7 Glaciers, Deserts, and Wind

Big idea

Weathering and Erosion

Q: What surface features do ice, water, and wind form?

A glacier slowly advances down a valley in Alaska's Glacier Bay National Park.

VIRGINIA SCIENCE STANDARDS OF LEARNING

ES.1.b, ES.1.c, ES.1.d, ES.1.f, ES.2.c, ES.7.a. **See lessons for details.**

INQUIRY
TRY IT!

HOW DOES PRESSURE AFFECT ICE CRYSTALS?

Procedure

1. Obtain a beaker full of ice crystals, either by collecting snow outside or by scraping ice crystals from the inside surfaces of a freezer. Use a hand lens to observe the loose crystals. Sketch their appearance in your science notebook.
2. Use your hands to mold a snowball from the crystals. Then squeeze the snowball as hard as you can, making the snowball compact.
3. Use a table knife to cut the snowball in half. Observe the compressed crystals with your hand lens and sketch them.

Think About It

1. **Draw Conclusions** How did the ice crystals change after you squeezed them? Describe how pressure seems to affect ice crystals.
2. **Predict** The raw material for glaciers is snow. Predict how snowflakes will change under the increasing pressure of overlying snow.

7.1 Glaciers

ES.7 The student will investigate and understand geologic processes including plate tectonics. Key concepts include **a.** geologic processes and their resulting features.

Key Questions

What are the two types of glaciers?

How do glaciers move?

What distinguishes the various types of glacial drift?

What landscape features do glaciers form?

Describe the causes of the most recent ice age.

Vocabulary

- ice age
- glacier
- snowline
- valley glacier
- abrasion
- till
- moraine
- drumlin
- esker

Reading Strategy

Build Vocabulary Draw a table similar to the one below that includes all the vocabulary terms listed for the section. As you read the section, define each vocabulary term in your own words.

Vocabulary Term	Definition
Glacier	a. ?
Snowline	b. ?
Moraine	c. ?
Till	d. ?

CLIMATE IS a major factor in the processes that shape Earth's surface. In this lesson, you will learn about the strong link between climate and geology in studying how glaciers shape the land.

Types of Glaciers

As recently as 15,000 years ago, Earth was coming out of an ice age. An **ice age** is a period of time when much of Earth's land is covered in glaciers. A **glacier** is a thick ice mass that moves slowly over the land surface. About 15,000 years ago, up to 30 percent of Earth's land was covered by glaciers. In some areas, the glaciers were thousands of meters thick and covered entire continents. These massive glaciers shaped places such as Cape Cod, Long Island, and the Great Lakes. Today glaciers still cover nearly 10 percent of Earth's land area. In these regions, they continue to sculpt the landscape.

FIGURE 1 Valley Glacier A glacier in Alaska's Chugach Mountains slowly advances down this valley.

Glaciers originate on land in places where more snow falls than melts. The **snowline** is the lowest elevation in a particular area that remains covered in snow all year. At the poles, the snowline occurs at sea level. Closer to the equator, the snowline is near the top of tall mountains. Instead of completely melting away, snow above the snowline accumulates and compacts. The compressed snow fi st recrystallizes into coarse grains of ice. Further pressure from added snow above changes the coarse grains into interlocking crystals of glacial ice.

A glacier appears to be motionless, but it's not. Sit beside a glacier for an hour and you may hear a sporadic chorus of creaks, cracks, and groans as gravity pulls the mass of ice slowly downhill. Just like running water, groundwater, wind, and waves, glaciers are dynamic agents of erosion. They accumulate, transport, and deposit sediment. Thus, glaciers are an important part of the rock cycle. **There are two main types of glaciers: valley glaciers and ice sheets**.

Valley Glaciers Thousands of small glaciers exist in high mountains worldwide. These glaciers advance anywhere from a few centimeters to a few meters each day. **Valley glaciers** are ice masses that slowly advance down valleys that were originally occupied by streams. Valley glaciers flow between steep rock walls from the top of mountain valleys. Like rivers, valley glaciers can be long or short, wide or narrow, single or with branching tributaries. **Figure 1** shows a valley glacier in Alaska.

Ice Sheets In contrast to valley glaciers, *ice sheets* are enormous ice masses that flow in all directions from one or more centers and cover everything but the highest land. Ice sheets are sometimes called continental glaciers because they cover large regions, such as Antarctica and Greenland. They are huge compared to valley glaciers. Ice sheets covered much of North America during the recent ice age. **Figure 2** shows the two remaining ice sheets, which combined cover almost 10 percent of Earth's land area. One ice sheet covers about 80 percent of Greenland. It averages nearly 1500 meters thick, and in places it rises to 3000 meters above sea level.

The huge Antarctic Ice Sheet in the Southern Hemisphere is nearly 4300 meters thick in places. This glacier accounts for 90 percent of the world's ice, and it holds nearly two-thirds of Earth's fresh water. If it melted, sea level could rise 60 to 70 meters and many coastal cities would flood.

Reading Checkpoint *Where do ice sheets exist on Earth today?*

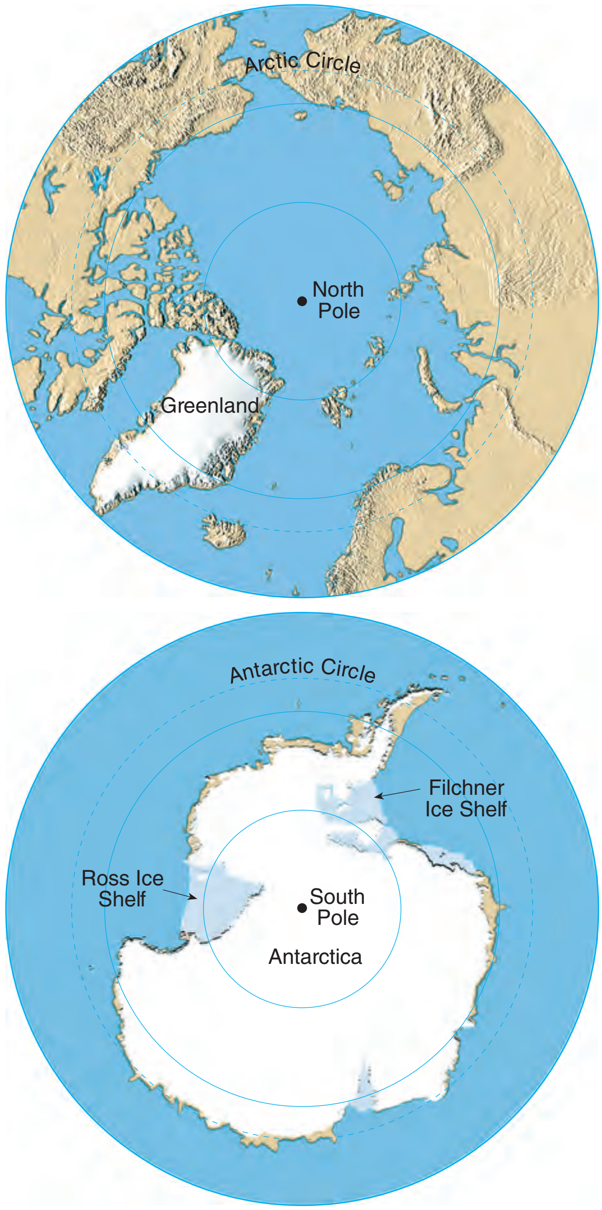


FIGURE 2 Ice Sheets The only present-day ice sheets are those covering Greenland and Antarctica.

How Glaciers Move

You might wonder how a glacier, which is solid, can move. **The movement of glaciers is referred to as flow. Glacial flow happens in two ways: plastic flow and basal slip.** Plastic flow involves movement within the ice. Under high enough pressure, the normally brittle ice begins to distort and change shape—a property known as *plasticity*. The weight of overlying ice exerts pressure on the ice below, causing it to flow. Plastic flow begins at about 50 meters below the glacier surface. Basal slip is the second cause of glacial movement. In basal slip, liquid water and mud at the bottom of the glacier reduce the friction between the glacier and the ground. The reduced friction and gravity cause the entire ice mass to slip and slide downhill.

The upper 50 meters of a glacier is not under enough pressure to have plastic flow. This layer of a glacier, called the *zone of fracture*, is brittle. The zone of fracture rides on the flowing ice below and experiences tension when the glacier moves over irregular terrain. This tension results in gaping cracks called *crevasses*, as shown in **Figure 3.** Crevasses are often hidden by snow and make travel across glaciers dangerous.

FIGURE 3 Zone of Fracture
Crevasses, such as this one in Pakistan, can extend 50 meters into the brittle, top layer of a glacier known as the zone of fracture.

Rates of Glacial Movement Different glaciers move at different speeds. Some flow so slowly that trees and other vegetation grow in the debris on their surface. Other glaciers can advance several meters per day. Some glaciers alternate between periods of rapid movement and periods of relatively little movement.

Budget of a Glacier Glaciers constantly gain and lose ice. Glaciers gain ice when snow accumulates and becomes ice at the head of the glacier in the *zone of accumulation*, shown in **Figure 4.** Here new snowfall thickens the glacier and promotes movement downhill. The area of the glacier below the snowline is called the *zone of wastage*. Here, the glacier loses mass as ice and any new snow melts away.

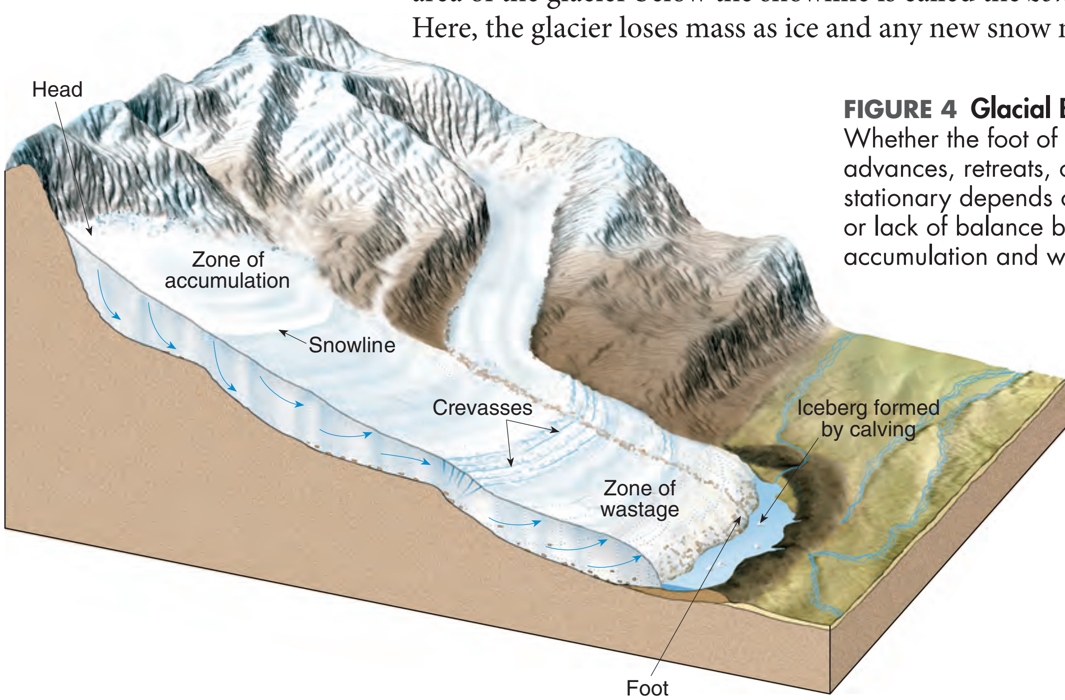


FIGURE 4 Glacial Budget
Whether the foot of a glacier advances, retreats, or remains stationary depends on the balance or lack of balance between accumulation and wastage.

FIGURE 5 Calving A Ice calves from the front of the Perito Moreno Glacier in Patagonia, Argentina. **B** Only 10 percent of an iceberg's mass is visible above the surface.

Whether the foot of a glacier advances, retreats, or stays in place depends on the glacier's budget. The glacial budget is the balance or lack of balance between accumulation at the head of a glacier and loss, or wastage, at the foot. If more ice builds up in the zone of accumulation than is lost from the zone of wastage, then the glacier advances. The glacier retreats when it loses ice faster than it gains ice. If a glacier gains ice at the same rate as it loses ice, the foot of the glacier remains stationary. Whether the foot of a glacier advances, retreats, or remains stationary, the ice within the glacier continues to flow downhill. In the case of a retreating glacier, the ice still flows downhill, but not rapidly enough to offset wastage.

In addition to melting, a glacier loses ice when large pieces break off t its foot. This process is called *calving*. Calving occurs where glaciers meet the ocean, as shown in **Figure 5A.** The pieces that break off i to the ocean are called *icebergs*. Because icebergs are just slightly less dense than seawater, they float low in the water. Only about 10 percent of their mass is visible above the surface, as shown in **Figure 5B.** The Greenland Ice Sheet calves thousands of icebergs each year. Many drift southward into the North Atlantic where they are hazardous to ships.

☐ **Reading Checkpoint** *What causes a glacier to retreat?*

PLANET DIARY

For links about **Glaciers,** go to PlanetDiary.com/HSES

FIGURE 6 **Glacial Abrasion**
A glacier smoothed and polished these rock surfaces in Canada's Hudson Bay. Rock fragments embedded in the glacier carved the scratches and grooves.

Glacial Erosion

Glaciers are nature's bulldozers. Their ice scrapes, scours, and tears rock from valley floors and walls. Glaciers then carry the rock fragments down the valley. They can carry rocks as big as buses over long distances. Some of these rock fragments become embedded in the bedrock under the weight of the glacier. The rest of the rock fragments drop at the glacier's foot.

Today's glaciers have limited importance as erosional agents as compared to the glaciers of the most recent ice age. **Many landscapes were changed by the widespread glaciers of the recent ice age.** These landscapes show the erosional power of ice.

How Glaciers Erode Glaciers mainly erode the land in two ways: *plucking* and *abrasion*. Plucking occurs when rocks and sediments from the bedrock become embedded in the ice as the glacier flows past them. Some of these rocks are plucked from the bedrock once they have been loosened by repeated cycles of water melting and freezing. When water freezes in cracks in the bedrock, it expands and pries the rock apart.

Abrasion is the second method of erosion. **Abrasion** occurs as the glacial ice and its load of rock fragments slide over bedrock. The fragments act like sandpaper to smooth and polish the rock surface below. Some of the bedrock and some of the rock carried by the glacier are crushed into fi ely grained rock particles, called rock flour. So much rock flour may be produced that streams of meltwater leaving the glacier often have the grayish appearance of skim milk. When the bottom of a glacier contains large rock fragments, long scratches and grooves may be gouged in the bedrock, as shown in **Figure 6.** These grooves, or striations, provide valuable clues to the direction of past glacial movement. By mapping the striations over large areas, geologists often can reconstruct the direction in which the ice flowed.

As is the case with other erosional agents, the rate of glacial erosion varies. Four factors determine the rate of glacial erosion: 1) rate of glacial movement; 2) thickness of the ice; 3) shape, amount, and hardness of the rock fragments in the ice at the bottom of the glacier; and 4) the type of surface below the glacier. The highest rates of erosion occur when glaciers that are very thick flow quickly, carrying lots of hard rocks over a much softer bedrock.

Reading Checkpoint *How do glaciers cause erosion?*

Landforms Formed by Glacial Erosion

Erosion by valley glaciers produces many spectacular features in mountainous areas. **Glaciers produce a variety of erosional landscape features, such as glacial troughs, hanging valleys, cirques, arêtes, and horns.** Compare and contrast the topography of the mountain setting in **Figure 7** before, during, and after glaciation. *Glaciation* is a period of time within an ice age that is marked by colder temperatures and glacier advances.

Glaciated Valleys Before glaciation, alpine valleys are usually V-shaped as a result of erosion by mountain streams. However, in mountain regions that have been glaciated, the valleys are no longer narrow. As a glacier moves down a valley once occupied by a stream, the glacier widens, deepens, and straightens the valley. The once narrow V-shaped valley is changed into a U-shaped valley, which is also called a *glacial trough.*

The amount of glacial erosion depends on the thickness of the ice flowing through a valley. For example, the amount of ice flowing through a main valley can be much greater than the amount advancing down smaller, side valleys that join the main valley. As a result, the main valley is eroded deeper than the smaller valleys, forming a glacial trough that is also deeper. When the ice retreats, the side valleys are left tanding higher than the main valley. These higher valleys are called *hanging valleys*. Rivers flowing from hanging valleys sometimes produce spectacular waterfalls, such as those in Yosemite National Park, California.

Reading Checkpoint *What is a glacial trough?*

VISUAL SUMMARY

FORMATION OF LANDFORMS BY VALLEY GLACIERS

FIGURE 7 **1.** Before glaciation, stream erosion formed a network of V-shaped valleys. **2.** The valley glacier erodes the mountainous region during glaciation. **3.** After glaciation, the landscape contains several erosional features.
Predict *What will happen to the glacial trough as the stream continues to flow through it?*

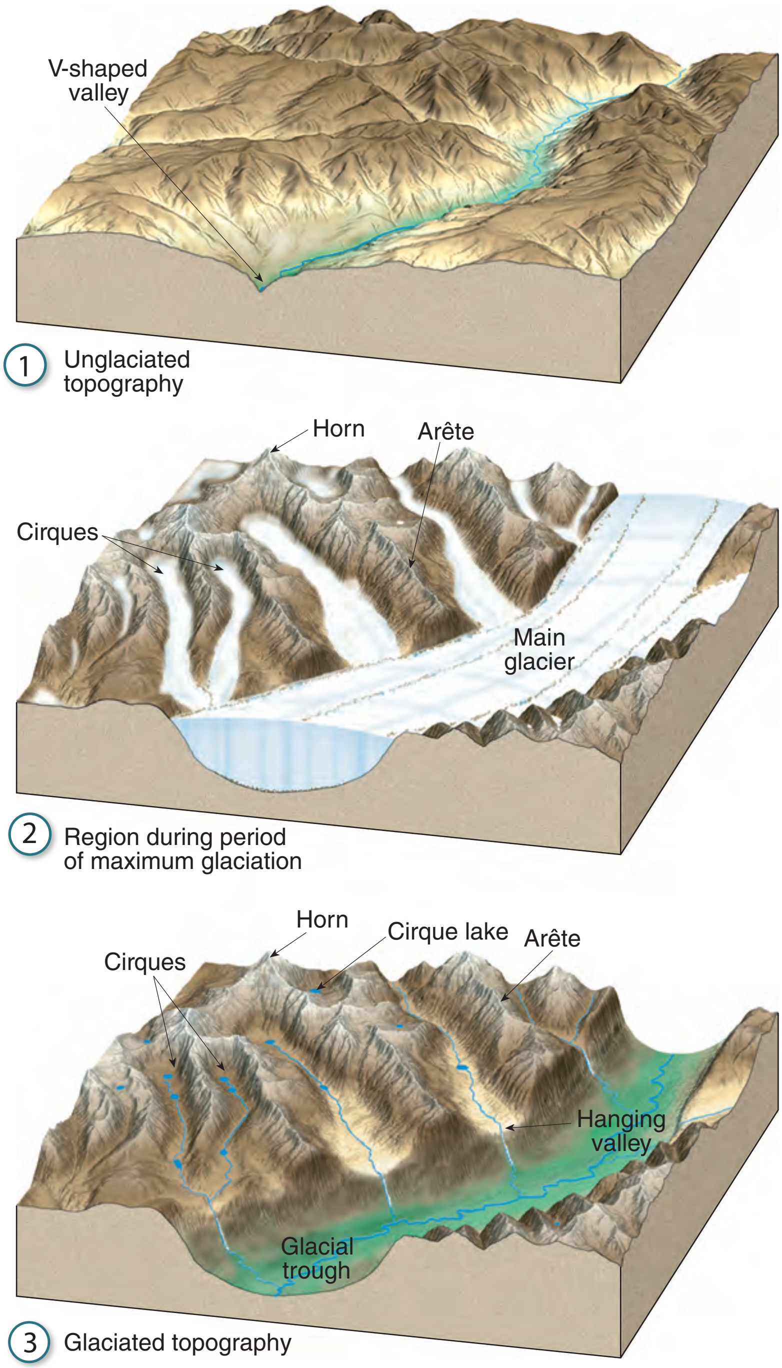


FIGURE 8 Cirque The plucking action of ice in a glacier's zone of accumulation produced this cirque in Canada's Yukon Territory.

Cirques A *cirque* is a bowl-shaped depression at the head of a glacial valley that is surrounded on three sides by steep rock walls, as shown in **Figure 8.** Cirques begin as irregularities in the mountainside. Glaciers carve cirques by plucking rock from along the sides and the bottom. The glaciers then act as conveyor belts that carry away the debris. Sometimes the melting glacier leaves a small lake, called a *cirque lake*, in the cirque basin.

Arêtes and Horns Valley glaciers also create snaking, sharp-edged ridges called *arêtes* and sharp, pyramid-like peaks called *horns*. Both of these features form because glacial erosion causes cirques to get bigger. Arêtes form where cirques occur on opposite sides of a divide. As the cirques get bigger, the divide separating them is reduced to a narrow, sharp ridge. Horns such as the Matterhorn in the Swiss Alps form when several cirques surround a single, high mountain. As the cirques get bigger, an isolated horn is produced.

Glacial Deposition

Glaciers transport huge loads of debris as they slowly advance across the land and deposit their loads where they melt. For example, in many areas once covered by the ice sheets of the recent ice age, the bedrock is rarely exposed because glacial deposits that are dozens—or even hundreds—of meters thick completely cover the terrain. Rocky pastures in New England, wheat fields in the Dakota plains, and rolling Midwest farmland are all landscapes resulting from glacial deposition. **The term *glacial drift* applies to all of the rock debris of glacial origin, no matter how, where, or in what form it was deposited. There are two types of glacial drift: ill and stratified drift.**

Till is material deposited directly by the glacier. It is deposited as the glacier melts and drops its load of rock debris. Rock debris does not sort in moving ice as it does in moving water and wind. Therefore, till deposits are usually mixtures of many particle sizes. Notice the unsorted till in **Figure 9.**

Stratified drift is rock debris laid down by glacial meltwater. Stratified drift contains particles that are sorted according to size and mass. Sand and gravel often make up stratified drift ecause fi er sediments remain suspended and are carried far from the glacier.

Rocks that are transported by a glacier and that differ from the underlying bedrock are called *erratics*. Erratics can range in size from small pebbles to huge boulders. Geologists can sometimes reconstruct the path of a long-gone glacier by tracing erractics back to their source.

Reading Checkpoint *What is glacial drift?*

FIGURE 9 Glacial Till This unsorted mixture of many different sediment sizes is glacial till. The inset photo shows the scratches a rock likely got from being dragged along by a glacier.

FIGURE 10 Medial Moraines The dark stripes running down the length of this glacier are medial moraines. They formed when valley glaciers merged and flowed together.

Moraines, Outwash Plains, and Kettles

Glaciers are responsible for a variety of depositional features, including moraines, outwash plains, kettles, drumlins, and eskers. When glaciers melt, they leave layers or ridges of till called **moraines.** These widespread glacial features come in several varieties.

Lateral and Medial Moraines The sides of a valley glacier gather large amounts of debris from the valley walls. *Lateral moraines* are ridges that form along the sides of glacial valleys from rock fragments that fall from the valley walls along the edge of the glacier. *Medial moraines* form when two valley glaciers join to form a single ice stream. The till that was once carried along the edges of each glacier joins to form a dark stripe of debris within the newly enlarged glacier as shown in **Figure 10.**

End Moraines and Ground Moraines Although the ice within a glacier continues to flow downhill, the foot of a glacier can remain stationary for long periods of time. This occurs when snow and ice build up in the zone of accumulation at the same rate that snow and ice melt in the zone of wastage. A glacier acts as a conveyor belt to carry rock debris to the foot of the glacier. When the ice there melts, it deposits the debris and forms a ridge called an *end moraine*. The longer the glacier's foot remains stationary, the larger the end moraine will get.

Ground moraines form when glaciers begin to retreat. The glacier foot continues to deliver and deposit rock debris as the ice melts away. However, instead of forming a ridge, the retreating glacier forms a rock-strewn, gently rolling plain. This ground moraine fills in low spots and clogs old stream channels. Ground moraines can thus result in poorly drained swamp lands.

End Moraines A glacier can cycle many times between being stationary or in retreat before the glacier melts completely. A glacier forms a new end moraine during a stationary period, then another ground moraine during a retreat. The end moraines that form when the glacier is temporarily stationary are *recessional moraines*. The farthest end moraine is the *terminal moraine*. The only difference between recessional and terminal moraines is their relative positions.

End moraines that formed in the recent ice age are prominent in the landscapes of the Midwest and Northeast. New York's Long Island is part of a series of end moraines stretching from eastern Pennsylvania to Cape Cod, Massachusetts. **Figure 11** shows the locations of these end moraines that form part of the Northeast coast.

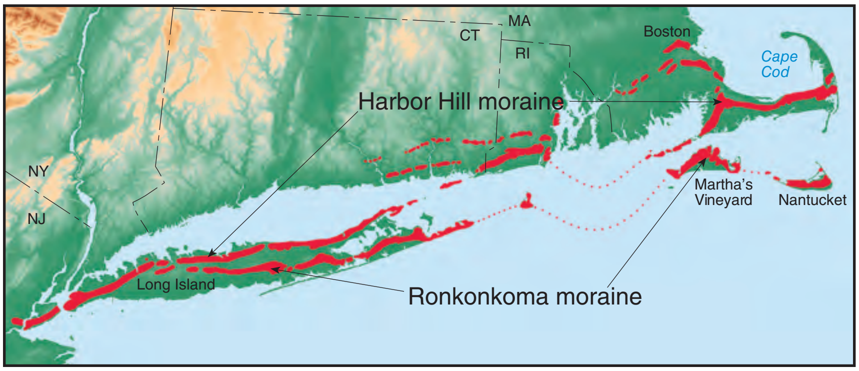


FIGURE 11 Ice Sheet Moraines Long Island, Cape Cod, Martha's Vineyard, and Nantucket are remnants of end moraines deposited by ice sheets.

Outwash Plains An outwash plain begins to form as streams of fast-moving meltwater emerge from the foot of a glacier. This water is often so choked with rock flour that it looks like milk. Once it leaves the glacier, the water slows and drops the rock debris in a broad, ramplike deposit downstream from the end moraine. This wide, gently sloping apron of rock debris is called an *outwash plain*.

Kettles and Kettle Lakes You can often fi d depressions and small lakes within end moraines and outwash plains. *Kettles* form when blocks of ice become buried in drift nd eventually melt. This melting leaves pits, or kettles, in the glacial rock material. If these kettles fill up with water, they are known as *kettle lakes*. Walden Pond in Concord, Massachusetts, shown in **Figure 12,** is a well-known example of a kettle lake. Thousands of kettle lakes dot the landscape of the Upper Midwest in Wisconsin and Minnesota.

FIGURE 12 A Kettle Lake Walden Pond, in Concord, Massachusetts, is a well-known example of a kettle lake. The writer, Henry David Thoreau, lived on the shores of the pond for two years starting in 1845.

Drumlins Moraines are not the only landforms deposited by glaciers. Some landscapes have many elongated parallel hills made of till, called **drumlins.** Drumlins are taller and steeper on one end, and they range in height from 15 to 60 meters and average 0.4 to 0.8 kilometer long. The steep side of the hill faces the direction the ice came from, and the gentler slope points in the direction the ice moved. In areas covered by ice sheets during the recent ice age, drumlins can occur in clusters called *drumlin fields*. Near Rochester, New York, one cluster contains nearly 10,000 drumlins. Their distinctive shapes show that they were molded by active glaciers.

Eskers Other areas have narrow, winding ridges made mainly of stratified drift, called **eskers.** Eskers are snakelike ridges composed of sand and gravel that were deposited by streams once flowing in tunnels beneath glaciers. They can be several meters high and many kilometers long. Many eskers are mined for their sand and gravel.

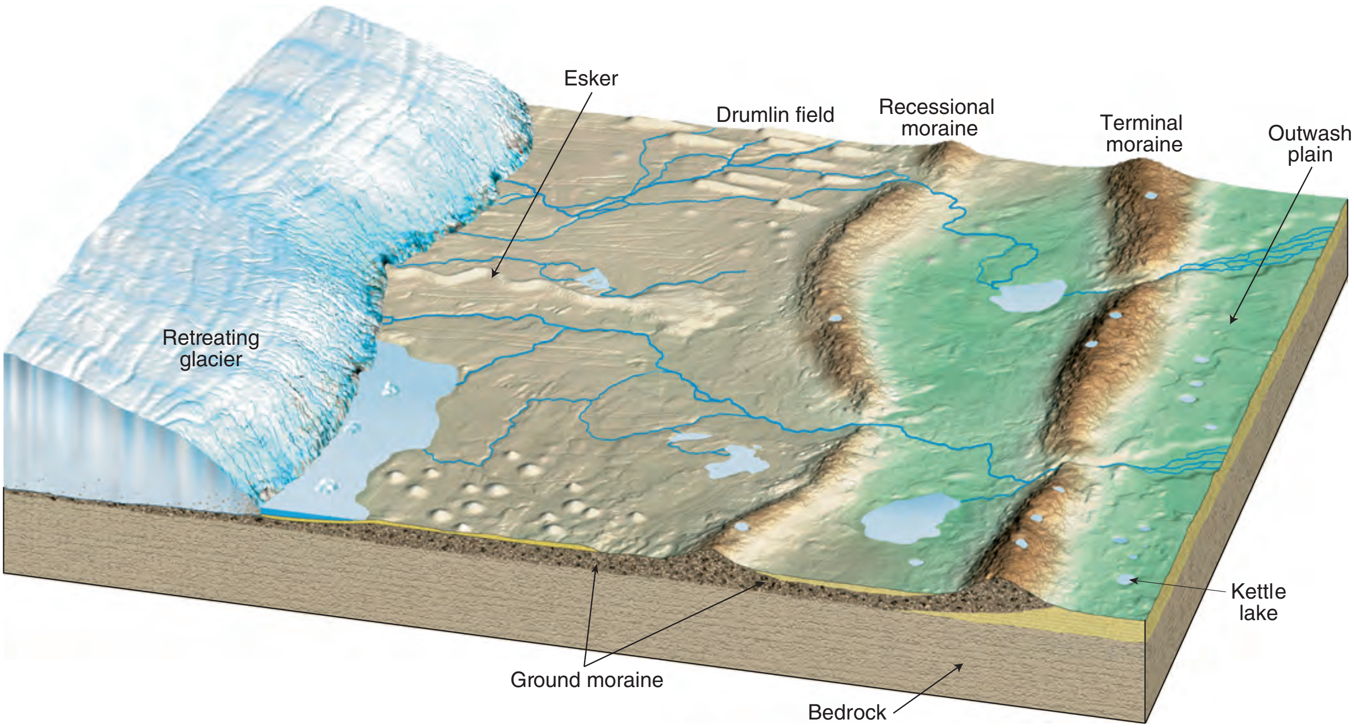


FIGURE 13 Glacial Deposition The terminal moraine marks the farthest extent of the glacier. Recessional moraines occur where a retreating glacier temporarily becomes stationary. **Infer** ***If the glacier were completely melted away, how would you be able to tell in which direction the glacier retreated?***

If you know what to look for, the signs of a once-glaciated landscape are unmistakable—especially from an airplane. **Figure 13** shows the depositional features of a glaciated landscape.

Reading Checkpoint *What depositional features do glaciers form?*

Glaciers of the Ice Age

Thousands of years ago, continental ice sheets and valley glaciers covered a lot more land than they do today. People once thought that glacial deposits had drifted in on icebergs or that they swept across the landscape in a catastrophic flood. However, scientific field investigations during the nineteenth century provided convincing evidence that an extensive ice age caused these deposits and many other features.

The most recent ice age is actually a series of glacial advances and retreats, which began two to three million years ago. **Continental glaciers repeatedly formed, spread, and melted as Earth's climate cooled and warmed. Each cycle of glaciation, or glacial period, lasted about 100,000 years.** Many of the glacial periods occurred while wooly mammoths and saber-toothed cats roamed the landscape.

FIGURE 14 **Ice Age** During the ice age, ice sheets covered large areas in the Northern Hemisphere. So much ice formed that sea level was more than 100 meters lower than it is today. (The map shows modern coastlines.)

Although the glaciers are in retreat right now, at the peak of this ice age, glaciers covered almost 30 percent of Earth's land. Glaciers covered large portions of North America, Europe, and Siberia, as shown in **Figure 14.** The Northern Hemisphere had twice as much ice as did the Southern Hemisphere, where glaciation was mostly confi ed to Antarctica.

Ice Age Effects on Drainage The ice sheets greatly affected the drainage patterns over large regions. For example, before glaciation, the Missouri River flowed through central Illinois northward toward Hudson Bay in Canada. Furthermore, the Great Lakes did not exist. Their locations were marked by lowlands with rivers that flowed toward the east. During the recent ice age, glacial erosion transformed these lowlands into wide, deep basins that filled with water and eventually became the Great Lakes.

The formation and growth of ice sheets triggered changes in climates beyond the glacial margins. This change in climate resulted in the formation of lakes in such areas as the Basin and Range region of Nevada and Utah. One of these lakes was ancient Lake Bonneville, which covered much of western Utah. The Great Salt Lake is all that remains of this glacial lake.

7.1 Assessment

Review Key Concepts

1. What are the two basic types of glaciers? Where is each type found?
2. Describe how glaciers move. Which property or properties of ice allow this movement?
3. How does glacial till differ from stratified drift? Describe one glacial feature made of each type of glacial drift.
4. Name three glacial features formed by erosion and three that are formed by deposition. What does each feature look like?

Think Critically

5. **Compare and Contrast** Compare and contrast advancing and retreating glaciers.
6. **Infer** The snowline at the poles is sea level. Close to the equator, the snowline occurs high up on the tallest mountains. What is the relationship between the distance from the equator and the snowline?

MATH PRACTICE

7. **Calculate** A glacier advances 20 meters over a period of about two months. What is its approximate rate of advance per day?

7.2 Deserts

ES.7 The student will investigate and understand geologic processes including plate tectonics. Key concepts include **a.** geologic processes and their resulting features.

IF YOU LIVE in a humid region and visit an arid region, or desert, it might seem as if you are going to another planet. In humid regions, the hills are rounded and the slopes are curved. By contrast, deserts often have angular rocks and surfaces covered in pebbles or sand, as shown in **Figure 15.**

To a visitor from a humid region, it may seem as though different forces act to shape the desert landscape. However, the processes of weathering and erosion shape both arid and wet regions. The differences merely reveal the effects of the same processes acting under different climatic conditions.

Key Questions

What roles do mechanical and chemical weathering play in deserts?

How does running water affect deserts?

Vocabulary

- alluvial fan
- playa lake

Reading Strategy

Summarize Write each blue heading in the section on a sheet of paper. Write a brief summary of the text for each heading.

Desert Streams
?
?
Interior Drainage
?
?

Weathering in Deserts

In humid regions, well-developed soils support an almost continuous cover of vegetation. Here slopes and rock edges are rounded. Such a landscape is due to the strong influence of chemical weathering. In contrast, the angular edges of rocks and slopes in deserts are a result of mechanical weathering. **Although chemical weathering occurs in deserts, mechanical weathering is far more dominant in shaping desert landscapes.** The lack of well-developed soils and abundant plant life allows mechanical weathering agents to break down and transport rocks in deserts.

FIGURE 15 A Desert Landscape Desert landscapes, such as California's Death Valley, have relatively few plants when compared to more humid climates.

Chemical weathering is not completely lacking in deserts, however. Chemical weathering can create clays and thin soils over long time spans. Many iron-bearing silicate minerals oxidize, producing the rust-colored stain that tints some desert landscapes. But a combination of a lack of moisture, fewer plants, and the resulting scarcity of organic acids from decaying plants means that the minerals in the rock debris remain unchanged.

Reading Checkpoint *Why do deserts experience less chemical weathering than humid regions?*

Water in Deserts

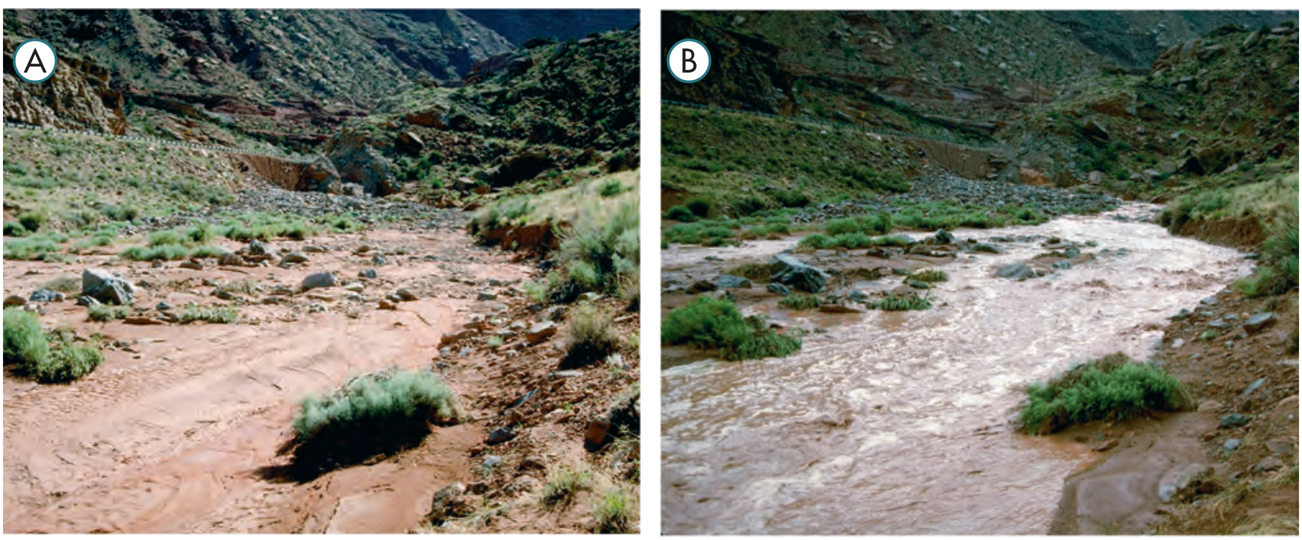
Water is a powerful erosive agent in deserts, partially because the sands are loose and exposed due to a lack of vegetation. Although scarce in deserts, water can rapidly change and shape the landscape, especially after it rains. **In deserts, water collects in streams and rivers that can erode mountains, deposit alluvial fans, and form playa lakes.**

Desert Streams In a desert, there are bridges with no water beneath them and dips in the road crossing empty stream channels. Deserts receive very little rain during the year. As a result, most desert streams are not permanent. In some years, stream channels may remain completely dry as shown in **Figure 16A.** But after a rain, streams may carry water for a few hours or a few days.

Desert streams are known for dangerous flash flooding after heavy rains. Heavy showers can release so much rain that the soil cannot absorb it, as shown in **Figure 16B.** Without vegetation, water quickly runs off the land. The floods end almost as quickly as they start, but the amount of erosion caused during a single, short-lived rain event is impressive. By contrast, in humid regions, a flood on a river such as the Mississippi can take days to reach its crest and days to subside.

Reading Checkpoint *How do floods differ between deserts and humid regions?*

FIGURE 16 Desert Streams
A Most of the time, stream channels in deserts remain dry.
B This is the same stream channel shortly after a heavy rain shower. Desert streams can cause a large amount of erosion in a short time.
Predict *How long will the water flow in this stream?*



Interior Drainage Most desert streams do not reach the ocean. As a result, most deserts have interior drainage. In the United States, the evolution of the landscape in the dry Basin and Range region is an excellent example of interior drainage. The region includes southern Oregon, Nevada, western Utah, southeastern California, southern Arizona and New Mexico, and far west Texas.

The early stages of this landscape evolution occurred during and following the uplift f mountains. Running water began eroding the mountains and depositing large quantities of debris in the basin. Sporadic, heavy rains caused large amounts of water heavily loaded with sediment to move down the mountain canyons. Emerging from the confi es of the canyon, the runoff pread over the gentler slopes at the base of the mountains and quickly lost speed. Consequently, most of its load was dumped within a short distance. The result was a cone of debris known as an **alluvial fan,** which forms at the mouth of a canyon. Over the years, the alluvial fans enlarged and merged with fans from adjacent canyons to produce an apron of sediment along the mountain front, as shown in **Figure 17.**

During the early stages of landscape evolution, elevation differences are the greatest. As erosion lowers the mountains, elevation differences diminish. By the late stages of landscape evolution, erosion has reduced the mountain areas to a few large bedrock knobs called *inselbergs.*

Each of the stages of landscape evolution can be observed in the Basin and Range region. Southern Oregon and northern Nevada contain recently, uplifted mountains in an early stage of erosion. Death Valley, California, and southern Nevada fit into the more advanced middle stage, whereas the late stage, with its inselbergs, can be seen in southern Arizona.

FIGURE 17 Alluvial Fans Over the years, alluvial fans enlarge and merge with fans from adjacent canyons to produce an apron of sediment along the mountain front. These features are common in mountainous deserts, such as in Death Valley, California.

FIGURE 18 Playa Lakes and Playas A The water in playa lakes may be less than a meter deep and very rich in minerals. **B** Playas can be identified by their cracked lake bed surface and salt crusts left behind by the evaporated water.

INQUIRY APPLY IT!

Q: *I heard that deserts are expanding. Is that true?*

A: Yes. The problem is called desertification, and it refers to the alteration of land to desertlike conditions as the result of human activities. It commonly takes place on the margins of deserts. It occurs when the modest natural vegetation in these marginal areas is removed by plowing or grazing. When droughts occur, the lack of vegetation allows heavy soil erosion to remove any remnants of fertile soil. Desertification is particularly serious in the region south of the Sahara Desert known as the Sahel.

Playa Lakes and Playas On the rare occasions of abundant rainfall, or snowmelt in the mountains, streams may flow across the alluvial fans to the center of the basin, converting the basin floor into a shallow **playa lake,** as shown in **Figure 18A.** Playa lakes last only a few days or weeks, before evaporation and infiltration remove the water. The dry, flat lake bed that remains is called a *playa.*

Permanent Streams Some permanent streams do manage to cross arid regions. The Colorado and Nile Rivers begin in well-watered mountains with huge water supplies. The rivers are full enough at the beginning to survive their desert crossings. The Nile River, for example, leaves the lakes and mountains of central Africa and covers almost 3000 kilometers of the Sahara without a single tributary adding to its flow. In contrast, rivers in humid regions generally gain water from both incoming tributaries and groundwater.

7.2 Assessment

Review Key Concepts

1. How do weathering processes affect deserts?
2. How are desert streams different from streams in humid locations?
3. Why is erosion by running water important in deserts?
4. How does a river survive crossing an arid region?

Think Critically

5. **Compare and Contrast** Compare and contrast the Nile River with the Mississippi River. Which factor is most responsible for their differences?
6. **Apply Concepts** Explain how evaporation and infiltration affect drainage systems in desert areas.

BIGIDEA WEATHERING AND EROSION

7. Describe how a desert stream might start to flow and the features its waters may create in the desert. Make sure to use the terms learned in this section.

7.3 Landscapes Shaped by Wind

ES.7 The student will investigate and understand geologic processes including plate tectonics. Key concepts include **a.** geologic processes and their resulting features.

COMPARED WITH running water, wind does not do nearly as much erosional work on the land even in deserts. But wind is still an important force. Farmers of the Great Plains experienced the power of wind erosion during the 1930s. After they plowed the natural vegetation from this semiarid region, a severe drought set in. The land was left xposed to wind erosion. Vast dust storms swept away the exposed, fertile topsoil. The area became known as the *Dust Bowl.*

Wind Erosion

As the drought in the 1930s shows, the wind can be very erosive to exposed sands and soils. Strong winds pick up, transport, and deposit great quantities of fi e sediment. In deserts, the soils are drier and generally have less vegetation to hold soil in place. Therefore, wind does its most effective erosional work in deserts. But wind can be very erosive to exposed sands and soils in any climate. **Wind erodes land surfaces in two ways: deflation and abrasion.**

Deflation

When the wind lifts nd removes loose particles such as clay and silt, **deflatio** occurs. Coarser sand particles roll or skip along the surface in a process called *saltation*. In the Dust Bowl, deflation lowered the land by a meter or more in only a few years, as shown in **Figure 19.**

Deflation also results in shallow depressions called *blowouts*. Thousands of blowouts dot the Great Plains. They range from small dimples less than 1 meter deep and 3 meters wide to depressions more than 45 meters deep and several kilometers across.

Key Questions

What are two ways in which wind causes erosion?

What types of landforms are deposited by wind?

What factors determine the shape of a sand dune?

Vocabulary

- deflation
- desert pavement
- loess
- dune

Reading Strategy

Outline Before you read, make an outline of this lesson. Use the orange headings as the main topics and the blue headings as subtopics. As you read, add supporting details.

Landscapes Shaped by Wind
I. Wind Erosion
A. Deflation
B. Abrasion
II. ___?___
A. ___?___

FIGURE 19 Wind Erosion The photo shows soil loss in the Dust Bowl. The mounds are the level of the land before deflation removed the topsoil. The mounds are 1.2 meters tall and are anchored by vegetation.
Apply Concepts *How did farmers contribute to ruining the land during the Dust Bowl?*

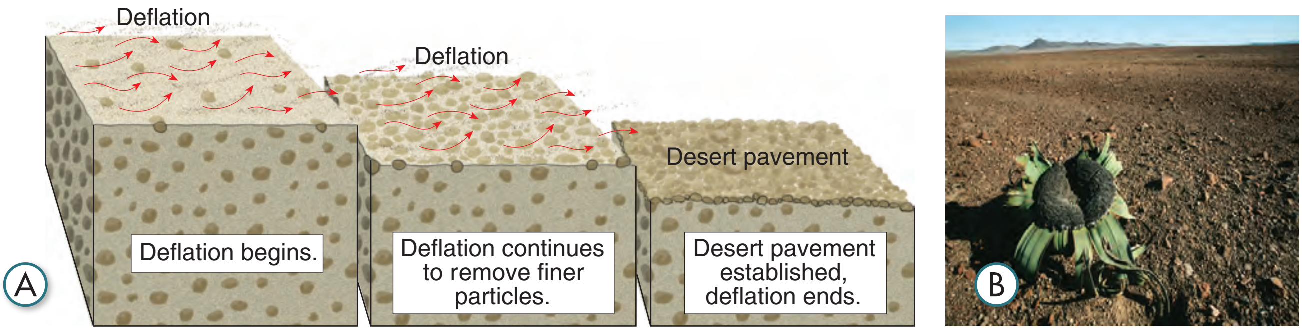


FIGURE 20 Deflation A These cross sections show how deflation removes the sand and silt of the desert surface until only coarser particles remain. These coarser particles concentrate into a tightly packed layer called desert pavement. **Predict** *What will happen if a vehicle disturbs this desert pavement?*

B Desert pavement such as this in southern Africa protects the surface from further deflation.

In portions of many deserts, the surface is characterized by a layer of coarse pebbles and cobbles that are too large to be moved by the wind. Deflation creates this kind of stony surface layer, called **desert pavement,** when it removes all the sand and silt and leaves only coarser particles as **Figure 20** shows. The remaining surface of coarse pebbles and cobbles protects the soils and sands below it from further deflation—unless vehicles or animals break it up. If something does disturb the surface, the wind is able to erode the unprotected soils and sands again.

Abrasion The second form of wind erosion is abrasion. Abrasion happens when windblown sand cuts and polishes exposed rock surfaces. Blowing sand can grind away at boulders and smaller rocks, sometimes sandblasting them into odd shapes. Abrasion is often credited for features such as balanced rocks that stand high atop narrow pedestals or the detailing on tall pinnacles. However, these features are not the results of abrasion. Sand rarely travels more than a meter above the surface, so sandblasting by wind is not typically seen above this height. However, in some areas, telephone poles have been cut through near the base.

Reading Checkpoint *What is deflation?*

FIGURE 21 Loess This vertical deposit of loess near the Mississippi River in southern Illinois is about 3 meters high.

Wind Deposits

Although wind does not produce many landforms through erosion, it does produce significant landforms by deposition. **Wind produces loess and sand dunes when it deposits its sediments.** Loess and sand dunes are common in deserts and along coasts.

Loess Thick deposits of wind-blown silt are called **loess.** Dust storms deposit loess over thousands of years. When streams or roads cut through loess, it maintains vertical cliffs and lacks any visible layers, as you can see in **Figure 21.** The thickest and most extensive deposits of loess on Earth occur in western and northern China, where the wind transported the silt from nearby deserts. This fi e, buff- olored sediment gives the Yellow River its name.

FIGURE 22 **Sand Dunes** Wind blows sand up the windward side of a dune in New Mexico's White Sands National Monument and drops it on the leeward side. Sand sliding down the leeward side results in the dune moving in the same direction the wind blows.

FIGURE 23 **Cross Beds** These cross beds are found in Utah.

In the United States, you can fi d loess in South Dakota, Nebraska, Iowa, Missouri, and Illinois, as well as portions of the Columbia Plateau in the Pacific Northwest. Unlike the deposits in China, the source of the loess in the United States and Europe is deposits of stratified drift. During the retreat of the ice sheets, many river valleys were filled with sediment deposited by meltwater. Strong westerly winds picked up the fi er sediment and dropped it as a blanket on the eastern sides of valleys.

Sand Dunes Sand particles fall to the ground when wind speed lessens and the energy available for transport diminishes, as happens at an obstruction. Sand deposits in mounds or ridges are called **dunes.** Dunes can begin near obstructions as small as a clump of vegetation or a rock. Once the sand starts to mound, it serves as its own obstruction and traps more sand. With enough sand and long periods of steady wind, the mound of sand becomes a dune.

Dunes often are steeper on the leeward side and slope more gently on the windward side. Wind blows sand grains up the windward side. Once the sand blows over the crest of the dune, the wind slows and the sand drops out. The leeward side of the dune becomes steeper, and the sand eventually slides down the slope, as shown in **Figure 22.** In this way, the dune tends to move in the same direction as the wind blows.

As sand is deposited on the leeward side of the dune, it forms layers that slope in the same direction in which the wind blows. These sloping layers are called *cross beds*. When the dunes are eventually buried under other layers of sediment and become sedimentary rock, the cross beds remain as a record of their origin, as shown in **Figure 23.**

Reading Checkpoint *How do obstructions help to form dunes?*

Types of Sand Dunes

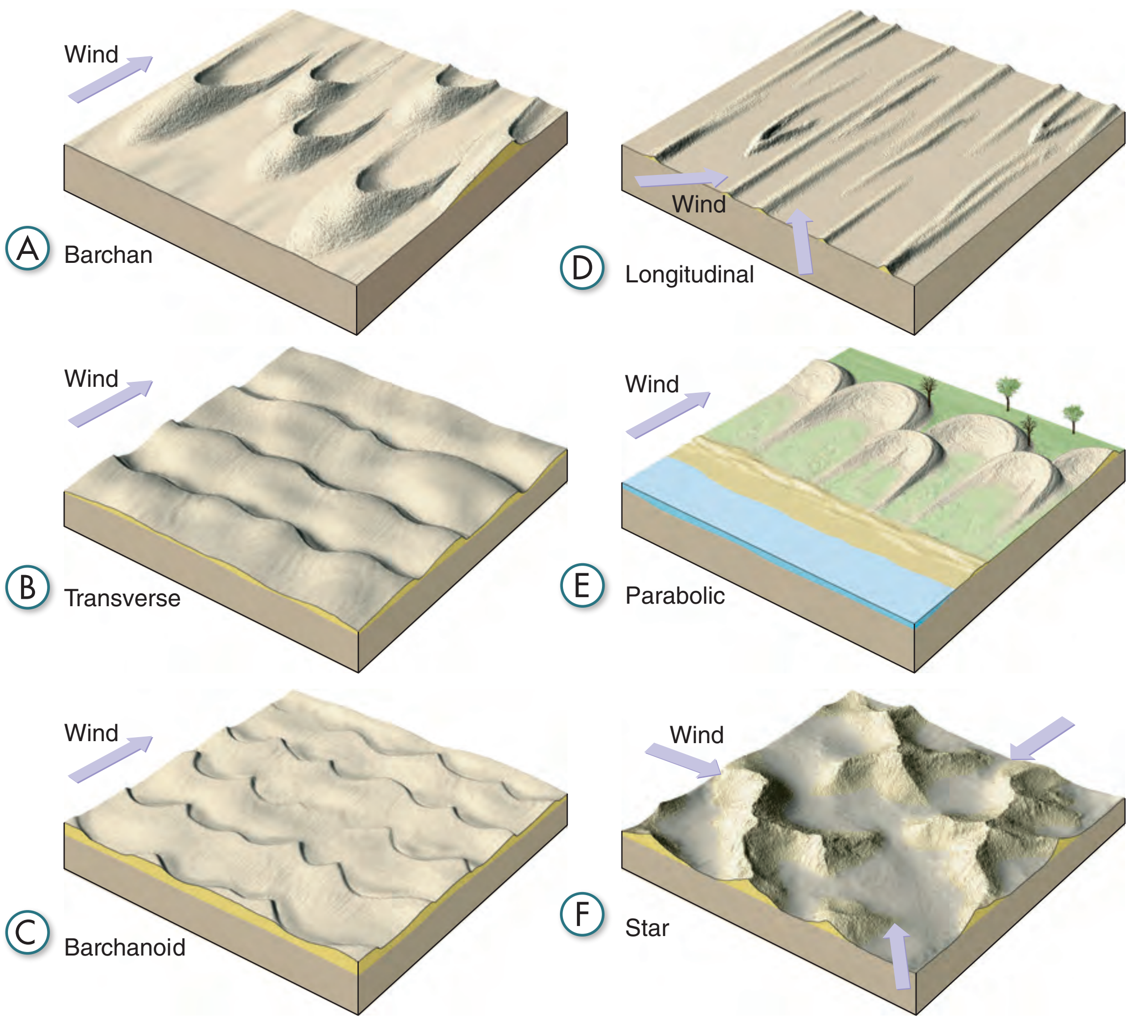
Dunes occur in a variety of consistent forms worldwide. **The shape of a sand dune depends on the wind direction and speed, how much sand is available, and the amount of vegetation. Figure 24** shows six different types of dunes.

Barchan Dunes Isolated sand dunes shaped like crescents are called *barchan dunes*. These form on flat, hard ground where vegetation and the supply of sand are limited. Barchan dunes move slowly and only reach heights of about 30 meters. If the wind direction is constant, barchan dunes remain symmetrical. One tip of the dune can grow larger than the other if the wind direction varies somewhat.

VISUAL SUMMARY

TYPES OF SAND DUNES

FIGURE 24 The speed and direction of wind, the supply of sand, and vegetation cover determine the formation of sand dunes. **Classify** *Which type of sand dune forms in coastal areas with some vegetation and strong onshore winds?*



Transverse Dunes If prevailing winds are steady, sand is plentiful, and vegetation is sparse, dunes form in a series of long ridges. They are called *transverse dunes* because these ridges are perpendicular to the direction of the wind. Transverse dunes are typical in many coastal areas. They also comprise the "sand seas" found in parts of the Sahara and Arabian deserts. Transverse dunes in both of these deserts reach heights of 200 meters, measure 1 to 3 kilometers across, and extend for distances of 100 kilometers or more.

Barchanoid Dunes A common dune form that is intermediate between a barchan and transverse dune is the *barchanoid dune*. These rows of sand form at right angles to the wind. The rows resemble a series of barchans that have been positioned side by side. You can see them in White Sands National Monument in New Mexico.

Longitudinal Dunes *Longitudinal dunes* are long ridges of sand that form parallel to the prevailing wind. These dunes occur where sand supplies are moderate and the prevailing wind direction varies slightly. In portions of North Africa, Arabia, and central Australia, longitudinal dunes can reach nearly 100 meters high and extend for more than 100 kilometers.

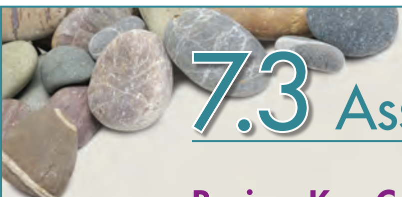
Parabolic Dunes *Parabolic dunes* look like backward barchans. Their tips point into the wind instead of away from it. They form where some vegetation covers the sand. Parabolic dunes often form along the coast where strong onshore winds and abundant sand are available.

Star Dunes *Star dunes* are isolated hills of sand mostly found in parts of the Sahara and Arabian deserts. Their bases resemble stars and they usually have three or four sharp ridges that meet in the middle. Star dunes develop in areas of variable wind direction, and they sometimes reach heights of 90 meters.

INQUIRY APPLY IT!

Q: *Aren't deserts mostly covered with sand dunes?*

A: Many people think a desert is covered in drifting sand dunes. Some deserts do have striking sand dunes. But sand dunes worldwide represent only a small percentage of the total desert area. Dunes cover only one-tenth of the world's largest desert, the Sahara and only one-third of the Arabian, the world's sandiest desert, is covered in dunes.



7.3 Assessment

Review Key Concepts

1. How does deflation lower the surface of the desert?

2. What would you expect to see in areas subject to abrasion?

3. What was the Dust Bowl? Why did it occur?

4. How does a dune help itself to grow?

5. What factors determine the shape of sand dunes?

Think Critically

6. **Compare and Contrast** Compare and contrast loess and sand dunes.

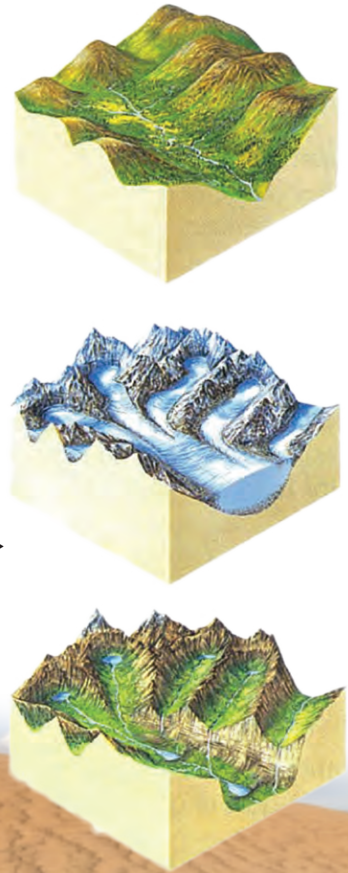
7. **Design an Experiment** Describe how you would conduct an experiment to determine the wind speed necessary to suspend sand, silt, and clay particles.

CONNECTING CONCEPTS

8. **Explain** Which dune type would you expect to travel the least? Explain your answer.

Erosion

Erosion is the process by which weathered sediment is picked up and carried away. Sediment can be moved by streams and rivers, ocean waves, glacial ice, gravity, or wind. The amount of sediment that is moved and the distance that it travels depend on the size and mass of the particles and the speed at which the eroding agent is moving. Erosion affects the landscapes of all the regions of the world.



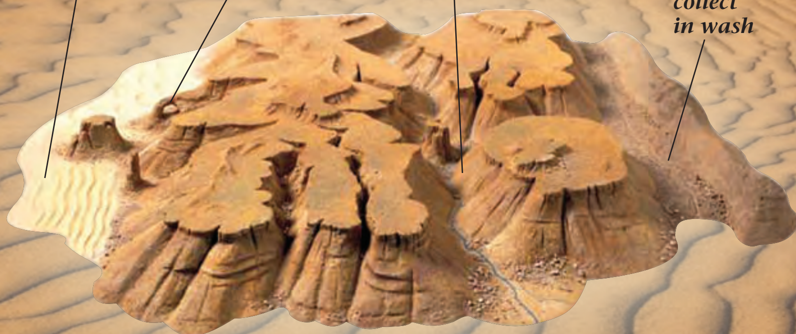
1. Before glaciation *A narrow, V-shaped river valley is surrounded by rounded mountains.*

2. During glaciation *Moving ice erodes mountaintops and carves wider valleys.*

3. After glaciation *The result is a U-shaped valley with rugged, sharp peaks above.*

EROSION BY GLACIAL ICE ▶
Huge masses of ice that move downhill are called **glaciers.** Over thousands or millions of years, they can scour mountainsides and dramatically change the shapes of valleys.

SAND DUNES
A dune begins to form where a plant or other obstacle slows the wind, which drops its load of sand. As the sand piles up, it creates an ever-growing barrier to the wind, causing more sand to be dropped. Eventually the dune crest may collapse like an ocean wave.



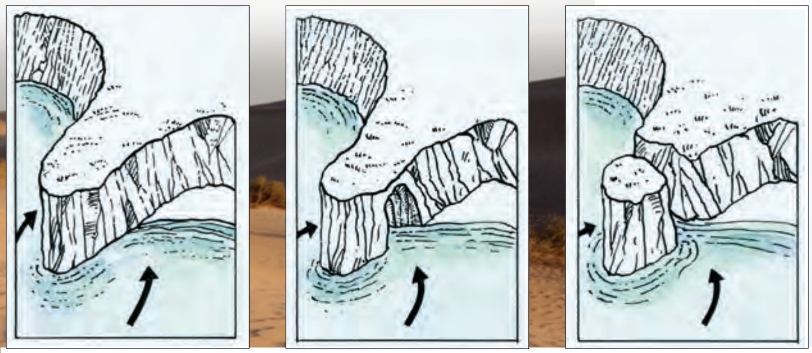
▲ EROSION IN ARID LANDS
When rare torrential rain comes to arid areas, entire mountainsides may be swept clean of boulders, rock fragments, sand, and clay. Flash floods move sediment down washes—the valleys of streams that are usually dry.

SEAS OF SAND
The huge amounts of sand that make up some deserts started out as rock that was weathered to form fine particles. The finer the particle, the farther it can be transported by agents of erosion.

WATER FLOWING
As water flows from highlands to the sea, sharp descents result in rapids and waterfalls. Flowing water is an important agent of erosion.▼

STREAM EROSION▲
Streams erode their banks and beds, continually widening and deepening them. In some cases, a canyon may result. A **canyon,** such as this one in Utah, is a deep valley with steep sides that have been eroded by river water.

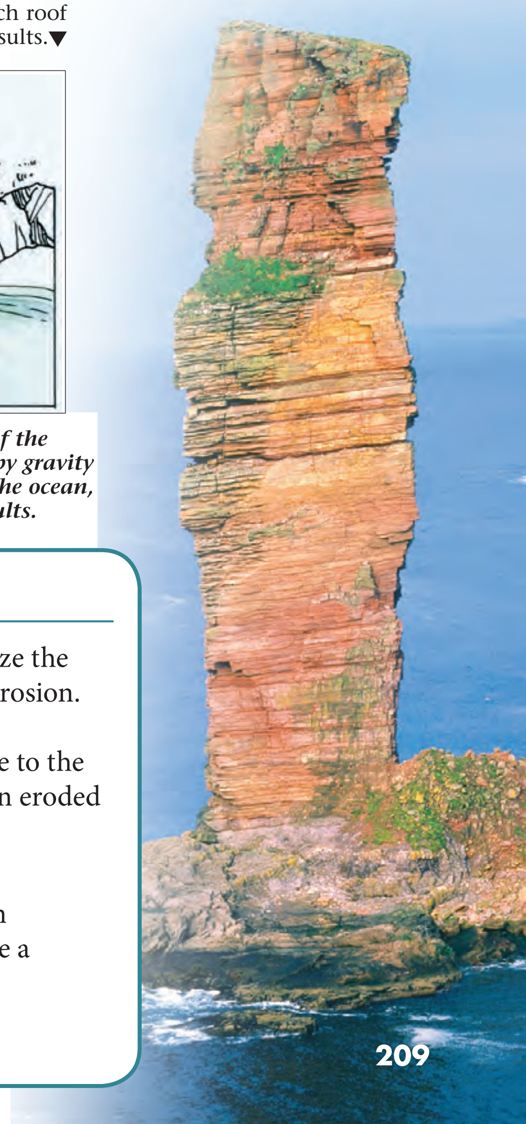
WAVE ACTION
Coastlines are constantly eroded by waves. Waves are formed by winds blowing over water. Cracked and soft rocks are eroded away first, forming arches. If the arch roof collapses, a **sea stack** results.▼



1. Headlands cause waves to curve.

2. An arch forms.

3. When the top of the arch is eroded by gravity and falls into the ocean, a sea stack results.



Sea stack off the British Isles

Assessment

1. **Key Terms** Define the following, using your own words: **(a)** erosion, **(b)** wash, **(c)** glacier, **(d)** canyon, **(e)** sea stack.
2. **Environmental Change** How does water gradually reshape the land?
3. **Physical Characteristics** What are some major physical characteristics of an arid landscape eroded by wind and rain?
4. **Physical Processes** Analyze the three diagrams of glacial erosion. How does the shape of an unglaciated valley compare to the shape of a valley that's been eroded by glaciers?
5. **Critical Thinking** **Analyze Cause and Effect** How can erosion on farmlands cause a reduction in agricultural production?

INQUIRY

EXPLORATION LAB

Interpreting a Glacial Landscape

Problem How can a topographic map allow you to interpret a glacially formed landscape?

Materials topographic map, piece of blank paper, pencil

Skills Interpret Maps, Infer, Draw Conclusions

Connect to the Big idea Topographic maps are valuable tools geologists use to interpret landscapes. Especially in the field—when your view can be limited—these maps not only help you determine your location, they can offer a bigger landscape picture than what is actually visible. See how well you can do at identifying glacial features on the map and interpreting them to reconstruct geologic history.

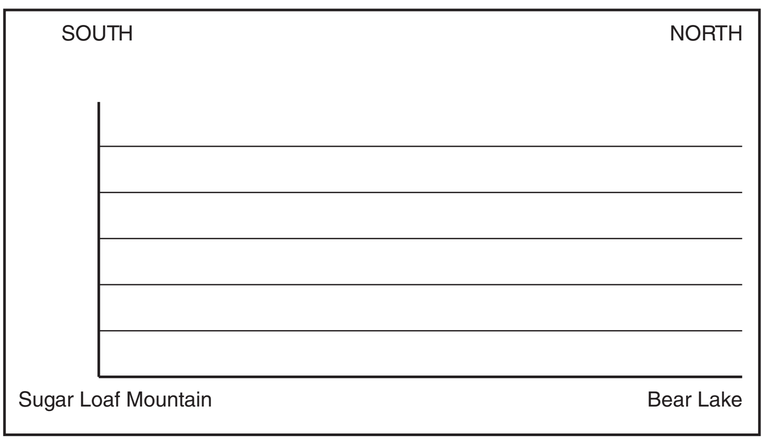
Procedure

1. Following line A on the map, sketch a topographic profile of the Lake Fork Valley onto the grid below.
2. Place the straight edge of your blank paper along the line and mark in pencil where it meets every fi h contour line (the darker guide contours).
3. Be sure to write the elevation of every fi h contour line along the *y*-axis of the profile grid.

Analyze and Conclude

1. **Analyze Data** How can you tell from your profile that the valley was formed by a glacier?
2. **Draw Conclusions** Use the map to help you describe the direction the glacier flowed through this valley. How can you tell?
3. **Interpret Maps** Which letter arrow points to cirques? You can refer to Figure 7 in your textbook for help.
4. **Interpret Maps** Which letter arrows point to hanging valleys?
5. **Interpret Maps** Which letter arrows point to arêtes?
6. **Interpret Maps** Name a peak on the map that is a horn.
7. **Infer** Feature E on the map is composed of glacial till. What type of glacial feature is E, and how did it form?
8. **Apply Concepts** Explain how Turquoise Lake formed.

GO FURTHER Use library or Internet sources to research a glacier of interest. Find out whether it is growing or shrinking and how the glacier is used by people and other organisms. Give a short presentation on your fi dings to the class. Include visual aids to help make your points.



ES.1 The student will plan and conduct investigations in which; **b.** technologies, including computers, probeware, and geospatial technologies, are used to collect, analyze, and report data and to demonstrate concepts and simulate experimental conditions; **c.** scales, diagrams, charts, graphs, tables, imagery, models, and profiles are constructed and interpreted; **d.** maps and globes are read and interpreted, including location by latitude and longitude; and **f.** current applications are used to reinforce Earth science concepts. **ES.2** The student will demonstrate an understanding of the nature of science and scientific reasoning and logic. Key concepts include **c.** observation and logic are essential for reaching a conclusion.

7 Study Guide

Big idea Weathering and Erosion

7.1 Glaciers

There are two main types of glaciers: valley glaciers and ice sheets.

The movement of glaciers is referred to as flow. Glacial flow happens in two ways: plastic flow and basal slip.

Whether the foot of a glacier advances, retreats, or stays in place depends on the glacier's budget. The glacial budget is the balance or lack of balance between accumulation at the head of a glacier and loss, or wastage, at the foot.

Many landscapes were changed by the widespread glaciers of the recent ice age.

Glaciers produce a variety of erosional landscape features, such as glacial troughs, hanging valleys, cirques, arêtes, and horns.

The term *glacial drift* applies to all of the rock debris of glacial origin, no matter how, where, or in what form it was deposited. There are two types of glacial drift: till and stratified drift.

Glaciers are responsible for a variety of depositional landscape features, including moraines, outwash plains, kettles, drumlins, and eskers.

Continental glaciers repeatedly formed, spread, and melted as Earth's climate cooled and warmed. Each cycle of glaciation, or glacial period, lasted about 100,000 years.

ice age (188)
glacier (188)
snowline (189)
valley glacier (189)
abrasion (192)
till (194)
moraine (195)
drumlin (196)
esker (196)

7.2 Deserts

Although chemical weathering occurs in deserts, mechanical weathering is far more dominant in shaping desert landscapes.

In deserts, water collects in streams and rivers that can erode mountains, deposit alluvial fans, and form playa lakes.

alluvial fan (201)
playa lake (202)

7.3 Landscapes Shaped by Wind

Wind erodes land surfaces in two ways: deflation and abrasion.

Wind produces loess and sand dunes when it deposits its sediments.

The shape of a sand dune depends on the wind direction and speed, how much sand is available, and the amount of vegetation.

deflation (203)
desert pavement (204)
loess (204)
dune (205)

7 Assessment

Review Content

Choose the letter that best answers the question or completes the statement.

1. Icebergs are produced when large pieces of ice break from the foot of a glacier during a process called
   a. plucking. **c.** calving.
   b. deflation. **d.** abrasion.

2. Which type of dune forms at right angles to the wind when there is abundant sand, a lack of vegetation, and a constant wind direction?
   a. barchan
   b. transverse
   c. longitudinal
   d. parabolic

3. Which area was NOT covered in ice sheets at the peak of the most recent ice age?
   a. Siberia **c.** North Africa
   b. Europe **d.** Antarctica

4. All rock debris of glacial origin is called
   a. till.
   b. glacial drift.
   c. stratified drift.
   d. outwash.

5. Which term is used to describe a dry channel in a desert?
   a. playa lake
   b. wash
   c. alluvial fan
   d. playa

6. The two major ways that glaciers erode land are abrasion and
   a. plucking. **c.** deflation.
   b. tension. **d.** slipping.

7. The most noticeable result of deflation in some places are shallow depressions called
   a. sinkholes. **c.** loess.
   b. blowouts. **d.** kettles.

8. In which of these places do extensive yellow loess deposits occur?
   a. Canada **c.** China
   b. Cambodia **d.** Australia

9. Which of the following is NOT a feature associated with valley glaciers?
   a. horn **c.** arête
   b. cirque **d.** loess

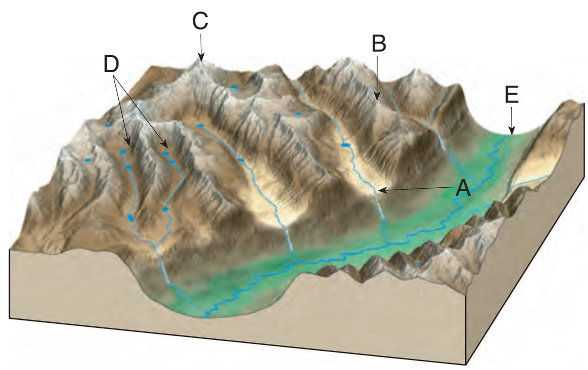
10. A broad, ramp-like surface of stratified drift built downstream from an end moraine is a(n)
   a. kettle.
   b. drumlin.
   c. outwash plain.
   d. terminal moraine.

Understand Concepts

11. Why is the uppermost 50 m of a glacier called the zone of fracture?

12. How do the erosional processes of plucking and abrasion work?

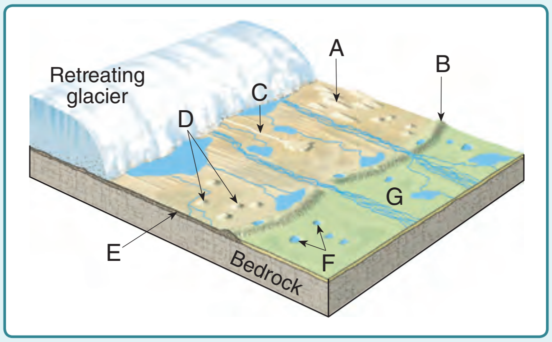
Use the diagram below to answer Question 13.



13. The area in the diagram was eroded by valley glaciers. For each feature listed below, write the letter of that feature in the diagram.
   a. cirque
   b. glacial trough
   c. hanging valley
   d. horn
   e. arête

14. Describe each type of moraine.
   a. end moraine
   b. lateral moraine
   c. ground moraine

15. For each feature listed below, write the letter of that feature in the diagram.



a. drumlin
b. outwash plain
c. esker
d. end moraine

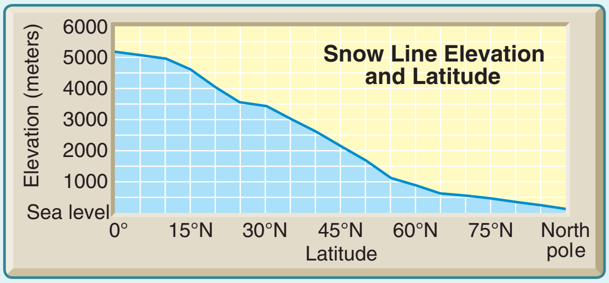
16. Describe how sand dunes move.
17. How does the transport of sediment by glaciers differ from transport by water?
18. How do desert streams differ from those in humid regions?
19. What results when desert pavement is disturbed?
20. Describe the relative importance of wind and running water in eroding the desert landscape.
21. How is it possible for ice to flow?
22. Why do crevasses only extend 50 meters or so beneath the surface of a glacier?

Think Critically

23. **Relate Cause and Effect** Explain how a glacier's budget determines whether it advances, retreats, or remains stationary.
24. **Compare and Contrast** In what ways are the erosional actions of wind, water, and glaciers similar? How are they different?
25. **Infer** Explain why glacial erratics will usually be made of rocks that differ from the bedrock in the area where they are found.

Analyze Data

Use the graph below to answer Questions 26–28.



26. **Interpret Graphs** What is the minimum elevation required for year-round snow on a mountain located on the equator?
27. **Infer** Suppose a 2000-meter tall mountain was located at 75 degrees north of the equator. What percentage of its height would have year-round snow?
28. **Draw Conclusions** Write a statement that summarizes the information in the graph.

Concepts in Action

29. **Use Models** Explain how you would model each type of sand dune using a fan, a pan full of sand, and some playing cards.
30. **Classify** Which types of landscape features described in this chapter resulted from erosion? Which types resulted from deposition?
31. **Writing in Science** Write a paragraph that summarizes the role of climate in the development of the landscapes discussed in this chapter.

Performance-Based Assessment

32. **Research** Eskers are one glacial feature that people have transformed into a resource. Find out why glacial sediments are useful, who mines them, how they mine them, and the extent of their commercial value. Explain whether glacial deposits are considered renewable or nonrenewable resources.

Virginia SOL Test Prep

Tips for Success

Avoiding Careless Mistakes Students often make mistakes when they fail to read a test question and the possible answers carefully. Read the question carefully and underline key words that may change the meaning of the question, such as *not, except,* or *excluding*. After choosing an answer, reread the question to check your selection.

Which of the following is *not* associated with water?

A desert stream
B outwash plain
C hanging valley
D blowout

(Answer: D)

Choose the letter that best answers the question.

1 Which of the following statements about ice sheets is *not* true?
A They cover 30 percent of Earth's land surface.
B They form where more snow accumulates than melts.
C They are also called continental glaciers.
D They can flow. ES.7.a

2 Which is *not* true of loess?
F Loess is a blanket of silt covering the landscape.
G The Yellow River in China is named for the loess that it transports.
H Wind carries and deposits the sediments that comprise loess.
J There are no loess deposits in the United States. ES.7.a

3 Under which of the following conditions will star dunes form?
A in areas where the direction of the wind changes
B in areas where the wind direction changes slightly and the sand supplies are moderate
C in areas with steady winds, and limited vegetation and supplies of sand
D along shores with strong onshore winds, lots of sand, and some vegetation ES.7.a

4 When a stream emerges from a mountain canyon, the stream slope is greatly reduced. As a result the sediment is deposited within a short distance and forms a (an)—
F playa lake
G alluvial fan
H sinkhole
J arête ES.7.a

5 Are glaciers a part of Earth's lithosphere or hydrosphere? Explain.
A lithosphere; When water falls to Earth's surface, it enters the lithosphere.
B lithosphere; Earth's lithosphere contains all solid objects on Earth's surface, including ice.
C hydrosphere; When glaciers melt, they enter the water cycle.
D hydrosphere; Earth's hydrosphere contains all of Earth's water, including ice. ES.7.a

If You Have Trouble With . . .

Question	1	2	3	4	5
See Lesson	7.1	7.3	7.3	7.2	7.1