Section 18.3

Objectives

- **Compare and contrast** features formed from magma that solidifies near the surface with those that solidify deep underground
- **Classify** the different types of intrusive rock bodies.
- **Describe** how geologic processes result in intrusive rocks that appear at Earth's surface.

Review Vocabulary

igneous rock: rock formed by solidification of magma

New Vocabulary

pluton
batholith
stock
laccolith
sill
dike

Intrusive Activity

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

Real-World Reading Link Have you ever been surprised when the icing on the inside of a layer cake was a different color or flavor than the icing on the outside? You might also be surprised if you could look inside Earth's layers because much volcanism cannot be seen at Earth's surface.

Plutons

Most of Earth's volcanism happens below the surface because not all magma emerges at the surface. Before it gets to the surface, rising magma can interact with the crust in several ways, as illustrated in **Figure 18.16.** Magma can force the overlying rock apart and enter the newly formed fissures. Magma can also cause blocks of rock to break off and sink into the magma, where the rocks eventually melt. Finally, magma can melt its way through the rock into which it intrudes. What happens deep in Earth as magma slowly cools? Recall from Chapter 5 that when magma cools, minerals begin to crystallize.

Over a long period of time, minerals in the magma solidify, forming intrusive igneous rock bodies. Some of these rock bodies are ribbonlike features only a few centimeters thick and several hundred meters long. Others are massive, and range in volume from about 1 km^3 to hundreds of cubic kilometers. These intrusive igneous rock bodies, called **plutons** (PLOO tahns), can be exposed at Earth's surface as a result of uplift and erosion and are classified based on their size, shape, and relationship to surrounding rocks.

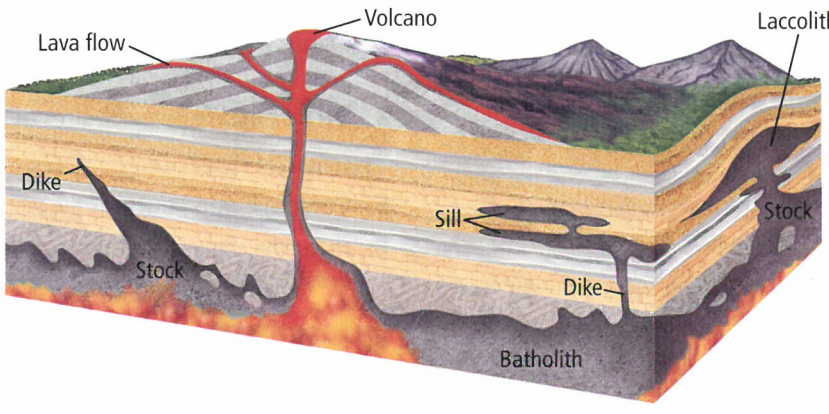


Figure 18.16 Magma moving upward solidifies and forms bodies of rock both at the surface and deep within Earth.

Batholiths and stocks The largest plutons are called batholiths. **Batholiths** (BATH uh lihths) are irregularly shaped masses of coarse-grained igneous rocks that cover at least 100 km^2 and take millions of years to form. Batholiths are common in the interior of major mountain chains.

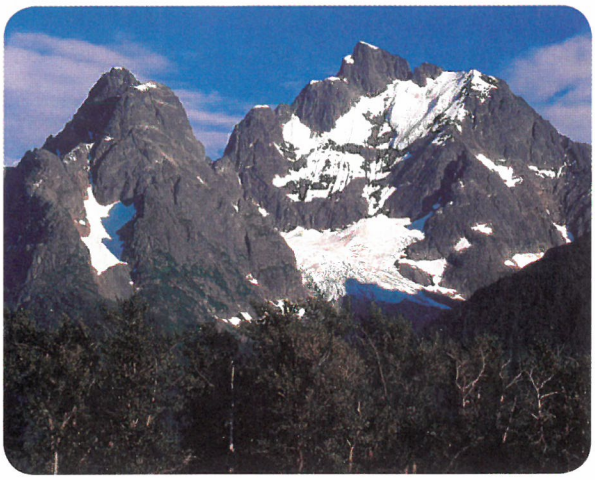
Many batholiths in North America are composed primarily of granite—the most common rock type found in plutons. However, gabbro and diorite, the intrusive equivalents of basalt and andesite, are also found in batholiths. The largest batholith in North America is the Coast Range Batholith in British Columbia, shown in **Figure 18.17;** it is more than 1500 km long. Irregularly shaped plutons that are similar to batholiths but smaller in size are called **stocks.** Both batholiths and stocks, shown in **Figure 18.16,** cut across older rocks and generally form 5 to 30 km beneath Earth's surface.

Laccoliths Sometimes when magma intrudes into parallel rock layers close to Earth's surface, some of the rocks bow upward as a result of the intense pressure of the magma body. When the magma solidifies, a laccolith forms, as shown in **Figure 18.16.** A **laccolith** (LA kuh lihth) is a lens-shaped pluton with a round top and flat bottom. Compared to batholiths and stocks, laccoliths are relatively small; at most, they are 16 km wide. **Figure 18.17** shows a laccolith in Red and White Mountain, Colorado. Laccoliths also exist in the Black Hills of South Dakota, and the Judith Mountains of Montana, among other places.

Reading Check **Contrast** What is the difference between a laccolith and a batholith?

Sills A **sill** forms when magma intrudes parallel to layers of rock, as shown in **Figure 18.16.** A sill can range from only a few centimeters to hundreds of meters in thickness. **Figure 18.17** shows the Palisades Sill, which is exposed in the cliffs above the Hudson River near New York City and is about 300 m thick. The rock that was originally above the sill has eroded. What effect do you think this sill had on the sedimentary rocks into which it intruded? One effect is to lift the rock above it. Because it takes great amounts of force to lift entire layers of rock, most sills form relatively close to the surface. Another effect of sills is to metamorphose the surrounding rocks.

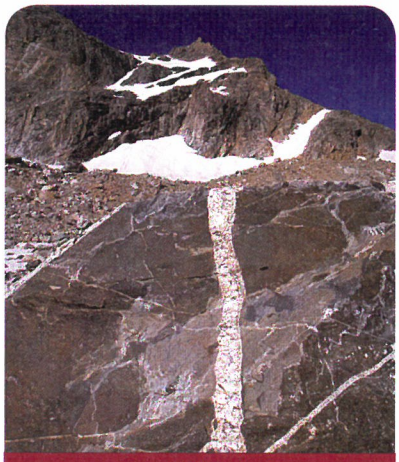
Figure 18.17 Batholiths, laccoliths, and sills form when magma intrudes into the crust and solidifies.



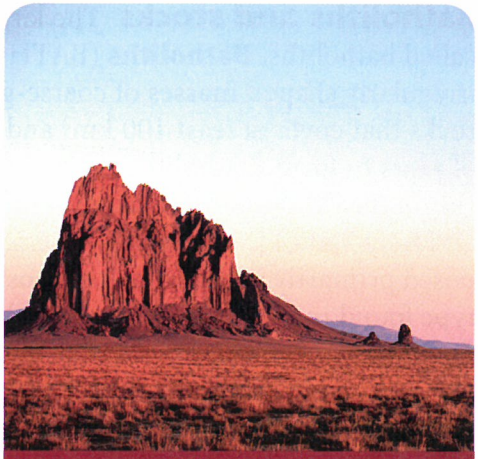
The Coast Range Batholith in British Columbia formed 5 to 30 km below Earth's surface.

Laccoliths push Earth's surface up, creating a rounded top and flat bottom.

The Palisades Sill in New York state formed more than 200 mya.



Dike



Volcanic neck

■ **Figure 18.18** Unlike sills, dikes cut across the rock into which they intrude. Sometimes dikes extend from the conduit of a volcano. When the volcano erodes, the more erosion-resistant conduit and dike are left standing. Try to imagine the volcano that once surrounded this volcanic neck in New Mexico. **Infer** *how big the volcano must have been.*

Dikes Unlike a sill, which is parallel to the rocks it intrudes, a **dike** is a pluton that cuts across preexisting rocks. Dikes often form when magma invades cracks in surrounding rock bodies. Dikes range in size from a few centimeters to several meters wide and can be tens of kilometers long. The Great Dike in Zimbabwe, Africa is an exception—it is about 8 km wide and 500 km long.

A volcanic neck occurs when the magma in a volcano conduit solidifies. Dikes are often associated with the conduit but do not always form the neck. Ship Rock in New Mexico, shown in **Figure 18.18,** has dikes extending from the neck.

Textures While the textures of sills and dikes vary, most are coarse-grained. Recall from Chapter 5 that grain size is related to the rate of cooling. The coarse-grained texture of most sills and dikes suggests that they formed deep in Earth's crust, where magma cooled slowly enough for large mineral grains to develop, as shown in **Figure 18.19.** Dikes and sills with a fine-grained texture formed closer to the surface where many crystals began growing at the same time, such as minerals of the sill in **Figure 18.19.**

■ **Figure 18.19** Plutons forming deep in Earth cool slowly, giving crystals time to grow. Larger crystals produce a coarse-grained rock. Intrusive rocks that form closer to Earth's surface cool more quickly. As a result, many crystals form rapidly at the same time, and the rock is finer-grained.

Coarse-grained dike

Fine-grained sill

Plutons and Tectonics

Many plutons form as the result of mountain-building processes. In fact, batholiths are found at the cores of many of Earth's mountain ranges. From where did the enormous volume of cooled magma that formed these igneous bodies come? The processes that result in batholiths are complex. Recall from Chapter 17 that many major mountain chains formed along continental-continental convergent plate boundaries. Scientists think that some of these collisions might have forced continental crust down into the upper mantle where it melted, intruded into the overlying rocks, and eventually cooled to form batholiths.

Plutons are also thought to form as a result of oceanic plate convergence. Again, recall from Chapter 17 that a subduction zone develops when an oceanic plate converges with another plate. Water from the subducted plate causes the overlying mantle to melt. Plutons often form when the melted material rises but does not erupt at the surface.

The Sierra Nevada batholith formed from at least five episodes of this type of igneous activity beneath what is now California. The famous granite cliffs found in Yosemite National Park, some of which are shown in **Figure 18.20,** are part of this vast batholith. Although they were once far below Earth's surface, uplift and erosion have brought them to their present position.

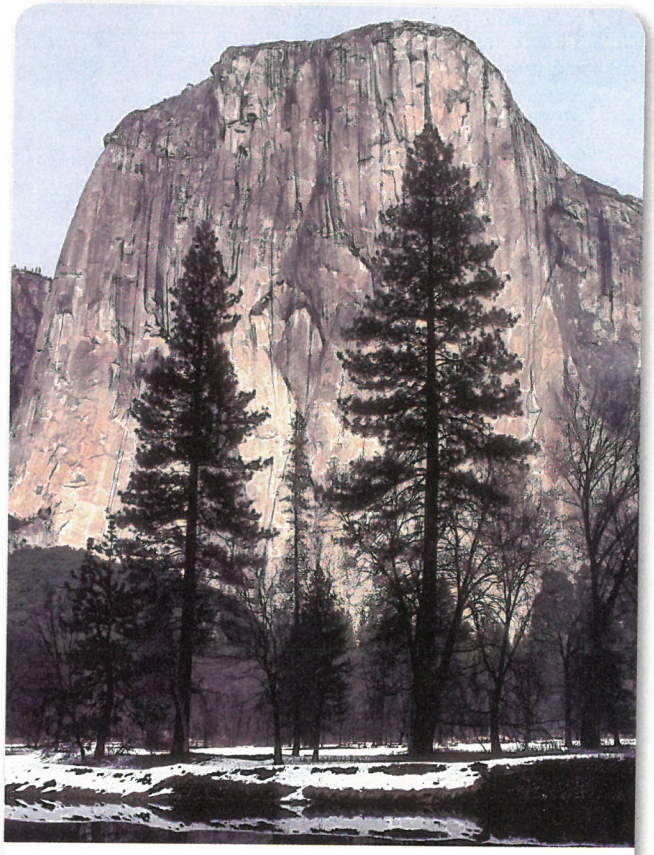


Figure 18.20 The granite cliffs that tower over Yosemite National Park in California are part of the Sierra Nevada batholith that has been exposed at Earth's surface.

Section 18.3 Assessment

Section Summary

- Intrusive igneous rocks are classified according to their size, shape, and relationship to the surrounding rocks.
- Most of Earth's volcanism happens below Earth's surface.
- Magma can intrude into rock in different ways, taking different forms when it cools.
- Batholiths form the core of many mountain ranges.

Understand Main Ideas

1. MAIN Idea **Compare and contrast** volcanic eruptions at Earth's surface with intrusive volcanic activity.
2. **Describe** the different types of plutons.
3. **Relate** the size of plutons to the locations where they are found.
4. **Identify** processes that expose plutons at Earth's surface.

Think Critically

5. **Predict** why the texture in the same sill might vary with finer grains along the margin and coarser grains toward the middle.
6. **Infer** what type of pluton might be found at the base of an extinct volcano.

WRITING in Earth Science

7. Write a defense or rebuttal for this statement: Of the different types of plutons, sills form at the greatest depths beneath Earth's surface.