MODULE 1: The Earth

- Origin, Age and Internal structure of the Earth; Materials of Earth; Earth as a closed system. Geomorphology - Weathering of rocks and its engineering considerations; Geological work of wind and running water.

Earth’s External Processes

Weathering, mass wasting, and erosion are called external processes because they occur at or near Earth’s surface and are powered by energy from the Sun. External processes are a basic part of the rock cycle because they are responsible for transforming solid rock into sediment.

Earth is a dynamic body. Some parts of Earth’s surface are gradually elevated by mountain building and volcanic activity. These internal processes derive their energy from Earth’s interior.

The external processes include:

1. Weathering—the physical breakdown (disintegration) and chemical alteration (decomposition) of rocks at or near

Earth’s surface.

2. Mass wasting—the transfer of rock and soil downslope under the influence of gravity.

3. Erosion—the physical removal of material by mobile agents such as water, wind, or ice.

Weathering

- Weathering occurs when rock is mechanically fragmented (disintegrated) and/or chemically altered (decomposed).
- 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.

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 5.3 shows that breaking a rock into smaller pieces increases the surface area available for chemical attack.

In nature, four physical processes are especially important in breaking rocks into smaller fragments: frost wedging, salt crystal growth, expansion resulting from unloading, and biological activity.

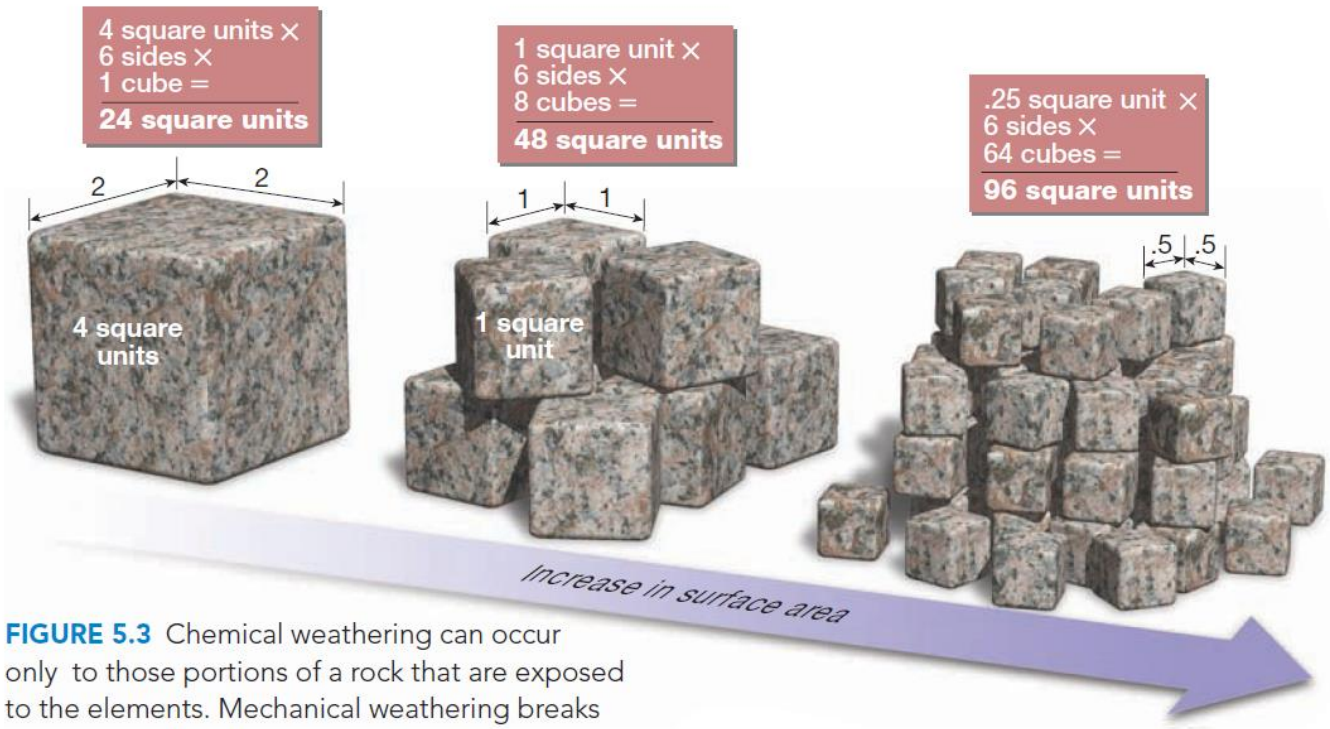


FIGURE 5.3 Chemical weathering can occur only to those portions of a rock that are exposed to the elements. Mechanical weathering breaks rock into smaller and smaller pieces, thereby increasing the surface area available for chemical attack.

Mechanical Weathering

FROST ACTION

The process wherein snow or ice inside cracks cause their expansion and the ultimate fragmentation of the rock is known as frost weathering, frost wedging, or ice wedging (Fig. 4.8). This process causes freeze–thaw weathering and is found mainly in the cold mountainous regions such as the Himalayan terrains in India Water expands as it freezes and widens the crevices in rocks until they shatter into pieces. Freezing also causes granular disintegration of porous rocks such as chalk.

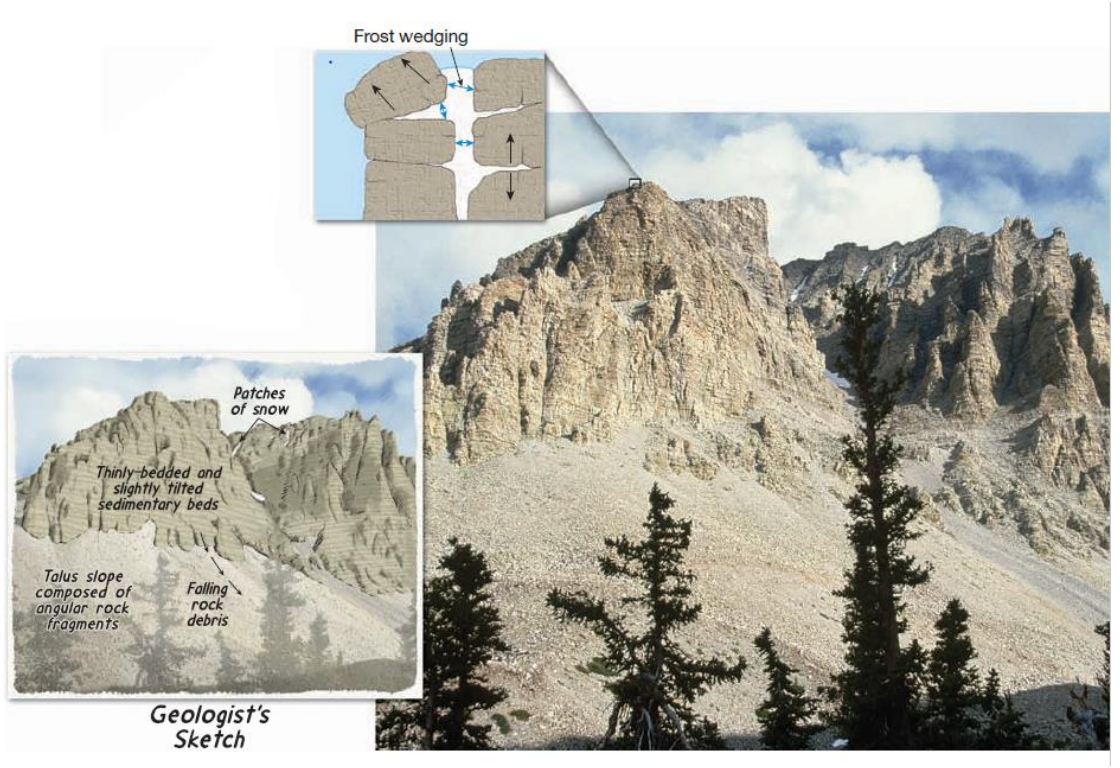


FIGURE 5.4 Frost wedging. As water freezes, it expands, exerting a force great enough to break rock. When frost wedging occurs in a setting such as this, the broken rock fragments fall to the base of the cliff and create a cone-shaped accumulation known as a talus slope. *(Photo by Tom Bean/Corbis)*

Mechanical Weathering

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 grow larger, they weaken the rock by pushing apart the surrounding grains or enlarging tiny cracks.

Mechanical Weathering

SHEETING

When large masses of igneous rock, particularly granite, are exposed by erosion, concentric slabs begin to break loose. The process generating these onionlike layers is called sheeting. It is thought that this occurs, at least in part, because of the great reduction in pressure when the overlying rock is eroded away, a process called unloading. Accompanying this unloading, the outer layers expand more than the rock below and thus separate from the rock body (FIGURE 5.5). Continued weathering eventually causes the slabs to separate and spall off, creating exfoliation domes.

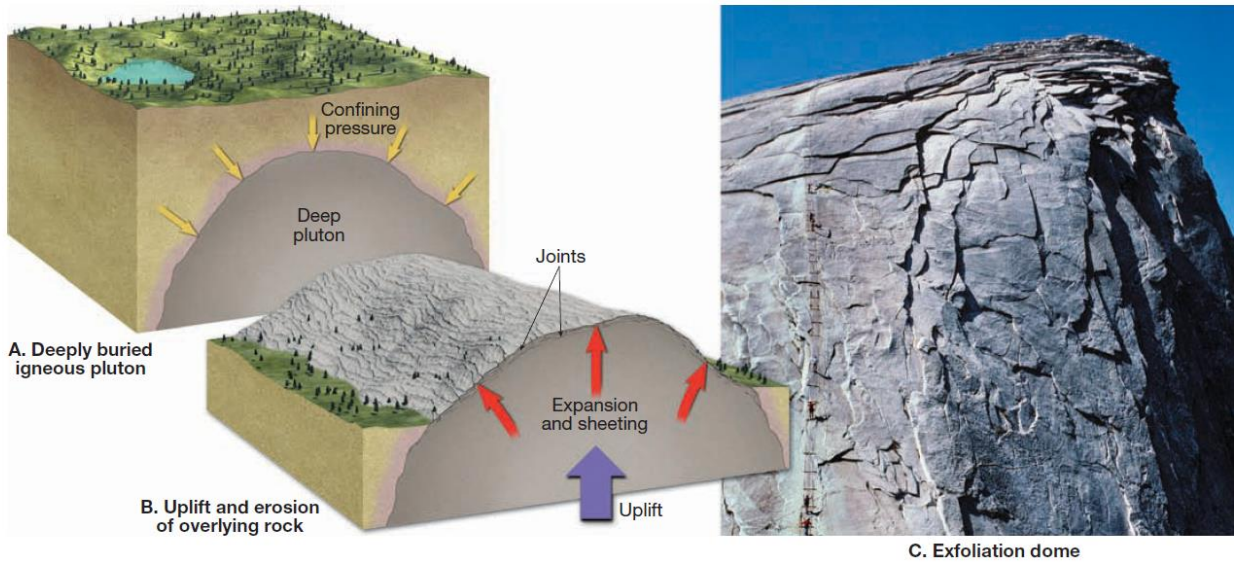
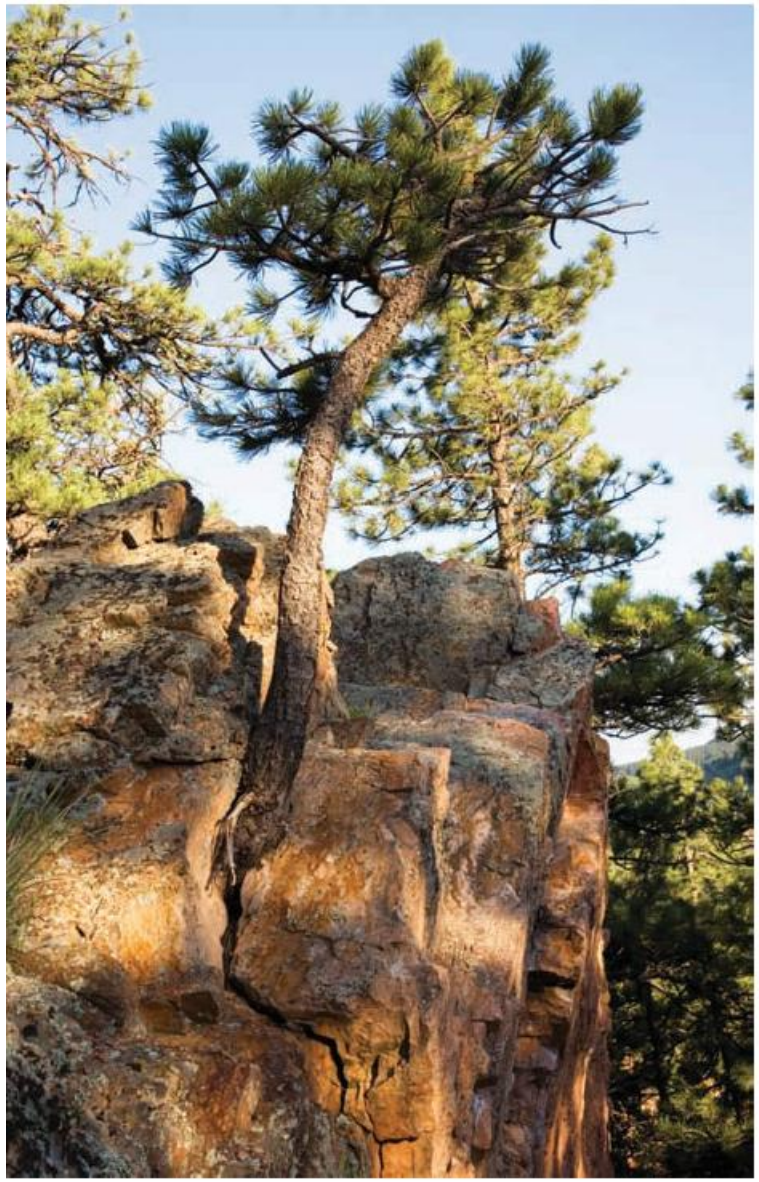


FIGURE 5.5 Sheeting is caused by the expansion of crystalline rock as erosion removes the overlying material. When the deeply buried pluton in **A.** is exposed at the surface following uplift and erosion in **B.**, the igneous mass fractures into thin slabs. The photo in **C.** is of the summit of Half Dome in Yosemite National Park, California. It is an exfoliation dome and illustrates the onionlike layers created by sheeting. *(Photo by Gary Moon/agefotostock)*

Biological Activity

Both mechanical and chemical weathering are accomplished by the activities of organisms. Plant roots in search of minerals and water grow into fractures, and as the roots grow, they wedge the rock apart (FIGURE 5.7).

FIGURE 5.7 Root wedging widens fractures in rocks and aids the process of mechanical weathering. Mt. Sanitas, Boulder, Colorado. *(Photo by Kristin Piljay)*



Chemical Weathering

Chemical weathering involves the complex processes that break down rock components and internal structures of minerals. Such processes convert the constituents to new minerals or release them to the surrounding environment. During this transformation, the original rock decomposes into substances that are stable in the surface environment. Consequently, the products of chemical weathering will remain essentially unchanged as long as they remain in an environment similar to the one in which they formed.

Oxidation

Oxidation happens when atmospheric oxygen combines with the compound (minerals) in some rocks. The most commonly observed oxidation process is that of Fe2+ (iron) and its combination with oxygen and water to form Fe3+ hydroxides and oxides such as hematite, limonite, and goethite. This gives the affected rock a reddish-brown colouration on the surface, which crumbles easily and weakens the rock. This process is better known as *rusting*.

FIGURE 12.10

Sandstone has been colored red by hematite, released by the chemical weathering of ferromagnesian minerals, Thermopolis, Wyoming. *Photo by Diane Carlson*

Carbonation

- *Carbonation* is a solution weathering process that is caused by the minerals in the rocks reacting with water containing a considerable amount of carbon dioxide. Limestone is readily dissolved by rainwater, which is acidified by carbon dioxide from the atmosphere or soil.
- Rain dissolves some carbon dioxide as it falls through the atmosphere, and additional amounts released by decaying organic matter are acquired as the water percolates through the soil. Carbonic acid ionizes to form the very reactive hydrogen ion (H^+) and the bicarbonate ion (HCO_3^-)
- Acids such as carbonic acid readily decompose many rocks and produce certain products that are water soluble. For example, the mineral calcite (CaCO3), which composes the common building stones marble and limestone, is easily attacked by even a weakly acidic so
- The overall reaction by which calcite dissolves in water containing carbon dioxide is:

$$\underset{\text{calcite}}{CaCO_3} + \underset{\text{carbonic acid}}{(H^+ + HCO_3^-)} \longrightarrow \underset{\text{calcium ion}}{Ca^{2+}} + \underset{\text{bicarbonate ion}}{2HCO_3^-}$$

Carbonation

The insoluble calcium carbonate is transformed into soluble products. In nature, over periods of thousands of years, large quantities of limestone are dissolved and carried away by underground water. This activity is clearly evidenced by the large number of subsurface caverns found (FIGURE 5.9).

FIGURE 5.9 Missouri's Meramec Caverns. The dissolving power of carbonic acid plays an important part in forming limestone caverns. (Photo

Spheroidal Weathering

In addition to altering the internal structure of minerals, chemical weathering causes physical changes. For instance, when angular rock masses chemically weather as water enters along joints, they tend to take on a spherical shape. Gradually the corners and edges of the angular blocks become more rounded. The corners are attacked most readily because of their greater surface area, as compared to the edges and faces. This process, called spheroidal weathering, gives the weathered rock a more rounded or spherical shape.

BIOLOGICAL WEATHERING

- In addition to mechanical and chemical weathering, rocks are also altered and decomposed by *biological weathering.* The main agent in biological weathering is the organic acids released by organisms such as bacteria, lichens, mosses, and decaying plants of many types. The acids attack the rock-forming minerals. The mineral composition can also be initiated and accelerated by soil organisms.
- The most common forms of biological weathering are the release of chelating compounds (i.e., organic acids) and of acidifying molecules (i.e., protons, organic acids) by plants so as to break down aluminium- and iron-containing compounds in the soils beneath them. The decaying remains of dead plants in soil may form organic acids, which when dissolved in water cause chemical weathering.