CHAPTER

13

Mass Wasting

Every year, small landslides destroy homes and farmland. Occasionally, an enormous landslide buries a town or city, killing thousands of people. Landslides cause billions of dollars in damage every year, about equal to the damage caused by earthquakes in 20 years. In many instances, losses occur because people do not recognize dangers that are obvious to a geologist.

Consider three recent landslides that have affected humans:

1. A movie star builds a mansion on the edge of a picturesque California cliff. After a few years, the cliff collapses and the house slides into the valley (Fig. 13–1a).
2. A ditch carrying irrigation water across a hillside in Montana leaks water into the ground. After years of seepage, the muddy soil slides downslope and piles against a house at the bottom of the hill (Fig. 13–1b).
3. Excavations for roads and high-rise buildings undercut the base of a steep hillside in Hong Kong. Suddenly, the slope slides, destroying everything in its path (Fig. 13–1c).

A landslide on steep, unstable slopes destroyed these expensive apartments and office buildings in Hong Kong. (Hong Kong Government Information Services)

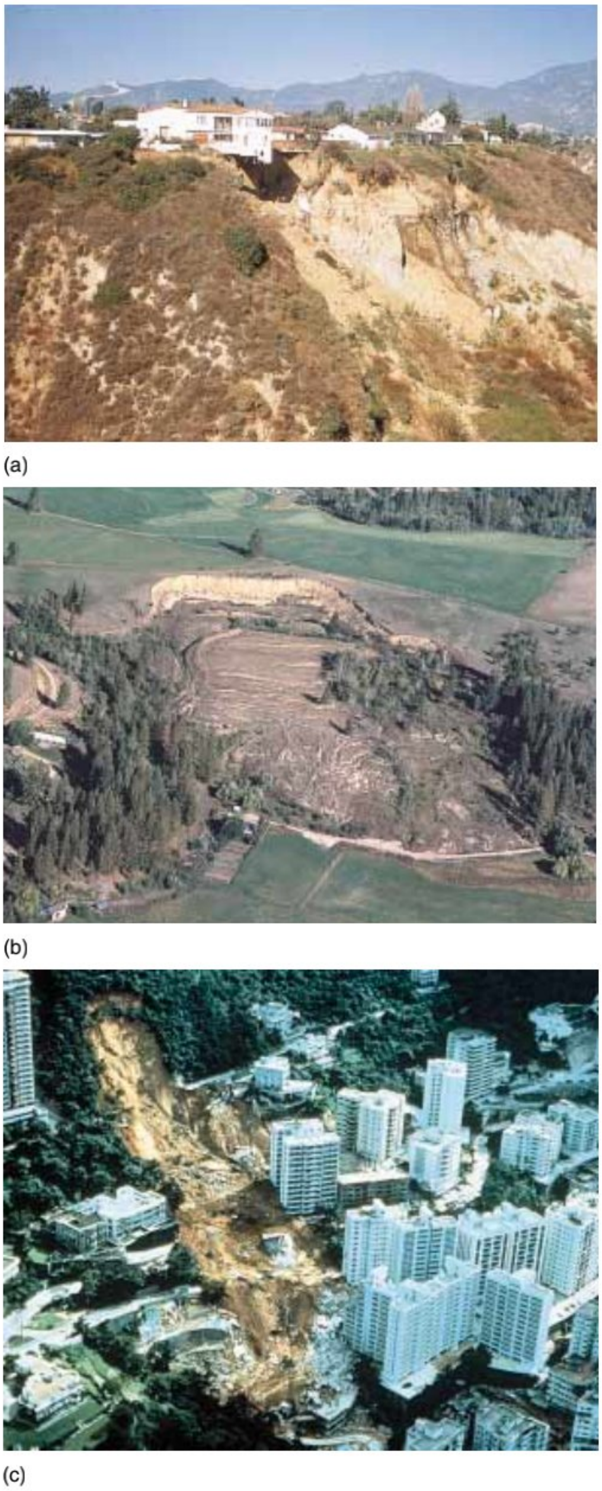

Figure 13–1 Landslides cause billions of dollars in damage every year. (a) A few days after this photo was taken, the corner of the house hanging over the gully fell in. (J. T. McGill, USGS) (b) A landslide, triggered by a leaking irrigation ditch, threatens a house in Darby, Montana. (c) An expensive landslide in Hong Kong. (Hong Kong Government Information Services)

13.1 MASS WASTING

Mass wasting is the downslope movement of Earth material, primarily under the influence of gravity. The word **landslide** is a general term for mass wasting and for the landforms created by such movements.

Think about the bedrock and soil on a hillside. Gravity constantly pulls them downward, but on any given day the rock and soil are not likely to slide down the slope. Their own strength and friction keep them in place. Eventually, however, natural processes or human activity may destabilize a slope to cause mass wasting. For example, a stream can erode the base of a rock cliff, undercutting it until it collapses. Rain, melting snow, or a leaking irrigation ditch can add weight and lubricate soil, causing it to slide downslope. Mass wasting occurs naturally in all hilly or mountainous terrain. Steep slopes are especially vulnerable, and landslide scars are common in mountainous country.

In recent years, the human population has increased dramatically. As the most desirable land has become overpopulated, large numbers of people have moved to more hostile and fragile terrain. In poor countries, people try to scratch out a living in mountains once considered too harsh for homes and farms. In wealthier nations, people have moved into the hills to escape congested cities. As a result, permanent settlements have grown in previously uninhabited steep terrain. Many of these slopes are naturally unstable. Construction and agriculture have destabilized others.

13.2 FACTORS THAT CONTROL MASS WASTING

Imagine that you are a geological consultant on a construction project. The developers want to build a road at the base of a hill, and they wonder whether landslides will threaten the road. What factors should you consider?

STEEPNESS OF THE SLOPE

Obviously, the steepness of a slope is a factor in mass wasting. If frost wedging dislodges a rock from a steep cliff, the rock tumbles to the valley below. However, a similar rock is less likely to roll down a gentle hillside.

TYPE OF ROCK AND ORIENTATION OF ROCK LAYERS

If sedimentary rock layers dip in the same direction as a slope, the upper layers may slide over the lower ones. Imagine a hill underlain by shale, sandstone, and limestone oriented so that their bedding lies parallel to the

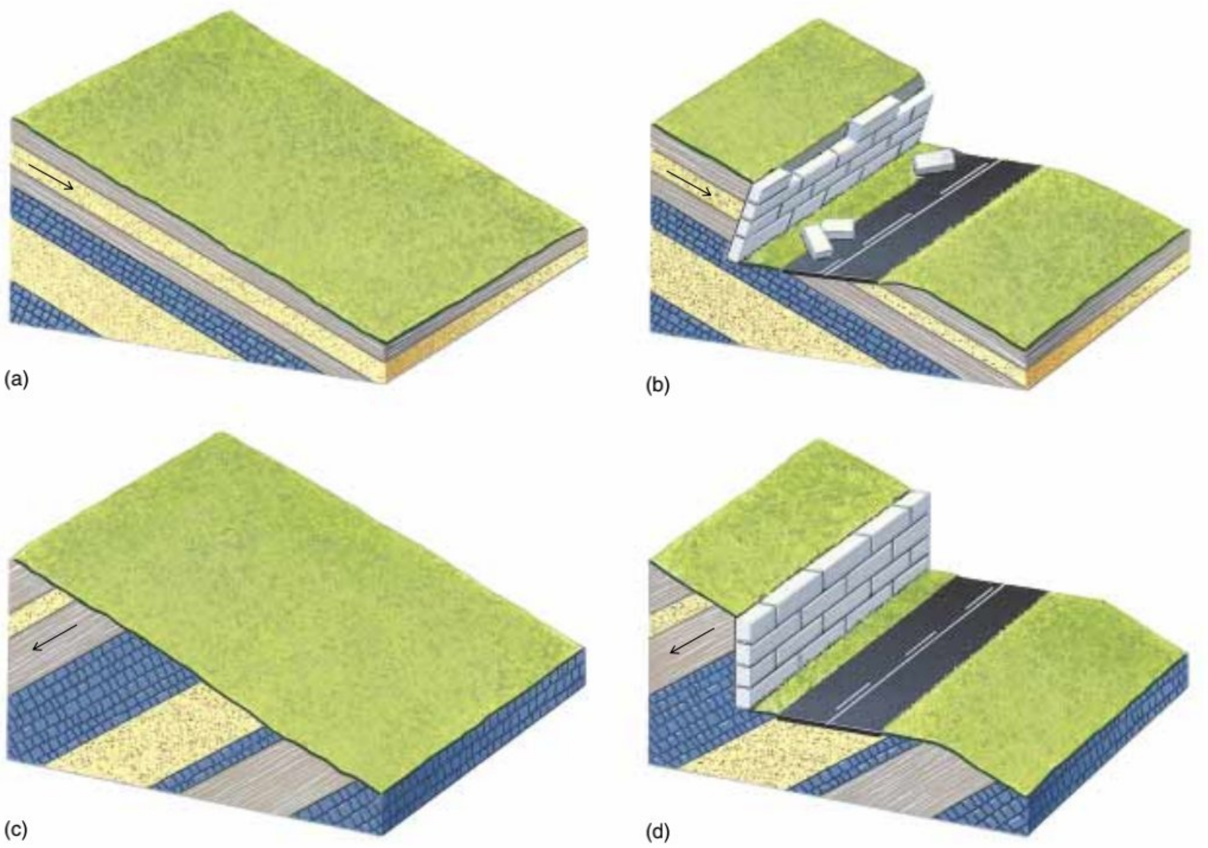

Figure 13–2 (a) Sedimentary rock layers dip parallel to this slope. (b) If a road cut undermines the slope, the dipping rock provides a good sliding surface, and the slope may fail. (c) Sedimentary rock layers dip at an angle to this slope. (d) The slope may remain stable even if it is undermined.

slope, as shown in Figure 13–2a. If the base of the hill is undercut (Fig. 13–2b), the upper layers may slide over the weak shale. In contrast, if the rock layers dip at an angle to the hillside, the slope may be stable even if it is undercut (Figs. 13–2c and 13–2d).

Several processes can undercut a slope. A stream or ocean waves can erode its base. Road cuts and other types of excavation can also destabilize it. Therefore, a geologist or engineer must consider not only a slope's stability before construction, but how the project might alter its stability.

THE NATURE OF UNCONSOLIDATED MATERIALS

The **angle of repose** is the maximum slope or steepness at which loose material remains stable. If the slope becomes steeper than the angle of repose, the material slides. The angle of repose varies for different types of material. Rocks commonly tumble from a cliff to collect at the base as angular blocks of talus. The angular blocks interlock and jam together. As a result, talus typically has a steep angle of repose, up to 45°. In contrast, rounded sand grains do not interlock and therefore have a lower angle of repose (Fig. 13–3).

WATER AND VEGETATION

To understand how water affects slope stability, think of a sand castle. Even a novice sand-castle builder knows that the sand must be moistened to build steep walls and

Figure 13–3 The angle of repose is the maximum slope that can be maintained by a specific material.

Figure 13–4 The angle of repose depends on both the type of material and its water content. Dry sand forms low mounds, but if you moisten the sand, you can build steep, delicate towers with it.

towers (Fig. 13–4). But too much water causes the walls to collapse. Small amounts of water bind sand grains together because the electrical charges of water molecules attract the grains. However, excess water lubricates the sand and adds weight to a slope. When some soils become water saturated, they flow downslope, just as the sand castle collapses. In addition, if water collects on impermeable clay or shale, it may provide a weak, slippery layer so that overlying rock or soil can move easily.

Roots hold soil together and plants absorb water; therefore, a highly vegetated slope is more stable than a similar bare one. Many forested slopes that were stable for centuries slid when the trees were removed during logging, agriculture, or construction.

Mass wasting is common in deserts and regions with intermittent rainfall. For example, southern California has dry summers and occasional heavy winter rain. Vegetation is sparse because of summer drought and wildfires. When winter rains fall, bare hillsides often become saturated and slide. Mass wasting occurs for similar reasons during infrequent but intense storms in deserts.

EARTHQUAKES AND VOLCANOES

An earthquake may cause mass wasting by shaking an unstable slope, causing it to slide. A volcanic eruption may melt snow and ice near the top of a volcano. The water then soaks into the slope to release a landslide.

13.3 TYPES OF MASS WASTING

Mass wasting can occur slowly or rapidly. In some cases, rocks fall freely down the face of a steep mountain. In other instances, rock or soil creeps downslope so slowly that the movement may be unnoticed by a casual observer.

Mass wasting falls into three categories: flow, slide, and fall (Fig. 13–5). To understand these categories, think again of building a sand castle. Sand that is saturated with water flows down the face of the structure. During **flow**, loose, unconsolidated soil or sediment moves as a fluid. Some slopes flow slowly—at a speed of 1 centimeter per year or less. On the other hand, mud with a high water content can flow almost as rapidly as water.

If you undermine the base of a sand castle, part of the wall may break away and slip downward. Movement of coherent blocks of material along fractures is called **slide**. Slide is usually faster than flow, but it still may take several seconds for the block to slide down the face of the castle.

If you take a huge handful of sand out of the bottom of the castle, the whole tower topples. This rapid, free-falling motion is called **fall**. Fall is the most rapid type of mass wasting. In extreme cases like the face of a steep cliff, rock can fall at a speed dictated solely by the force of gravity and air resistance.

Table 13–1 outlines the characteristics of flow, slide, and fall. Details of these three types of mass wasting are explained in the following sections.

FLOW

Types of flow include creep, debris flow, earthflow, mudflow, and solifluction.

Creep

As the name implies, **creep** is the slow, downhill movement of rock or soil under the influence of gravity. Individual particles move independently of one another, and the slope does not move as a consolidated mass. A creeping slope typically moves at a rate of about 1 centimeter per year, although wet soil can creep more rapidly. During creep, the shallow soil layers move more rapidly than deeper material (Fig. 13–6). As a result, anything with roots or a foundation tilts downhill. In many hillside cemeteries, older headstones are tilted, whereas newer ones are vertical (Fig. 13–7). Over the years, soil creep has tipped the older monuments, but the newer ones have not yet had time to tilt.

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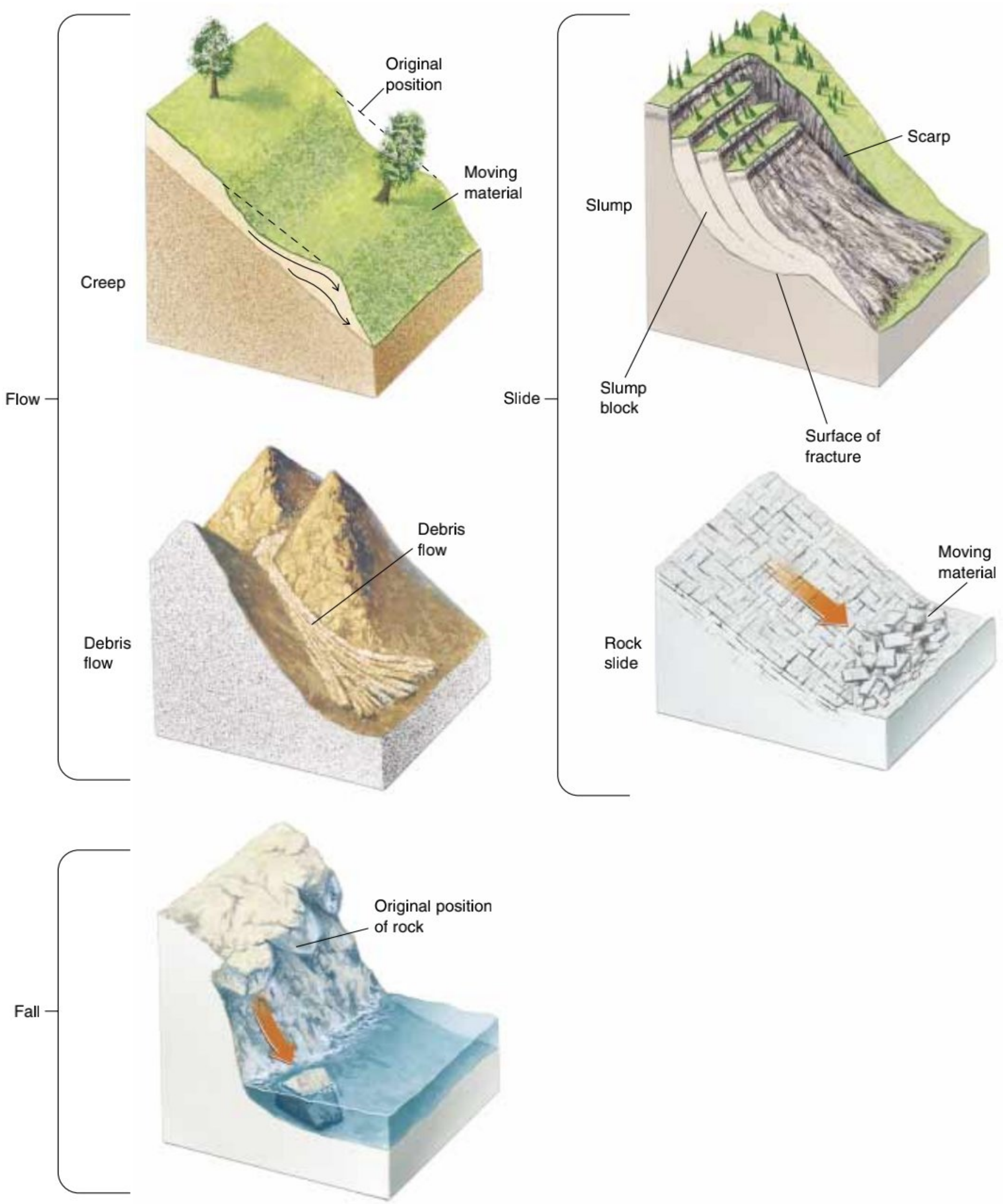


Figure 13–5 Flow, slide, and fall are the three categories of mass wasting.

Table 13–1 • SOME CATEGORIES OF MASS WASTING

TYPE OF MOVEMENT	DESCRIPTION	SUBCATEGORY	DESCRIPTION	COMMENTS
Flow	Individual particles move downslope independently of one another, not as a consolidated mass. Typically occurs in loose, unconsolidated regolith.	Creep	Slow, visually imperceptible movement	Trees on creep slopes develop pistol-butt shape
		Debris flow	More than half the particles larger than sand size; rate of movement varies from less than 1 m/year to 100 km/hr or more.	Common in arid regions with intermittent heavy rainfall, or can be triggered by volcanic eruption
		Earthflow and mudflow	Movement of fine-grained particles with large amounts of water	
		Solifluction	Movement of waterlogged soil generally over permafrost	Can occur on very gradual slopes
Slide	Material moves as discrete blocks; can occur in regolith or bedrock	Slump	Downward slipping of a block of Earth material, usually with a backward rotation on a concave surface	Trees on slump blocks remain rooted
		Rockslide	Usually rapid movement of a newly detached segment of bedrock	
Fall	Material falls freely in air; typically occurs in bedrock.	—	—	Occurs only on steep cliffs

Trees have a natural tendency to grow straight upward. As a result, when soil creep tilts a growing tree, the tree develops a J-shaped curve in its trunk called pistol butt (Fig. 13–8). If you ever contemplate buying hillside land for a home site, examine the trees. If they have pistol-butt bases, the slope is probably creeping, and creeping soil may tear a building apart.

Figure 13–6 Creep has bent layering in sedimentary rocks in a downslope direction. (Ward's Natural Science Establishment, Inc.)

Figure 13–7 During creep, the soil surface moves more rapidly than deeper layers, so the tombstone embedded in the soil tilts downhill.

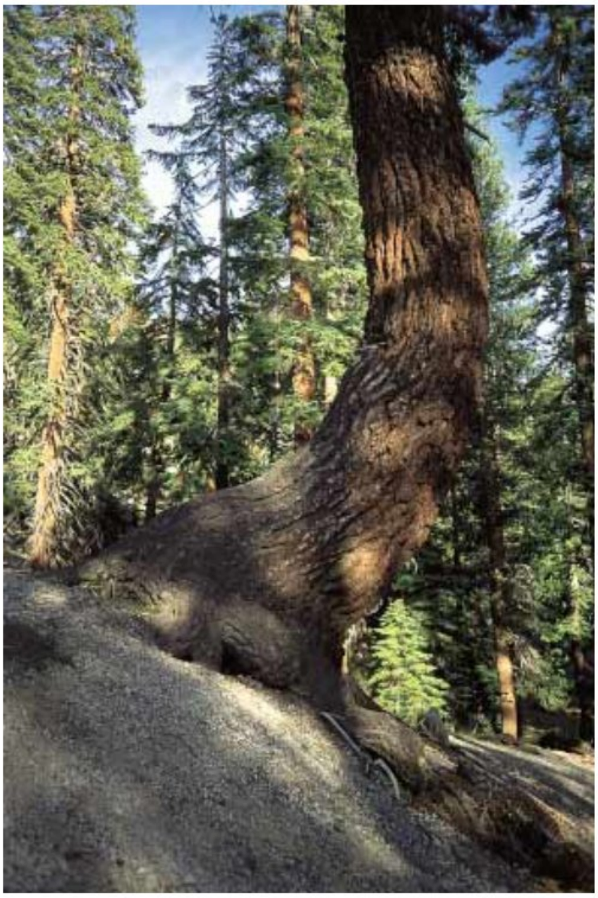


Figure 13–8 If a hillside creeps as a tree grows, the tree develops pistol butt.

Creep can also result from freeze–thaw cycles in the spring and fall in temperate regions. Recall that water expands when it freezes. When damp soil freezes, expansion pushes it outward at a right angle to the slope. However, when the Sun melts the frost, the particles fall vertically downward, as shown in Figure 13–9. This movement creates a net downslope displacement. The displacement in a single cycle is small, but the soil may freeze and thaw once a day for a few months, leading to a total movement of a centimeter or more every year.

Other factors that cause creep include expansion and shrinking of clay-rich soils during alternating wet and dry seasons, and activities of burrowing animals. Both of these processes move soil downslope in a manner similar to that of freeze–thaw cycles.

Debris Flows, Mudflows, and Earthflows

In a debris flow, mudflow, or earthflow, wet soil flows downslope as a plastic or semifluid mass. If heavy rain falls on unvegetated soil, the water can saturate the soil to form a slurry of mud and rocks. A slurry is a mixture of water and solid particles that flows as a liquid. Wet concrete is a familiar example of a slurry. It flows easily and is routinely poured or pumped from a truck.

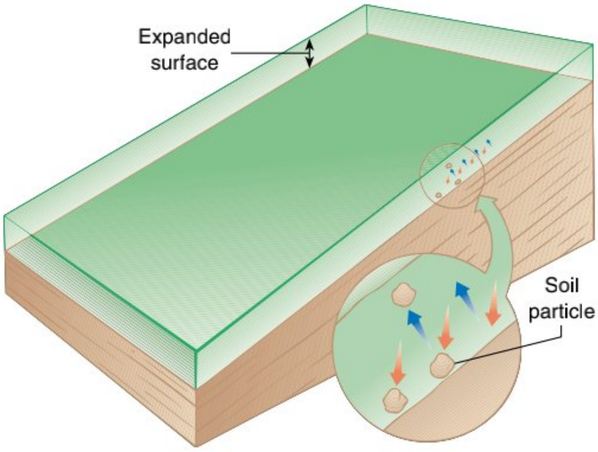


Figure 13–9 When soil expands due to freezing or absorption of water by clays, soil particles move outward, perpendicular to the slope. But when the soil shrinks again, particles sink vertically downward. The net result is a small downhill movement with each expansion–contraction cycle.

The advancing front of a flow often forms a tongue-shaped lobe (Fig. 13–10). A slow-moving flow travels at a rate of about 1 meter per year, but others can move as fast as a car speeding along an interstate highway. Flows can pick up boulders and automobiles and smash houses, filling them with mud or even dislodging them from their foundations.

Different types of flows are characterized by the sizes of the solid particles. A **debris flow** consists of a mixture of clay, silt, sand, and rock fragments in which more than half of the particles are larger than sand. In contrast, mudflows and earthflows are predominantly sand and mud. Some **mudflows** have the consistency of wet concrete, and others are more fluid. Because of its high water content, a mudflow may race down a stream channel at speeds up to 100 kilometers per hour. An **earthflow** contains less water than a mudflow and is therefore less fluid.

Solifluction

In temperate regions, soil moisture freezes in winter and thaws in summer. However, in very cold regions such as the Arctic and high mountain ranges, a layer of permanently frozen soil or subsoil, called permafrost, lies about a half meter to a few meters beneath the surface. Because ice is impermeable, summer meltwater cannot percolate

Figure 13–10 The 1980 eruption of Mount St. Helens melted large quantities of ice. The meltwater triggered characteristic lobe-shaped debris flows. (M. Freidman, USGS)

Figure 13–11 Arctic solifluction is characterized by lobes and a hummocky surface in Greenland. (R. B. Colton, USGS)

downward, and it collects on the ice layer. This leads to two characteristics of these soils:

1. Water cannot penetrate the ice layer, so it collects near the surface. As a result, even though many Arctic regions receive little annual precipitation, bogs and marshes are common.
2. Ice, especially ice with a thin film of water on top, is slippery. Therefore, permafrost soils are particularly susceptible to mass wasting.

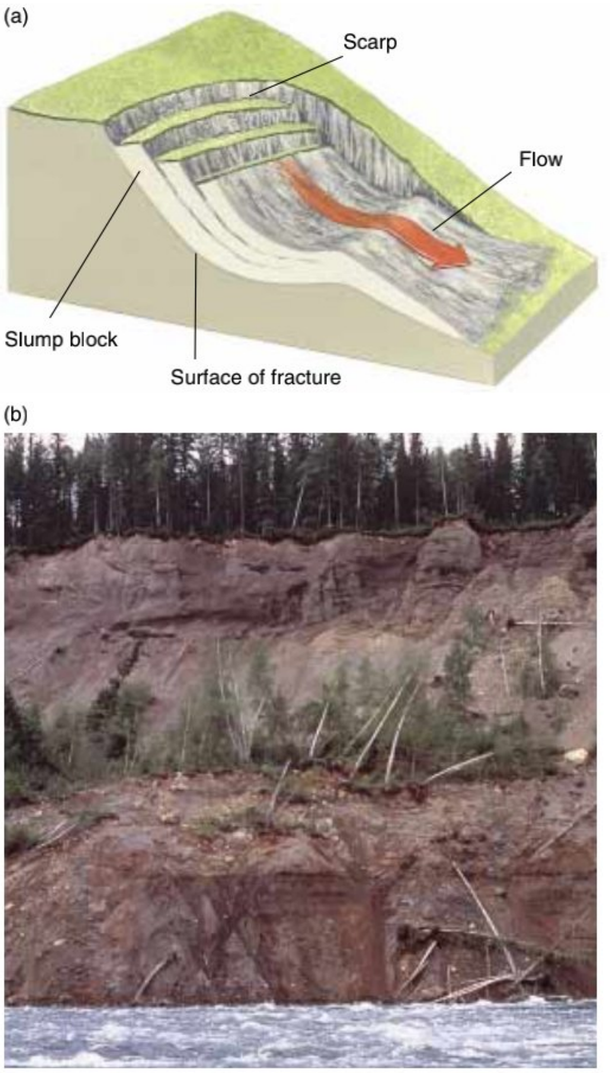
Solifluction is a type of mass wasting that occurs when water-saturated soil flows downslope. It is most common in permafrost regions, where the permanent ice layer causes overlying soil to become waterlogged, although it can also occur in the absence of permafrost (Fig. 13–11). Solifluction can occur on a very gentle slope, and the soil typically flows at a rate of 0.5 to 5 centimeters per year.

SLIDE

In some cases, a large block of rock or soil, or sometimes an entire mountainside, breaks away and **slides** downslope as a coherent mass or as a few intact blocks. Two types of slides occur: slump and rockslide.

A **slump** occurs when blocks of material slide downhill over a gently curved fracture in rock or regolith (Fig. 13–12). Trees remain rooted in the moving blocks. However, because the blocks rotate on the concave fracture, trees on the slumping blocks are tilted backward. Thus, you can distinguish slump from creep be-

Figure 13–12 (a) In slump, blocks of soil or rock remain intact as they move downslope. (b) Trees tilt back into the hillside on this slump along the Quesnell River, British Columbia.



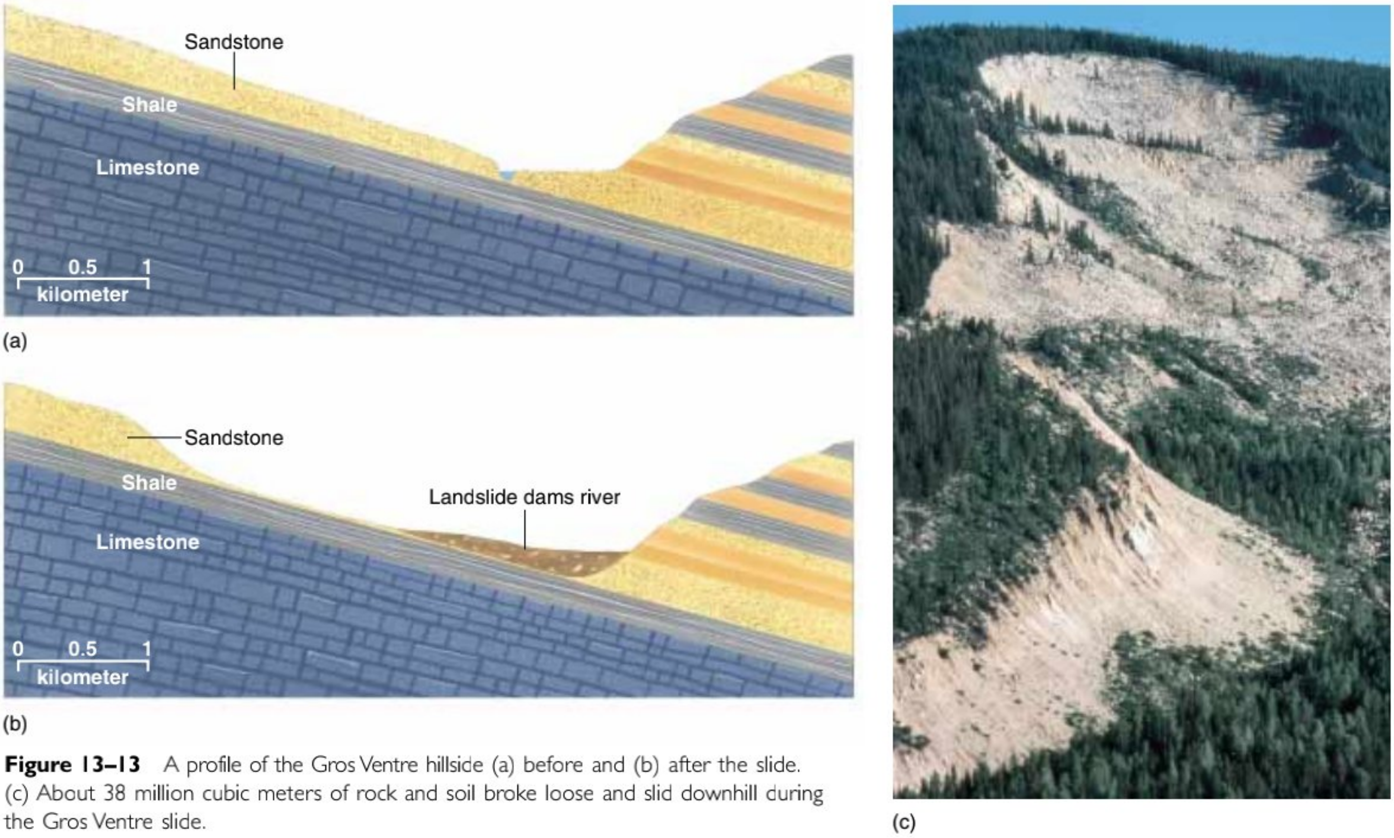


Figure 13–13 A profile of the Gros Ventre hillside (a) before and (b) after the slide. (c) About 38 million cubic meters of rock and soil broke loose and slid downhill during the Gros Ventre slide.

cause slump tilts trees uphill, whereas creep tilts them downhill. At the lower end of a large slump, the blocks often pile up to form a broken, jumbled, hummocky topography.

It is useful to identify slump because it often recurs in the same place or on nearby slopes. Thus, a slope that shows evidence of past slump is not a good place to build a house.

During a **rockslide**, or **rock avalanche**, bedrock slides downslope over a fracture plane. Characteristically, the rock breaks up as it moves and a turbulent mass of rubble tumbles down the hillside. In a large avalanche, the falling debris traps and compresses air beneath and within the tumbling blocks. The compressed air reduces friction and allows some avalanches to attain speeds of 500 kilometers per hour. The same mechanism allows a snow or ice avalanche to cover a great distance at a high speed.

CASE STUDY

Rock Avalanche near Kelly, Wyoming

A mountainside above the Gros Ventre River near Kelly, Wyoming, was composed of a layer of sandstone resting on shale, which in turn was supported by a thick bed of limestone (Fig. 13–13). The rocks dipped 15° to 20° toward the river and parallel to the slope. Over time, the Gros Ventre River had undercut the sandstone, leaving the slope above the river unsupported. In the spring of 1925, snowmelt and heavy rains seeped into the ground, saturating the soil and bedrock and increasing their weight. The water collected on the shale, forming a slippery surface. Finally, the sandstone layer broke loose and slid over the shale. In a few moments, approximately 38 million cubic meters of rock tumbled into the valley. The sandstone crumbled into blocks that formed a 70-meter-high natural dam across the Gros Ventre River. Two years later, the lake overflowed the dam, washing it out and creating a flood downstream that killed several people.

FALL

If a rock dislodges from a steep cliff, it falls rapidly under the influence of gravity. Several processes commonly detach rocks from cliffs. Recall from our discussion of weathering that when water freezes and thaws, the alternate expansion and contraction can dislodge rocks from cliffs and cause rockfall. Rockfall also occurs when a cliff is undercut. For example, if ocean waves or

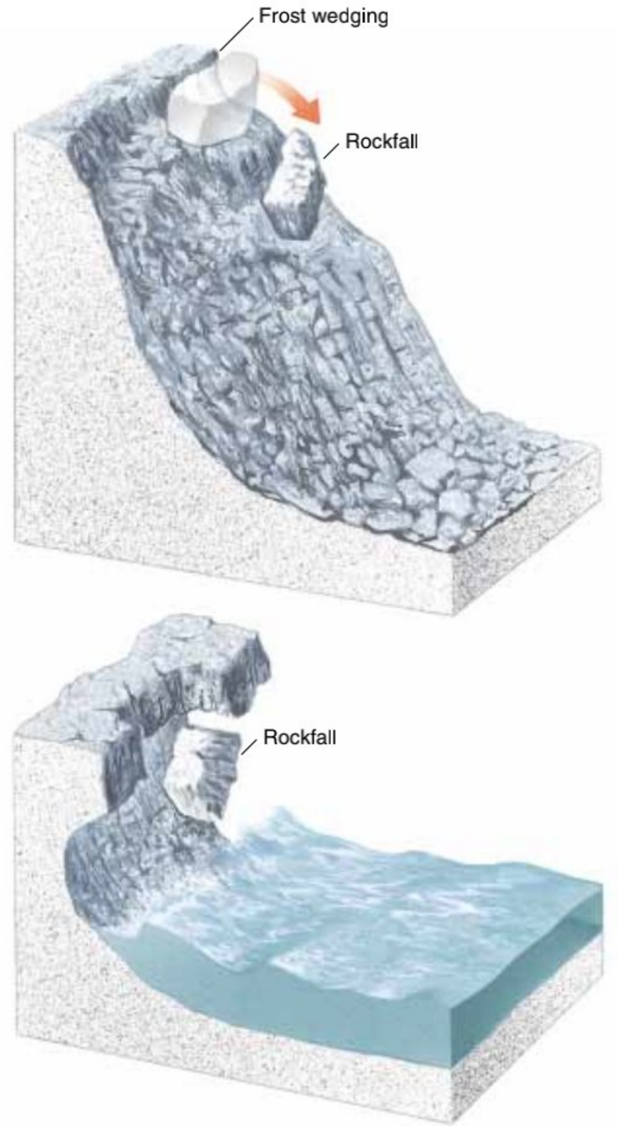


Figure 13–14 Rockfall commonly occurs in spring or fall when freezing water dislodges rocks from cliffs. Undercutting of cliffs by waves, streams, or construction can also cause rockfall.

a stream undercuts a cliff, rock above the waterline may tumble (Fig. 13–14).

13.4 THREE CASE STUDIES: MASS WASTING TRIGGERED BY EARTHQUAKES AND VOLCANIC ERUPTIONS

In many cases, an earthquake or volcanic eruption causes comparatively little damage, but it triggers a devastating landslide. Consider the following case studies.

The Madison River Slide, Montana

In August 1959, a moderate-size earthquake jolted the area just west of Yellowstone National Park. This region is sparsely populated, and most of the buildings in the area are wood-frame structures that can withstand quakes. As a result, the earthquake itself caused little property damage and no loss of life. However, the quake triggered a massive rockslide from the top of Red Mountain, which lay directly above a U.S. Forest Service campground on the banks of the Madison River. About 30 million cubic meters of rock broke loose and slid into the valley below, burying the campground and killing 26 people. Compressed air escaping from the slide created intense winds that lifted a car off the ground and carried it into trees more than 10 meters away. The slide's momentum carried it more than 100 meters up the mountain on the opposite side of the valley. The debris dammed the Madison River, forming a lake that was later named Quake Lake. Figure 13–15 shows the debris and some of the damage caused by this slide.

Nevado del Ruiz, Colombia

Recall the 1985 eruption of Nevado del Ruiz volcano in central Colombia that was briefly described in Chapter 5. The eruption itself caused only minor damage, but heat from the ash and lava melted large quantities of ice and snow that lay on the mountain. The rushing water mixed with ash, rock, and soil on the mountainside, forming a

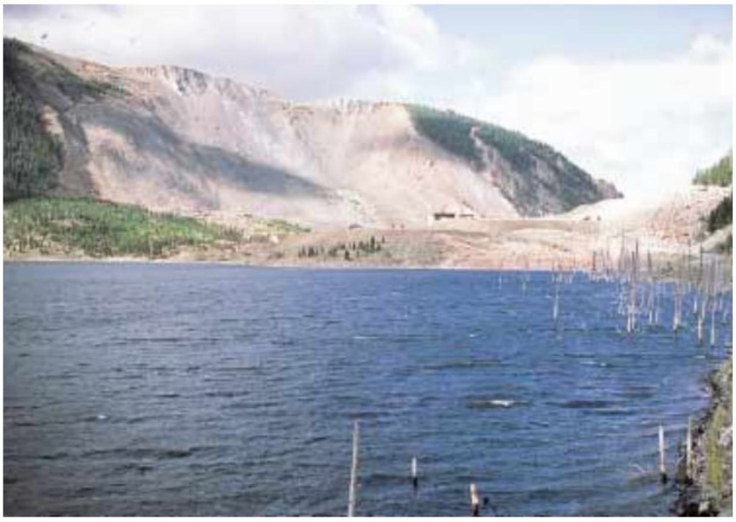


Figure 13–15 This landslide near Yellowstone Park buried a campground, killing 26 people. (Donald Hyndman)

mudflow that raced down gullies and stream valleys to the town of Armero, 48 kilometers from the mountain. The mudflow buried and killed 22,000 people in Armero and caused additional loss of life and property damage in a dozen other villages in nearby valleys.

CASE STUDY Mass Wasting in Washington

Several volcanoes in western Washington State have been active in recent geologic history. The 1980 eruption of Mount St. Helens blew away the entire north side of the mountain. The heat of the eruption melted glaciers and snowfields near the summit, and the water mixed with volcanic ash and soil to create mammoth mudflows. Although the eruption and mudflows killed 63 people, the total loss of life was small compared with the annihilation of Armero. Why was the death toll so much lower in the Mount St. Helens eruption? Is a catastrophic mass wasting event possible or likely elsewhere in Washington State?

The answer to the first question is twofold. First, geologists predicted the Mount St. Helens eruption. As a result, the United States Forest Service evacuated many residents and withdrew water from reservoirs so that the dams would partially contain the anticipated mudflows. Second, and perhaps more important, the region around the mountain is a forested park and there are no cities in the immediate vicinity.

Could other eruptions in Washington and nearby locations lead to much greater disasters? Unfortunately, the answer is yes. Mount Baker is an active, glacier-covered volcano that lies north of Seattle. Steam and gases still escape periodically from its crater (Fig. 13–16). A large eruption could melt the glaciers on the mountain to create mudflows similar to those that devastated the valleys below Mount St. Helens in 1980. Mount Baker lies 20 kilometers upriver from the town of Glacier, Washington, and less than 50 kilometers upriver from the city of Bellingham, which has a population of over 50,000. Recall that the city of Armero was 48 kilometers from Nevado del Ruiz. We can imagine an eruption initiating a mudflow that follows the valley leading to Glacier or even to Bellingham and buries the towns.

We are not predicting an eruption of Mount Baker or a disaster in Glacier or Bellingham; we are simply stating that both are geologically plausible. So the question remains: What should be done in response to the hazard? It is impractical to move an entire city. Therefore, the only alternative is to monitor the mountain continuously and hope that it will not erupt or, if it does, that it will provide enough warning that urban areas can be evacuated in time.

13.5 PREDICTING AND AVOIDING LANDSLIDES

Landslides commonly occur on the same slopes as earlier landslides because the geologic conditions that cause mass wasting tend to be constant over a large area and remain constant for long periods of time. Thus, if a hillside has slumped, nearby hills may also be vulnerable to mass wasting. In addition, landslides and mudflows commonly follow the paths of previous slides and flows. If

Figure 13–16 A wisp of steam rises near the summit of Mount Baker, in the lower center of the photograph.

an old mudflow lies in a stream valley, future flows may follow the same valley.

Many towns were founded decades or centuries ago, before geologic disasters were understood. Often the choice of a town site was not dictated by geologic considerations but by factors related to agriculture, commerce, or industry, such as proximity to rivers and ocean harbors and the quality of the farmland. Once a city is established, it is virtually impossible to move it. Furthermore, geologists' warnings that a disaster might occur are often ignored. After all, predictions of earthquakes and volcanic eruptions are sometimes incorrect. Even in areas known to be active, a quake or eruption may not occur for decades or even centuries.

Awareness and avoidance are the most effective defenses against mass wasting. Geologists construct maps of slope and soil stability by combining data on soil and bedrock stability, slope angle, and history of slope failure in the area. They include evaluations of the probability of a triggering event, such as a volcanic eruption or earthquake. Building codes then regulate or prohibit construction in unstable areas. For example, according to the *United States Uniform Building Code*, a building cannot be constructed on a sandy slope steeper than 27°, even though the angle of repose of sand is 35°. Thus, the law leaves a safety margin of 8°. Architects can obtain permission to build on more precipitous slopes if they anchor the foundation to stable rock.

SUMMARY

Mass wasting is the downhill movement of rock and soil under the influence of gravity. The stability of a slope and the severity of mass wasting depend on (1) steepness of the slope, (2) orientation and type of rock layers, (3) nature of unconsolidated materials, (4) climate and vegetation, and (5) earthquakes or volcanic eruptions.

Mass wasting falls into three categories: flow, slide, and fall. During **flow**, a mixture of rock, soil, and water moves as a viscous fluid. **Creep** is a slow type of flow that occurs at a rate of about 1 centimeter per year. A **debris flow** consists of a mixture in which more than half the particles are larger than sand. **Earthflows** and **mudflows** are mass movements of predominantly fine-grained particles mixed with water. Earthflows have less water than mudflows and are therefore less fluid. **Solifluction** is a type of flow that occurs when water-saturated soil moves downslope, usually over permafrost.

Slide is the movement of a coherent mass of material. **Slump** is a type of slide in which the moving mass travels on a concave surface. In a **rockslide**, a newly detached segment of bedrock slides along a tilted bedding plane or fracture. **Fall** occurs when particles fall or tumble down a steep cliff.

Earthquakes and volcanic eruptions trigger devastating mass wasting. Damage to human habitation can be averted by proper planning and engineering.

KEY WORDS

mass wasting	*222*
angle of repose	*223*
flow	*224*
slide	*224*
fall	*224*
creep	*224*
debris flow	*227*
mudflow	*227*
earthflow	*227*
solifluction	*228*
slump	*228*
rockslide	*229*
rock avalanche	*229*

REVIEW QUESTIONS

1. List and describe each of the factors that control slope stability.
2. What is the angle of repose? Why is the angle of repose different for different types of materials?
3. Explain how a small amount of water might increase slope stability, whereas a landslide might occur on the same slope during heavy rainfall or rapid snowmelt.
4. How does vegetation affect slope stability?
5. Why is mass wasting common in deserts and semiarid lands?
6. How do volcanic eruptions cause landslides?
7. How do earthquakes cause landslides?

8. Discuss the differences among flow, slide, and fall. Give examples of each.
9. Compare and contrast creep, debris flow, and mudflow.
10. What does a pistol-butt tree trunk tell you about slope stability?
11. Why is solifluction more likely to occur in the Arctic than in temperate or tropical regions?
12. Compare and contrast slump and rockslide.
13. Explain how trees are bent but not killed by slump. How are trees affected by rockslide?
14. How do landslides reach and destroy towns and villages many kilometers from the steep slopes where the slides originate?

DISCUSSION QUESTIONS

1. The Moon is considerably less massive than the Earth, and therefore its gravitational force is less. It has no atmosphere and therefore no rainfall. The interior of the Moon is cool, and thus it is geologically inactive. Would you expect mass wasting to be a common or an uncommon event in mountainous areas of the Moon? Defend your answer.
2. Explain how wildfires affect slope stability and mass wasting.
3. What types of mass wasting (if any) would be likely to occur in each of the following environments? a. A very gradual (2 percent) slope in a heavily vegetated tropical rainforest. b. A steep hillside composed of alternating layers of conglomerate, shale, and sandstone, in a region that experiences distinct dry and rainy seasons. The dip of the rock layers is parallel to the slope. c. A hillside similar to that of b, in which the rock layers are oriented perpendicular to the slope. d. A steep hillside composed of clay in a rainy environment in an active earthquake zone.
4. Identify a hillside in your city or town that might be unstable. Using as much data as you can collect, discuss the magnitude of the potential danger. Would the landslide be likely to affect human habitation?
5. Explain how the mass wasting triggered by earthquakes and volcanoes can have more serious effects than the earthquake or volcano itself. Is this always the case?
6. How do mudflows and debris flows transport automobile-sized boulders?
7. Develop a strategy for minimizing loss of life from mass wasting if Mount Baker should show signs of an impending eruption similar to those shown by Mount St. Helens in the spring of 1980. How would your strategy apply to towns such as Armero?