CHAPTER 18

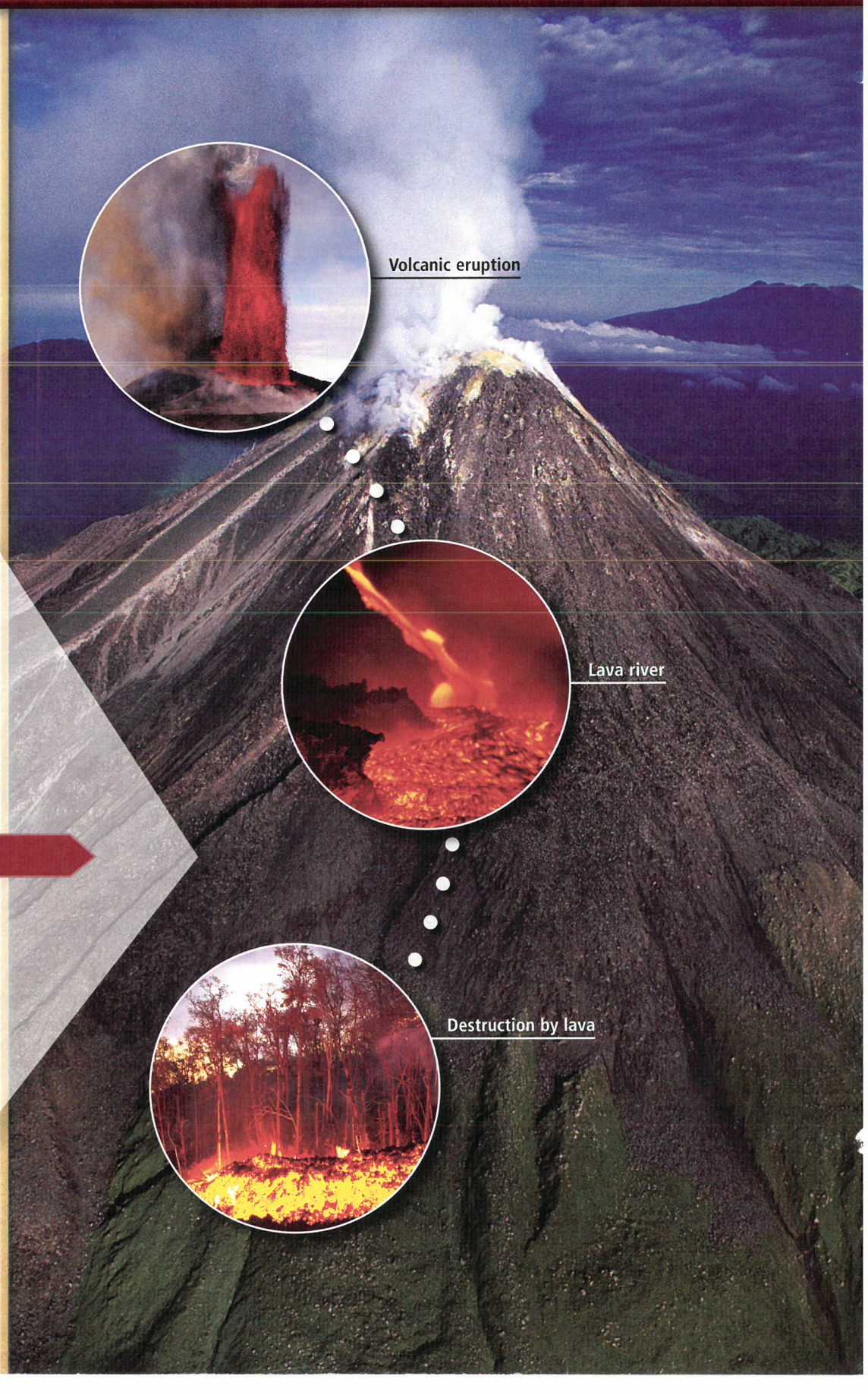
Volcanism

BIG Idea **Volcanoes develop from magma moving upward from deep within Earth.**

18.1 Volcanoes
MAIN Idea The locations of volcanoes are mostly determined by plate tectonics.

18.2 Eruptions
MAIN Idea The composition of magma determines the characteristics of a volcanic eruption.

18.3 Intrusive Activity
MAIN Idea Magma that solidifies below ground forms geologic features different from those formed by magma that cools at the surface.



GeoFacts

- All the lava from Kilauea could pave a road three times around Earth.
- There are 500 active volcanoes on Earth today.
- Magma comes from the Greek word meaning *dough*.
- Many of Earth's geographic features are caused by volcanoes.

Start-Up Activities

LAUNCH Lab

What makes magma rise?

Magma is molten rock that lies beneath Earth's surface. In this activity, you will model the movement of magma within Earth by making a "lava lamp."

Procedure

1. Read and complete the lab safety form.
2. Pour about 300 mL of **water** into a **600-mL beaker.**
3. Pour about 80 mL of **vegetable oil** into the beaker.
4. Sprinkle **table salt** on top of the oil while you slowly count to 5.
5. Add more salt to keep the movement going.

Analysis

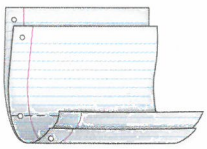
1. **Identify** which component of your model represents magma.
2. **Describe** what happened to the oil before and after you added the salt.
3. **Hypothesize** what causes the "magma" to rise.

FOLDABLES™ Study Organizer

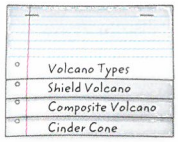
Classification of Volcanoes
Make this Foldable to help you understand volcanoes.

STEP 1 Stack ~~two~~ 4 sheets of notebook paper approximately 1.5 cm apart.

STEP 2 Fold up the bottom edges to form four tabs.



STEP 3 Staple along the folded edge. With the stapled end at the top, label the tabs as follows: *Volcano Types, Shield Volcano, Composite Volcano*, and *Cinder Cone*.



FOLDABLES **Use this Foldable with Section 18.1.**
As you study the section, write about the characteristics of each kind of volcano under each tab.

Earth Science Online

Visit glencoe.com to

- study entire chapters online;
- explore Concepts in Motion animations:
  - Interactive Time Lines
  - Interactive Figures
  - Interactive Tables
- access Web Links for more information, projects, and activities;
- review content with the Interactive Tutor and take Self-Check Quizzes.

Section 18.1

Objectives

- **Describe** how plate tectonics influences the formation of volcanoes.
- **Locate** major zones of volcanism.
- **Identify** the parts of a volcano.
- **Differentiate** between volcanic landforms.

Review Vocabulary

convergent: tending to move toward one point or to approach each other

New Vocabulary

volcanism
hot spot
flood basalt
fissure
conduit
vent
crater
caldera
shield volcano
cinder cone
composite volcano

Volcanoes

MAIN Idea **The locations of volcanoes are mostly determined by plate tectonics.**

Real-World Reading Link Road crews spread salt on icy winter roads because salt makes the ice melt at a lower temperature. At extremely high temperatures, rocks can melt. Often, if heated rocks are in contact with water, they melt more easily.

Zones of Volcanism

Volcanoes are fueled by magma. Recall from Chapter 5 that magma is a slushy mixture of molten rock, mineral crystals, and gases. As you observed in the Launch Lab, once magma forms, it rises toward Earth's surface because it is less dense than the surrounding mantle and crust. Magma that reaches Earth's surface is called lava. **Volcanism** describes all the processes associated with the discharge of magma, hot fluids, and gases.

As you read this, approximately 20 volcanoes are erupting. In a given year, volcanoes will erupt in about 60 different places on Earth. The distribution of volcanoes on Earth's surface is not random. A map of active volcanoes, shown in **Figure 18.1,** reveals striking patterns on Earth's surface. Most volcanoes form at plate boundaries. The majority form at convergent boundaries and divergent boundaries. Along these margins, magma rises toward Earth's surface. Only about 5 percent of magma erupts far from plate boundaries.

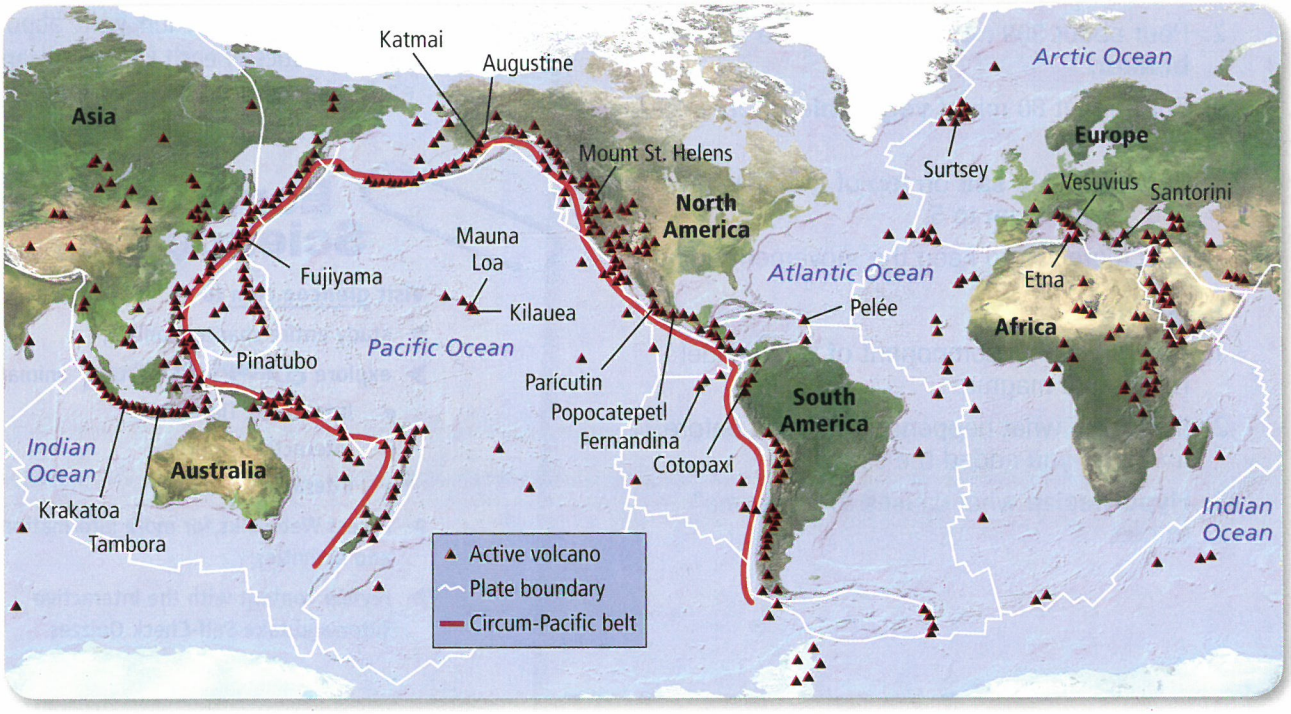


Figure 18.1 Most of Earth's active volcanoes are located along plate boundaries.

Convergent volcanism Recall from Chapter 17 that tectonic plates collide at convergent boundaries, which can form subduction zones—places where slabs of oceanic crust descend into the mantle. As shown in **Figure 18.2,** an oceanic plate descends below another plate into the mantle. As the oceanic plate descends, magma forms. The magma moves upward because it is less dense than the surrounding solid material. As it rises, the magma mixes with rock, minerals, and sediment from the overlying plate. Most volcanoes located on land result from oceanic-continental subduction. These volcanoes are characterized by explosive eruptions

Reading Check **Define** What is convergent volcanism?

Two major belts The volcanoes associated with convergent plate boundaries form two major belts, shown in **Figure 18.1.** The larger belt, the Circum-Pacific Belt, is also called the Pacific Ring of Fire. The name *Circum-Pacific* gives a hint about the location of the belt. *Circum* means *around* (as in circumference). The outline of the belt corresponds to the outline of the Pacific Plate. The belt stretches along the western coasts of North and South America, across the Aleutian Islands, and down the eastern coast of Asia. Volcanoes in the Cascade Range of the western United States and Mount Pinatubo in the Philippines are some of the volcanoes in the Circum-Pacific Belt. The smaller belt, which is called the Mediterranean Belt, includes Mount Etna and Mount Vesuvius, two volcanoes in Italy. Its general outlines correspond to the boundaries between the Eurasian, African, and Arabian plates.

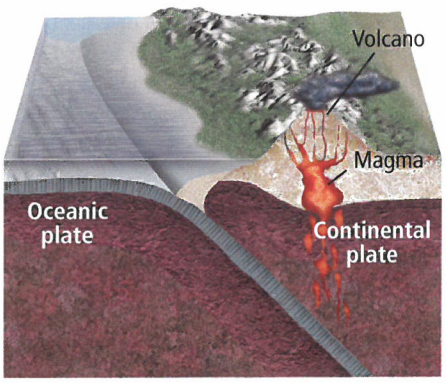


Figure 18.2 In an oceanic-continental subduction zone, the denser oceanic plate slides under the continental plate into the hot mantle. Parts of the plate melt and magma rises, eventually leading to the formation of a volcano.
Identify *a volcano from Figure 18.1 that is associated with oceanic-continental convergence.*

Concepts in Motion
Interactive Figure To see an animation of subduction, visit glencoe.com.

DATA ANALYSIS LAB

Based on Real Data*

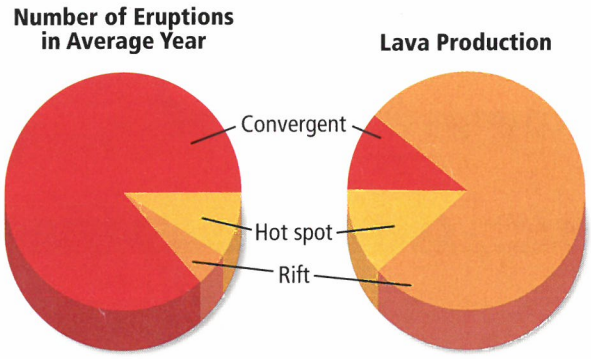
Interpret the Graph

How do zones of volcanism relate to lava production? Researchers classify types of volcanic eruptions and study how much lava each type of volcano emits during an average year. The circle graphs show data from 5337 eruptions and annual lava production for each zone.

Think Critically

1. **Describe** the relationship between the type of volcanism and annual lava production.
2. **Consider** Why is it important for scientists to study this relationship?
3. **Evaluate** What could be the next step in the researchers' investigation?

Data and Observations



*Data obtained from: Crisp, J. 1984. Rates of magma emplacement and volcanic output. *Journal of Volcanology and Geothermal Research* 20: 177–211.

Figure 18.3 Eruptions at divergent boundaries tend to be nonexplosive. At the divergent boundary on the ocean floor, eruptions often form huge piles of lava called pillow lava.

Concepts in Motion

Interactive Figure To see an animation of divergent plate boundaries, visit glencoe.com.

VOCABULARY

SCIENCE USAGE V. COMMON USAGE

Plume

Science usage: an elongated column

Common usage: a large, showy feather of a bird

Divergent volcanism Recall from Chapter 17 that at divergent plate boundaries tectonic plates move apart and new ocean floor is produced as magma rises to fill the gap. At ocean ridges, this lava takes the form of giant pillows like those in **Figure 18.3,** and is called pillow lava. Unlike the explosive volcanoes detailed in **Figure 18.4,** volcanism at divergent boundaries tends to be nonexplosive, with effusions of large amounts of lava. About two-thirds of Earth's volcanism occurs underwater along divergent boundaries at ocean ridges.

Reading Check **Convert** the fraction of volcanism that happens underwater to a percentage.

Hot spots Some volcanoes form far from plate boundaries over hot spots. Scientists hypothesize that **hot spots** are unusually hot regions of Earth's mantle where high-temperature plumes of magma rise to the surface.

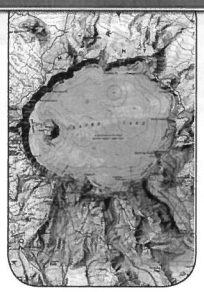
Figure 18.4

Volcanoes in Focus

Volcanoes constantly shape Earth's surface.

A.D. 79 Mount Vesuvius in Italy erupts, burying two cities in ash.

6000 B.C. — 3000 B.C.



4845 B.C. Mount Mazama erupts in Oregon. The mountain collapses into a 9-km-wide depression, known today as Crater Lake (topographic map).

1630 B.C. In Greece, Santorini explodes, causing tsunamis 200 m high. Nearby, Minoan civilization on the Isle of Crete disappears.

Hot spot volcanoes Some of Earth's best-known volcanoes formed as a result of hot spots under the ocean. For example, the Hawaiian islands, shown in the map in **Figure 18.5,** are located over a plume of magma. As the rising magma melted through the crust, it formed volcanoes. The hot spot formed by the magma plume remained stationary while the Pacific Plate slowly moved northwest. Over time, the hot spot has left a trail of volcanic islands on the floor of the Pacific Ocean. The volcanoes on the oldest Hawaiian island, Kauai, are inactive because the island no longer sits above the stationary hot spot. Even older volcanoes to the northwest are no longer above sea level. The world's most active volcano, Kilauea, on the Big Island of Hawaii, is currently located over the hot spot. Another volcano, Loihi, is forming on the seafloor southeast of the Big Island of Hawaii and might eventually rise above the ocean surface to form a new island.

Hot spots and plate motion Chains of volcanoes that form over stationary hot spots provide information about plate motions. The rate and direction of plate motion can be calculated from the positions of these volcanoes. The map in **Figure 18.5** shows that the Hawaiian islands are at one end of the Hawaiian-Emperor volcanic chain. The oldest seamount, Meiji, is at the other end of the chain and is about 80 million years old, which indicates that this hot spot has existed for at least that many years. The bend in the chain at Daikakuji Seamount records a change in the direction of the Pacific Plate that occurred 43 mya.

Hawaiian-Emperor Volcanic Chain

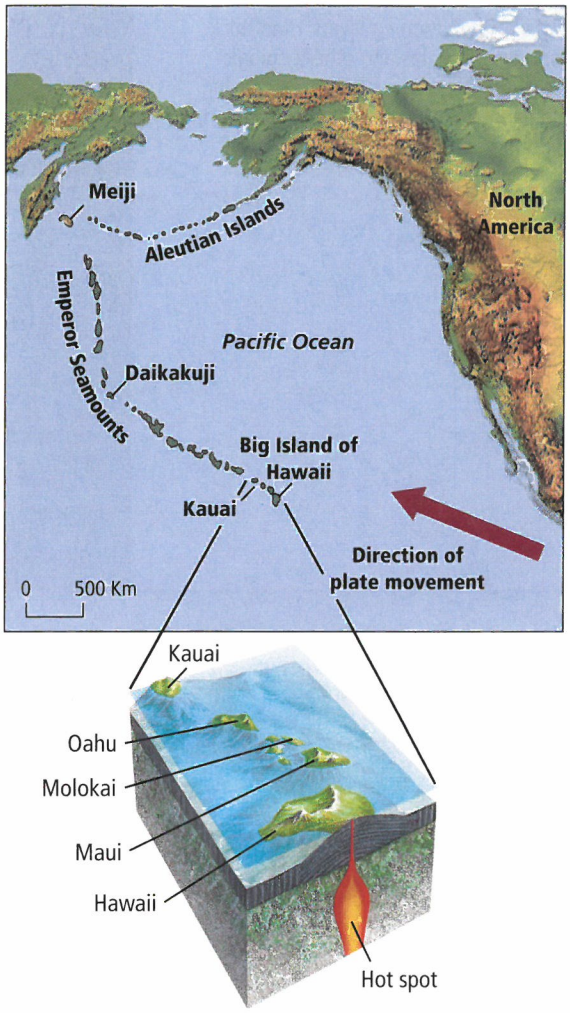


Figure 18.5 The Hawaiian islands have been forming for millions of years as the Pacific Plate moves slowly over a stationary hot spot that is currently located under the Big Island of Hawaii.

1980 In Washington, Mount St. Helens' eruption blasts through the side of the volcano. Most of the 57 fatalities are from ash inhalation.

1991 Mount Pinatubo erupts in the Philippines, releasing 10 km^3 of ash, reducing global temperatures by 0.5°C.

1800 — 1900 — 2000

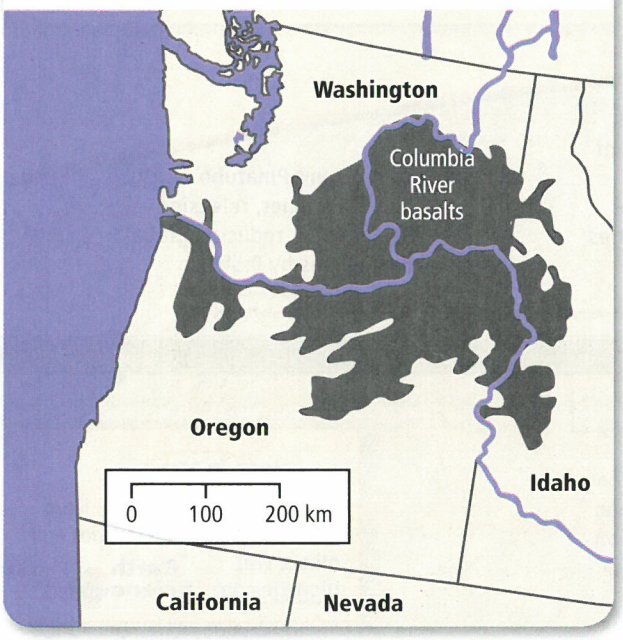
1883 In Indonesia, Krakatoa erupts, destroying two-thirds of the island and generating a tsunami that kills more than 36,000 people.

1912 Katmai erupts in Alaska with ten times more force than Mount St. Helens. This eruption is one of the most powerful in recorded history.

Concepts In Motion
Interactive Time Line To learn more about these discoveries and others, visit glencoe.com. Earth Science Online

Figure 18.6 Huge amounts of lava erupting from fissures accumulate on the surface, often forming layers 1 km thick. Over time, streams and other geologic forces erode the layers of basalt, leaving plateaus like this one in Palouse Canyon, Washington.

Figure 18.7 More than 17 mya, enormous amounts of lava poured out of large fissures, producing a basaltic plateau more than 1 km thick in the northwestern part of the United States.



Flood basalts When hot spots occur beneath continental crust, they can lead to the formation of flood basalts. **Flood basalts** form when lava flows out of long cracks in Earth's crust. These cracks are called **fissures.** Over hundreds or even thousands of years, these fissure eruptions can form flat plains called plateaus, as shown in **Figure 18.6.** As in other eruptions, when the lava flows across Earth's surface, water vapor and other gases escape.

Columbia River Basalts The volume of basalt erupted by fissure eruptions can be tremendous. For example, the Columbia River basalts, located in the northwestern United States and shown on the map in **Figure 18.7,** contain 170,000 km^3 of basalt. This volume of basalt could fill Lake Superior, the largest of the Great Lakes, 15 times. However, the Columbia River Basalts are small in comparison to the Deccan Traps.

Deccan Traps About 65 mya in India, a huge flood basalt eruption created an enormous plateau called the Deccan Traps. The volume of basalt in the Deccan Traps is estimated to be about 512,000 km^3. That volume would cover the island of Manhattan with a layer 10,000 km thick, or the entire state of New York with a layer 4 km thick. Some geologists hypothesize that the eruption of the Deccan Traps caused a global change in climate that might have influenced the extinction of the dinosaurs.

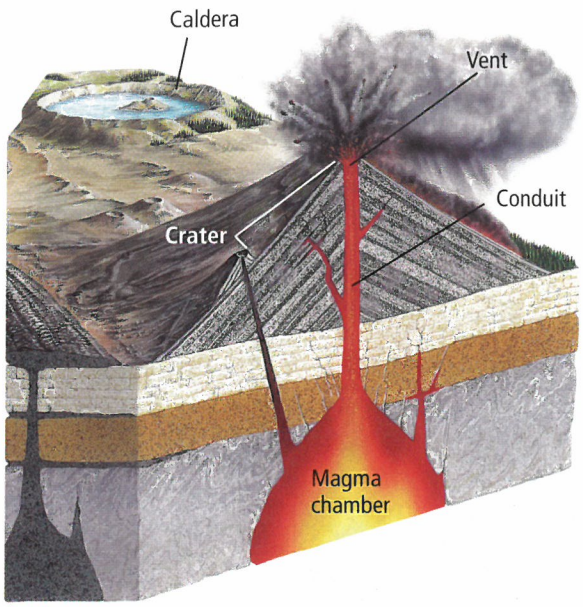


Figure 18.8 Magma moves upward from deep within Earth through a conduit and erupts at Earth's surface through a vent. The area around the vent is called a crater. A caldera can form when the crust collapses into an empty magma chamber.

Concepts In Motion **Interactive Figure** To see an animation of caldera formation, visit glencoe.com.

Anatomy of a Volcano

As you read in Chapter 5, when magma reaches Earth's surface it is called lava. Lava reaches the surface by traveling through a tubelike structure called a **conduit,** and emerges through an opening called a **vent.** As lava flows through the vent and out onto the surface, it cools and solidifies around the vent. Over time, layers of solidified lava can accumulate to form a mountain known as a volcano. At the top of a volcano, around the vent, is a bowl-shaped depression called a **crater.** The crater is connected to the magma chamber by the conduit. Locate the crater, conduit, and vent of the volcano shown in **Figure 18.8.**

Volcanic craters are usually less than 1 km in diameter. Larger depressions, called **calderas,** can be up to 50 km in diameter. Calderas often form after the magma chamber beneath a volcano empties from a major eruption. The summit or the side of a volcano collapses into the emptied magma chamber, leaving an expansive, circular depression. After the surface material collapses, water sometimes fills the caldera, forming scenic lakes. The caldera known as Crater Lake in southern Oregon formed when Mount Mazama collapsed.

MiniLab

Model a Caldera

How do calderas form? Calderas are volcanic craters that form when the summit or the side of a volcano collapses into the magma chamber that once fueled the volcano.

Procedure

1. Read and complete the lab safety form.
2. Obtain a **small box,** a **10-cm length of rubber tubing,** a **clamp,** and a **balloon** from your teacher.
3. Line the box with **newspaper** and make a small hole in the box and the newspaper with **scissors.**
4. Thread the neck of the balloon through the hole, insert the rubber tubing into the neck, securing it with **tape,** inflate the balloon by blowing through the tubing, and use the clamp to close the tubing.
5. Pour six cups of **sand** over the balloon.
6. Sculpt the sand into the shape of a volcano. You might need to vary the amount of sand and type of box to reach the desired effect.
7. Remove the clamp, releasing the air from the balloon. Observe your caldera forming, and record your observations
8. Compare your caldera to your classmates'.

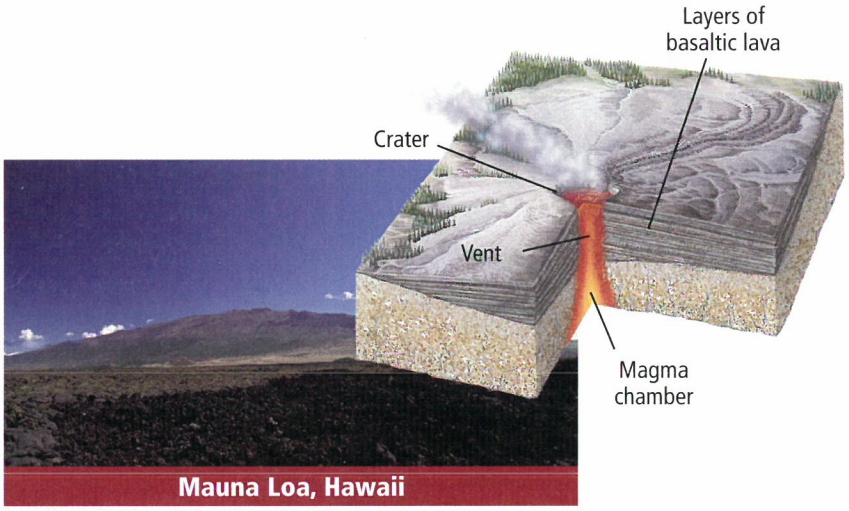
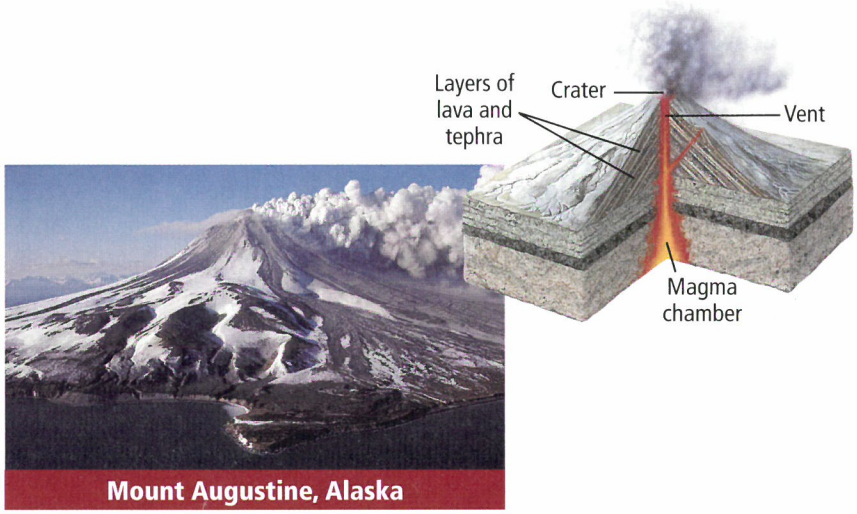
Analysis

1. **Sequence** the formation of the caldera.
2. **Compare** the features of a caldera with those of a crater.
3. **Infer** how the caldera will form if you vary how much you inflate the balloon.

Table 18.1 Types of Volcanoes

Concepts In Motion

Interactive Table To explore more about types of volcanoes, visit glencoe.com.

Description	Example of Volcanoes
Shield Volcanoes • Largest of the three types of volcanoes • Long, gentle slopes • Composed of layers of solidified basaltic lava • Quiet eruptions	 **Mauna Loa, Hawaii**
Cinder Cones • Smallest of the three types of volcanoes • Steep-sloped, cone-shaped • Usually composed of basaltic lava • Explosive eruptions • Usually form at edges of larger volcanoes	 **Lassen Volcanic Park, California**
Composite Volcanoes • Considerably larger than cinder cones • Tall, majestic mountains • Composed of layers of rock from explosive eruptions and lava flows • Cycle through periods of quiet and explosive eruptions	 **Mount Augustine, Alaska**

Types of Volcanoes

The appearance of a volcano depends on two factors: the type of material that forms the volcano and the type of eruptions that occur. Based on these two criteria, three major types of volcanoes have been identified and are shown in **Table 18.1.** Each differs in size, shape, and composition.

Shield volcanoes A **shield volcano** is a mountain with broad, gently sloping sides and a nearly circular base. Shield volcanoes form when layers of lava accumulate during nonexplosive eruptions. They are the largest type of volcano. Mauna Loa, which is shown in **Table 18.1,** is a shield volcano.

Cinder cones When eruptions eject small pieces of magma into the air, **cinder cones** form as this material, called tephra, falls back to Earth and piles up around the vent. Cinder cones have steep sides and are generally small; most are less than 500 m high. The Lassen Volcanic Park cinder cone shown in **Table 18.1** is 700 m high. Cinder cones often form on or very near larger volcanoes.

Composite volcanoes **Composite volcanoes** are formed of layers of hardened chunks of lava from violent eruptions alternating with layers of lava that oozed downslope before solidifying. Composite volcanoes are generally cone-shaped with concave slopes, and are much larger than cinder cones. Because of their explosive nature, they are potentially dangerous to humans and the environment. Some examples of these are Mount Augustine in Alaska, shown in **Table 18.1,** and several in the Cascade Range of the western United States, such as Mount St. Helens.

CAREERS IN EARTH SCIENCE

Volcanologist Scientists who study eruptions, lava, magma, and the conditions under which these form are volcanologists. Some work in the field, studying active volcanoes. Many volcanologists also work in the laboratory to understand how rocks melt to form magma. To learn more about Earth science careers, visit glencoe.com.

FOLDABLES

Incorporate information from this section into your Foldable.

Section 18.1 Assessment

Section Summary

- Volcanism includes all the processes in which magma and gases rise to Earth's surface.
- Most volcanoes on land are part of two major volcanic chains: the Circum-Pacific Belt and the Mediterranean Belt.
- Parts of a volcano include a vent, magma chamber, crater, and caldera.
- Flood basalts form when lava flows from fissures to form flat plains or plateaus.
- There are three major types of volcanoes: shield, composite, and cinder cone.

Understand Main Ideas

1. MAIN Idea **Explain** how the location of volcanoes is related to the theory of plate tectonics.
2. **Identify** two volcanoes in the Mediterranean Belt.
3. **Draw** a volcano, labeling the parts.
4. **Propose** Yellowstone National Park is an area of previous volcanism. Using a map of the United States, suggest the type(s) of tectonic processes associated with this area.

Think Critically

5. **Evaluate** the following statement: Volcanoes are only found along coastlines.
6. **Decide** whether a flood basalt is or is not a volcano.

MATH in Earth Science

7. If the Pacific Plate has moved 500 km in the last 4.7 million years, calculate its average velocity in centimeters per year. Refer to the *Skillbuilder Handbook* for more information.