CHAPTER

16

Deserts

Deserts evoke an image of thirsty travelers crawling across lifeless sand dunes. This image accurately depicts some deserts, but not others. Many deserts are rocky and even mountainous, with colorful cliffs or peaks towering over plateaus and narrow canyons. Rains may punctuate the long hot summers, and in winter a thin layer of snow may cover the ground. Although plant life in deserts is not abundant, it is diverse. Cactus, sage, grasses, and other plants may dot the landscape. After a rainstorm, millions of flowers bloom.

A **desert** is any region that receives less than 25 centimeters (10 inches) of rain per year and consequently supports little or no vegetation.[1] Most deserts are surrounded by **semiarid** zones that receive 25 to 50 centimeters of rainfall, more moisture than a true desert but less than surrounding regions.

Deserts cover 25 percent of the Earth's land surface outside of the polar regions and make up a significant proportion of every continent. If you were to visit the great deserts of the Earth, you might be surprised by their geologic and topographic variety. You would see coastal deserts along the beaches of Chile, shifting dunes in the Sahara, deep red sandstone canyons in southern Utah, and stark granite mountains in Arizona. The world's deserts are similar to one another only in that they all receive scant rainfall.

Throughout human history, cultures have adapted to the low water and sparse vegetation of desert ecosystems. Traditionally, many desert societies were nomadic, taking advantage of resources where and when they were available. Other desert cultures developed irrigation systems to water crops close to rivers and wells. Modern irrigation systems have improved human adaptation to dry environments and enabled 13 percent of the world's population to live in deserts. Two thirds of the world's crude oil lies beneath the deserts of the Middle East, transforming some of the poorest nations of the world into the richest. In the future, vast arrays of solar cells may convert desert sunlight to electricity.

[1]The definition of *desert* is most directly linked to soil moisture and depends on temperature and amount of sunlight in addition to rainfall. Therefore, the 25-centimeter criterion is approximate.

Deserts can be warm, cold, sandy, or rocky. This photograph shows sand dunes in a southwest African desert. (E. D. McKee/USGS)

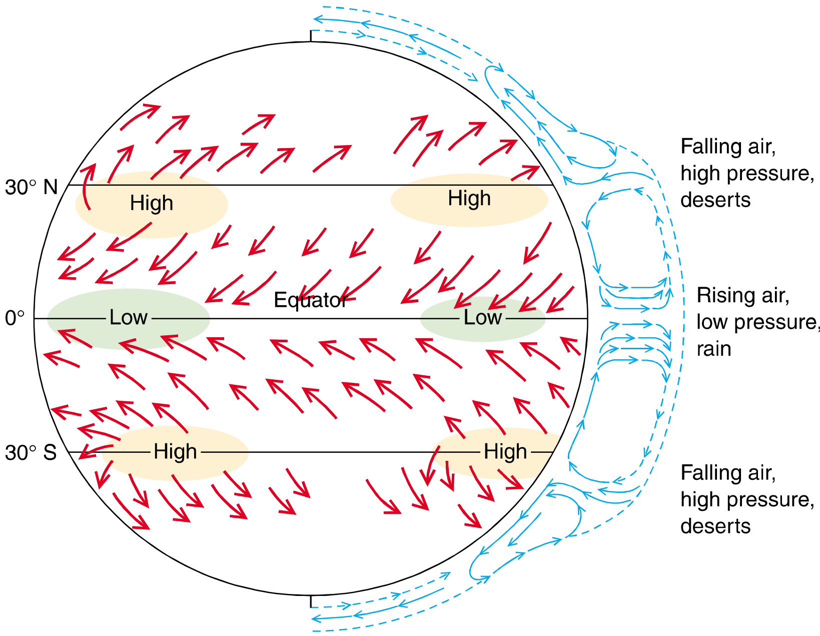


Figure 16–1 Falling air creates high pressure and deserts at 30° north and south latitudes. The arrows drawn inside the globe indicate surface winds. The arrows to the right show both vertical and horizontal movement of air on the surface and at higher elevations.

16.1 WHY DO DESERTS EXIST?

THE EFFECT OF LATITUDE

The Sun shines most directly near the equator, warming air near the Earth's surface. The air absorbs moisture from the equatorial oceans and rises because it is less dense than surrounding air. This warm, wet air cools as it ascends, and the water vapor condenses and falls as rain. For this reason, vast tropical rainforests grow near the equator. The rising equatorial air, which is now drier because of the loss of moisture, flows northward and southward at high altitudes. This air cools, becomes denser, and sinks back toward the Earth's surface at about 30° north and south latitudes (Fig. 16–1). As the air falls,

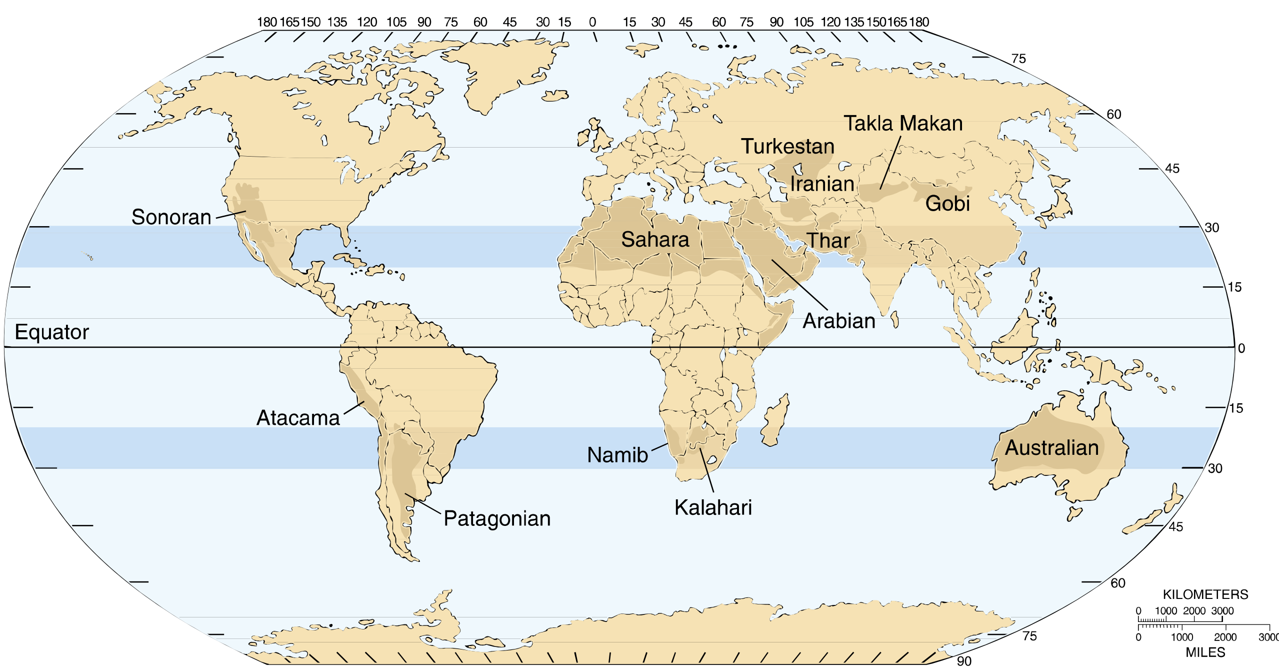


Figure 16–2 The major deserts of the world. Note the global concentration of deserts at 30° north and south latitudes. Most of the deserts are surrounded by semiarid lands.

Figure 16–3 Formation of a rain shadow desert. Warm, moist air from the ocean rises. As it rises, it cools and water vapor condenses to form rain. The dry, descending air on the lee side absorbs moisture, forming a desert.

it is compressed and becomes warmer, which enables it to hold more water vapor. As a result, water evaporates from the land surface into the air. Because the sinking air absorbs water, the ground surface is dry and rainfall is infrequent. Thus, many of the world's largest deserts lie at about 30° north and south latitudes (Fig. 16–2).

EFFECT OF TOPOGRAPHY: RAIN SHADOW DESERTS

When moisture-laden air flows over a mountain range, it rises. As the air rises, it cools and its ability to hold water decreases. As a result, the water vapor condenses into rain or snow, which falls as precipitation on the windward side and on the crest of the range (Fig. 16–3). This cool air flows down the leeward (or downwind) side and sinks. As in the case of sinking air at 30º latitude, the air is compressed and warmed as it falls, and it has already lost much of its moisture. This warm, dry air creates an arid zone called a **rain shadow desert** on the leeward side of the range. Figure 16–4 shows the rainfall distribution in California. Note that the leeward valleys are much drier than the mountains to the west.

CONTINENTAL COASTLINES AND INTERIORS

Because most evaporation occurs over the oceans, one might expect that coastal areas would be moist and cli-

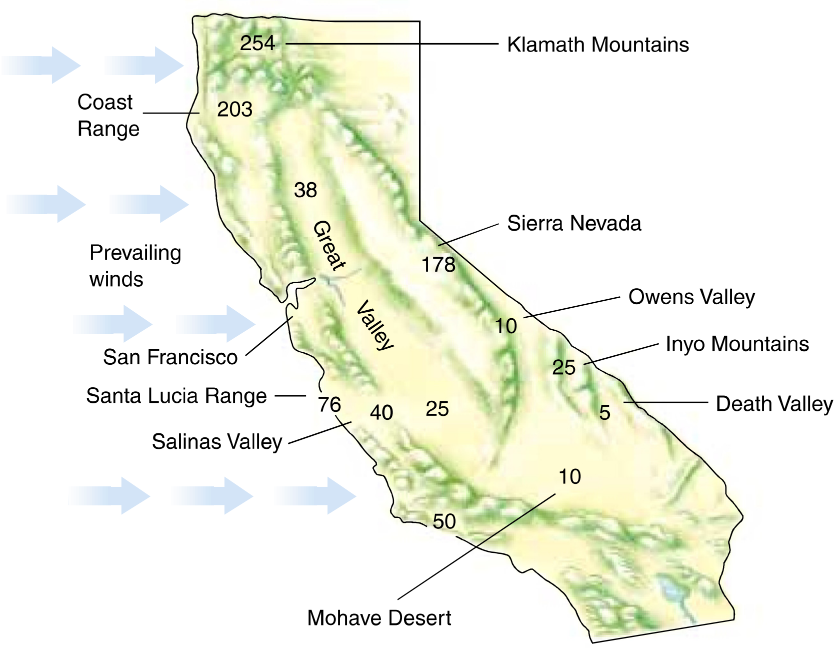


Figure 16–4 Rainfall patterns in the state of California. Note that rain shadow deserts lie east of the mountain ranges. Rainfall is reported in centimeters per year.

mates would become drier with increasing distance from the sea. This generalization is often true, but notable exceptions exist.

The Atacama Desert along the west coast of South America is so dry that portions of Peru and Chile have received no rainfall for a decade or more. Cool ocean currents flow along the west coast of South America. When the cool marine air encounters warm land, the air is heated. The warm, expanding air holds relatively little water vapor and absorbs moisture from the ground, creating a coastal desert.

The Gobi Desert is a broad, arid region in central Asia. The center of the Gobi lies at about 40°N latitude, and its eastern edge is a little more than 400 kilometers from the Yellow Sea. As a comparison, Pittsburgh, Pennsylvania, lies at about the same latitude and is 400 kilometers from the Atlantic Ocean. If latitude and distance from the ocean were the only factors, the two regions would have similar climates. However, the Gobi is a barren desert and western Pennsylvania receives enough rainfall to support forests and rich farmland. The Gobi is bounded by the Himalayas to the south and the Urals to the west, which shadow it from the prevailing winds. In contrast, winds carry abundant moisture from the Gulf of Mexico, the Great Lakes, and the Atlantic Ocean to western Pennsylvania.

Thus, in some regions deserts extend to the seashore and in other regions the interior of a continent is humid. The climate at any particular place on the Earth results from a combination of many factors. Latitude and proximity to the ocean are important, but the direction of prevailing winds, the direction and temperature of ocean currents, and the positions of mountain ranges also control climate.

Figure 16–5 Mechanical weathering, here at Castleton Tower in the Utah desert, produces angular landforms and steep cliffs in many deserts.

16.2 DESERT LANDFORMS

Landforms in humid climates are commonly smooth and rounded because abundant rain promotes chemical weathering. In a desert, however, chemical weathering is slower because less rain falls. Instead, mechanical weathering predominates and intermittent desert streams undercut rock outcrops. As a result, steep cliffs and angular landforms dominate many deserts (Fig. 16–5).

DESERT STREAMS

Large rivers flow through some deserts. For example, the Colorado River crosses the arid southwestern United States, and the Nile River flows through North African deserts (Fig. 16–6). Desert rivers receive most of their water from wetter, mountainous areas bordering the arid lands.

Figure 16–6 The Colorado River flows through the Utah desert. Most of the water flows from mountains to the east.

In a desert, the water table is often so low that water seeps out of the stream bed into the ground. As a result, many desert streams flow for only a short time after a rainstorm or during the spring, when winter snows are melting. A stream bed that is dry for most of the year is called a **wash** (Fig. 16–7).

DESERT LAKES

While most lakes in wetter environments intersect the water table and are fed, in part, by ground water, many desert lake beds lie above the water table. During the wet season, water enters a desert lake bed by stream flow and to a lesser extent by direct precipitation. Some desert lakes are drained by outflowing streams, while many lose water only by evaporation and seepage. During the dry season, water loss may be so great that the lake dries up completely. An intermittent desert lake is called a **playa lake**, and the dry lake bed is called a **playa** (Fig. 16–8).

Recall from Chapters 6 and 14 that water dissolves ions from rock and soil. When this slightly salty water evaporates, the ions precipitate to deposit salts and other evaporite minerals on the playa. Over many years, economically valuable evaporite deposits, such as those of Death Valley, may accumulate (Fig. 16–9).

FLASH FLOODS AND DEBRIS FLOWS

Bedrock or tightly compacted soil covers the surface of many deserts, and little vegetation is present to absorb moisture. As a result, rainwater runs over the surface to collect in gullies and washes. During a rainstorm, a dry stream bed may fill with water so rapidly that a **flash flood** occurs. Occasionally, novices to desert camping pitch their tents in a wash, where they find soft sand to sleep on and shelter from the wind. However, if a thunderstorm occurs upstream during the night, a flash flood may fill the wash with a wall of water mixed with rocks and boulders, creating disaster for the campers. By mid-

(a) (b)

Figure 16–7 Courthouse wash, (a) in the spring when rain and melting snow fill the channel with water and (b) in mid-summer, when the creek bed is a dry wash.

Figure 16–8 Mud cracks pattern the floor of a playa in Utah.

Figure 16–10 Alluvial fans form where steep mountain streams deposit sediment where they enter a valley. This photograph shows a fan in Death Valley.

morning of the next day, the wash may contain only a tiny trickle, and within 24 hours it may be completely dry again.

When rainfall is unusually heavy and prolonged, the desert soil itself may become saturated enough to flow. Viscous wet mud flows downslope in a debris flow that carries boulders and anything else in its path. Some of the most expensive homes in Phoenix, Arizona, and other desert cities are built on the slopes of mountains, where they have good views but are prone to debris flows during wet years.

PEDIMENTS AND BAJADAS

When a steep, flooding mountain stream empties into a flat valley, the water slows abruptly and deposits most of its sediment at the mountain front, forming an alluvial fan. Although fans form in all climates, they are particularly conspicuous in deserts (Fig. 16–10). A large fan may be several kilometers across and rise a few hundred meters above the surrounding valley floor.

If the mouths of several canyons are spaced only a few kilometers apart, the alluvial fans extending from each canyon may merge. A **bajada** is a broad depositional surface formed by merging alluvial fans and extending into the center of the desert valley. Typically, the alluvial fans merge incompletely, forming an undulating surface that may follow the mountain front for tens of kilometers. The sediment that forms the bajada may fill the valley to a depth of several thousand meters.

A **pediment** is a nearly flat, gently sloping surface eroded into bedrock. Pediments commonly form along the front of desert mountains. The bedrock surface of a pediment is covered with a thin veneer of gravel that is in the process of being transported from the mountains, across the pediment to the bajada (Figs. 16–11 and 16–12).

Figure 16–9 Borax and other valuable minerals are abundant in the evaporite deposits of Death Valley. Mule teams hauled the ore from the valley in the 1800s. (U.S. Borax)

Figure 16–11 The bajada in the foreground merges with the gently sloping pediment to form a continuous surface east of Reno, Nevada.

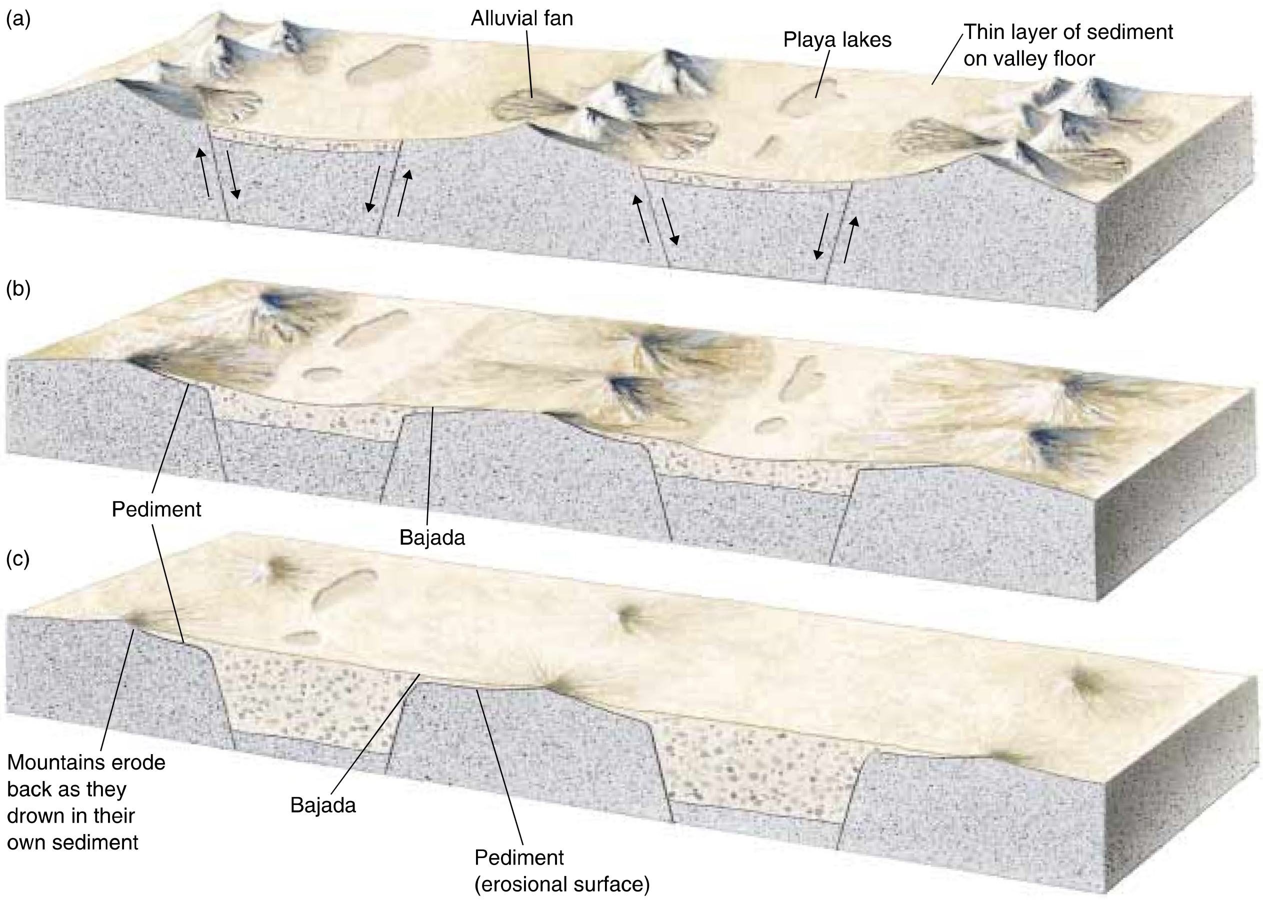


Figure 16–12 One scenario for the formation of bajadas and pediments. (a) The mountains and valleys were formed by block faulting. Desert streams deposit sediment to form alluvial fans. (b) Alluvial fans merge, creating a broad undulating surface called a bajada. (c) The mountain range erodes backward, creating a pediment along the mountain front.

Several different hypotheses have been suggested to explain pediment development. According to one, the streams flowing from desert mountains carry so much sediment that they develop braided channels that shift back and forth across the mountain front. Slowly, the streams erode a flat surface into bedrock. With time, the streams cut the pediment backward into the mountains. Another hypothesis suggests that pediments formed when the climate was wetter than it is today. The greater stream discharge eroded the mountain front rather than depositing alluvial fans.

It is commonly difficult to distinguish a pediment from a bajada because they form a continuous surface from the mountain front to the center of the valley. In addition, both are slightly concave upward and are covered with sand and gravel. To tell the difference, you would have to dig or drill a hole. If you were on a pediment, you would strike bedrock after only a few meters, but on a bajada, bedrock may be buried beneath hundreds or even thousands of meters of sediment.

16.3 TWO DESERT LANDSCAPES IN THE UNITED STATES

THE COLORADO PLATEAU

The Colorado Plateau covers a broad region across portions of Utah, Colorado, Arizona, and New Mexico. Through Earth history this region has been alternately covered by shallow seas, lakes, and deserts. Sediment accumulated, sedimentary rocks formed, and the land was later uplifted without much faulting or deformation, forming the Colorado Plateau. The Colorado River cut through the rock as it rose, to form a 1.6-kilometer-deep canyon, called Grand Canyon. Grand Canyon is intersected by smaller canyons formed by tributary streams.

A stream forms a canyon by downcutting and transporting sediment downslope. If the stream reaches a resistant rock layer, it erodes laterally, widening the canyon. Vertical joints occur in many of the rocks of the Colorado Plateau. As lateral erosion undercuts the cliffs, the walls collapse along joints to form vertical cliffs. The stream continuously removes the eroded rock, leaving steep angular mountains called mesas and buttes. A **plateau** is a large elevated area of fairly flat land. The term plateau is used for regions as large as the Colorado Plateau as well as for smaller elevated flat surfaces. A **mesa** is smaller than a plateau and is a flat-topped mountain shaped like a table. A **butte** is also a flat-topped mountain characterized by steep cliff faces and is smaller and more tower-like than a mesa (Fig. 16–13). Each of these features can be seen on the Colorado Plateau.

DEATH VALLEY

Death Valley is a deep depression in southeastern California, with a maximum depth of 82 meters below sea level (Fig. 16–14). It is a classic rain shadow desert and receives only a scant 5 centimeters of rainfall per year. However, the mountains to the west receive more abundant moisture, and during the winter rainy season, streams flow from the mountains into the Valley, eroding the rock to form broad pediments. Because Death Valley is a basin, rivers cannot flow from the valley to the sea. As a result, sediment collects to form alluvial fans and bajadas along the mountain front and sand dunes on the valley floor. Stream water collects in broad playa lakes that dry up under the hot summer sun.

Like Death Valley, many desert regions in the American West have no through-flowing drainage. Because intermittent streams dry up within the basins, sediment is not flushed out and accumulates to become thousands of meters thick. In some cases, the sediment fills the valleys nearly to the tops of the mountains.

16.4 WIND IN DESERTS

When wind blows through a forest or across a prairie, the trees or grasses protect the soil from wind erosion. In addition, rain accompanies most windstorms in wet climates; the water dampens the soil and binds particles together. Therefore, little wind erosion occurs. In contrast, a desert commonly has little or no vegetation and rainfall, so wind erodes bare, unprotected soil. One can

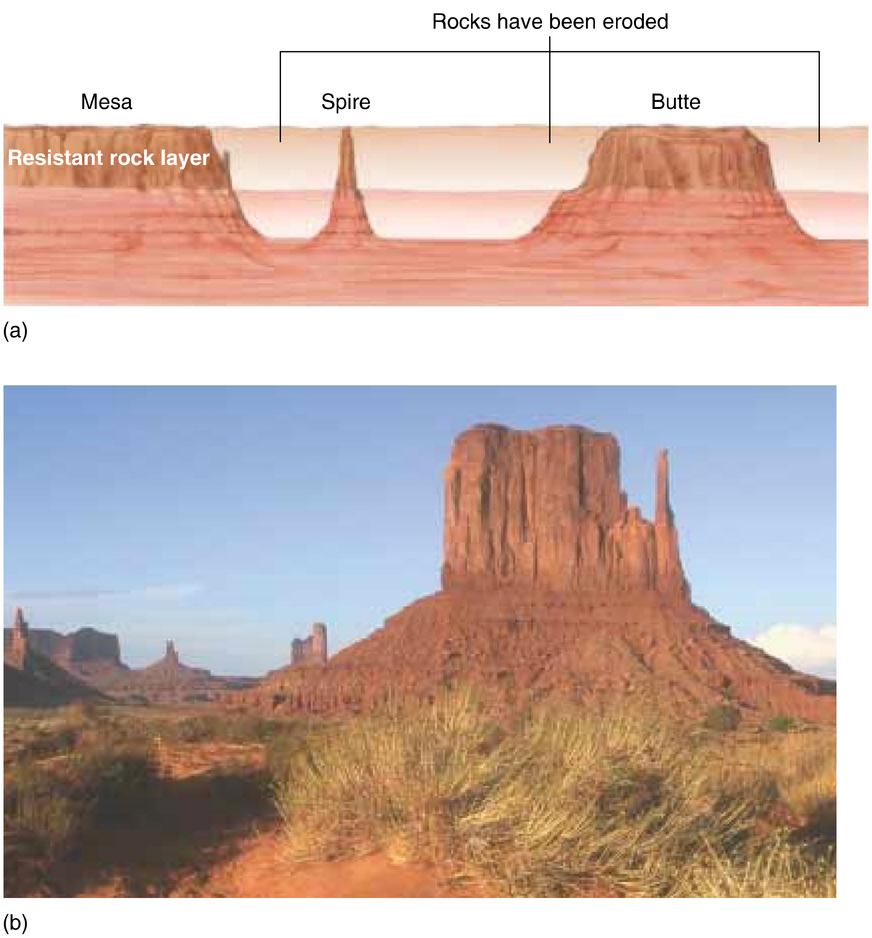


Figure 16–13 (a) Spires and buttes form when streams reach a temporary base level and erode laterally. (b) A landscape in Monument Valley, Arizona.

Figure 16–14 Sediment eroded from surrounding mountains is slowly filling Death Valley.

hardly think about deserts without imagining a hide-behind-your-camel-type sandstorm.

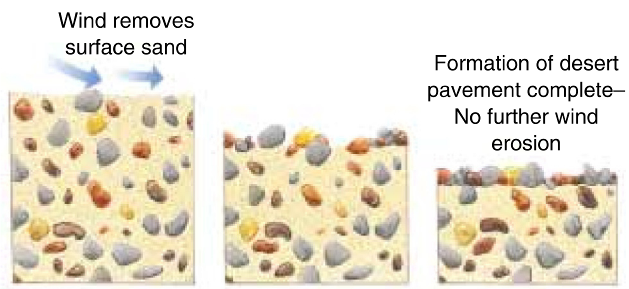
WIND EROSION

Wind erosion, called **deflation**, is a selective process. Because air is much less dense than water, wind moves only small particles, mainly silt and sand. (Clay particles usually stick together, and consequently wind does not erode clay effectively.) Imagine bare soil containing silt, sand, pebbles, and cobbles (Fig. 16–15a). When wind blows, it removes only the silt and sand, leaving the pebbles and cobbles as a continuous cover of stones called **desert pavement** (Fig. 16–15b). Desert pavement prevents the wind from eroding additional sand and silt, even though they may be abundant beneath the layer of stones. Thus, most deserts are rocky and covered with gravel, and sandy deserts are relatively rare.

TRANSPORT AND ABRASION

Because sand grains are relatively heavy, wind blows sand near the surface (usually less than 1 meter above the surface) and carries it only a short distance. In a windstorm, the sand grains bounce over the ground by saltation. (Recall from Chapter 14 that sand also moves by saltation in a stream bed.) In contrast, wind carries fine silt in suspension. Skiers in the Alps commonly encounter a silty surface on the snow, blown from the Sahara Desert and carried across the Mediterranean Sea.

Windblown sand is abrasive and erodes bedrock. Because wind carries sand close to the surface, wind erosion occurs near ground level. If you see a tall desert pinnacle topped by a delicately perched cap, you know that the top was not carved by wind erosion because it is too



(a)

(b)

Figure 16–15 (a) Wind erodes silt and sand but leaves larger rocks behind to form desert pavement. (b) Desert pavement is a continuous cover of stones left behind when wind blows silt and sand away.

Figure 16–16 Wind abrasion (here in Lago Poopo, Bolivia) selectively eroded the base of this rock because windblown sand moves mostly near the surface.

Figure 16–18 Dunes near Lago Poopo, Bolivia.

high above the ground. However, if the base of a pinnacle is sculpted, wind may be the responsible agent (Fig. 16–16). (Salt cracking at ground level also contributes to the weathering of desert rocks.)

Cobbles and boulders lying on the desert surface often have faces worn flat by windblown sand. Such rocks, called **ventifacts**, often have two or three flat faces because of changing wind directions (Fig. 16–17).

DUNES

A **dune** is a mound or ridge of wind-deposited sand (Fig. 16–18). As explained earlier, wind removes sand from the surface in many deserts, leaving behind a rocky desert pavement. The wind then deposits the sand in a topographic depression or other place where the wind slows down. Approximately 80 percent of the world's desert area is rocky and only 20 percent is covered by dunes. Although some desert dune fields cover only a few square kilometers, the largest is the Rub Al Khali (Empty Quarter) in Arabia, which covers 560,000 square kilometers, larger than the state of California.

Dunes also form where glaciers have recently melted and along sandy coastlines. A glacier deposits large quan-

Figure 16–17 A ventifact shows flat faces scoured by windblown sand. (Courtesy of Scott Resources/Hubbard Scientific)

Figure 16–19 Many blowouts are only a meter or two deep, but some can be much larger. The grassy surface on top of the hummock is the level of the prairie before wind erosion occurred. (Courtesy of N. H. Darton, USGS)

tities of bare, unvegetated sediment. A sandy beach is commonly unvegetated because sea salt prevents plant growth. Thus, both of these environments contain the essentials for dune formation: an abundant supply of sand and a windy environment with sparse vegetation.

Dunes form when wind erodes sand from one location and deposits it nearby. A saucer or trough-shaped hollow formed by wind erosion in sand is called a **blowout**. In the 1930s, intense, dry winds eroded large areas of the Great Plains and created the Dust Bowl. Deflation formed tens of thousands of blowouts, many of which remain today. Some are small, measuring only 1 meter deep and 2 or 3 meters across, but others are much larger (Fig. 16–19). One of the deepest blowouts in the world is the Qattara Depression in western Egypt. It is more than 100 meters deep and 10 kilometers in diameter. Ultimately, the lower limit for a blowout is the water table. If the bottom of the depression reaches moist soil near the water table, where water binds the sand grains, wind erosion is no longer effective.

If wind-transported sand moves over a rock, a natural depression, or a small clump of vegetation, the wind slows down in the downwind, or **lee**, side of the obstacle. Sand settles out in this protected zone. The growing mound of sand creates a larger windbreak, and more sand accumulates, forming a dune. Dunes commonly grow to heights of 30 to 100 meters, and some giants exceed 500 meters. In places, they are tens or even hundreds of kilometers long.

Most dunes are asymmetrical. Wind erodes sand from the windward side of a dune, and then the sand slides down the sheltered leeward side. In this way, dunes migrate in the downwind direction (Fig. 16–20). The leeward face of a dune is called the **slip face**. Typically, the slip face is about twice as steep as the windward face.

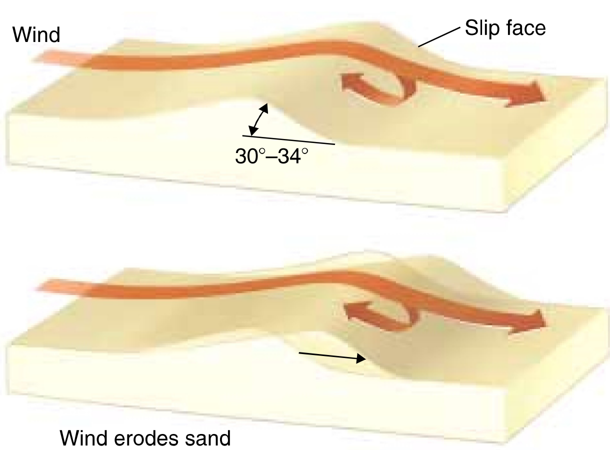


Figure 16–20 The formation and migration of a sand dune.

Migrating dunes overrun buildings and highways. For example, near the town of Winnemucca, Nevada, dunes advance across U.S. Highway 95 several times a year. Highway crews must remove as much as 4000 cubic meters of sand to reopen the road. Engineers often attempt to stabilize dunes in inhabited areas. One method is to plant vegetation to reduce deflation and stop dune migration. The main problem with this approach is that desert dunes commonly form in regions that are too dry to support vegetation. Another solution is to build artificial windbreaks to create dunes in places where they do the least harm. For example, a fence traps blowing sand and forms a dune, thereby protecting areas downwind. Fencing is a temporary solution, however, because eventually the dune covers the fence and resumes its migration. In Saudi Arabia, dunes are sometimes stabilized by covering them with tarry wastes from petroleum refining.

Fossil Dunes

When dunes are buried by younger sediment and lithified, the resulting sandstone retains the original sedimentary structures of the dunes. Figure 16–21 shows a rock face in Zion National Park in Utah. The sloping sedimentary layering is not evidence of tectonic tilting but is the original steeply dipping layers of the dune slip face. The beds dip in the direction in which the wind was blowing when it deposited the sand. Notice that the planes dip in different directions, indicating changes in wind direction. The layering is an example of **cross-bedding**, described in Chapter 7.

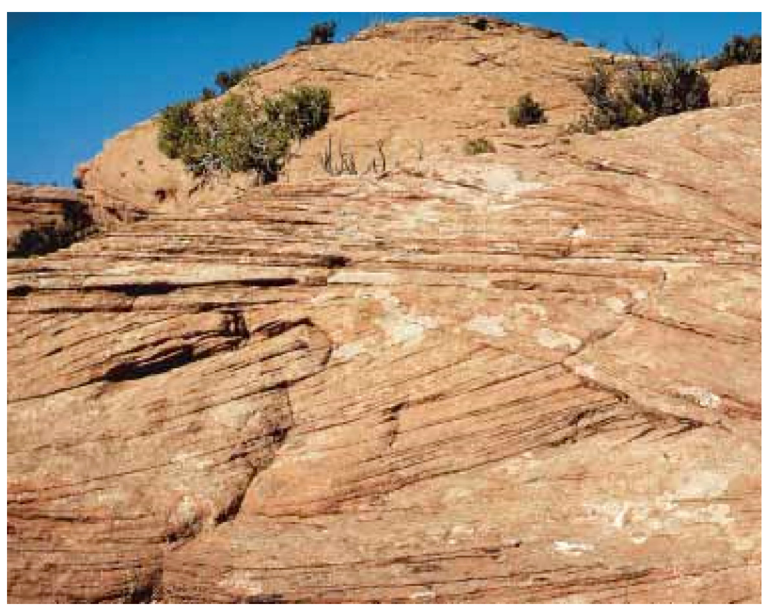


Figure 16–21 Cross-bedded sandstone in Zion National Park preserves the sedimentary bedding of ancient sand dunes.

Types of Sand Dunes

Wind speed and sand supply control the shapes and orientation of dunes (Fig. 16–22). **Barchan dunes** form in rocky deserts with little sand. The center of the dune grows higher than the edges (Fig. 16–23a). When the dune migrates, the edges move faster because there is less sand to transport. The resulting barchan dune is crescent shaped with its tips pointing downwind (Fig. 16–23b). Barchan dunes are not connected to one another, but instead migrate independently. In a rocky desert, barchan dunes cover only a small portion of the land; the remainder is bedrock or desert pavement.

If sand is plentiful and evenly dispersed, it accumulates in long ridges called **transverse dunes** that align perpendicular to the prevailing wind (Figs. 16–22b and 16–24). They are shaped like sand ripples, although they are much larger.

If desert vegetation is plentiful, the wind may form a blowout in a bare area among the desert plants. As sand is carried out of the blowout, it accumulates in a **parabolic dune**, the tips of which are anchored by plants on

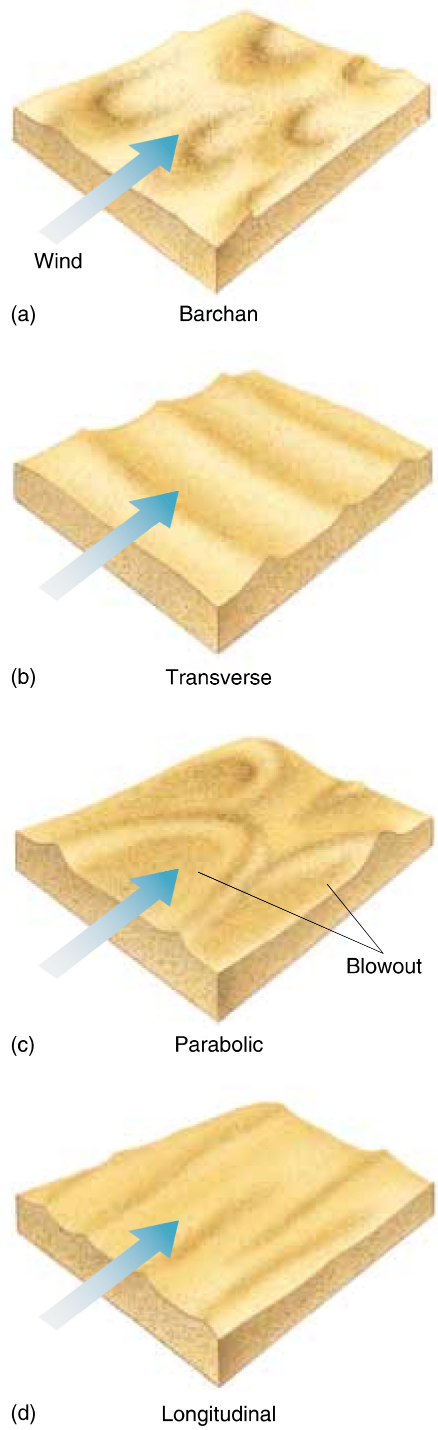


Figure 16–22 Sand dunes take on different shapes depending on sand supply and variations in wind direction. (a) Barchan dunes. (b) Transverse dunes. (c) Parabolic dunes. (d) Longitudinal dunes.

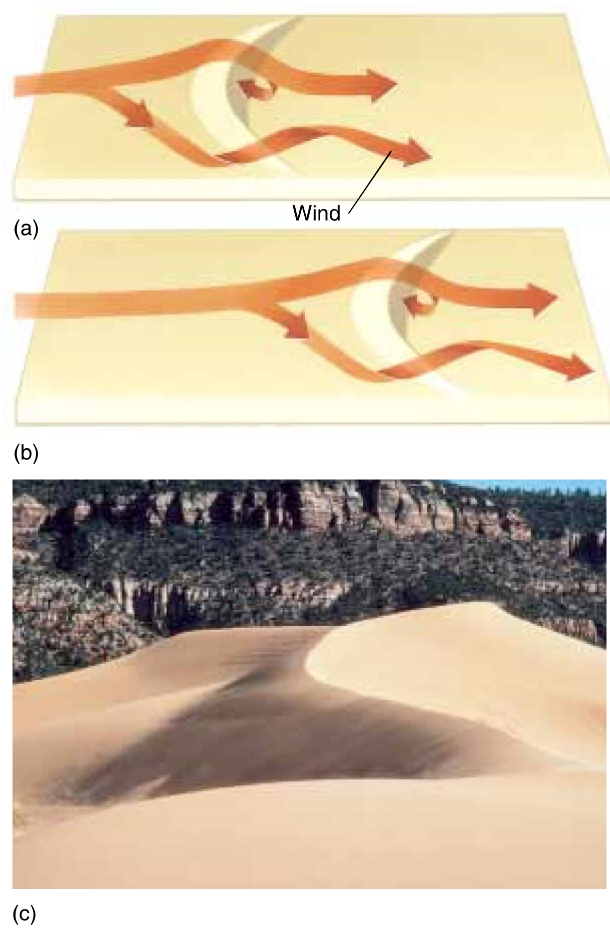


Figure 16–23 (a and b) When sand supply is limited, the tips of a dune travel faster than the center and point downwind, forming a barchan dune. (c) A barchan dune in Coral Pinks, Utah.

Figure 16–24 Transverse dunes form perpendicularly to the prevailing wind direction in regions with abundant sand, such as this part of the Oregon coast. (Galen Rowell/Mountain Light)

each side of the blowout (Figs. 16–22c and 16–25). A parabolic dune is similar in shape to a barchan dune, except that the tips of the parabolic dune point into the wind. Parabolic dunes are common in moist semidesert regions and along seacoasts.

If the wind direction is erratic but prevails from the same general quadrant of the compass and the supply of sand is limited, then long, straight **longitudinal dunes** form parallel to the prevailing wind direction (Figs.

Figure 16–25 A parabolic dune in Death Valley, California, has formed where wind blows sand from a blowout, and grass or shrubs anchor the dune tips. (Martin G. Miller/Visuals Unlimited)

Figure 16–26 Longitudinal dunes on the Oregon coast form where the wind is erratic and the sand supply is limited. (Albert Copley/Visuals Unlimited)

16–22d and 16–26). In portions of the Sahara Desert, longitudinal dunes reach 100 to 200 meters in height and are as much as 100 kilometers long.

LOESS

Wind can carry silt for hundreds or even thousands of kilometers and then deposit it as **loess** (pronounced luss). Loess is porous, uniform, and typically lacks layering. Often the angular silt particles interlock. As a result, even though the loess is not cemented, it typically forms vertical cliffs and bluffs (Fig. 16–27).

The largest loess deposits in the world, found in central China, cover 800,000 square kilometers and are more than 300 meters thick. The silt was blown from the Gobi and the Takla Makan deserts of central Asia. The parti-

Figure 16–27 Villagers in Askole, Pakistan, have dug caves in these vertical loess cliffs.

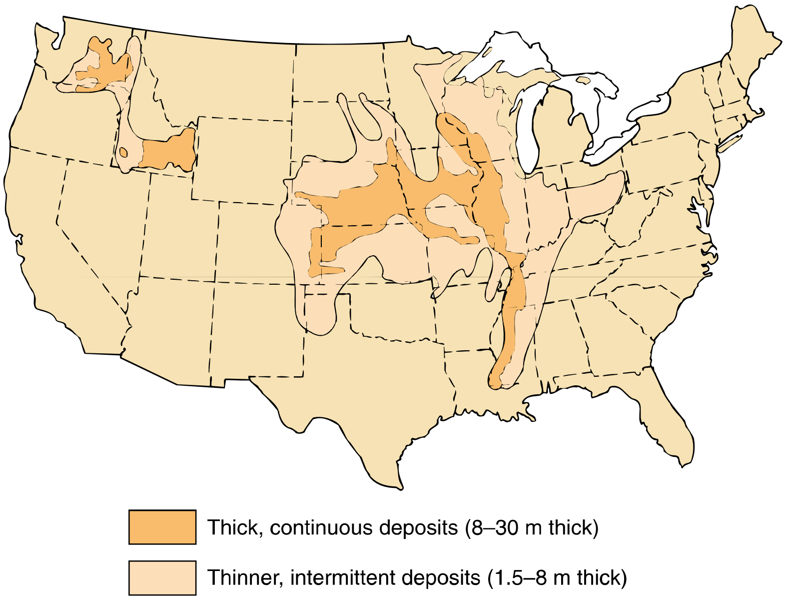


Figure 16–28 Loess deposits in the United States.

cles interlock so effectively that people have dug caves into the loess cliffs to make their homes. However, in 1920 a great earthquake caused the cave system to collapse, burying and killing an estimated 100,000 people.

Large loess deposits accumulated in North America during the Pleistocene Ice Age, when continental ice sheets ground bedrock into silt. Streams carried this fine sediment from the melting glaciers and deposited it in vast plains. These zones were cold, windy, and devoid of vegetation, and wind easily picked up and transported the silt, depositing thick layers of loess as far south as Vicksburg, Mississippi.

Loess deposits in the United States range from about 1.5 meters to 30 meters thick (Fig. 16–28). Soils formed on loess are generally fertile and make good farmland. Much of the rich soil of the central plains of the United States and eastern Washington State formed on loess.

SUMMARY

Deserts have an annual precipitation of less than 25 centimeters (10 inches). The world's largest deserts occur near 30° north and south latitudes, where warm, dry, descending air absorbs moisture from the land. Deserts also occur in rain shadows of mountains, continental interiors, and coastal regions adjacent to cold ocean currents.

Chemical weathering is slow in deserts because water is scarce, and mechanical processes may form angular landscapes. Desert streams are often dry for much of the year but may develop **flash floods** when rainfall occurs. **Playa lakes** are desert lakes that dry up periodically, leaving abandoned lake beds called **playas**. Alluvial fans are common in desert environments. A **bajada** is a broad depositional surface formed by merging alluvial fans. A **pediment** is a planar erosional surface that may lie at the base of a mountain front in arid and semiarid regions.

The Colorado Plateau desert is distinguished by through-flowing streams. The water carries sediment away, forming canyons. The plateaus have been eroded to form **mesas** and **buttes**. Death Valley has no external drainage, and as a result, the valley is filling with sediment eroded from the surrounding mountains.

Deflation is erosion by wind. Silt and sand are removed selectively, leaving larger stones on the surface and creating **desert pavement**. Sand grains are carried short distances and a meter or less above the ground by **saltation**, but silt can be transported great distances at higher elevations. Wind erosion forms **blowouts**. Windblown particles are abrasive, but because the heaviest grains travel close to the surface, abrasion occurs mainly near ground level.

A **dune** is a mound or ridge of wind-deposited sand. Most dunes are asymmetrical, with gently sloping windward sides and steeper **slip faces** on the lee sides. Dunes migrate. The various types of dunes include **barchan dunes**, **transverse dunes**, **longitudinal dunes**, and **parabolic dunes**. Wind-deposited silt is called **loess**.

KEY WORDS

desert *280*
rain shadow desert *283*
wash *285*
playa lake *285*
playa *285*
flash flood *285*
bajada *286*
pediment *286*
plateau *288*
mesa *288*
butte *288*
deflation *289*
desert pavement *289*
ventifact *290*
dune *290*
blowout *291*
slip face *291*
cross-bedding *291*
barchan dune *292*
transverse dune *292*
parabolic dune *292*
longitudinal dune *293*
loess *293*

REVIEW QUESTIONS

1. Why are many deserts concentrated along zones at 30° latitude in both the Northern and Southern Hemispheres?
2. List three conditions that produce deserts.
3. Explain why angular topography is common in desert regions.
4. Why do flash floods and debris flows occur in deserts?
5. Why are alluvial fans more prominent in deserts than in humid environments?
6. Compare and contrast floods in deserts with those in more humid environments.
7. Compare and contrast pediments and bajadas.
8. Why is wind erosion more prominent in desert environments than it is in humid regions?
9. Describe the formation of desert pavement.
10. Describe the evolution and shape of a dune.
11. Describe the differences among barchan dunes, transverse dunes, parabolic dunes, and longitudinal dunes. Under what conditions does each type of dune form?
12. Compare and contrast desert plateaus, mesas, and buttes. Describe the formation of each.
13. Compare the effects of stream erosion and deposition in the Colorado Plateau and Death Valley.

DISCUSSION QUESTIONS

1. Coastal regions boast some of the wettest and some of the driest environments on Earth. Briefly outline the climatological conditions that produce coastal rainforests versus coastal deserts.
2. Explain why soil moisture content might be more useful than total rainfall in defining a desert. How could one region have a higher soil moisture content and lower rainfall than another region?
3. Discuss two types of tectonic change that could produce deserts in previously humid environments.
4. Imagine that you lived on a planet in a distant solar system. You had no prior information on the topography or climate of the Earth and were designing an unmanned spacecraft to land on Earth. The spacecraft had arms that could reach out a few meters from the landing site to collect material for chemical analysis. It also had instruments to measure the immediate meteorological conditions and cameras that could focus on anything within a range of 100 meters. The batteries on your radio transmitter had a life expectancy of two weeks. The spacecraft landed and you began to receive data. What information would convince you that the spacecraft had landed in a desert?
5. Deserts are defined as areas with low rainfall, yet water is an active agent of erosion in desert landscapes. Explain this apparent contradiction.
6. Compare and contrast erosion, transport, and deposition by wind with erosion and deposition by streams.
7. Imagine that someone told you that an alluvial fan had formed by wind deposition. What evidence would you look for to test this statement?
8. What type of dunes form under the following conditions? (a) Relatively high vegetation cover, sand supply, and wind strength. (b) Low vegetation and sand supply.
9. What type of environment would produce fossilized seashells embedded in lithified sand dunes?