Section 1 Where Are the Volcanoes and Earthquakes?

Learning Outcomes

In this section, you will

- **Search, describe,** and **account for** patterns in the global distribution of volcanoes and earthquakes.
- **Find** the latitude and longitude of volcanoes and past earthquakes nearest to your community.
- **Make** inferences about possible locations of future volcanic and earthquake activity.
- **Describe** the interior structure of Earth.
- **Connect** volcanoes and earthquakes with the theory of plate tectonics.

What Do You See?

Think About It

Volcanic eruptions and earthquakes are sudden and often destructive events. When they occur, they grab headlines and our attention.

- **Can volcanoes form anywhere on Earth? Why or why not?**
- **Can earthquakes occur anywhere on Earth? Why or why not?**

Record your ideas about these questions in your *Geo* log. Be prepared to discuss your responses with your small group and the class.

Investigate

In this *Investigate*, you will plot the locations of volcanoes and earthquakes on a world map. You will then compare the information on your map to that on the *This Dynamic Planet* map to find patterns in volcano and earthquake distribution.

Part A: The Distribution of Volcanoes and Earthquakes

1. Obtain a blank copy of the world map and some colored pencils.

a) Plot the locations of the volcanoes shown in *Table 1* (on the next page). Use a colored pencil to draw small triangles that mark their locations. (Remember that the lines of latitude run from east to west and the lines of longitude run from north to south.)

2. Using the same world map from *Step 1*:

a) Make a key to show the color that you used for the volcano triangles.

b) What patterns do you see in the distribution of volcanoes on Earth?

c) What areas seem to have many volcanoes?

d) What areas seem to have no volcanoes? What ideas do you have about why this might be so?

3. Choose a different colored pencil.

a) Plot the locations of earthquakes shown in *Table 2* (on the next page) using small dots.

b) Add this information to your key.

c) What patterns do you see in the distribution of earthquakes on Earth?

d) What areas seem to have many earthquakes?

e) What areas seem to have no earthquakes? What ideas do you have about why this might be so?

f) What relationships do you observe between the patterns of volcanoes and the patterns of earthquakes? How could you explain this? Talk it over with your group.

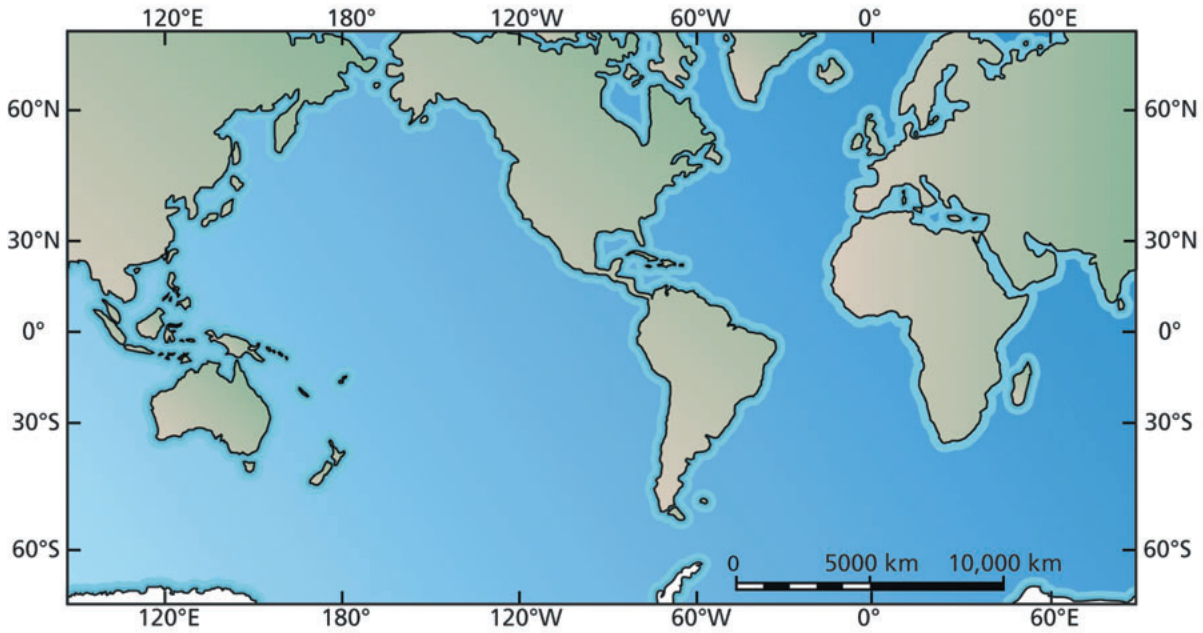

Table 1: Global Volcanic Activity Over a One-Month Period

Latitude	Longitude	Region
1°S	29°E	DR Congo, Eastern Africa
38°N	15°E	Aeolian Islands, Italy
37°N	15°E	Sicily, Italy
15°S	71°W	Peru
0°	78°W	Ecuador
12°N	87°W	Nicaragua
0°	91°W	Galapagos, Ecuador
19°N	103°W	Western Mexico
19°N	155°W	Hawaii, United States
56°N	161°E	Kamchatka, Russia
54°N	159°E	Kamchatka, Russia
43°N	144°E	Hokkaido, Japan
39°N	141°E	Honshu, Japan
42°N	140°E	Hokkaido, Japan
1°S	101°E	Sumatra, Indonesia
4°S	145°E	Papua New Guinea
5°S	148°E	Papua New Guinea
15°S	167°E	Vanuatu
16°N	62°W	Montserrat, West Indies
12°N	86°W	Nicaragua
37°N	25°W	Azores

Table 2: Global Earthquake Activity Over a One-Week Period

Latitude	Longitude	Region
47°N	151°E	Kuril Islands
28°S	178°W	Kermadec Islands
30°N	52°E	Iran
36°N	140°E	Honshu, Japan
34°N	103°E	Gansu, China
40°S	177°E	New Zealand
0°	36°E	Kenya, Africa
38°N	21°E	Ionian Sea
16°N	47°W	North Mid-Atlantic Ridge
6°S	147°E	New Guinea
55°N	164°W	Unimak Island, Alaska
24°S	67°W	Argentina
13°N	91°W	Guatemala coast
4°N	76°W	Colombia
40°N	125°W	North California coast
5°S	102°E	South Sumatra, Indonesia
44°S	16°W	South Mid-Atlantic Ridge
51°N	179°E	Aleutian Islands
15°S	71°W	Peru
49°N	128°W	Vancouver, Canada
35°N	103°E	Gansu, China

Learning Through Technology

To use online resources to expand your understanding of where volcanoes and earthquakes occur on Earth, go to the *EarthComm* Web site at http://www.agiweb.org/education/earthcomm2/. There you will be able to use an interactive version of the *This Dynamic Planet* map to collect more detailed information on specific volcanoes and earthquakes around the world.

Part B: Volcanoes, Earthquakes, and Your Community

1. Obtain a copy of the *This Dynamic Planet* map. Look at the map legend to interpret the meaning of the various symbols on the map and how to use the map scale.

   a) What does each of the four kinds of triangles represent? Compare the *This Dynamic Planet* map to your world map from *Part A*. What patterns in volcano and earthquake distribution does the *This Dynamic Planet* map clarify?

2. Use the *This Dynamic Planet* map to help you complete the following. Write your answers in your log.

   a) Find the latitude and longitude of the three volcanoes closest to your community. Make a data table to record your results.

   b) Find and record the latitude and longitude of the three earthquakes that occurred closest to your school.

3. Use your findings to answer the following questions:

   a) Suppose that tomorrow a volcano forms somewhere in the United States. Could it form in or near your state? Support your answer with evidence from this *Investigate*.

   b) Suppose that tomorrow an earthquake occurs somewhere in the United States. Could it occur in or near your state? Support your answer with evidence from this *Investigate*.

   c) Compare your data with that of other groups in your class. Did your class agree on the locations of the nearest, historically active volcanoes and earthquakes? How did you resolve any differences?

Digging Deeper

THE GLOBAL DISTRIBUTION OF VOLCANOES AND EARTHQUAKES

Earth's Interior Structure

In the *Investigate*, you looked at the locations of volcanoes and earthquakes throughout the world. You saw that there is a pattern in which they are distributed across the surface of Earth. You will look closer at this pattern and learn more about volcanoes and earthquakes. However, first you need to understand a little bit about the internal structure of Earth.

Geologists (types of **geoscientists** who study the materials, processes, and history of Earth) divide Earth into layers by chemical composition. The layers are the core, the mantle, and the crust, as shown in *Figure 1* on the next page. Geologists base this division on several kinds of evidence. You will learn more about the evidence in later sections. You will also learn about the chemical structure of each layer.

The **crust** is the thin, solid, outermost layer of Earth. It is the thinnest layer and its rocks are also the least dense of all the layers. The crust is divided into **oceanic** and **continental crust**—the crust beneath the oceans and the crust that makes up the continents. The oceanic crust is younger than, and not as thick as, the continental crust.

Geo Words

geologist: a scientist who studies the materials, processes, and history of Earth.

geoscientist: a scientist who studies the processes of the geosphere, atmosphere, hydrosphere, cryosphere, and biosphere on Earth and other planets.

crust: the thin, solid, outermost layer of Earth.

oceanic crust: the crustal rocks that underlie the ocean basins.

continental crust: the crustal rocks that underlie the continents.

Geo Words

mantle: the zone of Earth below the crust and above the core. It is divided into the upper mantle and lower mantle with a transition zone between.

core: the central part of Earth; it is divided into an outer core that may be liquid and an inner core that may be solid.

lithosphere: Earth's crust and the uppermost part of the mantle.

asthenosphere: lower part of Earth's mantle that can flow very slowly.

Beneath Earth's crust is the **mantle**. The boundary between the crust and the mantle is well defined. There is a change in the chemical composition of the rocks. The rocks of the mantle are not the same as those of the crust. Most of Earth's mass is contained in the mantle.

Below the mantle, is the **core**. It is the innermost and hottest part of Earth.

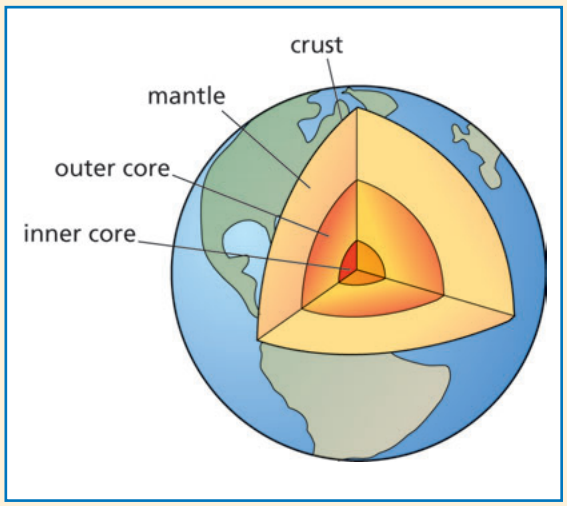

Figure 1 Schematic diagram showing the layered structure of Earth's interior.

Earth's interior can also be divided into layers based on physical properties. As you move from the crust to the interior of Earth, there is an increase in the temperature, pressure, and *density* of the materials. You will learn more about density in a later section. The topmost part of the mantle is cooler than the parts below. This uppermost part of the mantle moves as a rigid block, carrying the crust with it. The top part of the mantle, together with the crust, is called the **lithosphere**. Lower down in the mantle, it is hot enough so that the mantle material can flow very slowly, just like a very thick liquid. That part of the mantle is called the **asthenosphere**. Below the mantle lies the outer core, which is liquid. The innermost and hottest part of Earth is the inner core, which is primarily solid.

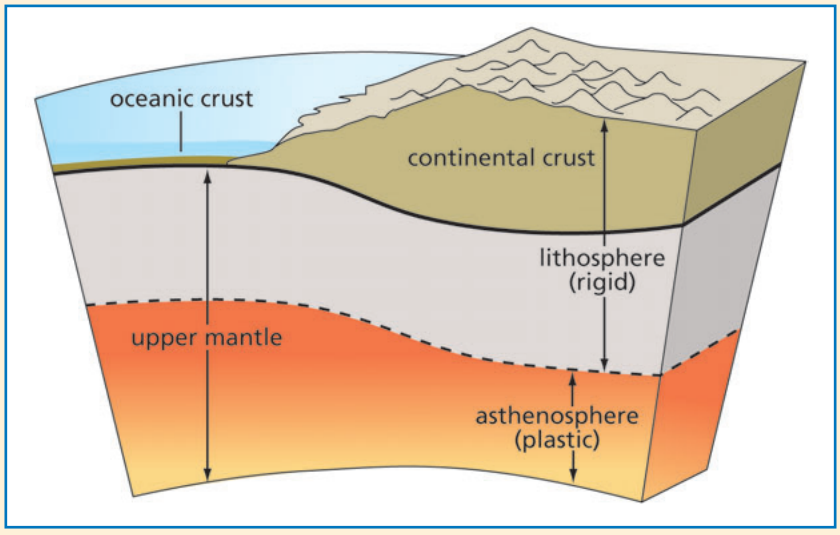

Figure 2 The layered structure of the upper mantle.

The Pattern of Volcanoes and Earthquakes

In the *Investigate,* you observed a pattern of volcanoes and earthquakes. You saw that the volcanoes and earthquakes were concentrated along the edges of some continents. For example, you saw that there are many volcanoes and earthquakes along the western coasts of North and South America. You also observed that volcanoes were concentrated in a linear pattern. They formed straight lines along the central parts of many ocean basins.

When you looked at the patterns on the *This Dynamic Planet* map, you saw that the surface of Earth is broken into gigantic slabs. These gigantic slabs are called **lithospheric plates**. These plates move in relation to one another. There are three types of movement at plate boundaries. The type of movement is used to differentiate the boundaries. There are **convergent plate boundaries** or collision boundaries, **divergent plate boundaries** or spreading regions, and **transform boundaries** or transform faults.

At a convergent plate boundary, two or more lithospheric plates move toward each other and collide. A divergent plate boundary exists between two plates that are moving away from each other. At a transform boundary, the relative motion of the plates is horizontal. You will learn more about what scientists know about how and why these plates move in a later section.

The theory that explains this large-scale movement of Earth's lithosphere is called **plate tectonics**. *Tectonics* comes from a Greek word meaning "builder." Geologists who study tectonics examine the structures and processes in the lithosphere. They study volcanoes and earthquakes and the forces and movements that create them.

Earth's Volcanoes and Their Locations

A **volcano** is a vent or fissure in Earth's crust that allows **magma**, gases, and ash to escape from below the surface. Magma is the molten rock material generated within Earth. When the molten rock comes out of a volcano, it is called **lava**. Geologists have known for a long time that there are many volcanoes along the edges of certain continents.

Figure 3 Lava flows occur on the continents and on the ocean floor.

Geo Words

lithospheric plate: a rigid, thin segment of the crust and part of the upper mantle. A lithospheric plate can be assumed to move horizontally and adjoins other plates.

convergent plate boundary: a region where two (or more) lithospheric plates move toward one another and collide.

divergent plate boundary: a region where lithospheric plates are moving away from each other.

transform boundary: a region where lithospheric plates are moving horizontally in relation to one another.

plate tectonics: a theory in which the lithosphere is divided into a number of plates that move relative to one another.

volcano: a vent in the surface of Earth through which magma and associated gases and ash erupt.

magma: naturally occurring molten rock material generated within Earth.

lava: fluid rock that comes out of a volcano.

Volcanoes can erupt under the ocean or on land. Volcanoes under the ocean form in the following way. All of Earth's ocean basins have a continuous mountain range extending through them. This range is called a **mid-ocean ridge**. These ridges are broad rises in the ocean floor. They are usually in water depths of 1000 or 2000 m. They are 50,000 km long in total. *Figure 4* shows a vertical cross section of a mid-ocean ridge. At the crest of the ridge there is a steep-sided **rift valley**. Magma from deep in Earth rises up into the rift valley to form volcanoes under the sea. Volcanic rocks on the floors of all the ocean basins are evidence that there are more volcanoes under water than on land. Volcanoes have also been observed by scientists in deep-diving submersibles. (A submersible is equipment that is intended for use under water.) At a few places along the mid-ocean ridges, as in Iceland, volcanic activity is especially high and volcanoes build up enough to form islands.

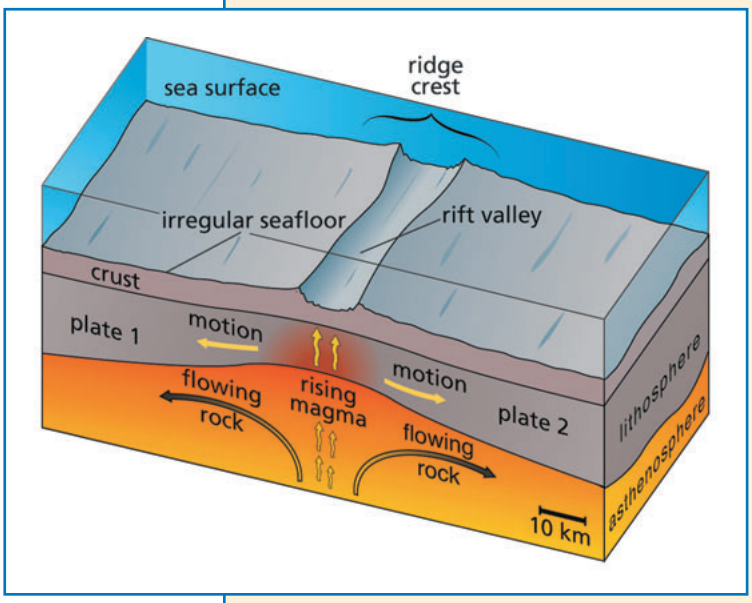

Figure 4 Cross section of a mid-ocean ridge.

Geo Words

mid-ocean ridge: a continuous mountain range extending through the North and South Atlantic Oceans, the Indian Ocean, and the South Pacific Ocean.

rift valley: the deep central cleft in the crest of the mid-ocean ridge.

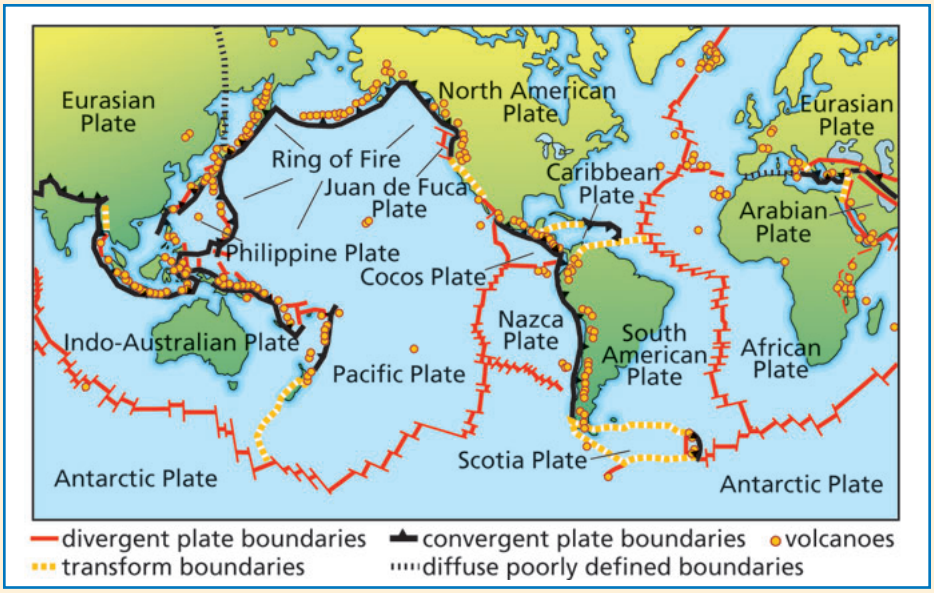

Figure 5 The plates of Earth and the Ring of Fire around the Pacific Ocean. The circles show active volcanoes.

Volcanoes that erupt on land are much more dangerous than volcanoes beneath the ocean. Eruptions along the western edge of the United States have formed the Cascades volcanic mountain range. They also form island chains, such as the Aleutians in Alaska. Volcanoes like these are common in a narrow belt all around the Pacific Ocean.

Geologists call this the "Ring of Fire." A famous example of an eruption along the Ring of Fire was the dramatic eruption of Mount Saint Helens in Washington in 1980. A small percentage of volcanoes occur in the interior of a plate. The Hawaiian Islands, shown in *Figure 6*, are an example. Studies of volcanic rock show that the islands get older the further northwest they are located. Only the youngest island, the "Big Island" of Hawaii, has active volcanoes.

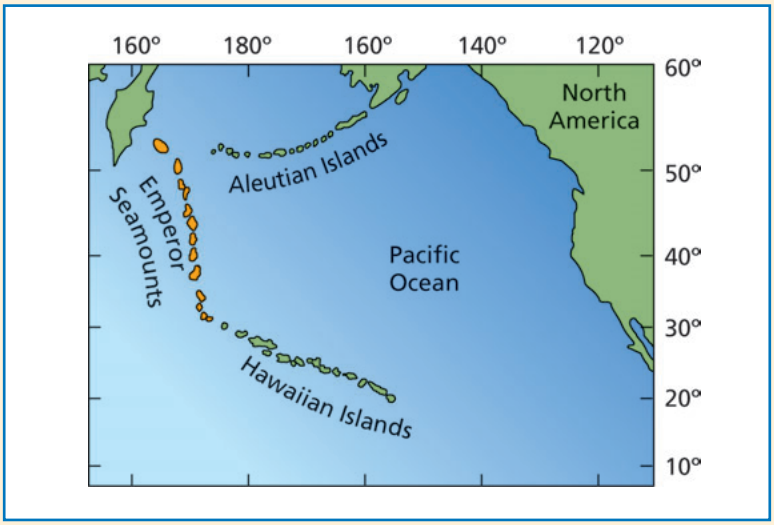

Figure 6 The Hawaiian Islands chain and the Emperor seamount chain.

Figure 7 Satellite image of the Hawaiian Islands.

Geo Words

hot spot: a fixed source of abundant rising magma that forms a volcanic center that has persisted for tens of millions of years.

seamount: an elevation of the seafloor, 1000 m or higher, either flat-topped or peaked.

earthquake: a sudden motion or shaking in Earth, caused by the abrupt release of slowly accumulated strain.

earthquake (seismic) wave: a general term for all elastic waves in Earth produced by earthquakes or generated artificially by explosions.

How do geologists explain the pattern of the Hawaiian Islands? Deep beneath Hawaii, there is a fixed source of abundant rising magma, called a **hot spot**. As a plate moves across this area, it passes over the fixed hot spot. Magma from the hot spot forces its way through the moving plate to form a chain of islands. The sharp bend in the chain was formed when the direction of movement of the plate changed abruptly at a certain time in the past. Far to the northwest, the chain consists of **seamounts**.

Earthquake Patterns and Plate Tectonics

Earthquakes are another geologic process that takes place on Earth's crust. An **earthquake** is a sudden motion or shaking of Earth as rocks break along an extensive surface within Earth. The concentration of earthquakes along plate boundaries is very high. (See *Figure 8*.) As you read earlier, Earth's plates move relative to one another at their boundaries. In some places, two plates slide past one another. In other places, plates move away from each other or toward each other. These motions cause forces in the rocks near the plate boundaries. When the forces build up to be greater than the strength of the rocks, the rocks break, causing an earthquake. The sudden release of energy as rocks rupture causes intense vibrations called **earthquake (seismic) waves** that extend in all directions.

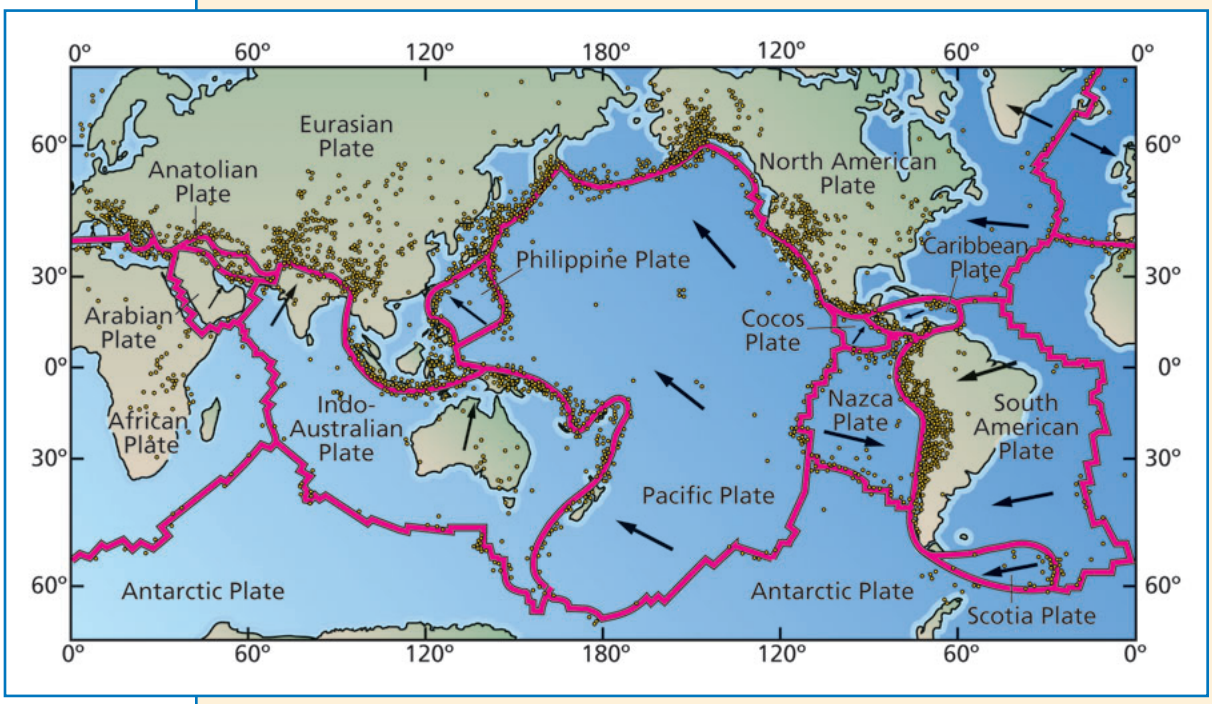

Figure 8 The directions that Earth's lithospheric plates move are shown by arrows. The circles show earthquake locations.

Earthquakes usually occur at some depth below the surface of Earth. The place in Earth where rupture (the break) occurs is called the earthquake **focus** (plural: **foci**). The **epicenter** is the geographic point on Earth's surface directly above the focus. (See *Figure 9.*) The depths of earthquake foci match the types of boundaries where the earthquakes occur.

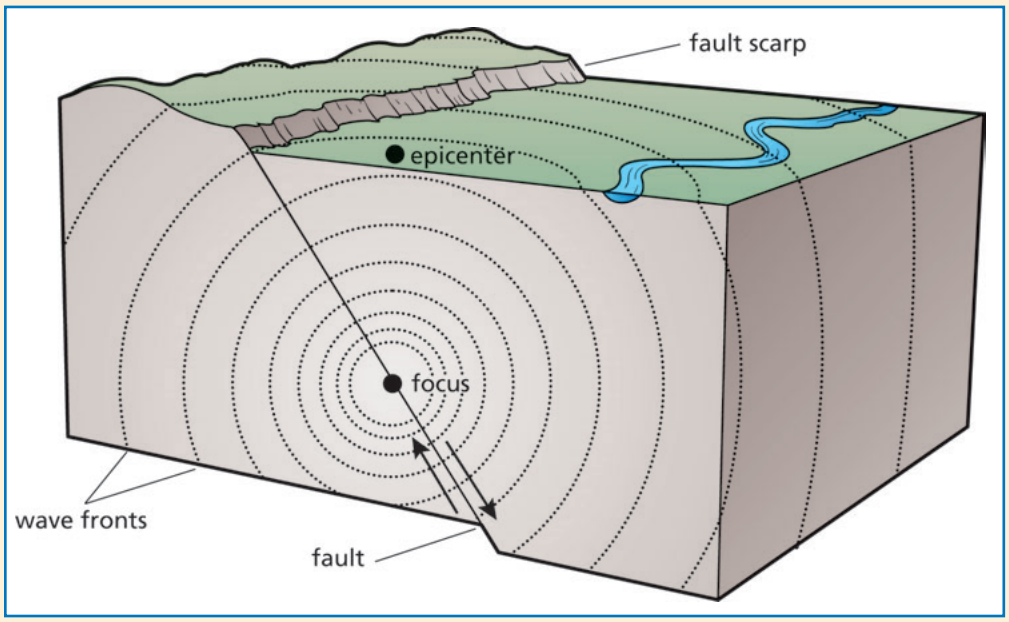

Figure 9 The relationship between the focus and the epicenter of an earthquake.

Earthquakes and volcanoes are closely related to the movement of Earth's crust. However, they do not always happen in the same places. During explosive volcanic activity the crust can be fractured. This breaking of the crust is often accompanied by the release of seismic waves. Other kinds of volcanism happen without any great shaking of the ground. Movements of the crust that release earthquakes may occur without any volcanoes. For example, the movement of Earth crust along the San Andreas Fault in California does not involve volcanoes.

Figure 10 Aerial photograph of the San Andreas Fault.

Geo Words

focus (plural: foci): the point of an earthquake within Earth where rupture first occurs to cause an earthquake.

epicenter: the point on Earth's surface directly above the focus of an earthquake.

Checking Up

1. Name three main layers of Earth.
2. What is the difference between the lithosphere and the asthenosphere?
3. What evidence do geologists have that volcanoes occur on the ocean floor?
4. What is the Ring of Fire and where is it located?
5. Where do most volcanoes on land form?
6. How are rift valleys formed?
7. What are hot spots? Provide an example of a hot spot on Earth.
8. What is an earthquake?
9. Explain how earthquake waves are generated by an earthquake.
10. What is the relationship between the focus and the epicenter of an earthquake?

Think About It Again

At the beginning of this section, you were asked the following:

- **Can volcanoes form anywhere on Earth? Why or why not?**
- **Can earthquakes occur anywhere on Earth? Why or why not?**

Record your ideas about these questions now. Use the distribution of volcanoes and earthquakes evidence you examined in this section as part of your explanation.

Reflecting on the Section and the Challenge

The data you examined showed patterns in the locations of Earth's volcanoes and earthquakes. You saw that volcanoes are abundant along the edges of certain continents. Volcanoes are far more abundant under water than on land. You found that most earthquakes occur along linear belts in oceans. You also found scattered or broad bands of earthquakes on most continents. This is information that you will need to include in the game that you develop.

Understanding and Applying

1. What difficulties did you have finding the latitude and longitude of volcanoes and earthquakes?
2. Where on Earth do most volcanoes occur? Explain your answer.
3. Where on Earth do most earthquakes occur? Explain your answer.
4. In your own words, describe the likely cause of historically active volcanoes in:
   a) the continental United States.
   b) the Aleutian Islands and southern Alaska.
   c) the Hawaiian Islands.
5. Based on your results from the *Investigate*, list the five states that you feel are most likely to experience the next volcanic eruption. Explain each choice.
6. Do most volcanoes on land occur in the Northern Hemisphere or the Southern Hemisphere? Explain why you think this is so.
7. Compare the cause of earthquakes in California with those in Indonesia.
8. ***Preparing for the Chapter Challenge***

   For your game, think about the global distribution of volcanoes and earthquakes. How is Earth structured in such a way that volcanic eruptions and earthquakes occur at these locations? What questions can you ask about where most volcanoes and earthquakes occur in North America and where they have not happened recently?

Inquiring Further

1. **Forming questions to investigate**

   Write down other questions you have about the causes of volcanoes and earthquakes and their effects. How would you go about gathering information to answer these questions? Write your ideas in your log.

2. **Earth science careers**

   Do you think you would like to study volcanoes or earthquakes for a career? To see what a volcanologist or seismologist does at work, visit the *EarthComm* Web site at http://www.agiweb.org/education/earthcomm2/.

3. **Eruptions near your community**

   Find out more about the historical eruptions of the volcanoes nearest to your community. The *Volcano World* Web site lists hundreds of historically active volcanoes. (Consult the *EarthComm* Web site for current addresses.)

4. **Volcanoes and the water on Earth (the hydrosphere)**

   Do some research to find answers to the following questions and any other questions that you have formed.

   - How do volcanoes at mid-ocean ridges affect the temperature of seawater?
   - How do volcanoes change the chemistry of seawater?
   - How does seawater affect the composition of the volcanic rock that is formed at the mid-ocean ridge?
   - Would volcanoes affect a small body of seawater, such as the Red Sea, the same way as a large ocean, such as the Atlantic?
   - Can a change in the volume of volcanic rock formed at mid-ocean ridges change sea level?