section 3

Standard—7.3.7: Give examples of some changes in Earth's surface that are abrupt, such as earthquakes and volcanic eruptions. . . .

Also covers: 7.3.4, 7.3.18 (Detailed standards begin on page IN8.)

Earthquakes, Volcanoes, and Plate Tectonics

as you read

What You'll Learn

- **Explain** how the locations of volcanoes and earthquake epicenters are related to tectonic plate boundaries.
- **Explain** how heat within Earth causes Earth's plates to move.

Why It's Important

Most volcanoes and earthquakes are caused by the motion and interaction of Earth's plates.

Review Vocabulary

asthenosphere: plasticlike layer of mantle under the lithosphere

New Vocabulary

- rift
- hot spot

Earth's Moving Plates

At the beginning of class, your teacher asks for volunteers to help set up the cafeteria for a special assembly. You and your classmates begin to move the tables carefully, like the students shown in **Figure 14.** As you move the tables, two or three of them crash into each other. Think about what could happen if the students moving those tables kept pushing on them. For a while one or two of the tables might keep another from moving. However, if enough force were used, the tables would slide past one another. One table might even slide up on top of another. It is because of this possibility that your teacher has asked that you move the tables carefully.

The movement of the tables and the possible collisions among them is like the movement of Earth's crust and uppermost mantle, called the lithosphere. Earth's lithosphere is broken into separate sections, or plates. When these plates move around, they collide, move apart, or slide past each other. The movement of these plates can cause vibrations known as earthquakes and can create conditions that cause volcanoes to form.

Figure 14 Like the tables pictured here, Earth's plates are in contact with one another and can slide beneath each other. The way Earth's plates interact at boundaries is an important factor in the locations of earthquakes and volcanoes.

Spencer Grant/PhotoEdit, Inc.

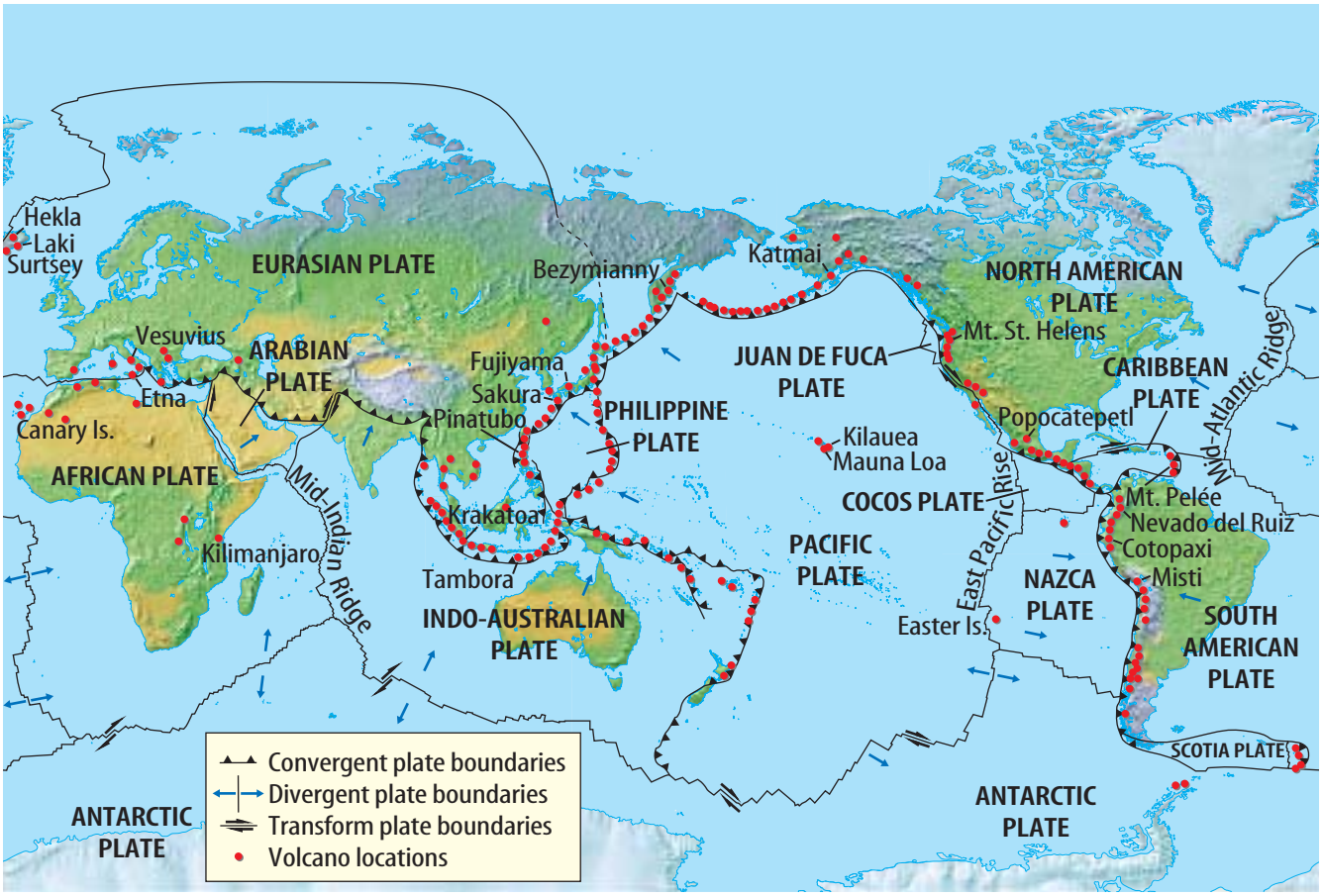

Figure 15 Earth's lithosphere is divided into about 13 major plates. Where plates collide, separate, and slip past one another at plate boundaries, interesting geological activity results.

Where Volcanoes Form

A plot of the location of plate boundaries and volcanoes on Earth shows that most volcanoes form along plate boundaries. Examine the map in **Figure 15.** Can you see how this indicates that plate tectonics and volcanic activity are related? Perhaps the energy involved in plate tectonics is causing magma to form deep under Earth's surface. You'll recall that the Soufrière Hills volcano formed where plates converge. Plate movement often explains why volcanoes form in certain areas.

Divergent Plate Boundaries Tectonic plates move apart at divergent plate boundaries. As the plates separate, long cracks called **rifts** form between them. Rifts contain fractures that serve as passageways for magma originating in the mantle. Rift zones account for most of the places where lava flows onto Earth's surface. Fissure eruptions often occur along rift zones. These eruptions form lava that cools and solidifies into basalt, the most abundant type of rock in Earth's crust.

Reading Check *Where does magma along divergent boundaries originate?*

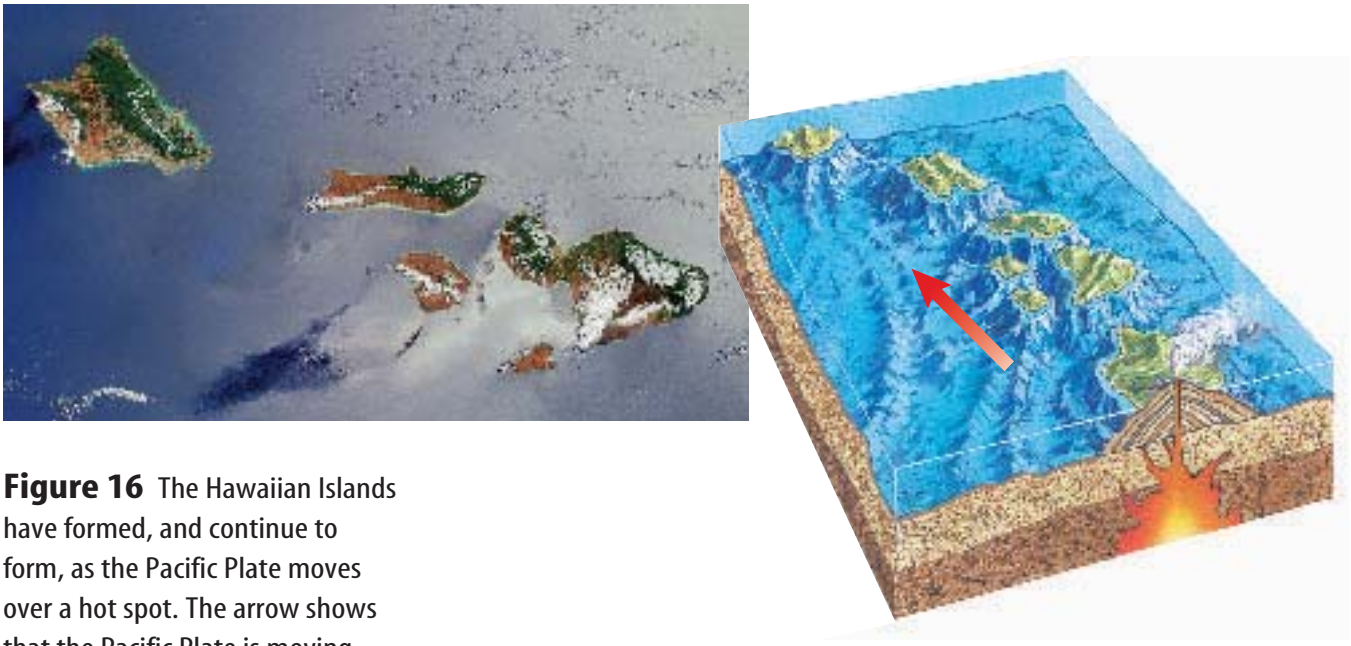

Figure 16 The Hawaiian Islands have formed, and continue to form, as the Pacific Plate moves over a hot spot. The arrow shows that the Pacific Plate is moving north-northwest.

Convergent Plate Boundaries A common location for volcanoes to form is along convergent plate boundaries. More dense oceanic plates sink beneath less dense plates that they collide with. This sets up conditions that form volcanoes.

When one plate sinks beneath another, basalt and sediment on an oceanic plate move down into the mantle. Water from the sediment and altered basalt lowers the melting point of the surrounding rock. Heat in the mantle causes part of the sinking plate and overlying mantle to melt. This melted material then is forced upward. Volcanoes have formed in this way all around the Pacific Ocean, where the Pacific Plate, among others, collides with several other plates. This belt of volcanoes surrounding the Pacific Ocean is called the Pacific Ring of Fire.

Hot Spots The Hawaiian Islands are volcanic islands that have not formed along a plate boundary. In fact, they are located well within the Pacific Plate. What process causes them to form? Large bodies of magma, called **hot spots,** are forced upward through Earth's mantle and crust, as shown in **Figure 16.** Scientists suggest that this is what is occurring at a hot spot that exists under the present location of Hawaii.

Reading Check *What is a hot spot?*

Volcanoes on Earth usually form along rift zones, subduction zones (where one plate sinks beneath another), or over hot spots. At each of these locations, magma from deep within Earth is forced upward toward the surface. Lava breaks through and flows out, where it piles up into layers or forms a volcanic cone.

INTEGRATE Chemistry

Melting Points The melting point of a substance is the temperature at which a solid changes to a liquid. Depending on the substance, a change in pressure can raise or lower the melting point. Do research to find out how pressure affects the formation of magma in a mantle plume in a process called decompression melting.

CONTENTS

Moving Plates Cause Earthquakes

Place two notebooks on your desk with the page edges facing each other. Then push them together slowly. The individual sheets of paper gradually will bend upward from the stress. If you continue to push on the notebooks, one will slip past the other suddenly. This sudden movement is like an earthquake.

Now imagine what would happen if tectonic plates were moving like the notebooks. What would happen if the plates collided and stopped moving? Forces generated by the locked-up plates would cause strain to build up. Both plates would begin to deform until the elastic limit was passed. The breaking and elastic rebound of the deformed material would produce vibrations felt as earthquakes.

Earthquakes often occur where tectonic plates come together at a convergent boundary, where tectonic plates move apart at a divergent boundary, and where tectonic plates grind past each other, called a transform boundary.

Earthquake Locations If you look at a map of earthquakes, you'll see that most occur in well-known belts. About 80 percent of them occur in the Pacific Ring of Fire—the same belt in which many of Earth's volcanoes occur. If you compare **Figure 17** with **Figure 15,** you will notice a definite relationship between earthquake epicenters and tectonic plate boundaries. Movement of the plates produces forces that generate the energy to cause earthquakes.

Friction Friction is a force that opposes the motion of two objects in contact. Do research to find out different types of friction in a literary and figurative sense.

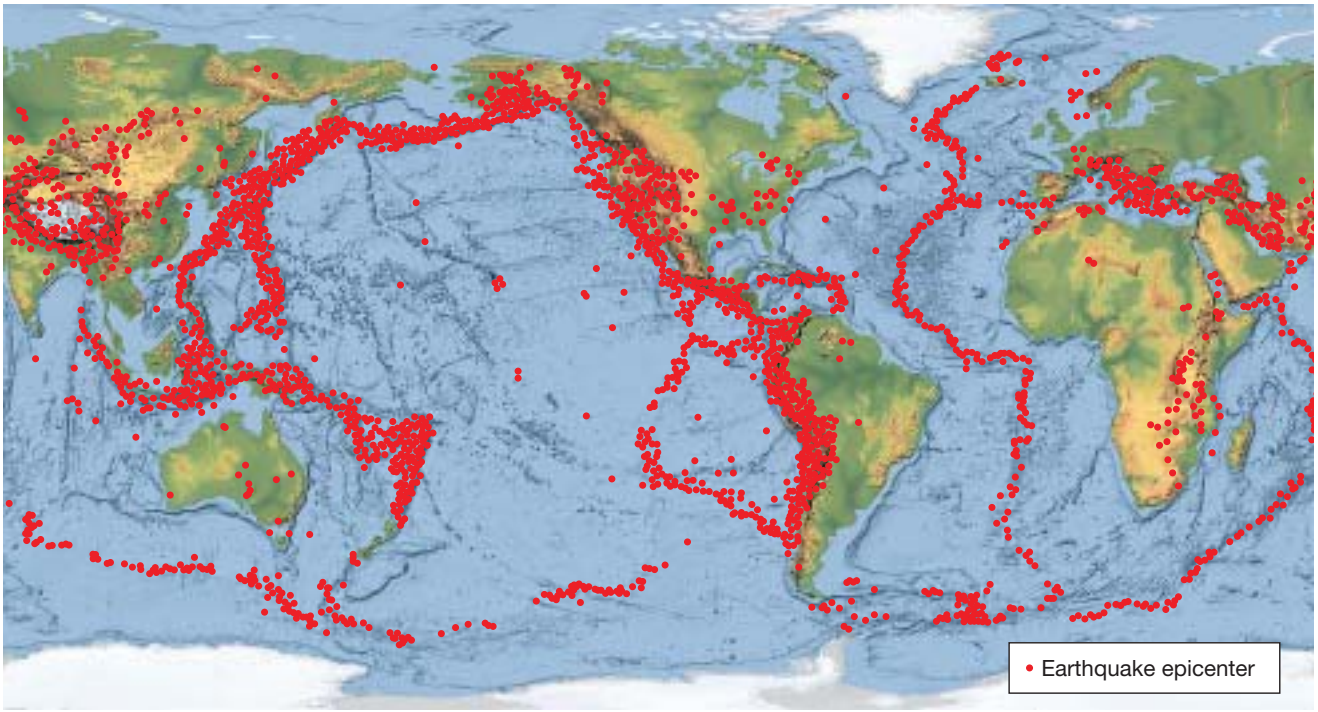

Figure 17 Locations of earthquakes that have occurred between 1990 and 2000 are plotted below.

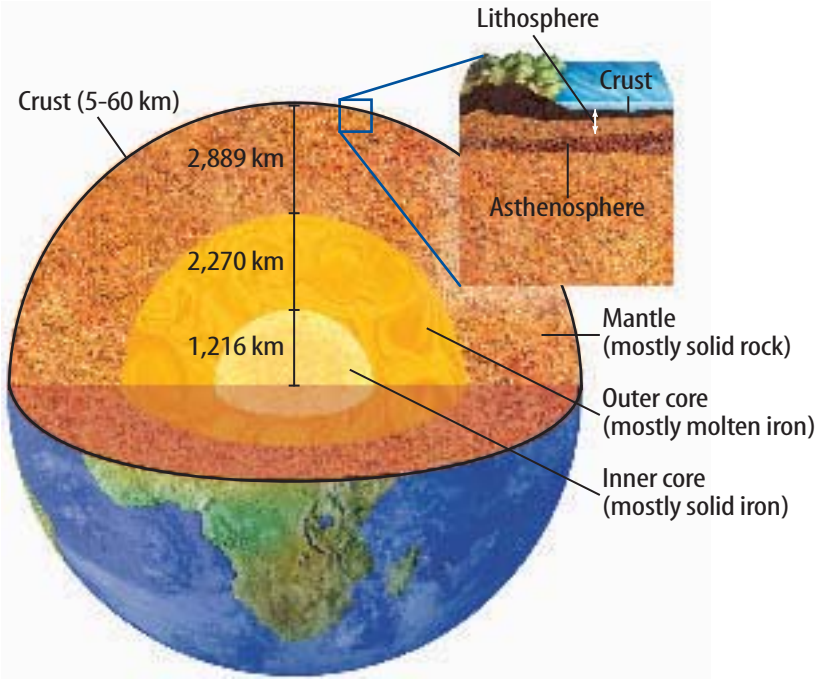

Figure 18 Seismic waves generated by earthquakes allow researchers to figure out the structure and composition of Earth's layers.

Earth's Plates and Interior

Researchers have learned much about Earth's interior and plate tectonics by studying seismic waves. The way in which seismic waves pass through a material depends on the properties of that material. Seismic wave speeds, and how they travel through different levels in the interior, have allowed scientists to map out the major layers of Earth, as shown in **Figure 18.**

For example, the asthenosphere was discovered when seismologists noted that seismic waves slowed when they reached the base of the lithosphere of the Earth. This partially molten layer forms a warmer, softer layer over which the colder, brittle, rocky plates move.

Applying Math — Calculate

P-WAVE TRAVEL TIME There is a relationship between the density of a region in Earth and the velocity of P-waves. How can you calculate the time it would take P-waves to travel 100 km in the crust of Earth?

Density and Wave Velocity

Region	Density	P-Wave Velocity
Crust	2.8 g/cm^3	6 km/s
Upper mantle	3.3 g/cm^3	8 km/s

Solution

1 *This is what you know:*

- velocity: $v = 6$ km/s
- distance: $d = 100$ km

2 *This is what you need to find:*

How long would it take a P wave to travel?

3 *This is the procedure you need to use:*

- $t = d/v$
- $t = (100 \text{ km})/(6 \text{ km/s}) = 16.7$ s

4 *Check your answer:*

Solve $v = d/t = (100 \text{ km})/(16.7 \text{ s}) = 6$ km/s

Practice Problems

1. Calculate the time it takes P-waves to travel 300 km in the upper mantle.
2. How long will it take a P-wave to travel 500 km in the crust?

ScienceOnline For more practice, visit in7.msscience.com/math_practice

What is driving Earth's plates? There are several hypotheses about where all the energy comes from to power the movement of Earth's plates.

In one case, mantle material deep inside Earth is heated by Earth's core. This hot, less dense rock material is forced toward the surface. The hotter, rising mantle material eventually cools. The cooler material then sinks into the mantle toward Earth's core, completing the convection current. Convection currents inside Earth, shown in **Figure 19,** provide the mechanism for plate motion, which then produces the conditions that cause volcanoes and earthquakes. Sometimes magma is forced up directly within a plate. Volcanic activity in Yellowstone National Park is caused by a hot spot beneath the North American Plate. Such hot spots might be related to larger-scale convection in Earth's mantle.

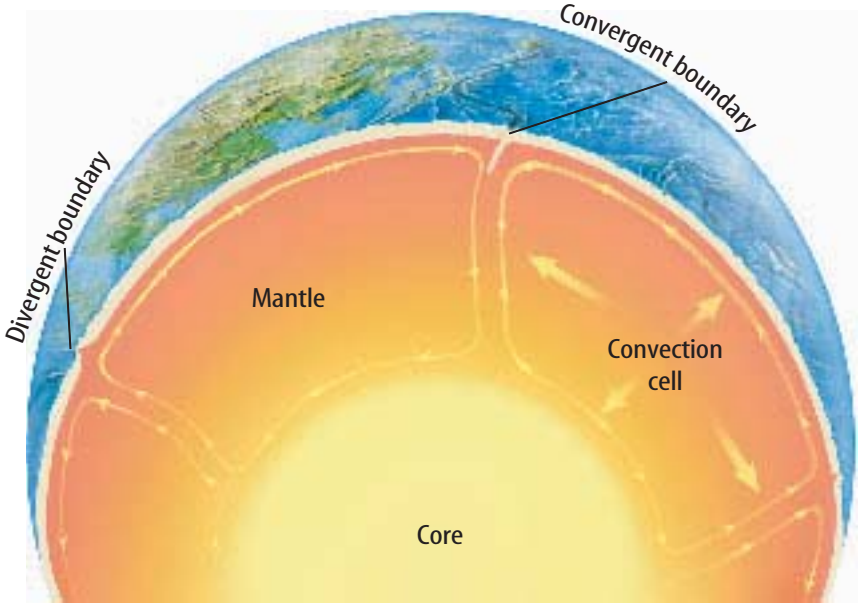

Figure 19 Convection of material in Earth's interior drives the motion of tectonic plates.

section 3 review

Summary

Earth's Moving Plates

- Earth's lithosphere is broken into plates that move around the planet.

Where Volcanoes Form

- Plates move apart at divergent plate boundaries, creating fissure eruptions.
- Plates collide at convergent plate boundaries.
- Many volcanoes form at convergent plate boundaries.
- Volcanoes may also form along rift zones, subduction zones, or over hot spots.

Moving Plates Cause Earthquakes

- Earthquakes often form at plate boundaries.
- Seismic waves have been used to determine the characteristics of Earth's interior.
- Convection currently may drive tectonic plate movement.

Self Check

1. **Identify** Along which type of plate boundary has the Soufrière Hills volcano formed?
2. **Predict** At which type of plate boundary does rift-volcanism occur?
3. **Explain** how volcanoes in Hawaii form.
4. **Recognize Cause and Effect** Why do most deep earthquakes occur at convergent boundaries?
5. **Think Critically** Subduction occurs where plates converge. This causes water-rich sediment and altered rock to be forced down to great depths. Explain how water can help form a volcano.

Applying Skills

6. **Form Hypotheses** Write a hypothesis concerning the type of lava that will form a hot spot volcano. Consider that magma in a hot spot comes from deep inside Earth's mantle.