Objectives

- **Explain** how glaciers form.
- **Compare and contrast** the conditions that produce valley glaciers with those that produce continental glaciers.
- **Describe** how glaciers modify landscapes.
- **Recognize** glacial features.

Review Vocabulary

latitude: distance in degrees north and south of the equator

New Vocabulary

glacier
valley glacier
continental glacier
cirque
moraine
outwash plain
drumlin
esker
kame
kettle

Glaciers

MAIN Idea **Glaciers modify landscapes by eroding and depositing rocks.**

Real-World Reading Link Have you ever wondered what formed the landscape around you? Glaciers might have left deposits of sediment as well as carved features in rock that you see every day.

Moving Masses of Ice

A large, moving mass of ice is called a **glacier.** Glaciers form near Earth's poles and in mountainous areas at high elevations. They currently cover about 10 percent of Earth's surface, as shown in **Figure 8.20.** In the past, glaciers were more widespread than they are today. During the last ice age, which began about 1.6 mya and ended more than 10,000 years ago, ice covered about 30 percent of Earth.

Areas at extreme northern and southern latitude, such as Greenland and Antarctica, and areas of high elevations, such as the Alps, have temperatures near 0°C year-round. Cold temperatures keep fallen snow from completely melting, and each year the snow that has not melted accumulates in an area called a snowfield. Thus, the total thickness of the snow layer increases as the years pass. The accumulated snow develops into a glacier. The weight of the top layers of snow eventually exerts enough downward pressure to force the accumulated snow below to recrystallize into ice. A glacier can develop in any location that provides the necessary conditions. Glaciers can be classified as one of two types—valley glaciers or continental glaciers.

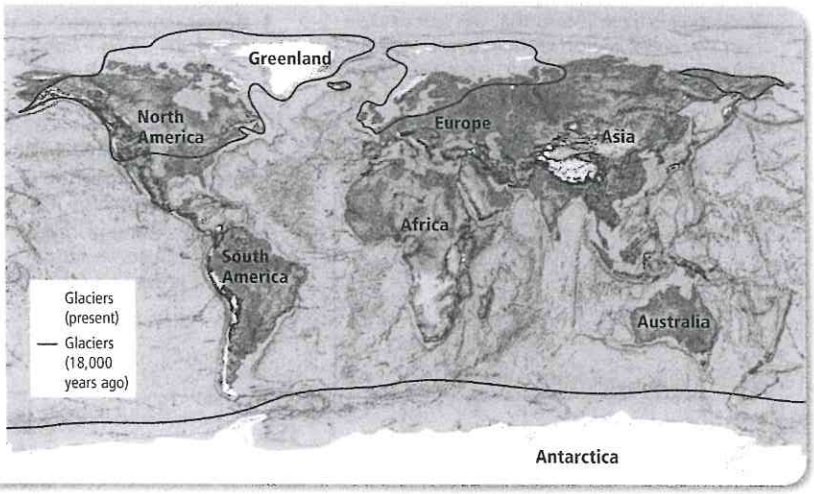


Figure 8.20
Glaciers around the world have changed in distribution throughout geologic time.
Infer *what changes have occurred in the distribution of glaciers around the world.*

Concepts In Motion
Interactive Figure To see an animation of glacier formation, visit glencoe.com.

In the Field

Preserved in the Glacial Ice He might have been a traveling salesman, a sheepherder, or a hunter; what is fairly certain is that he lived around 2000 B.C. This Copper Age "Ice Man," discovered in 1991 by a group of hikers in the Alps on the border of Italy and Austria, is one of the oldest, most complete, and best-preserved mummified bodies ever found. His tool kit and fragments of his clothes, including a leather boot stuffed with grass, were found to be amazingly intact. Scientists theorize that the body was naturally preserved in an airtight pocket of glacial ice. The remains are kept in a bulletproof refrigerated case in a northern Italian town. Hundreds of tourists visit every year to wonder about the identity, the cultural origins, and the tragic fate of the mysterious Ice Man.

1 Focus

Focus Transparency

Before presenting the lesson, project **Section Focus Transparency 22** and have students answer the accompanying questions. EL

MAIN Idea

Glacial Features Show students an older photo of a valley glacier in a valley and a more recent photo after a valley glacier receded. Ask them to identify the features left by the glacier. U-shaped valley, scratches and grooves, outwash plain, hanging valleys

2 Teach

Teacher Content Support

Glaciers Most of Earth's freshwater supply is locked up in the form of glaciers. Glaciers are found in areas where climatic conditions can sustain their formation and preservation year-round. Today, most of the glaciers on Earth exist in Greenland and Antarctica, but they can also be found at high elevations on most continents.

Earth has experienced ice ages for approximately 20–30 percent of its history. The most recent ice age occurred during the Pleistocene Epoch and ended approximately 10,000 years ago. Since then, Earth has been experiencing an interglacial period with temperatures approximately 15°C warmer, resulting in the melting of most of the glaciers formed during that time.

Caption Question Fig. 8.20
There are fewer glaciers now than in the past.

Concepts In Motion
Interactive Figure Students can see an animation of glacier formation at glencoe.com.

Teacher Content Support

Glacial Budget Glaciers form when more snow falls annually than melts or evaporates. Freshly fallen snow has a low density; generally, its volume consists of as much as 90 percent air. However, the snow quickly settles and compacts to the point at which air might comprise 50 percent or less of its volume. As the snow becomes packed, along with some melting and refreezing, the snow becomes even more compact. The accumulation of snow over the years leads to the formation of large snowfields. The pressure of overlying snow results in the recrystallization of the snow into ice and thus the formation of a glacier. Close inspection of glacial ice has revealed a crystal pattern similar to the patterns of coarse-grained rocks such as granite.

DATA ANALYSIS LAB

About the Lab

- Ask students whether they know of any method used to determine what Earth's climates were like hundreds of years ago.
- See also Etheridge, D. M., G. I. Pearman, and P. J. Fraser. 1992. Changes in tropospheric methane between 1841 and 1978 from a high accumulation rate Antarctic ice core. *Tellus B* 44 (4): 282–294.

Think Critically

1. The highest amount of radioactivity was between 410–425 cm. The lowest amount was between 115–150 cm.
2. Radioactivity levels dropped in the ice cores.
3. The amount of radioactivity in the ice cores probably decreased unless there were other nuclear accidents.
4. Ice cores contain whatever material was in the atmosphere and indicate human activities such as nuclear testing and natural activities such as volcanic eruptions.

FOLDABLES
Incorporate information from this section into your Foldable.

Valley glaciers Glaciers that form in valleys in high, mountainou areas are called **valley glaciers.** The movement of a valley glacier occurs when the growing ice mass becomes so heavy that the ice maintains its rigid shape and begins to flow, much like toothpaste. Fo most valley glaciers, flow begins when the accumulation of snow and ice exceeds 20 m in thickness. As a valley glacier moves, deep cracks i the surface of the ice, called crevasses, can form.

The speed of a valley glacier's movement is affected by the slope of the valley floor, the temperature and thickness of the ice, and the shap of the valley walls. The sides and bottom of a valley glacier move more slowly than the middle because friction slows down the sides and bottom where the glacier comes in contact with the ground. Movement downslope is usually slow—less than a few millimeters per day. Over time, as valley glaciers flow downslope, their powerful carving action transitions V-shaped stream valleys into U-shaped glacial valleys.

Reading Check **Describe** how V-shaped valleys become U-shaped.

Continental glaciers Glaciers that cover broad, continent-sized areas are called **continental glaciers.** These glaciers form in cold climates where snow accumulates over many years. A continental glacier is thickest at its center. The weight of the center forces the rest of the glacier to flatten in all directions. In the past, when Earth experienced colder average temperatures than it does today, continental glaciers covered huge portions of Earth's surface. Today, they are confined to Greenland and Antarctica.

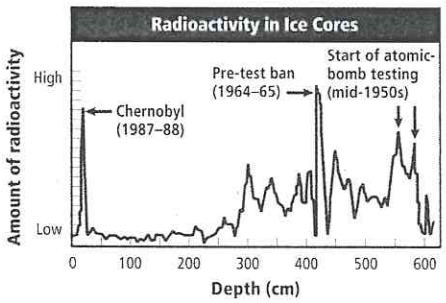
DATA ANALYSIS LAB

Based on Real Data*

Interpret the Data

How much radioactivity is in ice cores?
Glaciologists have found that ice cores taken from the arctic region contain preserved radioactive fallout. Data collected from the study of these ice cores have been plotted on the graph.

Data and Observations



Think Critically

1. **Determine** the depth in the ice cores where the highest and lowest amounts of radioactivity were found.
2. **Describe** what happened to the amount of radioactivity in the ice cores between the pretest ban and Chernobyl.
3. **Infer** what happened to the amount of radioactivity in the ice cores after Chernobyl.
4. **Explain** what information or material other than radioactive fallout you think ice cores might preserve within them.

*Data obtained from: Mayewski, et al. 1990. Beta radiation from snow. *Nature* 345:25.

Reading Check Glacial erosion transforms a V-shaped valley to a U-shaped valley.

FOLDABLES

RUBRIC available at glencoe.com

Earth Science Journal

Valley and Continental Glaciers

Ask students to use their textbooks and other resources to make a table in their Earth science journals to compare valley and continental glaciers. Students should include the characteristics of the glaciers, including thickness and coverage. OL

RUBRIC available at glencoe.com

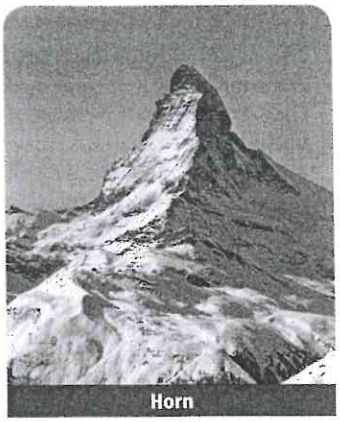


Figure 8.21 Glacial erosion by valley glaciers creates features such as cirques, horns, and hanging valleys.

acial movement Both valley glaciers and continental gla-
rs move outward when snow gathers at the zone of accumula-
n, a location in which more snow falls than melts, evaporates, or
olimates. For valley glaciers, the zone of accumulation is at the
o of mountains, while for continental glaciers, the zone of accu-
ılation is the center of the ice sheet. Both types of glaciers recede
ıen the ends melt faster than the zone of accumulation builds up
ow and ice.

lacial Erosion

all the erosional agents, glaciers are the most powerful because of
eir great size, weight, and density. When a valley glacier moves, it
eaks off pieces of rock through a process called plucking. When
ıciers with embedded rocks move over bedrock, they act like the
ains on a piece of sandpaper, grinding parallel scratches into the
drock. Small scratches are called striations, and larger ones are
lled grooves. Striations and grooves provide evidence of a glacier's
story and indicate its direction of movement.

Glacial erosion by valley glaciers can create features like those
own in **Figure 8.21.** At the high elevations where snow accumu-
es, valley glaciers also scoop out deep depressions, called
rques. Where two cirques on opposite sides of a valley meet, they
rm a sharp, steep ridge called an arête. When there are glaciers
ı three or more sides of a mountaintop, the carving action creates
steep, pyramid-shaped peak. This is known as a horn. The most
mous example of this feature is Switzerland's Matterhorn.

Valley glaciers can also leave hanging valleys in the glaciated
ndscape. Hanging valleys are formed when tributary glaciers con-
erge with the primary glaciers and later retreat. The primary gla-
er is so thick that it meets the height of the smaller tributary
acier. When the glaciers melt, the valley is left hanging high
ɔove what is now a river in the primary valley floor. Hanging val-
ys today are often characterized by waterfalls where the tributary
lacier used to be.

Identify Misconceptions

Students might think that Earth's surface generally stays the same in most places.

Uncover the Misconception
Ask students to describe how the local landscape has changed over 100, 1000, 10,000, and 100,000 years.

Demonstrate the Concept
Show the class some evidence of change in examples such as the following: an old photograph of a familiar place where change is evident, a rock with striations on it, and samples of soil and rocks. Explain that all these examples provide evidence that change is a constant occurrence on Earth's crust.

Assess New Knowledge
Ask students to describe in their Earth science journals how Earth's surface changes.

Across the Curriculum

Art Have students each draw with pencil or charcoal or paint with tempera or watercolor paints a landscape that includes glacial features. The glacial features should be labeled.

Demo

Model Downslope Movement
Mix flour with a little water to make a thick, doughlike mixture. Place the dough on an inclined board and have students check the position of the dough several times during the class period. Place toothpicks in different locations on the dough so students can observe changes in the position of the toothpicks. OL

Caption Question Fig. 8.22 On a topography map, a drumlin will resemble a hill with one side steeper than the other.

Figure 8.22 Elongated landforms called drumlins can be grouped together as a drumlin field in areas once covered by continental glaciers.
Describe *how you could identify a drumlin on a topographic map.*

Glacial Deposition

Glacial till is the unsorted rock, gravel, sand, and clay that glaciers carry embedded in their ice and on their tops, sides, and front edge. Glacial till is formed from the grinding action of the glacier on underlying rock. Glaciers deposit unsorted ridges of till called **moraines** when the glacier melts. Terminal moraines are found alo the edge where the retreating glacier melts, and lateral moraines are located parallel to the direction of a valley glacier flow.

Outwash When the farthest ends of a glacier melt and the glaci begins to recede, meltwater floods the valley below. Meltwater contains gravel, sand, and fine silt. When this sediment is deposited by meltwater carried away from the glacier, it is called outwash. Becau of the way water transports sediment, outwash is always sorted by particle size. The area at the leading edge of the glacier where the meltwater flows and deposits outwash is called an **outwash plain.**

Drumlins, eskers, and kames Continental glaciers that mov over older moraines form the material into elongated landforms call **drumlins,** shown in **Figure 8.22.** A drumlin's steeper slope faces th direction from which the glacier came. Streams flowing under meltir glaciers leave long, winding ridges of layered sediments called **eskers** shown in **Figure 8.23.** A **kame** is a mound of layered sediment deposited at the retreating glacier face and is conical in shape. Kames are also shown in **Figure 8.23.**

MiniLab

Model Glacial Deposition

How do glaciers deposit different types of rocks and sediments? Glaciers are powerful forces of erosion. As they move across the land, they pick up rocks and sediments, and carry them to new locations. When a glacier melts, these materials are left behind and deposits form in different shapes.

Procedure

1. Read and complete the lab safety form.
2. Work with a group of 2 to 3 other students. One student should obtain four **glaciers** from your teacher.
3. Place the glaciers on a **baking pan.** In front of each glacier, place a **popsicle stick** (to prevent the glacier from sliding down the pan).
4. Place a **textbook** under one end of the baking pan (your glaciers should be toward the elevated end of the pan).
5. Observe what happens as the glaciers melt. Record your observations in your science journal.
6. Dispose of your materials as your teacher instructs.

Analysis

1. **Discuss** Did the materials differ in the way they were deposited by the melting ice cubes? Were your results similar to those of your classmates? Explain.
2. **Explain** how this activity modeled the formation of meltwater.
3. **Apply** Which materials in this activity modeled glacial till?
4. **Apply** How did this activity model glacial deposition and the formation of a moraine?

MiniLab

See the MiniLab worksheet in your FAST FILE.

RUBRIC available at glencoe.com

Purpose Students will model glacial deposition by comparing four glaciers of different materials.

Process Skills observe and infer, describe, think critically

Additional Material Earth science journal

Safety Precaution Approve lab safety forms before work begins.

Teaching Strategy

- Save time by preparing the ice cubes before class. Prepare the glaciers by filling slots of an ice cube tray 1/2 full with either sand, soil, or aquarium gravel. Fill the rest with water and freeze overnight.
- Depending on the temperature of the classroom, the ice cubes will take 15–35 minutes to melt.
- Have students set up their trays at the beginning of the class period and then make their observations at the end of the period.
- Placing the ice cubes under a lamp will accelerate the rate of melting. Have students work in groups to compare glacial melting.

Expected Results Materials will be transported and deposited differently according to material type.

Analysis

1. Answers will vary depending on the materials used.
2. Meltwater formed from the melting ice cube just as meltwater forms from the melting glacier.
3. The materials embedded in the ice cube represented glacial till.
4. The ice cubes containing various sediments represented glaciers that had picked up rocks and other debris. The materials deposited by the ice cubes created small ridges that modeled moraines.

Assessment

Performance Have students use ice cubes with frozen sand to model the formation of lateral moraines, terminal moraines, and medial moraine.

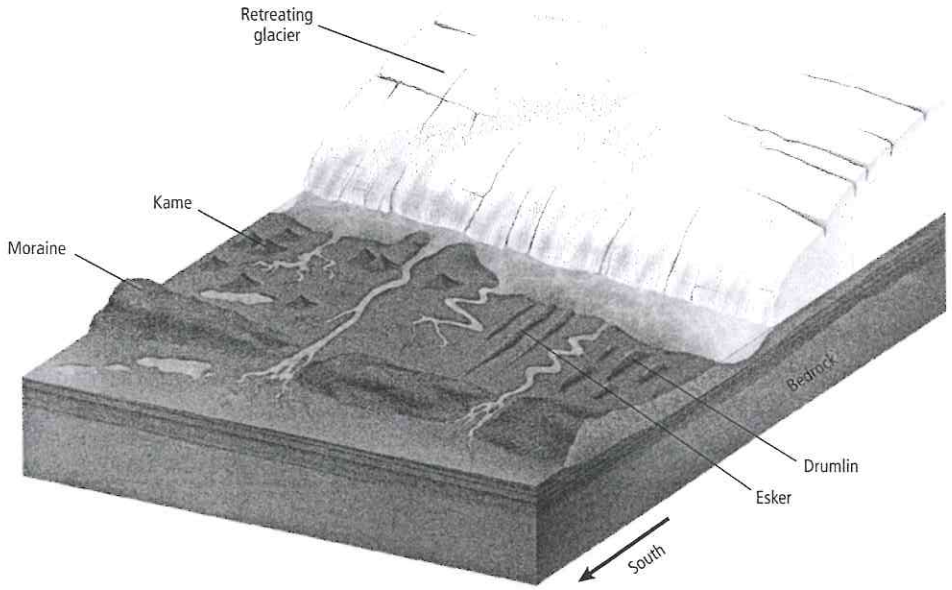
Demo

Model Moraines Have students create their own moraines by pushing a block of ice through a mixture of sand, soil, and pebbles on a slightly slanted board. They should identify the terminal and lateral moraines. As the ice melts, discuss outwash and have students identify where an outwash plain might occur. BL OL

Visualizing Continental Glacial Features

NATIONAL GEOGRAPHIC

gure 8.23 Continental glaciers carve out vast regions of landscape, leaving behind distinctive features ch as kames, eskers, drumlins, and moraines.



ames are short cone-shaped mounds of rted deposits. They are shaped from out- ash left as glaciers recede.

Eskers are long ridges of sorted deposits. They are shaped from outwash deposited by water flowing through tunnels in the glacier.

Drumlins are shaped as the glacier moves over old moraines. They are unsorted.

Concepts In Motion To explore more about glacial features, visit glencoe.com.

Earth Science Online

Purpose

Students will compare and contrast continental glacial features.

Discussion

Glacial Melting Share with students the fact that investigators at NASA have used satellite imagery, airborne laser altimeter flights, and the Global Positioning System to determine that Greenland's ice sheets are experiencing an increase in the rate of melting. Ask students to share their thoughts about the reason for the apparent increase in melting rate. Responses might include global warming and El Niño. Students might wish to know what information is available about coastline changes resulting from the increase in melting rates. Effects on shorelines have been negligible, but if the melting rate continues to increase, changes in coastlines will occur. AL

Model

Glacial Landscapes Have students use clay to model glacial landscapes. List the features that students should include in their models, such as moraines, drumlins, eskers, and kames. BL EL

Concepts In Motion Students can explore more about glacial features at glencoe.com.

Earth Science Online

Demo

Model Outwash Place a plastic bag full of water in a freezer. Once it is frozen, remove the ice from the plastic bag and place it on a large tray that has soil evenly spread over it. Slightly incline the tray by placing a book under one end. Sprinkle dirt randomly on the block of ice. Have students monitor the changes in the block of ice. Allow the block of ice to melt, and then have students compare the patterns of runoff and deposition to those of a glacial landscape. BL

Caption Question Fig. 8.24
Kettles would appear as depressions on a topographic map.

3 Assess

Check for Understanding

Summarize Have each student develop five review questions. Collect all questions and randomly select questions for members of two opposing teams to answer.

Reteach

Observe and Infer Show a video about glaciers that will review the features covered in the section. Provide students with a list of features to check off as they view the video.

Assessment

Skill Have students each develop a concept map using the following terms and phrases: *valley glacier, continental glacier, V-shaped valley, U-shaped valley, cirque, more snow falls than melts each year, high elevations, large broad areas,* and *till.* More snow falls than melts each year → 1) high elevations → valley glacier → cirque → V-shaped valley → U-shaped valley → till; 2) large broad areas → continental glaciers → till. Use the Performance Task Assessment List for Concept Maps in **PASC,** p. 161.

Figure 8.24 These kettle lakes in North Dakota are a result of glacial retreat. **Describe** *how you might be able to locate kettles on a topographic map.*

VOCABULARY

SCIENCE USAGE V. COMMON USAGE

Kettle

Science usage: a steep-sided depression formed by a glacier

Common usage: a metallic pot used for cooking

Glacial lakes Sometimes, a large block of ice breaks off a continental glacier and the surrounding area is covered by sediment. When the ice block melts, it leaves behind a depression called a kettle hole. After the ice block melts, the kettle hole fills with water from precipitation and runoff to form a kettle lake. **Kettles** or kettle lakes, such as those shown in **Figure 8.24,** are common in New England, New York, and Wisconsin. With valley glaciers, cirques can also fill with water, and they become cirque lakes. When a terminal moraine blocks off a valley, the valley fills with water to form a lake. Moraine-dammed lakes include the Great Lakes and the Finger Lakes of northern New York, which are long and narrow.

Mass movements, wind, and glaciers all contribute to the changing of Earth's surface. These processes erode landforms constantly, and in many ways, they also impact human populations and activities.

Section 8.3 Assessment

Section Summary

- Glaciers are large moving masses of ice that form near Earth's poles and in mountain areas.
- Glaciers can be classified as valley glaciers or continental glaciers.
- Glaciers modify the landscape by erosion and deposition.
- Features formed by glaciers include U-shaped valleys, hanging valleys, moraines, drumlins, and kettles.

Understand Main Ideas

1. MAIN Idea **Describe** two examples of how glaciers modify landscapes.
2. **Explain** how glaciers form.
3. **Compare and contrast** the characteristics of valley glaciers and continental glaciers.
4. **Differentiate** among different glacial depositional features.

Think Critically

5. **Evaluate** the evidence of past glaciers that can be found on Earth today.
6. **Infer** whether valley glaciers or continental glaciers have shaped more of the landscape of the United States.

WRITING in Earth Science

7. Deduce how you might distinguish a lake formed in a cirque and a lake formed in a kettle.

Section 8.3 Assessment

1. Through erosion, glaciers can create cirques, horns, or hanging valleys. Through deposition, glaciers can create drumlins, eskers, and kames.
2. Glaciers form when cold temperatures prevent fallen snow from completely melting, so that the accumulated snow develops into a glacier. The weight of the top layers of snow exert pressure to force the snow to recrystallize.
3. Valley glaciers are much smaller than continental glaciers. They form in the valleys of high mountains and move down the valley when they become too heavy to contain their ridged shape. Continental glaciers cover continents. They are thickest in the center and thin out around the edges.
4. The outwash plain is the surface over which meltwater flows. Drumlins are elongated mounds, eskers are winding ridges, and kames are mounds.
5. Evidence of past glacial activity includes depositional features, such as drumlins, eskers, and kames, and erosional features, such as cirques and horns.
6. Continental glaciers have the power to shape great parts of the landscape, and have affected much of the continents of the northern hemisphere. Valley glaciers can carve dramatic features, but affect less in terms of area.
7. **RUBRIC** available at glencoe.com Shape and location might distinguish lake types.