Section 1

Rocks and Weathering

Reading Preview

Key Concepts

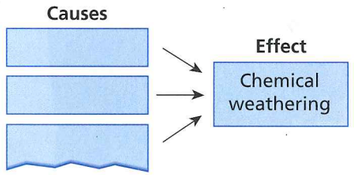
- How do weathering and erosion affect Earth's surface?
- What are the causes of mechanical weathering and chemical weathering?
- What determines how fast weathering occurs?

Key Terms

- weathering
- erosion
- uniformitarianism
- mechanical weathering
- abrasion
- ice wedging
- chemical weathering
- oxidation
- permeable

Target Reading Skill

Relating Cause and Effect A cause makes something happen. An effect is what happens. As you read, identify the causes of chemical weathering. Write them in a graphic organizer like the one below.



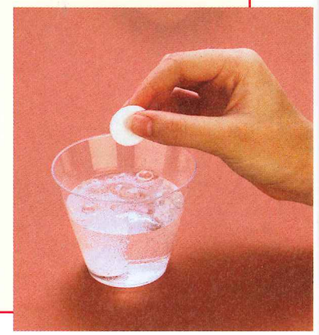
Lab zone **Discover Activity**

How Fast Can It Fizz?

1. Place a fizzing antacid tablet in a small beaker. Then grind up a second tablet and place it in another beaker. The whole tablet is a model of solid rock. The ground-up tablet is a model of rock fragments.
2. Add 100 mL of warm water to the beaker containing the whole tablet. Then stir with a stirring rod until the tablet dissolves completely. Use a stopwatch to time how long it takes.
3. Add 100 mL of warm water to the beaker containing the ground-up tablet. Then stir until all of the ground-up tablet dissolves. Time how long it takes.

Think It Over

Drawing Conclusions Which dissolved faster, the whole antacid tablet or the ground-up tablet? What variable affected how long it took each of them to dissolve?



Imagine a hike that lasts for months and covers hundreds of kilometers. Each year, many hikers go on such treks. They hike trails that run the length of America's great mountain ranges. For example, the John Muir Trail follows the Sierra Nevada mountains. The Sierras extend about 640 kilometers along the eastern side of California. In the east, the Appalachian Trail follows the Appalachian Mountains. The Appalachians stretch more than 3,000 kilometers from Alabama to Canada.

The two trails cross very different landscapes. The Sierras are rocky and steep, with many peaks rising 3,000 meters above sea level. The Appalachians are more rounded and gently sloping, and are covered with soil and plants. The highest peaks in the Appalachians are less than half the elevation of the highest peaks in the Sierras. Which mountain range do you think is older? The Appalachians formed more than 250 million years ago. The Sierras formed only within the last 10 million years. The forces that wear down rock on Earth's surface have had much longer to grind down the Appalachians.

Weathering and Erosion

The process of mountain building thrusts rock up to the surface of Earth. There, the rock is exposed to weathering. **Weathering** is the process that breaks down rock and other substances at Earth's surface. Heat, cold, water, and ice all contribute to weathering. So do the oxygen and carbon dioxide in the atmosphere. Repeated freezing and thawing, for example, can crack rock apart into smaller pieces. Rainwater can dissolve minerals that bind rock together. You don't need to go to the mountains to see examples of weathering. The forces that wear down mountains also cause bicycles to rust, paint to peel, sidewalks to crack, and potholes to form.

The forces of weathering break rocks into smaller and smaller pieces. Then the forces of erosion carry the pieces away. **Erosion** (ee ROH zhun) is the removal of rock particles by wind, water, ice, or gravity. **Weathering and erosion work together continuously to wear down and carry away the rocks at Earth's surface.** The weathering and erosion that geologists observe today also shaped Earth's surface millions of years ago. How do geologists know this? Geologists make inferences based on the principle of **uniformitarianism** (yoon uh fawrm uh TAYR ee un iz um). This principle states that the same processes that operate today operated in the past.

There are two kinds of weathering: mechanical weathering and chemical weathering. Both types of weathering act slowly, but over time they break down even the biggest, hardest rocks.

Reading Checkpoint What is the difference between weathering and erosion?

FIGURE 1
Effects of Weathering
The jagged peaks of the Sierra Nevadas (bottom) formed within the last 10 million years. The more gently sloping Appalachians (top) have been exposed to weathering for 250 million years.
Inferring *How can you tell that the Sierra Nevadas formed much more recently than the Appalachians?*

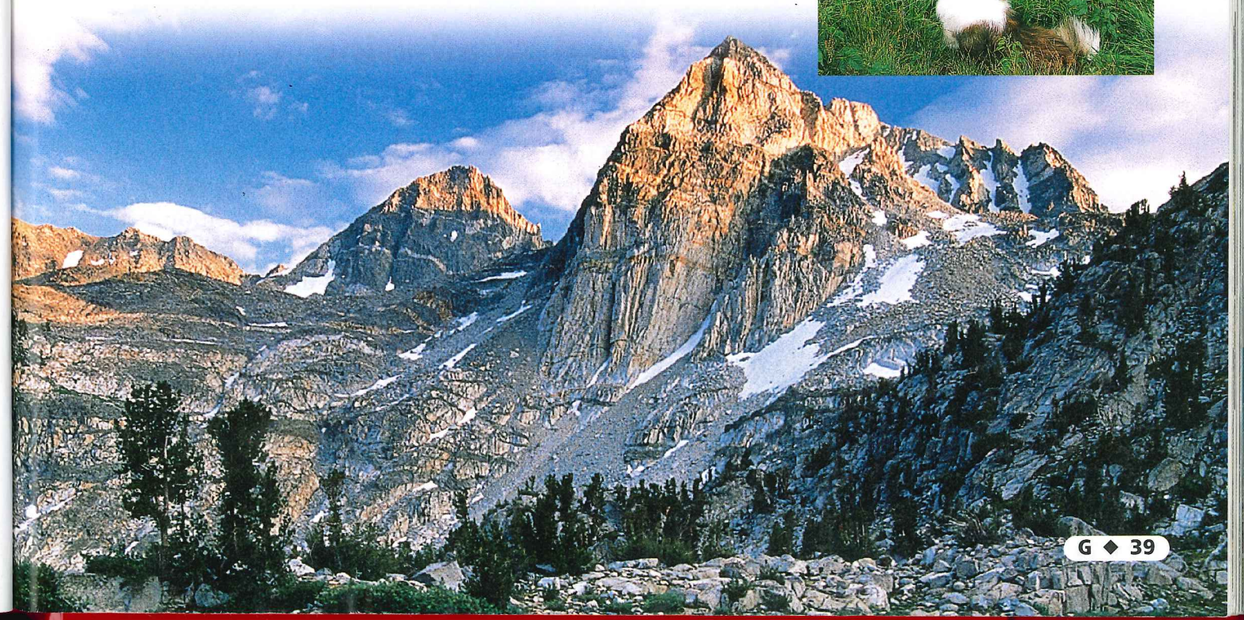
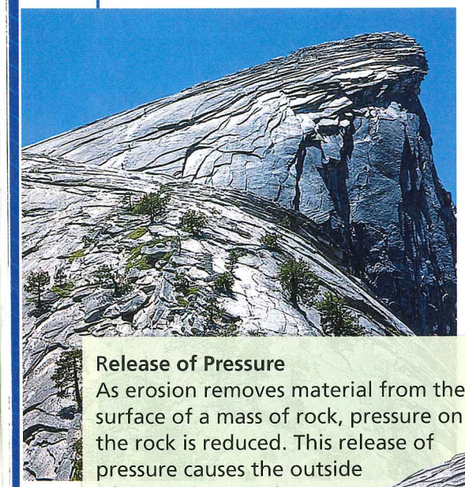


FIGURE 2

Forces of Mechanical Weathering

Mechanical weathering affects all the rock on Earth's surface.

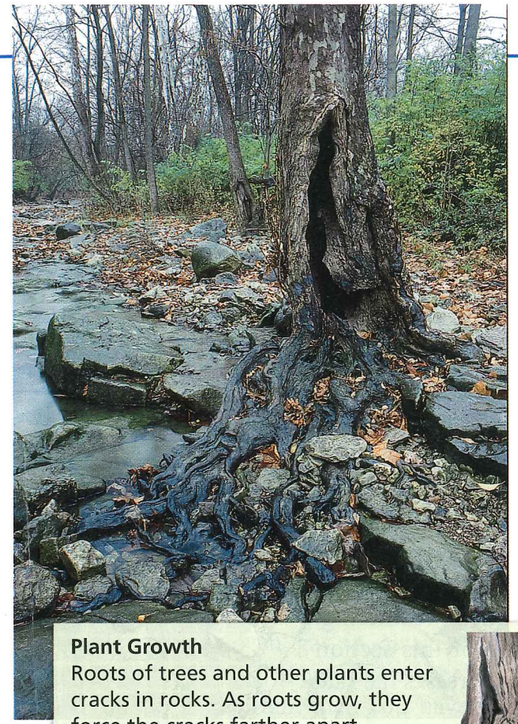
Forming Operational Definitions *Study the examples of mechanical weathering, then write a definition of each term in your own words.*



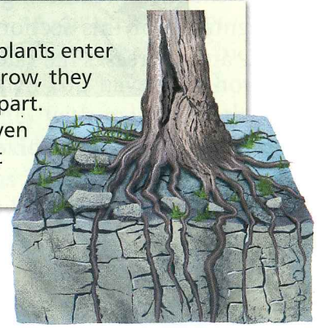
Release of Pressure
As erosion removes material from the surface of a mass of rock, pressure on the rock is reduced. This release of pressure causes the outside of the rock to crack and flake off like the layers of an onion.

Freezing and Thawing
When water freezes in a crack in a rock, it expands and makes the crack bigger. The process of ice wedging also widens cracks in sidewalks and causes potholes in streets.

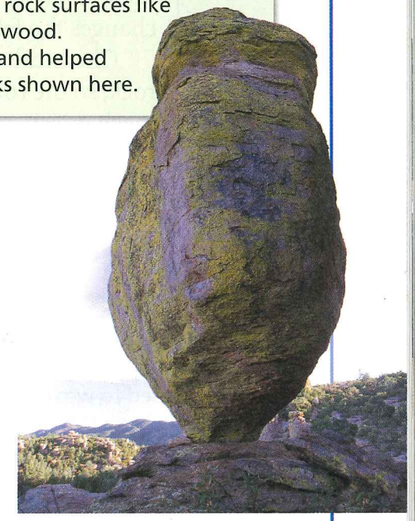
Animal Actions
Animals that burrow in the ground—including moles, gophers, prairie dogs, and some insects—loosen and break apart rocks in the soil.



Plant Growth
Roots of trees and other plants enter cracks in rocks. As roots grow, they force the cracks farther apart. Over time, the roots of even small plants can pry apart cracked rocks.



Abrasion
Sand and other rock particles that are carried by wind, water, or ice can wear away exposed rock surfaces like sandpaper on wood. Wind-driven sand helped shape the rocks shown here.



Mechanical Weathering

If you hit a rock with a hammer, the rock may break into pieces. Like a hammer, some forces of weathering break rock into pieces. The type of weathering in which rock is physically broken into smaller pieces is called **mechanical weathering.** These smaller pieces of rock have the same composition as the rock they came from. If you have seen rocks that are cracked or split in layers, then you have seen rocks that are undergoing mechanical weathering. Mechanical weathering works slowly. But over very long periods of time, it does more than wear down rocks. Mechanical weathering eventually wears away whole mountains.

The causes of mechanical weathering include freezing and thawing, release of pressure, plant growth, actions of animals, and abrasion. The term **abrasion** (uh BRAY zhun) refers to the grinding away of rock by rock particles carried by water, ice, wind, or gravity.

In cool climates, the most important force of mechanical weathering is the freezing and thawing of water. Water seeps into cracks in rocks and then freezes when the temperature drops. Water expands when it freezes. Ice therefore acts like a wedge that forces things apart. Wedges of ice in rocks widen and deepen cracks. This process is called **ice wedging.** When the ice melts, the water seeps deeper into the cracks. With repeated freezing and thawing, the cracks slowly expand until pieces of rock break off.

Reading Checkpoint How does ice wedging weather rock?

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Chemical Weathering

In addition to mechanical weathering, another type of weathering attacks rock. **Chemical weathering** is the process that breaks down rock through chemical changes. **The causes of chemical weathering include the action of water, oxygen, carbon dioxide, living organisms, and acid rain.**

Each rock is made up of one or more minerals. Chemical weathering can produce new minerals as it breaks down rock. For example, granite is made up of several minerals, including feldspar, quartz, and mica. As a result of chemical weathering, granite eventually changes the feldspar minerals to clay minerals.

Chemical weathering creates holes or soft spots in rock, so the rock breaks apart more easily. Chemical and mechanical weathering often work together. As mechanical weathering breaks rock into pieces, more surface area becomes exposed to chemical weathering. The Discover activity at the beginning of this section shows how increasing the surface area increases the rate of a chemical reaction.

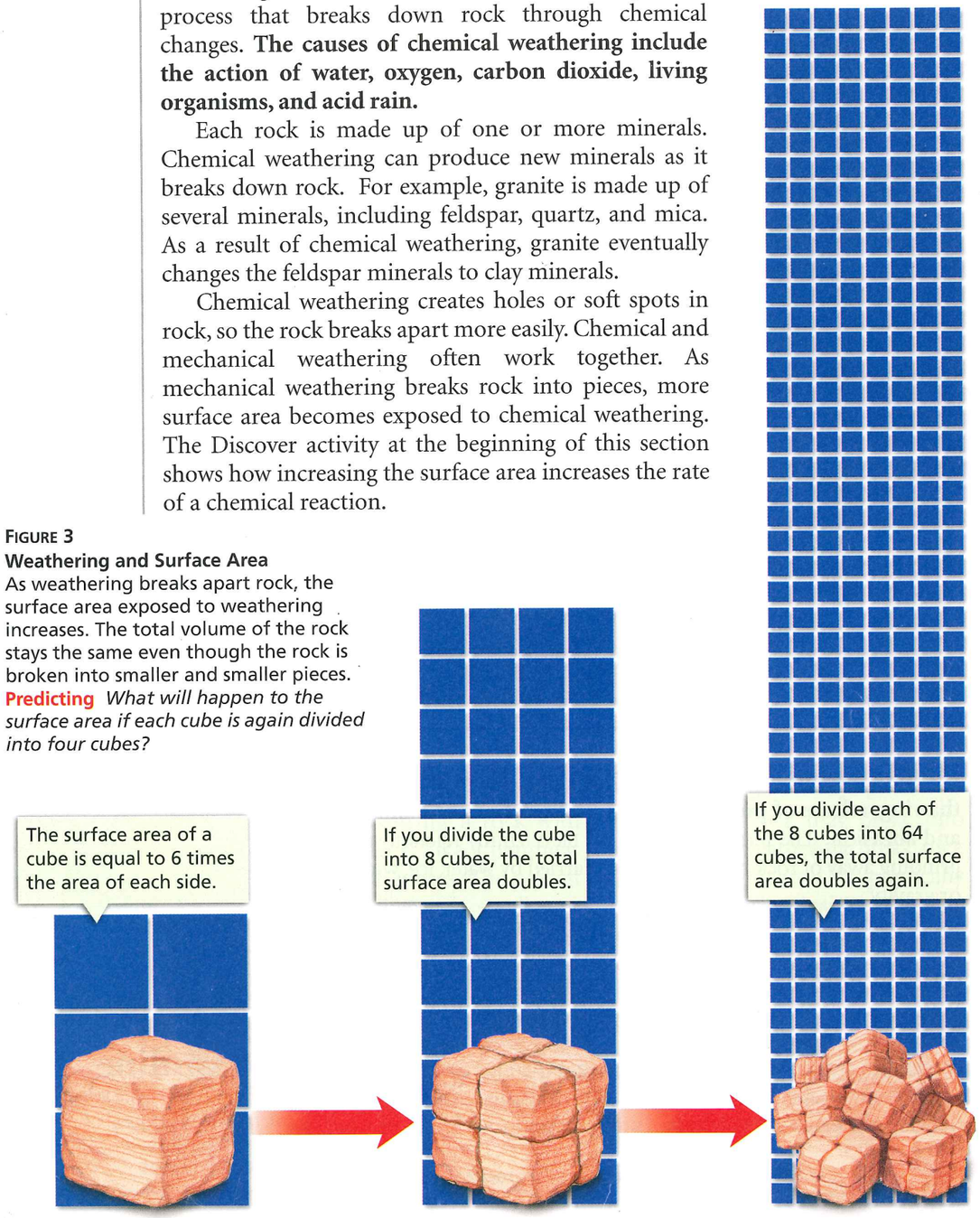


FIGURE 3
Weathering and Surface Area
As weathering breaks apart rock, the surface area exposed to weathering increases. The total volume of the rock stays the same even though the rock is broken into smaller and smaller pieces.
Predicting *What will happen to the surface area if each cube is again divided into four cubes?*

FIGURE 4
Effects of Chemical Weathering
Acid rain chemically weathered these stone gargoyles on the cathedral of Notre Dame in Paris, France.

Water Water is the most important cause of chemical weathering. Water weathers rock by dissolving it. When a rock or other substance dissolves in water, it mixes uniformly throughout the water to make a solution. Over time, many rocks will dissolve in water.

Oxygen The oxygen gas in air is an important cause of chemical weathering. If you have ever left a bicycle or metal tool outside in the rain, then you have seen how oxygen can weather iron. Iron combines with oxygen in the presence of water in a process called **oxidation.** The product of oxidation is rust. Rock that contains iron also oxidizes, or rusts. Rust makes rock soft and crumbly and gives it a red or brown color.

Carbon Dioxide Another gas found in air, carbon dioxide, also causes chemical weathering. Carbon dioxide dissolves in rainwater and in water that sinks through air pockets in the soil. The result is a weak acid called carbonic acid. Carbonic acid easily weathers rocks such as marble and limestone.

Living Organisms Imagine a seed landing on a rock face. As it sprouts, its roots push into cracks in the rock. As the plant's roots grow, they produce weak acids that slowly dissolve rock around the roots. Lichens—plantlike organisms that grow on rocks—also produce weak acids that chemically weather rock.

Acid Rain Over the past 150 years, people have been burning large amounts of coal, oil, and gas for energy. Burning these fuels can pollute the air with sulfur, carbon, and nitrogen compounds. Such compounds react chemically with the water vapor in clouds, forming acids. These acids mix with raindrops and fall as acid rain. Acid rain causes very rapid chemical weathering.

Reading Checkpoint **How can plants cause chemical weathering?**

Lab zone Try This Activity

Rusting Away

Here's how you can observe weathering.

1. Moisten some steel wool and place it in a closed container so it will not dry out.
2. Observe the steel wool after a few days. What has happened to it?
3. Take a new piece of steel wool and squeeze it between your fingers. Remove the steel wool from the container and squeeze it between your fingers. What happens? Wash your hands when you have finished.

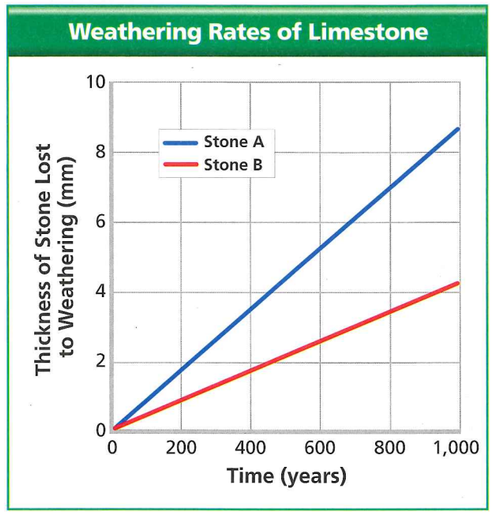
Predicting If you kept the steel wool moist for a longer time, what would eventually happen to it? How is the weathering of steel wool like the weathering of a rock?

Math Analyzing Data

Which Weathered Faster?

The graph shows the rate of weathering for two identical pieces of limestone that weathered in different locations.

1. **Reading Graphs** What does the *x*-axis of the graph represent?
2. **Reading Graphs** What does the *y*-axis of the graph represent?
3. **Reading Graphs** How much thickness did Stone A lose in 1,000 years? How much thickness did Stone B lose in the same period?
4. **Drawing Conclusions** Which stone weathered at a faster rate?
5. **Inferring** Since the two identical pieces of limestone weathered at different rates, what can you infer caused the difference in their rates of weathering?



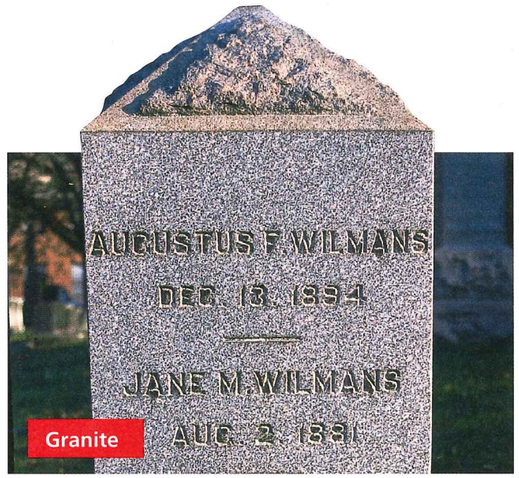
Rate of Weathering

Visitors to New England's historic cemeteries may notice a surprising fact. Slate tombstones carved in the 1700s are less weathered and easier to read than marble gravestones from the 1800s. Why is this so? Some kinds of rocks weather more rapidly than others. **The most important factors that determine the rate at which weathering occurs are the type of rock and the climate.**

Type of Rock The minerals that make up the rock determine how fast it weathers. Rock made of minerals that do not dissolve easily in water weathers slowly. Rock made of minerals that dissolve easily in water weathers faster.

Some rock weathers more easily because it is permeable. **Permeable** (PUR mee uh bul) means that a material is full of tiny, connected air spaces that allow water to seep through it. Permeable rock weathers chemically at a fast rate. Why? As water seeps through the spaces in the rock, it dissolves and removes material broken down by weathering.

Climate Climate refers to the average weather conditions in an area. Both chemical and mechanical weathering occur faster in wet climates. Rainfall provides the water needed for chemical changes as well as for freezing and thawing.



Chemical reactions occur faster at higher temperatures. That is why chemical weathering occurs more quickly where the climate is both hot and wet. Granite, for example, is a very hard rock that forms when molten material cools inside Earth. Granite weathers so slowly in cool climates that it is often used as a building stone. But in hot and wet climates, granite weathers more rapidly and eventually crumbles apart.

FIGURE 5
Which Rock Weathers Faster? These two tombstones are about the same age and are in the same cemetery, yet one has weathered much less than the other.
Inferring *Which type of stone weathers faster, granite or marble? Explain.*

Reading Checkpoint **How does rainfall affect the rate of weathering?**

Section 1 Assessment

Target Reading Skill **Relating Cause and Effect** Refer to your graphic organizer about the causes of chemical weathering to help you answer Question 2 below.

Reviewing Key Concepts

1. a. **Defining** What is weathering?
   b. **Defining** What is erosion?
   c. **Predicting** Over millions of years, how do weathering and erosion change a mountain made of solid rock?
2. a. **Defining** What is chemical weathering?
   b. **Comparing and Contrasting** Compare and contrast mechanical weathering and chemical weathering.
   c. **Classifying** Classify each as chemical or mechanical weathering: freezing or thawing, oxidation, water dissolving chemicals in rock, abrasion, acid rain.
3. a. **Identifying** What are two factors that affect the rate of weathering?
   b. **Relating Cause and Effect** A granite monument is placed outside for 200 years in a region with a cool, dry climate. What would its rate of weathering be? Explain.

Lab zone At-Home Activity

Ice in a Straw Demonstrate one type of weathering for your family. Plug one end of a drinking straw with a small piece of clay. Fill the straw with water. Now plug the top of the straw with clay. Make sure that the clay plugs do not leak. Lay the straw flat in the freezer overnight. Remove the straw the next day. What happened to the clay plugs? What process produced this result? Be sure to dispose of the straw so that no one will use it for drinking.