

HS Volcanoes

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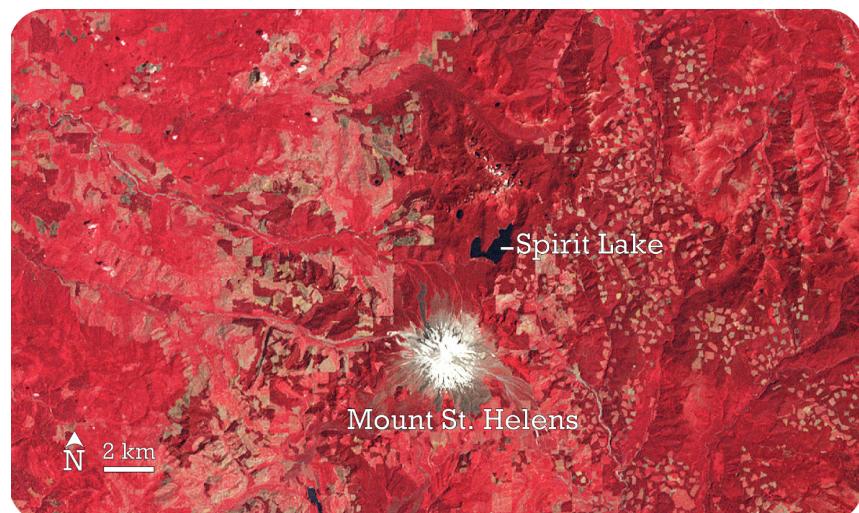
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CHAPTER

1**HS Volcanoes****CHAPTER OUTLINE**

- 1.1 Where Volcanoes Are Located
- 1.2 Volcanic Eruptions
- 1.3 Types of Volcanoes
- 1.4 Volcanic Landforms and Geothermal Activity
- 1.5 References



Above are two false-color Landsat satellite images of Mount St. Helens and vicinity. The first image is from August 29, 1979. Just months later, in March 1980, the ground began to shake. Red indicates vegetation; patches of lighter color are where the region was logged.

The second image is from September 24, 1980, four months after the large eruption on May 18. The relics of the eruption are everywhere. The mountain's northern flank has collapsed, leaving a horseshoe shaped crater. Rock and ash have blown over 230 square miles. Dead trees are floating in Spirit Lake and volcanic mudflows clog the rivers. A more recent image shows that vegetation has begun to colonize at the farther reaches of the area affected by the eruption.

1.1 Where Volcanoes Are Located

Lesson Objectives

- Describe how the locations of volcanoes are related to plate tectonics.
- Suggest why volcanoes are found at convergent and divergent plate boundaries.
- Describe how intraplate volcanoes can form.

Vocabulary

- fissure

Introduction

Volcanoes are a vibrant manifestation of plate tectonics processes. Volcanoes are common along convergent and divergent plate boundaries. Volcanoes are also found within lithospheric plates away from plate boundaries. Wherever mantle is able to melt, volcanoes may be the result.

See if you can give a geological explanation for the locations of all the volcanoes in [Figure 1.1](#). What is the Pacific Ring of Fire? Why are the Hawaiian volcanoes located away from any plate boundaries? What is the cause of the volcanoes along the mid-Atlantic ridge?

Volcanoes erupt because mantle rock melts. This is the first stage in creating a volcano. Remember from the chapter “Rocks” that mantle may melt if temperature rises, pressure lowers, or water is added. Be sure to think about how melting occurs in each of the following volcanic settings.

Convergent Plate Boundaries

Why does melting occur at convergent plate boundaries? The subducting plate heats up as it sinks into the mantle. Also, water is mixed in with the sediments lying on top of the subducting plate. This water lowers the melting point of the mantle material, which increases melting. Volcanoes at convergent plate boundaries are found all along the Pacific Ocean basin, primarily at the edges of the Pacific, Cocos, and Nazca plates. Trenches mark subduction zones, although only the Aleutian Trench and the Java Trench appear on the map above ([Figure 1.1](#)).

Remember your plate tectonics knowledge. Large earthquakes are extremely common along convergent plate boundaries. Since the Pacific Ocean is rimmed by convergent and transform boundaries, about 80% of all earthquakes strike around the Pacific Ocean basin ([Figure 1.2](#)). Why are 75% of the world’s volcanoes found around the Pacific basin? Of course, these volcanoes are caused by the abundance of convergent plate boundaries around the Pacific.

A description of the Pacific Ring of Fire along western North America is a description of the plate boundaries.

- Subduction at the Middle American Trench creates volcanoes in Central America.
- The San Andreas Fault is a transform boundary.
- Subduction of the Juan de Fuca plate beneath the North American plate creates the Cascade volcanoes.
- Subduction of the Pacific plate beneath the North American plate in the north creates the Aleutian Islands volcanoes.

Active Volcanoes, Plate Tectonics, and the “Ring of Fire”



FIGURE 1.1

World map of active volcanoes.

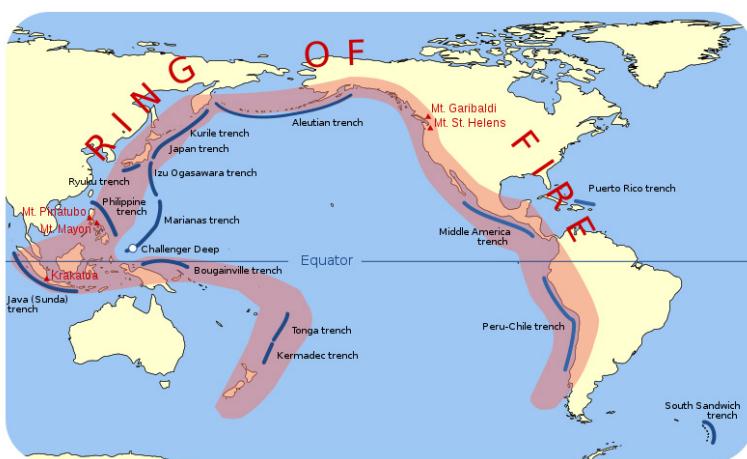


FIGURE 1.2

The Pacific Ring of Fire is where the majority of the volcanic activity on the Earth occurs.

The Cascades are shown on this interactive map with photos and descriptions of each of the volcanoes: http://www.iris.edu/hq/files/programs/education_and_outreach/aotm/interactive/6.Volcanoes4Rollover.swf.

This incredible explosive eruption of Mount Vesuvius in Italy in A.D. 79 is an example of a composite volcano that forms as the result of a convergent plate boundary (3f): <http://www.youtube.com/watch?v=1u1Ys4m5zY4&featu>

re=related (1:53).



MEDIA

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Divergent plate boundaries

Why does melting occur at divergent plate boundaries? Hot mantle rock rises where the plates are moving apart. This releases pressure on the mantle, which lowers its melting temperature. Lava erupts through long cracks in the ground, or **fissures**.

Footage of Undersea Volcanic Eruptions is seen in National Geographic Videos, Environment Video, Habitat, Ocean section: <http://video.nationalgeographic.com/video/player/environment/>.

- Fantastic footage of undersea volcanic eruption is in the “Deepest Ocean Eruption Ever Filmed.”
- “Giant Undersea Volcano Revealed” explores a volcano and its life off of Indonesia.

Volcanoes erupt at mid-ocean ridges, such as the Mid-Atlantic ridge, where seafloor spreading creates new seafloor in the rift valleys. Where a hotspot is located along the ridge, such as at Iceland, volcanoes grow high enough to create islands (**Figure 1.3**).



FIGURE 1.3

A volcanic eruption at Surtsey, a small island near Iceland.

Eruptions are found at divergent plate boundaries as continents break apart. The volcanoes in **Figure 1.4** are in the East African Rift between the African and Arabian plates.

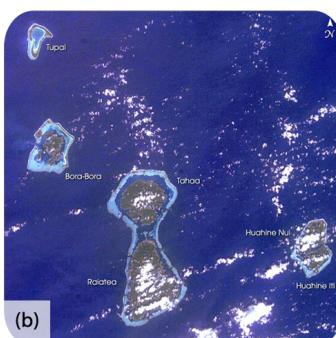
Volcanic Hotspots

Although most volcanoes are found at convergent or divergent plate boundaries, intraplate volcanoes are found in the middle of a tectonic plate. Why is there melting at these locations? The Hawaiian Islands are the exposed peaks of a great chain of volcanoes that lie on the Pacific plate. These islands are in the middle of the Pacific plate. The

**FIGURE 1.4**

Mount Gahinga and Mount Muhabura in the East African Rift valley.

youngest island sits directly above a column of hot rock called a mantle plume. As the plume rises through the mantle, pressure is released and mantle melts to create a hotspot (**Figure 1.5**).

**FIGURE 1.5**

(a) The Society Islands formed above a hotspot that is now beneath Mehetia and two submarine volcanoes. (b) The satellite image shows how the islands become smaller and coral reefs became more developed as the volcanoes move off the hotspot and grow older.

Earth is home to about 50 known hot spots. Most of these are in the oceans because they are better able to penetrate oceanic lithosphere to create volcanoes. The hotspots that are known beneath continents are extremely large, such as Yellowstone (**Figure 1.6**).

A hot spot beneath Hawaii, the origin of the voluminous lava produced by the shield volcano Kilauea can be viewed here(3f): <http://www.youtube.com/watch?v=byJp5o49IF4&feature=related> (2:06).

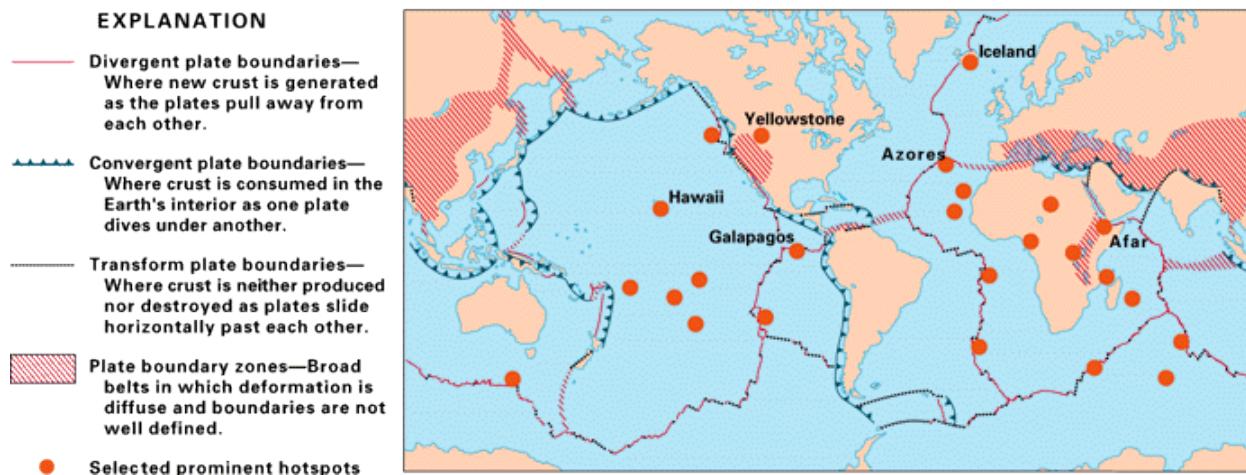
**MEDIA**

Click image to the left for more content.

How would you be able to tell hotspot volcanoes from island arc volcanoes? At island arcs, the volcanoes are all about the same age. By contrast, at hotspots the volcanoes are youngest at one end of the chain and oldest at the other.

Lesson Summary

- Most volcanoes are found along convergent or divergent plate boundaries.
- The Pacific Ring of Fire is the most geologically active region in the world.

**FIGURE 1.6**

Prominent hotspots of the world.

- Volcanoes such as those that form the islands of Hawaii form over hotspots, which are melting zones above mantle plumes.

Review Questions

1. Why are there volcanoes along the west coast of the United States?
2. Why does melting occur at divergent plate boundaries?
3. In **Figure 1.1**, explain the geologic reason for every group of volcanoes in the diagram.
4. How did the Pacific Ring of Fire get its name? Does it deserve it?
5. What is a mantle plume?
6. Suppose a new volcano suddenly formed in the middle of the United States. How might you explain what caused this volcano?

Points to Consider

- Some volcanoes are no longer active. What could cause a volcano to become extinct?
- Hot spots are still poorly understood by Earth scientists. Why do you think it's hard to understand hotspots? What clues are there regarding these geological phenomena?
- Volcanoes have been found on Venus, Mars, and even Jupiter's moon Io. What do you think this indicates to planetary geologists?

1.2 Volcanic Eruptions

Lesson Objectives

- Explain how magma composition affects the type of eruption.
- Compare the types of volcanic eruptions.
- Distinguish between different types of lava and the rocks they form.
- Describe a method for predicting volcanic eruptions.

Vocabulary

- active volcano
- dormant volcano
- effusive eruption
- eruption
- explosive eruption
- extinct volcano
- lahar
- magma chamber
- pyroclastic flow
- tephra
- viscosity

Introduction

In 1980, Mount St. Helens blew up in the costliest and deadliest volcanic eruption in United States history. The eruption killed 57 people, destroyed 250 homes and swept away 47 bridges (**Figure 1.7**).



FIGURE 1.7

Mount St. Helens on May 18, 1980.

Mt. St. Helens still has minor earthquakes and eruptions. The volcano now has a horseshoe-shaped crater with a lava dome inside. The dome is formed of viscous lava that oozes into place.

Magma Composition

Volcanoes do not always erupt in the same way. Each volcanic **eruption** is unique, differing in size, style, and composition of erupted material. One key to what makes the eruption unique is the chemical composition of the magma that feeds a volcano, which determines (1) the eruption style, (2) the type of volcanic cone that forms, and (3) the composition of rocks that are found at the volcano.

Remember from the Rocks chapter that different minerals within a rock melt at different temperatures. The amount of partial melting and the composition of the original rock determine the composition of the magma. Magma collects in **magma chambers** in the crust at 160 kilometers (100 miles) beneath the surface.

The words that describe composition of igneous rocks also describe magma composition.

- Mafic magmas are low in silica and contain more dark, magnesium and iron rich mafic minerals, such as olivine and pyroxene.
- Felsic magmas are higher in silica and contain lighter colored minerals such as quartz and orthoclase feldspar. The higher the amount of silica in the magma, the higher is its **viscosity**. Viscosity is a liquid's resistance to flow (**Figure 1.8**).



FIGURE 1.8

Honey flows slowly. It is more viscous than water.

Viscosity determines what the magma will do. Mafic magma is not viscous and will flow easily to the surface. Felsic magma is viscous and does not flow easily. Most felsic magma will stay deeper in the crust and will cool to form igneous intrusive rocks such as granite and granodiorite. If felsic magma rises into a magma chamber, it may be too viscous to move and so it gets stuck. Dissolved gases become trapped by thick magma. The magma churns in the chamber and the pressure builds.

Eruptions

The type of magma in the chamber determines the type of volcanic eruption. Although the two major kinds of eruptions – explosive and effusive - are described in this section, there is an entire continuum of eruption types. Which magma composition do you think leads to each type?

Explosive Eruptions

A large **explosive eruption** creates even more devastation than the force of the atom bomb dropped on Nagasaki at the end of World War II in which more than 40,000 people died. A large explosive volcanic eruption is 10,000 times as powerful. Felsic magmas erupt explosively. Hot, gas-rich magma churns within the chamber. The pressure becomes so great that the magma eventually breaks the seal and explodes, just like when a cork is released from a bottle of champagne. Magma, rock, and ash burst upward in an enormous explosion. The erupted material is called **tephra** (**Figure 1.9**).



FIGURE 1.9

Ash and gases create a mushroom cloud above Mt. Redoubt in Alaska, 1989. The cloud reached 45,000 feet and caught a Boeing 747 in its plume.

Scorching hot tephra, ash, and gas may speed down the volcano's slopes at 700 km/h (450 mph) as a **pyroclastic flow**. Pyroclastic flows knock down everything in their path. The temperature inside a pyroclastic flow may be as high as $1,000^{\circ}\text{C}$ ($1,800^{\circ}\text{F}$) (**Figure 1.10**).



FIGURE 1.10

(a) An explosive eruption from the Mayon Volcano in the Philippines in 1984. Ash flies upward into the sky and pyroclastic flows pour down the mountainside. (b) The end of a pyroclastic flow at Mount St. Helens.

A pyroclastic flow at Montserrat volcano is seen in this video: <http://faculty.gg.uwyo.edu/heller/SedMovs/Sed%20Movie%20files/PyroclasticFlow.MOV>.

Prior to the Mount St. Helens eruption in 1980, the Lassen Peak eruption on May 22, 1915, was the most recent Cascades eruption. A column of ash and gas shot 30,000 feet into the air. This triggered a high-speed pyroclastic flow, which melted snow and created a volcanic mudflow known as a **lahar**. Lassen Peak currently has geothermal activity and could erupt explosively again. Mt. Shasta, the other active volcano in California, erupts every 600 to 800 years. An eruption would most likely create a large pyroclastic flow, and probably a lahar. Of course, Mt. Shasta could explode and collapse like Mt. Mazama in Oregon (**Figure 1.11**).

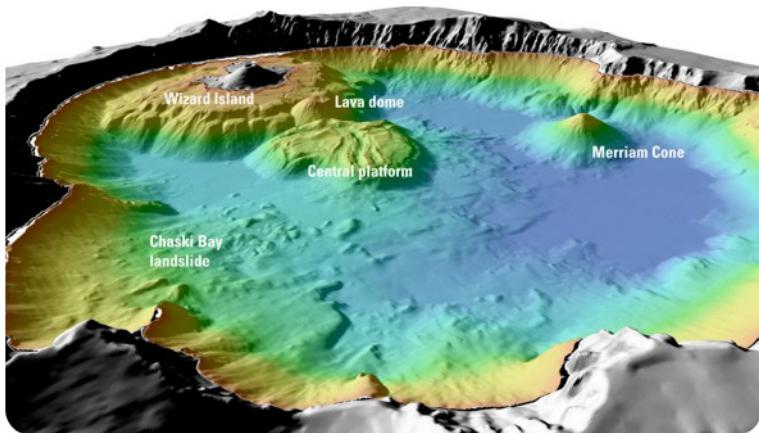


FIGURE 1.11

Crater Lake fills the caldera of the collapsed Mt. Mazama, which erupted with 42 times more power than Mount St. Helens in 1980. The bathymetry of the lake shows volcanic features such as cinder cones.

Volcanic gases can form poisonous and invisible clouds in the atmosphere. These gases may contribute to environmental problems such as acid rain and ozone destruction. Particles of dust and ash may stay in the atmosphere for years, disrupting weather patterns and blocking sunlight (**Figure 1.12**).

Effusive Eruptions

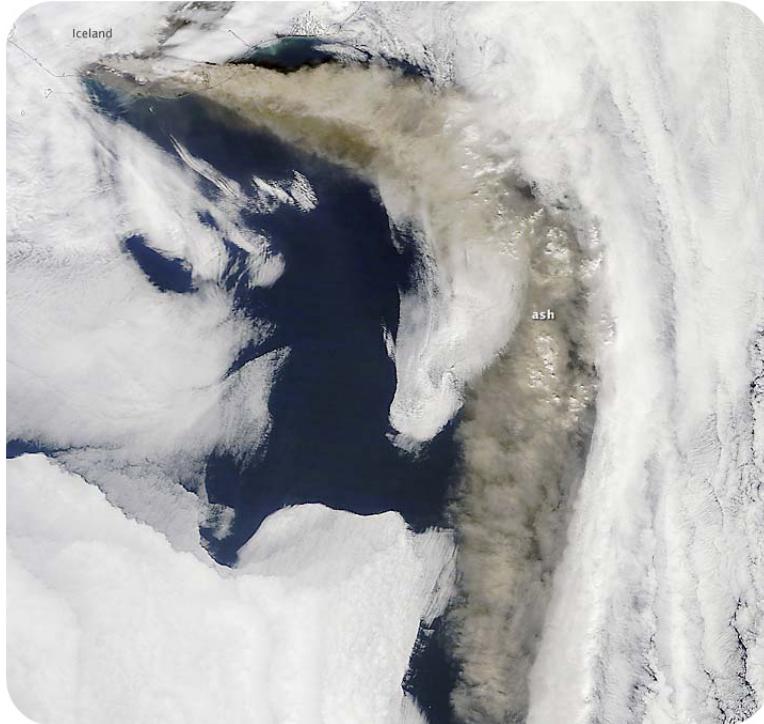
Mafic magma creates gentler **effusive eruptions**. Although the pressure builds enough for the magma to erupt, it does not erupt with the same explosive force as felsic magma. People can usually be evacuated before an effusive eruption, so they are much less deadly. Magma pushes toward the surface through fissures. Eventually, the magma reaches the surface and erupts through a vent (**Figure 1.13**).

- The Kilauea volcanic eruption in 2008 is seen in this short video: <http://www.youtube.com/watch?v=BtH79yxBIJi>.
- A Quicktime movie with thermal camera of a lava stream within the vent of a Hawaiian volcano is seen here: http://hvo.wr.usgs.gov/kilauea/update/archive/2009/Nov/OverflightFLIR_13Jan2010.mov.

Low-viscosity lava flows down mountainsides. Differences in composition and where the lavas erupt result in three types of lava flow coming from effusive eruptions (**Figure 1.14**).

- Undersea eruption videos are seen here <http://news.discovery.com/videos/earth-undersea-eruption-now-in-stereo.html> and here <http://news.discovery.com/videos/earth-underwater-volcano-caught-on-video.html>

Although effusive eruptions rarely kill anyone, they can be destructive. Even when people know that a lava flow is approaching, there is not much anyone can do to stop it from destroying a building or road (**Figure 1.15**).

**FIGURE 1.12**

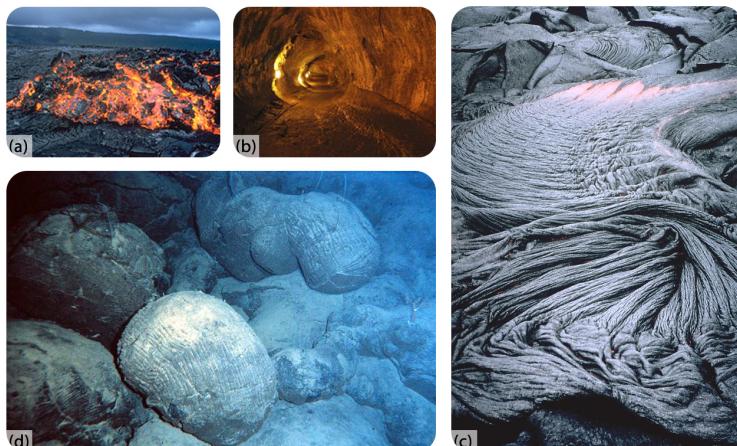
The ash plume from Eyjafjallajökull

**FIGURE 1.13**

In effusive eruptions, lava flows readily, producing rivers of molten rock.

Predicting Volcanic Eruptions

Volcanologists attempt to forecast volcanic eruptions, but this has proven to be nearly as difficult as predicting an earthquake. Many pieces of evidence can mean that a volcano is about to erupt, but the time and magnitude of the eruption are difficult to pin down. This evidence includes the history of previous volcanic activity, earthquakes, slope deformation, and gas emissions.

**FIGURE 1.14**

(a) A

**FIGURE 1.15**

A road is overrun by an eruption at Kilauea volcano in Hawaii.

History of Volcanic Activity

A volcano's history – how long since its last eruption and the time span between its previous eruptions – is a good first step to predicting eruptions. Which of these categories does the volcano fit into?

- **Active:** currently erupting or showing signs of erupting soon.
- **Dormant:** no current activity, but has erupted recently ([Figure 1.16](#)).
- **Extinct:** no activity for some time; will probably not erupt again.

Active and dormant volcanoes are heavily monitored, especially in populated areas.

Earthquakes

Moving magma shakes the ground, so the number and size of earthquakes increases before an eruption. A volcano that is about to erupt may produce a sequence of earthquakes. Scientists use seismographs that record the length and strength of each earthquake to try to determine if an eruption is imminent.

**FIGURE 1.16**

Mount Vesuvius destroyed Pompeii in 79 AD. Fortunately this volcano is dormant because the region is now much more heavily populated.

Slope Deformation

Magma and gas can push the volcano's slope upward. Most ground deformation is subtle and can only be detected by tiltmeters, which are instruments that measure the angle of the slope of a volcano. But ground swelling may sometimes create huge changes in the shape of a volcano. Mount St. Helens grew a bulge on its north side before its 1980 eruption. Ground swelling may also increase rock falls and landslides.

Gas Emissions

Gases may be able to escape a volcano before magma reaches the surface. Scientists measure gas emissions in vents on or around the volcano. Gases, such as sulfur dioxide (SO_2), carbon dioxide (CO_2), hydrochloric acid (HCl), and even water vapor can be measured at the site (Figure 1.17) or, in some cases, from a distance using satellites. The amounts of gases and their ratios are calculated to help predict eruptions.

**FIGURE 1.17**

Scientists monitoring gas emissions at Mount St. Helens.

Remote Monitoring

Some gases can be monitored using satellite technology (**Figure 1.18**). Satellites also monitor temperature readings and deformation. As technology improves, scientists are better able to detect changes in a volcano accurately and safely.



FIGURE 1.18

An Earth-Observation Satellite before launch.

Since volcanologists are usually uncertain about an eruption, officials may not know whether to require an evacuation. If people are evacuated and the eruption doesn't happen, the people will be displeased and less likely to evacuate the next time there is a threat of an eruption. The costs of disrupting business are great. However, scientists continue to work to improve the accuracy of their predictions.

Lesson Summary

- The style of a volcanic eruption depends on magma viscosity.
- Felsic magmas produce explosive eruptions. Mafic magmas produce effusive eruptions.
- Explosive eruptions happen along the edges of continents and produce tremendous amounts of material ejected into the air.
- Non-explosive eruptions produce lavas, such as a'a, pahoehoe, and pillow lavas.
- Volcanoes are classified as active, dormant, or extinct.
- Signs that a volcano may soon erupt include earthquakes, surface bulging, and gases emitted, as well as other changes that can be monitored by scientists.

Review Questions

1. What are the two basic types of volcanic eruptions?

2. Several hundred years ago, a volcano erupted near the city of Pompeii, Italy (**Figure 1.19**). Archaeologists have found the remains of people embracing each other, suffocated by ash and rock that covered everything. What type of eruption must have this been?



FIGURE 1.19

Pompeii the last day.

3. What is pyroclastic material?
4. Name three substances that have low viscosity and three that have high viscosity.
5. Why might the addition of water make an eruption more explosive?
6. What are three names for non-explosive lava?
7. What factors are considered in predicting volcanic eruptions?
8. Why is predicting a volcanic eruption so important?
9. Given that astronomers are far away from the planets they study, what evidence might they look for to determine the composition of a planet on which a volcano is found?

Further Reading / Supplemental Links

- The top five volcano web cams and video: <http://news.discovery.com/videos/earth-top-5-volcano-webcams-and-videos.html>

Points to Consider

- What would you look for to determine if an old eruption was explosive or non-explosive?
- Given the different styles of eruptions discussed above, what do you think the shapes of volcanoes are?
- Where do you think the names a'a and pāhoehoe came from?
- Do earthquakes always indicate an imminent eruption? What factors about an earthquake might indicate a relationship to a volcanic eruption?

1.3 Types of Volcanoes

Lesson Objectives

- Describe the basic shapes of volcanoes.
- Compare the features of volcanoes.
- Describe the stages in the formation of volcanoes.

Vocabulary

- caldera
- cinder cone
- composite volcano
- shield volcano
- supervolcano

Introduction

A volcano is a vent through which molten rock and gas escape from a magma chamber. Volcanoes differ in many features such as height, shape, and slope steepness. Some volcanoes are tall cones and others are just cracks in the ground ([Figure 1.20](#)). As you might expect, the shape of a volcano is related to the composition of its magma.



FIGURE 1.20

Mount St. Helens was a beautiful, classic, cone-shaped volcano. The volcano

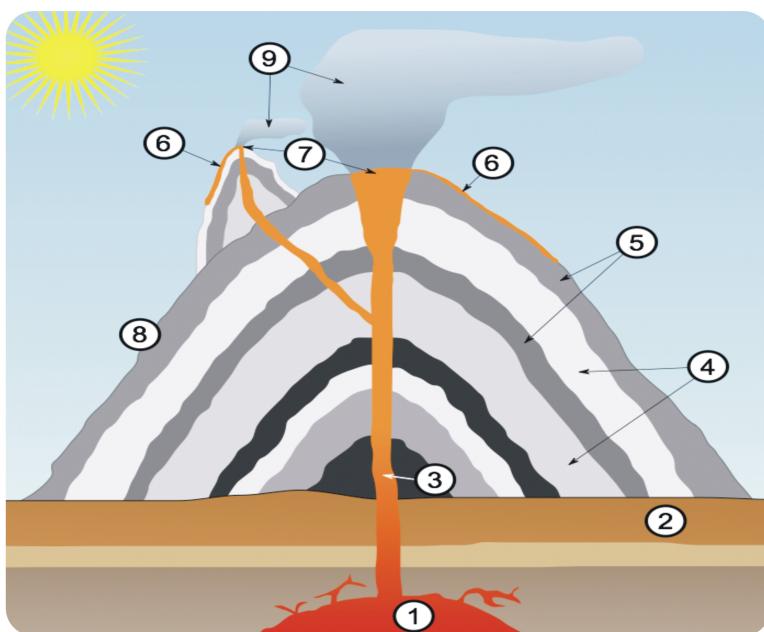
Composite Volcanoes

Composite volcanoes are made of felsic to intermediate rock. The viscosity of the lava means that eruptions at these volcanoes are often explosive ([Figure 1.21](#)).

The viscous lava cannot travel far down the sides of the volcano before it solidifies, which creates the steep slopes of a composite volcano. Viscosity also causes some eruptions to explode as ash and small rocks. The volcano is constructed layer by layer, as ash and lava solidify, one upon the other ([Figure 1.22](#)). The result is the classic cone shape of composite volcanoes.

**FIGURE 1.21**

Mt. Fuji, the highest mountain in Japan, is a dormant composite volcano.

**FIGURE 1.22**

A cross section of a composite volcano reveals alternating layers of rock and ash: (1) magma chamber, (2) bedrock, (3) pipe, (4) ash layers, (5) lava layers, (6) lava flow, (7) vent, (8) lava, (9) ash cloud. Frequently there is a large crater at the top from the last eruption.

Shield Volcanoes

Shield volcanoes get their name from their shape. Although shield volcanoes are not steep, they may be very large. Shield volcanoes are common at spreading centers or intraplate hot spots ([Figure 1.23](#)).

The lava that creates shield volcanoes is fluid and flows easily. The spreading lava creates the shield shape. Shield volcanoes are built by many layers over time and the layers are usually of very similar composition. The low viscosity also means that shield eruptions are non-explosive.

This *Volcanoes 101* video from National Geographic discusses where volcanoes are found and what their properties come from ([3e](#)): http://www.youtube.com/watch?feature=player_profilepage&v=uZp1dNybgfc (3:05).

**FIGURE 1.23**

Mauna Loa Volcano in Hawaii is the largest shield volcano on Earth with a diameter of more than 112 kilometers (70 miles). The volcano forms a significant part of the island of Hawaii.

**MEDIA**

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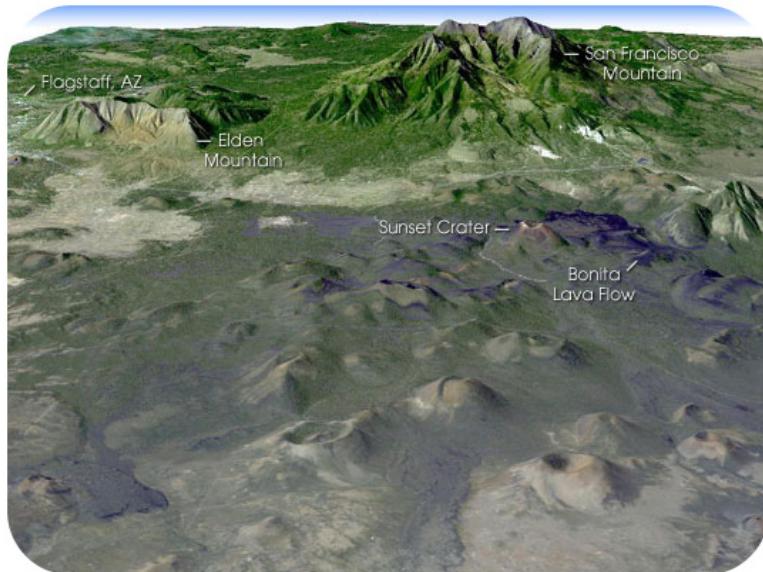
Cinder Cones

Cinder cones are the most common type of volcano. A cinder cone has a cone shape, but is much smaller than a composite volcano. Cinder cones rarely reach 300 meters in height but they have steep sides. Cinder cones grow rapidly, usually from a single eruption cycle ([Figure 1.24](#)). Cinder cones are composed of small fragments of rock, such as pumice, piled on top of one another. The rock shoots up in the air and doesn't fall far from the vent. The exact composition of a cinder cone depends on the composition of the lava ejected from the volcano. Cinder cones usually have a crater at the summit.

**FIGURE 1.24**

In 1943, a Mexican farmer first witnessed a cinder cone erupting in his field. In a year, Paricut

Cinder cones are often found near larger volcanoes ([Figure 1.25](#)).

**FIGURE 1.25**

This Landsat image shows the topography of San Francisco Mountain, an extinct volcano, with many cinder cones near it in northern Arizona. Sunset crater is a cinder cone that erupted about 1,000 years ago.

Supervolcanoes

Supervolcano eruptions are extremely rare in Earth history. It's a good thing because they are unimaginably large. A supervolcano must erupt more than 1,000 cubic km (240 cubic miles) of material, compared with 1.2 km³ for Mount St. Helens or 25 km³ for Mount Pinatubo, a large eruption in the Philippines in 1991. Not surprisingly, supervolcanoes are the most dangerous type of volcano.

Supervolcanoes are a fairly new idea in volcanology. The exact cause of supervolcano eruptions is still debated. However, scientists think that a very large magma chamber erupts entirely in one catastrophic explosion. This creates a huge hole or **caldera** into which the surface collapses (**Figure 1.26**).

The largest supervolcano in North America is beneath Yellowstone National Park in Wyoming. Yellowstone sits above a hotspot that has erupted catastrophically three times: 2.1 million, 1.3 million, and 640,000 years ago. Yellowstone has produced many smaller (but still enormous) eruptions more recently (**Figure 1.27**). Fortunately, current activity at Yellowstone is limited to the region's famous geysers.

Long Valley Caldera, south of Mono Lake in California, is the second largest supervolcano in North America (**Figure 1.28**). Long Valley had an extremely hot and explosive rhyolite about 700,000 years ago. An earthquake swarm in 1980 alerted geologists to the possibility of a future eruption, but the quakes have since calmed down.

- An interactive image of the geological features of Long Valley Caldera is available here:

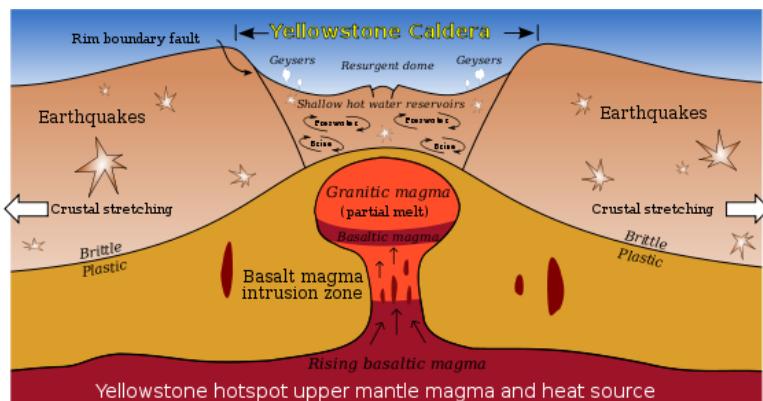
http://www.iris.edu/hq/files/programs/education_and_outreach/aotm/interactive/B&R_LongValleyCaldera.swf

A supervolcano could change life on Earth as we know it. Ash could block sunlight so much that photosynthesis would be reduced and global temperatures would plummet. Volcanic eruptions could have contributed to some of the mass extinctions in our planet's history. No one knows when the next super eruption will be.

Interesting volcano videos are seen on National Geographic Videos, Environment Video, Natural Disasters, Earthquakes: <http://video.nationalgeographic.com/video/player/environment/>. One interesting one is "Mammoth Mountain," which explores Hot Creek and the volcanic area it is a part of in California.

**FIGURE 1.26**

The caldera at Santorini in Greece is so large that it can only be seen by satellite.

**FIGURE 1.27**

The Yellowstone hotspot has produced enormous felsic eruptions. The Yellowstone caldera collapsed in the most recent super eruption.

Lesson Summary

- Composite, shield, cinder cones, and supervolcanoes are the main types of volcanoes.
- Composite volcanoes are tall, steep cones that produce explosive eruptions.
- Shield volcanoes form very large, gently sloped mounds from effusive eruptions.
- Cinder cones are the smallest volcanoes and result from accumulation of many small fragments of ejected material.
- An explosive eruption may create a caldera, a large hole into which the mountain collapses.
- Supervolcano eruptions are devastating but extremely rare in Earth history.

**FIGURE 1.28**

The hot water that gives Hot Creek, California, its name is heated by hot rock below Long Valley Caldera.

Review Questions

1. Rank, in order, the four types of volcanoes from smallest to largest in diameter.
2. What factor best determines what type of volcano will form in a given area?
3. Which type of volcano is most common?
4. Why do pahoehoe and a'a lava erupt from shield volcanoes? Why don't they erupt from composite volcanoes?
5. Why are cinder cones short-lived?
6. If supervolcanoes are so big, why did it take so long for scientists to discover them?

Points to Consider

- Composite volcanoes and volcanic cones usually have craters on the top. Why are the craters sometimes U- or horseshoe-shaped?
- Think about plate boundaries again. What type of volcanoes do you think are found at convergent, divergent, and transform boundaries? How about at intraplate sites?
- Some people have theorized that if a huge asteroid hits the Earth, the results would be catastrophic. How might an asteroid impact and a supervolcano eruption be similar?

1.4 Volcanic Landforms and Geothermal Activity

Lesson Objectives

- List and describe landforms created by lava.
- Explain how magma creates different landforms.
- Describe the processes that create hot springs and geysers.

Vocabulary

- geyser
- hot spring
- lava dome
- lava plateau

Introduction

Volcanoes are associated with many types of landforms. The landforms vary with the composition of the magma that created them. Hot springs and geysers are also examples of surface features related to volcanic activity.

Landforms from Lava

Volcanoes and Vents

The most obvious landforms created by lava are volcanoes, most commonly as cinder cones, composite volcanoes, and shield volcanoes. Eruptions also take place through fissures (Figure 1.29). The eruptions that created the entire ocean floor are essentially fissure eruptions.



FIGURE 1.29

A fissure eruption on Mauna Loa in Hawaii travels toward Mauna Kea on the Big Island.

Lava Domes

When lava is viscous, it flows slowly. If there is not enough magma or enough pressure to create an explosive eruption, the magma may form a **lava dome**. Because it is so thick, the lava does not travel far from the vent. ([Figure 1.30](#)).



FIGURE 1.30

Lava domes are large, round landforms created by thick lava that does not travel far from the vent.

Lava flows often make mounds right in the middle of craters at the top of volcanoes, as seen in the [Figure 1.31](#).



FIGURE 1.31

Lava domes may form in the crater of composite volcanoes as at Mount St. Helens

Lava Plateaus

A **lava plateau** forms when large amounts of fluid lava flows over an extensive area ([Figure 1.32](#)). When the lava solidifies, it creates a large, flat surface of igneous rock.

Land

Lava creates new land as it solidifies on the coast or emerges from beneath the water ([Figure 1.33](#)).

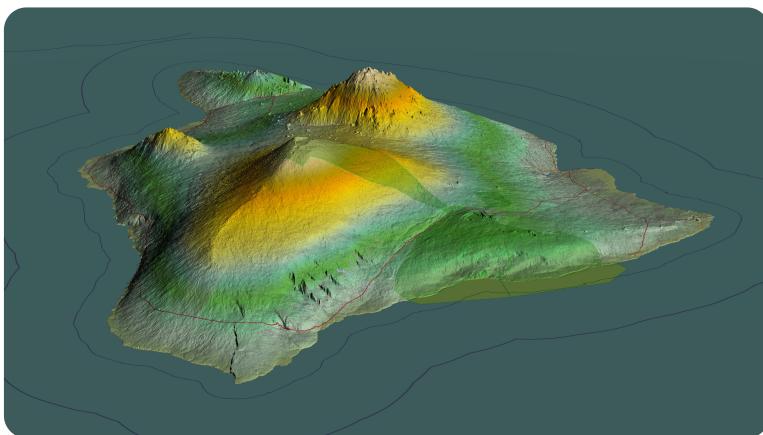
Over time the eruptions can create whole islands. The Hawaiian Islands are formed from shield volcano eruptions that have grown over the last 5 million years ([Figure 1.34](#)).

**FIGURE 1.32**

Layer upon layer of basalt have created the Columbia Plateau, which covers more than 161,000 square kilometers (63,000 square miles) in Washington, Oregon, and Idaho.

**FIGURE 1.33**

Lava flowing into the sea creates new land in Hawaii.

**FIGURE 1.34**

A 3-D computer generated view of the Big Island of Hawaii with its five volcanoes.

Landforms from Magma

Magma intrusions can create landforms. Shiprock in New Mexico is the neck of an old volcano that has eroded away ([Figure 1.35](#)).



FIGURE 1.35

The aptly named Shiprock in New Mexico.

Hot Springs and Geysers

Water sometimes comes into contact with hot rock. The water may emerge at the surface as either a hot spring or a geyser.

Hot Springs

Water heated below ground that rises through a crack to the surface creates a **hot spring** ([Figure 1.36](#)). The water in hot springs may reach temperatures in the hundreds of degrees Celsius beneath the surface, although most hot springs are much cooler.

Geysers

Geysers are also created by water that is heated beneath the Earth's surface, but geysers do not bubble to the surface – they erupt. When water is both superheated by magma and flows through a narrow passageway underground, the environment is ideal for a geyser. The passageway traps the heated water underground, so that heat and pressure can build. Eventually, the pressure grows so great that the superheated water bursts out onto the surface to create a geyser. [Figure 1.37](#).

Conditions are right for the formation of geysers in only a few places on Earth. Of the roughly 1,000 geysers worldwide and about half are found in the United States.

Lesson Summary

- Viscous lava can produce lava domes along a fissure or within a volcano.
- Lava plateaus form from large lava flows that spread out over large areas.

**FIGURE 1.36**

Even some animals enjoy relaxing in nature's hot tubs.

**FIGURE 1.37**

Castle Geyser is one of the many geysers at Yellowstone National Park. Castle erupts regularly, but not as frequently or predictably as Old Faithful.

- Many islands are built by or are volcanoes.
- Igneous intrusions associated with volcanoes may create volcanic landforms.
- When magma heats groundwater, it can reach the surface as hot springs or geysers.

Review Questions

1. What are four different landforms created by lava?
2. What is the major difference between hot springs and geysers?
3. The geyser called Old Faithful has been erupting for perhaps hundreds of years. One day, it could stop. Why might geysers completely stop erupting?
4. After earthquakes, hot springs sometimes stop bubbling, and new hot springs form. Why might this be?

Points to Consider

- What might the Earth look like if there were no tectonic plates? Are there any planets or satellites (moons) that may not have tectonic plates? How is their surface different from that of the Earth?
 - The largest volcano in the solar system is Olympus Mons on Mars. How could this volcano have formed?
 - What kind of land formations are the result of volcanic activity? Are all of these created by extrusive igneous rocks?
 - How are hydrothermal vents at mid-ocean ridges like the geysers of Yellowstone?
-
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