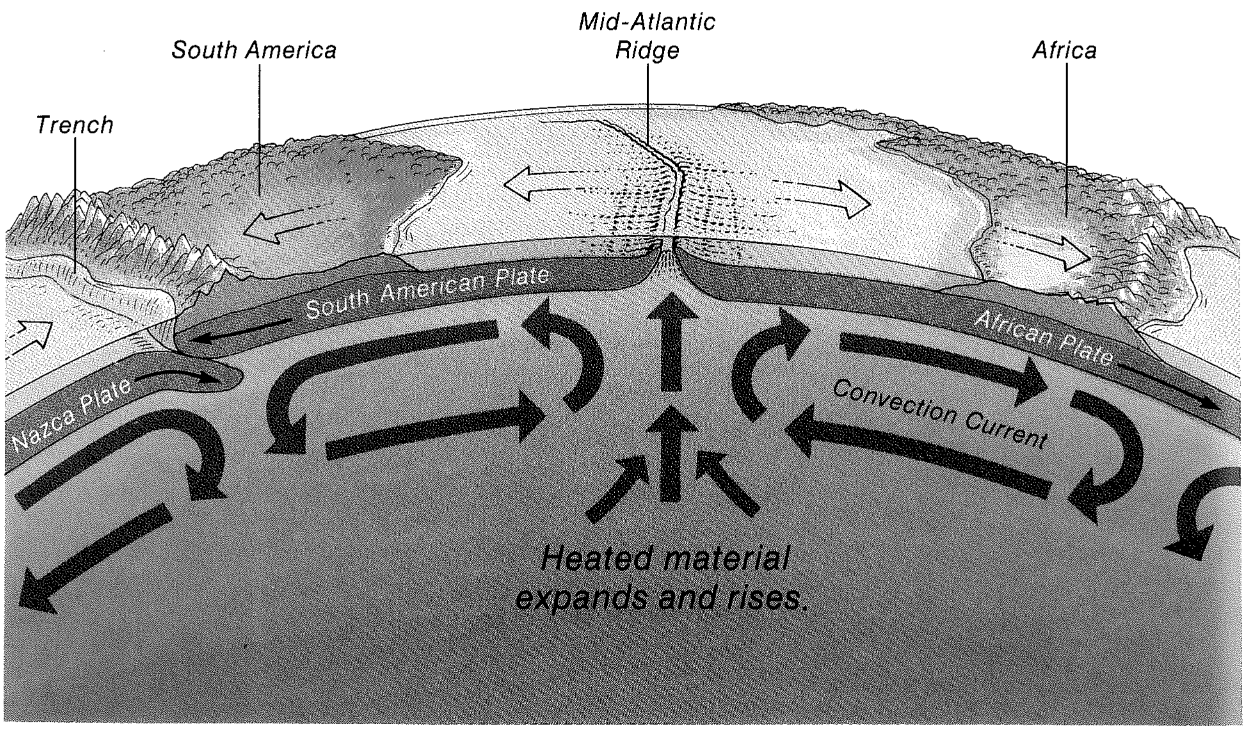
The composition of the lithosphere is basically that of the igneous rock basalt. The continents, however, are a major exception. Continental crust has a composition more like that of the igneous rock granite. Because granite is less dense (lighter) than basalt, continents occur as pieces embedded in the more dense (heavier) lithosphere.

Topic 3 Why Do the Plates Move?

The Lithospheric plates rest upon a layer within the mantle called the **asthenosphere.** This layer is thought to cause plate movement.

The asthenosphere has a composition similar to the lithosphere above, but it has very different properties. The rock of the asthenosphere is partially melted. As a result, it can flow very slowly. Scientists think that this flow takes the form of very large and slow-

13.2 The moving lithospheric plates rest upon the asthenosphere. Convection currents within the asthenosphere are the driving force behind lithospheric plate movement.



moving convection currents. Within such currents, material expands and rises upon heating but contracts and sinks upon cooling.

Where the convection currents within the asthenosphere are rising, new material continually arrives at Earth's surface and pushes older material aside. This push drives the lithospheric plates apart. The South American Plate and the African Plate are an example.

Where cooler, denser currents within the asthenosphere seem to be sinking, the plates of the lithosphere are pulled together. This motion is thought to be the reason for the Nazca Plate sliding beneath the South American Plate.

TOPIC QUESTIONS

Each topic question refers to the topic of the same number.

1. **(a)** What is plate tectonics? **(b)** Identify plates that are moving apart; moving together or colliding; and sliding past each other.
2. **(a)** Describe the structure and properties of the lithosphere. **(b)** How are the composition and density of continental crust different from that of the rest of the lithosphere?
3. **(a)** Where is the asthenosphere? **(b)** What is the major property of the asthenosphere? **(c)** How do the lithospheric plates move where convection currents are rising? **(d)** How do the plates move where convection currents are sinking?

Current RESEARCH

Seeing Earth's Interior

As you will learn in Chapter 15, most of what is known about Earth's interior is based on the detailed study of earthquake, or seismic waves. These energy waves travel outward from an earthquake's origin. Based on the material they encounter as they travel through Earth's many layers, these waves of energy may speed up, slow down, or be stopped altogether.

Scientists are currently using a technique called seismic tomography to peer inside Earth. Seismic tomography can be compared to a computerized tomography scan (CT) of the human body. A CT scan—called a "cat scan"—gives a three-dimensional view of the inside of the human body by piecing together X ray images from all directions. Various organs and bones absorb X rays differently and show up differently on the CT image.

Using seismic data from stations all over the world, researchers have put together three-dimensional images of what is happening in the mantle. The images show what appear to be hot masses rising up through the asthenosphere at the mid-ocean ridges. Beneath the continents, tomograms reveal cool, thick areas, which may show the thicker continental crust. Current research in seismic tomography centers on the subduction of plates and how deep oceanic plates are carried into the mantle before melting.

OBJECTIVES

A Describe the theory of continental drift and list some evidences that Alfred Wegener used to support the theory.

B Discuss the relationship between earthquakes, volcanoes, and plate boundaries.

C Explain what is meant by normal and reversed polarity, discuss the pattern of magnetic polarity at spreading centers, and relate this pattern to plate tectonics.

D Discuss heat flow and elevation of the seafloor as evidence of seafloor spreading.

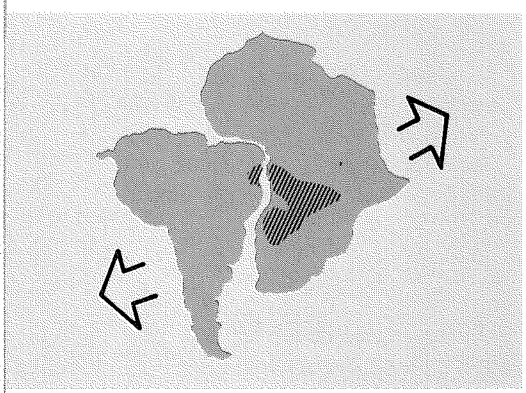
II Evidence for Plate Tectonics

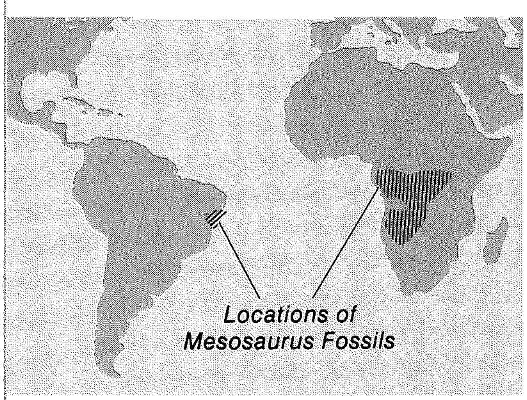
Topic 4 Africa and South America

The idea that Earth's solid surface might be moving and changing is not new. When the first reliable world maps were made in the seventeenth century, people noted the remarkable similarities in the shape of the west coast of Africa and the east coast of South America. The suggestion was eventually made that the two continents had once been part of a larger continent that had broken and moved apart. This idea was the start of a theory called *continental drift.*

The most famous version of the theory was proposed in 1912 by Alfred Wegener, a German scientist. In addition to the similarities in continental shape, Wegener found other evidence to show that Africa and South America must have been joined once. He noted that the fossil remains of *Mesosaurus,* a small reptile that lived 270 million years ago, are found in Brazil and in South Africa but are not found anywhere else on Earth. This peculiar distribution is easily explained if the two continents were joined at that time. Wegener also noted that some particularly distinctive rocks are found on both continents. The rocks at these locations would match nicely if the two continents were joined.

Wegener's theory of continental drift was debated for several years after its proposal. It was subjected to ridicule until the 1960's. At that time, new discoveries about such seemingly unrelated phenomena as earthquakes, volcanoes, magnetism, and crustal heat flow added support to Wegener's ideas. The theory of continental drift was expanded and became the theory of plate tectonics.





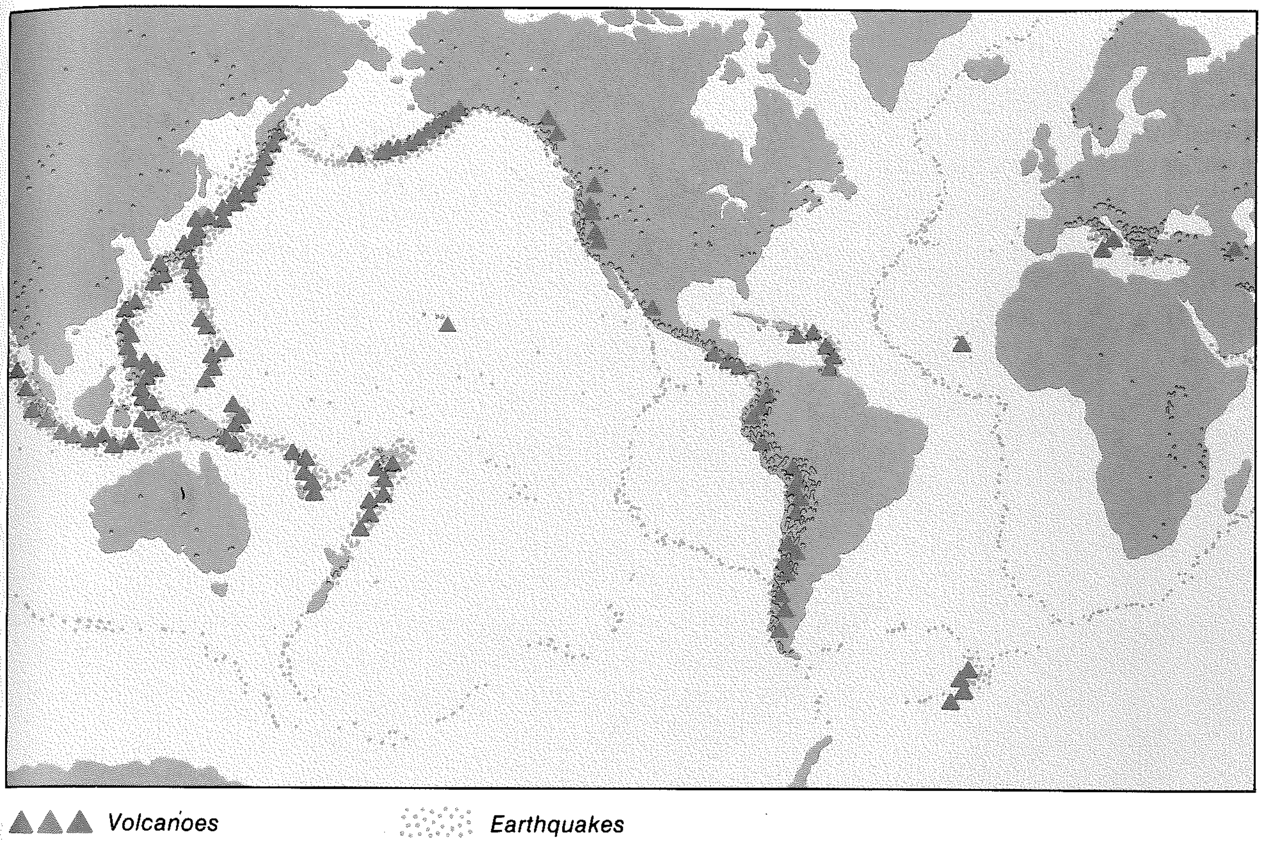
13.3 The theory of continental drift implies that Africa and South America were once joined. Fossil evidence on both continents seems to back the theory.

Topic 5 Earthquakes and Volcanoes

Scientists have long observed that earthquakes do not occur randomly throughout the world, but occur in rather limited belts. They have also noted that these same belts contain most of Earth's volcanoes. The locations of the belts became clear with the understanding of plate tectonics. The belts where earthquakes and volcanoes are located mark the location of *plate boundaries.*

It is not hard to understand why plate boundaries are active areas. These boundaries are places where one plate is moving relative to another plate. Stresses build up along the boundary, and when the stress becomes too great, fractures form and earthquakes occur. The boundaries are also areas of high heat flow, where molten rock moves upward to Earth's surface and forms volcanoes.

The largest active belt is the one that nearly surrounds the Pacific Ocean. In an average year, 90 percent of all the world's earthquakes occur there. Many famous volcanoes are found along this belt. Among them are Mount St. Helens in Washington State, Mount Katmai in Alaska, Mount Fujiyama in Japan, and Mount Pinatubo in the Philippine Islands.



13.4 This map shows the locations of the world's earthquake and volcano belts. The belts are also the location of plate boundaries.

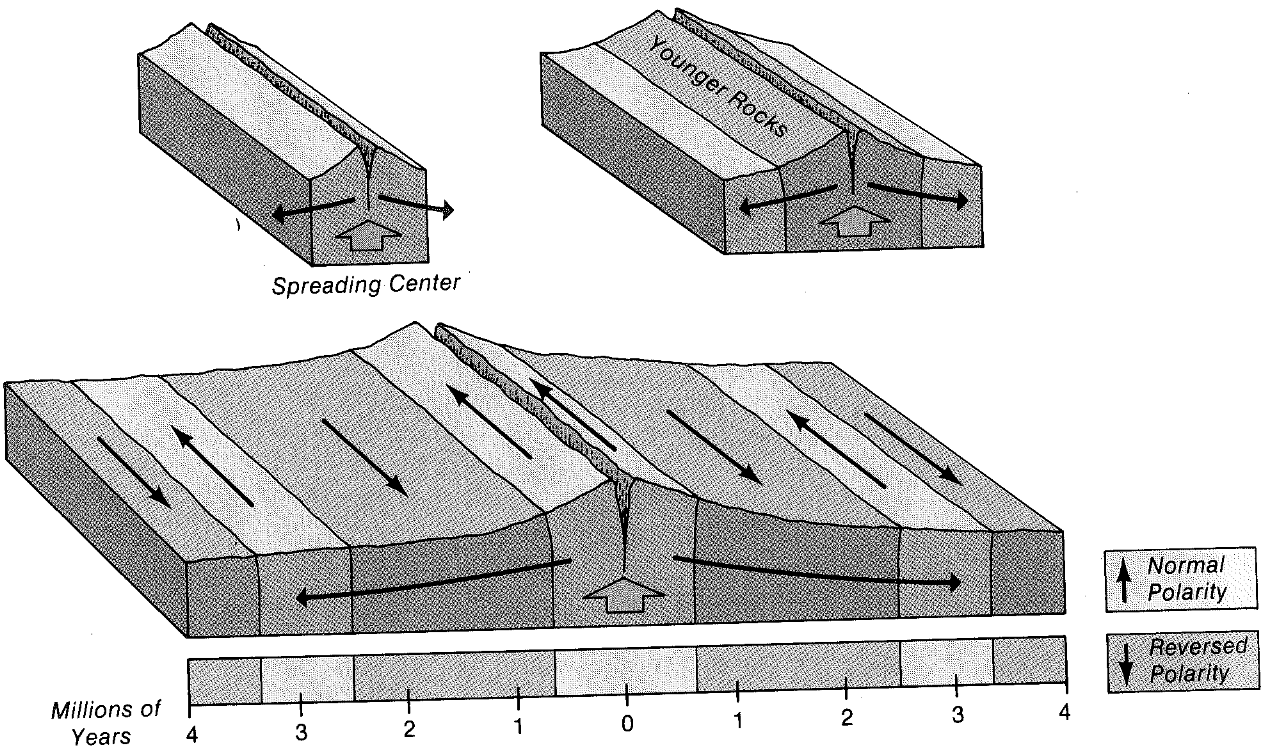
Topic 6 Magnetism

Some igneous rocks contain minerals that are magnetic. These minerals provide a record of the direction of Earth's magnetic poles at the time the rock formed. When this record was studied in igneous rocks on the continents, it was discovered that Earth's crust has apparently shifted or drifted since the rocks were formed. There is also evidence that Earth's magnetic poles had often been reversed. The present north magnetic pole became the south magnetic pole and the present south magnetic pole became the north magnetic pole. Scientists found that there have been four major periods of normal and reversed polarity within the past four million years (see Figure 13.5).

Magnetic polarity reversals also show in bands in the igneous rocks on the ocean floor. Where the lithospheric plates are moving apart, the polarity reversals occur in bands parallel to and on opposite sides of the plate boundaries. Scientists compared the magnetic bands found in the rock on both sides of the boundary with the actual age of the rock. They determined that the youngest rocks of the ocean floor are at the spreading plate boundaries, and that the ocean floor becomes increasingly older away from the boundaries.

13.5 There have been four major polarity reversals in the past four million years. Geologists use the knowledge of magnetic polarity to compare the ages of rocks near spreading centers on the ocean floor.

Using this observation, scientists theorize what happens in the areas where the lithospheric plates are moving apart. These areas are **spreading centers.** Lava wells up from deep within Earth and continuously forms new rocks there. At the same time, older rocks move away from the boundary equally in both directions. As the lithospheric plates move apart, they carry their continents with them.



Topic 7 **Heat Flow and Seafloor Elevation**

If convection currents within the asthenosphere are the driving force behind the movement of the lithospheric plates, some evidence for their existence should be found at spreading centers. Heat flow provides that evidence.

Heat flow is a measure of the amount of heat leaving the rocks of the lithosphere. The values for heat flow are unusually high in the areas of spreading centers and decrease away from the centers. This is exactly what should happen if spreading centers are places where hot convection currents are bringing magma to the surface forming new oceanic crust.

The elevation of the seafloor provides additional evidence of heat flow. Because heated materials expand, spreading centers have higher elevations than the rest of the seafloor. Elevations decrease away from spreading centers as the rocks cool and contract.