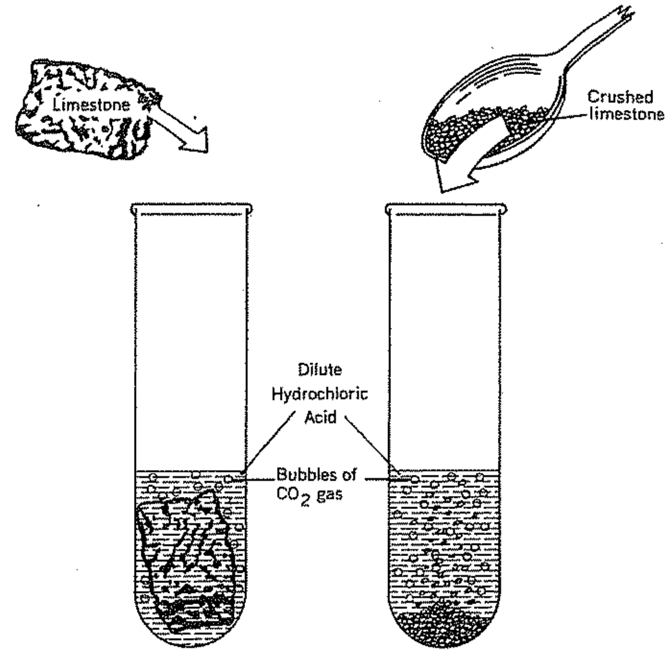

Fig. 4-1.

5. Of the two pieces of limestone you had originally, one piece may have been slightly larger than the other. Could this difference in the size of the original samples have had any effect on the results of this laboratory investigation?

Explain. ____

____

Weathering of Rock

You have learned that Earth's crust was formed from molten materials that cooled and solidified into rock. The crust, or bedrock, is usually covered by layers of sand, gravel, or soil. These materials come largely from bedrock that has been subjected to weathering by water, ice, and other agents. **Weathering** is the breaking down of rocks at or near Earth's surface into smaller and smaller pieces. Weathering may also result in the formation of new substances from elements in the original rocks. There are two types of weathering: *physical weathering* and *chemical weathering.*

PHYSICAL WEATHERING

Physical weathering is the process by which rocks are broken down into smaller fragments without undergoing any change in chemical composition. Physical weathering is mainly caused by the freezing of water, the expansion of rock, and the activities of plants and animals.

Frost Wedging. In areas with temperate and cold climates, as well as in high mountainous areas, rocks are weathered by the action of freezing water. During the daytime, when the temperature is above the freezing point of water (0°C), rainwater, melted snow, or ice trickles into cracks in the rocks. At night, when the temperature falls below the freezing point of water, the water trapped inside the rocks changes into ice.

When water freezes, it increases in volume by about 9 percent. The expansion of water into ice pushes against the sides of the cracks with great force, wedging the rocks apart (see Fig. 4-2). This process, which is characterized by a cycle of daytime thawing and refreezing at night, is called **frost wedging.**

Frost wedging causes large rock masses, especially the rocks exposed on mountaintops, to be broken into smaller pieces. Frost wedging can have the same effect on pavement. During the winter, water trapped in cracks in the pavement freezes into ice. The ice often expands enough to crack the pavement and form potholes.

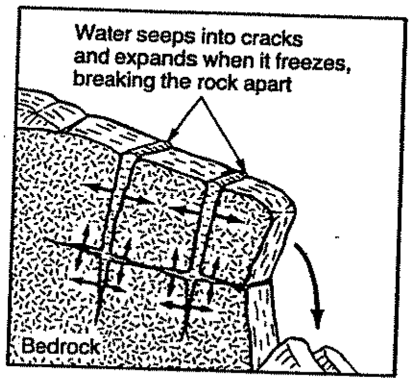

Fig. 4-2. Frost wedging of a rock.

Exfoliation. Weathering continually breaks down exposed bedrock into smaller fragments, which are then carried away by wind and water. Consequently, rock formed deep underground (under great pressure) becomes exposed at Earth's surface. The release of the overlying pressure causes the newly exposed bedrock to expand, forming cracks parallel to the rock's surface. Then, frost wedging causes large, curved slabs of rock to peel away from the main body of the rock. The peeling away of the outer layers from a rock is called **exfoliation.** Rounded mountaintops called *exfoliation domes* are formed in this way (see Fig. 4-3).

Miners and quarry workers have been injured and killed by exfoliation. As a mine shaft or quarry pit is dug into the bedrock, the removal of rock causes a rapid decrease in pressure on the surrounding bedrock. The reduced pressure can result in sudden exfoliation, sending dangerous missiles of rock flying through the air.

nimals and Plants. Insects, earthworms, abbits, woodchucks, and many other animals burrow through the soil. The tunnels these organisms make often expose parts of the bedrock to the weathering action of the air and water. Frost wedging or chemical action can then break down the bedrock. In addition, the act of burrowing through soil helps to break down rock particles into smaller and smaller pieces.

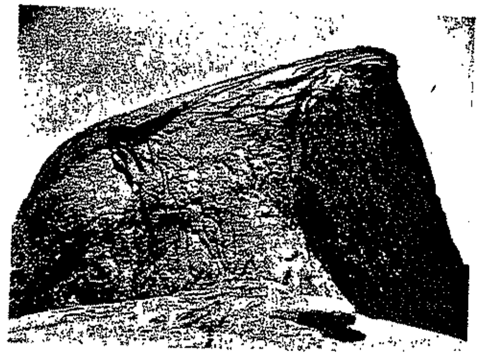

Fig. 4-3. Exfoliation dome.

You may have seen trees that appear to be growing out of solid rock. Trees occasionally grow in soil that has collected in small cracks in the bedrock. In other cases, trees grow in soil upon which a cracked boulder is resting. In either case, as the tree continues to grow, it exerts great pressure against the cracks in the rock. The pressure causes the rock to split apart even wider (see Fig. 4-4).

Fig. 4-4. Growing trees can split rocks.

CHEMICAL WEATHERING

Exposure to air, water, and organisms can change the minerals in a rock into new substances that have different chemical compositions. These new substances are generally softer or weaker than the original materials, so they tend to cause the rock to crumble and fall apart. The breaking down of rocks through changes in their chemical composition is called **chemical weathering.** An example of chemical weathering is the change of feldspar in granite to clay. When acted upon by water, the feldspar changes into powdery clay minerals. Feldspar and clay have different chemical compositions.

Water, oxygen, and carbon dioxide are the main agents of chemical weathering. When water and carbon dioxide combine chemically, they produce a weak acid that can break down rocks. Rocks also are weathered chemically by the action of acids produced by plants and animals. These acids are formed by living plants and by the decomposition of plant and animal materials.

Action of Acids. You may have noticed that the exposed surfaces of bedrock sometimes appear to be covered by a grayish or bluish-green crust. A closer look reveals that this colored crust actually consists of tiny plants called *lichens*. Lichens "eat" rocks by releasing acids that slowly dissolve the minerals in the rocks.

In addition, the action of bacteria and other microscopic organisms on dead plants and animals changes the composition of their remains. As these changes take place, acids are produced. The acids then dissolve the minerals in the rocks, and the rocks crumble apart.

Water. When water comes into contact with certain minerals, the water combines chemically with these minerals and changes them. This kind of chemical weathering is called **hydrolysis.** You learned that when water reacts with the feldspar in granite, the feldspar changes into clay. Clay is much softer than the original feldspar. Thus, the process of hydrolysis weakens granite, making it more susceptible to physical weathering.

Oxygen. When an iron nail is exposed to the atmosphere, rusting takes place. That is because iron, in the presence of moisture, combines chemically with oxygen in the atmosphere. The combining of oxygen with another substance is called **oxidation.** The oxidation of an iron nail produces a powdery reddish-brown substance called *rust*. Rust is composed mainly of a chemical compound called *iron oxide*.

Oxidation also takes place in rocks that contain iron-bearing minerals. When these rocks are exposed to oxygen in the atmosphere, the minerals slowly change into softer, more crumbly substances. Like an iron nail that rusts when exposed to oxygen and moisture, the iron-bearing minerals in these rocks also rust when exposed to the atmosphere.

The chemical weathering of rocks that contain iron often produces reddish or brownish soils. Many of the world's largest iron ore deposits were formed by chemical weathering. For example, the great deposits of iron ore in Minnesota and upper Michigan were formed over a vast period of time by the chemical weathering of basalt, an igneous rock that contains iron.

Carbon Dioxide. When carbon dioxide and water combine chemically, they form a weak acid called **carbonic acid.** (A common name for carbonic acid is *soda water*, which is made by dissolving carbon dioxide gas, under pressure, in water.) As you learned in Chapter 2, when you place a drop of hydrochloric acid on a rock containing calcite, bubbles of carbon dioxide gas appear on the rock. At the same time that the hydrochloric acid is dissolving the calcite, carbon dioxide gas is being released.

Like hydrochloric acid, carbonic acid dissolves calcite from rocks, but much more slowly. The world's largest underground caverns were formed by this type of chemical weathering. The original limestone bedrock was gradually dissolved by water containing carbonic acid. The water then carried the dissolved limestone away, leaving the hollow spaces called *caverns*. (Caverns are described more fully in Chapter 5.)

RESISTANCE TO WEATHERING

The ability of a rock to resist weathering depends mainly on the mineral composition of the rock and on the number of cracks in the rock. Rocks that consist mostly of quartz are more resistant to either physical or chemical weathering than most other kinds of rocks. The chemical weathering of quartz is very slow because quartz does not combine readily with other substances. Unlike rocks that contain abundant quartz, rocks that consist mainly of feldspar weather rapidly, especially in warm, moist parts of the world. In these

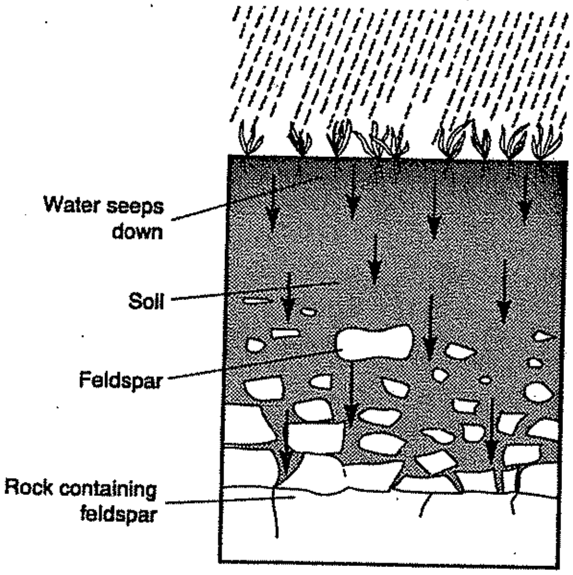

Fig. 4-5. Chemical weathering changes feldspar into clay.

areas, chemical weathering rapidly changes feldspar into clay (see Fig. 4-5).

Granite consists mainly of quartz and feldspar. Although granite is a relatively hard rock, the chemical weathering of feldspar eventually causes granite to crumble. Quartz weathers also, but at a much slower rate than feldspar. Eventually, physical weathering breaks down the quartz into small grains of sand.

In general, sedimentary rocks weather more rapidly than other rock types because sedimentary rocks consist of many small grains that are cemented together. Poorly cemented sedimentary rocks, such as some shales and sandstones, contain small air spaces between the grains. Consequently, water easily penetrates the rocks. If the water freezes within these rocks, the rocks are broken apart by frost wedging.

If water dissolves the cement holding the grains of a sedimentary rock together, the grains will separate. Cements that consist of iron compounds or calcite dissolve more rapidly than do cements composed of silica compounds. In moist climates, therefore, sedimentary rocks cemented by calcite and iron compounds weather rapidly, whereas those cemented by silica are more resistant to weathering.

Cracks in a rock also cause the rock to weather more rapidly. The more cracks in a rock, the faster that weathering will split the rock into fragments. Once a large rock has been split into smaller fragments, the smaller fragments can then be broken down more rapidly by the action of air and water.

You observed this effect in your laboratory investigation. In this investigation, the crushed limestone in one test tube provided more exposed surfaces for the acid to act upon than the unbroken piece. Thus, the crushed limestone weathered more rapidly than the large piece of limestone in the other test tube.

Soil

The **soil** consists of particles formed by physical and chemical weathering. Soil usually contains particles of sand, clay, various minerals, tiny living organisms, and humus. **Humus** is the decayed remains of plants and animals. In addition, some types of soil have large numbers of air spaces between their particles.

SOIL TYPES

Soils are divided into three main classes, according to texture. These classes are *sandy soils*, *clay soils*, and *loamy soils*. You can determine the texture of each soil type by squeezing and rubbing a small amount of moist soil between your fingers.

Sandy soils feel gritty, and their particles do not bind together firmly. Sandy soils are porous, which means that water passes through them rapidly. Consequently, sandy soils do not hold much water. Adding a large amount of humus to a sandy soil permits the soil to hold more water.

Clay soils feel smooth and greasy, and their particles bind together firmly. Clay soils are usually moist, but they do not permit water to pass through easily.

Loamy soils feel somewhat like velvet, and their particles clump together. Loamy soils consist of a mixture of sand, clay, and silt. A loamy soil holds water well and permits some water to pass through.

SOIL LAYERS

As shown in Fig. 4-6, a typical soil consists of three different layers. The top layer (the soil layer in which most plants grow) is called the **topsoil.** Only the topsoil contains humus. Because the topsoil contains humus, it tends to be darker than the underlying soil layers. Topsoil ranges in thickness from about 10 to 60 centimeters (cm). Topsoils contain different amounts of sand, clay, and humus. Loamy soil is the best kind of topsoil for growing crops, such as corn, oats, and wheat.

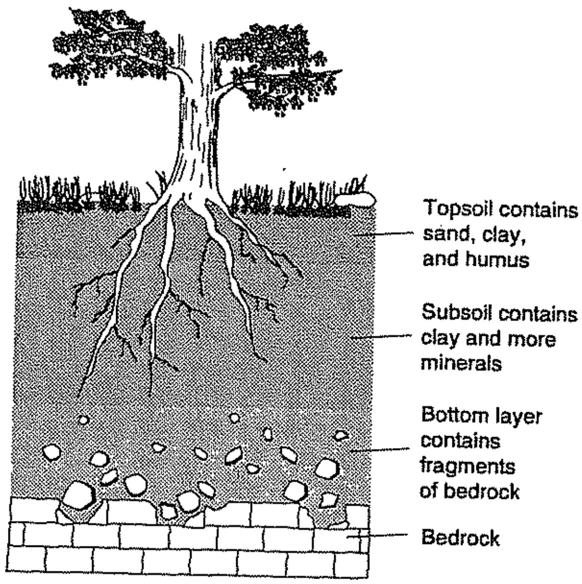

Fig. 4-6. Soil layers.

Underneath the topsoil is the second layer of soil, or **subsoil.** The subsoil contains more clay and various minerals than the topsoil. The subsoil is usually reddish, brownish, or yellowish. Larger plants, especially trees, extend their roots into the subsoil.

The bottom layer of soil, which may extend several meters downward, consists mostly of rock fragments produced by the physical and chemical weathering of the bedrock. The color of the bottom layer of soil depends largely on the color of the underlying bedrock.

Although the bottom two layers of the soil are relatively thick, the topsoil is always a thin layer. Even fertile farmlands have a relatively thin layer of topsoil. Because topsoil is a loose material, it is easily carried away by wind and water. In the 1930s, winds blew away billions of tons of topsoil from the farmlands of the Plains states. The dust was carried in great clouds more than 3000 kilometers east to the Atlantic Ocean. The United States still loses large amounts of topsoil each year because of the destructive action of wind and water. Topsoil conservation is discussed in Chapter 9.

CHAPTER REVIEW

Science Terms

The following list contains all of the boldfaced words found in this chapter and the page on which each appears.

carbonic acid (p. 52)
chemical weathering (p. 52)
exfoliation (p. 51)
frost wedging (p. 51)
humus (p. 53)
hydrolysis (p. 52)
oxidation (p. 52)
physical weathering (p. 50)
soil (p. 53)
subsoil (p. 54)
topsoil (p. 54)
weathering (p. 50)

Matching Questions

On the blank line, write the letter of the item in column B that is most closely related to the item in column A.

Column A

____ 1. breakdown of rocks into smaller pieces

____ 2. breaking apart of rocks by ice

____ 3. peeling away of outer rock layers

____ 4. chemical weathering by water

____ 5. chemical combination of CO_2 and H_2O

____ 6. remains of plants and animals in soil

____ 7. uppermost soil layer, having humus

____ 8. second layer of soil, having more clay

Column B

a. hydrolysis
b. topsoil
c. carbonic acid
d. subsoil
e. humus
f. physical weathering
g. frost wedging
h. exfoliation
i. oxidation

Multiple-Choice Questions

On the blank line, write the letter preceding the word or expression that best completes the statement.

1. The destructive effects of frost wedging are most likely to take place on
a. city streets *b.* mountaintops *c.* country roads *d.* lake shores 1 ____

2. A mass of rock from which tons of overlying material are being removed should
a. contract *b.* expand *c.* change chemically *d.* crumble 2 ____

3. Ants, worms, and burrowing animals help weather bedrock mostly by
a. carrying particles of rock to the surface
b. secreting chemicals
c. crushing small particles
d. digging tunnels that expose the bedrock to air and water 3 ____

4. The substances that are mainly responsible for chemical weathering in nature are water, carbon dioxide, and
a. oxygen *b.* nitrogen *c.* hydrochloric acid *d.* frost 4 ____

5. When carbon dioxide and water combine chemically, they form
a. calcium bicarbonate *b.* clay *c.* limestone *d.* carbonic acid 5 ____

6. Ordinarily, the rock that is most resistant to weathering is
a. limestone *b.* shale *c.* granite *d.* sandstone 6 ____

7. Humus refers to
a. minerals in the soil *c.* sandy soil
b. decayed plant and animal matter *d.* silt 7 ____

8. The soils in which most plants grow best are
   a. loamy soils *b.* sandy soils *c.* clay soils *d.* silt soils 8 ____

9. Topsoil usually ranges in depth from several centimeters to about
   a. 60 cm *b.* 100 cm *c.* 160 cm *d.* 200 cm 9 ____

10. The bottom layer of soil is usually composed of
    a. clay *c.* broken bedrock
    b. sand *d.* decayed animal and plant remains 10 ____

Modified True-False Questions

In some of the following statements, the italicized term makes the statement incorrect. For each incorrect statement, write the term that must be substituted for the italicized term to make the statement correct. For each correct statement, write the work "true."

1. *Weathering* is the physical and chemical breakdown of rock. 1 ____________
2. The expansion of water that occurs during freezing is an example of a *chemical* action. 2 ____________
3. The separation of the outer layers from a mass of rock is called *exfoliation.* 3 ____________
4. Clay can be produced by the *chemical* breakdown of feldspar. 4 ____________
5. A coating of bluish-green material on a mass of rock is an indication that the rock is probably being broken down by the *chemical* action of lichens. 5 ____________
6. Hydrolysis is to feldspar and water as rusting is to iron and *carbonic acid.* 6 ____________
7. Rocks containing large amounts of quartz usually weather *slowly.* 7 ____________
8. In moist regions, rocks cemented by calcite weather at a *slower* rate than do rocks cemented by silica compounds. 8 ____________
9. The greater the number of cracks in a rock, the *faster* the rock will weather. 9 ____________
10. Fertile soils consist of a mixture of sand, clay, and *pebbles.* 10 ____________