GLOBAL EDITION

# Essentials of Geology

TWELFTH EDITION

Frederick K. Lutgens • Edward J. Tarbuck • Illustrated by Dennis Tasa

ALWAYS LEARNING

PEARSON

# ESSENTIALS OF GEOLOGY

## 12e
## GLOBAL EDITION

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Boston Columbus Indianapolis New York San Francisco Upper Saddle River
Amsterdam Cape Town Dubai London Madrid Milan Munich Paris Montréal Toronto
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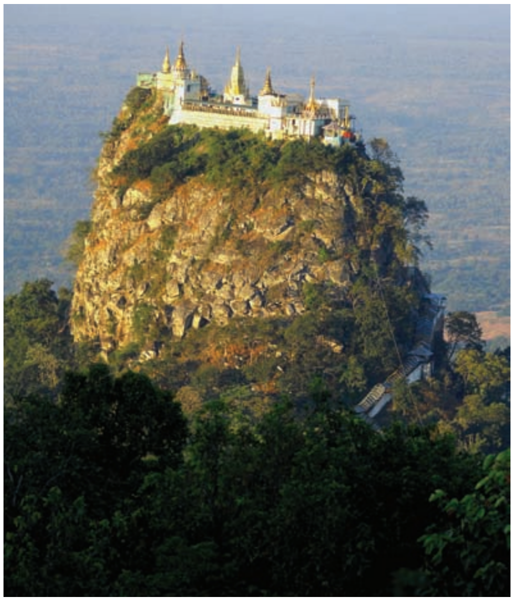
6. This image shows the Buddhist monastery Taung Kalat, located in central Myanmar (Burma). The monastery sits high on a sheer-sided rock made mainly of magmas that solidified in the conduit of an ancient volcano. The volcano has since been worn away.
   - **a.** Based on this information, what volcanic structure do you think is shown in this photo?
   - **b.** Would this volcanic structure most likely have been associated with a composite volcano or a cinder cone? Explain how you arrived at your answer.

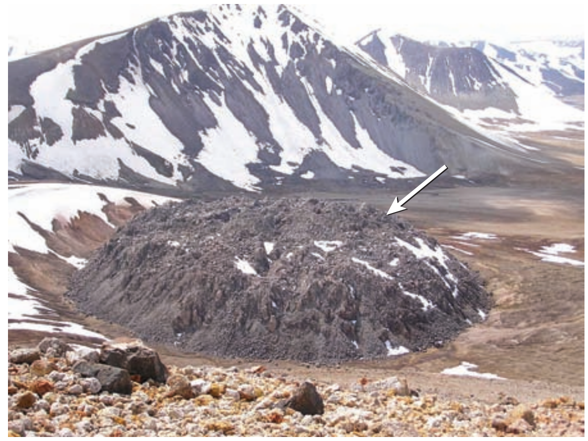


Taolmor/Dreamstime

7. i) Match each of the lava types with one of the options mentioned in the table below: submarine basaltic lava, pyroclastics, subaerial basaltic lava flow, Rhyolitic lavas, Basalts, Subaqueous silicic lava, Archaean, Divergent plate boundary, Glassy pyroclasts
   - **a.** Pahoehoe lava
   - **b.** Ash flow
   - **c.** Pillow lava
   - **d.** Mesa lavas
   - **e.** Hyaloclastite
   - **f.** Komatiites
   - **g.** Shards
   - **h.** Columnar joints
   - **i.** Basaltic magma

   ii) What are the different mechanisms by which pyroclastic flows are generated?

8. Examine the accompanying photo and name the volcanic landform identified by the white arrow.



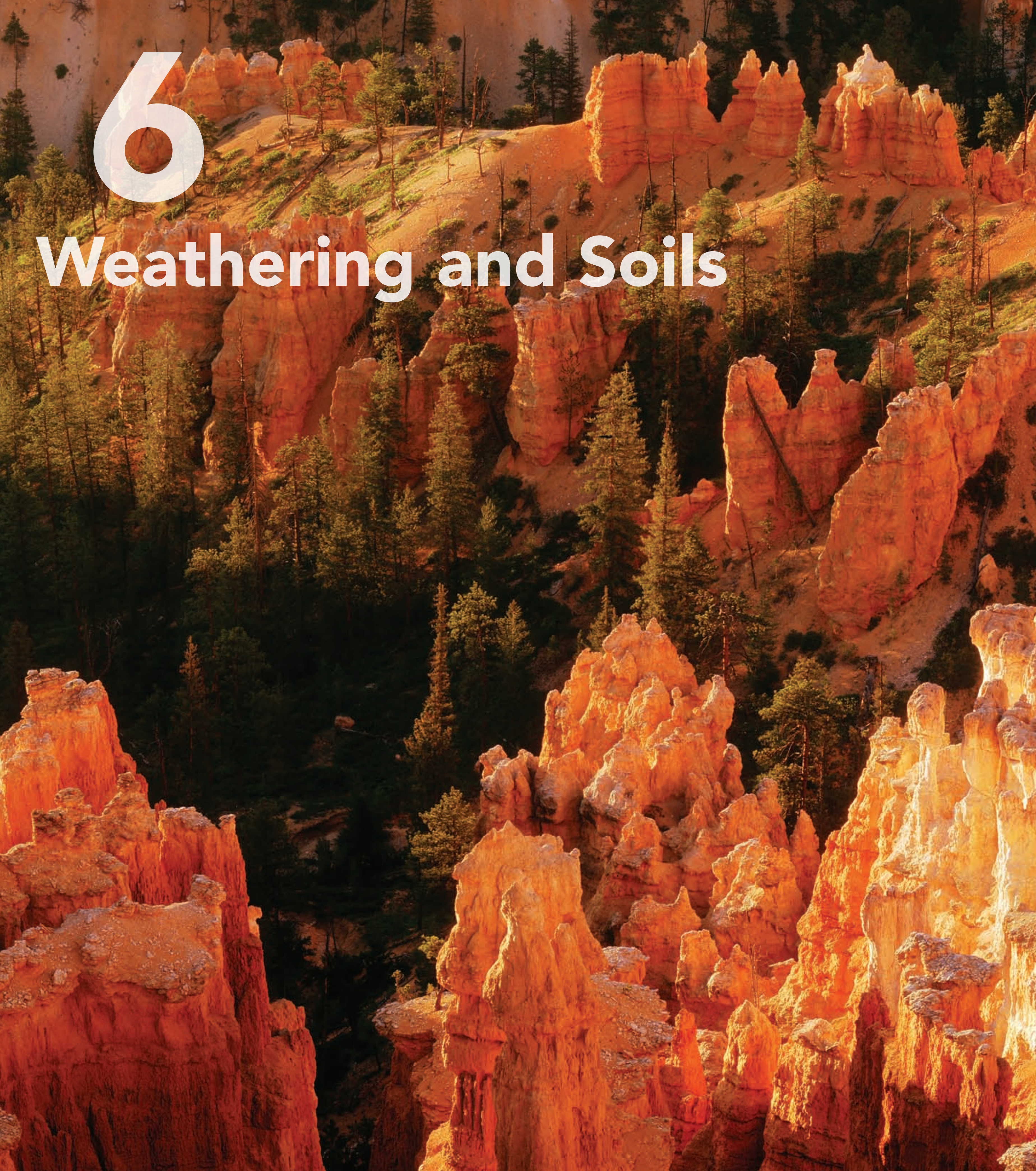
USGS

9. What are ignimbrites? State the various textures commonly found in the ignimbrites. Match ignimbrites with any one of the following:
   - **a.** Deccan trap volcanism
   - **b.** Mt. St. Helens

10. The accompanying image shows a geologist at the end of a large flow consisting of lava blocks that traveled down the flank of Mount Augustine.
    - **a.** What is this type of flow called?
    - **b.** What do volcanologists call the structure composed of broken lava blocks (emitting steam) visible near the summit of this volcano?

USGS

# 6 Weathering and Soils



# Focus on Concepts

Each statement represents the primary learning objective for the corresponding major heading within the chapter. After you complete the chapter, you should be able to:

**6.1** Define *weathering* and distinguish between the two main categories of weathering.

**6.2** List and describe four examples of mechanical weathering.

**6.3** Discuss the importance of water and carbonic acid in chemical weathering processes.

**6.4** Summarize the factors that influence the type and rate of rock weathering.

**6.5** Define *soil* and explain why soil is referred to as an *interface*.

**6.6** List and briefly discuss five controls of soil formation.

**6.7** Sketch, label, and describe an idealized soil profile.

**6.8** Explain the need for classifying soils.

**6.9** Discuss the detrimental impact of human activities on soil.

**6.10** Relate weathering to the formation of certain ore deposits.

Weathering processes helped shape the rock formations in Utah's Bryce Canyon National Park. *(Photo by Michael Collier)*

**Earth's surface is constantly changing.** Rock is disintegrated and decomposed, moved to lower elevations by gravity, and carried away by water, wind, or ice. In this manner, Earth's physical landscape is sculpted. This chapter focuses on the first step of this never-ending process—weathering. What causes solid rock to crumble, and why do the type and rate of weathering vary from place to place? Soil, an important product of the weathering process and a vital resource, is also examined.

## 6.1 Weathering

Define *weathering* and distinguish between the two main categories of weathering.

**Weathering** involves the physical breakdown (disintegration) and chemical alteration (decomposition) of rock at or near Earth's surface. Weathering goes on all around us, but it seems like such a slow and subtle process that it is easy to underestimate its importance. Yet weathering is a basic part of the rock cycle and thus a key process in the Earth system. Weathering is also important to humans—even to those of us who are not studying geology. For example, many of the life-sustaining minerals and elements found in soil, and ultimately in the food we eat, were freed from solid rock by weathering processes. As the chapter-opening photo, **Figure 6.1**, and many other images in this book illustrate, weathering also contributes to the formation of some of Earth's most spectacular scenery. Of course these same processes are also responsible for causing the deterioration of many of the structures we build.

**Figure 6.1 Arches National Park** Mechanical and chemical weathering contributed greatly to the creation of the arches and other rock formations in Utah's Arches National Park. *(Photo by Whit Richardson/Aurora Open/SuperStock)*

There are two basic categories of weathering. **Mechanical weathering** is accomplished by physical forces that break rock into smaller and smaller pieces without changing the rock's mineral composition. **Chemical weathering** involves a chemical transformation of rock into one or more new compounds. These two concepts can be illustrated with a large log. The log disintegrates when it is split into smaller and smaller pieces, whereas decomposition occurs when the log is set afire and burned.

Why does rock weather? Simply, weathering is the response of Earth materials to a changing environment. For instance, after millions of years of uplift and erosion, the rocks overlying a large, intrusive igneous body may be removed, exposing it at the surface. This mass of crystalline rock—formed deep below ground, where temperatures and pressures are high—is now subjected to a very different and comparatively hostile surface environment. In response, this rock mass will gradually change. This transformation of rock is what we call weathering.

In the following sections we will examine the various types of mechanical and chemical weathering. Although we will consider these two categories separately, keep in mind that mechanical and chemical weathering processes usually work simultaneously in nature and reinforce each other.

**Concept Checks 6.1**

1. What are the two basic categories of weathering?
2. How do the products of each category of weathering differ?

# 6.2 Mechanical Weathering

List and describe four examples of mechanical weathering.

When a rock undergoes *mechanical weathering,* it is broken into smaller and smaller pieces, each retaining the characteristics of the original material. The end result is many small pieces from a single large one. **Figure 6.2** shows that breaking a rock into smaller pieces increases the surface area available for chemical attack. An analogous situation occurs when sugar is added to a liquid. In this situation, a cube of sugar dissolves much more slowly than an equal volume of sugar granules because the cube has much less surface area available for dissolution. Hence, by breaking rocks into smaller pieces, mechanical weathering increases the amount of surface area available for chemical weathering.

In nature, four important physical processes lead to the fragmentation of rock: frost wedging, salt crystal growth, expansion resulting from unloading, and biological activity. In addition, although the work of erosional agents such as wind, waves, glacial ice, and running water is usually considered separately from mechanical weathering, it is nevertheless related. As these mobile agents transport rock debris, particles continue to be broken and abraded.

## Frost Wedging

If you leave a glass bottle of water in the freezer a bit too long, you will find the bottle fractured, as in **Figure 6.3**. The bottle breaks because liquid water has the unique property of expanding about 9 percent upon freezing. This is also the reason that poorly insulated or exposed

**Did You Know?**

The intense heat from a brush or forest fire can cause flakes of rock to break from boulders or bedrock. As the rock surface becomes overheated, a thin layer expands and shatters.

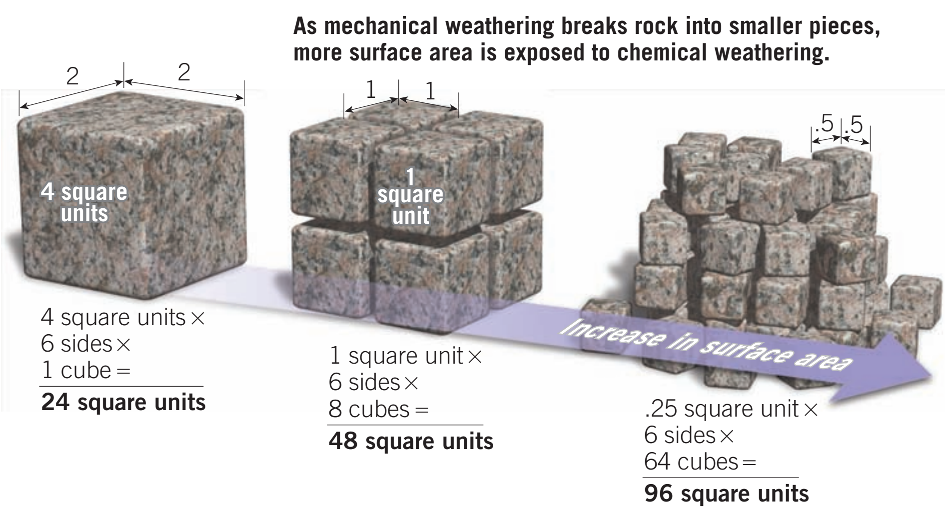
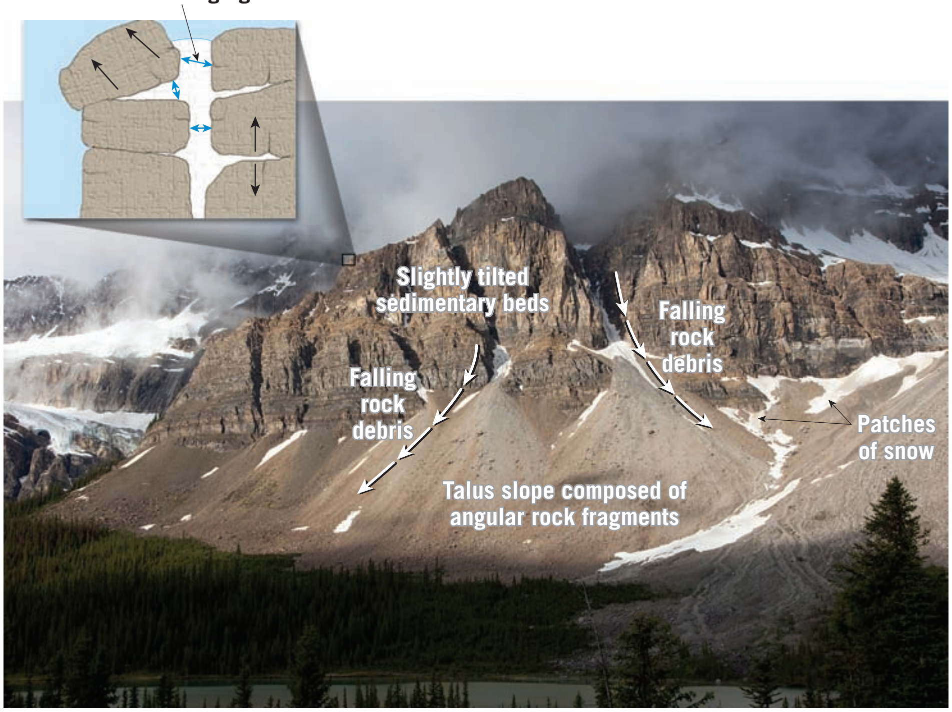



**Figure 6.2 Mechanical weathering increases surface area** Mechanical weathering adds to the effectiveness of chemical weathering because chemical weathering can occur only on exposed surfaces.

**Figure 6.3 Ice breaks bottle** The bottle broke because water expands about 9 percent when it freezes. *(Photo by Bill Aron/Photo Edit)*




**SmartFigure 6.4 Ice breaks rock** In mountainous areas, frost wedging creates angular rock fragments that accumulate to form talus slopes. *(Photo by Marli Miller)*

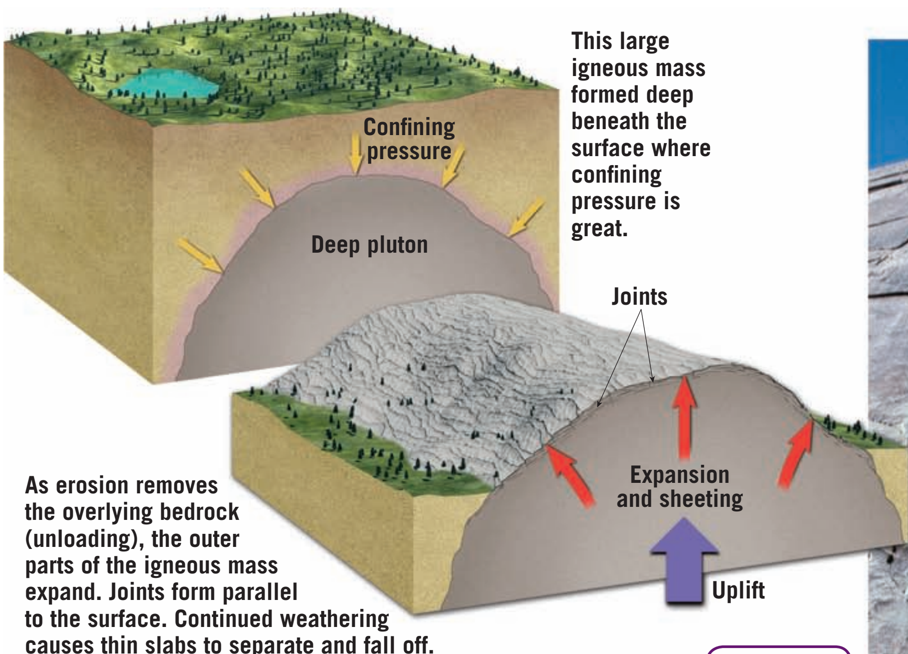
water pipes rupture during frigid weather. You might also expect this same process to fracture rocks in nature. This is, in fact, the basis for the traditional explanation of **frost wedging.** After water works its way into the cracks in rock, the freezing water enlarges the cracks, and angular fragments are eventually produced (**Figure 6.4**).

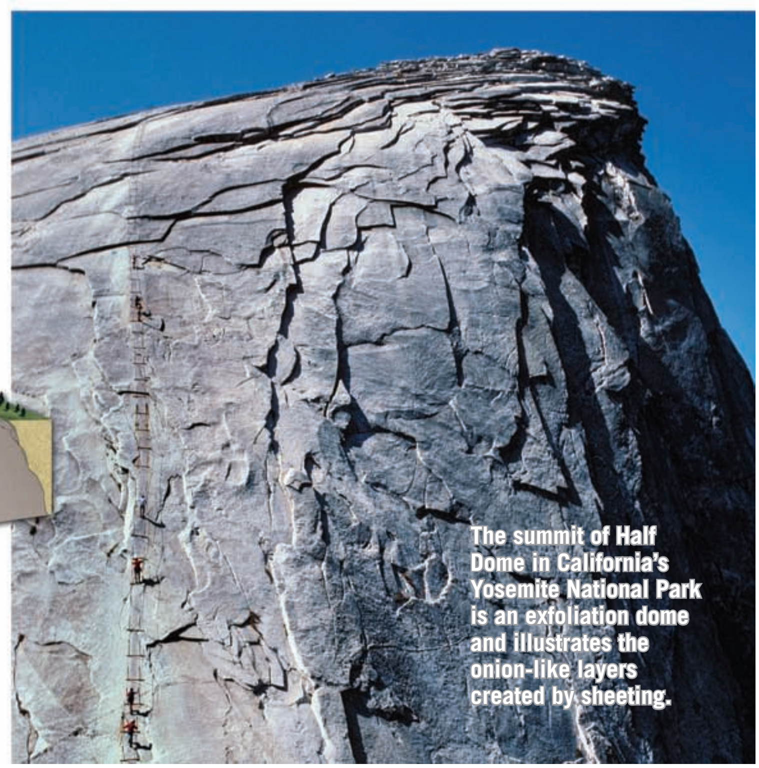
For many years, the conventional wisdom was that most frost wedging occurred in this way. However, research has shown that frost wedging can also occur in a different way.* It has long been known that when moist soils freeze, they expand, or *frost heave,* due to the growth of ice lenses. These masses of ice grow larger because they are supplied with water migrating from unfrozen areas as thin liquid films. As more water accumulates and freezes, the soil is heaved upward. A similar process occurs within the cracks and pore spaces of rocks. Lenses of ice grow larger as they attract liquid water from surrounding pores. The growth of these ice masses gradually weakens the rock, causing it to fracture.

## Salt Crystal Growth

Another expansive force that can split rocks is created by the growth of salt crystals. Rocky shorelines and arid regions are common settings for this process. It begins when sea spray from breaking waves or salty groundwater penetrates crevices and pore spaces in rock. As this water evaporates, salt crystals form. As these crystals gradually

*Bernard Hallet, "Why Do Freezing Rocks Break?" *Science* 314(17): 1092-1093, November 2006.




**SmartFigure 6.5**
**Unloading leads to sheeting** Sheeting leads to the formation of an exfoliation dome. *(Photo by Gary Moon/AGE Fotostock America, Inc.)*