Chapter 3
Causes and Types of Landslides

What is a Landslide?

The term "landslide" is used to describe a wide variety of processes that result in the perceptible downward and outward movement of soil, rock, and vegetation under gravitational influence. The materials may move by: falling, toppling, sliding, spreading, or flowing.

Although landslides are primarily associated with steep slopes, they also can occur in areas of generally low relief. In these areas landslides occur as cut-and-fill failures (highway and building excavations), river bluff failures, lateral spreading landslides, the collapse of mine-waste piles (especially coal), and a wide variety of slope failures associated with quarries and open-pit mines. Underwater landslides on the floors of lakes or reservoirs, or in offshore marine settings, also usually involve areas of low relief and small slope gradients.

Why Do Landslides Occur?

Landslides can be triggered by both natural and man-induced changes in the environment. The geologic history of an area, as well as activities associated with human occupation, directly determines, or contributes to the conditions that lead to slope failure. The basic causes of slope instability are fairly well known. They can be **inherent**, such as weaknesses in the composition or structure of the rock or soil; **variable**, such as heavy rain, snowmelt, and changes in ground-water level; **transient**, such as seismic or volcanic activity; or **due to new environmental conditions**, such as those imposed by construction activity (Varnes and the International Association of Engineering Geology, 1984).

Human Activities

Human activities triggering landslides are mainly associated with construction and involve changes in slope and in surface-water and ground-water regimes. Changes in slope result from terracing for agriculture, cut-and-fill construction for highways, the construction of buildings and railroads, and mining operations. If these activities and facilities are ill-conceived, or improperly designed or constructed, they can increase slope angle, decrease toe or lateral support, or load the head of an existing or potential landslide. Changes in irrigation or surface runoff can cause changes in surface drainage and can increase erosion or contribute to loading a slope or raising the ground-water table (Figure 6). The ground-water table can also be raised by lawn watering, waste-water effluent from leach fields or cesspools, leaking water pipes, swimming pools or ponds, and application or conveyance of irrigation water. A high ground-water level results in increased pore-water pressure and decreased shear strength, thus facilitating slope failure. Conversely, the lowering of the ground-water table as a result of rapid drawdown by water supply wells, or the lowering of a lake or reservoir, can also cause slope failure as the buoyancy provided by the water decreases and seepage gradients steepen.

Natural Factors

There are a number of natural factors that can cause slope failure. Some of these, such as long-term or cyclic climate changes, are not discernible without instrumentation and/or long-term record-keeping.

Climate

Long-term climate changes can have a significant impact on slope stability. An overall decrease in precipitation results in a lowering of the water table, as well as a decrease in the weight of the soil mass, decreased solution of materials, and less intense freeze-thaw activity. An increase in precipitation or ground saturation will raise the level of the ground-water

Figure 6. Aerial view of the Savage Island landslide on the east shore of the Columbia River, Washington, 1981. This landslide was caused by irrigation water (photograph by Robert L. Schuster, U.S. Geological Survey).

table, reduce shear strength, increase the weight of the soil mass, and may increase erosion and freeze-thaw activity. Periodic high-intensity precipitation and rapid snowmelt can signifcantly increase slope instability temporarily (Figure 7).

Erosion

Erosion by intermittent running water (gully ing), streams, rivers, waves or currents, wind, and ice removes toe and lateral slope support of potential landslides.

Weathering

Weathering is the natural process of rock deterioration which produces weak, landslide-prone materials. It is caused by the chemical action of air, water, plants, and bacteria and the physical

Figure 7. The remains of a house where three children died in a mudflow in Kanawha City, West Virginia. The movement was triggered by heavy rainfall from a cloudburst on July 9, 1973 (Lessing et al., 1976).

action brought on by changes in temperature (expansion and shrinkage), the freeze-thaw cycle, and the burrowing activity of animals.

Earthquakes

Earthquakes not only trigger landslides, but, over time, the tectonic activity causing them can create steep and potentially unstable slopes.

Rapid sedimentation

Rivers supply very large amounts of sediment to deltas in lakes and coastal areas. The rapidly deposited sediments are frequently underconsolidated, and have excess pore-water pressures and low strengths. Such deltaic sediments are often prone to underwater delta-front landsliding, especially where the sediments are rich in clay and/or contain gas from organic decomposition.

Wind-generated waves

Storm waves in coastal areas are known to trigger underwater landsliding in deltas by cyclically loading weak bottom sediments.

Tidal or river drawdown

Rapid lowering of water level in coastal areas or along river banks due to tides or river discharge fluctuations can cause underwater landsliding. The process in which weak river bank or deltaic sediments are left unsupported as the water level drops is known as "drawdown."

Types of Landslides

The most common types of landslides are described below. These definitions are based mainly on the work of Varnes (1978).

Falls

Falls are abrupt movements of masses of geologic materials that become detached from steep slopes or cliffs (Figures 8a, b). Movement occurs by free-fall, bouncing, and rolling. Depending on the type of earth materials involved, the result is a rockfall, soilfall, debris fall, earth fall, boulder fall, and so on. All types of falls are promoted by undercutting, differential weathering, excavation, or stream erosion.

Topple

A topple is a block of rock that tilts or rotates forward on a pivot or hinge point and then separates from the main mass, falling to the slope below, and subsequently bouncing or rolling down the slope (Figures 9a, b).

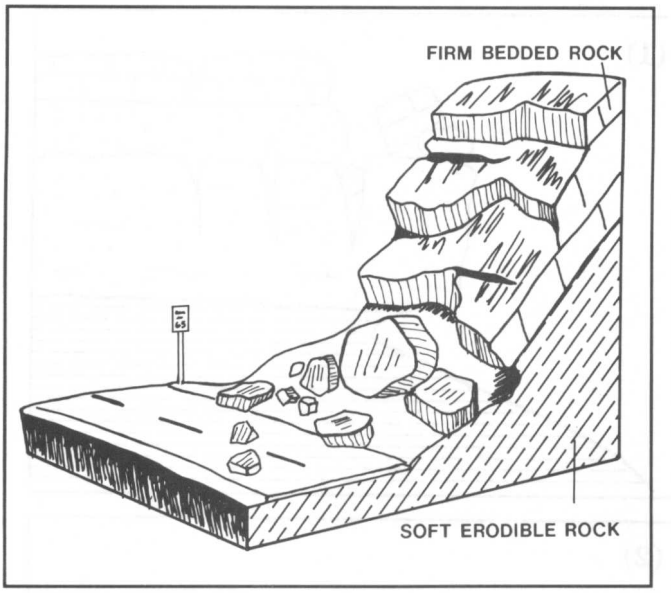
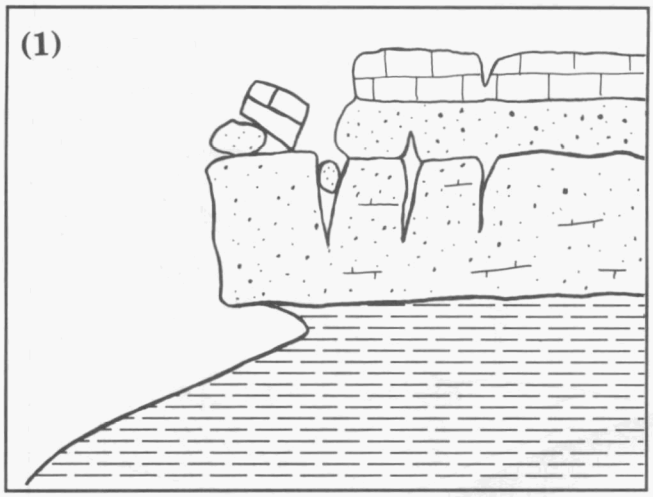


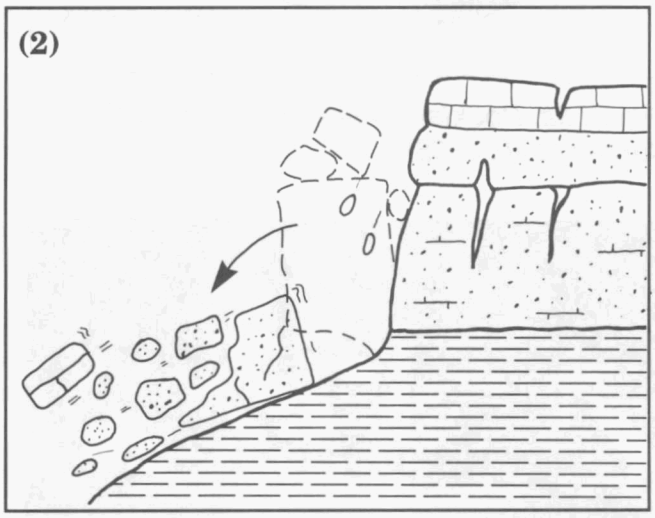
Figure 8a. Rockfall (Colorado Geological Survey et al., 1988).

Figure 8b. Rockfall on U.S. Highway 6, Colorado (photograph by Colorado Geological Survey).

Slides

Although many types of mass movement are included in the general term "landslide," the more restrictive use of the term refers to movements of soil or rock along a distinct surface of rupture which separates the slide material from more stable underlying material. The two major types of landslides are rotational slides and translational slides.





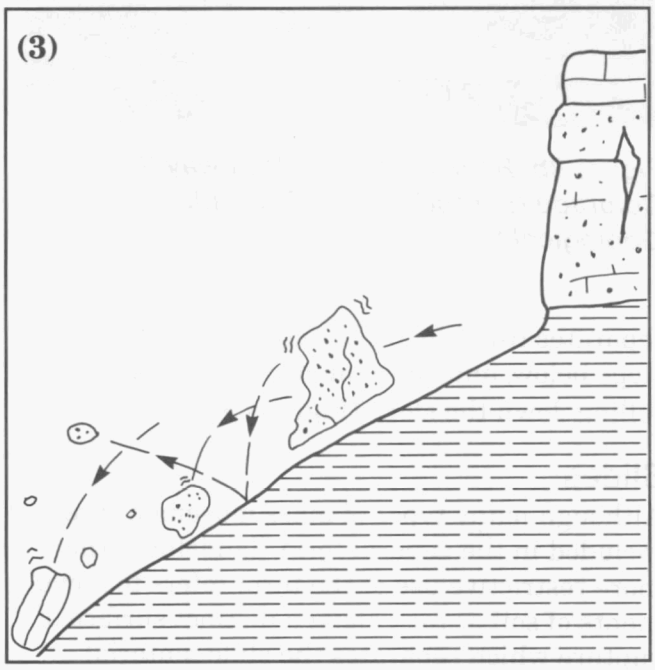


Figure 9a. Topple (Colorado Geological Survey et al., 1988).

Figure 9b. Topple, western Colorado (photograph by Colorado Geological Survey).

Rotational slide

A rotational slide is one in which the surface of rupture is curved concavely upward (spoon shaped) and the slide movement is more or less rotational about an axis that is parallel to the contour of the slope (Figures10a, b). A "slump" is an example of a small rotational slide.

Translational slide

In a translational slide, the mass moves out, or down and outward along a relatively planar surface and has little rotational movement or backward tilting (Figure 11). The mass commonly slides out on top of the original ground surface. Such a slide may progress over great

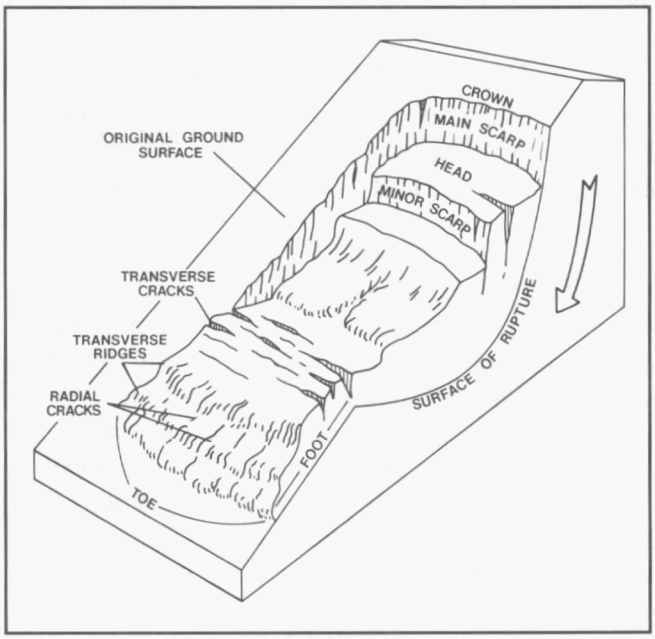


Figure 10a. Rotational landslide (modified from Varnes, 1978).